8005050207

VOLUME II Part 3

three mile island

A REPORT TO THE COMMISSIONERS AND TO THE PUBLIC

MITCHELL ROGOVIN
director

GEORGE T. FRAMPTON, JR.
deputy director

NUCLEAR REGULATORY COMMISSION
SPECIAL INQUIRY GROUP

AVAILABILITY OF REFERENCES

The documents cited in this volume are primarily of four types:

1. NRC-originated material or material presented to or developed for the NRC
2. Material developed by or for other Federal and State bodies
3. Open literature publications consisting of copyrighted books, magazine articles, newspaper clippings, national and society standards, and other society publications (transactions, conference proceedings, reports, etc.)
4. Publications of the United Nations

The NRC-originated material and that presented to or developed for the NRC has been placed in the NRC Public Document Room (PDR) at 1717 H Street, N.W., Washington, DC. It is available for inspection and for copying for a fee. Orders may be placed in person, by mail or by telephone. Both paper copy and microfiche can be purchased. Paper copy is 8 cents per page for standard size paper (8 X 11 ½ inches) and 11 cents per page for larger size paper (drawings and foldouts). Microfiche copies are 25 cents per diazo duplicate. A minimum charge of $2.00 plus postage is made for mail orders. When ordering by telephone or mail, acknowledge a willingness to assume charges for all orders but do not send payment. Orders will be processed and mailed with a bill from the PDR contractor for this service. The telephone is (202) 634-3274 and the address is

NRC Public Document Room
1717 H Street, N.W.
Washington, DC 20555

The NRC documents cited in this volume that are available in the PDR consist of the following:

1. Dispositions (both those taken by the President's Commission and those taken by the Special Inquiry Group. These are indicated by name and page number.)
2. Memorandums and letters (internal, external and those received by NRC and others)
3. Interviews (These are indicated by name and page number.)
4. Regulatory Guides
5. Standard Review Plan (NUREG-75/087)
6. Technical Specifications (generic or docket specific)
7. SECY papers (NRC staff papers for Commission consideration)
8. Commission Issuances (labeled, for example, 4 AEC 768, 6 NRC 1218, where "4" is the volume number, "AEC" indicates pre 1975 issuances, "NRC" is post 1975, and "768" is the page number. These issuances present Commission opinions and decisions.)
9. ACRS transcripts and reports (Advisory Committee on Reactor Safety)
10. Docket material (for example, Docket 50-320 is Three Mile Island 2. A Docket 50 file contains all materials pertinent to a specific powerplant.)
11. Branch technical positions (from Office of Nuclear Reactor Regulation)
12. NRC contracts (for example, NRC-05-77-044)
13. NRC Inspection and Enforcement Manual
14. Commissioner speeches

15. Public Announcements
16. Board Notifications (to ASLB and participants in proceedings)
17. Transcripts of Operating License Hearings (in Docket Files)
18. Operating licenses and amendments (in Docket files)
19. NRC Management Directives (that is, Manual Chapters)
20. Transcripts of NRC Commission meetings
21. Proceedings of Atomic Safety and Licensing Boards
22. IE Circulars and Preliminary Notifications (PN)
23. Vendor and licensee topical reports (for example, B&W, Met Ed, and GPU reports)
24. NRC Inspection Reports
25. Meeting summaries
26. Plant logs, charts, data
27. Reference foreign documents
28. NUREG and NUREG/CR series reports

Some formal NRC reports, which are listed as NUREG-XXXX or NUREG/CR-XXXX, may be purchased over the counter at the PDR. Reports not available at the PDR and NRC Regulatory Guides are best obtained by those who have deposit accounts with the Superintendent of Documents, U.S. Government Printing Office, by calling (301) 492-7333 or writing:

Attn: Publications Sales Manager
Division of Technical Information and Document Control
U.S. Nuclear Regulatory Commission
Washington, DC 20555

These documents may also be purchased from the National Technical Information Service (NTIS). Either write to NTIS or call the Sales Desk at (703) 557-4650. The address is

National Technical Information Service
Springfield, Va. 22161

The material developed by or for other Federal or State bodies is available from the organization cited or, in the case of reports prepared by other Federal agencies, the documents are available for purchase from the U.S. Government Printing Office, the National Technical Information Service, or the Public Document Room of the particular agency. The documents cited in this volume that fall in this category are the following:

Federal

Acts of Congress (Public Laws)
Federal Register
Congressional hearings
General Accounting Office (GAO) reports
Senate reports (S. Rep.)
Congressional Reports (Cong. Rep.)
House reports (H. Rep.)
ERDA reports
DOE reports
Federal Energy Regulatory Commission (FERC) Dockets
Internal Revenue Service Ruling and Bulletins (com. Bul and Rev. Rul.)
Military Specifications (Mil. Spec.)
HEW reports
National Academy of Science reports
National Council on Radiation Protection (NCRP) reports
National Laboratory Reports (Savannah River Laboratory, Lawrence Livermore Laboratory)
EPA Manual of Protective Action Guides
Federal Response Plan for Peacetime Nuclear Emergencies
Federal Aviation Administration
U.S. Department of Labor
WASH reports (WASH-1400 and others)

State

D.C. Circuit Court (D.C. Cir.)
Pennsylvania Consolidated Statutes (Penn. Consol. Stat.)
Pennsylvania Supreme Court (Pa. Super. Ct.)
Pennsylvania Public Utilities Commission (PaPUC) hearings and proceedings
New Jersey Board of Public Utility Commissioners
Pennsylvania-New Jersey-Maryland (PJM) Interconnection Agreement
Ohio Public Utilities Commission (Ohio PUC) hearings
Ohio Statutes (Ohio St.)
Pennsylvania Emergency Management Agency

The open literature publications cited may be available in public libraries and are, of course, available from the publisher. Documents of this type are always copyrighted. Those cited in this volume include newspapers, books, journals, national and industry standards, and association and society transactions and reports.

The publications of the United Nations are available from that organization.

CONTENTS

Appendices

Appendix III.7 (Continued)

OUTLINE OF VOLUME II
PARTS 1, 2, AND 3

III. RESPONSE TO THE ACCIDENT

A UTILITY RESPONSE

1. INTRODUCTION

On March 28, 1979, because of weaknesses in the methods used to ensure that licensed nuclear powerplants are designed and operated safely, a small loss-of-coolant accident that should have had trivial consequences progressed into a serious accident. Hundreds of thousands of people living in central Pennsylvania were severely frightened, and their activities were disrupted. Hundreds of millions of dollars of damage occurred to the powerplant.

This section of the report presents the results of the Special Inquiry Group's (SIG's) examination of Met Ed's response during and following the accident. By reviewing what occurred and with the advantage of hindsight, shortcomings and failings are identified, and corrective actions are recommended.

Each of the next six subsections address a separate aspect of the utility's response to the accident. In actuality, the six aspects are interrelated either through timing, personnel involved, or subject matter. At the end of each subsection, the findings and recommendations regarding that part of the report are presented.

Others reviewing this information may develop additional findings and different recommendations. This report describes what the SIG believes to be the relevant events of the utility's response to the accident so that weaknesses and failures can be identified and corrected. The subsection on Plant Operations Response examines the actions that the plant operators, Met Ed management, and their advisors either performed or directed during the accident; the major operating decisions that were made and by whom; and their reasons for the decisions. The Radiological Emergency Response subsection describes the utility's implementation of their emergency plan, including how the plant personnel responded, what went right, and what went wrong. The following subsection on the massive Industry Support effort from throughout the United States describes one of the most impressive but little publicized aspects of the accident. This effort contributed substantively in controlling the consequences of the accident and ensuring the safe shutdown of the reactor. The Industry Support section ends the discussion of Met Ed's response to the accident. Three other subsections address special topics related to the utility's response. Reporting of Critical Information to the NRC discusses the results of the SIG's inquiry into whether or not utility personnel or others willfully withheld information from the NRC about the seriousness of the accident; Management Overview of Three Mile Island reviews the background of key Met Ed personnel involved in the management and control of activities at the Unit 2 facility; and the Radiation Emergency Plan and Training subsection discusses the plan and training that governed the utility's initial response.

2. PLANT OPERATIONS RESPONSE

a. Introduction and Summary

The accident at Three Mile Island, which began with a loss-of-feedwater transient at 4:00 a.m. on March 28, 1979, immediately involved the plant's onshift operating staff. Members of the operating staff not then on shift—including Gary Miller, the TMI Station Manager, and all other supervisors—were quickly involved in responding to the accident. Company personnel other than plant staff were also ultimately involved. Utility management above the station manager level from the Met Ed offices in Reading, Pa., the General Public Utility (GPU) offices in New Jersey, and an offsite "staff" technical group—the General Public Utility Service Corporation (GPUSC) engineering organization, with home offices in New Jersey—became involved in the operating decisions that finally reestablished core cooling shortly before 8:00 p.m. that evening.

John Herbein, Vice President of Generation for Met Ed, was a key utility manager; he was the company official directly responsible for the operation of TMI. Herbein's office was in Reading, Pa. The Station Manager, Gary Miller, reported directly to Herbein. Another key individual was Robert Arnold, Vice President of Generation for GPUSC; with an office in Parsippany, N.J. GPUSC was not responsible for TMI at the time of the accident, having transferred what responsibility it had to Met Ed at the completion of the startup and test program. Arnold's group did, however, contain the company's largest pool of powerplant engineering talent, which consisted of about 85 engineers and scientists working directly on powerplant design.

During the accident's first 2 hours, the operating crew on shift and the supervisors who came in to assist them, did not realize that reactor coolant was being lost through an open pressurizer relief valve, and thus allowed a small loss-of-coolant accident to continue. They severely throttled flow from the high pressure injection system. If this system had been allowed to function automatically, as intended, it would have mitigated the effects of the loss-of-coolant and cooled the core. The operators' actions, which led to the severe core damage that characterized the TMI accident, resulted from their failure to understand basic plant conditions that were indicated to them, or to follow appropriate procedures or prudent operating practices, any one of which could have prevented the severe core damage. This demonstrated a deep and significant weakness of the operating crew on shift. (Deficiencies in procedures and control room design, which also contributed to the operators' errors, are discussed elsewhere in this report.)

During a conference call from 6:00 to 6:40 a.m., Herbein, Miller, and others also failed to diagnose the basic plant problems. Miller and Herbein were lacking a great deal of key information that was available to the operators, such as knowledge of the throttled high-pressure injection flow. However, they did know of one key symptom, low reactor coolant system pressure, that could have led them to effective corrective action.

By 6:18 a.m., the core was being damaged and a partial fuel melting could have begun within less than an hour. A combination of sound decisions by incoming supervisors and additional automatic actuations of the high-pressure injection system served to avoid the imminent meltdown danger. At 6:18 a.m., incoming Shift Supervisor, Brian Mehler, decided to isolate the open pressurizer relief valve, stopping the loss-of-coolant. Although this only addressed part of the problem, it did avoid the immediate melting problems. At 7:20 a.m. and at 8:00 a.m., the high-pressure injection system was again initiated automatically; some cooling water was pumped into the reactor coolant system, and the fact that it was actuated and operating was clearly indicated in the control room. At 8:00 a.m., Miller made the sound decision to leave the high-pressure injection system in operation; at 9:15 a.m., he decided to increase reactor coolant system pressure. Combined with high-pressure injection flow, this provided a reasonable cooling procedure.

Although it was not fully recognized at that time, the core was severely damaged. The plant staff had a difficult task; there were no systems available that had been designed to cool a damaged core and no procedures available indicating how best to attempt such cooling. The method being attempted apparently was not working.

At 11:30 a.m., when the high pressure strategy did not appear to be condensing the steam bubbles and refilling the reactor coolant system with water, Miller, with Herbein's concurrence, decided to pursue a low pressure strategy. This strategy involved venting through either the pressurizer relief valve, the pressurizer vent valve, or both, until the reactor system pressure was decreased to levels where the contents of the core flood tanks could be injected into the system. The strategy erroneously assumed that, at the lower pressure, the injection of water from the core flood tanks would be significant and would cool the core. Although this assumption was invalid, because only a fraction of the water in the core flood tanks would be injected, the strategy still might have been effective if it were implemented in conjunction with maximum or near maximum high-pressure injection flow, but instead, the operators throttled the high-pressure injection flow again.

At 1:15 p.m., Herbein directed Miller to stop discharging steam through the atmospheric dump valves. This decision at first glance appeared questionable, but after evaluation, we do not consider it unreasonable.

At 2:00 p.m., Miller, Herbein, and George Kunder, Unit 2 Superintendent of Technical Support, left the plant for about 2 ½ hours to brief Lt. Gov. Scranton. Although Miller has stated that he would not have gone if he hadn't felt the plant was stable and under control, we nevertheless consider his departure poor judgment. The core was not being effectively cooled and there was no good evidence that things were well in hand.

Upon returning from the briefing at 4:30 p.m., Herbein stepped in to override the plant staff's strategy for core cooling. This decision (repressurizing and running a reactor coolant pump) resulted in a known stable and effective core cooling mode for the first time since the initial accident. Herbein was assisted by Arnold in reaching this decision. At that time, Arnold and his group in Parsippany had become concerned, and on their own initiative, had gathered enough information to diagnose the basic problem and recommend effective corrective action.

This positive intervention by utility management was somewhat fortuitous in that no responsibilties for reviewing operating decisions had been planned or assigned to the management. Not all utilities have either as large an engineering staff or executives with appropriate backgrounds to enable them to direct actual plant operations during emergencies.

Although a reasonable organization for plant operations was improvised by the plant staff on the spot, deficiencies that result from the lack of preplanning and emergency drills were evident. (Radiological aspects of emergencies had been organized and practiced, but plant operations aspects had not.) Some of the key supervisors involved in the operating decisions were not well prepared to step in and direct plant operations during an emergency. There were some communication problems among the plant staff and with outside organizations.

On Wednesday evening, March 28, with a reactor coolant pump running and core cooling established, the utility management and staff believed things were under control. They did not recognize that the core had been extensively damaged or that the reactor coolant system contained a large quantity of hydrogen, and thus did not suspect these threats to continued core cooling. These factors were not fully understood until Friday, March 30. This delay in recognition was due to not understanding the significance of some information that suggested severe core damage, and lack of information that more clearly and forcefully indicated serious core damage.

There had been no prior planning to apply the utility's technical resources and outside assistance to an accident recovery effort, and such application did not begin in earnest until Friday morning when it was generally realized that significant problems still existed. This slow start, along with the numerous demands of recovery from the accident, led NRC officials to view the utility as technically weak in relation to the needs of the accident. However, we have concluded that the utility, in terms of technical capability, is as good as the median nuclear utility.

In the interim, because critical things did not go wrong, the lack of understanding did not materially worsen the physical course of the accident, except for delaying recovery action. It did, however, increase the risk involved because appropriate contingency planning and mitigating actions were not underway. Lack of understanding also affected the public's perception of the accident because early reports indicated things were well in hand, but later reports indicated they were not.

Beginning on Friday, when the continuing problems were generally recognized, the utility management and staff began effective action to obtain assistance, plan for contingencies, and direct daily plant operations to eliminate the hazards. The recovery effort was massive, involving hundreds of people and many organizations. It included enough active involvement by the NRC and others to be considered a joint industry-Government effort. Inevitably, without prior planning and practice, some confusion and difficulties arose.

Whereas much of the responsibility for permitting a relatively simple accident to escalate into the most damaging nuclear accident in the history of the industry must be borne by the operating staff and the utility management, many individual and corporate actions taken in response to the accident were effective in ensuring minimal consequences to public safety.

b. People Involved

Plant Staff

Figure III-1 provides a simplified organization chart indicating the key plant staff personnel involved in Unit 2 plant operating decisions.

The shift crew on duty at TMI-2 during the early morning shift on March 28, 1979, included 10 operations personnel, 4 of whom had current NRC operating licenses. William Zewe, Shift Supervisor

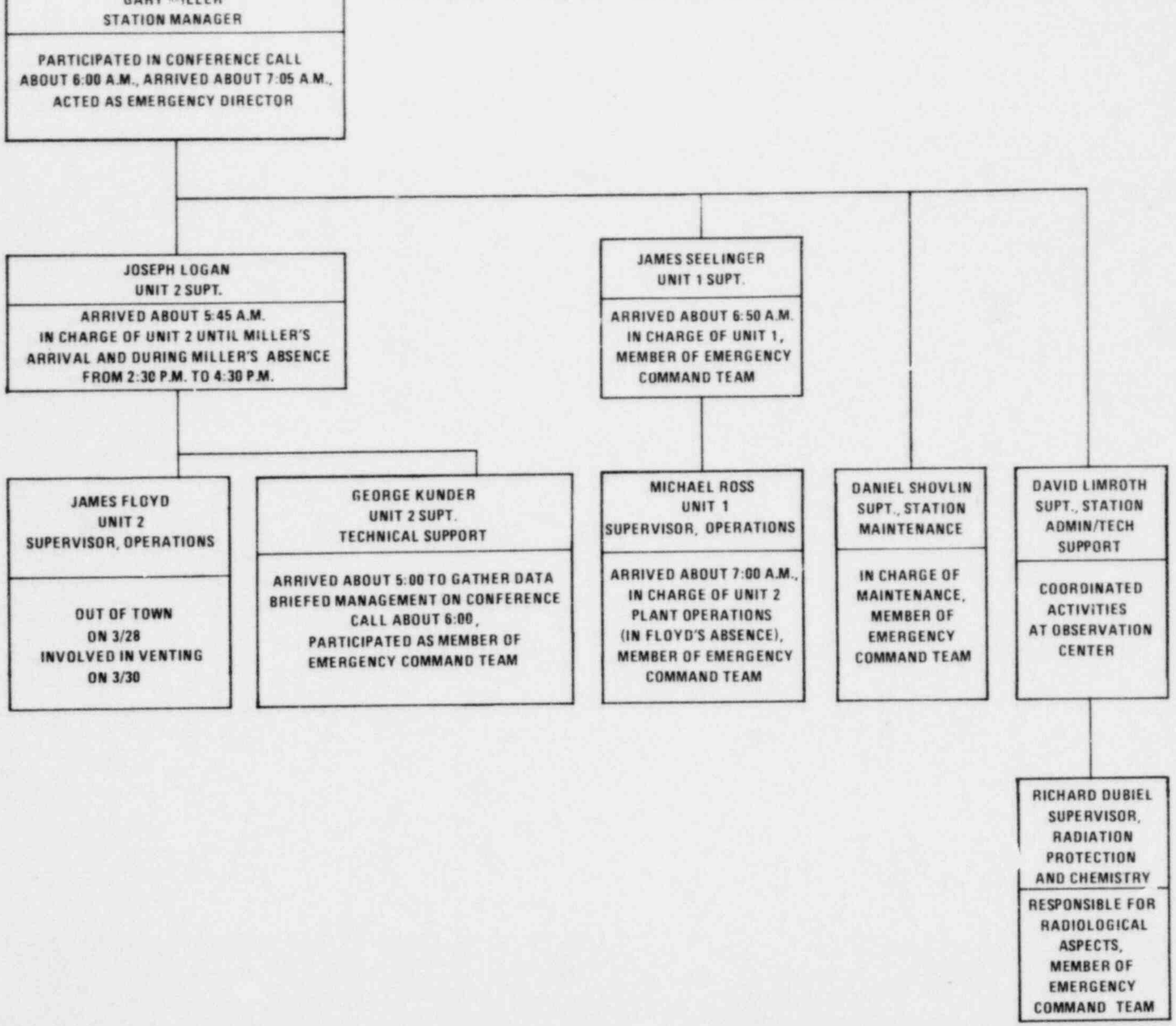
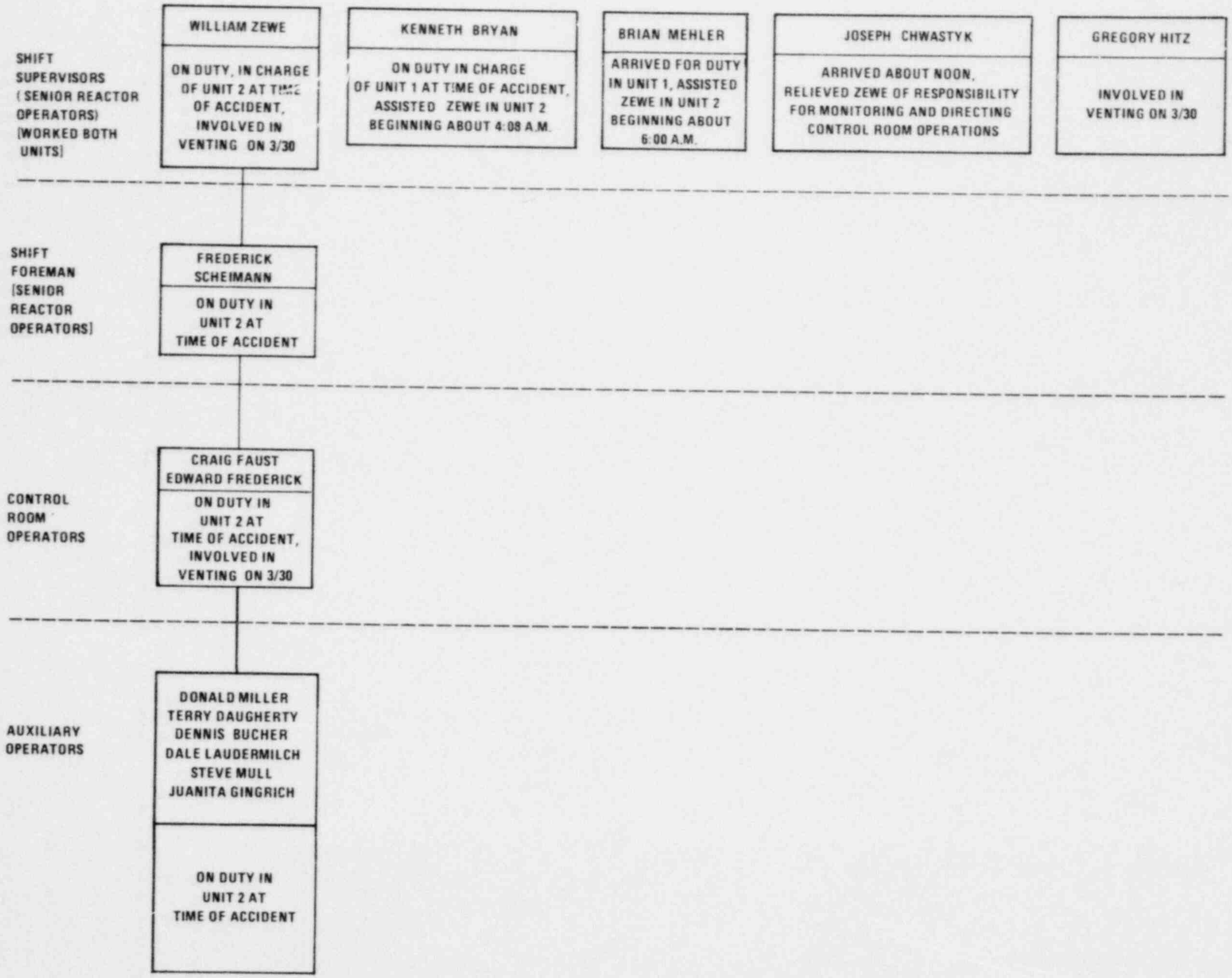


FIGURE III-1. Key Plant Personnel Involved in Unit 2 Operations on March 28, 1979


SHIFT SUPERVISORS (SENIOR REACTOR OPERATORS) [WORKED BOTH UNITS]
WILLIAM ZEWE
ON DUTY, IN CHARGE OF UNIT 2 AT TIME OF ACCIDENT, INVOLVED IN VENTING ON 3/30
KENNETH BRYAN
ON DUTY IN CHARGE OF UNIT 1 AT TIME OF ACCIDENT, ASSISTED ZEWE IN UNIT 2 BEGINNING ABOUT 4:08 A.M.
BRIAN MEHLER
ARRIVED FOR DUTY IN UNIT 1, ASSISTED ZEWE IN UNIT 2 BEGINNING ABOUT 6:00 A.M.
JOSEPH CHWASTYK
ARRIVED ABOUT NOON, RELIEVED ZEWE OF RESPONSIBILITY FOR MONITORING AND DIRECTING CONTROL ROOM OPERATIONS
GREGORY HITZ
INVOLVED IN VENTING ON 3/30
SHIFT FOREMAN [SENIOR REACTOR OPERATORS]
FREDERICK SCHEIMANN
ON DUTY IN UNIT 2 AT TIME OF ACCIDENT
CONTROL ROOM OPERATORS
CRAIG FAUST
EDWARD FREDERICK
ON DUTY IN UNIT 2 AT TIME OF ACCIDENT, INVOLVED IN VENTING ON 3/30
AUXILIARY OPERATORS
DONALD MILLER
TERRY DAUGHERTY
DENNIS BUCHER
DALE LAUDERMILCH
STEVE MULL
JUANITA GINGRICH
ON DUTY IN UNIT 2 AT TIME OF ACCIDENT

and the person in charge of Unit 2, had 7 years of nuclear experience at the TMI station. He had been licensed by the NRC as a senior reactor operator for more than 5 years. Zewe is a high school graduate with 6 years of nuclear training and operating experience as an enlisted man in the U.S. Navy nuclear program before he joined Met Ed in 1972. Zewe was assisted by Frederick Scheimann, Shift Foreman, a high school graduate who had 8 years of nuclear training and operating experience as an enlisted man in the U.S. Navy nuclear program before joining Met Ed in 1972. Sheimann was promoted to shift foreman in 1978 and became licensed as a senior reactor operator by the NRC at that time.

Manipulating the reactor controls at Unit 2 that morning were Craig Faust and Edward Frederick, both of whom were high school graduates having several years of nuclear training and operating experience in the U.S. Navy nuclear program before joining Met Ed in late 1973. Faust and Frederick received their NRC reactor operator licenses in late 1977 for the startup of Unit 2. Supporting the control room operators were auxiliary operators Donald Miller, Terry Daugherty, Dennis Bucher, Dale Laudermilch, Steve Mull, and Juanita Gingrich. These operators perform activities that take place outside of the control room, such as valving operations, testing, operational maintenance, and equipment surveillance. Additionally, there were four radiation chemistry technicians and one trainee on duty that morning to support the operating crews at the station. With respect to the capabilities of this particular crew, Zewe's supervisor, James Floyd, Unit 2 Operations Supervisor, believed that the crews were balanced, and that this crew was neither a great deal better nor a great deal worse than the other five crews.[1]

On March 28, the Unit 1 operations crew, who would normally be under Zewe's control along with the Unit 2 crew, were being directly supervised by another shift supervisor, Kenneth Bryan. (Unit 1 was in startup preparation having just completed a refueling outage. During periods of high activity it was the station practice to assign a shift supervisor to each reactor.) Zewe called on Bryan for assistance shortly after the start of the accident. Bryan is a high school graduate who joined the Met Ed nuclear program in 1969 as a trainee with no prior nuclear experience. He had been licensed on Unit 1 for about 3 years and had obtained a senior reactor operator license on Unit 2 in early 1978. Another shift supervisor who assisted Zewe about 2 hours after the accident started was Brian Mehler. Mehler's nuclear training experience and licensing history parallel Bryan's.

Other station personnel who arrived in the control room after the accident began, but prior to the declaration of an emergency and activation of the Met Ed emergency plan, included Joseph Logan, Unit 2 Superintendent; George Kunder, Unit 2 Superintendent of Technical Support; and Michael Ross, Unit 1 Operations Supervisor. Of these three, Kunder was the first to arrive (at 4:50 a.m.); he was the on-call duty officer. Kunder, a graduate mechanical engineer from Pennsylvania State University, had 10 years of nuclear training and experience at TMI Unit 1. He held a senior reactor operator license for Unit 1 and was in training for a license at Unit 2. Kunder had transferred to his Unit 2 position 3 months before the accident. Logan, who arrived in the control room at 5:45 a.m., had been informed shortly after 4:00 a.m. of the plant trip, but not of subsequent developments. Logan is a graduate engineer from the U.S. Naval Academy with 20 years of nuclear training and operating experience in the naval nuclear program. After serving for 30 years as a commissioned naval officer, he joined Met Ed in a training status in early 1978. Logan obtained a senior reactor operator license on Unit 2 in late 1978 and became the Unit 2 Superintendent 3 months before the accident. Michael Ross was in Unit 1 when Zewe called him about 6:00 a.m. and asked him to come to the Unit 2 control room. Ross is a high school graduate with 8 years of nuclear training and operating experience as an enlisted man in the U.S. Navy nuclear program before joining Met Ed in 1968. Ross had held various NRC operating licenses since 1969, including a senior reactor operator license on Unit 2 since late 1977. He was a shift supervisor at Units 1 and 2 prior to his promotion to Unit 1 Operations Supervisor in late December 1978.

Although he was not a Met Ed employee, Leland Rogers, the B&W Site Manager, should be mentioned here. He assisted the station manager on March 28, providing advice and communications with B&W. Rogers, a high school graduate, had 15 years of operating and instructional experience as an enlisted man in the naval nuclear program. This career was followed by 2½ years of experience in testing and startup of Westinghouse reactor plants, after which Rogers spent 6½ years with B&W at the Three Mile Island site.

Company Management and Staff

Figure III-2 provides a simplified organization chart indicating key company managers and staff groups involved in plant operations and support.

A key manager was John Herbein, Met Ed's Vice President of Generation. He was the corporate off-

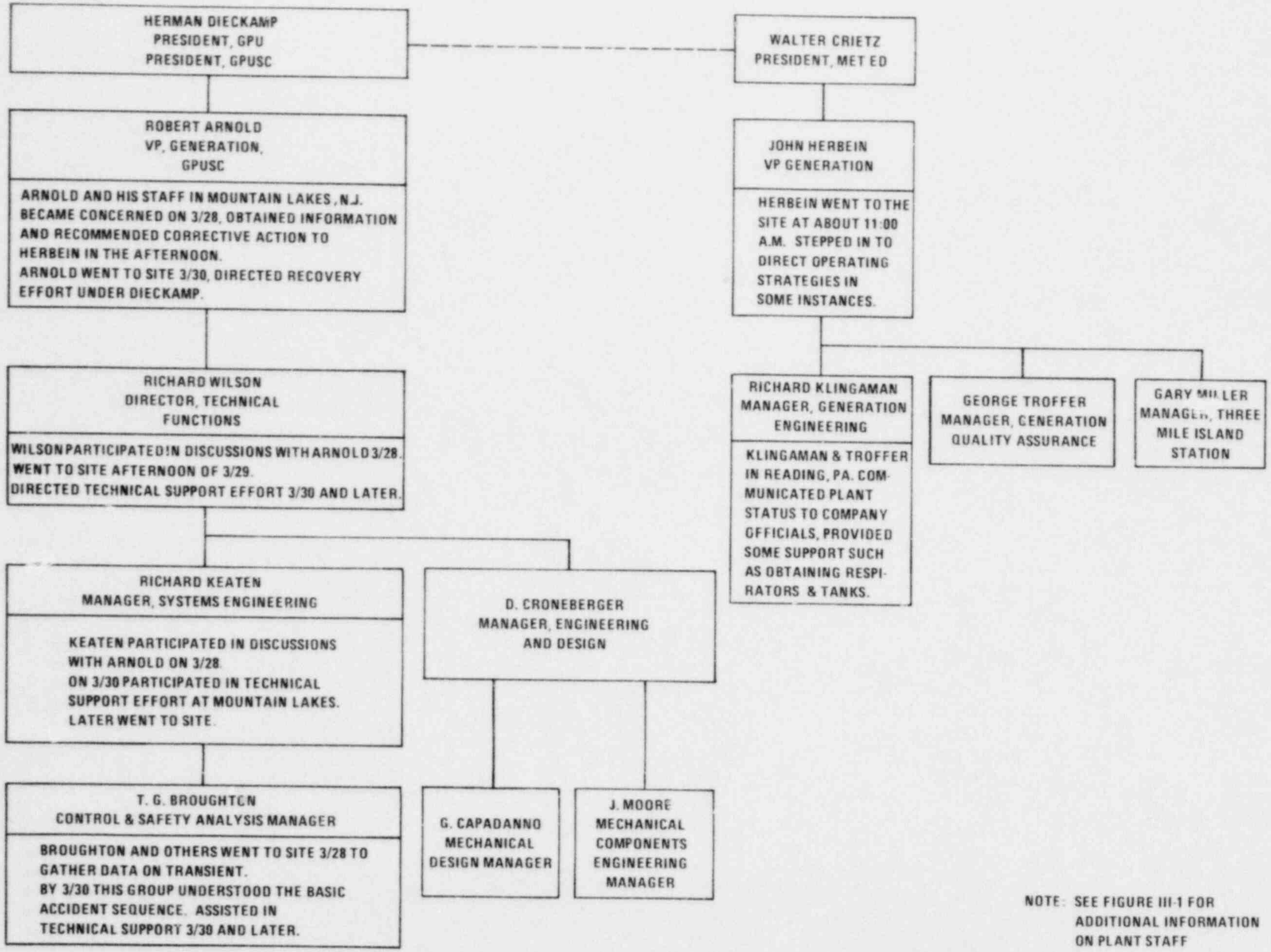


FIGURE III-2. Key Company Management and Staff Involved in Plant Operations and Support icer directly responsible for operation of the Three Mile Island Station as well as other Met Ed generating stations. An engineering graduate of the U.S. Naval Academy, Herbein's background includes training as an officer in the U.S. naval nuclear program, licensing as a senior reactor operator on the Saxton and TMI-1 reactor plants, and supervisory experience at the Saxton and Three Mile Island stations. Herbein's background was significant because on the afternoon of March 28, he stepped in to override the recommendations of the plant staff and directed changes in the operating strategy. A utility official, lacking a nuclear background of Herbein's type, would be less likely to actually direct the plant staff in this manner during an emergency.

Herbein reported to Walter Creitz, President of Met Ed. Creitz reported to Herman Dieckamp, President of GPU. The Three Mile Island station manager, Gary Miller, reported to Herbein. (An intermediate manager, L.L. Lawyer, Manager-Generation Operations, was in the line between Herbein and Miller for matters such as correspondence with the NRC, but not for operational matters.) Miller is an engineering graduate of the U.S. Merchant Marine Academy. His background includes experience in a shipyard as a civilian test engineer for naval reactors and he held a senior reactor operator license for TMI-1. Also reporting to Herbein were various Generation Division staff groups in Reading, Pa., including those headed by Richard Klingaman, Manager Generation Engineering; and George Troffer, Manager Generation Quality Assurance.

Klingaman's group of 25 engineers was responsible for engineering support in the operation of the TMI and other Met Ed generating stations. The GPUSC Generation Division, in Parsippany, N.J., contained a larger pool of powerplant engineering talent. It provided engineering services for the entire GPU system—Met Ed, the Pennsylvania Electric Company, and the Jersey Central Power and Light Company. The primary emphasis of the GPUSC group was on engineering new powerplants and major modifications to existing plants—not on engineering support for operating plants. However, when the Met Ed engineering group needed assistance in dealing with a plant problem it would usually consult with GPUSC, at least as a first step, before involving an architect-engineer firm. These GPUSC engineers reported to Robert Arnold, Vice President Generation, GPUSC. Arnold reported to Herman Dieckamp, the President of GPU. Richard Wilson, Director of Technical Functions, reported to Arnold and in turn several engineering managers, including Robert Keaten, Manager Systems Engineering, reported to Wilson.

Arnold's background includes training and considerable operating experience as an officer in the U.S. naval reactor program and management of the construction and testing of the TMI station. Collectively, those reporting to Arnold provided a pool of people with extensive experience in the design and operation of several different types of reactor plants.

The backgrounds of Arnold and his staff were significant. By the afternoon of March 28, Arnold's staff had, primarily on its own initiative, found out enough to become concerned and then to make operating recommendations through Arnold to Herbein. Herbein concurred with these recommendations to repressurize the reactor coolant system and to restart a reactor coolant pump, and he directed the plant staff to carry them out. Some utilities have smaller technical staffs. A smaller group or a group with less collective experience would have been less likely to become involved in this manner. For example, Klingaman's Met Ed engineering group and the small group of NRC personnel in the control room and Region I did not diagnose that the reactor core was not being adequately cooled. On the other hand, NRC Headquarters and B&W Headquarters, two larger groups, did diagnose the basic problem that afternoon when they found out about the hot-leg temperatures.

The point is that some utilities have smaller technical staffs than GPUSC and some utility executives do not have as much nuclear operating background as do Arnold and Herbein. Thus, they would be less likely to intervene in plant operating decisions, especially under emergency conditions. The need for such intervention in this accident, suggests the need for prompt action to upgrade operating staff capabilities and to provide them with the means for obtaining immediate expert advice from outside sources to backup emergency operating decisions.

c. Shift Operations Before Declaration of Emergency (4:00 a.m.-6:55 a.m., March 28)

Background

At 4:00 a.m. on March 28, 1979, Bill Zewe, Shift Supervisor, was sitting in the Unit 2 shift supervisor's office doing paperwork when he heard several annunciator alarms in the control room. Looking out into the control room, Zewe saw several annunciators light up on the integrated control system panel. As Zewe hurried into the control room, he noticed that the main turbine had tripped and then the reactor tripped. Zewe recalled that prior to the trip the "only real problem we had was resin stuck in the line between the number 7 polisher (condensate polisher) and the receiving tank."[2] (Later it was found that the outlet valves from the condensate polishers had closed and that interrupted the flow of water in the feedwater system—this caused the main feed pumps to trip. A trip of the main feed pumps closes the main turbine steam stop valves.)

Fred Scheimann, Shift Foreman, was at the condensate polisher in the auxiliary building helping unclog the stuck resin when he "started hearing loud thunderous noises like a couple of freight trains."[3] (A phenomenon termed "water hammer" often occurs in large pumping systems when water flow is suddenly interrupted.) Scheimann rushed to the control room when he heard Zewe announce "turbine trip-reactor trip" over the plant speakers.

At 4:00 a.m., Ed Frederick and Craig Faust, control room operators, were performing routine activities. Frederick recalled they had been "charging our make up tank inventory [borated water] to compensate for leakage that we had through the relief valves on the pressurizer." He also said that the pressurizer spray valve was on manual operation and opened to lower the boron concentration of the borated water in the pressurizer.[4] (The pressurizer is a pressure vessel used to adjust the pressure in the reactor coolant system. It is normally half-filled with borated water with a steam bubble in the top half. Steam leakage through any of the three overpressure protection valves, one relief and two safety valves, connected to the pressurizer steam space will raise the boron concentration of the water in the pressurizer—much like boiling water in a tea kettle will concentrate impurities.)

Plant designers knew that safety valves, if actuated to release high pressure, had a high likelihood of not completely closing when the pressure had been reduced. The resultant leakage might exceed NRC license limits and require a costly plant shutdown to perform remedial maintenance in the leaking valve. To avoid the necessity for such shutdown, a relief valve designed to open at a lower pressure than the safety valves was provided. The intent was that for most pressure transients the relief valve would open and limit the pressure rise so that the safety valves would not need to be actuated. However, the relief valve also might not close completely upon pressure reduction and might leak at a rate in excess of that permitted by the NRC. However, unlike the case for a safety valve, where NRC requirements did not permit the installation of an intervening valve, a separate block valve was installed between the relief valve and the pressurizer. In this way, the valve's closure after a pressure reduction could terminate any leakage through the relief valve if it did not fully close after its operation. The safety and relief valve system was designed so that the flow from the valves, whether caused by valve operation or valve leakage, was piped to a large collection tank—the reactor coolant drain tank—located in the reactor building. The piping from each of the three valves, called the discharge piping, was provided with temperature indicators that were used to detect valve leakage. Immediately prior to the accident, one of the three valves was leaking. The operators were not sure which one it was because all three discharge pipes join and all were hot. The discharge pipe temperature downstream of the relief valve was 180°F. Plant procedures required closure of the upstream valve to "block" leakage through the relief valve if the discharge pipe temperature exceeded 130°F. This procedure was not followed and the block valve was left open.

Craig Faust, who had just completed recording instrument readings, saw and heard the annunciator alarms from the trip of the main feed pumps. Faust pointed to the alarms and told Frederick, "We're in trouble—something's going wrong in the plant."[5] Thus began a series of events leading to a "small break loss-of-coolant accident," which, among other things, ultimately led to extensive core damage, generation of huge amounts of hydrogen gas, and the release of radioactive gases into the environment.

Small break loss-of-coolant accidents were postulated by the plant designers. To avoid fuel damage in the event of such an accident, instruments were installed to detect the loss of coolant (sensed by either low reactor coolant system pressure or high reactor building pressure), and automatically start the high pressure injection system. This system was designed to inject a reserve of coolant into the reactor system at a rate of up to 1000 gallons per minute to prevent fuel damage.

On March 28, a small break occurred when the pilot-operated relief valve atop the pressurizer stayed open after it should have closed. (The valve opened as it should have a few seconds after the turbine tripped when the pressure in the reactor coolant system increased because of thermal expansion of the coolant. When the main turbine tripped, it no longer extracted heat from the reactor coolant system and so the coolant began to heat up. The system pressure continued to increase until it tripped the reactor protection system, which automatically shutdown the reactor, then operating at 97% of its licensed power level. After shutdown, the reactor power output remained at a few percent of its initial output because of decay heat—energy released from radioactive decay of fission products. The steam generator then extracted enough heat to decrease the temperature of the reactor coolant and the reactor pressure decreased because of thermal contraction or "shrink" of the coolant so that the relief valve should have closed. The preceding events happened rapidly—about 12 minutes for the entire process.)

With the relief valve open, steam escaped at a rate of about 110 000 pounds per hour (equivalent to 220 gallons per minute of water) further decreasing the reactor coolant system pressure. About 2 minutes after this sequence of events began, instrumentation detected that pressure in the coolant system decreased to 1640 psig (normal pressure was 2155 psig), which is indicative of a loss-of-coolant accident. The instrumentation automatically started the high-pressure injection system, which then pumped coolant into the system at a rate of about 1000 gallons per minute. The shift crew quickly placed the system on manual operation and restricted the makeup rate to about 25 gallons per minute for the next 3 hours. Although the shift crew observed that the reactor pressure had decreased more than they had expected, they failed to recognize that the pressurizer relief valve was open until Brian Mehler, the oncoming shift supervisor, pointed it out to them at 6:18 a.m.—about 20 minutes after Mehler arrived in the control room. Closure of the block valve stopped the loss of coolant and pressure, but by that time too much coolant had been lost and the fuel elements were extremely hot and undergoing severe damage. (Subsequent studies have shown that the block valve was closed just in time. If the existing conditions had continued for another hour a partial core melting could have begun.)

We have evaluated the critical operating decisions made by the shift crew that morning, which worsened the outcome of the accident. These decisions involved: (1) failure to isolate the open pressurizer relief valve earlier, (2) interference with the operation of the high-pressure injection emergency core cooling system, and (3) shutdown of the reactor coolant pumps.

Failure to Isolate Relief Valve Earlier

Approximately 12 seconds after the main feed pumps tripped, the reactor coolant system pressure decreased to 2205 psig—the closure setpoint for the pressurizer relief valve. The relief valve remained open. A few seconds later, the discharge pipe temperature downstream of the relief valve reached 239°F.

Between 4:04 and 4:10 a.m., the continued discharge caused the reactor coolant drain tank pressure relief valve to lift and begin discharging steam and water into the reactor building. The reactor building sump pumps started and began pumping the collected water into the auxiliary building.

At 4:14 a.m., a rupture disc at the top of the reactor coolant drain tank burst when the tank pressure reached 192 psig. (The rupture disc provides overpressure protection for the tank for flow rates larger than the tank relief valve can handle.)

Zewe recalled looking at the reactor coolant drain tank monitoring panel in the control room at about 4:20 a.m. and noticing "that the drain tank had a high temperature and zero pressure. The running pump [used to pump water from tank] had a very low discharge pressure [which] means that we had ruptured the reactor coolant drain tank."[6] Zewe also noted that the reported temperature on the discharge pipe from the relief valve was about 228° to 230°F—which was only 30° to 40°F higher than normal—and did not indicate to him that the valve was still open. He expected that the temperatures would exceed 300°F if the valve were open. At about 4:30 a.m. the reactor building atmosphere coolers were shifted to fast speed to combat rising pressure and temperature in that building's atmosphere. At 4:38 a.m., an auxiliary operator reported to the control room that both reactor building sump pumps were running and was told to turn them off. By 5:00 a.m., the reactor building temperature had increased from 120° to 170°F and the reactor building pressure had increased from 0 to 2.5 psig. This resulted from the continuing discharge of high temperature reactor coolant from the pressurizer relief valve to the reactor building, via the now open drain tank. At 4:27 a.m., and again at 5:21 a.m., Zewe had Ken Bryan, Unit 1 Shift Supervisor, obtain a computer printout for the pressurizer relief valve discharge pipe temperature. Bryan reported a reading of about 228°F, but the relief valve discharge pipe temperature was actually 283°F. (During our interview, Bryan told us that he made a mistake in reading the discharge pipe temperature and called out the temperature downstream of a safety valve instead of the relief valve.)[7] At 6:18 a.m., operations personnel again obtained a computer printout for the valve discharge pipe temperature. This time, the pressurizer relief valve discharge pipe temperature was 229°F, about 35°F hotter than the safety valve discharge lines.[8] The block valve was then closed, stopping the leakage through the open pressurizer relief valve.

Mehler, the oncoming shift supervisor, arrived in the control room around 6:00 a.m. He told us that after glancing at reactor coolant instruments, he concluded that there was a steam bubble in the hot legs of the reactor coolant system piping.

> I based the steam bubble in the hot leg because the pressurizer was solid [filled with borated water] and the [reactor] pressure was low so that means there had to be a steam bubble somewhere else, forcing the water up into the pressurizer... I went to the computer and punched out the temperatures on both the code relief [safety] valves and electromatic [pressurizer relief valve] and based on that I assumed the electromatic was leaking.[9]

(Mehler also recognized that such conditions could also be caused by a loss of pressurizer heaters, and directed others to check the heaters.) Mehler then ordered that the block valve be closed.[10]

Frederick corroborated Mehler's statement in that he testified that the block valve was closed at the suggestion of a shift supervisor coming in for the next shift. However, Frederick considered that the valve was closed out of desperation because they could think of nothing else to do to bring the reactor back under control.[11,12] Thus, 20 minutes after his arrival, Mehler made a correct decision and took action to start bringing the reactor back into control, too late to avoid fuel damage, but soon enough to prevent fuel melting. Although the shift crew had searched for 2 hours for the cause of what Frederick called "screwy plant conditions" (low pressure in the reactor system, high water level in the pressurizer), they were unable to diagnose the problem. Similarly, plant staff supervisors arriving in the control room—Kenneth Bryan, Unit 1 Shift Supervisor, 4:08 a.m.; George Kunder, Unit 2 Superintendent of Technical Support, 4:50 a.m.; and Joseph Logan, Unit 2 Superintendent, 5:45 a.m.—were also unable to diagnose the problem.

Although the operators' failure to isolate the relief valve sooner involved some lack of knowledge, some violation of procedures, and some failure to choose the more prudent course of action, it appears to us that poor human engineering practices in the design and management of the facility contributed heavily to this failure. Plant instrumentation signals displayed in the control room gave, at least in hindsight, abundant evidence that the pressurizer relief valve was open; but we believe that deficiencies in the display of this information in the control room, deficiencies in information in the control room, deficiencies in training of the plant staff, and deficiencies in the plant procedures and management practices all contributed to the failure to diagnose that the relief valve was open. The contributing factors that we believe were significant are the following:

- The signal (illumination of a red light on a control console) used to inform operators that the valve is open indicated that the valve was closed. The operator chose to believe that the valve was closed.
- Personnel believed that the temperature downstream of an open relief valve would be higher than 300°F, up to 550°F. They were unaware of thermodynamic considerations whereby expansion of the high-pressure steam exiting the relief valve would limit the temperature of the released steam to below 300°F. Therefore, personnel misinterpreted the discharge pipe temperatures as indicating the relief valve had opened, but actually it no longer was open.
- The signals displayed in the control room to inform the operators of the condition of the reactor coolant drain tank, which could confirm the continuing relief valve discharge, were deficient in that the information was displayed on instruments out-of-view of the operator's normal work location. Neither the meters that were used to display the information nor the alarm system assured that the operator would be alerted to abnormal conditions in the drain tank. (The meter readings confused the operators after the rupture disc burst because tank pressure and level returned to near normal levels; only the temperature remained abnormal.)
- Personnel were unaware of the reactor coolant system response to a loss-of-coolant accident from the steam space of the pressurizer. They were unaware that steam may form elsewhere in the system and force reactor coolant (borated water) into the pressurizer.
- Plant procedures were ambiguous and did not provide adequate instructions to permit the operator to identify or cope with a small break loss-of-coolant accident originating in the steam space of the pressurizer. These procedures emphasized that reactor coolant pressure and pressurizer level both decrease during loss-of-coolant accidents.
- The operating procedure required closing the pressurizer relief block valve if the relief valve discharge pipe temperature exceeded the normal temperature of 130°F, and again if it exceeded the alarm setpoint of 200°F. Contrary to the procedure, management allowed the pressurizer relief block valve to remain open although the temperature in the valve's discharge piping exceeded the normal limits. This condition persisted for

weeks prior to March 28. After the accident began, the operators continued violating the same procedure although the temperature then exceeded the higher limit as well.

- The operators could have chosen to take the prudent approach with respect to this issue, that is, to close the block valve just in case. However, they did not do so. We believe this decision was made because they thought the relief valve was closed.

Interference with High-Pressure Injection

Approximately 2 minutes after the main feed pump trip, the loss of reactor coolant through the open pressurizer relief valve depressurized the reactor coolant system to 1640 psig, whereupon the high-pressure injection system was automatically actuated. The two high-pressure injection pumps began injecting 1000 gallons per minute of borated water into the reactor coolant system in accordance with the plant design and procedures for mitigation of small break loss-of-coolant accidents. (This would have replenished the coolant losses occurring through the open relief valve.) The emergency safeguard signal was bypassed by the operator about 1 minute after the high pressure system actuated. Bypass of the signal is *required*, by the TMI-2 emergency procedure for loss of reactor coolant or system pressure,[13] to allow the operator to limit each pump to a flow of 500 gallons per minute. (Bypassing the signal returns control of the high pressure system to the operator—manual operation—to permit throttling of pump flows to prevent pump "runout." Runout is a condition where a centrifugal pump is pumping at a flow rate that "runs out" beyond its characteristic pressure-flow curve. If the flow rate is excessive, cavitation may occur and destroy the pump impeller.) Regarding the bypass action, Frederick gave a different reason when he explained "We were afraid about going solid in the pressurizer and seeing high pressure spikes. I believe we took manual control of the ES [Engineered Safety Features] to prevent going solid."[14] At the time the engineered safeguard signal was bypassed, the level of water in the pressurizer was rapidly approaching the high-level alarm point.

At 4:05 a.m., about 1 minute after the bypass placed the high-pressure injection system within the operator's control, one pump was turned off and flow from the remaining pump was sharply restricted. Additionally, the letdown flow out of the reactor coolant system was increased so that the average net difference between the pump flow into the system and letdown flow out of the system was 25 gallons per minute. Thus, the letdown flow exacerbated the loss-of-coolant accident condition resulting from the open pressurizer relief valve. Zewe directed the above actions and he said:

> I wanted to bypass ES so that we secure (sic) the make-up pump [high-pressure injection pump] and shut the high-pressure injection valves after we verified that everything had lit off for the high-pressure injection. ... So, I said try to go to max letdown [160 gallons/min.] to try to letdown to hold the pressurizer level and then we thought the pressurizer level instruments were failing so we checked all three pressurizer levels.[15]

The check of pressurizer levels was apparently made because, in spite of the operator's efforts, the pressurizer level continued to increase and by 4:06 a.m. it appeared to be full of water (solid). (The operators equated a "full pressurizer" with a "full reactor coolant system." During normal conditions, the pressurizer has the hottest water in the system; hence, any steam in the system would be above the borated water in the pressurizer. Consequently, plant designers only provided instrumentation on the pressurizer to inform the operator of the amount of coolant in the reactor coolant system. However, for "pressurized water reactors" with coolant above 212°F, this is only true if the coolant system has "pressurized water." The continuing loss of coolant through the open pressurizer relief valve lowered the temperature of the borated water in the pressurizer, which lowered the pressure in the reactor coolant system. This depressurization continued until steam voids formed in the reactor coolant being circulated through the reactor pressure vessel and system piping. These voids then forced water into the pressurizer, keeping it full. As more and more coolant was lost through the pressurizer and the letdown system, the amount of steam voids in the coolant system increased, causing reactor coolant pressure to remain fairly constant at the saturation pressure of about 1100 psig until about 6:30 a.m.)

During our interview with Zewe, Scheimann, Frederick, Faust and other licensed operating personnel, we found that they had not received training in plant response to a small break loss-of-coolant accident in the pressurizer steam space. Furthermore, the Babcock & Wilcox operations training manuals[13] used by Met Ed at their training center, and the TMI-2 Final Safety Analysis Report reviewed by the NRC contained no discussion or data reflecting plant response to the aforementioned accident. Zewe said:

> I did not know why the pressurizer level was indicating so high or why the pressure was holding

low, but we seemed to be fairly *stable*. (Emphasis added.)... With George [Kunder] and Ken [Bryan] and Fred [Scheimann] and Ed [Frederick] and Craig [Faust] in there... we just were trying to put our heads together to come up with the weird indications that we had. The high-level [water level in pressurizer], and it really didn't dawn on me or anyone else at that point, that we had really transferred that bubble.[17]

Previous analyses available at the NRC and B&W, as well as precursor events, showed that plant operators could be and had in the past been fooled into turning off the high-pressure injection system pumps during a small break loss-of-coolant accident caused by a stuck open pressurizer relief valve. (The other operators had, however, arrived at the appropriate corrective actions a few minutes later.) Met Ed's operators were unaware of all of this. Why the Met Ed operators were not given benefit of this knowledge and experience is another story covered elsewhere in this report.

The operating decision to interfere with the high-pressure injection emergency cooling system apparently resulted in part from failure to equip plant operations personnel with the specific knowledge, instruction, and plant status information relevant to a loss of coolant from the pressurizer steam space. The evidence indicates that the operating personnel did not know they were experiencing a loss-of-coolant accident and that they tried to cope with the situation. Inexplicably, however, it appears that personnel in the control room did not immediately reinitiate the high-pressure injection system after the block valve was closed at 6:18 a.m., stopping the loss of coolant through the pressurizer relief valve. Zewe claimed during his deposition with us on September 11, 1979 that he did indeed have "full high-pressure injection on" from the time the block valve was closed until 7:00 a.m. or so when the reactor coolant system was repressurized.[18] This conflicts with his earlier statements,[19] however, and plant data do not support the contention in that this pressure would have consumed about 40 000 gallons of borated water but the total usage from the borated water storage tank was 15 000 gallons between 4:00 and 7:00 a.m.[20]

It is evident that Met Ed's training of the personnel was deficient, especially in the specifics of the plant's response to a leaking pressurizer relief valve; nonetheless, we do not believe it is feasible that specific training, procedures, and instruments can be provided in usable form for every conceivable situation at a nuclear powerplant. Some reliance has to be placed on people to make reasonable decisions during unforeseen situations. We do not believe the operations personnel exercised reasonable, let alone prudent, judgment when they interferred with the emergency cooling system while the known initiating condition—low reactor coolant system pressure—persisted.

Shutdown of Reactor Coolant Pumps

Reactor coolant pumps 1B and 2B were stopped at 5:14 a.m. At 5:41 a.m., the remaining reactor coolant pumps 1A and 2A were also stopped, terminating forced cooling through the core. Zewe explained the following:

> We were looking at the temperature-pressure curves from the coolant pumps and we started to get abnormal fluctuation in outflow instruments from the reactor coolant pumps. So I decided to stop two reactor coolant pumps at this time. We were about... 540° average temperature at this point. We secured two of the coolant pumps and then the flow came down to about 50% and stayed like that for I'm not sure how long—but a couple of minutes anyway—and then the flow started to fluctuate some more. Then, we secured all the coolant pumps and then we kept on feeding with the high-pressure injection pumps at this point.[21]

Frederick added the following:

> At the time we turned them [reactor coolant pumps] off, they weren't pumping what they should have anyway, because we had two pumps running and only showing 60% flow. We should have had 80-90-100% flow in one loop. Because we secured the RC pumps in the other loop, flow should have been 100%. But it wasn't. So it seemed like we were losing flow to the pumps. So we turned them off...[14]

After the pumps were turned off, the then existing condition of a partially filled reactor coolant system could not support natural circulation (convection) cooling. The circulating coolant was a froth of liquid and steam that removed enough heat from the fuel to prevent cladding damage. When the pumps stopped, the liquid and steam separated; the remaining liquid in the reactor pressure vessel was insufficient to cover the fuel elements. The fuel then began to heat up because part of the heat being generated by the decay heat effect was not being removed. Cladding damage apparently occurred over the upper 8 to 9 feet of the 12-foot long fuel rods when the clad was cooled by steam rather than water.

The decision to shut down the reactor coolant pumps was consistent with the equipment protection provisions of the plant operating procedures. When reactor coolant pressure and temperature conditions degraded, the coolant pumps worked effectively in cooling the fuel elements even though the pumps experienced cavitation and vibration.

The operators did not ascertain the cause for the abnormal pump conditions and did not take the apparent corrective actions to restore subcooled coolant conditions in the reactor coolant system. Again, there is no indication that the operators knew the basic theory of pressurized water reactors, that is, hot reactor coolant remains as a liquid only by keeping the pressure up—as in a household pressure cooker.

Other Actions

Three other early operator actions that have received some notoriety are discussed briefly below. Because these actions have been addressed by other investigations and none of them materially altered the physical course of the accident, we have not analyzed them in detail.

Closed Emergency Feedwater Block Valves

One highly publicized operating error was the early blockage of emergency feedwater flow to the steam generators by two improperly closed emergency feedwater block valves. The blockage lasted until 8 minutes into the accident, when a Unit 1 shift supervisor who had come into the Unit 2 control room, and the Unit 2 operators diagnosed the problem and opened the valves.

The 8-minute blockage had only a minor direct material effect on the physical course of the accident. It made the reactor coolant system hotter and thus boiling occurred earlier than it otherwise would have. However, with the pressurizer relief valve remaining stuck open and the high-pressure injection flow remaining throttled, the boiling and eventual core damage would have occurred anyway.

Along with many other factors, the blockage might, however, have helped to confuse the operators. Lacking emergency feedwater flow, the steam generators boiled dry and stopped removing substantial amounts of heat from the reactor coolant system about 1 minute into the accident. This stopped the reactor coolant system cooldown, which in turn caused pressurizer level to stop decreasing and to increase faster than it would have otherwise. When the pressurizer level appeared to be recovering the operators took their normal actions—throttling high-pressure injection flow—in response to the increasing pressurizer level. During this time, the more rapid recovery of pressurizer level and subsequent throttling actions, or simply finding the block valves closed, might have helped to confuse or distract the operators.

The question of how the block valves came to be closed has been investigated by Met Ed, by the NRC-IE investigation, and by the President's Commission. The President's Commission staff report on this subject summarized the other two investigations and added its own evaluation in order to express the then-current state of knowledge on this matter. Several possibilities were explored but the actual cause of the valve closure was not determined. We have little to add, but will summarize the four possibilities that the President's Commission staff report listed as the most likely reasons for the valves being closed. The interested reader is referred to the President's Commission staff report[22] and to the NRC-IE investigation report[23] for further discussion.

The first of the likely possibilities listed by the President's Commission staff report is that the valves were left closed after a surveillance procedure that was performed about 42 hours prior to the accident. Those who performed the surveillance have stated that the valves were not left closed. The improper condition would have had to go unnoticed by the control room operators during several shifts in order for this to be the reason. However, it is possible that the maintenance crew is mistaken. No records indicating reopening were retained. It is also possible that monitoring of the control boards during intervening shifts was so sloppy that the condition went unnoticed.

The second possibility listed in the staff report is that the valves were mistakenly closed by the control room operators during the very first part of the accident. This could have been a simple mistake. Alternately, it could have been a deliberate but unauthorized part of the normal strategy to limit the pressurizer level and reactor coolant pressure decrease following a turbine trip. Blocking auxiliary feedwater flow, by closing the block valves or by some other means, could stop the cooldown and thus limit the pressurizer level and pressure drop. There are indications that this may have been done on previous reactor trips.[24]

The operators that were on duty when the accident occurred have denied any knowledge of such a practice, however.[25] No evidence has been found indicating that the emergency feedwater flow was blocked at the beginning of the transient in order to limit the pressurizer level and pressure decrease. (Furthermore, the lack of anomalies in the record of the emergency feedwater pressure from the control room recorder chart indicates that if such action took place, it took place prior to about 36 seconds into the accident, which is possible but quite fast.)

The third possibility listed in the staff report is that the valves were mistakenly closed from a control point outside the control room. This was considered possible but remotely so. The fourth possibility, which is also listed in the staff report as remote, is that the valves were closed on purpose to cause trouble. No evidence has been found for either the third or fourth possibility. Other possibilities, such as control circuit malfunction, have also been investigated but were considered even less likely in the President's Commission staff report.

Diesel Generator Lockout

The plant's emergency diesel generators will start automatically upon a loss of offsite power to the plant's safety circuits or when the safety features (such as high-pressure injection) are automatically actuated. When the high-pressure injection system actuated automatically at 2 minutes into the accident, the emergency diesel generators started but did not assume any electrical load because the emergency circuits were still being powered from offsite power. Since offsite power had not been lost, the operators stopped the diesel generators, as required by procedures, to prevent damage that might occur from sustained operation without load. The diesel generators should have then been left aligned for further automatic starts if needed.

However, on the basis of an unjustified assumption that offsite power would be available, and to prevent further unnecessary starts in the event of further safety system actuations, the diesel generators were disabled by blocking the fuel supply to the engines. This left the diesels unavailable for automatic starting in the event of a loss of offsite power. Manual starting, by restoring the fuel supply, would have been time consuming and many of the operators did not even know the fuel supply was blocked. At about 9:30 a.m. an electrical engineer noticed this condition and had the fuel supply restored. Switches in the control room were still used to block automatic restart, but if offsite power were lost, the diesels could have at least been started quickly from the control room.

Core Flood Tank Isolation

At about 6:00 a.m., when the reactor coolant pressure was about 800 psig and decreasing, the core flood tank isolation valves were reportedly closed. The core flood tanks were normally maintained at 600 psig and this action was supposedly taken to prevent the tanks from injecting water into the reactor coolant system.

This action would have made no difference to the course of the accident because the core flood tanks would not have injected any significant amount of water. However, closing of the valves would be contrary to emergency core cooling system (ECCS) procedures because a loss-of-coolant accident was in progress. Further discussion is provided in the NRC-IE investigation report.[26]

Weakness of Shift Crew

There were two significant abnormalities in plant status that adversely affected reactor safety following the turbine and reactor trip at 4:00 a.m.: the emergency feedwater system flow was blocked by closed valves and the pressurizer relief valve was open.

The operating crew on shift was able to diagnose and correct one of these abnormalities, the blocked emergency feedwater flow, within 8 minutes after the turbine and reactor trip. This adjustment was made despite the handicap of numerous alarms, indications, and actions to be taken, which competed for the attention of the operators. The operators did not, however, diagnose the open pressurizer relief valve or respond correctly to the loss of coolant that resulted therefrom.

During the first 2 hours of the accident, the operators made two basic errors that led to the severe core damage—failure to quickly isolate the open pressurizer relief valve by closing its block valve and failure to continue automatic operation of the high-pressure injection system. Either rapid isolation of the relief valve (within a few minutes) or allowing the high-pressure injection system to perform its automatic safety function (within 1½ to 2 hours) would have prevented the severe core damage and thus, the consequences of the accident as we now know them.

These mistakes resulted largely from failure to understand the significance of basic information that was indicated to the operators and was considered by them over long periods of time. Proper understanding should have led logically to one or both of the appropriate corrective actions. Alternately, failure to understand basic plant conditions contributed to not following appropriate procedures or good operating practice. Existing procedures, if followed, would have led to both of the appropriate corrective actions. Reasonably good operating practice would have dictated allowing a safety device (the high-pressure injection system) to continue functioning since the condition that caused its actuation (low pressure) was still present.

Of the two basic mistakes, the throttling of high-pressure injection flow was the more significant. The particular path for the loss-of-coolant accident that occurred happened to be isolatable, if properly diagnosed, but another leak path might not have been. A more fundamental shortcoming is the inability to tell that there is a loss of coolant occurring at some point in the system or, lacking that, the understanding that it is important to keep the pressure above the saturation pressure in a pressurized water reactor.

Admittedly, the operators were confused by the expectation that pressurizer level would drop during a loss-of-coolant accident and by a desire not to fill the pressurizer solid. Furthermore, with many alarms going off we do not criticize the operators' failure to diagnose anything for the first 20 minutes or so. However, this went on for a much longer time, and the symptoms were well known and continuously considered.

In addition, throttling the high-pressure injection flow demonstrated a basic disregard for safe and prudent operating practice. A safety device had actuated and the actuation signal, low pressure, was still present, yet it was immediately overridden without careful consideration of whether or why low pressure might be needed. Again, the operators were misled by a procedure to immediately start high-pressure injection after a turbine trip to avoid excessive pressurizer level shrink. It was natural then to terminate the high-pressure injection flow after pressurizer level had been recovered. However, the severe throttling of injection flow continued for a long time although the symptoms of the basic problem were well known, clearly evident, and under consideration.

The failure to understand basic plant status information and the failure to follow appropriate required procedures or safe and prudent operating practices (any of which would have terminated the accident with negligible consequences) indicate significant weaknesses in the knowledge, training, capabilities, and discipline of the operators on shift, at least with respect to fundamental plant safety concepts. To be sure, poor human engineering practices contributed to the accident. These practices provided a set of complex and confusing procedures, a complex and confusing control room, and ill-considered procedural remedies for engineering problems.

One such area that we consider to have contributed directly to the incapability on the part of the shift crew was the crew's size. Only four licensed operators were available to pay attention to the many alarms and pertinent indications that exist during accidents and transients, to look after more than two dozen complex control panels, to take appropriate actions, to supervise and make basic safety decisions, and to perform required notifications of offsite organizations. The crew size needed for these activities could not be determined without a task analysis that considered a particular plant's design and the training, background, and capabilities of the personnel. However, four operators seem to be clearly inadequate for handling an accident in the TMI plant. Whereas this number exceeded the NRC's requirements, the requirements also appear inadequate. Further discussion on requirements for minimum shift crews is provided elsewhere in this report.

Overall, the weakness evidenced at TMI-2 with respect to basic plant safety considerations appears to be fundamental and deep. We view this weakness as a problem within the system that designed the plant, developed the operating and emergency procedures, trained the crew and set its size, licensed the facility and the operators, approved the overall operations staff, and placed the people there that morning.

d. First Management Involvement, Conference Call (6:00 to 6:40 a.m., March 28)

Background

Management's first involvement came when Herbein, who was in Philadelphia, participated in a conference call with Miller and Rogers, at their homes, and Kunder, in the control room. This call lasted from about 6:00 to 6:40 a.m. on March 28, 1979. Rogers was the B&W Site Manager, and Kunder was the Superintendent of Technical Support for TMI-2.

Miller initiated the conference call. He had initially been notified of the plant trip shortly after it occurred at 4:00 a.m. At 5:15 a.m., having heard nothing further, Miller called the plant. He was informed that the engineered safeguards system had actuated, the pressurizer level was high, and the reactor coolant system pressure was low. He did not consider the engineered safeguards actuation, by itself, to be unusual following a turbine and reactor trip. However, high pressurizer level combined with low reactor coolant system pressure was considered anomalous and cause for concern. He called up Seelinger and Shovlin, informed them that Unit 2 had a problem, and told them to report to the site as soon as possible. Miller then initiated the conference call with Herbein, Rogers, and Kunder.

When the call began at 6:00 a.m., Kunder had been in the control room for a little more than an hour. Joseph Logan, the Unit 2 Superintendent, was nominally in charge. He had been in the control room for a few minutes and was engaged in determining the plant status. Kunder participated in the conference call from the glass enclosed shift supervisor's office in the back of the control room. Apparently, control room personnel including Logan, Ross, and Mehler were not generally aware at the time that Kunder was briefing the others.[27] At the time, Kunder had not diagnosed the true problems—a loss-of-coolant accident with throttled high-pressure injection flow. Kunder's lack of understanding of the true problems and his isolation from the control room operators during the call appear to have contributed to a lack of reporting some significant information.

The pilot-operated relief valve (PORV) was still discharging reactor coolant into the reactor building. This valve was isolated later, during the conference call, by closing its block valve at 6:18 a.m. The loss of coolant through the open pressurizer relief valve had depleted the reactor coolant inventory and the reactor coolant system contained significant quantities of steam.

The last pair of reactor coolant pumps had been off since 5:41 a.m. The control room operators were attempting to establish natural circulation core cooling flow. Natural circulation was the only accepted, analyzed, and qualified means of providing cooling water flow through the core when the reactor coolant pumps were not running, assuming the correct reactor coolant volume had been maintained. This effort was failing because steam (and later hydrogen gas) in the reactor coolant system was blocking natural circulation flow. Previously, while they were still running, the reactor coolant pumps had forced sufficient cooling flow through the core despite the steam content, which was degrading pump performance and coolant effectiveness.

Core damage was beginning and proceeding during the conference call, so it was too late to completely preclude core damage. However, had the actual plant situation been diagnosed and had corrective action—such as full high-pressure injection system flow—been prescribed, the amount of core damage could have been limited. Subsequent problems with core cooling caused by physical core damage and hydrogen generation also could have been reduced.

Discussion and Decisions

During the conference call, basic plant conditions were described as the following: both main feed pumps tripped, the condenser hotwell flooded, the reactor tripped on high pressure, and the reactor code safety valves opened causing the rupture disc on the reactor coolant drain tank to burst. (Actually it was the single PORV that had stuck open and caused this, not the opened code safety valves). Furthermore, the reactor coolant system was at a lower pressure than expected, the reactor coolant pumps were shutdown, the plant had been taken solid (pressurizer full of water rather than being about half-full of steam), and it was believed that this was due to high pressure injection. Moreover, the pressurizer level was at 370 inches, the reactor coolant pressure was at 700 psi, and the reactor coolant temperature was 500°F. The emergency feedwater system was in use to promote natural circulation, and feedwater to the B steam generator had been secured because of a suspected tube leak in the generator.[28,29]

The participants discussed the possibility that the pressurizer level reading might be false. It was decided that the instrument readings should be believed. One participant recalled mention of a water level in the containment sump but would not consider that surprising with the reactor coolant drain tank rupture disc blown (as had happened before at TMI-2 and other plants). There was no discussion of the 8-minute delay in obtaining emergency feedwater flow. (The delay had been caused by two improperly closed valves, which were discovered and opened about 8 minutes into the transient.) Kunder was not aware of this at the time of the call. The participants did not recall any discussion of the fact that high-pressure injection had been throttled, although Kunder was aware of this at the time of the call. The participants agreed that it was desirable to start the reactor coolant pumps to reestablish forced cooling flow through the core. Miller and Rogers were to report to the site.

This action may seem reasonable assuming no great problems in the plant. However, we now know that the conference call participants did not understand the real situation.

Points Missed

Pressure and Temperature Relationships

The reactor coolant system pressure and temperature were reported as 700 psi and 500°F, respectively, which was an accurate representation of the conditions that existed a few minutes before the conference call. Considering the accuracy of the instruments, and the fact that higher coolant temperatures would exist in parts of the core, this indicated boiling in the reactor coolant system. At 700 psig, pure water boils at 505°F. (During the conference call the hot-leg temperature rose dramatically, but this was not reported.)

One of the most basic concepts in a pressurized water reactor, indeed the source of its name, is to keep the pressure above the boiling point for the temperature that exists. This keeps the coolant in a liquid phase, preventing the water from boiling to steam. If steam is formed in large quantities because of high temperature, low pressure, or both, the steam will be less effective in removing heat from the core and the core may be overheated.

The participants realized that reactor coolant pressure was anomalously low and inconsistent with pressurizer level. However, they neither pursued the significance of the low pressure to the point of realizing that it implied bulk boiling in the reactor coolant system, with the attendant core cooling problems, nor did they check to see whether or not the pressure was low enough to cause a problem. Had the implications been realized in terms of boiling, corrective action could have been taken to increase the pressure with the high-pressure injection pumps and thus, stop the boiling and condense the steam.

The participants did not pursue an explanation for the low pressure in order to find the cause—the stuck-open relief valve. Had this cause (which is by definition and in effect a small loss-of-coolant accident) been determined, the corrective action would have been to ensure that the high-pressure injection system was operating, since the system's specific purpose is to mitigate small loss-of-coolant accidents.

Natural Circulation

The conference call participants decided to restart the reactor coolant pumps. They considered this a desirable or preferable operating mode, but, not realizing that natural circulation was not working, they did not consider this or any other action to be a drastic necessity.[30]

Running the reactor coolant pumps to provide forced cooling flow through the core immediately after any reactor shutdown is a more normal and prudent operating mode. Natural circulation is considered a backup means. However, if natural circulation is working it does provide adequate core cooling and makes it unnecessary to run the reactor coolant pumps. On the other hand, if natural circulation is blocked for some reason (the case that was actually developing in the plant), then the situation requires that, if core damage is to be avoided or limited, some cooling means must be found.

The participants did not recall any discussion about whether or not natural circulation was working. They did not receive any data that would cast doubt on natural circulation (other than low reactor coolant system pressure). This lack of information is significant because, if the question had even been raised, it could well have led to information casting serious doubt on natural circulation and warranting extreme concern and action to establish core cooling flow.

As discussed in the preceding section, the reactor coolant pressure and temperature indicated boiling and attendant problems with core cooling. Aside from being a less effective coolant, quantities of steam, if present, are likely to block natural circulation flow. For this reason there are procedural restrictions on the pressures and temperatures at which natural circulation is to be attempted. The plant was, at the time, well outside those restrictions.

When the conference call began, the actual reactor coolant system hot- and cold-leg temperatures had begun diverging, indicating differences of 59° and 24°F in the A loop and B loop, respectively. These differences would not be startling. At the conclusion of the conference call, the temperature differences had increased to about 300°F, with hot-leg temperatures of about 720° and 780°F in the two loops, respectively. These data, which were not reported, indicated more clearly and forcefully the failure of natural circulation and the presence of superheated steam in the hot legs. (Much later in the day when offsite agencies such as GPU engineering, B&W Headquarters, and NRC Headquarters found out about the hot-leg temperatures, they were readily able to diagnose the significance of the temperature readings.)

The B steam generator pressure had dropped to a very low level of about 40 psi at 6:00 a.m. and remained there during the call, indicating virtually no heat transfer into that generator. The A steam generator pressure had dropped to about 700 psi at the beginning of the call and to about 400 psi at the end of the call, indicating little heat transfer to that generator. This information, also not reported, raised considerable doubt about whether natural circulation was working.

One possible course of action at that time would have been to run the reactor coolant pumps in an attempt to force cooling flow through the core, disregarding possible pump damage resulting from low reactor coolant system pressure and steam content. A natural companion to this course would be to increase the high-pressure injection flow to raise pressure and lessen the amount of steam. This would enhance reactor coolant pump effectiveness and lessen the likelihood of pump damage.

Another possible course of action would have been to increase the high-pressure injection flow and raise the reactor coolant system pressure. This step would possibly have condensed steam in the system and allowed natural circulation to work or simply to cover the core with water. The high-pressure injection flow could also have been increased in combination with more vigorous venting and lower reactor coolant system pressure in an attempt to establish a flow of cooling water from the high-pressure injection pumps through the core and out the PORV or pressurizer vent valve.

Pilot-Operated Relief Valve Leakage

During the conference call Rogers asked about the status of the PORV block valve. His concern was to ensure that the discharge of reactor coolant, which was known from the blown rupture disc, had been stopped. The response, which Kunder obtained from unidentified control room personnel, was simply that the PORV block valve was shut.[31-35] Mehler, who directed shutting the block valve, did not recall any awareness of the conference call or the question. A more complete report about the PORV (that it had remained open for more than 2 hours) might have significantly changed the participants' perception of plant status. Alternately, further questioning might have elicited more comprehensive information.

Knowing that the block valve had only recently been shut, should have suggested the possibility that, until recently, the PORV had been open, releasing reactor coolant inventory. If so, that would have explained the reactor coolant system pressure, which was known to be anomalously low without a good explanation. Abundant data were available upon followup questioning to confirm that the PORV had been open. Had the open state of the relief valve, which amounts to a small loss-of-coolant accident, been understood, then the importance of maintaining ample high-pressure injection flow should have been realized because the specific purpose of the high-pressure injection system is to mitigate small loss-of-coolant accidents.

Radiation Levels

Conference call participants did not recall mention of any indications of radiation problems. Prior to the call, some radiation alarms had been received in the reactor building. However, these were alarms that triggered at relatively low levels and would not have been considered abnormal in light of the blown rupture disc on the reactor coolant drain tank. During the conference call, additional indications and alarms of somewhat higher levels began to be received as core damage proceeded. If known to the participants, these would probably have caused additional concern and thus, might possibly have led to more vigorous actions to cool the core.

Shortly after the conference call was terminated, further radiation alarms and indications of still higher levels were received. These later indications were clearly startling and led to the declaration of a site emergency at 6:55 a.m.

Summation

The failure to grasp an understanding of the true plant conditions during the conference call can be ascribed to the following factors. The first factor was failure to understand or pursue known information—primarily, the failure either to comprehend the implications of the low reactor coolant system pressure or to find a good explanation for why it existed. Apparently there was a lack of skepticism or a lack of willingness to believe the worst, i.e., that the plant might be in very serious trouble, the control room operators might have gone completely astray, and that a crisis existed with a critical need to get to the bottom of things and correct the situation. This is, of course, a natural human reaction in many circumstances, but training could foster a more skeptical approach to plant operating decisions. (Other examples occurred during the day. For example, when Arnold learned of the containment dome monitor reading he believed that it was due to moisture affecting the instrument rather than extremely high radiation levels.)

The second factor was the isolation of Kunder from the control room and his lack of awareness of additional data that more clearly and forcefully indicated serious problems. For example, Kunder was unaware of the hot-leg temperature reading that rose during the call or of the radiation readings that became truly alarming shortly after the call ended.

The third factor was the nature of the reports from the control room, for example, the incomplete information on PORV block valve closure.

e. Early Response after Declaration of Site Emergency (7:00 a.m. to noon, March 28)

Operating Organization

As core damage was proceeding during the conference call, radioactive fission products were escaping from the core into the reactor coolant system. From there they were leaking into the reactor building and into process piping systems. Miller was notified at about 6:45 a.m. of the abnormal radiation readings and he left immediately for the site, arriving in the control room at about 7:05 a.m. At

6:55 a.m., Zewe declared a site emergency based on readings on area radiation monitors and process piping radiation monitors.

When Miller arrived he was briefed by Zewe and others and formed an emergency command team that included Ross in charge of plant operations (directing Zewe), Logan in charge of verifying compliance with procedures, and Kunder in charge of communications and technical support. Rogers was requested to provide technical support and communication with B&W. Other members of the team were Shovlin, in charge of maintenance, Dubiel in charge of radiological concerns, and Seelinger in charge of Unit 1. Miller declared that these individuals were to be the funnels through which matters in their respective areas would be discussed. Other personnel, including Mehler and Zewe, also participated in team meetings from time to time. When NRC inspectors arrived later in the day, they attended the team meetings, were encouraged to offer any suggestions they might have, and were asked to state any problems they might have with proposed courses of action.

At about the time the emergency management team was being formed, many additional operators were available in the control room. Ross stationed additional operators at the control panels with shift foremen and shift supervisors backing them up and coordinating their activities.

We consider reasonable the emergency command team structure that was selected. It had the advantage of bringing to bear the collective knowledge of several people. Miller clearly retained the responsibility for making the decisions, after discussing various options. Miller considered the funneling of communications important because there was so much happening. He stated that even with the funneling he had very little time to think. Presumably, without it, he would have had none.

Similarly, we consider reasonable placing operators on all or most of the control panels in the control room, backed up and coordinated by supervisors. The control room is large and complex with many control panels. It would be impossible for a few operators to keep close track of occurrences at the many panels during changing conditions. Again, the abilities of more people were brought to bear by this approach.

Of course, when a large team is used rather than a small team, a disadvantage in terms of possible confusion comes along with the advantage of bringing many people's talents to bear. Nevertheless, we have no criticism of the basic organization chosen.

We do believe, however, that there were weaknesses in the organization's performance that contain lessons for future planning of emergency organizations. The emergency command team missed some important points during the day. For example, it did not discuss the stuck-open PORV and throttling of high-pressure injection flow, which were the basic causes of the accident. This awareness would have lent more insight to the discussions. The team did not clearly understand the complete significance of the hot-leg temperatures. Time was spent discussing the questionable notion that the hot-leg temperature detectors might not indicate the correct temperature in a steam environment. Core thermocouple readings were not discussed, but a questionable theory about the core flood tanks cooling the core was endorsed by the team.

There was some confusion in the control room. Early in the day, for example, Miller directed that the high-pressure injection system be kept on. The intent of this direction was subverted during the afternoon. Key personnel have expressed different opinions about whether or not the high-pressure injection system was cross connected, vital information considering the mode of operating this system in the afternoon. As Miller was leaving for Harrisburg, he was not aware of the containment pressure spike, nor were Logan or Kunder aware of it, but others were aware of it and thought everyone else knew about it. During Miller's absence, Joseph Chwastyk, Shift Supervisor, and Ross were pursuing different strategies to lower the hot-leg temperature.

We believe that part of the problem was weakness in the qualifications of individuals to handle emergencies. The need for better operator qualifications and for basic consideration of human engineering is clear with respect to individual control room operators' abilities to diagnose and handle emergencies. Some individuals involved in the emergency command team were not well prepared to take charge of plant operations during an accident, nor to diagnose plant conditions with a critical eye, nor to override operators' decisions where appropriate.

Aside from upgrading individual capabilities, we believe that a preplanned and practiced organization for directing plant operations during emergencies would have improved performance. Some confusion can be expected in any emergency of this nature (some is all we found evidence of); however, the performance of the emergency command team and the existence of some confusion in the control room suggest a need to organize and plan for conducting plant operations during emergencies. An essential part of such planning would be to drill, particularly with respect to communications within the plant organizations, as has been done in the past for the radiological aspects of emergencies.

Miller has stated that communicating with outside organizations placed a significant burden on him in trying to manage the emergency. We agree that this must have been a burden. He held many telephone briefings for both company and State officials, and there was a 2½-hour absence to brief the Lieutenant Governor. Miller noticed a tendency for outside officials to want to speak to someone in charge. He and others have recommended that this be considered in future emergency planning by including a designated communicator in the emergency response organization to handle such contacts. More fundamentally, Miller has stated that communications that have been practiced, work.

Plant Status

Aside from forming the emergency management team, Miller spent his first half hour or hour concentrating on radiological concerns and the required notifications of offsite organizations before turning his attention to plant operations. During this initial period, at about 7:24 a.m., he declared a general emergency based on indicated radiation levels in the reactor building.

When Miller and the emergency management team turned their attention to plant operation at about 7:45 a.m., the reactor coolant pumps were still off and reactor coolant system pressure was still fairly low at about 1500 psi. Pressure had increased to about 2100 psi at 7:00 a.m. following closure of the PORV block valve at 6:20 a.m., and in connection with the running of one reactor coolant pump from 6:54 to 7:13 a.m. The hot-leg temperatures were high at about 780° F, the cold-leg temperatures were low at about 300° F. Natural circulation was not working. The hot legs were vapor bound. The high-pressure injection pumps were injecting cold water, perhaps at reduced flow. Reactor coolant pressure was being kept low by intermittent venting of the pressurizer into the reactor building and, perhaps, by reducing high-pressure injection flow. Although it was not known at the time, subtle changes in several plant variables indicated that severe core damage and mechanical disarrangement had occurred by 7:45 a.m.

High-Pressure Injection Flow

An early decision made by Miller at approximately 8:00 a.m., was to allow the high-pressure injection system to continue functioning because not enough was understood about plant conditions to be sure it was safe to turn it off. Miller instructed Ross to leave the high-pressure injection system on and not secure it without his permission.[36] This decision followed a discussion by the emergency command team, who had initially decided to turn the system off. However, Miller then changed his mind and countermanded the decision within about 5 minutes. It was Miller's intention to allow the system to function, as it would have automatically, until plant conditions were better understood.

We consider this sound thinking. In general, it is good operating practice not to defeat safety devices while the actuating signal is still present or until it is thoroughly understood that the devices are not needed. It also appears that throughout the day the better chance for adequate core cooling lay with higher injection flow.

Miller did not specify the system alignment to be used or the minimum flow rate to be maintained. However, automatic operation would imply about 900 gallons per minute of net injection flow with full two-pump operation. (The exact flow rates would vary depending on reactor coolant system pressure.) The minimum automatic system capability would be about 450 gallons per minute, which corresponds to assuming that only one pump runs. Later in the afternoon, in response to questions from the control room, B&W recommended maintaining at least 400 gallons per minute. Miller depended upon the operators to choose the minimum flow to be consistent with this direction.

We have not determined highly accurate values for high-pressure injection flow rate during the day. It is apparent, however, that following Miller's instructions, the operators did maintain substantial net injection flow, well in excess of 450 gallons per minute, until the period of plant depressurization starting at 11:30 a.m. During the depressurization period, which lasted until 5:30 p.m., the net injection flow was considerably reduced.[20,37]

The operators had severely throttled high-pressure injection flow in the first few hours of the accident in an attempt to reduce pressurizer level to its normal operating range. The reasons for throttling the flow during the depressurization period are not so clear, but some possible contributing factors are discussed below.

The pressurizer level was still high—Intermittent attempts were made during the afternoon to draw a bubble in the pressurizer by turning on the pressurizer heaters. Apparently this did result in pressurizer level decreases at times. We do not, however, think the operators were throttling high-pressure injection flow at this time either to reduce pressurizer level or to draw a bubble in the pressurizer.

As discussed above, Miller had not been specific about what flow rate should be maintained. Zewe and others wanted to use the minimum flow rate that would still assure core cooling. Less flow would reduce the frequency of opening and closing the PORV block valve to maintain reactor coolant system pressure. The operators had been concerned about possible failure of the block valve under frequent cycling during the previous high pressure operating mode. In addition, the goal during this period was to reduce reactor coolant system pressure, which the reduction of injection flow could help, and which might also have contributed to a desire to use the minimum adequate flow rate. At the beginning of the depressurization period, the operators recalled first attempting to throttle high-pressure injection flow to about 225 gallons per minute, but since it was difficult to throttle to such a low value, they maintained flow at about 340 gallons per minute.[38]

In their testimony, the operators apparently concentrated on indicated high-pressure injection system flow rather than net injection flow (which would be approximately the high-pressure injection flow minus letdown flow). For example, Zewe and others recalled the total indicated high-pressure injection flow as being in the neighborhood of 340 gallons per minute during the depressurization period.[38] This figure appears to be close to the minimum automatic system capability (about 450 gallons per minute, or the B&W recommendation of at least 400 gallons per minute). On the other hand, borated water storage tank (BWST) level readings at 1:15 and 5:20 p.m. indicate, at most, a net injection rate of about 150 gallons per minute during this 4-hour period.

The operators were operating the letdown system throughout the day— This water came from the reactor coolant system and was recycled back into the system through high-pressure injection pumps. (Such flow would not have existed in an automatic operation.) If the letdown system flow was near its maximum flow rate of about 160 gallons per minute, that could eliminate most of the discrepancy between the estimated net injection rate of 150 gallons per minute and the operator's recollections of about 340 gallons per minute of high-pressure injection system flow.

Thus it is possible that the operators, seeking the minimum adequate flow, maintained a high-pressure injection system flow rate in the neighborhood of 340 gallons per minute, neglecting the letdown flow, which should be subtracted to obtain net injection flow. If so, it can be said on their behalf that the letdown water was cooled prior to recycling into the reactor coolant system and thus, letdown flow could be expected to contribute in some sense to core heat removal. This would have been true if the system was full of water and circulating the water through the core. However, the system was not full and the actual needs were either to replace lost reactor coolant inventory; to establish a cooling water flowpath from the high-pressure injection pumps through the core and out the pressurizer safety, relief, and vent valves; or to do both. For these purposes, it was net injection flow that was important. The net injection flow of about 150 gallons per minute was, for several hours, much less than the 1000 gallons per minute that the high-pressure injection system could provide.

There is the possibility of an operating error resulting in inadvertent cutbacks in injection flow— Attempts were being made during the afternoon to bias the high-pressure injection flow to the "C" injection path (that is, through valve MU-V-16C). One way to accomplish this would be to close valves MU-V-16A and "B" in the other two injection paths. If this were done, leaving only the "A" pump running (as was the case most of the afternoon), it would cut off nearly all flow. (This condition would occur provided valve MU-V-17 was in an automatic mode and closed because of a high pressurizer level signal, and provided the manual cross connect valves were shut as they should have been.) We do not believe that this potential error resulted in severely throttled high-pressure injection flow, at least not for long periods of time. Ross testified that when attempts were made to bias flow to the "C" leg, the "C" pump was started, which would then provide flow via valve MU-V-16C. Furthermore, if the flow were inadvertently reduced by such an error, the reduction would have been indicated on the high-pressure injection system flow meters at the very time the operators were adjusting the flow, and therefore the operators must have been reading the flow meters.

Other Early Actions

One of the emergency management team's first decisions was to restart a reactor coolant pump to establish forced cooling water flow through the core. One pump was started at 8:08 a.m., but was tripped by the operators in less than a minute because of low current and low flow, indicating that the reactor coolant loop was vapor bound. It was considered that continuing to run the pump in a vapor bound loop would not pump water through the core and might damage the pump, possibly causing a seal failure, which would create a small loss-of-coolant accident.

Early in the day the team established its priorities as (1) protection of the public, (2) covering and cooling the core, and (3) protection of plant personnel and equipment. Protecting plant personnel and equipment was actually second but cooling the core was the way to accomplish this.[39] We consider these reasonable, even in retrospect.

Miller requested readings from the incore thermocouples; instruments not intended or qualified for postaccident service of this sort. However, Miller believed they might give useful information about core cooling and perhaps confirm that natural circulation was working. Several readings were taken and reported to Miller by Ivan Porter. The readings varied from 80° to 2620° F. Because these thermocouples are all located in the same horizontal plane a few inches above the active core region, this range of temperatures, all at the same time, did not appear real. For this reason, and because the qualifications of the thermocouple for these conditions were doubted, Miller and Porter did not consider the readings reliable. Miller later told us they had to be considered reliable in the sense of indicating the possibility of high temperatures in the core, but not in the sense of indicating what the actual temperatures were. He did not recall discussing the readings with the emergency command team; however, he did later report on the general nature of the readings to Herbein with the caveat that they were probably not reliable. Porter also felt that the readings were unreliable and later told us that the hot-leg temperatures were a better and more reliable indication of core cooling conditions.

Many other thermocouple temperature readings were taken by the instrument technicians shortly thereafter, and were left in a book in the control room when unnecessary personnel were evacuated from the site. However, the book was not read by Porter or Miller. Further details on the handling of these thermocouple readings are provided later in this section of the report.

Decision to Increase Pressure

At approximately 9:15 a.m., Miller decided to increase reactor coolant system pressure. Pressure was raised to about 2100 psi by closing the PORV block valve to stop venting of the pressurizer. Pressure was then maintained at this level by intermittently (and frequently) opening the PORV block valve to vent the pressurizer. It was hoped that this higher pressure would collapse and condense the steam bubbles in the reactor coolant system.[40,41] Had this strategy been successful, the system would have refilled with water, and natural circulation or the reactor coolant pump operation could have provided cooling water flow through the core.

Aside from that, at least some consideration was given to the fact that this action, by itself, could establish a core cooling flow path from the high-pressure injection pumps through the core, out the PORV, and into the reactor building.[42] In either event, we believe the best chance for adequate core cooling lay with high-pressure injection flow. It appears that the operators did indeed maintain substantial injection flow. For example, the average net injection flow between about 8:30 and 10:30 a.m. is estimated to have been 640 gallons per minute.[20]

The strategy did not appear to be successful in condensing the steam bubbles because the hot-leg temperatures remained high, even though reactor coolant system pressure was maintained at about 2100 psi for more than 1½ hours. In addition, no significant amount of heat was being transferred to the steam generators. The lack of success was apparent; the reasons were not.

We consider this strategy to have been reasonable. A similar strategy did work later in the afternoon, after more gas had been vented from the reactor coolant system. The net injection flow at this time could have been somewhat higher, which might have given the strategy a somewhat better chance for success. It would have required more vigorous venting, possibly eliminating more hydrogen from the reactor coolant system and providing greater cooling water flow through the core. However, the net injection flow rate, if not at the maximum, does appear to have been substantial and well in excess of the minimum one pump design capabilities of the high-pressure injection system.[43]

It is possible the reactor coolant system was partly refilled with water in the cold legs (where the reactor coolant pumps are located) if not in the tops of the hot legs (where the hot-leg temperature detectors are located). If so, it might have been possible during this period at high pressure to establish effective core cooling by running a reactor coolant pump and obtaining partial flow despite the gas content. This had been done earlier in the day with considerable steam vapor and would be done again later that afternoon although considerable hydrogen remained in the system. No attempt was made to run a pump at this time. The general feeling was that, since it had been tried earlier without success, it would be futile to try again until the vapor binding in the reactor coolant loops had been eliminated. We have no criticism of this reasoning since there may have been too much gas in the system at that time for successful reactor coolant pump operation.

As indicated by the hot-leg temperature, the strategy was not successful in completely freeing the system of gas, at least in the time allowed it, because the core was very hot; producing steam, hydrogen, or both, from water contacting the hot portions. This would tend to keep the system full of gas and cause water flow to bypass the hot portions of the core on its way to being vented from the pressurizer. To the extent that the gas was hydrogen, it could not be condensed; nor could any steam that remained hotter than about 642° F be condensed at the 2100 psi pressure.

Even if the operating staff had realized that the core was badly damaged and that there was considerable noncondensible gas in the system, they did not have a cooling system that had been specifically designed to work under those circumstances. Emergency core cooling systems are, instead, designed to actuate rapidly and automatically to prevent such overheating, damage, and hydrogen generation. (We are not saying these systems will or will not cool cores damaged to various degrees. Rather, since they weren't designed to do so, we don't know to what extent they can be effective.) No prior consideration was given to which strategies would provide the best chance of cooling a damaged core. Thus, the operating staff would have had to improvise on the spot even if the nature of core damage had been correctly understood.

Furthermore, aside from damaged core consideration, there was no specific procedure or system design for cooling even an intact core under these circumstances (reactor coolant pumps not available and natural circulation blocked). Here, the design philosophy was similar. If the reactor coolant pumps became unavailable, natural circulation was designed to work and cool the core, preventing steam formation and the consequent blockage of natural circulation.

Decision to Depressurize

At about 11:00 a.m., it was decided to depressurize the reactor coolant system. The pressurizer was vented into the reactor building, reducing reactor coolant system pressure to about 500 psi. Intermittent venting continued to maintain a low pressure until about 5:30 p.m. Throttled high-pressure injection flow was maintained.

A primary reason for changing the strategy was the apparent lack of success in filling the reactor coolant system with the previous high pressure strategy, since the hot-leg temperatures had remained high. There was also concern that injection flow had been bypassing the core on its way to the PORV (a concern that continued throughout the day) and the related concern that the core might be uncovered. Finally, there was concern that the PORV block valve might fail under the frequent cycling in the previous operating mode.

Several accomplishments were expected from the new strategy. The most frequently cited was the expectation that the core flood tanks would aid in core cooling. The two core flood tanks are water accumulators maintained at 600 psi by compressed nitrogen volume on top of the water. They are connected to safety injection nozzles in the reactor vessel above the core. In the event of a large loss-of-coolant accident, the tanks are designed to rapidly inject cold water through check valves when the reactor coolant system pressure drops suddenly below 600 psi.

It was expected, therefore, that if the core was not covered, the flood tanks would inject water when reactor coolant system pressure dropped below 600 psi. On the other hand, if the core was covered, the lack of injection was expected to demonstrate that this was the case. This theory sounds reasonable on the surface, but it was incorrect.

When the system pressure is dropped to 500 psi by venting, only about 8% of the core flood tank water can be injected through the existing loop seal piping arrangement—enough to drop the nitrogen bubble pressure to 500 psi. If another piping configuration had been used whereby piping ran continuously downward from the core flood tank to the safety injection nozzles rather than through a loop seal, all the water could have flowed into the reactor vessel with gas bubbling up into the core flood tank. However, that configuration was not used in this plant. (The loop seal would not adversely affect the intended function of the tank, which is injecting water during a large pipe break accident. It only became significant in these particular circumstances.)

When a drop of only about a foot in tank level was noticed it was taken to be confirmation that the core was covered. On the contrary, the drop corresponded approximately to the amount of water discharge that could be expected under these conditions.

Later, after the initial blowdown to 500 psi, the pressure rose a bit above 500 psi and the operators vented more vigorously trying to reduce the pressure further. (The PORV was open for more than an hour, with the pressurizer vent valve also open during the last half hour). The pressure dropped only to 440 psi, probably being held up by gas heating, steam generation in the hot core, or both. After that they vented only intermittently, allowing the pressure to drift up to about 650 psi at 5:30 p.m.

A second expectation was that, if pressure could be reduced much below 400 psi, the decay heat removal system could be run. This low pressure system is normally used for core cooling after the reactor coolant system has been cooled and depressurized. It was not used that day because the pressure did not get low enough.

Another expectation held by several key people was that the pressurizer venting, in combination with high-pressure injection flow, would create a cooling water flow path through the core. This was a reasonable expectation. The hot, damaged core would tend to force more flow to bypass it and go through other pathways on the way to the PORV than would an intact core. As with the previous high pressure strategy, the best chance for adequate cooling by this method would have been with maximum injection flow. Ample high-pressure injection flow would tend to keep the pressure up, competing against the aims of the other two methods. In any event, injection flow was severely throttled.

Finally, this strategy, which addressed concerns about failure of the valve from frequent cycling, did reduce the frequency of cycling the PORV block valve.

In evaluating the depressurization decision, we recognize that the emergency command team was faced with an apparent lack of success in ensuring core cooling through natural circulation and therefore had a need to do something different. The team was also handicapped by the lack of an effective system or procedure for meeting these circumstances. However, because the decision to depressurize was heavily based on the incorrect theory that the core flood tanks would ensure core cooling if the pressure were lowered, we cannot consider it a reasonable decision. Apparently, various people involved either did not know of the loop seal piping or did not understand what its effect would be, or, if these factors were understood, did not consider how little water would be injected by the reduction of pressure.

The second expectation—reducing pressure enough to allow operation of the decay heat removal system—was not unreasonable in that it might have worked if the system had been cool and solid. However, it was not feasible with the large gas content; the existing system vent capacity; and the hot, damaged core. The core was apparently producing enough steam from water that contacted it to maintain system pressure above 440 psi, even when all the available vent valves were open. (Alternately, the water may have been converted to hydrogen in the hot core, but the volume increase would be about the same in either case.)

The third expectation—to establish cooling water flow from the high-pressure injection point to the pressurizer vent points—was reasonable. To a degree, however, it was inconsistent with the other aims. Ample high-pressure injection flow would give the best chance for success with this method, which is inconsistent with the throttling of high-pressure injection flow that occurred.

This depressurization may have contributed to the success of a later high pressure strategy by venting additional hydrogen from the system. This was done by the initial blowdown and it was not necessary to continue it for 6 hours.

f. Offsite Activities

Met Ed Headquarters Activity

Richard Klingaman of the Generation Division at Met Ed Headquarters in Reading, Pa., was informed of the site emergency at about 7:00 a.m. He and George Troffer, also of the Generation Division, informed numerous company staff and management personnel, including Creitz and Arnold.

For the rest of the day (March 28) and during the following day (March 29), Generation Division personnel in Reading primarily performed communication functions. They received several reports from the plant site and reported the status to company staff and management personnel. Occasionally, messages were relayed from organizations that were having difficulty contacting the control room. Many calls offering outside assistance were received.

During the evenings of March 28 and March 29, Generation Division personnel in Reading assisted company public information personnel in answering public inquiries about plant status. The public inquiries were primarily from the press and from concerned citizens.

The Generation Division personnel in Reading did not influence decisions on plant operations for a variety of reasons. Klingaman told us that the reports from the plant summarized the plant status and outlined the planned actions rather than providing data upon which an independent diagnosis could be made. Miller said that these reports were intended to convey information that could be passed on to others rather than to obtain assistance or advice. Generally, the planned actions appeared reasonable at the time and thus, did not impel the Generation Division personnel to question them. Finally, by 11:40 a.m., Herbein, who was the head of the Generation Division, was at the plant.

Herbein Activities

Throughout the day, Miller and Herbein had several discussions about plant operations. Their testimony generally includes few details concerning those discussions where Herbein concurred with Miller. More information is available concerning the issues where Herbein made a decision contrary to Miller's recommendation.

At about 9:30 a.m., Herbein was told by Creitz to go to the site. He left Philadelphia by helicopter at about 11:00 a.m. and arrived at the Observation Center at about 11:40 a.m. He discussed the emergency by telephone with Miller and remained at the Observation Center until about 1:15 p.m., when he met the press on the lawn outside. After this press conference, at about 2:00 p.m., Herbein left for a briefing of Lt. Gov. Scranton in Harrisburg with Miller and Kunder.

Since about 10:00 a.m., the plant staff (emergency management team) had been maintaining a high reactor coolant system pressure (between 2000 and 2100 psig) by injecting water with the high-pressure injection system, and venting from the pressurizer as necessary to maintain pressure within this band. At about the time Herbein arrived at the center, the decision was made to depressurize the reactor coolant system to enable the core flood tanks to inject water and possibly to allow operation of the decay heat removal system. Herbein believed he was informed of this decision and concurred. This basic mode of operation was to continue until Herbein and Miller returned from the Lieutenant Governor's office at about 4:30 p.m.

In the first telephone conversation at the Observation Center, Herbein recalled being told that the radiation readings in the reactor building had required the declaration of a general emergency and he was briefed on the status of the plant. He recalled being under the impression that some fuel had failed, the core was covered, natural circulation was working, safety systems were working, and the radiation levels around the plant were very low.[44]

Herbein may have been told of steam bubbles in the hot legs.[45] He probably learned of the hot-leg temperatures and the initial set of core thermocouple readings sometime later in the day.[46]

Herbein did not learn of the containment pressure spike that occurred at 1:50 p.m. until it became general knowledge on Friday morning.[47] He was probably unaware on Wednesday that the PORV had failed to close. This can be assumed since Miller, his source of information, was not aware of it, and until Thursday afternoon or later Herbein was unaware that high-pressure injection flow had been severely cut back.[48,49]

During this first period at the Observation Center, Herbein made two significant decisions that were, in essence, contrary to the advice and recommendations of the plant staff: the decision to stop discharging steam to the atmosphere and the decision to take Miller and Kunder to the briefing of the Lieutenant Governor. These decisions are discussed in the following sections.

g. Decision to Stop Discharging Steam (1:15 p.m., March 28)

Background

Herbein's decision to stop discharging steam to the atmosphere warrants discussion. This action appears at first glance to be questionable because it deprived the operators of what would normally be the heat sink for core cooling when the main condenser is not available. However, upon closer examination the decision does not appear unreasonable.

The direction to stop discharging steam to the atmosphere was given at about 1:15 p.m. Since 11:40 a.m., the operators had been following a strategy of venting from the pressurizer to lower reactor coolant system pressure. In connection with high-pressure injection flow it was believed that this venting would provide cooling water flow through the core. It was also hoped that the lower pressure would allow the core flood tanks to inject water to provide confirmation of core coverage and possibly allow operation of the decay heat removal system. In addition, at that time the operators were discharging steam from the secondary side of the steam generators to the atmosphere, hoping to further cool the steam generators and establish natural circulation flow on the primary side, which is the normal means of providing core cooling flow under these circumstances.

Herbein had heard of releases of radioactive materials off site, which he wanted to stop; and of generator tube leakage, which indicated that the steam discharged to the atmosphere might be a source of the release. Miller at first objected to stopping the discharge on the grounds that it would deny him the heat sink for core cooling. He was also convinced that this steam was not the source of offsite releases. Eventually, Miller gave in and stopped the discharge.

Apparent Concern

We have evaluated this decision primarily because it would appear, at first glance, to be questionable; eliminating what is normally the heat sink for core cooling.

Following a reactor shutdown without a loss-of-coolant accident and before the reactor coolant system has been cooled and depressurized to allow operation of the decay heat removal system, decay heat is removed from the core by running the reactor coolant pumps to force reactor cooling water through the core. If the reactor coolant pumps are not available, as was the case here, natural circulation flow in the reactor coolant system is utilized. In either case, the heat is transferred to the steam generators and is in turn removed by discharging steam from the secondary side of the steam generators to the main condenser. If the main condenser is not available, as was also the case here, the heat is removed by discharging this steam to the atmosphere through the atmospheric dump valves.

Natural circulation in the reactor coolant system consists of reactor cooling water being heated in the core, rising to the hot-leg piping, and flowing to the steam generator. There it is cooled, sinks to the cold-leg piping, and flows back to the core. When attempting to establish natural circulation, as the operators were doing here, it is important to cool the steam generators by adding feedwater to the secondary side and by discharging steam from the same side. This cooling, along with heating in the core, provides the thermal driving head for natural circulation flow on the primary side (the reactor coolant system).

If natural circulation flow has been deficient (or the reactor coolant system pressure has been low) allowing the generation of steam bubbles, those steam bubbles tend to block natural circulation flow. This is the case that existed in the plant. Among other things, in this case one would want to cool and fill the secondary side of the steam generator as much as possible by injecting feedwater and discharging steam, hoping to condense enough steam on the primary side to reestablish natural circulation flow. This is what the plant staff wanted to do.

At the time it was decided to stop discharging steam to the atmosphere the main condenser was unavailable for dumping steam because condenser vacuum had been lost. Discharging steam to the condenser without vacuum would overpressurize it. As it later turned out, the operators were left without a steam discharge path for several hours until condenser vacuum had been reestablished.

The methods discussed above are the only accepted, analyzed, and qualified methods for core cooling, for normal operations, and—prior to cooldown and depressurization of the reactor coolant system—for conditions permitting decay heat removal system operation. Thus, this decision appears to deny the operators the only accepted method of core cooling available—feeding and discharging steam from the secondary side of the steam generators, to the maximum extent possible to establish natural circulation flow on the primary side. Furthermore, this was done to stop the discharge of steam that did not contain significant quantities of radioactivity.

Another apparent concern was the impression expressed by some plant staff personnel, that the decision resulted largely from heavy pressure by the State Government to eliminate the visible steam plume that resulted from dumping steam to the atmosphere. If true, that would represent a dangerous precedent, but we found no evidence that this was the case.

Actual Core Cooling Situation

When the decision to stop discharging steam was made, plant conditions were highly abnormal and nothing was lost by securing steam discharge. At that time, both steam generators were fairly full and cold and they remained that way throughout the afternoon. This indicates little heat transfer from the primary to the secondary sides because the primary sides of the steam generators were full of steam and hydrogen. This mixture was indeed blocking natural circulation flow. The substantial amounts of noncondensible hydrogen (unknown at the time) could not be condensed to help unblock natural circulation flow. Also, since the steam generators remained full and cold anyway, additional steaming to cool them further would have produced very little additional thermal driving head to condense steam and promote natural circulation.

The alternate method of core cooling that Herbein discussed with Miller was high-pressure injection flow into the reactor coolant system combined with venting from the pressurizer into the containment, hopefully establishing a cooling water flow path across the core. This is, in effect, creating a small LOCA so that the high-pressure injection system can cool the core. This method had not been analyzed, reviewed, accepted, qualified by testing, nor included in procedures as had the other, accepted methods discussed above. However, it was well known as a possible backup method in the event that steam generator cooling should fail. The alternate method was at least as reasonable as the accepted method—natural circulation—which was not working and could not be made to work by discharging steam.

Herbein recalled believing at the time of the decision that natural circulation was not working very effectively to cool the core because of steam binding in the hot legs.[50]

Other Factors

Herbein had learned about radiation levels above normal background values, which indicated some offsite releases, and believed that the steam discharge could be the source. He suspected this because he was aware that a primary to secondary leak had been identified earlier in the day.[51] Miller, on the other hand, was more convinced that the steam discharge was not the source of the releases of radioactive materials.[52]

Upon securing the discharge to atmosphere, one would expect the operators to establish condenser vacuum and dump steam to the condenser. Any radioactive materials released from the condenser would be processed through charcoal adsorber units, removing most of the material prior to releases to the atmosphere. This would then provide a steam discharge path with far lower release rates in case the steam was the source of the releases of radioactive materials. The operators set out to do this but, as it turned out, they ran into problems and it took several hours to establish this discharge path.

Herbein had been made aware by someone that there was pressure from the State Government to stop discharging steam. He had no conversations himself with State Government personnel. Believing that this was a factor to be considered, Herbein discussed it with Miller but made the decision primarily in an attempt to stop the releases of radioactive material.[53]

Although many people in the control room had the same impression of State pressure to stop discharging steam, we did not run across any direct knowledge of where this impression originated. One NRC inspector did recall urging such action. However, it doesn't really matter where this impression originated. As Herbein stated, if the State had a concern, it would have been the same concern that motivated him as he balanced various factors—to stop the releases.[54]

Summation

On balance, we do not believe the decision to stop discharging steam was unreasonable.

h. Key Personnel Leave for Harrisburg (2:00 p.m., March 28)

Background

Another action warranting discussion was Herbein's decision to go to Harrisburg to brief Lt. Gov. Scranton, taking key personnel with him. To the extent that it involved removing Miller and Kunder from the plant, the action was, in essence, contrary to Miller's initial recommendation. Miller eventually did acquiesce, and along with Kunder and Herbein left to brief the Lieutenant Governor in Harrisburg shortly after 2:00 p.m. They returned to the site about 4:30 p.m.

The request for a briefing had come earlier from Lt. Gov. Scranton to Creitz. Creitz decided that Herbein would be the appropriate individual, and told Herbein to attend the briefing.

To our knowledge, the Lieutenant Governor did not have reason to think that he should not be briefed because the company personnel were more urgently needed at the plant to set up core cooling. The Met Ed public statements and Miller's telephone briefing of the Lieutenant Governor had not indicated such a situation. In any event, we are not evaluating Lieutenant Governor Scranton's decision to request a briefing because we believe the responsibility for recognizing the plant situation and, if necessary, either refusing the request or sending someone else rested with the company.

The action was questionable because Herbein, Miller, and Kunder absented themselves from the plant for about 2½ hours at a time when the core had been badly damaged and was not effectively cooled. Moreover, there was confusion, an accurate diagnosis of the true situation was lacking, and a hydrogen burn had just occurred. On the other hand, not all of this was understood at the time, numerous qualified people were available to run the plant, and communications were maintained during their absence.

Plant Status

At the time that Herbein, Miller, and Kunder left, the operators had been following a strategy of venting from the pressurizer to lower the reactor coolant system pressure. It was intended that this would provide cooling water flow through the core, in conjunction with high-pressure injection flow. In addition, it was hoped that the lower pressure would allow the core flood tanks to inject water providing confirmation of core coverage and, possibly, allow operation of the decay heat removal system.

A hydrogen burn occurred in the reactor building at 1:50 p.m., shortly before Miller's departure. This burn resulted in a 28-psi pressure spike and starting of the containment spray pumps. Miller recalled hearing a thud at this time, but not being aware of the pressure spike or of the containment spray pumps running.

Prior to leaving, Miller noticed a small drop in core flood tank levels and some change in reactor coolant temperature, which he considered to be indications of success for the core cooling strategy. Later, as the lowered hot-leg and increased cold-leg temperature indications became more pronounced, they were attributed by Ross to biasing injection flow to the "C" leg, and by Chwastyk to drawing a bubble in the pressurizer.

Reasons for Leaving and Precautions Taken

Herbein was under the impression that firsthand knowledge had been specifically requested by Lt. Gov. Scranton, and he felt it was necessary to take someone from the plant staff with him.[55] Miller initially objected but then directed Kunder to gather data on plant conditions and to accompany himself and Herbein to Harrisburg.[56]

Miller and Herbein stated that there were numerous qualified people available in the plant at that time. Logan was left in charge with instructions to maintain the status quo. The emergency management team had been set up and had been functioning for several hours. NRC and B&W representatives were on site.

Miller took a telephone beeper so he could be paged, if necessary, during the trip. If needed, he would be only about 20 minutes away. Once at the Lieutenant Governor's Office, telephone contact with the control room was established and maintained.

Drawbacks of Decision

We know now that the basic problem with key personnel leaving at that time was that things were confused, the true situation in the plant had not yet been diagnosed, and effective corrective actions had not yet been prescribed. Thus, if these key people had stayed, it might have helped to alleviate confusion or to arrive at effective corrective action sooner.

There were numerous people in the control room, and they had to wear respirators at various times during the day. These factors alone tended to create confusion.

It is difficult to conclude, from interviews and depositions, that there was a coherent plan for core cooling in effect during the absence of the key personnel, other than to maintain the status quo. For example, Chwastyk, who was in charge of the control room, was attempting to draw a bubble in the pressurizer and attributed the reactor coolant temperature responses to these actions. Chwastyk's action was unknown to Ross, who was in charge of overall operation and a member of the emergency management team. Ross, meanwhile, believed that attempts to bias high-pressure injection flow to the "C" leg were the significant actions and attributed the temperature response to this. Logan and Rogers do not recall any plan other than to maintain the status quo.

Chwastyk recalls diagnosing the containment pressure spike as an explosion associated with venting the pressurizer, and of so informing Miller prior to his departure. Ross, while not thinking of the pressure spike as an explosion, did realize that the pressure spike had occurred and the containment spray pumps had started. He discussed the noise with Miller and believed that Miller also knew that the pressure spike had occurred and the containment spray pumps had started.

Miller, however, recalled only asking about the noise and being told that it was probably caused by a ventilation damper. He did not recall being aware of the pressure spike or the containment spray pump operation, much less of the diagnosis of an explosion. Nor did Herbein recall Miller informing him of these occurrences. These events would all have taken place shortly before Miller left for Harrisburg. If the confusion and rush of leaving was a reason why some of this information did not reach Miller, as it could have been, then leaving was certainly a drawback.

Possible Consequences

At about 2:30 p.m., Arnold called the control room to express concerns as to whether the primary system was solid. He spoke to Rogers who said that the conclusion of the emergency management team was that the core had always been covered.

The decision to repressurize and then to run a reactor coolant pump was made by Herbein, in consultation with Arnold, at about 4:30 p.m. upon his return from Harrisburg. At best, if Herbein had not gone to brief the Lieutenant Governor, he might have brought about this decision sooner. For example, if he had discussed matters with Arnold at about 2:30 p.m., Herbein might have reached the decision at that time. Because massive core damage had already occurred by the time Herbein left, however, it does not appear that reaching this decision 1 or 2 hours earlier would have materially altered the physical course of the accident.

One can speculate that, had Miller stayed, he might have recognized the containment pressure spike, and either understood its significance or informed others who might have comprehended its significance. If the significance of this event had been generally conceived on Wednesday, one can further speculate that in the next few days the overall situation would have been safer because (1) actions to handle the hydrogen bubble would have been taken sooner, shortening the time that this presented a potential threat to continued core cooling and (2) contingency planning would have been implemented faster, reducing the risk involved.

Summation

Although it did not materially worsen the physical course of the accident, on the basis of what we now know, the decision to leave the plant does not appear sound because the true plant situation had not been diagnosed and effective corrective action had not been prescribed. On balance, we believe that it was poor judgment for the two top management personnel at the site to depart when there was no overwhelming evidence that the plant was being cooled down effectively. Ample evidence of uncertainty and doubt apparently also exist in the minds of others in the control room. The leader's place is at the source of the problem until it is completely resolved. The judgment to leave may be another case of not wanting to believe bad news. Full preparation and planning, particularly of communications with appropriate offsite officials, could have avoided the accident's severity.

I. General Public Utilities Service Corporation (GPUSC) Activities

Background

Robert Arnold at GPUSC, the company's primary pool of engineering expertise, was informed of the plant trip at 7:59 a.m. Arnold subsequently held several discussions with his staff and by telephone with company personnel at the plant. Although GPUSC had no formal responsibility for plant operation, the GPUSC personnel became very concerned as they found out more about the plant status. Eventually, at about 4:30 p.m., they recommended to Herbein to repressurize the plant. Herbein agreed and directed that it be done. This action, along with the subsequent starting of a reactor coolant pump, resulted in a stable core cooling mode that was maintained for about 3 weeks.

Chronology

Arnold was notified of the emergency in a brief telephone call from George Troffer, Met Ed Manager of Quality Assurance, at about 7:59 a.m. He was told the following: that there had been a turbine and a reactor trip, there appeared to be a primary to secondary leak in the B steam generator, there were increased radiation levels in the reactor building and a site emergency had been declared.[57] Arnold was under the impression that the site emergency had been declared because of the steam generator tube leak, however, he was unaware of the very high reactor building dome monitor radiation reading and the declaration of a general emergency. At the time, Arnold did not suspect any continuing problem with core cooling.[58]

Within about ½ hour Arnold discussed the plant trip with Creitz and Herbein and decided to send a team of five engineers to the site. The purpose of a team of engineers going to the site was to review the plant history and initiate the investigations that normally follow such a plant trip before returning the plant to power; however, they were not to assist in bringing the plant to a safe condition.[59] It was apparent that the information would be better obtained at the site than by telephone.

The team of five engineers left, and individual GPUSC members began arriving at the site at 2:00 p.m. Upon arrival, they began to gather data on what had happened.

Meanwhile, Arnold probably learned that the reactor coolant pumps were off during his first conversation with Herbein, shortly after 8:00 a.m.[60] Between approximately 10:00 and 10:30 a.m., Arnold and his staff discussed the situation with personnel in the control room. At this time, they learned of the very high containment dome radiation monitor reading. Arnold recalled suspecting there was a moisture problem with the instrument, causing the high reading. He retained this impression for days.[61,62] Wilson, on the other hand, did not recall discussions during the day where this reading was dismissed as erroneous or not meaningful.

At about this time, Arnold began to suspect that some fuel damage had occurred. He was informed by Troffer at about 11:45 a.m. that offsite releases had been detected.[63] By about 2:00 p.m. Arnold's staff told him of their concern that the reactor coolant system was not filled; that is, there was a steam bubble in the system outside the pressurizer, implying that the core was uncovered or was not being cooled effectively. Arnold recalled that this was based on data his staff had obtained independently from the plant rather than through himself.

In a telephone conversation shortly after 2:00 p.m., Arnold expressed concerns to Rogers in the control room about steam in the reactor coolant system, implying an uncovered core. Rogers responded with the plant staff's conclusion that the core was covered. Arnold did not believe that this was unreasonable.[64] At the time of this call, Miller and Herbein were briefing Lt. Gov. Scranton in Harrisburg.

After the call, Arnold's staff further discussed their concerns with him. In particular, they emphasized concern that steam bubbles in the system may not have been collapsed. These conversations increased Arnold's concern and he decided to press more forcefully for corrective action. Arnold later spoke with Herbein and emphasized the corrective action recommended by his staff. Although Arnold was now very concerned about steam in the system and a possible uncovered core, it did not cross his mind that a metal-water reaction had occurred or was proceeding.[65]

Inputs to Arnold

Wilson became concerned about core cooling around 10:00 a.m. when he learned that the reactor coolant pumps were off. He called Keaten from a meeting to discuss the situation. Keaten also recalled being concerned about core cooling and the efficacy of natural circulation from the time he found out that the reactor coolant pumps were off. Sometime later, probably in the afternoon, he found out that the hot-leg temperature indicator was pegged high. A brief analysis indicated superheated steam, implying the likelihood of a steam bubble, an uncovered core, and failure of natural circulation. He remembered drawing curves in Arnold's office to illustrate the point.

Wilson did not recall a consensus during the day on what action should be taken, but did recall that he and Keaten always felt that the reactor coolant pumps should be run to establish forced cooling flow. Wilson and Keaten did not recall being aware of the operators' plan to establish core cooling water flow from the high-pressure injection pumps, through the core and out of the pressurizer relief or vent valve.[66,67]

In addition, B&W headquarters probably had some influence on the thinking at GPUSC. B&W personnel had found out that high-pressure injection flow was throttled and the hot-leg temperatures were high. They were trying to get their recommendation to increase the injection flow to the control room. Deddens of B&W recalled calling Arnold at about 2:00 p.m. and again at about 4:30 p.m. with this recommendation. Although he did not dispute these conversations, Arnold did not recall them.

Summation

GPUSC, along with Herbein, played a vital role in establishing a stable core cooling mode on the afternoon of March 28. Like Herbein, the GPUSC personnel had no specific assigned responsibilities for emergency response, and were even further removed from responsibility for plant operation. Regardless, they did become involved as they found out more about the plant status.

The GPUSC participants uniformly stressed in their interviews that they were severely hampered by a lack of timely and accurate data concerning plant status. Indeed, although their afternoon recommendations and diagnoses turned out to be appropriate, they have stated that they had such meager data that they were not at all certain of the best course of action. Among the contributing factors were the nature of the reports from the control room and a reluctance to take the operators' time by asking for additional data, both of which could be resolved by planning for offsite diagnostic support.

j. Decision to Repressurize

At about 4:30 p.m. on March 28, Herbein, Miller, and Kunder returned from Harrisburg. Arnold discussed plant operation with Herbein and strongly recommended that the plant be repressurized and that a reactor coolant pump be started. They agreed on this course of action and Herbein agreed to direct the plant staff to carry it out. Herbein recalled steam in the hot legs and the lack of success in an earlier attempt to depressurize and operate the decay heat removal system as major reasons for the decision. Arnold also recalled that an important consideration was the desirability of returning to a mode of operation that they understood well.[68] Herbein imposed this decision on Miller and the plant staff who favored continuation of the low pressure strategy. The decision constituted a positive contribution by management in that it established a stable core cooling mode that would be maintained for about 3 weeks.

k. Wednesday Night, March 28

In the evening of March 28, after a reactor coolant pump was started, personnel at GPUSC headquarters felt that the accident had been terminated and was under control. GPUSC personnel generally were aware that there had been problems with core cooling and abnormal radiation readings, so they had to be aware of the possibility of some core damage. However, they have stated that they did not understand the severity of what had happened. Because they went home at about 9:00 p.m. Wednesday evening and on Thursday occupied themselves primarily with organizing an investigation and analysis program, their actions bear this out.

GPUSC personnel had been aware of hot-leg temperatures of more than 600°F during the day, and correctly inferred that this implied superheated steam and an uncovered or inadequately cooled core. Knowing this, one could then deduce that the core might possibly have reached much higher temperatures (above 2000°F) that could cause physical disarrangement, significant hydrogen generation, or both; that is, a metal-water reaction. Arnold stated that this possibility did not cross his mind and we have found no evidence that anyone else at GPUSC headquarters was thinking in these terms.

GPUSC personnel were not aware of an initial set of core thermocouple readings that could have prompted them to think in terms of severe core damage. This initial set of several readings included those as high as 2400°F and as low as 200°F, all in the same horizontal plane a few inches above the core. Such variations seemed quite inconsistent and thus, the readings were suspect. However, they did contain a direct suggestion of a very hot core, and if known might have prompted thinking in terms of possible severe core damage.

GPUSC personnel were aware of the containment dome radiation monitor reading, which was very high. Upon reflection or calculation, comparing this reading to predicted readings for design basis accidents could have indicated that, as a minimum, a substantial fraction of the fuel cladding was breached—but not necessarily that the core had undergone extensive physical disarrangement. Arnold believed the reading was probably caused by a moisture problem, partially because the indicated radiation levels were so high as to seem incredible. He retained this impression for days.[69] Wilson did not recall others dismissing the reading, but neither did they make the connection with a significant fraction of fuel rods being breached.

GPUSC personnel probably were not aware of a related matter—a projected dose calculation that had been made at the site. The calculation, following prescribed procedures, was based on the containment dome monitor reading and an assumed containment leak rate. It then projected dose rates greater than 10 R/h off site, a startling and unbelievable figure. Of course, this was merely a reflection of the radiation monitor reading and the assumed leak rates. The dose rates were checked by field measurements and the high values did not materialize because the containment was not leaking as much as had been assumed in the calculation. However, knowledge of the result of the calculation might have emphasized how startlingly high the dome monitor reading was and possibly could have led to further consideration of it.

GPUSC personnel were not aware of the leaking PORV and the throttling of high-pressure injection flow, which had caused the core damage. Nor were they aware of the containment pressure spike (hydrogen burn) that had occurred. The personnel were also unaware of the offsite radiation releases and probably not aware of specific radiation readings in the plant that qualitatively could indicate that the containment dome monitor reading might be correct.

Herbein was in a similar situation. He recalled his impressions as the following:

> I think we felt a lot better because forced circulation had been restored. We had hoped to go ahead and cool the system down with the reactor coolant pump and operating steam generator to the point where we could consider going over onto the decay heat. I think, we recognized we did have fuel damage and that there might want to be a more in-depth look at the implications of going over onto the decay heat system before we actually made the switch.[70]

Herbein was aware of the initial set of core thermocouple readings, which Miller had reported along with the caveat that they were probably not very reliable.[46] This lack of understanding of the extensive nature of core damage extended in essence to the NRC, B&W, and the plant operators as well as company management and staff. It continued until late Thursday night to Friday morning.

The core was physically disarranged and to a large extent this tended to block cooling water flow. The reactor coolant system contained significant quantities of hydrogen, which also tended to block cooling water flow. The situation was markedly different than it would have been with a basically intact core and some fuel rod cladding perforations. These factors seriously threatened continued core cooling in the event that the reactor coolant pumps were lost or the system pressure decreased. Hydrogen also could possibly present an explosion hazard when vented into the reactor build

Measures that could be taken to reduce this risk were not taken until later when the risks were understood. These measures include the following:

- Procedures could be developed to guide the operators into the best course of action in the event of various malfunctions.
- Precautions against both decreasing system pressure and against causing a hydrogen explosion could be taken.
- Contingency plans for early warning on a possible need for evacuation could be made.

As it turned out, core cooling was maintained and no further uncontrolled hydrogen burns occurred. Thus, although the lack of understanding increased the risk, the only effect on the course of the accident was to delay recovery.

This matter also affected the public perception of the accident, in that earlier reports indicated that things were pretty well in hand and later reports indicated considerable hazard.

I. Thursday, March 29

On Thursday the plant operators were still running a reactor coolant pump for forced cooling water flow through the core. The core was not cooling down as expected because it was physically disarranged and there was a substantial amount of hydrogen gas in the system. The makeup pumps were running to provide seal injection water to the reactor coolant pump seals, and the letdown system was operating to recycle this makeup water rather than depleting the inventory in the borated water storage tank (BWST). Radioactive gas from the reactor coolant system was accumulating in the makeup tank as a result of letdown system operation. This basic mode of operation would continue for many days.

Beginning Thursday night, when the noncondensible gas content of the reactor coolant sytem was recognized, the operators intermittently degassed the system by spraying coolant into the pressurizer and venting the gas from the pressurizer to the reactor building. However, the majority of the gas was removed from the reactor coolant via the letdown system.

During the day on Thursday, Herbein had a heavy schedule of briefing the press and other public figures. He recalled the following activities:

7:30 a.m.	-	Taping Television show
10:00 a.m.	-	Press Conference
About noon	-	Briefing members of the Public Utilities Commission
About 2:30 p.m.	-	Briefing a congressional delegation
Later	-	Briefing another congressional delegation[71]

Such activity obviously presented a problem with respect to gaining a better understanding of true plant conditions. Herbein stated that he had believed it was a problem, but also something that must be done.[72] As with the Lieutenant Governor's request for a briefing on Wednesday afternoon, we are not evaluating the decisions by the press and public officials to seek information. To our knowledge, they did not have reason to think that they should not be briefed because company officials were needed at the plant to assess the true situation. In our view, the responsibility for recognizing this need rested with the company.

Herbein recalled checking periodically on plant status, authorizing a reactor coolant sample, and discussing the need for resources at the site with Miller and GPUSC. Arnold's primary emphasis on Thursday was on organizing the investigation, analysis, and recovery effort. He found out from the GPUSC engineers at the site that high-pressure injection flow had been cut back and discussed this with Dieckamp at about 11:00 a.m. This helped explain the radiation readings that indicated core damage. If the high-pressure injection system had been allowed to function automatically, they would not have expected core damage.[73] Arnold and Dieckamp also discussed their belief that Herbein did not know of this as yet. Their perception of core damage at that time was cladding perforations in perhaps 0.5% or 2% of the fuel rods.

Keaten spent time organizing the investigation, analysis, and recovery. It was decided to send Wilson and additional personnel to the site. Wilson would lead the investigation, which would be more formal than what had been envisioned on Wednesday. Wilson arrived at the site at about 2:00 p.m., and at about 5:00 p.m. he met with Miller and others to discuss the investigation.

One of the subjects of discussion was Wilson's desire to proceed quickly with operator interviews. After this meeting, Wilson recalled concluding that the situation was worse than had been previously thought and that as much assistance as possible should be obtained in bringing the plant under control. As Wilson recalled, this conclusion was not based on specific evidence of the plant's condition such as the core thermocouple readings, the hydrogen burn, or the noncondensible gas bubble in the reactor coolant system. He did not know about these things at the time. Rather, the conclusion was based on general indications such as the need to wear respirators on site, the lack of progress in cooling down, Kunder's request for engineering assistance in the control room, some understanding by GPUSC engineers of the initial stages of the transient, and perhaps, Miller's feeling that the recovery was not sufficiently complete to allow operators to be interviewed. Wilson recalled conveying his impression that the situation was worse than previously thought and that both Arnold and Vollmer of the NRC needed a great deal of assistance on Thursday evening.[74]

Arnold recalled being told of the possibility of significant core damage; but until he came to the site on Friday morning he did not realize the extent to which the plant was in an unstable condition.[75] Vollmer recalled agreement that most of the fuel pins had probably leaked.[76]

Thursday evening, personnel in the control room suspected that there was a noncondensible gas bubble in the reactor coolant system. They began determining the bubble's size and requested calculations concerning its nature.[77,78] Sometime Thursday night or Friday morning, control room personnel became aware of the containment pressure spike.[79] The significance of this spike became commonly known on Friday morning.

m. Friday, March 30: Releases of Radioactive Gas

It is likely that the events of Friday morning and early afternoon on March 30, provided the most disquieting moments of the accident for the residents of the towns near Three Mile Island. Shortly after 12:30 p.m., Governor Thornburgh recommended that pregnant women and preschool children living within a 5-mile radius of Three Mile Island leave the area and that schools within this area be closed. Earlier in the day, Kevin Molloy, Director of Emergency Preparedness for Dauphin County, warned citizens during a radio broadcast that an evacuation might soon begin. It had also become publicly known that a helicopter had measured a 1200 mR/h reading over the TMI-2 vent stack at 8:01 a.m.

The drama of the day seems to have been the result of a misperception of the significance of the 1200 mR/h reading on the part of NRC staff in Bethesda, and a misinterpretation by a Pennsylvania civil defense official of a phone conversation with a Met Ed employee. It is somewhat ironic that the concern for public safety arose, not from occurrences within the reactor building that houses the reactor system and thereby captures the attention of the public, but from problems within the auxiliary building. In the following paragraphs, the workings of several of the systems within the auxiliary building and actions taken by the control room operators to stem serious difficulties with these systems will be explained. Finally, the effects of the actions will be discussed in the context of the ensuing evacuation plans.

The Makeup Tank

The makeup tank is a part of the makeup system. Water is continually removed from the reactor coolant system for purposes of purification and testing, and the makeup system replaces this water in order to maintain a constant inventory within the reactor coolant system. The makeup pumps pump water into the coolant system and inject water into the seals of the reactor coolant pumps. The makeup tank provides the source of water to the makeup pumps.

Normally, the letdown and makeup of the reactor coolant is a fairly routine procedure, but the presence of noncondensible gases—created by the uncovering of the core on Wednesday—severely impeded proper flow in the makeup system. The letdown from the reactor system flows into the low pressure makeup tank. In the makeup tank, any gases in the water from the reactor coolant system—including any gaseous fission products such as krypton and xenon—separate from the water as a result of the lower pressure, and tend to collect at the top of the tank.

The operators feared an increase in gas pressure because at 80 psig, the relief valve (MUV-R1) in piping leading from the makeup tank to the makeup pumps would open and dump the tank water into the reactor coolant bleed tank. Then, the usual source of water to the makeup pumps would be lost and suction would have to be taken from the BWST. This concerned the operators because they considered the BWST inventory an important and a last reserve source of water in case of another cooling problem in the core.

A vent valve (MU-V-13) at the top of the makeup tank (where the gas would naturally collect) leads to a vent header from which gas is pulled out by a gas compressor into a waste gas decay tank. This vent system permits transfer of radioactive gases from the makeup tank into storage tanks where radioactivity decays before release to the environment. Unfortunately, leakage in this vent system allowed some of the radioactive gases to escape into the auxiliary and fuel handling buildings where they passed through the ventilation filters of these buildings and up the vent stack to the outside.

Bill Zewe, the Shift Supervisor on duty from 10:30 p.m. Thursday night until 1:00 p.m. on Friday, testified that the operators were aware of the relationship between the opening of the vent valve and the release of radioactive gases into the environment.

> We could see it off-site. Every time we would vent, there would be about 30 to 40 minutes of a delay between the opening of the vent to where we could actually monitor external to the plant.[80]

The operators were faced with a dilemma: they wanted to ensure that water was maintained in the makeup tank, but the best way to do this—the venting of gas to the vent header—caused releases of radioactive gases into the environment.

A procedure was developed to deal with the conflicting issues. The venting was performed in short bursts by opening the vent valve until the vent header pressure reached about 15 psig. The valve would then be closed until the waste gas compressor pumped the gas from the vent header into the waste gas decay tanks and dropped the vent header pressure to about 5 psig. At that point, the operator would reopen the makeup tank vent valve until the header pressure again reached 15 psig.

This process was continued until the desired pressure was achieved in the makeup tank. (It should be noted that this procedure required the entrance of an auxiliary operator into the auxiliary building to start the waste gas compressor. The operator had to wear respiratory protection equipment to protect himself from airborne radioactive materials in the "aux" building.) This method of relieving the makeup tank of some of the noncondensible gases, while not allowing pressure in the vent header to get too high, minimized the releases of radioactive gas into the auxiliary building—and subsequently to the outside atmosphere—and kept the pressure in the makeup tank below the relief valve set point of 80 psig.

At 4:35 a.m. on Friday, the very thing the operator had been trying to avoid happened: the relief valve opened and all of the water in the makeup tank ran into the reactor coolant bleed tank. The operators were forced to transfer suction to the BWST and face the possibility of a loss of their primary source of borated water.

Beginning of Continuous Venting

Testimony does not always coincide as to the role of the personnel involved in the opening of vent valve (MU-V-13), but one thing is certain: only four men—James Floyd, Bill Zewe, Greg Hitz, and Craig Faust—played significant parts in the decision to vent at 7:10 a.m. No matter how each perceives the influence of his own and his fellow workers' roles, there is complete accord among them that the venting of the gas in the makeup tank was necessary, and the method applied was the best available.

Greg Hitz arrived on site at 6:00 a.m. to relieve Bill Zewe. Upon entering the control room, Hitz was informed by Faust and Ed Frederick that they "were trying to hold the pressure in the make-up tank but weren't very successful because [it was]... gradually increasing."[81] One of the operators said "... we are not keeping up and will have to do something," and in fact, an auxiliary operator was getting ready to enter the auxiliary building to restart the waste gas compressors as the first step in the cycling of the vent valve, a task which had been periodically required all night.[81] Hitz remembers closely monitoring the situation at this point, and he is "pretty sure" the relief valve cycled open and shut two and three times. Finally, they were unable to keep the valve from cycling, and the levels in the bleed tanks continued to rise. Hitz became duly worried: "My fear was draining the BWST to the bleed tanks and overflowing the bleed tanks onto the floor of the basement through the vent."[82]

Floyd recalls, "We were still in a situation which we did not fully understand."[83] When the makeup tank lost all of its water at 4:35 a.m., suction for the makeup pump had been switched to the BWST. Why were the bleed tank levels rising as the BWST level dropped? Zewe best analyzed the quandary: They didn't perceive how they "were transferring the water from the BWST into the make-up tank system and into the reactor coolant bleed tank.... It [the system] is not designed or intended to function going from the BWST to the make-up to the bleed tanks.... That was a path we had never explored before."[84] Water was being lost from the BWST through two routes. As letdown flow dumped into the makeup tank, gas escaped from the reactor coolant water and kept pressure in the tank above the relief valve setpoint, so the newly arrived reactor coolant water went into the bleed tanks. Water was also flowing into the makeup tank from the pump minimum-flow recirculation line. This recirculation line allowed the makeup pumps to run even when they were not supplying water to the reactor coolant system by allowing the pumps to discharge a minimal flow of water, which theoretically went from the makeup pumps to the makeup tank and back to the pumps. In this instance, however, the water entered the makeup tank and was swept through the relief valve into the bleed tanks.

Zewe was out of the control room being interviewed by GPU personnel between about 5:45 and

7:00 a.m. He was absent from the control room when the different tank levels began to indicate a serious loss of water from the BWST. Floyd believes that when Zewe returned to the control room, Zewe quickly noticed the increasing level in the bleed tank—something the others had overlooked—because he had not looked at the gauges in at least an hour and a quarter, so for him the cumulative rise in level was noticeable.[85] Zewe stated that when he returned to the control room, he was apprised of zero level in the makeup tank, a 2- or 3-foot loss from the BWST, and bleed tanks "overflowing with a high level."[86]

A decision was made at this point to open the vent valve. Floyd testified during a public hearing before the President's Commission that he ordered the valve opened.[87] Zewe, Faust, and Hitz have testified that Floyd had no active role in this decision.[88] On September 13, Floyd, aware of the testimony of the others, stated "whether the operator [Faust] was looking at Mr. Zewe or looking at me at that particular moment in time, who he took his instructions from at that particular moment, I don't know."[89] The extent of Floyd's role in the venting order, in no way changes the fact that no one in the control room disagreed with the plan, and all four men directly involved advocated the action.

Another disagreement in testimony arises over the question of just when it was decided to *continuously* vent. Floyd claims that from the outset, he thought in terms of continuous venting.[90,91] Floyd's version is contradicted by Zewe and Hitz. Zewe initially wanted to simply reseat the relief valve and he intended to shut the vent valve when makeup tank pressure decreased to 65 psig. When 65 psig was attained, Zewe, "under strong urging from Mr. Faust"[92] and after conferring with Hitz, decided to leave the vent open and monitor the radiation levels. In this manner, they would "then just take the gas buildup in small puffs from thereon instead of a great big release every so often."[92] Zewe, Faust, and Hitz tend to agree on the circumstances surrounding the venting. Because they were working at the control panel during the procedure, we can cautiously assume that the decision to leave the vent open evolved both as radiation readings were studied; and as the advantages of small, continuous releases of radioactive material were compared with large, acute releases.[93]

Once the pressure in the makeup dropped below 80 psig, the relief valve reseated and the operators turned on two demineralized water transfer pumps in order to get water into the makeup tank by the quickest means available. This enabled them to switch suction for the makeup pumps from the BWST to the makeup tank. Eventually, the waste transfer pumps were used to pump water from the reactor coolant bleed tanks into the makeup tanks, thus resolving the problem.

Although the continuous venting that started at 7:10 a.m. had some unfortunate byproduct as regards the evacuation concerns, from an operating standpoint the venting seems justifiable. Floyd was troubled over losing the "one source of water between me and another LOCA."[94] Floyd also feared the release of radioactive gas through the reactor coolant bleed tanks, "If we were relieving the gas through that route, it was all going out to the public." Floyd believed that releasing radioactive gas through the *vent valve* meant that at least some of the gas would end up in the waste gas decay tank, hence lessening offsite releases.[95] Faust feared a loss of BWST inventory. Hitz also worried about the BWST inventory and had as a "first priority" the prevention of the overflow of the bleed tanks "back through the vent lines, into the traps, and on the floor."[96]

A loss of BWST inventory could have forced the makeup system to have been placed in the recirculation mode from the reactor building sump. This would have resulted in contamination of other pumping equipment and possibly caused the release of radioactive material into the environment because of equipment leaks.

Furthermore, alternate methods of relieving gas from the makeup tank looked less desirable than the continuous venting procedure. Letdown and seal return flow to the makeup tank could have been stopped, consequently arresting gas buildup in the tank; but securing of the seal return flow increased the probability of seal failure on the reactor coolant pumps.[97]

It should be added that after Friday, copper tubing, which passed between the makeup tank and the reactor building, was installed. Gases from the makeup tank could then be directed into the reactor building, which acted as a large gas storage tank. This line was never used, but Floyd has testified that if it had existed on Friday, he would have preferred using the line to the venting procedure—if it had no leaks. Such a line would have precluded the troublesome releases of radioactive materials to the outside.[98]

Assessing the judgments and actions of the Met Ed employees against the backdrop of the drawn out nature of the accident, the unforeseen difficulties encountered by the operators, and the necessity of balancing limited radioactive gas releases with a desirable makeup tank pressure, we can only conclude that the operators did what was required of them.

Other Issues

The principal concern until now has been the response of the control room operators and supervisors to a situation that posed a threat to the stability of Unit 2 and to the health of the public. The effects of the 7:10 a.m. venting, however, raised problems for the Governor of Pennsylvania's Office; the NRC Headquarters in Washington, D.C. and Bethesda; and various local, State, and Federal agencies responsible for the evacuation plans (not to mention the public, who experienced unnecessary apprehension). Therefore, we explored the part that the Unit 2 control room personnel played in the evacuation scare.

During a now famous conversation, James Floyd spoke to a Pennsylvania Emergency Management Agency (PEMA) official, and to use Floyd's own words, "... maybe one of the classic miscommunications of all time took place at that point."[99] The official interpreted Floyd's words to mean that Unit 2 had an uncontrolled release and PEMA should be prepared to evacuate people situated downwind of the plant. Coupled with the "horrible coincidence" involving the 1200 mR/h reading (wherein NRC Headquarters misperceived the cause and location of the reading) and Floyd's contacts with the civil defense personnel, his words undoubtedly produced an ingredient that aided in the distorted sense of things that followed.[100]

Friday was a day plagued with horrendously poor communications, and this problem can even be seen among the people in the Unit 2 control room. Gary Miller, who was on site early Friday morning, was contacted by Mike Ross regarding the venting and radioactive gas release. When Miller arrived in the control room around 7:30 a.m., he put Zewe in charge of plant operations, whereas Hitz was responsible for communications.[101,102] Unfortunately, before and after the delineation of duties, Hitz and Floyd were duplicating communications tasks; Floyd's call to civil defense personnel bypassed the normal communication channel that had been established through the emergency control station. Floyd, however, said that in prior drills he had frequently made the call to the State civil defense.[103]

Following are some examples of the poor communication on that day.

1. Floyd requested that a helicopter monitor releases "immediately after the fact (of venting)," but he did not discuss the request with anyone in the control room, nor did he know that Hitz had also called Unit 1 concerning the same subject.[104-106]
2. After Hitz had been assigned to head the communications effort he asked Unit 1 personnel to notify PEMA, Margaret Reilly, and Thomas Gerusky of the Pennsylvania Bureau of Radiation Protection of the venting. Neither Hitz nor Zewe knew what Floyd's activities were at this point, yet during this period Floyd had the regrettable conversation with civil defense regarding evacuation readiness.[107-109]

The above examples would appear as mere quibbles, however, to the public most affected by the poor communications. In the context of Friday's events, these examples clearly portray the need for a planned and accurate dissemination of information from the control room to the emergency control station and to Government agencies. Not only will an accurate flow of reliable data be maintained through the implementation of such a plan, but a minimal number of people will be needed to distribute the information. As Floyd said, "I wasn't happy about having to be on the phone in the first place. I would have much sooner been in the control room listening to the radiation levels, so I was hurried.... As for the pace of the conversation [with PEMA], it may have been hurried because I was in a hurry to get off the phone."[110] In addition, all communications planning should be developed with a view of the type of protracted accident that occurred at Three Mile Island. From this experience it seems that communicating gets more difficult and more subject to obstruction as time goes on.

n. Beginning of Recovery

On Friday, March 30, several factors combined to make the company management and staff aware of the nature and seriousness of the remaining problems in the plant. Problems associated with the buildup of radioactive gas in the makeup tank had resulted in offsite releases, which were quickly and widely reported by the news media.

The containment pressure spike on March 28 and its diagnosis as a hydrogen burn became generally known. The existence of high core thermocouple readings on March 28 and the hydrogen gas content in the reactor coolant system also became generally known. The GPUSC engineers had completed a fairly accurate analysis of the initial sequence of events that had caused the core damage.

An organization to assist in the recovery started evolving on Friday. With respect to technical support, GPU engineers were stationed in the control room to gather information and to assist in understanding plant conditions. They reported to T. Gary Broughton, GPUSC Manager of Control and Safety Analyses, in a trailer on site, and he in turn reported to Wilson in a trailer off site. These activities were maintained 24 hours a day from that time on. The groups eventually became those labeled 1, 2, and 3 on Figure III-3, which shows the recovery organization.

At GPUSC headquarters there was a rush of activity to answer requests for engineering information from the site. These activities also took place on a 24-hour basis. Similar activities were taking place at Burns and Roe headquarters (where the plant was originally designed), and at B&W headquarters. Eventually, many of the GPUSC engineers were sent to the site and absorbed into the technical support organizations there. Much of the Burns and Roe effort came to be the plant modifications group, labeled 4 on Figure III-3. B&W set up an onsite group (not shown on Figure III-3) in addition to providing technical assistance from its headquarters.

The management began requesting personnel from outside the company to assist in the recovery. Dieckamp requested assistance from nuclear industry sources such as the Electric Power Research Institute, utilities, nuclear steam system suppliers, architect-engineers, and consultants; Government agencies and laboratories such as NASA, Oak Ridge and Argonne; individuals such as N. J. Palladino, Dean of Engineering at Pennsylvania State University; Sol Levy, nuclear engineering consultant; and from companies such as the Electric Boat division of General Dynamics. Also on Friday, the NRC arrived in force, began taking an interest in plant operations, and—parallel to Met Ed's efforts—began requesting outside personnel for assistance.

The response to these requests for assistance were massive and rapid, with hundreds of people on site during the weekend. On Wednesday, April 4, Dieckamp drafted an organization chart for the recovery organization, which essentially formalized the functions that had been evolving since Friday and corresponded to Figure III-3.

o. Recovery

Once the recovery began, the hazards were generally recognized and appropriate actions were taken to eliminate them. One major feature was an early decision not to change the core cooling mode, unless necessitated by a problem such as a loss of reactor coolant pumps, because the existing mode was known to be stable and effective, at least in the short term.

Early recognition that the long term goal was natural circulation, and that the reactor coolant system should be degassed to allow natural circulation to work was another major feature. This followed from recognition that, in time, reactor coolant pumps or other equipment vital to the existing mode would likely fail, probably because of the radiation levels inside the reactor building.

The reactor coolant system was degassed primarily by the removal of gases from the letdown flow through the makeup tank and venting to the waste gas vent header, and by spraying coolant into the pressurizer where a significant fraction of the hydrogen gas would separate from the liquid coolant. Next the gas was vented from the pressurizer into the reactor building. There were some early "fits and starts" to this latter procedure when the NRC, taking a more conservative view than the company, was concerned that an explosive concentration of hydrogen might build up in the reactor building. However, these differences were resolved and it was not necessary to delay this degassing technique until reactor building hydrogen recombiners were installed.

Some degassing also resulted from continued letdown system operation. Gas accumulated in the makeup tank and was pumped to the waste gas storage tanks, from where it was eventually vented back into the reactor building. Leakage in the letdown and waste gas systems gave continuing releases of radioactive material from the plant vent. Although the releases were not large enough to threaten public health, measures such as installation of additional charcoal filters in the auxiliary building ventilation system were taken to reduce them.

There was, for a time, a disagreement between NRC and Met Ed about whether or not the hydrogen bubble could explode inside the reactor coolant system. No explosion was actually possible because of lack of oxygen. Such an explosion, if it were to occur, would raise the possibility of further disarrangement of the core and the possibility of damage to the reactor coolant system. This dispute was resolved by about Sunday night. Regardless of whether or not the bubble could explode inside the reactor coolant system, the common goal was always to get rid of the gas bubble.

Numerous contingency questions were addressed. For example, plans and procedures were

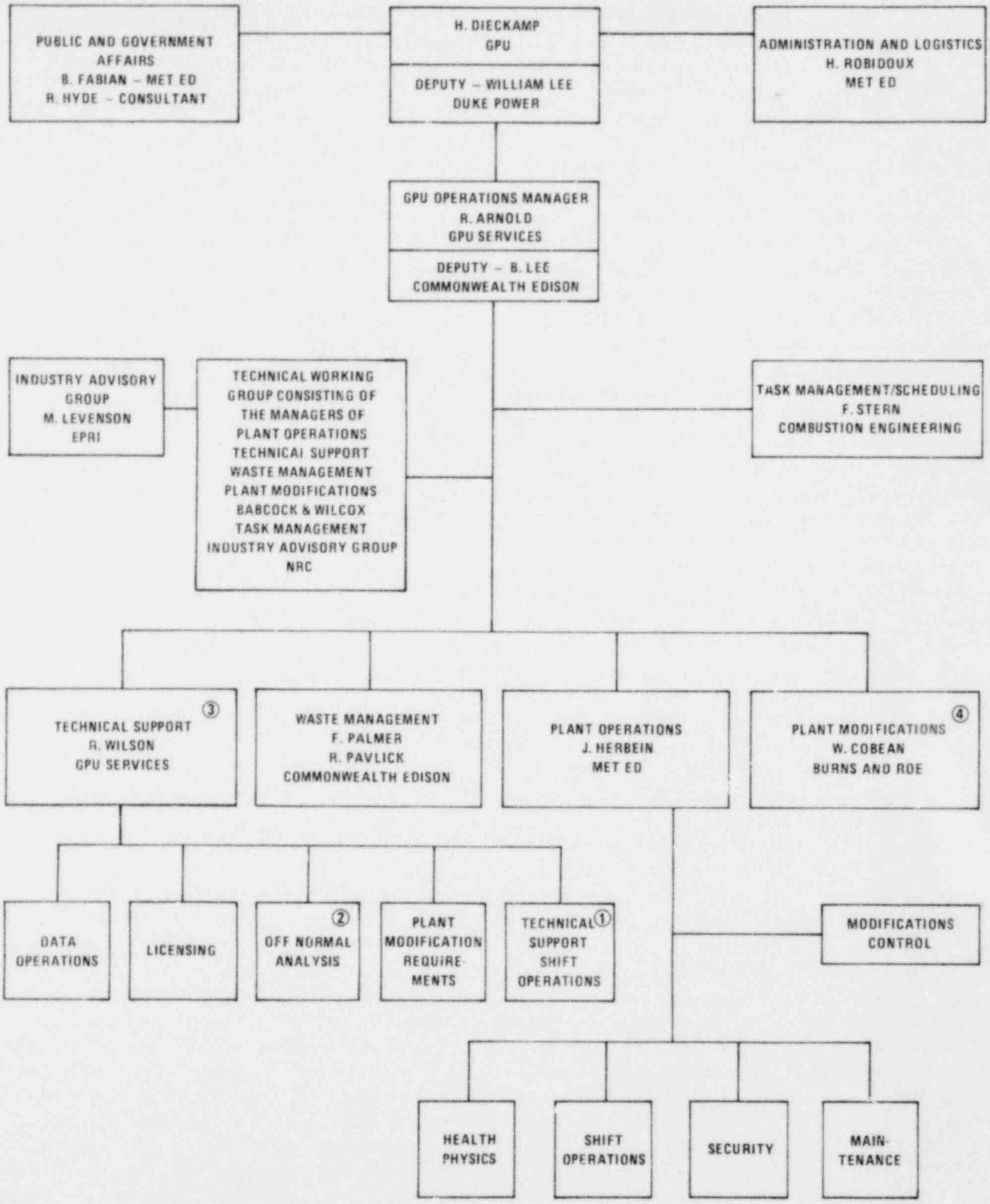


FIGURE III-3. Company TMI Recovery Organization developed on how to respond to equipment failures, such as losing a reactor coolant pump or pressurizer level indication. Estimates were made of how long critical equipment might remain functional in the radiation fields inside the reactor building. Studies were also made of various alternative scenarios that could occur if the situation were seriously degraded. Conditions such as flooding the containment to cool the core could be set up if it became necessary.

If the reactor coolant pumps had all been lost before degassing made natural circulation feasible, the ECCS could have been used for core cooling. However, this probably would have resulted in increased releases of radioactive materials because of inherent leakage in portions of the piping systems outside the reactor building. After the plant was degassed and cooled down, the decay heat removal system could have been used as well but with similar inherent problems of releases of radioactive materials through leaking components. Construction of a leak tight analog of the decay heat removal system was begun to eliminate the leakage, if this mode of cooling became necessary.

Construction was also started on a leak-tight backup system to circulate cold water through the B steam generator. Its purpose would be to provide a driving head for natural circulation, without the need to depend on the regular installed plant systems and without their inherent leakage characteristics. In addition, a backup piping system was built to provide stable and positive control of plant pressure without reliance on the pressurizer level instruments inside the reactor building. This system was eventually put into service when the pressurizer level instruments failed.

In considering various recovery actions, the consequences were evaluated before the actions were taken. For example, when the reactor building hydrogen recombiners were placed in service, considerable planning effort was devoted to precautions against causing a hydrogen burn or explosion because there was uncertainty about the hydrogen concentration in the reactor building. Similar precautionary efforts were devoted to venting the radioactive gas waste storage tank contents back into the reactor building because these tanks contained considerable quantities of hydrogen. It was possible the tanks also contained significant amounts of oxygen, which not only indicated a need to prevent setting off an explosion, but also to get the gases back inside the reactor building.

As indicated on Figure III-3, the organization was headed by Herman Dieckamp with William Lee, a Vice President of Duke Power Company, serving as Deputy. Robert Arnold headed the technical operations aspects of the recovery with Byron Lee, a Vice President of Commonwealth Edison, serving as Deputy. Richard Wilson headed the GPU technical support effort—providing engineers in the control room, analyzing off-normal conditions that existed or might exist, developing procedures, gathering and analyzing data, and developing requirements for plant modifications. The modifications were designed by the plant modifications group, consisting of Burns and Roe personnel and headed by William Cobean, a Vice President of Burns and Roe. Actual plant operations were handled by Herbein's groups. The Industry Advisory Group (IAG) was a "think tank" type of operation consisting of high level industry representatives. All of the groups were very heavily reinforced with outside personnel sent to assist in the recovery. The NRC and B&W organizations, which are not shown on Figure III-3, also played significant roles. Thus, the overall recovery represented a joint industry and Government effort.

Decisions were discussed in meetings of the Technical Working Group (see Figure III-3). At these meetings, senior representatives of the various groups—including NRC, B&W, the GPU technical support group, and the Met Ed operations group—met to propose and discuss actions. Company personnel chaired the meetings and were responsible for making the decisions. A consensus was achieved for most decisions. The NRC, by virtue of its legal authority to issue orders, did have the authority and, therefore, implicit responsibility to override a decision whenever that seemed necessary.

Key GPU personnel involved in the technical support effort believed that the NRC presence was helpful. Their impression was that, generally, NRC personnel were working on solving the problems rather than taking the more usual regulatory stance of reviewing and criticizing proposals made by others, without responsibility for expediting the schedule. They perceived constant pressure from the NRC to get things done quickly to move on with the job of recovery.[111,112] In contrast, William Lee perceived the NRC presence as having the opposite effect.[113] As can be expected with hundreds of additional personnel assisting in the operation, there was confusion. With regard to framing the organization, for example, Dieckamp stated:

> Wednesday morning [April 5] Warren Owen and John McMillan grabbed ahold of me and said, 'Look, we have got to organize this thing.' We closeted ourselves and began to lay out the organi-

zation structure that ultimately became established.[114]

Although we have not performed detailed evaluation of the many decisions made during the recovery effort with respect to placing the reactor in a safe shutdown condition, it is obvious that the decisions were successful, and involved effective and prudent consideration of the problems and alternatives. A later section of this report gives a more detailed discussion of industry support in the recovery operation.

p. Diagnostic Capabilities of Plant Staff

We believe that the diagnostic capabilities demonstrated by the plant staff and those who came to their assistance during the first few hours of the accident were weak.

This should not be taken as placing the entire responsibility for the accident upon the operating staff. Heavy burdens of responsibility must be borne by the NRC, the utility management, the designers of the reactor and plant systems, and by a complacent industry in general. However, whereas the operating staff can be considered as the last link in a chain of responsibility, they are essential to safety.

In evaluating the plant operating staff's performance during the first day there were instances of failure to grasp the basic significance of facts that were well known for long periods of time, and which should have been understood. Failure on the part of the crew to grasp the significance of the low reactor coolant system pressure at the time of the accident, for example, was nearly universal. This was largely a failure to get back to basics. The need to keep the pressure high is a fundamental design concept of a pressurized water reactor; it is the reason for the name. The pressure was well known to be anomalously low. It should have been understood that when the pressure gets low, the hot water in the system will boil, and if this goes very far, core cooling will be ineffective. The result is analogous to what happens when the cap is removed from the hot pressurized radiator on a running automobile engine.

The corrective action, full high-pressure injection flow, should have been evident to a group of individuals who had spent most of their adult lives "living" with pressurized water reactors. Had this measure been taken at any time during the first 1½ or 2 hours, the severe core damage could have been avoided (even without recognizing or isolating the leaking PORV). Furthermore, the high-pressure injection system tried to do this automatically but it was bypassed and overridden.

Even lacking such understanding, had the LOCA procedure come to mind and been followed, high-pressure injection flow would have been maintained, preventing serious core damage. A reactor coolant system pressure decrease and the presence of water in the reactor building (both conditions were evident in the control room) are two classic symptoms of a small loss-of-coolant accident.

A good explanation for the low pressure was not found. There was ample evidence, available and known to the operators, that the PORV was leaking. For a variety of reasons, they misinterpreted the information to conclude that the PORV was not leaking, and then left the block valve open rather than closing it as simple prudence would dictate, or in accordance with the procedures established for corrective action upon detection of high PORV discharge pipe temperatures.

Had the block valve been closed early in the accident sequence, perhaps before 10 or 20 minutes had elapsed, the entire problem would have been eliminated. Later, perhaps in the first hour and a half, recognition that the PORV had not closed should have alerted the staff to the fact that the plant had been undergoing a long term, small loss-of-coolant accident, and that there was need for high-pressure injection flow to protect the plant and the public.

There were also some apparent weaknesses on the part of those who came in to assist or take charge of the operating staff. The primary examples are an early failure to understand low pressure and high temperature in the reactor coolant system, and later in the day, the development and implementation of the erroneous core flood tank theory. Although they didn't have as much time as the shift crew to think about it, the conference call participants (Herbein, Miller, Kunder, and Rogers) missed the significance of the low reactor coolant system pressure and high temperatures at about 6:00 a.m. Later in the day, the entire emergency command team apparently endorsed the questionable core flood tank theory, which could only result from a lack of knowledge of plant design and arrangement or comprehension of the simple physical principles involved.

Part of the reason for management's failure was its ready acceptance of the correctness of the operators' interpretations and actions. A prudent amount of management skepticism would have been truly enlightening. For example, during the conference call a simple approach of skeptical operating staff questioning would have likely brought forth further information, readily available to the group in the control room. This information should have permitted the conference call participants to determine that the PORV had been leaking and was the cause of the low pressure. However, the participants accepted the simple report that the block valve was closed, presumably assuming that the operators had this area well in hand. In another example later in the day, many of those involved had a great deal of difficulty believing the worst—that the core was uncovered, badly damaged, or both—despite indications such as radiation levels, hot-leg temperatures, and possible high core thermocouple temperatures.

The qualifications of some of the key personnel selected by management suggest that management did not really expect these supervisors to step in and independently diagnose plant operating conditions and to either assure that the operators' actions were correct or to provide direction to correct operator errors. Had this involvement been expected, the key personnel for such operating decision backup could have been predesignated, and the individuals could have studied to become expert on the plant details and accident considerations. They could have had current operating licenses and received training by actually checking operator actions on the simulator.

A brief summary of some of the key individuals' qualifications is provided below. Emphasis is placed on the areas that indicate whether or not the personnel had trained themselves as completely as they might have on plant details and operations, and if they had really expected the need to perform independent diagnoses and make independent operating decisions.

Kunder, a graduate engineer with 15 years of nuclear experience, arrived on site about 4:50 a.m. He was the on-call duty officer and later was a member of the emergency command team. He had held an operating license on Unit 1, which is a similar plant with somewhat different details and a different control room. Although Kunder was in training for a license on Unit 2, he neither knew the details as well as he did for Unit 1, nor sufficiently well to be comfortable about actually operating Unit 2.[115,116] Even after reviewing the situation for nearly an hour prior to the conference call, Kunder was not in a position to discern and correct the basic operating error at that time (lack of high-pressure injection to mitigate the low pressure).

Logan, a graduate engineer with 20 years of experience operating naval reactors, which in detailed design are different from the TMI-2 plant, arrived on site about 5:45 a.m., as the reactor coolant pumps were being secured. He was in charge until Miller arrived, and was later a member of the emergency command team. Logan had spent about a year qualifying for a senior operating license on Unit 2, which he obtained about 4 months prior to the accident. Although this time was obviously adequate to obtain a license, we would not consider it ample to really master the different details of a newer and much more complex plant. After reviewing the plant status for nearly an hour, Logan wanted to get the reactor coolant pumps running. (The same conclusion was reached independently by the conference call participants at about the same time.) By itself, we consider this reasonable in that it was an attempt to force cooling water flow through the core when the core was not being cooled. However, along with the others, he missed the significance of the low pressure.

Ross, who also became a member of the emergency command team, arrived on site about 6:20 a.m. He had considerable experience both as an enlisted man operating naval nuclear plants and operating the TMI plants. He was licensed to operate both units and had been a shift supervisor until his promotion to Unit 1 Operations Supervisor about 3 months prior to the accident. Approximately the time he arrived, the PORV was being isolated and it was known that the PORV had been open for a long period of time. Even so, Ross did not perceive the true significance of that information; that a small LOCA had been occurring for hours and it was imperative to initiate full injection flow.

Leland Rogers, the B&W Site Manager, also had considerable experience as an enlisted man operating naval reactors. He had been at the TMI station for more than 6 years and should have had expert knowledge of details of plant construction. However, Rogers had not been trained or licensed as an operator on B&W commercial reactor plants. Rogers participated in the conference call at 6:00 a.m., and later reported reactor coolant temperature to B&W headquarters in Lynchburg, Va., as about 300° F. That was, however, the cold-leg temperature. It was not until about 1:30 p.m. that B&W found out about the high hot-leg temperatures. (It must be noted that it was not considered B&W's responsibility to provide qualified operators to step in and correct problems during emergencies.)

Miller, who was in charge and who arrived on site about 7:05 a.m., was a graduate engineer with several years of startup and test experience both in naval reactors and at TMI-1 prior to moving up into TMI management. Although Miller held an operating license on Unit 1 for 6 months, he had spent little time operating the Unit and had never been licensed on Unit 2. Aside from missing the significance of low pressure along with the other conference call participants, Miller had no part in the early operating errors prior to core damage. Later in the day, the lack of detailed Unit 2 knowledge could have contributed to such things as the lack of specificity in Miller's high-pressure injection order in the morning, or his endorsement of the core flood tank theory in the afternoon.

There were some bright spots concerning diagnostic capability. A few minutes after arriving at 6:00 a.m., Mehler diagnosed the low pressure as probably being caused either by failed pressurizer heaters or a pressurizer leak, and he initiated actions to close the PORV block valve and to check the pressurizer heaters. This solved part of the problem.

After turning his attention to plant operation at about 7:45 a.m., Miller directed that the high-pressure injection system be allowed to operate, which appears to be a basically sound decision taken for sound reasons. Similarly, the decision to increase pressure at about 9:15 a.m. (in conjunction with high-pressure injection flow) apparantly was a basically sound decision. As it turned out, however, it was not feasible to condense all of the gas bubbles at that time because of the hot, damaged core and the presence of hydrogen.

These bright spots with respect to individual diagnostic capabilities are relatively isolated, and on balance, the operating staff and its management must be found severely deficient in this basic need. As stated previously, the fault is not the operating staff's alone. Responsibility must be accepted in large measure by the NRC, the utility management, and the plant designers. Immediate actions must be taken to improve and upgrade the qualifications and training of operating staffs at nuclear plants, and to substantially improve the diagnostic capabilities of both the plant's operators and operations supervisors and managers. These steps must be taken in addition to corrective actions to improve plant designs, to incorporate human factors considerations in the designs and operating procedures, to provide for immediate offsite expert diagnostic assistance, and to increase regulatory surveillance.

q. Prior Planning for Early Offsite Support

Before the accident, the early emergency planning did not assign any significant responsibilities to the offsite utility management and staff; these were assigned to the plant staff. Nor did the formal emergency planning emphasize plant operations to mitigate emergencies. Reactor operating practices, procedures, and training—particularly the emergency operating procedures—contain information on plant operation to mitigate accidents. We do not mean to imply that this information should be condensed and included in the emergency plan, but rather that more explicit consideration needs to be given to the assignment of definitive responsibilities for those emergency managers who will make the decisions related directly to reactor plant stability and who will back up those decisions. The emphasis was on radiological aspects, including assessment of any releases of radioactive materials that might be occurring, and the communication of this information to civil authorities. This situation was usual, rather than unusual, with respect to formal emergency planning.

In the TMI-2 accident the plant staff failed to understand plant conditions over a period of many hours. During this time, the flow of meaningful plant data to the management and staff, particularly to GPUSC, was meager. (B&W Headquarters and NRC Headquarters had similar problems getting meaningful information.) Once GPUSC did get some key plant information, the basic core cooling problem was diagnosed and appropriate corrective action was recommended. This suggests that a formal plan to transmit plant data to a group of experts off site, in order to back up the operators' diagnoses and actions, would be helpful. An alternate suggestion is, of course, to upgrade diagnostic capabilities on site.

The plant staff and others in the control room did respond to numerous offsite requests for information that day—so much so that it appeared burdensome—and a great deal of information was transmitted.[117] The problem was in getting out the more meaningful information. For example, the hot-leg temperatures, which were key indicators of the existing problems, were generally slow to be reported off site. The core thermocouple readings, which complemented the hot-leg temperatures, were reported only to Herbein. The open state of the PORV and the throttling of high-pressure injection flow, which were the original causes of the problems, were not reported off site. The containment pressure spike was not reported. These factors suggest that an effective plan for offsite data transmittal to provide backup for the operators' diagnoses should attempt to: (1) get the information out without burdening the operators, and (2) get out basic plant information independent of or in addition to what the reporting person perceives as significant. These goals could be furthered by use of designated communicators, mechanized data transmittal, or both.

However, in discussing this, it must be remembered that the severe core damage began occurring about 2 hours after the initial feedwater transient. Considerable effort and expense would be associated with planning to provide reliable and effective diagnostic backup within 1 to 2 hours of a transient, particularly when the operators do not realize that a routine transient is turning into an accident. The TMI-2 accident would have required some form of continuously manned monitoring station to check on the operator's actions without any clear signs of trouble to prompt such checking, and which detected the plant trip and then independently determined the plant conditions. Immediate offsite monitoring might also allow onsite personnel to feel less responsible for taking the correct actions because they would know immediate help was available. The operating staff must be assigned clear front line responsibility for the safety of the plant and the public. The offsite expert diagnostic support must be advisory, encouraging utility management to insist on a high quality operations staff, and to impress upon each individual supervisor and manager the vital need to upgrade and maintain his or her individual capabilities for sound diagnostic assessment.

r. Prior Planning for Longer Term Offsite Support

During the first few days after the accident, remarks were made by NRC personnel indicating that Met Ed's technical capabilities were thin.[118] It appears that such remarks were based on the NRC's perception of the company's performance in relation to the needs of the accident, rather than comparing the numbers and experience of the company's technical personnel to those available in other utilities.

Denton and his NRC colleagues were concerned about the amount of planning for contingencies. Denton noted that although company personnel might have been thinking about contingencies, there was nothing in writing and there were no procedures. Denton stated, "I wanted GPU to get into the mode where they could answer any question my staff raised..."[119] Case believed there were indications that should have propelled company personnel into different courses of action than those taken.[120] Grimes stated that later in the accident, the company lacked critical faculty.[121] Eisenhut indicated that the company needed technical talent to help them through the emergency.[122] Hendrie did contact Creitz to ensure that the company would ask for whatever technical assistance was needed, as it was available in the nuclear industry. He was told that this was already underway.[123]

As alluded to in Denton's testimony, a part of the concern may have been the NRC's perception that the company didn't have enough answers quickly enough. Somebody in the company may have been thinking of what to do in certain circumstances, but no procedures had been developed and Denton was unaware of this. A larger part of the problem appears to be the delay in mobilizing the resources available and applying them to the problems that existed. As discussed previously in this report, the utility management believed that the situation was under control. Much of Thursday was spent briefing the press and public figures and planning for an orderly investigation, analysis, and recovery process rather than following plant operations and applying technical support resources. Thus, on Friday when Denton arrived, the company was only beginning its technical support effort. Finally, of course, the demands of the accident for technical resources and evaluations were great. As Eisenhut stated, the company did need a great deal of assistance, which was obtained and used.

NRC staff officials did not rate the company as particularly weak in comparison to typical or median nuclear utilities. Case placed the company in the middle of three categories of utility technical competence—toward the lower half of that middle group.[124] Eisenhut envisioned two groups of utilities, a small group in the first category and a large group in the second category of utility technical competence. He placed the Three Mile Island utility somewhere in the large second group.[125]

Although the Special Inquiry Group has not performed a detailed comparative study, it is also our judgment that in terms of the numbers and experience of technical personnel available, including that in GPUSC, this utility is not particularly weak in comparison to a median utility that operates a nuclear powerplant. In fact, we would judge this utility to be better than the median in these terms.

We believe that the demands for technical assistance associated with this accident provide clear evidence of a need for improved capabilities to marshal and apply technical support resources to the long term recovery effort (that is, after the first day) by using company and outside personnel. This need is believed to exist in other utilities as well.

s. Summary of Findings and Recommendations

Findings

- The crew on shift during the first 2 hours after the accident began, failed to properly diagnose basic plant information that was known to them and failed to follow appropriate procedures or prudent operating practices, any of which would have prevented severe core damage and made the consequences of the accident insignificant. Their actions demonstrated fundamental and deep weaknesses in diagnostic capabilities, knowledge, and training with respect to basic reactor safety concepts.

- At 2 hours and 18 minutes into the accident, when the loss of coolant was stopped, the core was being severely damaged and partial fuel melting was probably quite close. A series of sound decisions by incoming supervisors and automatic actions that served to improve the situation then began. Although it was too late to avoid core damage and not all the appropriate steps were immediately taken, these actions did avoid the immediate fuel melting problems.
- There was no system available that had been designed to cool the core after severe core damage and there was no procedural guidance on how to attempt core cooling in the event of such core damage (or even in the event of natural circulation blockage with an undamaged core).
- Although the plant staff did not realize that the core was badly damaged, they did recognize that normal cooling methods were inadequate and attempted to cool the core with improvised methods. The task was difficult. Improvised methods that were reasonable, with or without core damage, did not appear to work.
- Plant staff supervisors shared in the early failures to diagnose the basic plant problems. After core damage had occurred they made some sound decisions and these helped prevent fuel melting. Some errors were made later in the day, but these did not materially worsen the physical course of the accident, except to delay effective recovery action.
- During the day, there was some confusion within the plant staff and some communication problems within the staff and between the staff and offsite groups. Some key supervisors were not aware of some significant information. The flow of meaningful information to capable offsite groups was meager and slow.
- There was little, if any, prior preparation for handling plant operations during a postaccident emergency. A reasonable organization was improvised, at the time, to employ the numerous operators and supervisors available. However, the organization had not been set up beforehand and had not been trained or drilled. Some key supervisors involved in operating decisions were not well prepared to step in and direct plant operations. Communications within the plant staff and with outside organizations had not been practiced. There was no planning to obtain assistance or advice from offsite groups.
- The failures of plant staff supervisors indicate basic weaknesses in their understanding of the plant, in their diagnostic capabilities, in the qualifications set for their positions, and in the definition of their duties and organization for plant operations, and the training and drilling for such operations.
- Company management shared in the early failures to diagnose the basic plant problem and the plant staff supervisors' errors during the day. Later on the day of the accident, management stepped in to direct changes in the plant operating strategy that establishes a stable and effective core cooling mode.
- The management's intervention at that time was somewhat fortuitous. There was no prior planning for offsite support or review of operating decisions, and the people involved were quite hampered by a lack of meaningful information. The intervention resulted from the initiative of a large group of engineers with broad nuclear experience and the actions of two vice presidents with strong nuclear backgrounds. Not all utilities have staffs with these capabilities.
- On Wednesday evening and Thursday, there was a widespread lack of understanding of the extent of core damage and the remaining threats to core cooling. This increased the risk involved, but because certain critical malfunctions did not occur during this time, the basic physical sequence of the accident was not adversely affected, except to delay recovery actions. The lack of understanding may have altered the public's perception in that initial reports indicated things were well in hand, but later reports were more alarming.
- Although it caused great alarm, the Friday morning venting of the makeup tank represented a reasonable balance by the plant staff of the risks and benefits involved in various operating options.
- The utility did not begin to apply its resources and outside assistance to the recovery effort in earnest until Friday, when it became generally understood that significant problems remained. This slow start, combined with the numerous demands of recovery from the accident, led NRC officials to perceive the utility as technically weak in relation to the needs of the accident. The utility was not technically weak, however, in comparison to the median nuclear utility.
- Once the recovery began Friday evening, massive resources were brought to bear and it be-

came, in effect a joint industry-Government effort. The hazards were generally recognized and appropriate actions were taken to eliminate them, with due consideration of the risks involved in various options. Appropriate contingency planning was instituted.

Recommendations

- Prompt action should be taken to upgrade the diagnostic and emergency response capabilities of personnel licensed to operate reactor plants, and of their supervisors up to at least the level of unit superintendent. Whereas these individuals will be the first to respond to an accident, improvement in their capabilities will provide the most direct and immediate improvement in the level of safety associated with operating reactor plants. Accordingly, the recommended action should be assigned the highest priority.
- On the same priority basis, onshift manning levels should be increased, if necessary, to conform with levels determined to be needed by the results of accident response task analyses conducted to define the tasks that may need to be performed in the event of serious accidents, including those that might involve significant core melting.
- Supervisors of licensed reactor operators, up to at least the level of unit superintendent, should be required to hold a senior reactor operator license on any unit to which they are assigned supervisory responsibilities for normal or emergency operations.
- The inplant individual (shift manager or equivalent) assigned the responsibility for the safety of operation and in direct charge of the operators in the control room, should have a college degree in a technical discipline closely related to reactor plant design and operations, and at least 3 years of operating experience. This requirement should be met as soon as practicable but not later than July 1, 1983. Exceptions should be rare and rigorously justified.
- The duties and responsibilities and the qualifications and training of all personnel assigned to support the unit operators and their supervisors in maintaining the unit in a state of preparedness, for both effective normal operation and for emergency accident situations, should be reassessed and upgraded so as to be consistent with the upgraded levels of the reactor operators and their supervisors.
- Each utility licensed to operate a nuclear plant should revise its emergency procedures for inplant response to accidents in order to have plans available for the organization and efficient use of off-duty operating staff personnel, who would be expected to report to the site in the event of an accident. The procedures should specify frequent training and drill programs to assure effective emergency implementation of this organization.
- Each utility licensed to operate a nuclear plant should take immediate action to provide the operations staff with the means to acquire prompt expert advice from offsite sources in order to better assess and respond to emergency situations. The plans, organization, and training for the provision and use of such assistance should be based on the immediate implementation of interim measures which should be developed into a final program approved by the NRC in accordance with its requirements not later than January 1, 1982.
- Each utility licensed to operate a nuclear plant should develop procedural guidance for the use of the operations staff in responding to situations beyond the normal design bases of the facility. Included in these guidelines should be procedures for the following:

  -- cooling a severely damaged reactor or an undamaged core for which natural circulation cooling is blocked;
  -- preventing containment failure in the event of a significant core meltdown;
  -- responding to natural phenomena in excess of those considered in the design bases for the plant; and
  -- other events beyond the normal design bases, such as loss of all electrical power.

  We do not advocate making all of these events part of the design bases or developing more highly detailed and confusing procedures for the operators to try to memorize. We have in mind sufficient guidance so that the operators understand what they can do to combat these situations and to make sensible decisions about which course of action might be most effective. Discussions, training seminars, and drills should be conducted to ensure that plant operating personnel provide input to the procedures and can use them effectively for guidance in the event of need.
- Each utility licensed to operate a nuclear plant should develop plans for effective mobilization and use of industry resources for the mitigation of consequences and for recovery from reactor accidents.

REFERENCES AND NOTES

[1]Floyd dep. at 135-136.

[2]Zewe Interview on March 30, 1979 (Met Ed) at 1.

[3]Scheimann Interview on March 30, 1979 (Met Ed) at 1.

[4]Frederick Interview on March 30, 1979 (Met Ed) at 2.

[5]Faust Interview on March 30, 1979 (Met Ed) at 1.

[6]Zewe Interview on March 30, 1979 (Met Ed) at 3.

[7]Bryan dep. at 27-28.

[8]NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," NUREG-0600, at IA-40, August 1979.

[9]Mehler dep. (Oct. 11, 1979) at 7, 9.

[10]*Id.* at 5-6, 9.

[11]Pres. Com. Hearing (May 30, 1979) at 118-120.

[12]"Report of the President's Commission on the Accident at Three Mile Island," Washington, D. C. at 100, October 1979.

[13]TMI Unit 2 Emergency Procedure 2202-1.3, Revision 11, 10/6/78, "Loss of Reactor Coolant/Reactor Coolant System Pressure," Sections A-3.2.2 and B-3.4 and 3.5.

[14]Frederick Interview on March 30, 1979 (Met Ed) at 5.

[15]Zewe Interview on March 30, 1979 (Met Ed) at 2.

[16]Two basic B&W training manuals are used by the TMI training group for discussions of plant response to transients. These manuals were reviewed by the SIG staff at the TMI training office. One was a five part manual used with videotape, and includes a collection of instrument traces from the B&W simulator showing instrument responses to various plant transients. The second manual includes discussions of transients and their effects on the Integrated Control System regulation of the nuclear steam supply systems.

[17]Zewe Interview on April 6, 1979 at 10:15 a.m. (GPUSC) at 4.

[18]Faust, Frederick, Scheimann, and Zewe dep. at 95.

[19]Zewe Interview on April 23, 1979 (IE) at 58.

[20]NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," NUREG-0600, Section 4.3.2, August 1979.

[21]Zewe Interview on March 30, 1979 (Met Ed) at 4.

[22]Technical Staff Analysis Report to President's Commission on the Accident at Three Mile Island, "Closed Emergency Feedwater Valves," Washington, D.C., October 1979.

[23]NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," NUREG-0600, Section 4.2 at I-4-5, August 1979.

[24]Summary of telephone conversation between D. Hunter and D. Allison, December 21, 1979.

[25]Faust, Frederick, Scheimann, and Zewe dep. at 229 et seq.

[26]NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," NUREG-0600, Section 4.6 at I-4-28, August 1979.

[27]Logan instructed Kunder to brief Miller. During the call he was not aware that it was in progress. Afterwards he asked if Kunder had briefed Miller. Ross and Mehler were not aware of the call. The question has not been specifically asked of the remaining control room personnel. However, none has mentioned any awareness in numerous recounts of the events that morning.

[28]Herbein Interview on May 10, 1979 (IE) at 6-7.

[29]Notes taken by John Herbein at 6:00 a.m. on March 28, 1979, Document TM 0398 (Herbein dep., Exhibit 12).

[30]Herbein dep. at 6.

[31]Rogers dep. at 11-12.

[32]Rogers dep., Exhibit 3111 at 6.

[33]Rogers Interview on May 4, 1979 (IE) at 11.

[34]Kunder Interview on April 25, 1979 (IE) at 22.

[35]Miller Interview on May 7, 1979 (IE) at 44-46 (tapes 159 and 160) suggests that the PORV may have been reported shut rather than the block valve since Miller recalled the impression that the operators looked at a "demand light." Kunder first indicated that it was the block valve, but in a later interview on May 17, 1979 (IE) at 33, Rogers was not sure that it was the block valve. Herbein's IE interview did not indicate which was reported. If the report did involve the PORV rather than the block valve it could possibly have occurred before 6:18 a.m. However, we consider it more likely that the block valve was reported shut as directly stated in Kunder's and Roger's initial IE interviews.

[36]G. P. Miller dep. (Sept. 20, 1979) at 12-13.

[37]This would be true, at least when the injection rates are averaged over periods of hours, provided that the BWST level readings which give such averages are not seriously in error and that the water taken from the BWST was pumped into the reactor coolant system as it should have been rather than being lost elsewhere. One possible but uncommon interpretation of the plant response data would indicate that much of the apparent BWST injection water was not pumped into the reactor coolant system. That interpretation is discussed elsewhere in this report.

[38]Faust, Frederick, Scheimann, and Zewe dep. at 136 et seq.

[39]Rogers dep., Exhibit 3111 at 12.

[40]Faust, Frederick, Scheimann, and Zewe dep. at 111.

[41]Rogers dep. at 22.

[42]Ross dep. (Sept. 18, 1979) at 16-18.

[43]The net injection rate is based heavily on BWST level decrease. One possible but uncommon interpretation of the plant response data holds that this BWST water was not pumped into the reactor coolant system as it should have been, but was lost elsewhere. This possible interpretation is discussed elsewhere in this report.

[44]Herbein dep. at 15-16.

[45]*Id.* at 16.

[46]Herbein dep. at 17.

[47]Herbein dep. at 56.

[48]G. P. Miller dep. at 6.

[49]Arnold dep. at 27.

[50]Herbein dep. at 29.

[51]Letter from M. Diaz, Shaw, Pittman et al. to G. Frampton, SIG, Subject: Response to Request for Information, dated August 7, 1979.

[52]G. P. Miller dep. (Sept. 20, 1979) at 21-22.

[53]Herbein dep. at 26-31.

[54]*Id.* at 31.

[55]Herbein Interview on May 10, 1979 (IE) at 10, 16.

[56]G. P. Miller Interview on May 7, 1979 (IE) at 19-21.

[57]Arnold Interview on May 9, 1979 (IE) at 10.

[58]Arnold dep. at 8.

[59]Arnold Interview on May 9, 1979 (IE) at 12-14.

[60]Arnold dep. at 9.

[61]Arnold Interview on May 9, 1979 (IE) at 17.

[62]Arnold dep. at 12.

[63]Arnold Interview on May 9, 1979 (IE) at 17-18.

[64]Arnold dep. at 20.

[65]Arnold Interview on May 9, 1979 (IE) at 20-21.

[66]Keaton dep. at 13.

[67]R. Wilson Interview Memo (Oct. 8, 1979) (not yet signed) at 4.

[68]Arnold dep. at 20-23.

[69]*Id.* at 5-6, 12.

[70]Herbein dep. at 43.

[71]Herbein Interview on May 10, 1979 (IE) at 17-18.

[72]Herbein dep. at 54.

[73]Arnold dep. at 27-28.

[74]R. Wilson Interview Memo (Oct. 8, 1979) (not yet signed) at 6-7.

[75]Arnold dep. at 26, 31, 33-34.

[76]Vollmer dep. at 36.

[77]Moore Interview on June 11, 1979 (IE) at 4, 5, 13.

[78]Nitti dep. at 4-5.

[79]Moore Interview on June 11, 1979 (IE) at 12.

[80]Faust, Frederick, Scheimann, and Zewe dep. at 11.

[81]Hitz dep. at 11.

[82]*Id.* at 14.

[83]Floyd dep. at 28

[84]Faust, Frederick, Scheimann, and Zewe dep. at 22-23.

[85]Floyd dep. at 34.

[86]Faust, Frederick, Scheimann, and Zewe dep. at 20.

[87]Pres. Com. Hearing (May 31, 1979) at 173, 178.

[88]Faust, Frederick, Scheimann, and Zewe dep. at 26-27.

[89]Floyd dep. at 31.

[90]*Id.* at 30-33.

[91]Pres. Com. Hearing (May 31, 1979) at 172-181.

[92]Faust, Frederick, Scheimann, and Zewe dep. at 26.

[93]Hitz dep. at 20-22.

[94]Pres. Com. Hearing (May 31, 1979) at 172.

[95]Floyd dep. at 29.

[96]Hitz dep. at 26.

[97]Floyd dep. at 55.

[98]*Id.* at 66-67.

[99]Pres. Com. Hearing (May 31, 1979) at 178-179.

[100]Floyd dep. at 92.

[101]G. P. Miller dep. (Sept. 20, 1979) at 51-52.

[102]Faust, Frederick, Scheimann, and Zewe dep. at 57.

[103]Floyd dep. at 90.

[104]*Id.* at 72-75.

[105]Faust, Frederick, Scheimann, and Zewe dep. at 30-31, 57-58.

[106]Hitz dep. at 23.

[107]*Id.* at 23-25.

[108]Faust, Frederick, Scheimann, and Zewe dep. at 31.

[109]Pennsylvania Emergency Management Agency Log, Message 15, Time 8:40 a.m., dated March 30, 1979.

[110]Floyd dep. at 84-85.

[111]Keaten dep. at 84-86.

[112]R. Wilson Interview Memo (Oct. 8, 1979) (not yet signed) at 9.

[113]W. Lee Interview Memo (Dec. 21, 1979) (not yet signed) at 3.

[114]Dieckamp dep. at 35.

[115]Kunder dep. at 125-127.

[116]Kunder dep. at 143-145 (Pres. Com.).

[117]"TMI Station, March 28, 1979 Event, Unit Two, G. P. Miller, Station Manager," (Miller dep., Exhibit 114).

[118]Hendrie dep. (Oct. 23, 1979) at 133-134.

[119]Denton dep. (Oct. 23, 1979) at 25, 26, 36.

[120]Case dep. at 75-76.

[121]Grimes dep. at 249.

[122]Eisenhut dep. at 209.

[123]Hendrie dep. at 131-132.

[124]Case dep. at 132-134.

[125]Eisenhut dep. at 205-206.

3. RADIOLOGICAL EMERGENCY RESPONSE

a. Introduction and Summary

The Metropolitan Edison Company activated their radiological emergency plan to cope with a reactor accident at Unit 2 of their Three Mile Island nuclear powerplant near Middletown, Pa., on March 28, 1979 at 6:55 a.m. This plan was based on Federal requirements for operators of nuclear powerplants, and had been coordinated with the Commonwealth of Pennsylvania emergency plan. However, we found that parts of TMI's written emergency plan did not fully conform with all of the existing NRC guidance on such plans. NRC's staff had been aware of these differences for several months, but had not notified Met Ed. Conceivably, some of these differences were shortcomings that had a negative impact on the response to the accident. However, the deviations from NRC's guidance delayed rather than prevented the desired response or action.

Coping with the effects of this reactor accident was the first real test of Met Ed's radiological emergency plan. The Special Inquiry Group looked into how well this plan worked to see what could be learned.

During the first day, the Met Ed emergency organization was frequently reorganized to adjust to changing conditions. Lacking a strong and clearly defined chain of command, individuals lost contact with the organizational structure and took independent actions—some beneficial, some ill-advised. Emergency procedures designed to guide the response were in some cases less effective than they should have been and in others were not followed.

With the exception of the TMI-2 control room staff and those personnel in direct contact with the control room, most Met Ed staff involved had only a limited understanding of what had happened or the potential for more serious consequences. Still they came to the plant early, stayed late, and worked diligently for many days in efforts designed to protect the health and safety of the public. In this effort, that portion of the plant staff responsible for collection and distribution of offsite exposure information was reasonably effective.

Although the response of many individuals on the plant staff was commendable, there were problems in such areas as recognition that an emergency existed, organization and the chain of command, and staffing and timeliness of determining offsite radiation levels. These problems were influenced by shortcomings in the emergency plan and preparations. Frequent drills contributed to the ability of plant personnel to implement the initial response to the accident. Equipment provided for the preplanned communications to State and Federal agencies worked well and was adequate; however, as more people and organizations got involved, the normal telephone system quickly became overloaded. The early response was aided by the availability of a full day-shift crew, but plans were inadequate for either an extended or augmented response. Radiation monitoring instrument limitations including design, installation, operation, and availability, hampered the initial offsite dose assessment calculations and the subsequent field monitoring response. Improvements in these deficient areas are needed to provide an acceptable emergency response capability on the part of Met Ed.

The majority of TMI staff who responded to the radiological emergency were not involved with control or mitigation of the inplant radiation levels or releases of radioactive material. Their principal tasks, with respect to offsite releases of radioactive material, were to identify and assess potential offsite exposures and to notify the State of their findings. This enabled the State to take appropriate protective actions for the public. Officials of the Pennsylvania Bureau of Radiation Protection generally were satisfied that Met Ed adhered to their commitment to provide information and assistance. Margaret Reilly, Chief of the Environmental Radiation Division of the Pennsylvania Bureau of Radiation Protection, later said, "I really don't have any great complaints with them [Met Ed] I think they upheld their end of the bargain."[1]

b. Identification and Declaration of Emergency

On March 27, at 11:00 p.m., the crew that was to operate TMI-2 until 7:00 a.m. the next day began work. The operating crew included a shift supervisor, a shift foreman, two control room operators, and six auxiliary operators. The radiation chemistry technicians (rad chem tech) on that shift included four technicians and one trainee. At 4:00 a.m. on March 28, the turbine and then the reactor tripped as a result of a loss of feedwater to the steam generators and the resulting primary system pressure transient. The pressurizer pilot-operated relief valve (PORV) opened, as designed, but failed to close, causing a loss of cooling water from the reactor coolant system into the reactor building. This constituted a small loss-of-coolant accident. The loss of reactor coolant water resulted in a drop in pressure in the reactor from 2435 to 1015 psig in about 20 minutes, and an increase of 1.4 psig in the reactor building in 15 minutes.

Approximately 4:30 a.m., Terry Daugherty, an auxiliary operator, saw that the reactor building sump pumps were working and that a reactor building high sump alarm had been received. As he left the area, Daugherty observed a visual alarm on a nearby radiation detection instrument (RH-14/HP-210), and reported the operation of the sump pumps, the high sump alarm, and the radiation instrument alarm to Ed Frederick, a control room operator. Daugherty was directed to make a radiation survey in the area of the radiation detection instrument. The survey indicated a radiation level of less than one-tenth of a milliroentgen per hour (mR/h), which was not much in excess of the radiation levels usually observed in the area. Daugherty's observations concerning the sump pumps and sump level alarm were reported to William Zewe, Shift Supervisor, who directed that the reactor building sump pumps be turned off because he believed the receiving liquid waste storage tanks were almost full. The reactor building sump pumps were manually turned off at 4:38 a.m.

The criteria for declaration of a site emergency (TMI Emergency Procedure 1670.2) include "loss of primary coolant pressure, coincident with a high reactor building pressure and/or high reactor building sump level." One could have interpreted the conditions that existed at this time to conform to this criteria. However, Zewe interpreted the conditions in a way that precluded the declaration of a site emergency. He believed that the reactor coolant system pressure had stabilized, and that the increase in reactor building pressure and the high reactor building sump level were not sufficient cause to declare an emergency.[2] No site emergency was declared.

As part of the normal post-trip procedure, Dave Zeiter, a rad chem tech, collected a sample of Unit 2 primary coolant in the sample room located near the Unit 1 radiation protection laboratory area about 5:00 a.m. The sample was analyzed for boron, and a significantly lower concentration was observed than existed before the trip. Therefore, a second sample was requested.

Also at that time, the Radiation Protection and Chemistry Supervisor, Richard Dubiel, was called and instructed to report to the plant. Between 5:00 and 5:20 a.m., three radiation alarms were received—the reactor building air particulate monitor and two liquid process monitors near the reactor building. Zewe did not recall the air particulate monitor alarm; he was aware, however, of the two process monitor alarms, which he attributed to a crud burst (a release of deposited radioactive material from the internal surfaces of the reactor coolant system). He also believed that the emergency procedures referred only to area radiation monitors and not to process monitors when considering the requirements for the declaration of an emergency. The emergency plan identifies one of the conditions for declaration of a local emergency as the point at which "more than 1 radiation monitor in a single building reaches their alarm setpoint." Procedure 1670.1, Local Emergency Procedure, on the other hand, describes one of the conditions for declaring an emergency as the point at which "one or more radiation monitors in a single building reach their high alarm setpoint. More than one radiation monitor reaches the low alarm setpoint." Between 5:15 and 5:45 a.m., the levels indicated by certain radiation monitors continued to increase and several reached the preset alarm level. No local emergency was declared.

Dubiel arrived on site at 5:40 a.m. and was asked to change the charcoal cartridge and particulate filter in the reactor building air monitor. He and Mike Janouski, a rad chem tech, were unable to complete the change when they found the sample line full of water, indicating a steam environment in the reactor building.

Two more primary coolant samples were collected. The last sample, taken about 6:00 a.m., indicated a still lower boron concentration and a factor of 10 above normal concentrations of radioactive material. These concentrations had not been determined in the two earlier samples.

At 6:18 a.m. the PORV block valve was closed, terminating the continued loss of reactor-cooling water through this path. After closing the PORV block valve, two area radiation monitors, a reactor building air particulate monitor, and an incore panel area monitor, reached their alarm setpoints (the air particulate monitor for the second time). At 6:30 a.m. Dubiel was asked to arrange an entry into the reactor building; however, because of the impending 7:00 a.m. shift change and subsequent events, the entry was never attempted.

Between 6:30 and 7:00 a.m., several area and process radiation monitors alarmed because of increasing radiation levels. Radiation surveys were performed by rad chem techs John Donnachie, Mike Janouski, and Richard Brenner. Joe Deman, a Radiation Protection Foreman, directed the surveys in the TMI-2 auxiliary building. Brenner detected levels in excess of the 5 R/h range of his survey instrument, while Donnachie and Janouski, using a higher range instrument (teletector) measured 10 R/h at the doorway to the makeup tank room. Terry Daugherty and Dale Laudermilch, auxiliary operators, were also in the auxiliary building when, according to Laudermilch, Daugherty observed, "Hey, we're getting water out of the floor drains...[the] aux building sump is overflowing."[3] Shortly thereafter, Janouski came running through the area and told them to "get the hell out."[3] Janouski's actions were coincident with the declaration of a site emergency by Zewe. Meanwhile, Juanita Gingrich, a former plant security guard who recently began training as an auxiliary operator, was working in the adjacent turbine building. Gingrich was manually rotating the "B" main feedpump turbine one-half turn every 2 minutes. Later she explained, "I had to keep doing that to keep the shaft from warping...that was one you always have to do everytime the turbine trips, cause they never got it [motorized turning gear] fixed yet."[4] When asked if an evacuation of the turbine building was required Gingrich acknowledged, "Yeah, shortly after that they gave the evacuation....And then, after that, they told me I should stay down here."[4] Gingrich stayed until she was relieved at 8:00 a.m. in spite of audible alarms from the atmospheric radiation monitor located at the nearby condenser vacuum pump.[5] (Gingrich left the site around 10:00 a.m. after being checked and found free of contamination.)

Approximately 6:40 a.m., a fourth primary coolant sample was collected. The sample contained roughly 140 microcuries per milliliter ($\mu Ci/ml$) of gross gamma activity. This level of activity was approximately 350 times the normal level. Process sample lines, including reactor coolant sample lines from Unit 2, run to the Unit 1 sample room. The Unit 2 sample lines were not shielded in Unit 1. When the coolant sample was collected about 6:40 a.m., the increased radiation levels from the primary coolant in the sample lines caused area radiation monitors to sound alarms in the Unit 1 sample room and the nearby hot machine shop. Consequently, the technician stopped recirculation of primary coolant through the sample lines.

At 6:45 a.m. Dubiel instructed Mike Kuhn, a rad chem tech, to call Tom Mulleavy, Radiation Protection Supervisor and Fred Huwe, a Radiation Protection Foreman, and ask them to report to the plant. When the alarm in the hot machine shop area monitor rang at 6:48 a.m., a survey showed radiation levels of 1.5 R/h on the sample lines and 500 mR/h in the general area. Dubiel notified George Kunder, the Unit 2 Superintendent of Technical Support, who was in the control room, of the increasing radiation levels. Kunder later stated:

> Dick [Dubiel] called up very shortly thereafter and I heard him screaming over the page 'George Kunder, George Kunder, line one' and I answered. Dick said, 'George, the sample line had just went up to 600 mR/h,' and at that point I realized 'oh my God we're failing fuel' and I yelled at Joe [Logan, Unit 2 superintendent]. I said 'Joe, we're failing fuel, Dick's got 600 mR/h at the sample lines,' and that was right around 6:45 in that region and I said 'hey, we're into site emergency, it's the real thing,' and a site emergency was declared.[6]

Zewe said later:

> I declared a site emergency because the radiation levels were going up, and it was getting worse and we really didn't know at that time exactly where the activity was coming from, and then we had a report that the aux[iliary] building drains were backing up and that the water in the drains was the source of the radiation going out the station vent. All our radiation monitors in the building showed this....[7]

Dubiel put Janouski in charge at the emergency control station located in the Unit 1 radiation protection laboratory area, and then hurried to the Unit 2 control room as the site emergency alarm was sounded and announced. The site emergency was declared at 6:55 a.m. based on the alarms of process and area monitors.

Gary Miller, the Station Manager, arrived and took over as the emergency director, declaring a general emergency at 7:24 a.m. This declaration was based on a reading in excess of 8 R/h on the reactor building containment dome monitor (HP-R-214). The declaration was in keeping with the requirements of Procedure 1670.3, General Emergency Procedure. It should be noted that the HP-R-214 detector, an ion chamber, was shielded with enough lead to reduce the instrument response by a factor of 100. The dome monitor reading increased 200-fold between 7:13 and 7:18 a.m. before leveling off at 200 R/h, which was assumed to be indicative of a dose rate of 20 000 R/h in the reactor building.

During our review, we found that the TMI emergency plan, contrary to the guidance in Regulatory Guide 1.101, had no Emergency Alert Class. Such a classification is described as involving "specific situations that can be recognized as creating a hazard potential that was previously nonexistent or latent."[8] It is possible, that had such an emergency classification existed in the TMI plan, an alert might have been declared earlier. Nonetheless, information was available in the control room indicating that the plant conditions were degrading and the criteria listed in the emergency plan for the declaration of a site emergency were exceeded as early as 4:38 a.m.

c. Organization and Staffing

With the declaration of a site emergency, the Unit 2 control room staff began implementing Procedure

1670.2, Site Emergency. The Unit 2 control room became the emergency control center. The emergency procedures identify specific duties and responsibilities with respect to certain organizational positions and functional responsibilities. The procedures also specify alternates and require appropriate training for each identified position and responsibility. Changing the operating organization to one designed for emergency response disrupted the normal chain of command and communication. This change occurred as the regular day shift was arriving for work. The emergency organization established following the announcement of a site emergency is shown in Figure III-4.

"Plant Operations" continually assessed and corrected plant conditions to establish or maintain stability and to mitigate the consequences of the accident. The "Radiological Assessment" group assessed and estimated the accident's radiological consequences. The "Emergency Control Station Director" was responsible for the assembly and deployment of various onsite and offsite monitoring teams, monitors, repair parties, and emergency chemistry personnel. The "Accountability" group controlled access to the site, assembled nonessential personnel, and accounted for personnel on site.

Although there was some confusion as to assignments, by the time Miller arrived at 7:05 a.m., the various groups had begun to function. Personnel due for the 7:00 a.m. shift change were on site or arrived shortly after the site emergency was announced. Miller informed the staff that he was assuming the role of Emergency Director, and he established a command team that reported to him. The resulting organization differed in some respects from the earlier one, as shown in Figure III-5. As Miller described the following:

> Basically, I set up this emergency command team in the early hours as I arrived at the plant and the radiation emergency was in progress, by essentially forming my senior people into a network to supervise, conduct the emergency, and report to me while bringing the plant to a safe condition.[9]

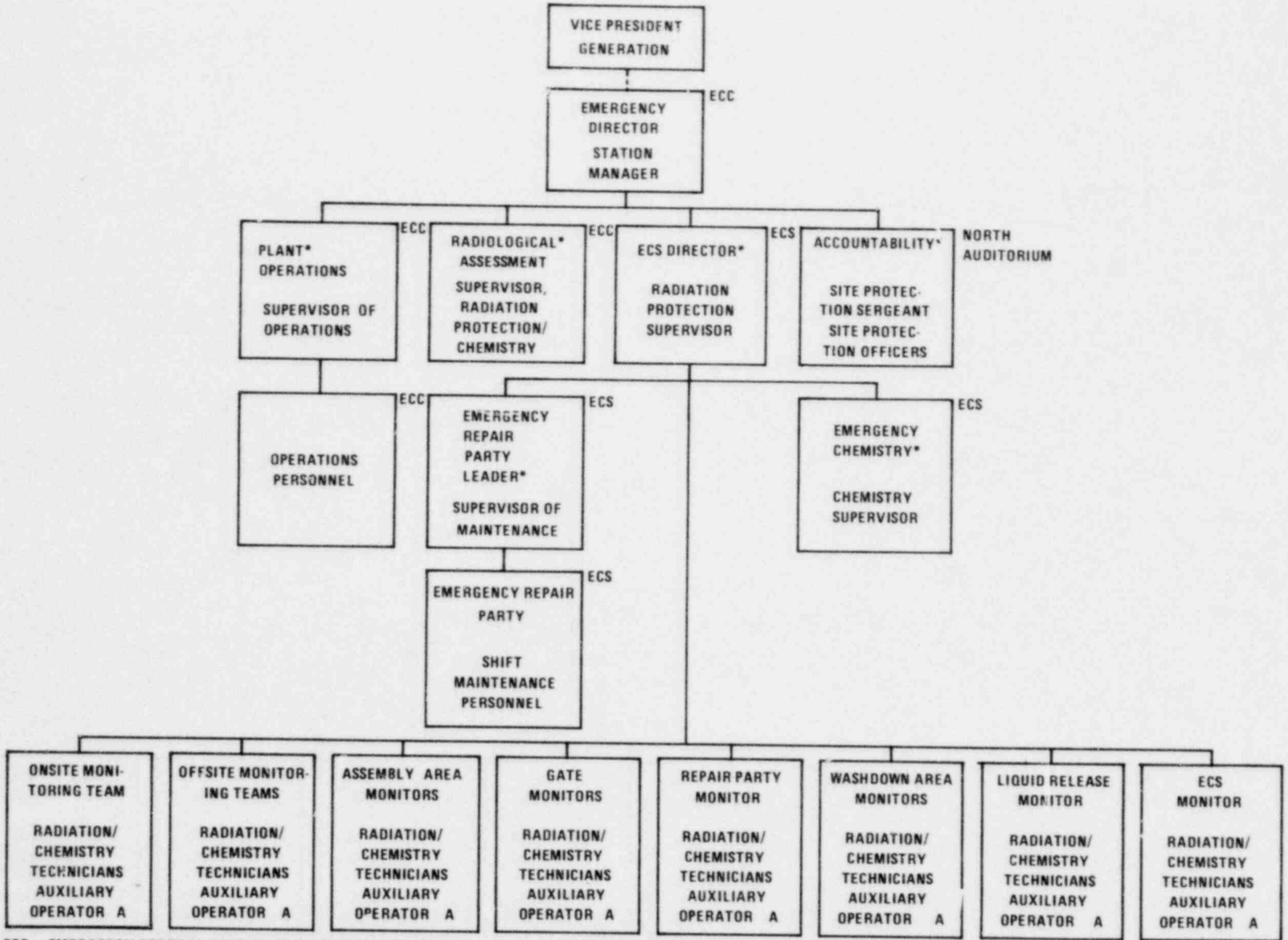
Dubiel later said that although this organization differed from the emergency plan, it was an organizational structure that had been included in drills.

Between 6:55 a.m. (when Dubiel instructed Janouski to set up the emergency control station at the Unit 1 radiation protection laboratory area) and 7:35 a.m. (when Mulleavy arrived and assumed his role as Emergency Control Station Director), there was some confusion as to who was in charge. Radiation Protection Foreman Deman arrived at the plant before the site emergency was declared, and after talking to Dubiel, entered the plant to make surveys. After the emergency was declared Deman quickly returned to what was now the emergency control station. When Janouski saw Deman he assumed he was relieved and began to function as a member of a monitoring team. Pete Velez, another Radiation Protection Foreman, arrived about 7:05 a.m. and worked with Deman in getting the onsite and offsite monitoring teams started. Both men then directed their attention to other activities. Huwe arrived at 7:15 a.m., and believing that no one was in charge of the emergency control station, assumed that responsibility until relieved by Mulleavy about 7:35 a.m. Mulleavy remained as the Emergency Control Station Director until the next day.

The next organizational change occurred about 9:00 a.m. when increasing radiation levels and airborne radioactive materials caused personnel to move the emergency control station to the Unit 2 control room. This revised organization is shown in Figure III-6. The loss of the radiation protection laboratory area facilities denied access to the only operating multichannel gamma analyzer. With the loss of this capability, Met Ed was no longer able to analyze for iodine-131 in the presence of noble gases. As a result, personnel in both units, including those in the control rooms, were later required to wear respirators when this might not have been otherwise required. The loss of this area denied access to radiation protection equipment and supplies, and to the personnel decontamination showers and facilities. The transfer of the emergency control station to the Unit 2 control room went smoothly. It was an evolution that had been included in one of the emergency plan drills conducted in 1978.

As originally conceived, the repair parties operated out of the emergency control station and their activities were coordinated by the director of the emergency control station. This assured that radiological controls designed to limit personnel exposures would be followed and that maximum radiological information would be gained from each entry into a contaminated or radiation area. Under the organizations established prior to 8:00 a.m., repair parties were established in both the Unit 2 control room and emergency control station. By 8:00 a.m. all repair party personnel had been relocated to the Unit 2 control room. After the emergency control station was relocated, Dubiel and Mulleavy redistributed the radiological workload. Mulleavy retained control of the on- and offsite monitoring teams; Dubiel assumed direct control of inplant radiation protection functions. As a result of this change, some loss of control and information occurred that might have been avoided under the initial organization.

Between 10:00 and 11:00 a.m., the emergency control station was relocated to the Unit 1 control room where it remained for an extended period.



ECC - EMERGENCY CONTROL CENTER, UNIT 2 CONTROL ROOM
ECS - EMERGENCY CONTROL STATION, UNIT 1 CHEMISTRY/HEALTH PHYSICS LAB AREA
* - FUNCTIONAL TITLE ADDED FOR CLARITY, LICENSEE'S PLAN LISTS NORMAL DUTY TITLES

FIGURE III-4. Organization Described in Emergency Plan

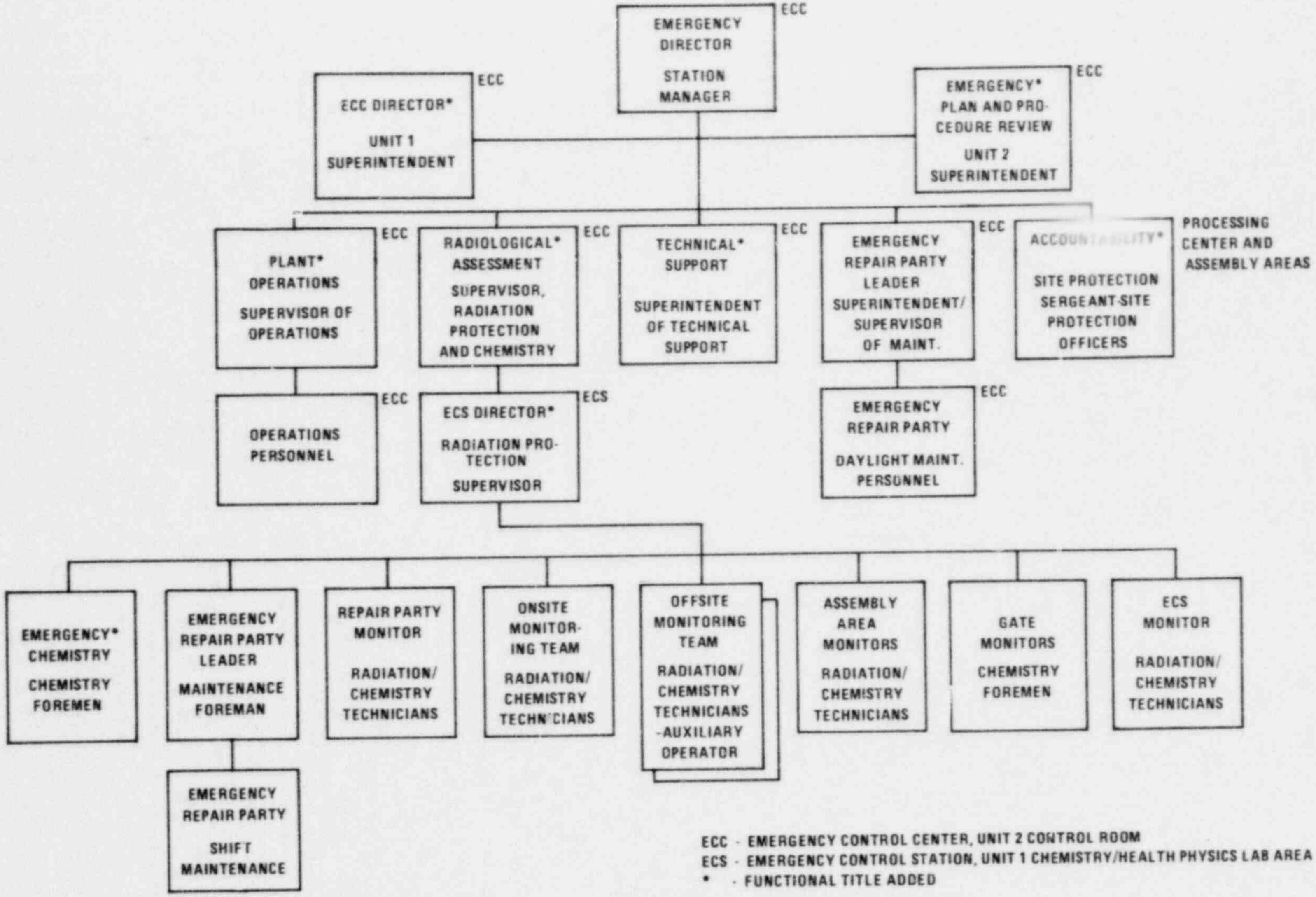
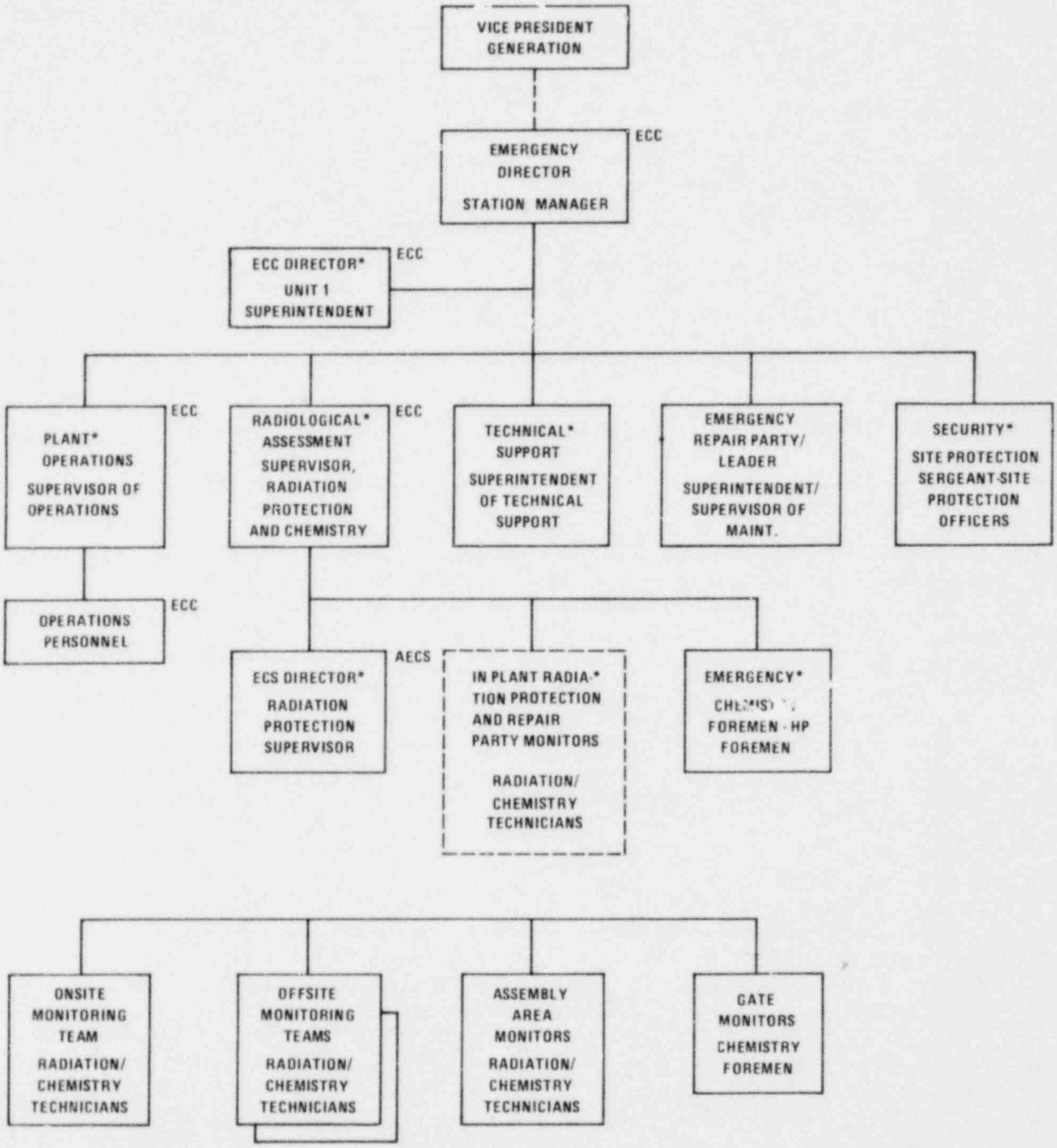


FIGURE III-5. Emergency Organization in Effect on March 28, 1979, 7:30 a.m.-9:00 a.m.



ECC - EMERGENCY CONTROL CENTER - UNIT 2 CONTROL ROOM
AECS - ALTERNATE EMERGENCY CONTROL STATION - UNIT 2 CONTROL ROOM
* - FUNCTIONAL TITLE ADDED

FIGURE III-6. Emergency Organization in Effect on March 28, 1979, 9:00 a.m.-11:00 a.m.

The emergency organization stabilized with this move and continued without significant change. The final organization is shown in Figure III-7.

As a result of increasing radiation levels at the onsite assembly area, all nonessential personnel were evacuated from the island at 11:10 a.m. Met Ed deviated from the original concept of organization and staffing laid out in the emergency plan. The change in reporting channels apparently left some personnel adrift and unfamiliar with the existing chain of command.

Some rad chem techs stated that they reported to any of the available radiation protection foremen. Furthermore, some personnel assumed functions that were not the best use of their abilities, e.g., two chemistry foremen worked as gate monitors, and two newly hired and untrained rad chem techs performed more complex duties at a monitoring and decontamination station. However, the evidence does not indicate that this matter made a significant difference during the emergency response.

Miller continued as Emergency Director until about 2:00 p.m. when he, Kunder, and Jack Herbein, Vice President of Generation, left the area to brief Lt. Gov. Scranton in Harrisburg. Although Miller objected to leaving the plant, he did not feel the safety of the public was jeopardized by his departure.[10] Miller returned to the plant at about 4:30 p.m. This absence by Miller appeared not to have any impact on the execution of the radiological emergency plan. After his return, Miller continued as Emergency Director until he left the site around 2 o'clock the following morning. Joe Logan, Unit 2 Superintendent, took over as Emergency Director until Miller's return a few hours later. Logan reported to the Unit 2 control room at 5:45 a.m. on March 28, and did not leave until noon on March 29.

By the evening of March 28, many of the plant staff were exhausted. Management was slow to recognize that the emergency wasn't going to end conveniently like the drills. In the absence of planning for an extended response, management belatedly began setting up revised shift schedules and sending members of the staff home. Twelve-hour shifts were planned, but some individuals worked for extended periods of 24 to 30 hours. In one case, Ed Egenrider, a rad chem tech, worked 48 hours without relief.

In the days following March 28, the emergency response organization remained substantially unchanged. Shifts were established and personnel were replaced. The emergency control center remained in the Unit 2 control room where concerns were mainly directed to stabilizing and cooling the reactor. None of the principals involved in the organization were able to state when the emergency ended.

The emergency control station remained in the Unit 1 control room from which the onsite and offsite monitoring teams were directed. These monitoring activities continued until the first half of July; long after onsite and offsite radiation levels had returned to preaccident levels.

Emergency Director-Succession, March 28-29, 1979

Miller took over as Emergency Director when he arrived in the Unit 2 control room at 7:05 a.m. Herbein arrived at the TMI Observation Center around 11:40 a.m., at which time he received a telephone briefing on the plant's status from Miller. Herbein was under increasing pressure from the Governor's Office for information about the plant's status.[11,12] As a result, Miller said he was "directed [by Herbein] to go to the Lieutenant Governor's office, and, therefore, I departed the site at approximately 1430 with as much information as I could about the incident."[13] Satisfied that the plant was reasonably stable, Miller left the control room around 2:00 p.m. at which time Logan was placed in charge of the plant as Emergency Director. Logan's original assignment had been to assure that all actions required by procedures and the emergency plan were accomplished. Michael Ross, Unit 1 Supervisor of Operations, was placed in charge of Unit 2 operations. Both Logan and Ross had been in the control room since early morning.

James Seelinger, Unit 1 Superintendent, was called to the Unit 2 control room by Ross shortly after Miller left the plant. Seelinger believed that Ross wanted organizational support for the emergency plan activities, which Seelinger provided. Seelinger remained in the Unit 2 control room until Miller returned from the Lieutenant Governor's Office about 4:30 p.m. Seelinger then returned to the emergency control station in the Unit 1 control room. When Miller returned he reassumed the position of Emergency Director and remained in full command until about 8:00 p.m., when, believing that senior Met Ed management (Herbein) had taken over direction of activities, he considered himself to be a Shift Superintendent/Emergency Director. Miller recalled that on the night of the 28th he appointed Seelinger as his alternate, an assignment that remained in effect for about a week.[14] Seelinger and Ross recalled that the transition to shifts occurred after they returned to the plant on March 29.[15,16]

Herbein left the Observation Center and the immediate area between 1:30 and 2:00 a.m.[17] Seel-

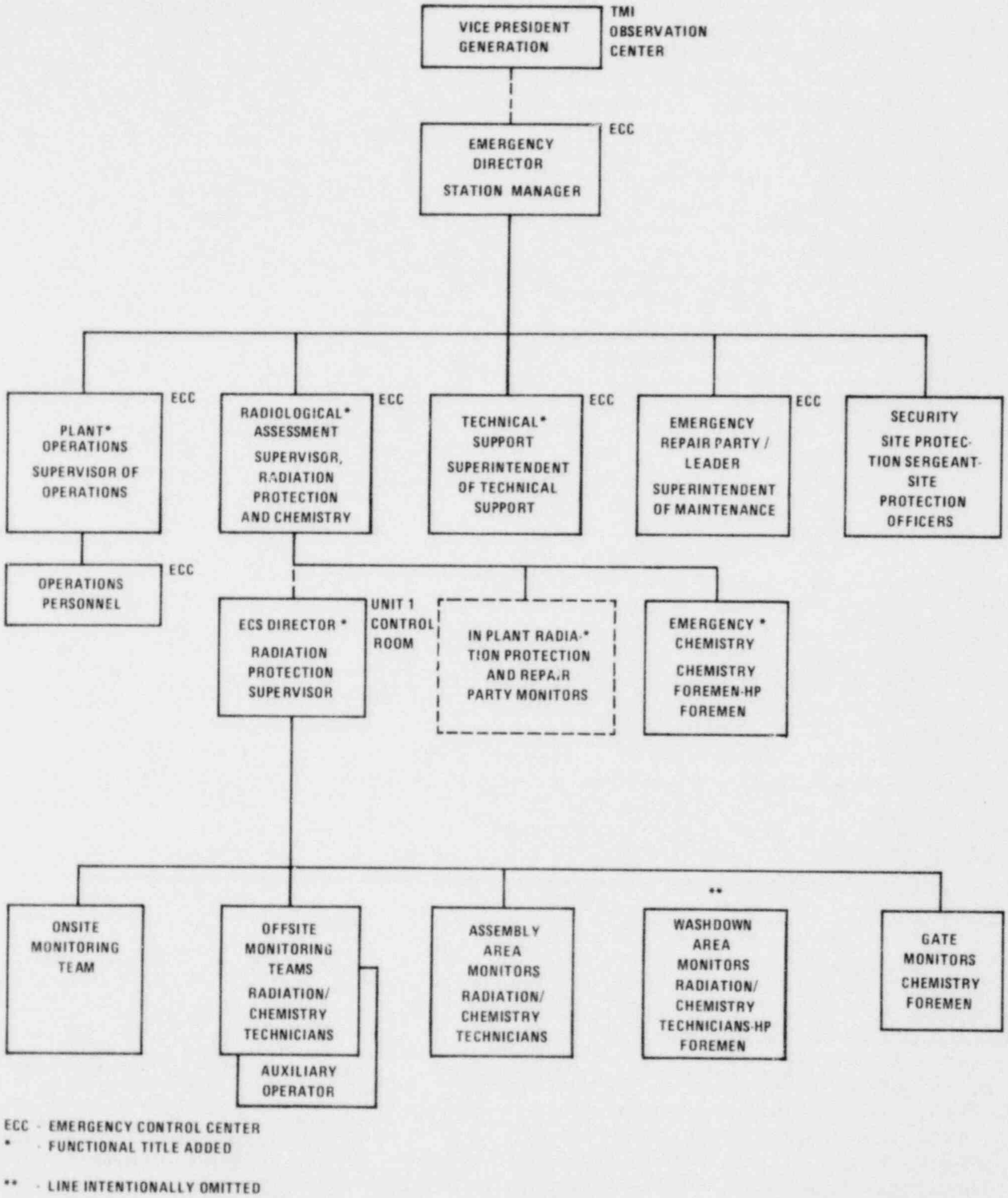


FIGURE III-7. Emergency Organization in Effect on March 28, 1979, 11:00 a.m.-8:00 p.m.

inger returned to the Unit 2 control room between 9:00 and 10:00 p.m. Seelinger, Ross, and Miller went to their homes about 3:00 a.m., and Kunder went home sometime between 3:00 and 4:00 a.m.[15,16,18] The departure of these four men left Logan in charge as Shift Superintendent/Emergency Director.

On March 29, a shift schedule was set up that provided for continuity in the Shift Superintendent/Emergency Director position. Although the position of emergency director remained in the organization, it became a less effective part of Met Ed's response to the radiological emergency. The shift superintendent/emergency director was increasingly concerned with inplant matters relating to control and cooling of the reactor.

Continued operation of the makeup system was required to ensure that the operating reactor coolant pump would continue to force cooling of the damaged reactor core on both the 28th and 29th. Because of the buildup of gases in the makeup tank from outgassing of reactor coolant, the operators periodically vented the makeup system to the waste gas header in the auxiliary building. The evening of the 29th, operators were aware that this process was a major source of the radioactive gases that were released from the plant, and which were observed above the plant vent on both the 29th and 30th. The high radiation level of 1200 mR/h measured above the plant vent at 8:01 a.m. on the 30th, caused the evacuation scare later that day and contributed to the Governor's subsequent decision to advise pregnant women and preschool children within a 5-mile radius of the plant to leave the region, and to close the schools within that area.

We could find no evidence that the operator action of venting the makeup tank to the vent header was discussed with, or approved by, the emergency director. Moreover, the reason for the venting and the control methods used during venting were not communicated to Met Ed, the NRC, or State officials who were both surprised and alarmed by the high radiation levels above the plant on the 30th. On the morning of the 30th, there apparently was confusion about who was in charge of plant operation. Zewe testified that he and another supervisor, Greg Hitz, made the decision and took the action to vent the makeup tank. James Floyd, the Unit 2 Operations Supervisor, has testified that he made the decision. In either case, apparently neither informed Logan, who was functioning as the Emergency Director at this time. Miller, who was outside of the plant buildings in his office when the activities took place, came to the control room after the venting was in progress.[19]

Emergency Control Station and Monitor Team Evolution

When the emergency control station was relocated to the Unit 1 control room between 10:00 and 11:00 a.m. on March 28, Mulleavy was the Director. Under his direction the dose assessment calculations, which began earlier in the Unit 2 control room, and the on- and offsite monitoring activities, which were controlled from the emergency control station, were continued. Mulleavy left the plant about 3:00 a.m. on March 29, and was replaced by William Potts, the Unit 1 Superintendent of Technical Support.

Mulleavy returned to the emergency control station on Wednesday afternooon or evening and rotated with Potts until he was relieved by Alexis Tsaggaris, Station Maintenance Supervisor from Met Ed's fossil fueled powerplant at Reading, Pa.

Tsaggaris, prior to his assignment at Reading, had been training supervisor at TMI and was closely involved in emergency plan training. Potts and Tsaggaris rotated as directors of the emergency control station. During the postaccident period the emergency control station had engineers who performed dose assessment calculations, as well as health physics and environmental specialists who directed the monitoring teams and interpreted the data. A consultant, Sydney Porter of Porter-Gertz, worked in the emergency control station after he arrived on the evening of March 28. Porter had assisted in the preparation of the TMI emergency procedures and some of the drill scenarios.

Fatigue of the monitoring teams and the necessity for maintaining and expanding the followup resulted in the decision to use non-TMI radiation protection technicians in this effort. By midnight on the 28th, support was arriving from sister utilities. According to the visitor registration log, the first personnel were from the Salem plant of the Public Service Electric and Gas Company of New Jersey. They were followed by personnel from the Susquehanna plant of the Pennsylvania Power and Light Company. Included in the latter group was William Allen, Dubiel's counterpart who was put to work in the emergency control station. Philadelphia Electric Company personnel arrived on March 30.

Fourteen technicians (rad techs) from Nuclear Support Services Inc. (a firm that supplies contract radiation protection services to the industry) arrived at TMI on the 29th, four arrived on the 30th, and five on the 31st. Most were used as offsite monitors enabling the Met Ed rad chem techs to return to TMI to perform inplant monitoring activities. Monitoring teams were staffed and manning schedules developed at the Observation Center command post on March 29. The three monitoring teams available on the 28th were expanded to five on the 29th, and six on the 30th. A seventh team was later established for a short period.

Corporate Response-Development

Early in the morning of the 29th, a command post and long range planning and logistical unit was established at the Observation Center by senior Met Ed and General Public Utilities (GPU) personnel. These individuals had no assigned role in the TMI emergency response, however. The buildup of support by Met Ed and GPU was significantly aided by the fact that utilities customarily respond to disaster or accident-caused service disruptions.

Response of Plant Personnel

A general comment by members of the plant staff was that there was no panic and that the emergency plan went well. Not unexpectedly, the Unit 2 control room became crowded on many occasions; some estimates were that as many as 40 to 50 persons were in the control room at various times. Miller said, "I spent many periods clearing the Control Room in order to maintain the calm atmosphere that was evident throughout the day."[20]

Some of the events of March 28, belie the belief of the staff. In certain cases individuals were instructed to carry out assignments involving significant potential exposures when appropriate radiation detection instruments were not available and when the task was unnecessary. Some of these instructions apparently were given without regard to acceptable radiation protection practices or adequate knowledge of plant conditions. The problems encountered in implementing inplant radiation protection controls are discussed in detail elsewhere in this report. When the emergency control station could not be occupied because of increasing radiation levels or airborne radioactive material, it was moved to the alternate emergency control station in the Unit 2 control room. The move began at 9:12 a.m. and was completed by 9:17 a.m. Plant personnel involved in the relocation said it went well because it had been one of the scenarios practiced in a previous drill.

The staff responded to the accident with the dedication and concern warranted by the situation. The plant's radiation protection staff consisted of four radiation protection foremen, the chemistry foremen, and four 4-man rad chem tech crews who were on duty or reported for duty about 7:00 a.m. Two crews totaling eight individuals were off duty. Donnachie, a member of one of the two offduty shift crews, was working an overtime shift when the accident occurred. Three of the seven remaining off duty rad chem techs, reported or attempted to report to the site early when they learned of the accident. The evidence indicates that personnel fulfilled their obligation for protection of the public to the best of their abilities.

d. Dose Assessment and Onsite and Offsite Monitoring

With the announcement of a site emergency, Howard Crawford, a nuclear engineer, reported to the Unit 2 control room to perform onsite and offsite radiation dose assessment calculations. Shortly after 7:00 a.m. Crawford examined the two radiation monitors of greatest significance--HP-R-214, the reactor building dome monitor (gamma); and HP-R-219, the station vent monitor (particulate, iodine, and gas). He found that the most significant value was displayed by HP-R-214, which he then used as the basis for his initial calculations. According to Crawford, the meter reading was 300 R/h for the dome monitor at that time.

Procedure 1670.4, Radiological Dose Calculations, is one of the implementing procedures of the emergency plan; its purpose is to obtain early information for the decisions necessary to limit the public's exposure during a nuclear accident. Using this procedure, dose rates at offsite locations were estimated based on measured or potential airborne releases from the plant and prevailing meteorological conditions.

The evidence suggests that the initial calculation (completed shortly after 7:18 a.m.) estimated a radiation dose rate due to noble gases of 10 R/h in Goldsboro. Plant personnel considered this estimate to be abnormally high because the pressure in the reactor building was less than that assumed for the calculation. The calculation was based on the design basis reactor building leak rate of 0.2 weight percent per day of the contained volume at a reactor building pressure of 56 psig. At the time, the actual reactor building pressure was 2 to 2-½ psig. The estimate, however, was communicated at 7:35 a.m. to the Pennsylvania Bureau of Radiation Protection, which alerted the Pennsylvania Emergency Management Agency authorities for possible evacuation of nearby Goldsboro and Brunner Island. By 7:45 a.m. the results of an onsite survey made at a location between the plant and the community of Goldsboro revealed that the radiation dose rate was less than 0.001 R/h (1 mR/h). Hence, the 10 R/h estimated dose rate at Goldsboro could not exist, and the evacuation alert was canceled by the Pennsylvania Bureau of Radiation Protection at 8:15 a.m. Subsequently, radiation surveys at Goldsboro at 8:32 a.m. also showed that dose rates were less than 1 mR/h. (Details about the actions taken by the plant staff with respect to the initial calculation are provided elsewhere in this section of the report.)

Onsite and offsite radiation monitoring teams were assembled and dispatched from the emergency control station after the declaration of the site emergency. The teams normally consisted of two rad chem techs designated by the emergency control station director. The teams took walkie-talkies and picked up prepackaged emergency monitoring kits at the process center (Security Search Facility) at the north end of Unit 1. Before leaving the process center, the teams inventoried the kit contents to verify that the instruments would work. The teams were then directed from the emergency control station to locations marked on maps contained in each kit. The activities of the on and offsite monitoring teams are known principally from the emergency control center–emergency control station log of communications. The initial teams sent out were given names of "Alpha," "Bravo," and "Charlie."

Personnel evaluating exposure data found that very few of the dose rate measurements made by the teams on March 28 distinguished between open (beta-gamma) and closed (gamma) window instrument readings, or identified the instruments used by the teams. This oversight created problems in the subsequent attempts to confirm data used for population exposure calculations.

The Alpha team was dispatched at 7:25 a.m. to an area on Three Mile Island almost directly west of the Unit 2 plant vent to make dose rate measurements and collect iodine samples. At 7:46 a.m., a dose rate of less than 1 mR/h was reported at that location by the team. At 7:57 a.m., a second survey team reported a dose rate of less than 1 mR/h at the Observation Center east of the Unit 2 plant vent. At 8:02 a.m. offsite team Charlie was directed to location W-11 in Goldsboro. At 8:10 a.m. a report of less than 1 mR/h in Royalton, north of the plant, was received from team Charlie on the way to Goldsboro. Team Bravo was initially dispatched to the area east of the plant and later joined team Charlie at Goldsboro.

On the morning of the accident the wind was blowing very lightly (2–4 miles per hour) out of the east toward Goldsboro. Goldsboro is only 1.4 miles from the plant but is across the river and is not easily accessible. For the offsite team to reach Goldsboro, it was necessary to drive a distance of 20 to 30 miles. The first recorded measurement from Goldsboro was at 8:32 a.m., about 1 hour after the initial dose rate calculation. (During the seven emergency plan drills conducted during 1978, an offsite monitoring team was never required to travel to the west shore of the Susquehanna River.)

The first reports received from Goldsboro were that less than 1 mR/h was detected and that an air sample was being collected. At 9:00 a.m., reports were received from all three teams in the field (Alpha on site, Bravo and Charlie in the Goldsboro area) that dose rates were less than 1 mR/h. The results of analyses of air samples for iodine-131 collected in Goldsboro and on site were near the minimum detectable level. The observed radiation and iodine-131 levels were substantially below the levels predicted by the early dose assessment calaculations. Team Alpha began to observe increasing dose rates of up to 3 mR/h in the TMI north parking lot about 10:30 a.m. The levels on site continued to increase for 12 to 13 hours, with peak readings on site of 365 beta-gamma/50 gamma mR/h.

The Pa. State Police supplied helicopters on March 28 at the request of the plant staff. Trooper E. Frantz, PSP Aviation Unit, flew a monitoring team over Royalton, Middletown, Highspire, Goldsboro, the Susquehanna River, and Unit 2 between 12:30 and 1:30 p.m. This was the only Met Ed aerial monitoring flight on March 28. (Other aerial surveys were made by Federal agencies on the 28th.) At 1:30 p.m., dose rates of 10 and 20 mR/h were measured above the Unit 1 cooling tower and Unit 2 reactor building. The emergency control station log records the measurements on this flight as "300 ft above Unit 2 Rx Bldg."

Land grade at Unit 2 is 304 feet above sea level, and the top of the Unit 2 building and plant vent are 473 and 463 feet, respectively, above sea level. Confusion in reporting altitude or elevation above sea level or surface features was a continual problem.

Measured offsite radiation levels on March 28 generally remained below background levels except for a reading of 50 mR/h at 3:48 p.m. on the road east of Unit 2 near the Observation Center. Between 10:30 and 11:00 p.m., levels of 13 and 12 mR/h were measured at the Kunkel School (5.6 miles NNW) and across the river from Olmstead (approximately 3.5 miles WNW). From 5:00 p.m. to midnight, the wind was blowing at 5 to 15 miles per hour toward the northwest. However, Met Ed did not make field measurements in this area until the measurement at Kunkel School.

Met Ed analyzed onsite and offsite air samples for iodine-131 using the Eberline SAM-2/RD-19 instruments. This equipment had a minimum detectable activity (MDA) for iodine-131 of approximately 5E-9 (μCi/cc) based on the volume sampled and background levels. Additionally, some samples were analyzed by offsite support laboratories using GeLi (lithium drifted germanium detector) spectrometer systems. A total of 27 samples were collected and analyzed prior to midnight on the 28th. Reported onsite concentrations (SAM-2) ranged from less than the MDA to 6.8 E-7 μCi/cc iodine-131. Reported offsite levels (SAM-2) ranged from less than MDA concentrations to 9.5 E-7 μCi/cc. Samples that were counted using GeLi systems identified the presence of noble gases, but iodine-131 was below the MDA of these systems, which are more accurate and more sensitive than the SAM-2 instruments.

After the initial efforts on March 28, the emergency control station staff continued dose asessment activities and established source terms principally based on field radiation measurements by the monitoring teams. When helicopters became available on March 29 and 30, readings in the plume—the invisible elongated cloud of radioactive gas extending down wind from the plant—were also used for source term calculations. As new field measurements became available, the source term data was corrected using the True Source Term calculation method. The use of this technique was necessary because much of the Unit 2 monitoring instrumentation was off scale or, as in the case of the dome monitor, resulted in unrealistic source terms. (This was because the dome monitor measured the radiation levels in the reactor building and not in a release pathway.) In the case of the plant vent monitor, the data, when available (i.e., monitor not off scale), was unreliable because of the very high background levels in the plant. When release of noble gases was detected in the Unit 1 plant vent, the source term calculation described in the procedures was used.

To make measurements establishing plume width and dose rates, monitoring teams were directed to locations where the plume was expected, on the basis of meteorological information, as a means of verifying the predicted dose rates. These methods of offsite dose assessment were continued until the Unit 2 plant vent monitor became more reliable.

The on- and offsite teams increased to seven on March 30 and continued monitoring activities on a 24-hour basis. The teams recorded the results of measurements, but were not instructed to maintain permanent records. When data was reported to the emergency control station, the team survey records were not retained and transmission errors could not be identified or corrected. The number of ground level surveys on and off the island increased substantially during this period. On March 28, the highest onsite level measure at a predetermined monitoring location was 365 beta-gamma/50 gamma mR/h. This level was not reached again; however, dose rates up to 150 beta-gamma/100 gamma mR/h and 150 beta-gamma/30 gamma mR/h were measured on March 29 and 31, respectively. Most measurements during this period were in the range of 5 to 70 beta-gamma mR/h.

The highest level at a predetermined offsite monitoring location was 50 mR/h (whether beta-gamma or beta is not recorded) on March 28. On March 29, the highest value was 30 beta-gamma/20 gamma mR/h with values generally falling to a few mR/h. On March 30, the highest offsite level was 10 beta-gamma/0.4 gamma mR/h. The highest value on March 31 was 12 beta-gamma/3 gamma mR/h across the river from the plant at the 500-kV substation. Many helicopter measurements, including those over the plant, plume definition measurements, and others at various locations over the countryside, were made during this period. These measurements were difficult to assess because they were made at altitudes of 600 to 1400 feet above sea level and ground level locations are not always clearly fixed relative to the aerial measurements.

The use of helicopters permitted verification of assessment calculations and provided a better basis for source term calculations than would have been available from ground level measurements. The number of monitoring teams provided greater assurance that significant offsite exposure levels were identified.

On April 1, the number of monitoring teams was reduced from seven to six. During the day, dose rates on Three Mile Island ranged up to 40 beta-gamma/20 gamma mR/h, with values usually in the range of 2–12 beta-gamma/0.5–1.5 gamma mR/h. Helicopter measurements went as high as 30 beta-gamma/5 gamma mR/h. Off site, the highest readings—7.5 beta-gamma/1.6 gamma mR/h—were seen at the Observation Center and more distant areas usually measured less than 1 beta-gamma mR/h.

The radiation levels on Monday, April 2, continued to fall. The high levels on the island were 15 beta-gamma/7 gamma mR/h with most readings less than 5 beta-gamma/1 gamma mR/h. The highest offsite reading was 1.6 beta-gamma/0.1 gamma mR/h with most readings less than 0.5 beta-gamma/0.1 gamma mR/h. Between 2:25 and 2:50 p.m., a gaseous release ranging from 90 to 400 beta-gamma mR/h was measured from a helicopter over the island. For most of the day, however, levels were in the range of a few to 15 beta-gamma mR/h. The number of monitoring teams on April 2 were reduced to five.

In later days on- and offsite dose rates continued to fall. The teams, reduced to four on April 3, were still on shift 10 days later. On April 8, all readings were less than 1 mR/h. On April 9, the high readings were 1.9 beta-gamma on the island, 0.43 beta-gamma/0.2 gamma in the air, and 2 beta-gamma/0.7 gamma off the island (all readings in mR/h). By April 13, most reports were less than 0.1 beta-gamma/0.l gamma mR/h on TMI and less than 0.01 beta-gamma/0.01 gamma mR/h off TMI.

Although the emergency response phase was winding down, monitoring activities continued. The onsite and offsite monitoring team activities were not terminated until the first half of July. Although air samples have not been discussed in detail, samples were collected. After the arrival of the NRC mobile laboratory on the evening of March 28 and the subsequent arrival of other mobile laboratories, the use of the SAM-2 instruments in the field essentially stopped. The increased sensitivity and resolution of the laboratory equipment made the SAM-2s superfluous.

e. Equipment Availability and Limitations

The ability of a nuclear powerplant's staff to respond to a radiological emergency is governed to a large extent by the ability to identify, measure, and quantify radiation levels and releases of radioactive materials. These activities are made possible by fixed process, effluent and area radiation monitors, fixed or semiportable inplant air monitors, and portable radiation survey instruments of various types. For measurements outside the plant buildings, portable survey instruments and air sampling and analysis equipment are required. The availability, use, and limitations of the portable and fixed inplant equipment is addressed elsewhere in this report. This section is limited to that equipment which the plant staff specifically designated for emergency use outside of the plant.

TMI Procedure 1670.12, Emergency Readiness Check List, identifies the numbers and types of emergency kits that are to be available as:

4	Radiation Emergency Kits
2	Wash Down Area Kits
1	Ambulance Kit
1	Emergency Clothing Kit
2	Control Room Emergency Kits
1	Medical Emergency Kit

Each Radiation Emergency Kit contained a PIC-6A (ion chamber survey instrument with ranges of 1-1000 mR and 5R/h); a SAM-2/RD-19 (battery operated Stabilized Assay Meter and detector); an air sampler; and maps, procedures, paper, pencil, sample collection, and retention equipment. A DC/AC inverter is used for operation of the air sampler. Normally, the four monitoring kits and the instruments are inventoried and checked quarterly. The kits are usually stored in the process center (North Search Facility). On March 28, however, only three kits were in the process center; the fourth kit was in the radiation protection supervisor's office because the SAM-2 was inoperable and had been since March 11, 1979. The SAM-2s contained in the kits were the only instruments of that type at the Three Mile Island Station. When the three available kits were checked on March 28, one of the SAM-2s was inoperable. The operability of the inverters was not checked, and so the first team to arrive in Goldsboro that morning had both an inoperable SAM-2 and inverter.

For the initial onsite and offsite monitoring effort, the principal survey instrument was the PIC-6A. From a total plant inventory of 14 PIC-6As, only the four in the emergency kits were available for use on March 28. As the need for additional radiation surveys increased, the available lower range RO-2 instruments (ion chamber with ranges up to 1 R/h) were placed in service. These instruments apparently performed adequately in the field.

The principal difficulty in performing field measurements involved measuring radioiodine. The accident had released significant quanitities of gaseous radioactive material, presumably including radioactive iodine. Met Ed had prepared for this possibility by including the SAM-2 (a battery powered dual channel gamma analyzer with a gamma scintillation detector capable of controlling the high voltage and limiting instrument drift) in the emergency kits. As designed, the instrument permitted independent counting of two channels or, if desired, subtraction of one channel from the other. As operated by Met Ed's rad chem techs only one channel was used, the other was held in reserve (not operating). During the accident the SAM-2/RD-19 was not effective in measuring radioactive iodine in the presence of noble gases. The result was that as noble gas concentrations rose so did the apparent iodine concentrations, but in reality radioiodine concentrations were not a significant problem.

The loss of the onsite laboratory counting facilities early on March 28 compounded the problem, which was not resolved until samples were taken by helicopter to the Bureau of Radiation Protection for analysis later on the 28th. Subsequent analysis of air samples using more sophisticated equipment established that no significant levels of radioiodine were found off site.

f. Transportation

Met Ed's emergency plan specifies that, "At least two vehicles can be quickly equipped ... for offsite monitoring."[21] On March 28, when Ed Egenrider and Thomas Leach were assigned to the first offsite survey teams, no Met Ed vehicles were immediately available. Egenrider finally commandeered a Met Ed vehicle after a 10-minute search, and Leach took his personal vehicle. Leach and Jim Randisi, team Charlie, arrived in Goldsboro about 8:30 a.m.

When the initial telephone notifications of offsite agencies were being made, Met Ed requested a helicopter to assist in transporting a monitoring team to Goldsboro. (The request was made at 7:17 a.m.) The helicopter arrived at the TMI north parking lot at 8:35 a.m., too late to transport the monitoring team. Met Ed had discussed the possible use of helicopters in the event of an emergency, but had not formalized arrangements with the Pa. State Police.

The police responded to the first request for a helicopter and during the day, two helicopters were either on site or at the Observation Center. On March 28, these helicopters transported air sample supplies to monitoring teams, and air samples from the Goldsboro area to the Holy Spirit Hospital for analysis by the Bureau of Radiation Protection. The helicopters were also used to warn boats away from the vicinity of the island.

g. Communications and Notifications

The communications equipment available to TMI staff on March 28 included the plant radiation emergency alarm system, the public address and telephone systems, the Met Ed tie line, Pennsylvania Bell dial telephone equipment, and battery powered telephones. Radio equipment included the Met Ed system radio; FM walkie-talkie radios; Dauphin County radio monitor; and the National Warning System (NAWAS), connected directly to the Pennsylvania Emergency Operations Center and State Police headquarters. On March 28, all of these systems were operational with the exception of the Dauphin County radio monitor, a frequency scanner. The monitor's unavailability had no impact on the course of the emergency response because telephones were used for communications between the plant and State and local agencies.

After the site emergency was declared at 6:55 a.m. on March 28, two plant engineers, Ronald Warren and Richard Bensel, began making the notification calls. Separate notifications were required for both the site and general emergency declarations. This sequence and timing is shown in Table III-1.

The planned notification sequence was for PEMA to receive notifications from the plant and in turn to notify the Pennsylvania Bureau of Radiation Protection, who then contacted the plant directly. The Bureau of Radiation Protection had difficulty returning the call to Unit 2. However, contact was obtained after a 3-minute delay and open telephone lines were established between the Bureau of Radiation Protection at Harrisburg and the Unit 2 control room at 7:25 a.m.; and between the Unit 2 control room and the NRC regional office near Philadelphia by 7:50 a.m.

The TMI telephone system on March 28 included a total of 14 two-way trunk lines (permitting calls either in or out) with more than 200 extensions, and 4 one-way trunks (one direction call only). Thirteen business lines (like normal residential service) were also available. By March 31, 21 business lines had been added. At the Observation Center on March 28 there was only one telephone, but by March 30, eight additional telephones had been installed. During the first week of April, approximately 40 more telephones were installed at TMI.

Radio communications, consisting of portable radios and walkie-talkies, were installed in the Observation Center permitting the accumulation of data from the on- and offsite monitoring teams. A log of activities and communications at the Observation Center was started at 8:15 a.m. on the 29th. The log was a minute-by-minute account of radiation readings, air sample results, personnel cleared to the site, reports of passing trains, requests for State Police assistance for traffic accidents, and locations of offduty personnel.

A second radio used for communications with the Unit 2 control room, offsite vehicles, and helicopters, was set up in the Observation Center within about 24 hours. Additional radios were ordered and received during the first week of April.

After the accident there was a constant flow of monitoring data over the open telephone line to the Bureau of Radiation Protection. From March 29 to 31, monitoring activities by non-Met Ed groups increased substantially, principally as a result of the U.S. Department of Energy monitoring activities. However, the flow of offsite monitoring information was almost always from Met Ed to others. Essen-

TABLE III-1. Sequence and timing of site and general emergency declarations

Agency Called	Person Contacted	Site Emergency Declared 6:55 a.m.	General Emergency Declared 7:24 a.m.
Pennsylvania Emergency Management Agency (PEMA)	Duty Officer	7:02 a.m.	7:35 a.m.
NRC-Region I, King of Prussia, PA	Answering Service	7:04 a.m.	7:40 a.m.
Met Ed Vice President (J. Herbein)	*	7:05 a.m.	7:40 a.m.
Met Ed, Manager, Generation Operations	Mgr., Generation Engineering	7:09 a.m.	7:30 a.m.
Dauphin County Civil Defense	Duty Officer	7:09 a.m.	7:30 a.m.
U.S. Department of Energy-Radiological Assistance Program	Duty Officer	7:09 a.m.	7:35 a.m.
Radiation Management Corp. (Consultant)	No Answer	7:13 a.m.	
	Philadelphia Electric Load Dispatcher		7:40 a.m.
Pennsylvania State Police	Dispatcher	7:18 a.m.	7:40 a.m.
American Nuclear Insurers	No Answer	7:20 a.m.	7:35 a.m.

*Herbein was in Philadelphia, unknown to the person making the call. He had been in contact with Miller earlier and could not be reached at the telephone listed in the procedures.

tially no monitoring information developed by others was given to Met Ed's emergency control station or to the Observation Center. The NRC regional group responding to the accident on the 28th did make survey measurements that were reported to the emergency control station.

Regarding Met Ed's commitment to provide information to the Bureau of Radiation Protection, Margaret Reilly, Chief, Division of Environmental Radiation, said during an interview:

> Q: Did you have any difficulties in the area of communications, them [TMI] not providing information that was requested? Any at all?
>
> REILLY: Not to my knowledge. We had sort of a generic communication problem, being so dependent on telephones. We perceived that before the accident, but all alternatives cost scratch, which I think we'll probably be getting now.
>
> Q: Then, from your viewpoint and the agreements that had been reached during the course of the incident, those agreements had in fact been met by the licensee [Met Ed]?
>
> REILLY: Correct[1]

Communications with the monitoring teams were almost exclusively by radio. Radio dead spots caused by terrain features presented problems, but there were no requirements and no particular stress was placed on this potential problem by the NRC.

h. Augmentation

Approximately 8:00 a.m. on March 28, Sydney Porter, Porter-Gertz Consultants, Inc., received a call from M. Buring, a Met Ed corporate technical analyst, requesting Porter to set up and be ready to implement the expanded Radiological Environmental Monitoring Program (REMP). Porter arrived at TMI at 8:25 p.m. and the first samples under the REMP were collected on March 29.

As word of the accident spread, various types of assistance and offers of asssistance were received. Technicians and radiation protection and monitoring equipment were supplied by many utility companies. The first arrivals were from the Salem, Susquehanna, Peach Bottom, and Oyster Creek nuclear powerplants. Similarly, technicians and equipment were received from the suppliers to the nuclear industry.

Because of the high airborne activity levels, the plant staff rapidly depleted the supply of air bottles for self-contained breathing apparatus. At 8:35 a.m. on March 29, the local fire company arrived at the Observation Center to fill air bottles, an action which was repeated several times on subsequent days.

Mobile laboratory facilities and whole-body counters arriving during this period included facilities operated by the NRC and contractors. The availability of GeLi counting systems near the site permitted more rapid evaluation of air samples, a capability Met Ed lost early on March 28. The first mobile laboratory to arrive (March 28, 7:30 p.m.) was operated by NRC personnel.

On March 28, helicopter support had been provided by the Pa. State Police. Met Ed arranged for helicopters on March 29, and eventually a total of three arrived, which were used for surveys and for moving equipment and samples.

At noon on the 29th, food was sent to the Observation Center for the operating crews. As the number of Met Ed and support personnel increased, availability of food became a problem. This was resolved by the establishment of a daily 24-hour mess tent. The influx of personnel was staggering. The initial onsite staff of about 530 increased by more than 1900 persons by April 17. This increase included approximately 240 staff from GPU and its subsidiaries, 200 from the NRC, and 1500 others.

i. Response vs. Reentry vs. Recovery vs. Emergency Termination

Miller said that his concern for plant stability was substantially reduced, and a change from emergency response to a recovery phase occurred about 8:00 p.m. on March 28, when a reactor coolant pump was started. At this time some confusion occurred between Miller and Herbein; Miller has testified that he thought Herbein became the focal point for decisions regarding the overall emergency response, exclusive of plant operation—Herbein stated that Miller remained in charge. Both left the site/Observation Center area around 2:00 a.m. leaving Logan in charge. At the same time, organizational changes were made to support an expanded long-term followup effort. There was no opportunity for a substantial reentry or recovery phase to begin because of the demands for continued on- and offsite monitoring by the available staff.

On March 30 and 31, the arrival of support from other utilities and nuclear support service groups permitted the Met Ed radiation protection staff to begin concentrating its resources for onsite activities. The Met Ed rad chem techs were then removed from the offsite monitoring teams. Later, contractor radiation technicians familiar with the plant from their earlier refueling activities, began replacing Met Ed rad chem techs in Unit 1. One Met Ed representative provided coordination between the two radiation protection groups. By early April, although the reactor was stable and being cooled, the accident, from a radiological standpoint, was not over. Releases were continuing and the response phase was still in progress. There was no definite point in time when the response changed to reentry or recovery.

The reentry and recovery phases were in progress, attempting to minimize releases while the emergency control station and monitoring teams were still in the response phase. The fact that a clearcut definition of the current action phase was missing made little or no difference. TMI Procedure 1670.15, Post Accident Re-entry and Recovery Plan, is correct in its stipulation that:

> A recovery plan, from a practical standpoint, must be flexible enough to adapt to existing, rather than theoretical conditions. It is not possible to anticipate in advance all the conditions that may be encountered in an emergency situation; therefore, the Three Mile Island Recovery Plan is addressed to general principles that will serve as a guide for developing a flexible plan of action.

j. Summary of Findings and Recommendations

Findings

- Declaration of a site emergency was delayed approximately 2 hours because plant personnel did not understand that a loss-of-coolant accident was in progress.
- Measurements of onsite and offsite radiation dose rates were not accomplished in a timely manner considering the extraordinarily high estimated offsite dose rate of 10 R/h.
- Initial onsite and offsite monitoring teams had neither the equipment nor expertise to perform time-

ly measurements of airborne radioiodine in the presence of radioactive noble gases.

- The supply of operable radiation monitoring equipment was inadequate to support the early response of onsite and offsite radiation monitoring teams.
- Initial calculations of onsite and offsite radiation dose rates (10 R/h) grossly overestimated the actual dose rate of less than 0.001 R/h. Unrealistic assumptions in the calculations resulted from limitations in the capability to monitor radioactive gaseous effluents from plant buildings.
- Absence of a clear chain of command in the emergency organization and the lack of a disciplined approach in the communication of information to State and Federal agencies led to the evacuation scare on March 30.
- Organization and staffing for the prolonged response to a radiological emergency had not been preplanned and was accomplished belatedly.
- Plant personnel carried out their assigned duties, stayed on the job, and worked diligently to achieve a safe shutdown of the reactor and to collect and distribute offsite dose information.
- Communication systems available at the onset of the accident were adequate for initial notifications, but were not adequate to support the expanded response that developed.
- Radio communications with offsite monitoring teams were limited by the range of the equipment and interference caused by the surrounding terrain.
- Pennsylvania Bureau of Radiation Protection personnel in contact with the plant staff believe that Met Ed provided the information and assistance called for by the emergency plan.
- The emergency plan was activated under ideal conditions, i.e., 2 hours advance warning to operating personnel, a slowly developing accident, good weather, absence of equipment damage or natural disaster, the start of a regular work day, State and Federal agencies were nearby, plant personnel had participated in several recently conducted accident drills, and initial radioactive material releases from the plant were minimal.
- The relocation of the emergency control station from Unit-1 to the Unit-2 control room went smoothly because it had been practiced during an emergency plan drill.

Recommendations

- Plant procedures and personnel training requirements related to radiological emergency recognition and response should be reviewed at all nuclear powerplants and upgraded to ensure that operating personnel can recognize abnormal conditions and initiate emergency response plans in a timely manner.
- Real-time, online radiation monitoring equipment should be installed around all nuclear powerplants. This equipment should be capable of measuring radioactive materials that may be released during reactor accidents, and use of this information should be included in emergency planning.
- Inplant and portable radiation monitoring instruments and trained personnel should be available at all nuclear powerplants to ensure that those radioactive materials that may be released during reactor accidents—including radioiodines—can be measured at multiple onsite and offsite locations.
- Emergency plans should include provisions for a prolonged radiological response effort and a clear chain of command. Additionally, guidance should be provided to ensure that the emergency director is promptly informed of critical information, and that State and Federal agencies are kept accurately informed of plant status and radiological conditions.
- Communications equipment should be provided at all nuclear powerplants to ensure unimpeded contact between inplant locations and all locations where offsite monitoring teams are likely to perform radiation dose rate measurements.
- Emergency plans should be suitably definitive to provide an adequate response to a realistically anticipated accident under adverse conditions such as inclement weather, minimum allowable staff, and a rapidly developing accident.

REFERENCES AND NOTES

[1]Gerusky, Reilly, and Dornsife Interview on May 3, 1979 (IE) at 53-54.

[2]NRC, "Investigation Into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," Investigative Report 50-320/79-10 (NUREG-0600), at II-2-3.

[3]Laudermilch Interview on March 30, 1979 (Met Ed).

[4]Gingrich Interview on March 30, 1979 (Met Ed).

[5]Gingrich Interview on March 22, 1979 (IE) at 8.

[6]Kunder Interview on April 25, 1979 (IE) at 29.

[7]Zewe Interview on March 30, 1979 (Met Ed) at 5.

[8]NRC, Regulatory Guide 1.101, "Emergency Planning for Nuclear Power Plants," at 1.101-4.

[9]Statement by G. P. Miller, Station Manager, May 7, 1979, Miller dep. (Pres. Com.), Exhibit 114, at 3.

[10]G. Miller Interview on May 7, 1979 (IE), Tape 158 at 20.

[11]Herbein Interview on May 10, 1979 (IE) at 9-10, 16.

[12]Herbein dep. at 31-32.

[13]Statement by G. P. Miller, Station Manager, May 7, 1979, Miller dep. (Pres. Com.), Exhibit 114, at 23.

[14]G. Miller Interview on May 7, 1979 (IE), Tape 159 at 1.

[15]Seelinger dep. at 105-106.

[16]M. Ross dep. (September 18, 1979) at 13-14.

[17]Herbein Interview on May 10, 1979 (IE) at 17.

[18]Kunder dep at 65.

[19]G. Miller dep. (September 20, 1978) at 50-51.

[20]Statement by G. Miller, Station Manager, May 7, 1979, Miller dep. (Pres. Com.) Exhibit 114, at 29.

[21]Metropolitan Edison Co., Three Mile Island Site Emergency Plan 1004, Sec. 2, Rev. 1 at 23.0.

4. INDUSTRY SUPPORT

a. Introduction and Summary

The support provided by organizations and individuals from outside the General Public Utilities (GPU) organization in the response and recovery effort to the TMI-2 accident, developed on March 28, 1979, in proportion with the awareness and understanding by the GPU management, including the General Public Utility Service Corporation (GPUSC) and Met Ed, of the extent and severity of the TMI-2 accident. The support grew from a few isolated requests for specific support on the day of the accident to the arrival at the TMI site on March 31 of hundreds of individuals and of truckloads and planeloads of equipment and material from throughout the country. The mobilization of support involved nearly the entire nuclear industry in the United States and the unselfish commitment by companies and individuals of resources at their disposal. While it took a few days to cast these resources, both human and equipment, into a structure for the recovery effort to use them more effectively, it must be remembered that this effort was initiated and implemented essentially without any preaccident planning by GPU or by the industry as a whole.

This section of the report discusses the industry support during the 10-day period beginning the day of the accident on Wednesday, March 28, and ending on about Saturday, April 7, 1979. During this time, three phases in the development of the industry support are identified: first, the limited support activities on March 28 and 29; followed by extensive requests for outside assistance from late March 29 through April 1, when GPU realized the severity of the accident and its potential consequences; and finally, the integration of the outside support personnel into the developing GPU recovery organization on April 1.

The next two subsections discuss the development of the industry support and its integration into the recovery organization. It includes the technical support for operations provided by nuclear steam supply system manufacturers, architect–engineers, and utility companies, and the function of industry executives summoned to the site for assistance. Subsequent subsections discuss the Industry Advisory Group, a think-tank of nuclear engineering and scientific talent from across the country that was assembled after the accident to evaluate plant operations from a "what if" aspect; the support provided by the Babcock & Wilcox Company, the designer and supplier of the reactor system, in the evaluation of the continuously changing plant conditions; and the support provided by the Burns and Roe organization, the architect–engineer for the plant, in the design, engineering, and construction of plant modifications following the accident.

b. Development of Industry Support

The requests for support from outside the GPU organization on the day of the accident, March 28, and on March 29, were based on the limited perception of the severity and extent of the accident by the onsite TMI-2 operations staff and by the GPU management. With respect to the need for such outside assistance, this perception on March 29 can be summarized as follows: the plant had experienced a severe transient but had been placed in a stable condition; a site and general emergency had been declared because of the radiation levels, both on site and off site.

The requests for outside assistance on March 28 and March 29 pertain to the radiation levels. They were initiated primarily by the plant operations staff and by the Met Ed staff in Reading, Pa. Circumstances and developments for some of the principal requests are summarized as follows.

During the site emergency, respirators were used intermittently by the onsite staff to remove airborne radioactivity from the air they were breathing. On March 28, the need for additional equipment was identified to the Met Ed staff in Reading. Richard Klingaman, the Met Ed Manager of Generation Engineering, immediately contacted vendors and nearby utilities requesting their assistance. One of the results was that a member of the Met Ed staff, who was at the Oyster Creek facility in New Jersey, returned at once to the TMI site bringing with him a carload of respirators.

Radiation Management Corporation (RMC) had a whole-body counter at the TMI site in connection with the refueling outage on Unit 1 (a whole-body counter is a radiation detection device used to identify and measure radioactive material in the human body). RMC was requested to perform whole-body counting and also to assist in environmental sample analyses and respirator testing. However, the whole-body counter could not be used because of high background radiation levels on site. It was put into operation on March 30, at the offsite substation.

Additional personnel were needed to staff radiation monitoring teams. The onsite staff and the Reading staff contacted the following organizations that provided manpower and radiation survey equipment on March 28 and 29: Nuclear Support Services, Salem Nuclear Power Station, Philadelphia

Electric Company, and Porter-Gertz Company. These organizations responded promptly by sending personnel and survey equipment to the site.

On March 28, the Reading offices requested the Tri State Laundry Company to move its mobile decontamination laundry unit to the site. The request was based on the expectation that a large volume of contaminated laundry would be generated, primarily by individuals working in the highly contaminated auxiliary building.

On March 29, the Met Ed staff in Reading became concerned about the substantial amounts of contaminated water that had accumulated in the containment building and in the auxiliary building. Although the level of radioactive contamination was not accurately known, it was apparent that the water would have to be stored at the site prior to its eventual disposal. Therefore, the Reading staff made an extensive survey of suppliers for storage tanks in the northeastern part of the country to obtain information on the availability, size, design pressure, location, and transportation aspects of such tanks. On March 30, the information was evaluated and extensive tank capacity was ordered. Independently, Burns and Roe initiated a similar survey at the direction of Herman Dieckamp, the President of GPU in Parsippany, N.J. (Dieckamp is also President of GPUSC, which is located in nearby Mountain Lakes, N.J.).

GPU and GPUSC managements believed until late on March 29, that the plant had been placed in a stable condition. This is evidenced by the fact that two small teams were sent to the TMI site on March 28 and 29 to investigate the cause of the transient and determine the necessary steps to return the facility to service. At that time, they apparently knew of no immediate need to involve outside organizations in that effort.

B&W, the nuclear steam system supplier for TMI-2, participated in the efforts to stabilize the plant on March 28. Leland Rogers, the B&W Site Operations Manager, at the request of Gary Miller, the Met Ed Station Manager, served on the emergency management team in the TMI-2 control room and assisted in the efforts to reestablish cooling of the reactor core. The B&W staff in Lynchburg, Va. had limited information about the plant status but were able to analyze plant conditions in sufficient detail on the afternoon of March 28, to recommend that the high pressure injection flow be increased. Communications between Lynchburg and the TMI-2 control room were indirect and the recommendation was made through the GPU offices in New Jersey. An open telephone line was established between Lynchburg and the control room later that evening.

Burns and Roe, the architect-engineer for TMI-2, offered assistance on March 28 and frequently thereafter. The first call for assistance from Burns and Roe was made by the TMI-2 operations staff on March 29, requesting a determination of the water level inside the containment. At this time, the requests to Burns and Roe were directed mostly to obtaining information rather than recommendations for recovery actions.

Although the requests from within the GPU organization for outside support were limited during the first 2 days, there were numerous offers of assistance from individuals and companies. Most of the offers were made by telephone calls to the Met Ed offices in Reading, and some were made to the GPUSC offices in New Jersey. Because of communication difficulties few calls offering assistance were received at the TMI site. The offers of assistance came from all parts of the nuclear industry, including nuclear steam system suppliers, constructors, architect-engineers, and nuclear utility companies. Many of the calls were made by individuals in personal contacts. However, because the exact status of the plant was not known to the GPUSC and Met Ed staffs, they were unable to identify areas where assistance was required.[1]

The GPUSC team, which had been dispatched to the TMI site on March 29, concluded by that evening that the plant conditions were not entirely stable and the situation in general was more serious than had been assumed earlier. This conclusion was reached after talking with members of the operations staff and was based in general on the continued high radiation levels in the containment, on the lack of progress that had been made in cooling the plant down, and on a preliminary evaluation of plant data such as the use and operation of the high-pressure injection system on the previous day. These observations were discussed between Richard Wilson, the GPUSC Director of Technical Functions, who was directing the investigative team at the TMI site, and Robert Arnold, the GPUSC Vice President for Generation in New Jersey. Arnold then apprised Dieckamp of these findings. It was concluded that the reactor core very likely had been uncovered to some degree on March 28, and may have experienced extensive damage leading to the release of large amounts of fission products. Based on this growing awareness and understanding, Dieckamp concluded that the full recovery from the accident was beyond the capability of the GPU organization and additional resources were required to evaluate and respond to the existing situation. The singular event that triggered the requests for outside support on a massive scale, and underlined the urgency for support, was the release of radioactive gases from the auxiliary building on the morning of March 30. Dieckamp described the situation to the Special Inquiry Group:

> It was at that point that I then sort of officially decided that we were going to need more help, more smarts, the best smarts we could get and began then to make inquiry throughout the industry to get assistance to give us a hand.[2]

The requests for assistance were made by many individuals within the GPU organization, both from the TMI site and from the GPUSC offices in New Jersey. In retrospect, the requests originating at the two locations can be differentiated: those from the site were related to problems regarding the immediate operation of the plant, while those from the GPUSC offices were directed to a more fundamental understanding of the plant conditions and to longer range recovery approaches. However, there was no clear distinction between the efforts.

The operations type problems from the site were directed primarily to the nuclear steam supply system manufacturers, not only B&W, but also Westinghouse, Combustion Engineering, and General Electric; and to other utility companies, primarily those with a B&W system. Direct telephone lines between the site and the cited organizations were arranged by Dieckamp and Wilson. Each of the reactor vendors was advised of the TMI-2 plant status on March 30, and specific and potential problems were identified for their evaluation and review. For example, the question of "how and when could it be attempted to go to natural circulation based on the current plant condition" was a top priority concern posed to all vendors.[3,4] Arnold, who arrived at the site on March 30, explained to the Special Inquiry Group the basis for the direct contacts to the vendors:

> Our purpose in doing that was to make available to us as directly as possible the analytical resources of those other three vendors as well as B&W, principally so that they could provide for us in terms of fuel analysis, thermal hydraulic analysis, advice on natural circulation, flow maldistribution, just to have them working on whatever problem we felt they might be able to contribute to, usually several if not all of the organizations working on any given important problem.[4]

This statement not only identifies the purpose of the direct communication links, but also explains the general approach that was taken by the GPU site group, namely, to obtain several expert opinions. Through these direct lines, the resources of each of the vendors were made available. In particular, the open telephone line between the TMI-2 control room and B&W in Lynchburg was used to request and relay information and recommendations. This link of communication was maintained on a 24-hour basis. Similarly, many requests for assistance, primarily by site operations staff, were directed to Burns and Roe, which also made itself available on a 24-hour basis.

The requests for assistance that originated within the GPU organization on March 30 and 31, apparently were principally based on the recognition that the plant was in a condition that previously had not been considered and had not been evaluated in the design of the plant. Dieckamp recognized that the best professional talent available was required to evaluate the current status of the plant, to determine the potential for and consequences of deteriorating conditions, and to determine a method to stabilize the plant.

The GPU management in New Jersey had a general understanding of the plant conditions; however, they were uncertain about the specific issues that had to be addressed. In his interview by the Special Inquiry Group Dieckamp stated the following:

> [Most of the requests for assistance] were not in relationship to clearly defined specific tasks but rather a feeling on my part that the tasks were of such a general magnitude and ... scope that we needed people with strong basic backgrounds, rather than narrow specialties.[5]

Bernard Cherry, the GPU Vice President for Corporate Planning, who participated in making the early requests for assistance, expressed the uncertainty about specific tasks when making his contacts by asking questions such as, "What do we have to be concerned with next? How can we construct a defense-in-depth?"[6]

The first requests were for individuals with experience and expertise in areas such as systems analysis, core hydraulic heat transfer, liquid and gaseous waste processing, and fuel performance. The individuals who responded to this request formed the nucleus of a group, initially referred to as the "Think-Tank" and later identified as the Industry Advisory Group.

The requests for assistance from New Jersey were made by members of the GPU management including Dieckamp, Cherry, William Murray, the GPU Vice President for Communications, and Robert Keaten, the GPUSC Manager for Systems Engineering. These individuals, through their many years of experience not only in technical aspects of the nuclear industry but also in management positions, had many personal contacts in the industry through which most requests were initiated. Whereas the primary objective was to mobilize expertise for the think-tank, requests for assistance were also made to obtain operational support. The following is a brief summary of some of the requests made from New Jersey and starting as early as the afternoon of March 29.

- The Electric Power Research Institute (EPRI) in California was requested on March 29 to assist in the evaluation of the TMI-2 accident. Edwin Zebroski of this organization made recommendations on methods for degassing of the reactor coolant system on March 30. He and his colleague, Milton Levenson, came to the TMI site on April 1.
- Atomics International in California was asked for assistance in evaluating the use and installation of the plant hydrogen recombiner for the removal of free hydrogen from the containment atmosphere. This organization made available an additional hydrogen recombiner.
- R. Brooksbank of Oak Ridge National Laboratory (ORNL) in Tennessee was requested to assist in the radioactive waste problem.
- Sol Levy in California was asked to come to the site and assist in thermal-hydraulic analysis of the reactor coolant system.
- Bechtel, the architect-engineer for other B&W reactor facilities, was requested on March 31 to provide assistance. A group under the direction of C. Judd was sent to the site. D. Stohr, Bechtel Project Manager for the Arkansas-One nuclear facility, was a member of the team. Bechtel had called GPU earlier offering assistance in evaluating steam generator isolation methods, overheated fuel pins, and operation of a solid system.
- Late Saturday, Larry Ybarrondo and Nick Kaufman of the EG&G Company in Idaho were asked to come to the site to assist in the core assessment and natural circulation evaluation.
- In addition to the assistance provided by the reactor vendors using direct telephone lines to the site, Cherry in New Jersey also requested assistance from the vendors on March 30. He had previously established a personal contact on March 28, with each of the vendors. Romano Salvatori of Westinghouse and Fred Stern of Combustion Engineering sent some of their people first to New Jersey where they received a briefing on the plant status on March 31. Subsequently they went to the site. GE sent a group directly to the site.
- On March 31, after becoming aware of the importance of the postulated explosion potential of the hydrogen bubble, Dieckamp contacted Dale Myers of the Department of Energy requesting that he identify and make available the best expertise in hydrogen burning and explosion characteristics. On April 1, Wilbur Riehl of the NASA Marshall Space Flight Center in Huntsville, Alabama, arrived at the site to evaluate (together with Zebroski of EPRI) the hydrogen explosion potential.
- William Lee, President of the Duke Power Company, was called by Dieckamp on March 31, for assistance from his organization in plant operations. (Duke is the operator of three nuclear units, each with a B&W nuclear steam supply system.) Lee dispatched a group of five individuals under the direction of Warren Owen, the Senior Vice President for Construction.

The personal involvement of Dieckamp in requesting additional support decreased after his arrival at the site on March 31. Requests for support during the following days were made by individuals working on specific problems and also in a self-propagating manner by those individuals who started to arrive at the site.

c. Integration of Industry Support into Recovery Organization

By March 31, people from throughout the country were arriving at the TMI site at a steady pace in response to GPU requests for support. Their travel to Harrisburg was delayed in some cases because of unavailability of commercial flights (United Airlines was on strike) and was expedited in other cases by using charter aircraft. The people came primarily from the reactor vendors, architect-engineers, utility companies, and nuclear support organizations. Until about April 4, the assignment of the individuals to a specific task presented a problem because of logistical and organizational confusion. On March 31, there were hundreds of people milling about at the Observation Center (directly across the river from the plant); not only individuals associated with the recovery effort, but also sightseers, members of the news media, and others. The confusion was compounded by the arrival of trailers at the Center, which was growing into what became known as "Trailer City," the offsite offices of the support organization. There was no single person to whom new arrivals to the GPU organization could report. The location for reporting was the Observation Center, although some individuals attempted unsuccessfully to gain direct access to the site. Frequently the individuals arriving did not know who within the GPU organization had requested their support or where that person could be located.

On March 31, there existed a Met Ed plant operations group under John Herbein, the Met Ed Vice

President for Generation, and a GPUSC technical support effort under Arnold. However, an overall GPU organizational structure did not exist at the site. Many activities were performed and developed concurrently by different individuals with little coordination among them. Because of the absence of such a structure, people were not fully aware of what support was available or where it was needed. Eventually the integration of the support individuals into an overall organization became more effective as expressed by Keaten:

> We intended to bring them in, talked to them on an individual basis about what their background and capability was, plugged them into the organization at a place that looked like they would fit the best; and then we constantly encouraged these people to come back to us, the managers, if they saw a place where they could fit better, because they knew their capabilities better than we did.[7]

The support provided by outside organizations can, in retrospect, be grouped into four categories. First, the broad technical expertise that was assembled in the Industry Advisory Group, which consisted essentially of non-GPU personnel and which was located separately and removed from the site. Second, a large contingency of systems analysts and design engineers, mostly from Burns and Roe, that formed the Plant Modifications Group. These two groups are discussed in separate subsections. Third, there were individuals from the reactor vendors (including B&W), from other architect-engineers, and from utility companies that primarily supported the Technical Support Group under Wilson. The fourth group consisted of executives from throughout the nuclear industry who provided support to GPU management in the decision-making process and by acting as their deputies. However, there was no clear distinction among the four categories and individuals could be assigned and reassigned to different groups.

Extensive support was required in the areas of system design and operation, and in particular in the area of nuclear plant operation. This expertise was provided by people from the reactor vendors, architect-engineers, and utility companies. Generally, they were assigned to the Technical Support Group under Wilson. They provided support in the preparation and evaluation of proposed step-by-step emergency procedures on an as-needed basis for members of the GPU group in the control room. Most effective in their assignments were individuals with operating experience in B&W plants. For example, Norman Pope, Superintendent of Operations for the three Duke Power B&W plants, was able to assume the role of supervisor of one shift in the Technical Support Group reporting directly to Wilson.

Individuals assigned to the control room collected general and plant status information that was continuously requested by other elements in the recovery organization, in particular by the Technical Support Group. Later, as they became more familiar with the plans and procedures for core cooling, they also provided guidance and background information to the operators.

Among the personnel from the reactor vendors and architect-engineers, individuals from the B&W and the Burns and Roe organizations were generally more effective because of their familiarity with systems and components of the plant. Members of other organizations had to go through a brief learning period to become familiar with the B&W terminology. More importantly, however, procedures prepared by these individuals had to be carefully checked to ensure that such procedures were based only on B&W systems and their proper application.

Owen described the utilization of outside personnel in his interview with the Special Inquiry Group:

> The outside support personnel were integrated into the GPU structure; however, they did not assume a line responsibility in plant operations. Their function was to advise and recommend. Reactor operators from other utilities did not perform active operation functions but provided technical support to the Met Ed operators licensed on TMI-2. This freed the Met Ed operators, and more reasonable shift durations could be assigned.[8]

Early in the week following the accident, company executives from throughout the nuclear industry became involved in the direction of the recovery effort. Through their presence at the site and their direct participation in the activities, they were able to determine what other assistance from their organizations was needed to contribute to the recovery effort. The executives would authorize and make such assistance available, frequently without a specific request from the GPU management. For example, Lee of the Duke Power Company, who came to the site on April 4, had initiated and authorized the use of one of the Oconee Units to evaluate the method selected to achieve natural circulation.

Industry executives were placed in direct charge of functional elements: Frank Palmer and Robert Pavlick of Commonwealth Edison Company as Managers of the Waste Management Group, Warren Cobean of Burns and Roe as the Manager of the Plant Modifications Group, and Fred Stern of Combustion Engineering as the Manager of the

Task Management and Scheduling effort. Stern directed the assignment of priorities and schedules for individual tasks within the recovery organization, and, most importantly, he coordinated these activities to ensure that overall plant objectives and priorities were met. Levenson of EPRI managed the Industry Advisory Group.

Direct support to Dieckamp, the GPU Chief Executive, and Arnold, the GPU Operations Manager of the TMI-2 Recovery Organization, was provided respectively by William Lee, President of Duke Power Company, and Byron Lee, Vice President of Commonwealth Edison Company, who were deputies to the two key GPU individuals. They had the authority and responsibility to perform any function when acting as deputy in the absence of the GPU executives; and, more importantly, they assisted and relieved them in performing their many functions during long days. Owen arranged for additional technicians and managers needed at the site.

In addition to serving specific functions within the GPU recovery organization, these executives were also members of the IAG and thus were constantly aware of any concerns by that group. They provided the GPU management with confidence and assurance that they had the full support of the nuclear industry. In their positions, they frequently acted as liaison between the GPU organization and the NRC onsite management.

The realization by the GPU management of the need for the participation of company executives in the overall direction of the recovery effort was influenced by the onsite NRC management. Owen, who had arrived at the site on April 1, as part of the Duke assistance team, talked with Harold Denton, Director of the NRC team at the site. Denton expressed his concerns about the GPU capability to respond to the many and diverse issues they were facing, and about their manpower availability, including management manpower, to keep on going around the clock.[9] On the morning of April 4, Owen called Bill Lee in Charlotte, N.C., and informed him that he felt uneasy about the way things were going. Owen also stated that there were continuing problems in communications among people at the site, that there was a definite need for an organizational structure for the entire support effort, and that there were continuing difficulties between GPU, Met Ed, and the NRC.[10]

Denton, in the interview by the Special Inquiry Group, expressed his concept of the need for company management participation:

> I became concerned about the ability of GPU to actually carry out the instructions and procedures that were being developed by this industry group or by my staff in terms of what should be done next, and I felt like the operating organization of GPU needed supplementing and in that case I did call people like Bill Lee and Byron Lee directly, and they responded, as I recall, the very same day. And flew there with their own shift supervisors and began to be integrated right into the operating organization....I think I asked Bill Lee to come. I knew he operated B&W plants. He had a staff with experience in operating similar plants, and told them it's his problem as to how does he get worked into the GPU organization, but that I thought GPU needed help and it needed help from anybody who had any experience with B&W plants...[11]

Shortly thereafter, Lee was called by William Kuhns, the Chairman of the Board of GPU, who told him that he (Kuhns) had discussed the need for Lee's presence and participation with Joseph Hendrie, Chairman of the NRC, and Denton. Lee left immediately by charter aircraft and arrived at the site in the early afternoon of April 4.

Dieckamp consulted with the company executives and asked for their advice on major problems and decisions, such as the development of a base plan to eventually achieve cold shutdown conditions and to determine what actions were to be taken by the control room staff in the event of any unexpected development or system failure. On April 3, the NRC expressed to him its concern that GPU apparently did not have a firm strategy for the solution of this problem. Dieckamp concurred in this assessment and immediately took action to develop such a strategy:

> Tuesday afternoon I closeted myself with MacMillan [Vice President of Babcock & Wilcox], Warren Owen, Bob Arnold, Dick Wilson and a couple more B&W guys and we just hammered out, point by point, what is the plan for going from where we are to cold shutdown. What is the route we are going to take? What is the step? What is the sequence? What is the rationale? What if this fails? What do we do next if this fails? What do we do if the pump fails? What were the fallback positions to that plan? It took us about six hours to hammer that out. There was a lot of reluctance to sign up for a plan. There was the sort of feeling that we have got a lot more analysis to do and I just hung in there with the things, that if we had to make the decision right now, what would it be, because that is what we were faced with. That, of course, in turn led to having in place in the control room, or at least to a degree, having in place in the control room at all times the fallback procedure....We put in place these procedures and their fallback procedures, while at the same time the NRC undertook to do their own review of that and comment on it, and in effect, approve, if you will.[12]

Outside executives were active participants in the development of the TMI-2 recovery organization on April 4. Although some functional elements had evolved earlier, the effectiveness of the recovery effort appeared to be worsening because an overall organizational structure for the interaction among such elements did not exist. This uncertainty of how and with whom to interact in the recovery organization was especially prevalent in the IAG. It led to a growing communications problem among people at the site, in particular for those from outside organizations because they had the additional unfamiliarity with conditions and surroundings. Communications with onsite personnel were a problem. Apparently no one at the site had been assigned responsibility for communications. Furthermore, many GPU personnel, operations staff, support staff, and management had been working long days since their arrival at the site. Individuals were exhausted and easily irritated. People seemed to be picking at each other for the smallest reasons. This condition of organizational instability was recognized by Dieckamp on Tuesday night, April 3.

> [When I reached the point] where I felt that I had a sufficient awareness of the major blocks of effort and their priorities that I felt I was able then to start talking about an organization to handle those, because up to that time things were in a very ad hoc state. People were becoming somewhat restless because of the ad hoc unstructured aspect of it... Wednesday morning Warren Owen and John MacMillan grabbed hold of me and said, 'Look, we have got to organize this thing,' we closeted ourselves and began to lay out the organization structure that ultimately became established.[13]

Bill Lee also participated in this effort after his arrival at the site. This organizational structure was identified as the "TMI-2 Recovery Organization," and was implemented on April 4. It resulted in improved understanding among individuals and groups. Particularly, the interactions between the recovery organization and the NRC improved as expressed by Dieckamp:

> It seemed to me that our composite organization functioned a heck of a lot more smoothly all of a sudden, whether it was less sort of competition, less regulator, regulatee, more of a combined composite approach to the problem. A lot of things seemed to just all of a sudden fall in place with the establishment of that organizational structure. I don't know what other factors might have contributed to the kind of maturing of the relationship that occurred on that time scale, but that is how I recall it happening.[14]

d. Industry Advisory Group

The Industry Advisory Group (IAG) was formed on the initiative of Dieckamp, who realized late on March 29, that the TMI-2 plant was in an upset condition that previously had not been considered in the design and accident analysis. To cope with the situation, he requested outside organizations and individuals to come to the TMI site and provide their assistance to GPU in determining the plant conditions and evaluating approaches to achieve a stable condition.

The first IAG members began to arrive in Harrisburg late on March 31. These members were Westinghouse and Combustion Engineering personnel who first went to the GPU offices in New Jersey where they received a briefing on the plant status. The individuals that formed the nucleus of the IAG arrived in Harrisburg throughout April 1. GPU had arranged for the IAG to use the Air National Guard Building at the nearby Harrisburg Airport. Most of the individuals went directly to that building; however, others were first directed to the TMI Observation Center. A general state of logistical confusion existed at this location due to the continuous arrival of support personnel, visitors, construction workers, and others. This situation was compounded by arrangements being made for the visit of President Carter. Because of this confusion it took hours, in some cases, to direct individuals to the Air National Guard Building.

In the early afternoon of April 1, there were approximately 30 individuals in the IAG. They exchanged whatever information they had available as individuals. However, in their effort to evaluate the conditions of the TMI-2 plant and to make recommendations, they were continuously struggling for information. It was in those early discussions that individuals took the lead in identifying important technical and management issues that would need to be resolved; others joined these efforts according to their expertise.

The first meeting of the IAG was held on April 1. The IAG received a detailed briefing of the plant status as it was conceived at that time by the GPU management. Dieckamp identified the following four specific questions GPU was facing:

1. What is the physical condition of the reactor core with respect to the degree of damage and its coolability?
2. What are the unique problems associated with the cooling system, and in particular, what are the specific problems associated with the bubble of noncondensible gases in the reactor vessel with respect to its size and explosion potential?
3. What reliable methods are available to achieve cold shutdown?
4. What are the problems associated with the radioactive waste and radiation releases?

Dieckamp was unable to provide the IAG with any specific guidance on how to attack those problems. In the SIG interview he recalled the following situation:

> Look, I don't know all of you guys in great detail, and I don't know each of your... greatest knowledge, but I think you yourselves know where you can best contribute to these four areas. Conglomerate yourselves into these groups that are working on the problems and go to work. That is about as much as I can tell you what to do.[15]

In a second briefing late on April 1, Denwood Ross and Roger Mattson of the NRC presented their view of the situation and the critical problem areas. Hendrie, the Chairman of the NRC, was also present at the meeting. One of the major subjects of discussion was the issue of the explosion potential of the hydrogen bubble in the reactor vessel. Zebroski, of EPRI, at that time strongly objected to the NRC concept and emphasized that this was not a problem.[16]

Subsequent to the meeting, the IAG organized itself under the direction of Levenson of EPRI, with Sol Levy, an industry consultant, and Zebroski as his deputies. It was a loosely structured group of individuals with a very high degree of expertise in a variety of disciplines. The group included representatives from the reactor vendors, research organizations, utility companies, academic institutions, national laboratories, and architect–engineers. While the original group at the site consisted of approximately 30 individuals, an enormous amount of additional support in the form of manpower and services was made available to the IAG through their respective home organizations. In this sense, the IAG was self-aggregating; eventually more than 100 persons had participated, for at least a short time, as members of the group.

The lack of information was identified as a problem on April 1, and continued to persist and reduce the efficiency of the IAG for some time. This struggle for information applied not only to the current plant conditions but also the design and normal operating conditions of the plant. This condition gradually improved when GPU assigned a few members of its staff to the group. These individuals provided the IAG with updated information on the plant status, plant characteristic data, and TMI-2 background documentation such as the Final Safety Analysis Report and plant drawings. They also identified individuals within the GPU staff with expertise in areas of interest to the IAG, and expedited communications between the IAG and these individuals and other elements of the TMI-2 recovery organization. On about April 7, this GPU group also assumed the function of documenting the written material prepared by the IAG. In addition to the GPU staff, members of the Burns and Roe organization were assigned to the IAG. They provided valuable information on the design, function, and location of the systems.

The function of the IAG, as originally perceived by Dieckamp on March 30, was to provide GPU with an overview evaluation of the conditions of the plant. The group was to look at these conditions from any imaginable viewpoint and advise GPU of the stability of the plant and the consequences of not maintaining the stability. The four questions identified to them by Dieckamp for their consideration fell within this scope. However, as the situation at the site developed, the scope of the IAG was changed. One assignment for the group was to review and evaluate operations and modifications proposed by other elements of the recovery organization. In this function the IAG would provide additional confidence in the appropriateness of the proposed activities. An example is the review of the different methods for establishing natural circulation that were under review. Another assignment was to independently assimilate, integrate, and interpret plant status information and data. The IAG would then decide and advise the TMI-2 Recovery Organization, normally through the Technical Working Group, whether the problems had been identified in sufficient depth. By about mid-April, the IAG assumed as a third responsibility the review of detailed procedures for plant recovery operations.

Arnold described his perception of the first two functions of the IAG as the following:

> I saw the Industry Advisory Group as primarily a group of very knowledgeable, experienced engineering and scientific people who would sit off at the side and do two things. They would review what we were doing, and we could influence the degree of detail to which they conducted that review because we could flag to them specific kinds of things we wanted them to really look at in a great deal of detail. So there was that type of reactive mode on their part. And secondly, they could take the information which was available to them—and we tried to make as much of the raw data, so to speak, available to them as we could, from a practical standpoint—and they could independently attempt to assimilate, integrate, and interpret that data and reflect back to us where we were with our line people, addressing the right problems, when our scope of activity was sufficient, when we were foreseeing the right types of problems that may be developing.[17]

On the evening of April 1, the IAG began considering the four top priority issues identified to them. A major contribution by the IAG was the review and evaluation of the explosion potential of the "hydrogen bubble" inside the reactor vessel. This effort under the direction of Zebroski, with the participation of Riehl of NASA, demonstrated convincingly that this issue was not a problem. However, the

IAG did not become fully effective until about a week after the accident began. Dieckamp expressed the following view:

> It really did not start having a significant effect until we set up the organization and people like Zebroski and Levenson sat in on the... technical working group and began to make direct input there... for the first several days the role of the Industry Advisory Group was one of getting up to speed and beginning to look at some of the longer range issues.... I don't think in the early days they had a significant impact on the direct operations.[18]

Arnold, the Manager of the TMI-2 Recovery Organization, similarly stated the following:

> Prior to the establishment of this organization, the middle of that first full week following the accident, I had very little interplay with that group.[19]

Because of this absence of an organizational structure during the first days, confusion existed among the groups of the recovery effort. The interaction between the IAG and the other elements was essentially between individuals involved in a particular effort. Once the formal TMI-2 Recovery Organization was established on April 4, the information flow between elements of that organization was accommodated through the Technical Working Group. This was a type of executive committee for operations assisting Arnold as the GPU Operations Manager. The managers (or their deputies) of the groups of the recovery organization attended the twice-daily meetings of the Technical Working Group, where assignments, priorities, and recommendations were discussed. The B&W and Burns and Roe organizations, although not identified as specific elements in the TMI-2 Recovery Organization, were also represented at these meetings. Levenson normally represented the IAG. Dieckamp maintained contact with the group through occasional attendance at these meetings. The Technical Working Group meetings identified the activities for the IAG and coordinated them with the overall recovery effort; however, the direct interaction among all staff, IAG and others, continued. Arnold stated the following to the Special Inquiry Group:

> We tried very hard to ensure there continued to be what I might call staff-to-staff communications, coordinations, flow of information and status, even after the formalization of this organization; because the time restraints that we were faced with or the time demands that we were faced with certainly would not have been reflected properly if we had insisted on all of that type of activity coming up through the Technical Working Group.[20]

This method of staff interaction provided for implementation of decisions reached at the Technical Working Group meetings. The functioning of the IAG was informal. Task assignments were made on a priority basis and results frequently had to be available in a short time. When a particular problem came up for which additional expertise was required, Levenson, as the director of the IAG, would contact the appropriate organizations or individuals and request their assistance, including their presence at the site. The problems assigned to the IAG for consideration and evaluation during the first week after the accident included the following:

- examination of controlled depressurization to achieve long term cooling status
- hydrogen in reactor coolant system
- dose assessment
- natural circulation with solid pressurizer
- operation of reactor coolant pumps at reduced speed
- removal of airborne radioactivity from containment
- investigation of particle bed
- degradation sequence study for the event of plant systems failure
- primary system cooling modes that use primary components as a heat sink
- safety of various cooling processes
- use of secondary system for long term cooling
- transfer of hydrogen from waste gas storage tank to the containment

A report of the IAG assessment was written for each of these activities; the report was then used as a basis for discussions at the meetings of the Technical Working Group.

The development of the entire industry support effort, and in particular that of the IAG, was shaped to a large degree by the interaction between the GPU organization and the NRC after the arrival of Denton at the site on the afternoon of March 30. As discussed earlier, the need for broad technical expertise to evaluate the situation at TMI-2 and to determine methods to achieve more stable conditions was realized by GPU management late on March 29. Requests for such support were then initiated by GPU management from New Jersey throughout March 30, and from the site on March 31.

Denton became concerned later on March 30, about the capability of GPU to provide sufficient manpower and expertise to the recovery effort. In a telephone call at about 7:00 p.m. on March 30, with Lee Gossick, the Executive Director for Operations of the NRC in Bethesda, Md., Denton commented:

> The utility is a little shy, in my view, of technical talent. We outnumber them. They are pretty thin. I'm trying to convince them to bring in comparable

levels from their own organization. Their cooperation is good, but it is obvious that they are a small outfit here and the guys are getting swamped with demand.[21]

Based on the interview by the Special Inquiry Group where he commented on this statement and provided further detail, Denton had two concerns. One concern was the difficulty his staff experienced in trying to obtain plant-specific information—such as containment volume and elevations of safety grade equipment inside the containment—that was needed to perform an independent NRC assessment of existing plant conditions. Denton expressed the need for this information as the following:

> I wanted GPU to get in the mode where they could answer any questions my staff raised to get into a more normal mode of NRC license review.[22]

Wilson, the GPUSC Director of Technical Functions, also recalled in his interview by the Special Inquiry Group that the unavailability of basic plant data and information created a problem in the response effort.

Denton's second concern was the apparent absence of an industrywide involvement in the ongoing activities, in particular the lack of participation by B&W. This understanding by the NRC of the GPU initiated and industrywide support effort resulted in interactions between the two organizations. Denton recalled that he informed Dieckamp of his concerns on March 30 without requesting any action by GPU:

> It was more of an inquiry, 'What are you planning to do?' And I seem to have had the feeling that whatever they were doing was not sufficient, and that while they did have some plans and something was going on, it just didn't satisfy me. I didn't direct him to do any more.
>
> I guess I would have to characterize that phone call as an information gathering phone call; and getting an answer that really didn't satisfy me and not knowing what the next course of action would be when I terminated that phone call.[22]

Dieckamp recalled that Denton contacted him on March 31. At about the same time he also received calls from Hendrie and Jack Watson of the White House staff with the same message, urging GPU to build up the support with experts from throughout the industry.[23] Arnold recalled the situation at that time as the following:

> I think during that time period on Saturday [March 31] I was identifying to Stello [Victor Stello, NRC Incident Response Action Coordination Team] and to Denton on occasion what resources we had working, what the scope of activity was that we were gearing up with.
>
> We were at that point getting Westinghouse geared up, we were getting CE and GE as well as B&W. This was being done basically through Wilson's group. We had Burns and Roe working heavily. I think one of the problems that existed in that first 2 or 3 days was that without the kind of formal organization that we put in place in the middle of the week, I was not able to adequately convey to Stello . . Denton the full scope of activities and resources that were going on at that time.
>
> I had to speak too much in general terms and I didn't have enough detailed information as to all of the things that were being done. They, I think, in retrospect—I thought at the time—failed to have confidence or full perception of what we already had underway in that Friday-Saturday-Sunday [March 30–April 1] time frame.[24]

The foregoing statement indicates that the communications between the GPU and NRC managements regarding urgency and type of outside support were ineffective. We now know GPU had initiated actions, but the NRC was unaware of these. Furthermore, while GPU requests were for technical expertise in a broad spectrum of subjects, the NRC also was looking for technical staff within GPU that could provide plant-specific design, operations, and status information. Although both managements realized the need for outside support, they did not coordinate the requests for such support and did not apprise each other of their respective efforts. Denton expressed his concern to the White House about the GPU technical capability and need for outside support on March 31, and passed on the names of some senior executives within the nuclear industry who he thought could effectively assist in the recovery efforts.[25]

Denton assumed that the White House subsequently played a large role in requesting these individuals to provide their personal and companywide support to the TMI-2 recovery effort. However, Watson, of the White House staff, apparently did not make any direct contacts with these individuals but called Dieckamp to advise him on Saturday morning of the NRC concerns:

> I underscored the sense of urgency that Harold Denton felt and asked the company's cooperation in getting those people assembled as quickly as possible. Mr. Dieckamp pledged his fullest support for his company to get that done. And in fact, it was done quickly.[26]

Dieckamp informed Watson of the GPU support activities already initiated at that time, but it reasonably can be assumed that the calls made by him on March 31 increased in urgency as a direct result of this request by the White House.

The lack of communication between NRC and GPU management in mobilizing the industry support effort became evident during the first week following the accident. Dieckamp recalled the following after arriving at the site on March 31:

> I began to realize that concurrent with this formation of the IAG, the NRC fellows had their own network out that was assessing all kinds of organizations, vendors, contractors, their national labs. I guess over the next few days we found that some of these organizations were finding themselves getting the same or similar or slightly different questions from the two sources, one from us and one from the NRC and we had a little bit of confusion occasionally out in some of these contractor shops in terms of who is calling what shots.
>
> Again, I think those things worked out. They were not really a critical problem other than a bit of a very minor piece of inefficiency, and that is a neutral word.[27]

The IAG assisted the entire TMI-2 Recovery Organization, including the NRC, by providing a broad range of expertise in any area of concern. The group analyzed specific plant conditions and their safety implications, based on fundamental scientific and engineering principles. The group analyzed the overall plant status with respect to the potential for deterioration of the conditions, including conceptual approaches to avert such deterioration. The IAG also contributed to the development of the long-range plan to ultimately achieve stable plant conditions. In performing these activities, the group provided the management of the recovery organization with assurance and confidence that the operational steps to be taken would not lead to unstable plant conditions. Through the IAG, advanced methods of analyses—such as the diagnostic efforts by Norbert Ackermann of Technology for Energy, Inc.—were applied to the recovery effort.

The problems encountered within the IAG and in its interaction with the other elements of the TMI Recovery Organization were seldom of a technical nature. During the interviews by the Special Inquiry Group, the technical problems were characterized frequently as "legitimate differences in technical opinions." They existed not so much within the IAG but between this group and other elements of the organization. However, in such cases a consensus was reached on how to proceed.

The location of the IAG at the Harrisburg Airport, removed from the confusion at the site, contributed to a rational mode of operation. The size of the IAG (not more than 40 members at any time) contributed to its effectiveness. More people easily could have created confusion and management problems within the group. Because of its size, the free exchange of information and ideas within the organization was enhanced.

The performance of the IAG was reviewed with members of the group and individuals who were associated with it. The following comments were expressed almost as a consensus.

- The major contribution of the IAG was the confidence and assurance it provided to the GPU and NRC management that the existing conditions at TMI were controllable. This confidence not only permeated the staff of the organization but also was expressed publicly.
- The availability of the IAG at an earlier date—for example, on March 29, instead of on April 1—possibly would have made only a small difference with respect to the subsequent physical events. The IAG potentially could have contributed to an earlier understanding of the severity of the accident. More importantly, it could have advised GPU and NRC management of the situation, and thus could have reduced the misunderstandings and concerns of the public and the technical community.
- The expertise that became available in the IAG does not exist and cannot be expected to exist within each utility company operating a nuclear powerplant.
- To be more effective in potential future operations, an industrywide effort should be initiated to preplan and coordinate the composition and operation of such a group.

e. Babcock & Wilcox Support Effort

The Babcock & Wilcox Company (B&W) designed and supplied the nuclear steam system for TMI-2. The design came out of the Nuclear Power Generation Division headquartered in Lynchburg, Va. At the time of the accident, Met Ed had a master services contract with B&W that called for assistance in the review and evaluation of the operation and performance of the nuclear steam system on an as-needed basis. Leland Rogers was the Site Operations Manager from B&W assigned to TMI Units 1 and 2 since 1972. Before March 1979, additional B&W personnel were assigned to TMI-2 to complete certain aspects of the startup activities.

The assistance by B&W in the response to the TMI-2 accident was provided in two ways: the onsite support by the B&W site staff, and the support by the B&W offices in Lynchburg. In the first case, Rogers, during a call at about 6:00 a.m. on March 28, was requested to report to the Unit 2 control room. He arrived on site at about 7:00 a.m. and became a member of the management team reporting to Gary Miller, the Station Manager. Roger's principal duties were to assist the Met Ed staff in the control room in the evaluation of plant conditions, to make recommendations concerning corrective actions, and to establish and maintain contact with B&W in Lynchburg. He attempted to contact the staff in Lynchburg at about 7:30 a.m. but was not successful because they had not yet reported for work. In a second call at about 7:45 a.m., Rogers contacted William Spangler, the B&W Manager for Startup Services, and advised him of the incident. He provided some specific plant status information: that the plant had experienced a loss of feedwater, turbine trip, reactor trip, and initiation of high pressure injection; the reactor coolant drain tank rupture disc had burst; there were indications of fuel failure; a high radiation level in the containment dome had been measured; reactor coolant pumps were tripped; there was an indication of primary to secondary system leakage; and a site emergency had been declared.[28]

A second call from Rogers to Lynchburg was scheduled for 9:30 a.m. to provide additional and updated information. The call did not take place because, by this time, Rogers was devoting his efforts to the control room management team and long-distance telephone communications from the control room were difficult to establish. Instead, communications from the control room to Lynchburg throughout the day were conducted through local calls to the private residence (local dialing) of Greg Schaedel, a member of Rogers' staff. It was not until 6:30 p.m. that a direct communications link between the Unit 2 control room and Lynchburg was established.

Based on the Special Inquiry Group's interviews of the GPUSC and Met Ed staffs, the requests by GPU for assistance from B&W in Lynchburg, and their participation in the decisionmaking process on March 28, were minimal. During the morning, B&W was requested (through Schaedel) to send two radiation chemists to the site to assist the plant chemistry staff in an evaluation of the water that had been transferred from the containment to the auxiliary building. Another request was for an evaluation and development of procedures to start one of the four reactor coolant pumps. This request was made at about 7:00 p.m. in a conference call between the operations staff at the site, the GPU technical staff in New Jersey, and the B&W staff in Lynchburg.[29,30,31]

In contrast, the activities that developed at the B&W offices in Lynchburg as a result of the telephone call from Rogers at 7:45 a.m. were substantial. Spangler informed his management of the TMI-2 event, and a task force of about 20 technical and management personnel was briefed on the TMI-2 situation at about 9:00 a.m., based on the information available. The task force concluded that the plant had gone through a transient that was not fully understood and that it was a serious situation. A list of specific information needed to more fully understand and evaluate the TMI-2 situation was prepared for discussion with Rogers in the telephone call scheduled for 9:30 a.m. It was also decided to immediately dispatch to the site, by charter aircraft, three engineers with expertise in the analysis of a loss-of-feedwater transient to assist Met Ed in the evaluation, and to provide Lynchburg with the more detailed information needed to determine requirements for startup of the plant. On arrival at the site, the engineers were unable to gain access to or make contact with Met Ed, and so joined Schaedel at his residence.

The participation of B&W Lynchburg in the TMI response effort on March 28 was severely handicapped by the absence of direct communications with the control room. Use of the indirect link of communication through Schaedel resulted in delayed, outdated, incomplete, and inconsistent information being provided to Lynchburg, as well as extreme difficulty in making recommendations from Lynchburg to the control room. An additional link for communications to the site was available intermittently through James Floyd, the Met Ed Operations Supervisor for TMI-2, who was in Lynchburg at the time. He was able to communicate directly with the Unit 1 control room. James Deddens, the Manager of the B&W Project Management Department, was the top B&W management official in Lynchburg in the absence of John MacMillan, the B&W Vice President, who was out of town. Deddens made repeated requests that day to Robert Arnold of GPUSC in New Jersey and to Richard Klingaman of Met Ed in Reading, Pennsylvania, to make a direct line available between the control room and Lynchburg. As stated earlier, this was finally accomplished at about 6:30 p.m.

B&W Lynchburg participated on March 28, in two essential activities: the initiation of the high-pressure injection flow and the starting of a reactor coolant pump. At around noon, additional information on the sequence of events and plant conditions had become available to B&W Lynchburg. When reactor coolant hot-leg temperatures were finally communicated, Lynchburg quickly realized that superheated steam was in the hot legs. B&W was aware that the four reactor coolant pumps had been turned off and the high pressure injection (HPI) pumps had either been turned off or throttled. Based on the hot-leg temperatures, B&W recommended that a minimum HPI flow of 400 gallons per minute be established to ensure removal of decay heat from the reactor core to achieve subcooled conditions. Lynchburg initially did not get this message directly to the Unit 2 control room; they instructed Schaedel at the site and Floyd in Lynchburg to relay this recommendation to the Unit 2 control room. At about 2:00 p.m., Deddens called Arnold in New Jersey to apprise him of the B&W evaluation and conclusions. He recommended that the HPI flow be increased and maintained at a minimum level of 400 gallons per minute. However it was not until 4:30 p.m. that the recommendation finally was implemented by the operations staff in the control room.[32] In the opinion of B&W, this delay was not the result of a disagreement by the control room staff on the recommendation. Deddens has recalled that:

> The impression I have is one of, let's say, a feeling of frustration in not being able to get that recommendation clearly defined and communicated to the control room.[33]

Arnold of GPU did not remember this recommendation but he also stated that B&W may well have made such a recommendation to him.[29] The other major activity was the B&W participation in starting one of the four reactor coolant pumps to reestablish forced reactor coolant flow through the core. The need and procedures for starting a pump were discussed in a conference call at about 7:00 p.m. B&W developed step-by-step procedures and maintained direct contact with the control room while the pump was started. In a final call at about 8:30 p.m. on March 28, Deddens discussed the plant status with Arnold and advised him that B&W would be available to him at any time.

A number of telephone contacts were made on March 28, between the NRC and the B&W Licensing Division in Lynchburg, mostly for the exchange of information and to provide the NRC with specific details on B&W systems and components. However, specific action by B&W apparently did not result from these calls. On March 29, at about 2:00 a.m., Donald Roy, the Manager of the B&W Engineering Department, was called by Victor Stello, a member of the NRC Incident Response Action Coordination Team (IRACT) in Bethesda, Md., but neither recalled the specific circumstances or substance of the call. However, the call did result in the reconvening of the senior members of the B&W technical staff at the B&W offices to evaluate the plant conditions.

A specific issue discussed between the NRC and B&W on March 29, was the bubble in the primary coolant system concerning its composition and explosion potential. In the evening of March 29, the NRC in Bethesda, Md., requested B&W to determine the maximum possible oxygen generation rate and content in the reactor vessel. Donald Nitti was the principal individual of B&W involved in this issue; the B&W Licensing Division provided the liaison with the NRC. Nitti calculated a maximum oxygen concentration of 5.5%, exclusive of the effect of dissolved hydrogen in the reactor coolant recombining with free oxygen to reduce this concentration. The specific calculations performed by B&W were telecopied to the NRC late on March 29.

Although the bubble issue was of extreme concern to the NRC and was subsequently discussed extensively between the NRC and B&W, there was apparently little interaction on this issue with GPU. Arnold recalled in his interview by the Special Inquiry Group that he was aware of a hydrogen explosion concern on March 31, but is not sure if this related to the containment or the reactor vessel. His first real awareness of the explosion potential in the reactor vessel came about on April 1, when Roger Mattson of the NRC briefed Harold Denton before President Carter's arrival at the site.[34,35]

The B&W support became a significant element in the TMI-2 recovery effort. It reached its full strength approximately 5 to 6 days following the accident. The B&W Lynchburg support organization that was established on March 29, was staffed 24 hours per day. Overall direction was provided by Deddens with an Operations Manager on each shift. Individuals with expertise in areas such as fluid systems, long term cooling, radiation chemistry, safety analysis and event sequence, plant design, and fuel and core analysis were assigned to each shift. In addition, the entire B&W organization in Lynchburg was available on an as-needed basis. The main participants were located in the Project Control Center, a large conference room provided with needed background information such as drawings and safety analysis reports. Direct telephone lines to the TMI-2 control room and support organizations at the plant site were established and maintained, in addition to other telephone lines. The substance of telephone calls and meetings was recorded, and in some cases tape recordings were made. By the weekend most of the analyses and recommendations were made in written form by the Lynchburg organization and telecopied to the site. Copies were also provided, when appropriate, to the GPUSC, the Burns and Roe organization in New Jersey, and the onsite NRC group.

Initially, the B&W support was provided directly to the operations staff in the Unit 2 control room. Support was later coordinated by Richard Wilson of GPUSC after he arrived at the site on March 29. The B&W support was directed to the identification of the plant status and to the evaluation and recommendation of specific actions such as methods for degasification of the primary system, reactor coolant pump operation stability, and alternative approaches for achieving natural circulation. In addition, B&W provided specific information such as drawings and analyses of the reactor and other systems and conditions.

The nucleus of the B&W group at TMI was the B&W site organization under Rogers. The three engineers and two radiochemists dispatched from Lynchburg to the site on March 28 became part of this group. On March 30, a B&W expert in reactor noise analysis arrived at the site to evaluate anomalies in the signals from the reactor coolant flow and pressure instrumentation. By April 2, the B&W site group had increased to about 30 people. They provided more immediate support to the Technical Support Group under Wilson than did the Lynchburg organization, and participated in the writing and review of step-by-step emergency procedures involving the reactor system and its components.

On April 2, the entire onsite B&W effort came under the direction of MacMillan, Vice President of B&W. The interaction of B&W and the TMI-2 Recovery Organization took place in different ways. Although there was no specific B&W element identified in the TMI-2 Recovery Organization, B&W operated as an organization, as evidenced by a B&W trailer at the site. There were different interfaces between B&W and the TMI-2 Recovery Organization: the representation of B&W in the Technical Working Group by MacMillan; the interaction of the B&W Lynchburg and onsite groups with the Technical Support Group; and the interaction with the IAG. B&W was represented on the IAG to provide liaison between the two organizations on issues being considered by both of them. The most notable are the methods and criteria to achieve natural circulation. The first interaction on this issue was a briefing of the IAG by the B&W staff from Lynchburg at TMI on April 2. Subsequently, there were many more communications on this subject, including discussions in Lynchburg.

The development of the B&W support effort occasionally was affected by Harold Denton of the NRC, who arrived at the TMI site on Friday afternoon, March 30. On Friday night or Saturday morning, he expressed to Dieckamp and Arnold his concern for adequate support by the industry in general, and by B&W in particular. Denton recalled the following:

> Whatever it was, I didn't find very reassuring as in sufficient depth or scope... I think at the time I was just inquiring of him what his plans were and letting him know that we had all these questions that he couldn't answer. And I recall having talked to some people at B&W during that day and seem to have come away with the feeling that B&W was also in a response mode, that they were answering their phone calls, but seemed to know even less about critical parameters than we did before I left Bethesda.
>
> There was a lot of information and a lot of analyses that we wanted done that only B&W could do, and in that case we wanted GPU to get B&W to make them and to produce people from B&W who understood their systems in sufficient depth...[36]

Arnold, while understanding the concern of Denton, did not consider the B&W support to be inadequate. Nevertheless, he called MacMillan, informed him of the NRC concerns, and requested and authorized the full support of B&W. He summarized his understanding of the conditions as the following:

> I didn't have the impression prior to that that B&W was holding back in any sense. Based on the conversation I had with John MacMillan, I am not sure they were. I don't know that I asked him specifically about that, but I certainly felt from that conversation that MacMillan was glad to have that sort of coverage of what he was doing, but that by and large he was already underway on that level of activity anyway.[37]

Another interaction by the NRC with the development of the B&W support effort occurred on April 1, after the NRC briefed the IAG on its perception of the major issues. Denton was concerned that B&W was not represented in the group and advised Dieckamp. Dieckamp acknowledged this fact and explained the following:

> I think what really happened to the B&W people, because they had other people on the site, who ever of B&W arrived just got co-opted into that activity on site.[38]

Dieckamp immediately called MacMillan requesting that B&W be represented at the site by high level management. MacMillan arrived on April 2, with senior engineers and, as stated earlier, briefed the IAG of the B&W perception of the plant status and identified the major problems facing them.

f. Burns and Roe Support Effort

The Burns and Roe Company was the architect–engineer of the TMI Unit 2. As such, the company had within its organization individuals knowledgeable and experienced in the design, equipment specifications, performance, interactions, and layout and location of secondary and auxiliary systems, and of components and plant structures. The participation of Burns and Roe in the response effort, like most other organizations, was initiated by a GPU request and grew in proportion with the comprehension of the severity of the accident by the GPU management. During the height of its involvement in the recovery effort, more than 300 individuals of the Burns and Roe organization were actively participating in the support effort.

Before March 28, the Burns and Roe activities for TMI-2 were conducted by a Project Group of approximately 40 individuals located in Paramus, N.J. The group was directed by Scott Dam, the Project Manager, who reported to Warren Cobean, Vice President for the Project Operations Division. The activities of the Project Group included updating of plant drawings to the as-built configuration, planning of plant modifications to be made during the first TMI-2 refueling outage, and the design of facilities and systems not covered under the original construction contract. (The group was performing similar functions for the Oyster Creek plant of Jersey Central Power and Light Company.) In addition to the Project Group, three technicians at the site coordinated the Burns and Roe effort with GPU and the Met Ed site organization. Richard Brownewell, Burns and Roe Site Engineer, managed the effort.

Burns and Roe officials were first informed of the TMI-2 accident at approximately 9:00 a.m. on March 28, in a telephone call from Brownewell to Cobean. Brownewell reported that he was unable to get onto the site because a site emergency had been declared, but he had no detailed plant status information. Cobean contacted Richard Wilson of GPUSC and told him that Burns and Roe would be ready to assist in whatever form necessary to respond to the event. There were no further contacts between Burns and Roe and GPU on the day of the accident.

On March 29, after learning about developments at TMI through the news media, Cobean contacted Arnold to inquire about the plant status and reiterated that Burns and Roe was ready to make any service available. Arnold indicated that GPU suspected the core had been uncovered; however, he made no request for Burns and Roe assistance.[39] Later on March 29, Burns and Roe received the first request for assistance from the TMI site. The request was for a calculation of the water level inside the containment, based on the water levels in various tanks that had emptied into the reactor coolant system and spilled into the reactor containment building. The request was based on a concern for potential flooding of instruments and equipment inside containment. A level of 2 feet of water was calculated and reported to the site. Although this level did not cause any flooding, it did cause concern within the Burns and Roe organization. However, no further call was made to apprise GPU management of the abnormality of the water level.[40]

Additional requests for assistance soon followed and continued to grow in number and scope during the next days. The requests originated at the site, primarily from the group under Wilson, and at the GPUSC offices in New Jersey. During this time, Cobean received numerous direct calls from Dieckamp to discuss the evolving situation and understanding of the TMI-2 conditions. The requests were for information on system and equipment performance and capability, special studies, answers to postulated "what if" situations, designs for interim systems and system connections, and recommendations on methods to increase plant stability. They related primarily to concerns for continued decay heat removal capability, control of primary coolant system temperature and pressure stability, available methods of primary coolant system degasification, and methods to minimize the release of radioactive gas and fluids to the environment. The last issue was raised by Dieckamp and resulted in a nationwide search for large tanks that could be used to store radioactive fluids and house activated charcoal (an identical search for tanks was underway at that time by the Met Ed offices in Reading).

As a result of the increasing requests for assistance, in the late afternoon of March 29, Cobean instituted a Burns and Roe response organization that provided support on a 24-hour basis. The nucleus of the organization was the Project Group, which was quickly supplemented by members of the Forked River Project Group and other resources from throughout the Burns and Roe organization and soon reached a size of about 200 members. Direct telephone lines to the TMI site were installed at the offices in New Jersey to facilitate the efforts of the response group.

Based on the many discussions on March 29 and 30, between Burns and Roe and the TMI site, GPU in New Jersey, and B&W in Lynchburg, Va., Cobean decided on March 30, that it would be beneficial if closer and more direct communication links were established between Burns and Roe and B&W. On March 31, he dispatched two engineers to Lynchburg to provide B&W with information on systems designed by Burns and Roe, and to provide technical liaison between the two organizations.

Also on March 31, Dieckamp requested Cobean to join the IAG and to provide TMI-2 plant specific expertise to the group with respect to the design criteria and installation and operation of secondary and auxiliary systems. In addition, Burns and Roe was requested to provide TMI-2 documentation and records, including as-built drawings, mechanical flow diagrams, system descriptions, electrical one-line diagrams, general arrangement drawings, and copies of the Final Safety Analysis Report. A group of about 10 individuals under the direction of Cobean arrived at the site on April 1 with the requested information, and went directly to the IAG offices.

The participation of the Burns and Roe organization in the TMI-2 support effort took place in many forms. At the TMI site, the organization participated in the IAG; provided the majority of manpower, including management, to the Plant Modifications Group; provided manpower to other elements of the recovery organization such as the Waste Gas Management and Technical Support Groups; was a member of the Technical Working Group; and acted as a consultant to Dieckamp. More than 100 members of the Burns and Roe staff were at the site. In addition, more than 200 members in New Jersey provided the backup to the site staff. During the time of Cobean's active assignment to the IAG from April I through April 3, Cobean was associated with the IAG subgroup in evaluating alternate schemes, including considerations of loss of offsite power, to bring the plant to a cold shutdown condition. Ed Wagner, the Burns and Roe Deputy Director for Engineering, participated in the subgroup under Ed Zebroski evaluating the core damage, including the hydrogen bubble concern. Burns and Roe also provided the IAG with manpower with TMI-2 expertise and with the technical information library.

On April 3, Dieckamp requested Cobean to develop, staff, and direct the Plant Modifications Group (PMG) in the TMI-2 Recovery Organization, which was being developed at that time. The responsibility of the PMG was the design, engineering, and any associated procurement of equipment and materials for all approved plant emergency modifications. The highest priorities were assigned to those modifications necessary for the long term cooldown of the reactor system to cold shutdown conditions, and for controlling and minimizing the releases of radioactive gases and fluids to the environment. The PMG was divided into four organizations: engineering and design, procurement, construction, and special projects.

The directives for the PMG generally came from the Technical Working Group (TWG), which met twice daily. Its members were the managers or their deputies of all groups of the TMI-2 Recovery Organization. The TWG received input from all managers, evaluated proposed plans or analyses, developed and agreed on the necessary criteria, and then provided direction to the operating groups to initiate the activities within their scope of responsibility. This procedure was not strictly adhered to at all times because of time limits. For example, the concern over the consequences from a loss of electrical power to the plant had been raised by the IAG. The potential consequences of such a situation were severe enough in the opinion of Cobean that he immediately initiated the steps for installation of two 2500 kilowatt diesel generators and obtained the concurrence of Arnold afterwards.

Burns and Roe provided the management and the majority of manpower to the PMG; however, other industry organizations also participated in the effort. Westinghouse supplied a substantial group of engineers and designs for an augmented decay heat removal system and for the decontamination of the diesel generator building and of the auxiliary and fuel handling buildings. The staff of the PMG also included manpower from United Engineers and Gilbert Associates. The implementation of plant modifications (including installation of equipment) was performed by skilled craftsmen under supervision by Catalytic Engineering Company.

A less apparent but important contribution provided by Burns and Roe was the availability of Cobean as a technical consultant and management executive to the GPU management.

g. Summary of Findings and Recommendations

Findings

- The industry support played a major role in assisting the GPU organization to achieve safe shutdown of the reactor and to mitigate the consequences of the accident.
- The TMI-2 emergency plan in effect on March 28, 1979, did not include provisions for technical support for plant operations; the plan was limited to the radiological response as required by the NRC.
- On March 28, Met Ed requested only limited assistance from its nuclear steam supply system designer and manufacturer (B&W in Lynchburg, Va.) and did not, therefore, effectively use the technical expertise available.
- Control room data indicating plant status were not communicated to B&W in Lynchburg, Va., in a timely manner on March 28.
- B&W personnel in Lynchburg, Va., managed to diagnose the lack of adequate core cooling from the hot-leg temperature data. They were then able to recommend actions to be taken to establish adequate core cooling.
- The architect–engineer, Burns and Roe, provided engineering expertise and information on the

plant, which helped in the diagnosis of plant conditions.

- Burns and Roe provided substantive support in the engineering and construction of systems and equipment changes that were made to mitigate the consequences of the accident.
- The manpower and technical expertise required to cope with the accident exceeded those available from the Met Ed and GPUSC organizations.
- Earlier mobilization of the TMI-2 recovery effort would have led to earlier assessments of plant conditions, development of corrective actions and plant modifications, and the achievement of plant stability.
- The fact that plant specific information was not readily available at the site delayed technical personnel in their efforts to place the plant in safe shutdown status and to mitigate the consequences of the accident.

Recommendations

- The NRC should require that the emergency plans for all nuclear powerplants include provisions to assure prompt technical support to plant operations personnel coping with a reactor accident and its consequences. Also, the NRC should ensure that adequate technical and managerial personnel and resources will be requested and integrated into a preplanned emergency organization for response to and recovery from an accident.
- The NRC should interact with nuclear industry organizations in defining the criteria and guidance for emergency planning.

REFERENCES AND NOTES

[1]Klingaman Interview Memo at 2-3.
[2]Dieckamp dep. at 21.
[3]Wilson Interview on June 1, 1979 (IE) at 23-24.
[4]Arnold dep. at 66-67.
[5]Dieckamp dep. at 44.
[6]Cherry Interview Memo at 1-4.
[7]Keaton dep. at 73-75.
[8]Owen Interview Memo at 6.
[9]*Id.* at 5.
[10]Lee Interview Memo at 1-2.
[11]Denton dep. (Oct. 4, 1979) at 45-46.
[12]Dieckamp dep. at 40-41.
[13]*Id.* at 35.
[14]*Id.* at 37.
[15]*Id.* at 31-33.
[16]Zebroski Interview Memo at 3-4.
[17]Arnold dep. at 57-58.
[18]Dieckamp dep. at 71-72.
[19]Arnold dep. at 54.
[20]*Id.* at 56.
[21]NRC Commission Meeting Transcripts (March 30, 1979) at 209.
[22]Denton dep. (Oct. 4, 1979) at 35-36.
[23]Dieckamp dep. at 29.
[24]Arnold dep. at 65.
[25]Denton dep. (Oct. 4, 1979) at 38, 42-43.
[26]Watson dep. at 104-105 (Pres. Com.).
[27]Dieckamp dep. at 29.
[28]Spangler dep. at 50-51. Exhibit #3104 at 1.
[29]Arnold dep. at 18-24.
[30]Keaten dep. at 38.
[31]Wilson Interview Memo at 10.
[32]Deddens dep. at 28-39.
[33]*Id.* at 41.
[34]Arnold dep. at 40-42.
[35]*Id.* at 60-68.
[36]Denton dep. (Oct 23, 1979) at 34-35, 44.
[37]Arnold dep. at 64.
[38]Dieckamp dep. at 39.
[39]Cobean dep. at 8.
[40]*Id.* at 27-31.

5. REPORTING CRITICAL INFORMATION TO THE NRC ON MARCH 28, 1979

a. Introduction and Summary of Conclusions

The severity of the Three Mile Island accident was not generally recognized until the morning of March 30, 2 days after the accident began and more than 1 day after the reactor itself had been brought to a relatively stable condition. However, information available in the control room of the stricken reactor plant during the day of Wednesday, March 28, clearly indicated that its core had been uncovered for a substantial period and that its fuel rods were critically damaged.

The question has therefore been raised whether such information was willfully withheld from the NRC by Met Ed's employees or management in an attempt to minimize or coverup the seriousness of the accident. Such an intentional failure to provide significant safety-related information by a licensee to the NRC might, among other things, constitute a violation of NRC regulations and statutes.

The specific items of information involved are the following:

1. Between 7:00 and 9:00 a.m. on March 28, personnel in the control room knew that temperatures in the reactor's "hot legs" (the piping through which reactor coolant leaving the core first passes) were greater than 700°F, several hundred degrees above normal. Through most of the day, these temperatures were elevated to this approximate level. These temperatures are well above the "saturation" point for the pressures at which the system was operating, indicating that superheated steam had formed in this piping. Continued elevation of hot-leg temperatures should have led to a conclusion that bulk boiling was occurring in the core area and that the core was, or had been, at least partly uncovered.
2. By about 9:00 a.m. on March 28, electrical technicians had measured temperatures in the core area, recorded by so-called "incore thermocouples," exceeding 2000°F. At least a few of these readings were reported to control room personnel.
3. At 1:50 p.m. on March 28, an instrument showing reactor building pressure indicated a rapid pressure increase from 4 psig to about 28 psig and back again in a few seconds. This pressure "spike" was later diagnosed as having been caused by burning of flammable hydrogen gas in the reactor building produced by high-temperature decomposition of the reactor fuel rods' cladding or outer sheathing.

With respect to item 1, hot-leg temperatures, it appears that this information was available to NRC inspectors who arrived in the Unit 2 control room about 11:00 a.m. on the morning of March 28, but that there was a 3- to 5-hour delay before hot-leg temperatures that clearly indicated saturation or superheat conditions reached offsite organizations. For example, such hot-leg temperature readings evidently did not reach B&W's engineering group in Lynchburg, Va., until about 1:30 p.m. on March 28, and were not reported to NRC's Bethesda Headquarters until about 12:30 p.m. It was after 2:00 p.m. before NRC response centers in Bethesda and the Region 1 learned of temperatures indicating substantial superheat. There may also have been a delay of several hours or more before GPUSC engineers in New Jersey learned of these temperatures.

Hot-leg temperatures well above saturation imply that a substantial portion of the core is at least partially uncovered and is being cooled, if at all, by steam rather than water. The elevated hot-leg temperatures were well known to control room personnel throughout the day and were generally perceived as indicative of a very serious problem in the reactor. However, if the full implications of these temperature readings were understood by those in the control room, their conclusions were not communicated to the outside. When offsite organizations—the NRC, B&W, and GPU engineers—learned of the high hot-leg temperatures in midday and early afternoon, they did not immediately draw the conclusion that the core was or had been uncovered; but individuals in each organization eventually expressed strong concern about that possibility. Several B&W engineers convinced their peers that the reactor was in serious condition and that high-pressure injection flow should be maintained. The NRC's Victor Stello, in a direct telephone conversation with the Unit 1 control room, urged that consideration be given to whether the core was uncovered. And GPU engineering officials and their boss, Robert Arnold, became extremely worried and eventually developed a strategy of repressurizing the reactor that brought core cooling back to stability on the evening of the first day.

The failure of control room personnel to communicate prompt and accurate information about hot-leg temperatures, and to grasp their implications, certainly raises questions about their competence, a matter discussed in our overall conclusions. However, there does not appear to be a substantial question as to whether this information was willfully withheld from the NRC.

With respect to items 2 and 3, however, precise and accurate information does not appear to have been communicated to responsible NRC officials. Therefore, the Special Inquiry Group (SIG) undertook an intensive inquiry into how this information was gathered, how it was interpreted, whether it was given credence, and to whom it was reported.

The SIG also conducted an inquiry into whether information about certain early radioactive dose estimates performed by Met Ed personnel (which turned out to be inaccurate) was withheld from the NRC. This information is the following:

4. Prior to 7:30 a.m., a control room meter and recorder signaled that radiation dose rates in the upper part of the reactor building increased 200-fold, to 20 000 R/h, over 5 minutes. From these readings, control room personnel calculated a potential radiation dose rate of 10 R/h at the west side of the site boundary, in the direction of Goldsboro, Pa.

Our factual findings with respect to items 2, 3, and 4 are discussed in detail below.

Our overall conclusion is that the evidence fails to establish that Met Ed management or other personnel willfully withheld information from the NRC. There is no question that plant information conveyed from the control room to offsite organizations throughout the day was incomplete, in some instances delayed and often colored by individual interpretations of plant status. Indeed, information conveyed by Met Ed, NRC, and B&W employees in the control room to their own managements and offsite organizations was in many cases incomplete and even inaccurate. However, we did not develop evidence to show that the causes of this breakdown in information flow went beyond confusion, poor communications, and a failure by those in the control room, including NRC and B&W employees, to comprehend or interpret the available information, a failing shared to some extent by offsite organizations as well.

A few individuals, both on site and off site, made statements and/or believed at some point on March 28, that the core had been uncovered, but the evidence does not indicate that anyone had a reasonable understanding of the severity of the accident until the night of March 29 at the very earliest. This misunderstanding appears to have been caused primarily by incomplete information available to any one particular individual or group about the trend of critical plant parameters (such as temperatures and pressures) over the course of the accident. Significantly, other parts of our investigation have shown that control room personnel were unwilling or unable to focus on reconstructing such information in the course of coping with the ongoing accident, and that comprehensive reporting of such data by control room personnel was never requested by Met Ed management, the NRC, or B&W managers during the day on March 28.

b. High Dose Rate Projections

Beginning at about 7:13 a.m. on Wednesday, March 28, 1979, a lead encased ion chamber located in the upper region of the TMI-2 reactor building signaled a 200-fold increase in radioactivity (to 20 000 R/h) over 5 minutes.[1] This sudden, gross contamination of the building's atmosphere apparently resulted from venting of highly radioactive gases from the pressurizer steam space into the open reactor building equipment drain tank.

Gross contamination of the reactor building atmosphere actuated visible and audible alarms in the control room and caused Station Manager Gary Miller to escalate the existing site emergency to a general emergency. "General Emergency" is Met Ed's most serious category of emergency and is reserved for plant conditions and accidents potentially dangerous to the general public. Miller's declaration of a general emergency at 7:24 a.m. initiated a cascade of actions by the plant staff to notify State and Federal agencies of the general emergency, assess potential offsite radiological consequences, and establish communication links to keep State officials informed of the radiological assessments.

The plant staff's initial step in assessing radiological consequences was to calculate potential offsite dose rates in the downwind direction by using data from inplant instrumentation. Recognizing that this first calculation was likely to be grossly inaccurate—the amount of radioactivity escaping from the plant into the atmosphere (defined as the source term in the equation) was based on a set of conservative assumptions, such as the amount of leakage from the reactor building—plant personnel performed actual measurements of the radioactivity at outside locations to correct the assumed source term. These actual offsite measurements would be used by State officials to decide what offsite protective actions should be taken to protect the public.

Plant engineer Howard Crawford apparently started the initial calculation of the potential offsite dose rate around 7:18 a.m., shortly after the 200-fold increase in radioactivity was detected. This calculation predicted a whole-body exposure rate of 10 R/h at the "low population zone boundary" in the downwind location.[2] At the time, there was wind of 4 miles per hour blowing towards Goldsboro, a community of 576 persons located 1.4 miles due west of the site. The calculation was checked by Richard Dubiel, Supervisor of Radiation Protection and Chemistry, who then promptly advised Thomas Gerusky, Director of the Pennsylvania Bureau of Radiation Protection, of the prediction.

Although the predicted dose rate was believed to be much too high, Gerusky instructed Margaret Reilly, Chief of Environmental Radiation Division, to notify the Pennsylvania Emergency Management Agency (PEMA). At 7:45 a.m., Reilly notified Kenneth Lamison, PEMA Operations Chief, to make preparations for possible evacuation of people from nearby Brunner Island and Goldsboro because of the predicted 10-R/h dose rate. At 8:15 a.m., Reilly advised the PEMA office that there were no outside releases detected and advised that the imposed evacuation alert be discontinued. Reilly's information came from Dubiel at the plant who, by that time, had received results of the initial outside radiation surveys.

A survey taken at 7:45 a.m. near the plant boundary immediately west of the reactor building revealed radiation levels less than 0.001 R/h. This survey confirmed that the significant offsite radiation levels calculated earlier, 10 R/h, did not exist.

The fact that NRC officials were not specifically aware of the initial offsite prediction of 10 R/h has raised the question whether Met Ed personnel intentionally withheld important information from the NRC that would have demonstrated that the accident was much more serious than was generally thought on Wednesday or Thursday. The evidence relative to this matter is set forth in the following paragraphs.

Miller took charge of the TMI-2 control room at 7:05 a.m. on March 28, 1979. About 10 minutes later the first strong indication of the seriousness of the TMI accident surfaced when the radioactivity levels in the reactor building dome increased 200-fold. Review of the chart from control room recorder HP-UR-1901 shows that this increase occurred after 7:00 a.m. and took place over 5 minutes. This rapid contamination of the reactor building's atmosphere was connected with a release of fission gases from the reactor coolant system. This statement is supported by other plant data that show that the block valve used to isolate the pressurizer pilot-operated relief valve (PORV) was reopened at 7:13 a.m. for 3 minutes after being closed since 6:18 a.m.

Opening this valve vented the pressurizer to the reactor building atmosphere via the stuck-open relief valve and through the open rupture disc on the reactor building drain tank. The recorder chart further shows that the 8-R/h trip level set on the control room meter for containment dome radiation monitor HP-R-214 was exceeded during the sudden 200-fold increase in radioactivity. Since Miller declared a site emergency at 7:24 a.m. based on the meter reading for HP-R-214 exceeding 8 R/h, and the pressurizer PORV block valve was reopened for 3 minutes beginning at 7:13 a.m., it is reasonable to fix the time of gross contamination of the reactor building atmosphere between 7:13 and 7:18 a.m. on March 28, 1979. The recorder chart also indicates that the radiation monitor HP-R-214 meandered around the 200-R/h reading throughout the morning. Because the HP-R-214 detector is an ion chamber encased in 2 inches of lead, plant procedures assume an attenuation factor of 100, hence, the 200-R/h meter reading is assumed equivalent to 20 000 R/h at the detector location. (Information developed after the accident indicates that the lead encasement design contains a weep hole permitting direct access of gases to the sealed ion chamber. This hole decreases the attenuation factor.)

Initial calculation of the projected offsite dose rates was completed by Crawford sometime after the 200-fold increase of radioactivity in the reactor building's atmosphere. In disputed testimony, Crawford's recollection was that he performed the calculation on the basis of an HP-R-214 meter reading taken between 6:55 and 7:10 a.m. on March 28, and this calculation predicted a dose rate of 40 R/h at location code "W-11" (Goldsboro).[3] However, no documentation, such as a calculation data sheet, supports his recollection. Crawford has also said that when the site emergency was declared at 6:55 a.m., he was lined up at the processing center outside the plant and subsequently went to the Unit 2 control room, obtained reference material, and set up a work place to perform his calculation.[4] It took Crawford several minutes to finish the preparations before beginning his calculations.

On the other hand, Dubiel, whom Crawford agreed was the one who checked his calculations, recalled that the projected offsite dose rate was 10 R/h and that this calculation was completed around 7:35 a.m.[5] Miller also does not recall a 40-R/h projection; rather, 10 R/h.[6]

Although the discrepancy is not critically significant to the question of withholding of information, there has been some confusion as to whether the projection was 10 or 40 R/h. Convincing evidence suggests that Dubiel's recollection is more accurate than Crawford's. In addition to fixing the time of the 200-fold increase in radioactivity in the reactor building to the period 7:13 to 7:18 a.m., offsite dose calculation sheets completed by Crawford on March 28 were available and were reviewed. Of these, the earliest has a time of 7:44 a.m. and has a calculation for the low population zone boundary towards Goldsboro using an HP-R-214 reading of 300 R/h.

It is apparent from the calculation sheet that the calculation was first completed using 2 miles per hour as the wind speed, and resulted in a calculated dose rate of 20 R/h. Then, the wind speed was changed to 4 miles per hour, which halved the projected dose rate to 10 R/h. Crawford then apparently marked over the 2 with a 1, resulting in a character that can easily be mistaken for a 4. The result of this calculation sheet was then transferred to an offsite code calculation log and thereon was entered 40 R/h instead of 10 R/h.[7] (As previously stated, the 40 vs. 10 R/h is of limited interest to the issue at hand. Our review was merely to clear the record on this and to clarify that, contrary to statements appearing in the NRC's Office of Inspection and Enforcement's investigation report on the accident, it appears that Crawford correctly read the control room meter and correctly applied the specified methodology during his calculations.)

The evidence indicates that the initial calculation of offsite dose rate was performed simultaneously with notifications to State and Federal agencies about the site and later the general emergency, and concurrent with the confirmatory radiation surveys at the west side site boundary. Gerusky of the State was informed of the projected dose rate at 7:35 a.m., which appears to be about the time that Crawford completed the calculation. State officials are responsible for determining and initiating actions for protecting the public, and Dubiel and Crawford evidently did the best they could in assessing and informing the State of the projected high dose rate at Goldsboro. Reilly of the State, in response to a question on whether Met Ed met its agreements with the State in terms of providing information and providing assistance, said, "I really don't have any great complaints with them. I think, in essence, they upheld their end of the bargain."[8] Reilly also said she thought Met Ed "told us what they thought was going on at the time."[8]

No documentation indicated that the NRC was notified. Transcripts of the March 28 telephone conversations that were tape recorded show that after Met Ed established communications with NRC Region I around 8:00 a.m., Met Ed personnel maintained continuous contact with Region I and were responsive in providing information.[9] Also, Met Ed dispatched an onsite survey team at 7:28 a.m. and had confirmatory radiation survey data by 7:45 a.m. that showed that 10 R/h at Goldsboro could not exist. Furthermore, by 7:50 a.m., offsite dose calculations using a revised source term were completed, projecting dose rates of less than 0.001 R/h at Goldsboro. Surveys conducted by Met Ed personnel in Goldsboro at 8:32 a.m. confirmed this projection.

In reviewing the NRC Region I accident message forms completed on March 28 and the transcripts of taped conversations between Met Ed and Region I, it appears that Dubiel and George Kunder, Superintendent of Technical Support, made the NRC aware of the high levels of radiation in the reactor building as indicated by the containment dome monitor. Dubiel and Kunder doubted that the radiation levels were as high as indicated—stating that they believed the steam environment existing in the containment affected the accuracy of the instrument. They were not alone in this belief; Bob Arnold, Vice President of Generation, GPUSC, in discussing his recollection of the 8:30 a.m. telephone call with Jack Herbein, Vice President of Generation, Met Ed, on March 28 stated:

> I think we talked to some extent about what they had seen on the radiation monitors—more specifically, the dome monitor ... I know that my tendency was to think that moisture in the containment building had probably given us failure of the instrument ...[10]

The telephone transcripts also show that at about 8:00 p.m. on March 28, Ronald Nimitz, NRC Region I Inspector, speaking from the control room at TMI to Lee Thonus, an inspector at the Region I Incident Response Center, had the following conversation:

> Nimitz: Now then, one's [Area Radiation Monitor] in the reactor building dome, it's an ion chamber apparently, it's right in the dome of the reactor [building]—and it's got a lead sheet in front of it; the factor reduction in the activity of about 100—the dose rates from the dome area.
>
> Thonus: We're familiar with that.
>
> Nimitz: Okay, they're saying that thing's reading 20 000 R per hour.
>
> Thonus: After you take the 100 into account?
>
> Nimitz: Yes.[11]

At 9:55 a.m. on March 29, when senior NRC staff briefed the assembled Commissioners in their Washington office, it was noted that the radiation exposure levels measured were recognized as signs of fuel failure, but the staff believed the very high levels measured in the reactor building dome were erroneously high.

Our analysis of the foregoing is that the licensee did not willfully withhold meaningful information from the NRC concerning high dose rate projections or the high levels of contamination inside the reactor building. The NRC was aware of the dome monitor indication showing dose rates as high as 20 000 R/h in the reactor building. NRC discounted this information.

Met Ed personnel promptly informed State authorities of the 10 R/h projected dose rate. We found no reason why Met Ed would purposefully withhold this information from the NRC. Telephone contact from Met Ed to NRC authorities was delayed until about 7:45 a.m. (NRC Region I answering service took calls from Met Ed at 7:04 and 7:40 a.m.). At about this time, Met Ed confirmed that the projected offsite dose rate of 10 R/h could not exist and by 7:50 a.m. had made a new projection of less than 0.001 R/h. Probably for this reason the 10 R/h was not discussed at any great length with the NRC, if discussed at all. Moreover, transcripts of tape recorded telephone conversations between the TMI control rooms and NRC show that the Met Ed personnel provided prompt and accurate answers to NRC questions about outside radiation levels and reactor building dome monitor readings throughout the day on March 28.

c. Incore Thermocouple Temperature Readings

Ivan Porter, Unit 2's Instrumentation Control Engineer, arrived in the control room about 6:30 a.m. and was told by Kunder that according to the instrumentation, hot-leg temperatures were off-scale high, system pressure was about 700 psi, and all the reactor coolant pumps were off. Because the temperature and pressure readings seemed anomalous to Porter, he attempted to verify the readings from "redundant instrumentation." Having done so, Porter reported to Kunder that he thought the instruments were reading properly. Next, Porter set out to get an actual reading of hot-leg temperatures by setting up a Fluke digital voltmeter across the wires leading into the computer console from the A loop hot-leg temperature detector, a resistance temperature detector (RTD). Extrapolating from the voltage reading he obtained, Porter concluded that the actual temperature in the A hot leg was about 715° to 721°F. Porter recalls reporting this information to Miller, Station Manager, and Mike Ross, Supervisor of Operations for Unit 1, some time between 7:00 and 8:00 a.m.[12]

At about this time, Miller asked Porter to "punch out" on the computer, temperature readings from the incore thermocouples. (Actually, the adjective "incore" is something of a misnomer, because the thermocouples are located just above the fuel elements, on the metal assemblies that hold the fuel rods in place. Thus, they measure the temperatures of the coolant water as it flows out of the core.) These instruments were not part of the regular instrumentation for TMI-2, as they are in some other reactors, but were placed in the reactor vessel as part of the startup and testing program. Miller knew that the incore thermocouples were not specially tested and "qualified" as instruments upon which it was assumed operators would rely in the case of an accident, but he was familiar with them from his experience on naval reactors.[13]

When Porter went to the computer terminal and "called up" a series of readings he found that, for many of the thermocouples, the computer printed out question marks rather than numbers. This effect indicated either that the instrument was malfunctioning or that it was giving a reading off the normal computer scale. Porter reported this phenomenon to Miller, who asked him whether there was any other way to read the instruments. Porter replied that he thought readings could be taken off the wires to the computer console, by hand-held instruments.[14,15]

Porter then recruited an instrument foreman, Nelson ("Skip") Bennett, and two instrument technicians, Thomas Wright and Roy Yeager. After locating some meters and drawings necessary to locate the correct wires, all four proceeded to a room directly below the computer on the floor underneath the control room.

According to Porter, after he had helped the other men locate the correct electrical cabinet and instructed them to try to determine from the voltages in the wires what temperatures were being measured by the thermocouples, he went upstairs to the control room, and then came back downstairs a few minutes later.[16,17,18] In the meantime, the other three men (apparently assisted by another foreman, Bob Gilbert) unscrewed the leads on several sets of wires and attached them across a Fluke digital thermocouple meter.[16,17] This meter converts voltages to temperature equivalents and actually reads out the temperatures being measured by the thermocouples. However, it requires that the computer wires be detached from inside the cabinet and attached to the meter, so taking readings was a fairly cumbersome process.

Porter recalls that when he returned downstairs, the technicians reported to him that they had taken about five readings. Two readings were about 2300°F—far in excess of "normal" readings in the 500° to 600°F range—and, Porter recalls, one or two readings were about 200°F, which would be much lower than anticipated even under normal cooldown circumstances. According to Porter, he then went back upstairs to the control room and reported these readings to Miller.[17,19]

In an interview of Porter by NRC's IE investigators on May 21, 1979, Porter recalled that Miller, upon hearing the numbers Porter related to him, asked what these readings meant. Porter did not recall precisely what he had answered, but remembered that his evaluation was that the thermocouples might have been destroyed or damaged. Porter stated that he knew the 200°F readings could not be correct—especially inasmuch as the hot-leg temperatures were around 700°F, far above normal—so he had no reason to believe that the high temperature readings were accurate either.[20] In a later IE interview, Porter reiterated that he did not really believe the high readings. And in a deposition conducted by the Special Inquiry Group, Porter testified:

> I continue to be amazed that everybody thinks that we should have placed 100 percent reliance on 2300 and tossed out 220 ... we went down and took three or four readings and they were just high and low and every place, just like what the computer said, so we went on to something else.[21]

A written statement prepared in April 1979 by Gary Miller and others in the control room on March 28 related that "the readings we got back from the penetration varied from 200° to 2400° to nothing," and that Miller did not have confidence in their accuracy (pp. 17-18). Miller and Porter discussed possible causes of inaccurate readings and Porter explained that the thermocouples or lead wires to them might have melted, causing junctions to fuse together and produce erroneous voltage readings. The "technical explanation," Miller said, was that the thermocouples were clearly "hot," which indicated high temperatures in the core area.[22] Porter said in an IE interview that he did not specifically recall discussing with Miller whether junctions might have melted, but agreed they may have discussed what might affect the readings.[48]

In any event, as Miller recalls it, Porter related only four or five readings to him, they had one short conversation, and Miller accepted Porter's evaluation that the readings were inaccurate without any detailed questioning of it.[22] Thereafter, according to both Miller and Porter, little or no attention was devoted to the matter. Porter does not recall discussing the readings with anyone else, though he cannot rule out the possibility that he did,[23] and Miller thinks that while some other people probably were aware of the readings from overhearing his conversation with Porter, there was no further discussion of them.[24]

Three of the men present during the time when the first readings referred to above were taken off the wires told IE interviewers that they recalled a comment being made in Porter's presence about the high temperature readings indicating that the core was or had been uncovered. Yeager recalled that after taking some initial readings, he turned around and told Porter that "the core is uncovered. Okay, Mr. Porter kind of doubted our word and didn't believe the readings, ... and says, 'I don't believe your readings.'"[25] He also recalled that they confirmed these readings with a second instrument—a voltmeter—before Porter left.

> I believe Ivan didn't want to believe what was taking place. I don't know whether it was an attitude of 'Hey, your measurements are wrong—you guys don't know what the heck you're doing'—or whatnot. I think the general consensus throughout the whole first day was, number one, nobody really knew what was actually happening, number two, some that had an inkling of what was happening didn't really want to believe what was going on.[26,27]

Wright also recalled to the IE investigators that after the technicians had taken about five readings, one or two of which were around 200°F and one or two around 2100°F, Porter appeared on the scene, and that Porter's response was that "the data didn't look too good."[28] Wright recalled that Porter said, "There's some there that are, that look too high ... that look like they'd been damaged."[29] Wright also remembered Yeager saying to Porter that the core was uncovered.[30]

Skip Bennett also told IE interviewers that he believed the subject of the core being uncovered came up in Porter's presence: he recalled that "they" made a statement to Porter that the core possibly had been uncovered.[31] Wright also stated that it was his personal view that while the high temperature readings could have been inaccurate, it was more likely that the core had been uncovered and then recovered, and that the temperatures were very slow in coming down.[32] Bennett said to the interviewers that he recalled "concern or disbelief" at the high readings, but that at the same time it was his feeling that Porter himself was "more or less in agreement" with everyone else about the possibility of core uncovering.[33]

Porter testified that he does not recall any discussion with the foremen and instrument technicians about the core possibly being or having been uncovered, but admits that it is possible that such a comment was made to him.[34] In a deposition taken by the SIG, Porter testified that he himself did not think that the incore thermocouple readings showed that the core had been uncovered.[35] At the same time, however, he said that he was very concerned about the hot-leg temperatures. And, in a previous IE review, when asked what his reaction had been to the 2300°F reading(s), Porter replied, "I guess I was afraid it was real."[36]

In the deposition of Porter by the SIG, he pointed out that he expected to see abnormally high incore temperatures on account of the high temperatures in the hot legs. But he maintained that he did not expect to see temperatures in the vicinity of 2000°F and above; and he consistently maintained that, because he firmly believed that the low temperature readings were clearly wrong, he had no reason to believe that the high temperature readings were in the right ballpark either.[37]

In any event, both Porter and Miller agree that there was no discussion between them of whether the high readings might mean that the core was uncovered or had recently been uncovered.[38,39,40] Their conversation was limited, according to the substance of their testimony, to the fact that the readings were not regarded by Porter as reliable and to the reasons why the wires from the thermocouples might be giving off such unreliable readings. When questioned as to whether discussion about the possibility that thermocouples or lead wires had melted would not have suggested a conclusion that the core was uncovered, regardless of the accuracy of the temperature readings, both Porter and Miller have maintained that they did not reach such a conclusion during the morning of March 28.

After Porter returned to the control room to brief Miller on the first four or five readings, the instrument technicians took a separate instrument called a digital voltmeter (which can be used to give voltage readings from incoming wires without detaching the wires and hooking them up to the meter itself) and used it to record voltage readings for at least 40 of the approximately 50 thermocouples. Using tables, these voltage readings could be extrapolated to give temperature readings. The voltage readings indicated that about 18 of the thermocouple leads showed temperatures above 1500°F scattered throughout the core in no particularly discernible pattern. Others were inexplicably low, in the 200° and 300°F range. These voltage readings were handwritten in a computer book by Bennett. The instrument technicians and foremen then returned to the control room where Bennett set the book on a console and left it there.[41,42]

These additional readings might have tended to confirm the validity of the higher temperature indications. However, Porter has testified that he did not look at them, and did not become aware of them until much later.[43] Porter testified that he probably knew that the instrument technicians were going to continue to take readings with a millivoltmeter, but he did not believe they were going to get useful information, and did not look in the computer book to see what they had come up with.[43,44]

Shortly thereafter, all of the other men involved, including Bennett and the instrument technicians, evacuated Unit 2 when increasing radiation levels in the control room caused a general order for nonessential personnel to leave the area.

One other issue concerning these readings has been the subject of some prior comment. Two of the four technicians and foreman present when the first readings were taken recalled in interviews by IE investigators that a few sets of wires indicated temperatures higher than 2100° to 2300°F. Wright told the IE investigators that when the technicians first started to take a complete set of readings with the millivoltmeter, one or two were up around 75 millivolts, corresponding to 4000°F.[45] Yeager recalled that at the very beginning, before Porter arrived, a number of preliminary readings were taken with the millivoltmeter and that the range was from about 690° up to 3700° or 4000°F.[46]

Porter consistently maintained that he was not told of any readings above about 2300°F, which is the number he related to Miller.[47] Such readings would have been spurious, since the chromel-alumel alloy of which the thermocouples are constructed melts at about 2700°F. (In subsequent days and weeks, almost all of the thermocouples recorded readings indicating that they were functional.)[48]

Porter pointed out in the deposition conducted with him by the SIG, that the conversion charts for millivolts to temperature stop at the voltage corresponding to 2500°F, and that a further straightline correlation would not necessarily be accurate, so that it is unlikely that an instrument technician could compute a 3700°F reading; and that a test he conducted of the Fluke digital instrument that reads out directly in degrees showed that it stops recording and starts "blinking" above 2462°F.[49]

Perhaps more significant, the pages from the computer book in which the complete set of millivolt readings were entered does not show any such high readings. Indeed, the highest is about 56 mV, corresponding roughly to 2580°F. Thus, no readings of 3700° to 4000°F were recorded when a comprehensive reading of all the terminals was conducted after Porter left for the control room.

The significance of the difference between 2300° and 3700°F appears to be that if the temperature in the core were in fact the higher number, one would know that the core was probably actually melting down. Porter's response and the response of others to this suggestion has been that since such a reading, in millivolts or on a Fluke digital reader, could not possibly have been regarded as reliable in any way, it would have been an even less significant indicator of trouble than a 2300° or 2500°F reading.

In the final analysis, we do not believe that the issue is a meaningful one. It is possible that initial millivoltmeter readings of about 75 mV were obtained, but it seems unlikely that they were communicated to Porter; if they were, it appears he discounted them out of hand. The important point is that even the 2300°F readings everyone acknowledges were obtained would have been enough to suggest a severely overheated core, if they had been believed. Porter's testimony was that he did not believe them, and so reported to Miller. Miller corroborates that account.

Did Porter or Miller have an affirmative obligation to report these readings to the NRC on the 28th? It would appear that if either man had such an obligation it was probably Miller: Porter had, after all, reported the information he had gleaned to the station manager and received no further instructions. Miller, on the other hand, has said that what he learned from Porter, together with his knowledge that these instruments were not "qualified" to withstand abnormal conditions, convinced him that he should not place any faith in the readings and that he thereafter gave them little thought:

> In other words, the unreliability part of it, my lack of usage or training in them didn't make them something that I needed. They weren't recognized anywhere other than in my mind from past experience. I just think that all came together in my mind to cause me not to go back and ask a lot of questions that I could ask today quite honestly. I think that combined with the number of events I was involved in in that next three to four hours caused me not to go back and ask some more questions and put a different emphasis on the readings.[50]

Miller's own testimony under oath, therefore, if taken at face value, rebuts any inferences of willful withholding of information. Moreover, Miller's testimony is substantially corroborated by Porter's testimony.

Miller probably informed his superior, Jack Herbein, of the thermocouple readings, at least in a general way, sometime in the late morning of the 28th after Herbein arrived at the Observation Center across the river from the island. Herbein testified that he believed he had been told that readings had been taken and high numbers obtained, but that these were discounted.[51] Herbein's testimony, therefore, further corroborates Miller's account.

Herbein himself, significantly, was not directly in contact with the NRC on the 28th. Moreover, at about the same time he arrived at the site, NRC inspectors were going on site into each control room and manning direct telephone lines from the control rooms to NRC Region I's Incident Response Center. Thus, between Miller and Herbein, it is reasonable to postulate that any direct responsibility for reporting critical plant information to the NRC evolved upon the former, rather than the latter.

Information that the incore thermocouples were off scale on the high end was apparently available to NRC inspectors in the Unit 2 control room, but probably was not transmitted to NRC Headquarters until at least midafternoon on the 28th. Even then, apparently, the very high numbers measured by the technicians that morning were not transmitted—even though the information was sitting in a computer book on one of the control room consoles.

Incident Response Center tapes indicate that NRC Headquarters asked for readings from the "thermocouples on the fuel assembly outlet" probably in the late morning.[52] During another conversation in midafternoon with the Unit 1 control room, an NRC employee noted that the information had been requested previously, "and I don't know if we ever got an answer back."[53] Greg Hitz, a Met Ed shift supervisor in the Unit 1 control room, is recorded on the tape as agreeing to try to get the information. Shortly after, Hitz reported that he could not get exact numbers because the computer was printing out question marks.[54]

Hitz recalled the following in a deposition taken by the Special Inquiry Group:

> The large range or spectrum in temperatures they looked at the in-core temperatures which ranged from 60 degrees to 1400 degrees. You look at that whole thing and say do I really believe this or not? ... I don't think that I paid particular attention to the in-cores because of what I was involved with. I would take the number and run it in and say they are reading this or that. I may have looked at the in-cores ...[55]

Victor Stello, in the Incident Response Center at Bethesda, recalled in deposition testimony "struggling" to try to get information about the incore thermocouple readings.[56] Stello has also testified that he recalled learning at some time on Wednesday that "the in-core thermocouples were reading question marks, which means they were reading off the range of high scale." Stello testified that he recognized that the thermocouples were therefore "broken" or that they were reading temperatures above 700°F.[57]

Miller, who had been gone from the control room between about 2:00 and 4:30 p.m. to brief the Lieutenant Governor at the Capitol in Harrisburg, had not conveyed the earlier high instrument readings on the incore thermocouples to others in the Unit 2 control room with whom Greg Hitz, in Unit 1, was communicating to get information being requested by NRC officials in Bethesda. There is no indication that NRC inspectors in Unit 2, who were in contact with Region 1's Incident Response Center throughout much of the afternoon, were specifically requested by their management to obtain this information.[58]

Significantly, Stello was able to conclude from the elevated hot-leg temperatures alone, that the reactor was probably in a serious condition involving bulk boiling in the core and possible core uncovery, as tapes of another conversation he had with Hitz about 4:00 p.m. that afternoon reveal. Porter's testimony that he too was primarily concerned about the high hot-leg temperatures suggests a similar attitude on his part. In other words, the fact that superheated steam bubbles had continued to exist in the hot legs for many hours should have been sufficient, by itself, to reveal that the core was extremely hot and might be partially uncovered. Nonetheless, the fact that incore thermocouple temperatures above 2000°F had been measured earlier that morning (if believed and accurately reported) would clearly have been corroborative of the serious nature of the accident.

In sum, the evidence indicates that only some of the actual readings taken by instrument technicians between 8:00 and 9:00 a.m. that morning were actually communicated to their supervisor, the instrumentation control foreman; and that neither he, the station manager to whom he reported the readings he had learned about, nor the vice president of Met Ed credited the readings as being accurate. It is not clear that any of the actual readings were communicated to the NRC on March 28, despite requests for such information, although the general range of readings may have been transmitted. Clearly, however, NRC officials in Bethesda learned some time in the afternoon of March 28 that the readings were off-scale high, that is, above 700°F, which was in itself significant information. Even this information, however, was delayed in transmission to the NRC.

Although it seems obvious that reporting of accurate information about the early morning readings would have given significant corroborative evidence about the seriousness of the accident, no evidence indicates that failure to report those readings was willful or was part of any attempt to hide the condition of the reactor or the seriousness of the accident from the NRC.

d. The Pressure Spike

At about 1:50 p.m. on Wednesday, March 28, 1979, a control room instrument that displays reactor containment building pressure indicated a sudden, short-lived but dramatic pressure increase in the reactor building. As an operator and at least two supervisors standing at the consoles watched, the pen-recorder on the instrument—which traces the level of building pressure on a slowly moving drum of graph paper with a scale from 0 to 80 pounds per square inch gauge (psig)—jumped almost straight up to about 28 psig then slowly fell back over the next 15 seconds to about 4 psig. At the same time, a sodium hydroxide "sprinkler" system in the reactor building that is triggered automatically (when containment pressure reaches a nominal pressure of 30 psig) came on. Several individuals in the control room heard a sound they later described as "thud."

At the time, little attention apparently was paid to this "pressure spike." Because the volume of the containment building is so large, many of those in the control room evidently could imagine no credible phenomenon that would have produced such a large pressure increase in so short a time. Some wrote off the instrument reading in their minds as having probably been caused by a stray electrical pulse or "transient" in the electrical wiring, rather than by an actual pressure surge in the reactor building.

When company employees examined the graph of the pressure spike late Thursday night in the light of evidence that had been collected earlier that day (including a reactor coolant sample that showed massive amounts of radioactive material in the coolant water), they realized that an explosion of flammable hydrogen gas must have taken place in the reactor building Wednesday afternoon.[59,60]

Key GPU officials and NRC personnel learned of the spike and its significance early Friday morning. The large amounts of hydrogen necessary to support such an explosion or "burn" could only have come from chemical decomposition at very high temperatures of a substantial amount of the reactor "cladding"—the protective outer sheathing of the fuel elements that surrounds and encloses the uranium fuel pellets. The cladding is made of a metal called Zircaloy-4, an alloy containing about 96% zirconium, which reacts rapidly with steam at temperatures above 2200°F to produce hydrogen gas. The gas, in turn, escaped from the reactor coolant system into the reactor building through the stuck-open PORV when the block valve behind the PORV was periodically opened to relieve overpressure in the reactor coolant system Wednesday morning, and again after 11:30 a.m. when the block valve was opened for long periods of time to depressurize the system.

Had the pressure spike been recognized as a hydrogen explosion early Wednesday afternoon, it would clearly have demonstrated that the reactor core was uncovered or had been uncovered for a long period of time. Moreover, the fact that temperatures high enough to produce zirconium-water reaction had been sustained in the reactor core for sufficiently long to create the amount of hydrogen necessary to cause such an explosion would have signalled that the core had been very close to a possible meltdown or had indeed experienced significant melting.

The fact that neither the existence of the spike nor its significance came to the attention of responsible NRC officials until Friday morning has raised the question whether Met Ed personnel intentionally withheld important information from the NRC that would have demonstrated that the accident was much more serious than was generally thought on Wednesday and Thursday. The evidence relative to this matter, including testimony which in some respects is inconsistent, follows.

When the pressure spike occurred, Station Manager Miller was in charge of the control room. At that time, Miller was preparing to leave Three Mile Island to brief Lt. Gov. Scranton at the Capitol in Harrisburg, approximately 25 minutes away by car. Miller would be accompanied by George Kunder, the Superintendent of Technical Support for Unit 2, who was also in or near the control room at 1:50 p.m. Miller's "deputy" in the control room (whom he left in charge of the plant when he departed for Harrisburg a few minutes later) was Joe Logan, the Superintendent for Unit 2.[61] Also in the control room area were at least three shift supervisors: Bill Zewe, who had been on shift at 4:00 a.m. when the accident began and remained throughout the day; Brian Mehler, who had arrived at about 6:00 a.m. in anticipation of taking over the normal 7:00 a.m. shift; and Joe Chwastyk, who had assumed responsibility for transmitting operating instructions to the control room operators at about 11:00 a.m. that morning, and was therefore directly "in charge" of the control room consoles. Also in the control room area were Mike Ross, the Supervisor of Operations for Unit 1, who was in charge of operations at the control room (Joe Logan was relatively the least experienced in the operating characteristics of the Unit, among the "management group" present)[62] and Lee Rogers, the B&W site representative. Logan, Ross, and Rogers had been present since early that morning.

Zewe has testified that he was standing directly behind the instrument panel, that he saw the spike "first," and that "everybody there" saw the spike. He recalls discussing with others, among them Ross and Chwastyk, what could have caused the spike and whether the instrument had registered an actual pressure excursion in the building or had malfunctioned. He recalls specifically some discussion of whether a stray electrical impulse in the circuitry might have caused the instrument indication. "Nobody," he recalled, "had good answers," and it was eventually concluded that an electrical transient in the circuit rather than actual pressure increase must have caused the pen-recorder's movement.[63] Zewe also recalls observing that the sodium hydroxide spray activated and shortly thereafter was ordered turned off when it became clear that the pressure increase, if any, had subsided. Significantly, Zewe does not recall discussing the pressure spike with, or even mentioning its existence to Gary Miller.[64]

Zewe's testimony is corroborated by Mike Ross, who testified that although he did not personally observe the spike as it occurred, his attention was called to it by a report that the building spray pumps had gone on.[65] Ross recalls discussing the spike with Zewe and concluding that it had been caused by an electrical spike in the circuitry, not by an actual pressure increase in the building.[66] Ross recalled the following:

> There were many people there, and it was common knowledge that it happened, but I don't think anybody ever sat down and analyzed it at the time ... I think we reached a hurried conclusion saying that we thought the spike was caused by either a malfunction of some kind, and we just went on taking care of business ...[67]

John Flint, a B&W engineer who had also been in the control room since early morning (and who, incidentally, testified in a deposition before the President's Commission that he personally had concluded in midmorning that the core had been uncovered),[68] said in an interview with a Met Ed investigator on April 20, 1979, that he was aware of the high pressure indication and the spray pump actuation, "and about the same time there was a double thud." Flint also stated the following:

> I personally did not think it was from the reactor containment building. I thought that it was the ventilation dampers cycling. It was very close to that sound, and since we had been in and out of respirators due to the levels in the control building, I just thought somebody had cycled the ventilation dampers again and related it to that.[69]

Joe Chwastyk, who was in the control room along with Zewe and observed the pressure spike as it occurred, also recalls that there was a "lot of conversation" about the spike and that "it immediately came to mind that we had some kind of instrument problem."[70] However, unlike the others, Chwastyk soon concluded that the spike could not have been caused by a stray electrical pulse because the spray pumps had come on and "there are two different pressure instruments used, one for the recorder and one for starting the pumps."[71] In other words, the fact that the reactor building spray pumps had been activated confirmed that an independent instrument had also detected a pressure surge in the reactor building.

Brian Mehler remembers coming out of the shift supervisor's office when he saw activity in the control room indicating that "an ES" (an activation of safety systems) had occurred, and observing the pressure spike trace. He too first "thought it could have been an electrical thing. But then looking at the spray pumps, I realized it couldn't have been."[72]

In fact, as Mehler recalls explaining to an NRC inspector who was present, the reason the actuation of the spray pumps tended to rule out an electrical transient as the cause of the pressure spike was essentially the same reason suggested by Chwastyk in his deposition. Mehler recognized that it was the "coincident logic" arrangement of the circuitry for the spray pump system that made such a possibility highly unlikely. There are three sensors in the reactor building that record building pressure. To reduce the possibility that the spray pumps will come on simply because one sensor malfunctions (thereby necessitating a time-consuming cleanup of the building), the logic circuitry for the spray pump system requires that at least two of the three sensors simultaneously record a pressure increase to 30 psi or above. Because the sensors are connected to the logic circuit by independent wiring, an electrical transient in the wiring leading to only one of the sensors (which might cause the control room instrument to record a spurious spike) would not activate the spray pumps; only a real increase in building pressure could conceivably have such an effect.

Strangely enough, others in the control room area have testified that while they too heard the "thud" described by Flint, they did not even become aware of the existence of a spike or the activation of the spray pumps on Wednesday. Gary Miller, the Station Manager, has consistently given statements and testimony that he heard a "loud deep noise" while standing in the control room shortly before he left for the Capitol, but that he does not believe he knew on that day either that there had been a spike in the building pressure instrumentation or that the spray pumps had activated.[73-77] Joe Logan gave similar testimony.[78]

Lee Rogers has also testified that he heard a noise and heard conversation or was told that the noise was probably caused by ventilation dampers in the control room ventilation system slamming shut.[79] (Miller has also testified that he recalls hearing someone comment that the noise might be the ventilation system.) Rogers also denies knowing either of the pressure spike or the spray pumps coming on.

George Kunder, who accompanied Miller to Harrisburg, does not recall hearing a noise or knowing on Wednesday of the pressure spike or the activation of the spray pumps.[80]

Immediately after the pressure spike, Joe Chwastyk recalls "a lot of conversation with just about everybody in the control room" about whether "anybody knew what was happening, because I didn't at the time."[81] Nor did Mehler immediately recognize what happened. But Mehler recalls that shortly thereafter, perhaps 10 minutes to an hour later, he and Chwastyk talked the matter over and realized that there might have been an explosion.[82,83] Chwastyk does not specifically recall the conversation with Mehler, but acknowledges it is quite possible that such a conversation occurred.[84] According to Chwastyk's recollection, some time after the event he began to ponder its significance and "it just flashed through [his] mind" that one of the control room foremen, Fred Scheimann, had manipulated a valve at precisely the same time that the pressure spike occurred. What Chwastyk realized was that if the valve position had been changed by the operation of a DC (direct current) motor in the containment building, the motor might have created a spark that could have detonated any flammable gas present. "And I think it was after someone related to me also the noise they had heard that I assumed then it was some sort of hydrogen explosion."[85]

Chwastyk himself "assumed it was hydrogen" that must have caused any explosion in the reactor building, admitting in testimony before us that he knew of nothing else that might have exploded.[86] Mehler has testified that he does not recall the possibility of hydrogen having come up in his conversation with Chwastyk that afternoon. He remembers thinking only that it might have been a "chemical reaction."[82,87] As Mehler recalls, he does not believe he considered hydrogen to have been the cause because he "didn't think hydrogen could form that quick in the building to that concentration in that period of time."[83] Mehler testified that the possibility of hydrogen never entered his mind until he read it in the news media.[88]

There is no question that after thinking the matter over, both men became quite concerned. Mehler recalls being "really a little scared."[89] As Chwastyk puts it, "It scared the hell out of me . . ."[90]

Therefore, at least two supervisors in the control room realized sometime shortly after the event that there had been an actual pressure excursion in the reactor building and that it had probably been caused by an explosion, and both were alarmed by their conclusions. Chwastyk agreed in testimony before us that his conclusion certainly "changed [his] view of how serious the situation had been up to then."[85] Whether their conclusions were communicated to anyone else in the control room on Wednesday, in particular to their superiors, is much less clear.

Mehler recalls that "we did inform the people in the [shift supervisor's] office that we did have the pressure spike, and just about everyone in the control room knew it."[91] He has testified that he believed both Ross and Miller were "in there," and that it is his recollection that both were informed that the spike indicated an actual pressure increase.[92] However, Mehler does not recall a discussion with anyone other than Chwastyk about the possibility of a "chemical reaction," although according to Mehler, he and Chwastyk did not discuss whether they should keep that possibility quiet.[91]

Chwastyk, who apparently considered the possibility of a hydrogen explosion more concretely than Mehler, testified that he could not be certain he related this possibility to Miller, but his best recollection was that he had done so, even though he does not specifically recall that hydrogen was mentioned.[92] Chwastyk definitely recalls that upon realizing that an explosion may have occurred, he sought Miller's permission to begin to try to redraw the "bubble in the pressurizer."[85,93] In an unsworn but transcribed interview with Chwastyk on October 11, 1979, he related at one point that during this request he had explained to Miller what he thought had happened with an explosion.[93] Later in the interview, Chwastyk said that he was "pretty sure" he told Miller about the explosion, but he was not sure he could swear to it:

> That's what I thought. Most definitely I did think that [an explosion had probably occurred]. Now, whether or not I related that to Gary then, now that I think about it, I don't really remember. I may have just gone back to Gary and asked permission again to redraw the bubble. I just can't remember if I related to him my thoughts at the time of the correlation of pressure spike in the operation of the valve.[94]

In a sworn deposition on October 30, when pressed on the issue, Chwastyk testified the following:

> My best recollection of that is that I did relate to Gary that we had some sort of an explosion. Whether I said it was hydrogen or not, I'm not sure. But I remember distinctly putting together the operation of the valve and the spike, and I think I related those thoughts to Gary.[95]

A few minutes later in the deposition, however, when it was pointed out to him that Miller's best recollection was that he had not learned of such an explosion until Friday morning, Chwastyk testified, "that could very well be true. Again, I can't absolutely—if Gary said—I may not have told him what I thought at the time, because I really wasn't certain."[96]

Asked whether he recalled talking with anyone in the control room on Wednesday, in addition to Miller, about his fear that a hydrogen explosion might have taken place, Chwastyk testified that he "probably" discussed it with Mehler, and felt "sure" he had discussed it with other individuals, but could not recall specifically anyone else with whom he might have discussed it, other than an inspector from the NRC.[97]

In spite of Chwastyk's testimony, neither our investigation nor any of the other investigatory groups to whose depositions and interview memoranda we have had partial or complete access[98] has been able to identify any Met Ed or B&W personnel who, on March 28, were told of or made the connection themselves between the pressure spike and the closing of a valve, or who considered it a possibility that the pressure spike represented an actual explosion. As pointed out, neither Miller, Kunder, Logan, nor Rogers has admitted that they even knew that there had been a pressure spike. Ross, Flint, and Zewe all remember knowing of the spike and the activation of the spray pumps, but did not conclude that the spike reflected an actual pressure surge nor did they conceive that an explosion could have occurred. Furthermore, an entry in the control room operator log book for the afternoon of March 28 notes that at 1:50 p.m. an engineered safeguards initiation signal was received, the reactor building sprays came on, and the reactor building pressure spiked up to 4 psi.

With respect to the question of Miller's knowledge, both Chwastyk and Mehler, as noted, believe that Miller was informed of the pressure spike, but Miller insists he did not learn of it until Friday. Ross, in a deposition conducted by the SIG on September 18, 1979, testified that both he and Miller were in the control room when the spray pump actuation and pressure spike were reported and that:

> We, being Miller, I and the group, looked back and said, guess we just felt that it was either one: something we just didn't understand, and we didn't associate it with anything else and we just went on.[99]

Ross seemed to think this had occurred after Miller returned from Harrisburg (which would have been after 4:30 p.m., several hours later). As he recalled, Zewe reported the spike to him, and "we came to the conclusion, be it right or wrong, that it was an electrical spike of some kind and not a pressure spike in the building."

Pressed in a later deposition taken on October 30, Ross said that his recollection about having any conversation with Miller on this subject was "a little vague," but he did remember being in the control room with Miller looking at some other instruments, the operators reporting that the building spray had come on, and Miller saying the following:

> Did you hear that, or did you feel that? Something to that effect. I'm not sure what that was. And we

just kind of went right by it. We looked at it and we told Gary, it's not time to get nervous now. We're going to have to go from where we are. And that's what we did.[100]

Ross further explained that his reference to getting "nervous" was that he thought perhaps Miller was "hearing things" or "imagining things." Ross did not recall if Miller actually looked at the pressure spike on the chart, and he does not recall any further discussion of the matter with Miller later in the afternoon when Miller returned from Harrisburg.[100]

In previous statements and testimony, Miller has been quite consistent in his account of when he first learned of the pressure spike and the diagnosis of a possible hydrogen explosion.[73-76] Confronted with the testimony of Chwastyk, Mehler, and Ross in a deposition on October 29, Miller continued to maintain that he did not learn of the pressure spike on March 28. Nor, he said, did he recall either a request from Chwastyk that afternoon to try to redraw a bubble in the pressurizer, or approving such a step in a conversation with Chwastyk.[101]

Furthermore, Miller has pointed out to us in the course of the investigation that he had absolutely no reason to conceal or cause anyone else to conceal this information had he known it on Wednesday. And he testified under oath that at no time did he withhold significant information of any kind or instruct anyone else in the control room to withhold such information from the NRC inspectors in the control room or from the NRC itself.[102]

Miller's April 1979 written statement, prepared for presentation to various congressional subcommittees and NRC's IE investigators, arose out of a joint effort to reconstruct the events of the first day of the accident by a number of individuals who were in the Unit 2 control room on March 28. After the accident, these individuals collegially attempted to create a reliable chronology of events. Miller has pointed out that those discussions were taped and that the tape would provide a more reliable indication of what various individuals knew or did not know the first day of the accident than their recollections today. He had also pointed out that during those conversations none of the individuals present recalled learning of a hydrogen burn or explosion the first day. We have reviewed a tape recording provided to us by Met Ed of this conversation, and it is consistent with Miller's testimony. The tape (side 1, about 10 minutes in) indicates that Miller recalled hearing a noise and turning to another individual to ask what it was. The tape suggests that Miller may have heard about the spray system going on at about 5:00 p.m., when he returned from the Capitol, but does not make clear whether that information was linked with the pressure spike.

According to Miller's recollection, he first learned that there had been a "hydrogen burn" from Met Ed consultant, Bill Lowe, when Miller came into work on Friday morning, March 30. He recalls that Lowe spoke to him about the pressure spike and diagnosis of it, and that Ivan Porter, the lead Instrumentation Control Engineer for Unit 2, showed him a graph of the spike on that same morning.[59,103]

Porter, who tends to corroborate Miller's account, testified in a deposition conducted by the SIG that he probably first learned of the pressure spike on the morning of the 30th, and that Gary Miller asked him to look at the charts and see if Porter thought they showed a "real valid indication versus, say, a malfunction of that pressure recorder the instrument supplied or whatever."[104] Porter undertook this assignment by looking at the strip charts for reactor coolant system pressure, which is measured relative to reactor containment building pressure. Observing that the graph for coolant system pressure decreased slightly for a short time at 1:50 p.m. (indicating a rise in building or reference level pressure), Porter concluded that the pressure spike had been a reliable indicator of building pressure, and communicated this information to Miller. Porter stated the following:

My impression was, I think he had just learned of it, and wanted me to look at the charts and stuff involved and tell him what I saw. I don't know, but I felt it was like somebody just told him, you guys had a hydrogen explosion, and he wanted me to take a look at the charts and stuff and tell him what I could find out from them.[104]

In this connection it may be significant that both Chwastyk and Mehler recall that they did not really figure out that the pressure spike might have been caused by an explosion until sometime after the event. Miller recalls that it was perhaps 30 minutes after he heard the noise that afternoon that he departed for Harrisburg. But State logs show that Miller, Kunder, and Herbein arrived at the Lieutenant Governor's office at 2:30 p.m., and Herbein's own records show his departure from the Observation Center across the river from Three Mile Island at 1:55 p.m. It is probably very close to a ½-hour trip from the plant and into Harrisburg, so Miller must have been virtually on his way out of the control room at the time the pressure spike occurred.

The timing of Chwastyk's request to Miller to "redraw the bubble" in the pressurizer is therefore rather puzzling. According to Chwastyk he spoke to Miller after he had connected in his own mind the pressure spike and the valve operation. However, this conversation would probably have been after Miller left the control room. Such a conversation could have been held after Miller returned at 4:30 to

5:00 p.m., but charts of various system parameters, including pressurizer level, suggest that Chwastyk may have begun to try to redraw a bubble beginning around 2:00 p.m. that afternoon; his account of his attempt to manipulate pressurizer level fits with the observed parameters in a number of respects. On the other hand, Ross (Chwastyk's superior after Miller left the control room, from 2:00 until 4:30 p.m.) testified that he recalls no attempt during this entire time to redraw a bubble in the pressurizer.[105]

Did anyone, then, other than Chwastyk, clearly realize on March 28 that a hydrogen explosion may have occurred? At one point in our investigation it appeared that some light might be shed on this question by testimony that an order had been given on Wednesday not to start any electric equipment in the reactor building for fear of the consequences of a spark. In an unsworn but transcribed interview on October 11, Mehler recalled that although he had not connected the pressure spike and simultaneous operation of a valve at 1:50 p.m., somebody else obviously had. Later that afternoon he was told not to start oil lift pumps that must be run before the main reactor coolant pump can be started: "not to do anything that could give an ignition."[83] Mehler recalled responding to Miller that he had already tested these pumps and they were ready to go.[10]

In a sworn deposition with Mehler several weeks later, he recalled that the instruction was "given in the shift supervisor's office not to start anything electrical...there were other people in the room. They would have been aware of the instructions. I believe the instruction came from Gary Miller." Mehler recalls telling Miller that he had already started the pumps, and recalls the comment being made, "Well, then I don't think we have anything left in the building." Mehler thinks it was somebody else, not himself, who made that comment.[107]

At the October 11 interview, Mehler was quite certain that the instruction not to start electrical equipment had been issued on March 28, prior to the attempt to restart one of the main reactor coolant pumps Wednesday evening:

> I can say for a fact and will go under oath and I will take a lie detector test, prior to running the reactor core (sic) pump, someone did tell us not to start anything and I remember telling Gary, it's too late now, I have already started them.[108]

However, by the time of the October 30 sworn deposition, he had become quite unsure of his recollection as to which day he received the orders.[109] In the deposition, Mehler testified that he believed the orders probably occurred either on Thursday, March 29, when he was also in the control room from about 1:00 p.m. until about 11:00 p.m., or on Friday, March 30.[110]

Why the change in recollection? Mehler testified that between October 11 and 30, he had talked with others who had been in the control room on March 28 (Miller, Ross, Zewe, and Chwastyk), and that none of them recalled the instructions having been given that day. Some, however, had told him they remembered such an instruction being given after March 28. Therefore, Mehler concluded that he must have been mistaken. Mehler acknowledged that his "own recollection, faulty or not, standing alone, has been that it was the 28th," but stated that it "seems funny, if I would be the only one that remembered it happening on the 28th when there were people in the room that don't remember it."[110]

Chwastyk also recalled the instruction not to start electrical equipment in the reactor building because of the spark potential, and that someone had just started the oil lift pumps. Chwastyk testified that he did not believe this could have happened on March 28, because he recalled the instruction having been given while he was physically present in the shift supervisor's office and he did not recall having been in that office at all on March 28.[111]

No other witnesses recalled such an instruction having been given on Wednesday, March 28. Control room operator Theodore Illjes stated in an NRC investigation report that the hydrogen explosion was discussed in the control room on the 28th. The NRC found that Illjes was apparently mistaken and that the discussion occurred on the 29th.[60] Our review of the evidence indicated that the NRC investigator's conclusion was correct. Additionally, William Lowe of Pickard, Garrick & Lowe, consultants to Met Ed, recalled in a SIG interview that the recorder trace showing the pressure spike was brought to him after 9:00 p.m. on March 29, and that he then notified Met Ed, GPU, and B&W personnel.[59]

The only contemporaneous documents that might shed light on when such an instruction was given are the control room log book and a set of notes taken throughout the first few days of the accident by two Met Ed employees, Don Barry and Walter "Bubba" Marshall, neither of whom is a licensed reactor operator. The notes, which are extremely sketchy for March 28, do not record such an instruction on any day. The control room log book contains an entry at 9:14 p.m. on Thursday the 29th: "Placed RCP lift pumps in off (minimize sparking potential in reactor building)."

Thus, an instruction not to start electrical equipment in the reactor building on account of an awareness of a potential hydrogen explosion apparently was issued shortly after 9:00 p.m. on Thursday. The log entry does not, however, necessarily reflect an awareness of the earlier explosion on Wednesday afternoon. Fear of the possibility of significant hydrogen in the reactor building due to fuel cladding failure could have given rise to such an order by Thursday night, even without knowledge or appreciation of the earlier pressure spike, because by that time the existence of a possible hydrogen "bubble" was beginning to be postulated.

Mehler recalls that it was Miller who gave the order; however, Miller's best recollection is that he was not in the control room at 9:15 p.m. on Thursday evening when the instruction was given.[112] In any event, Miller does not recall having given such an instruction at any time.

Mehler's recollection that the instruction not to start electrical equipment was given on March 28, was keyed to his recollection that it came just after he had started oil lift pumps for a reactor coolant pump. Mehler originally believed that this happened Wednesday because at that time the reactor coolant pumps were all off, and efforts were being made to restart at least one pump. No pumps were restarted on Thursday. However, preparations were apparently made Thursday or Friday to restart one of the nonoperating pumps in case the operating pump should for some reason trip off, and these preparations would require testing the oil lift pumps.

To summarize, only one person present in the control room on March 28—Chwastyk, the shift supervisor in charge of the consoles—has acknowledged that he realized the pressure surge was real, evaluated that in connection with a valve operation, and concluded that a hydrogen explosion had probably occurred in the reactor containment building. Others present either say they did not know of the pressure spike, or dismissed it as an electrical transient, except for Mehler, who feared that a chemical reaction had taken place but did not believe it was a hydrogen explosion (and therefore did not necessarily have a reason to believe that substantial core uncovering had occurred). Several say they heard a noise but believed it to have been the control room ventilation dampers cycling.

Chwastyk believes he related his conclusion to Miller, but is not certain that he did. Miller does not recall being aware of the pressure spike or the spray pumps coming on. Others testified that Miller probably was informed of these events. It may be significant that Kunder, who accompanied Miller to Harrisburg shortly thereafter, and a number of others in the control room have also testified that they were not aware of the spike.

According to documents tending to establish the time Miller and Kunder left for Harrisburg, Miller evidently departed the control room before Mehler and Chwastyk discussed the pressure spike among themselves and realized that there might have been an explosion. Thus, if Chwastyk related his conclusions to Miller, this would have occurred after Miller returned at about 4:30 or 5:00 p.m., at the time when Miller was instructed by Herbein to repressurize the system. However, such a supposition is inconsistent with Chwastyk's testimony that he recalls getting permission from Miller to redraw a bubble in the pressurizer, and with the charts showing that such efforts may have been made around 2:00 p.m. Neither Miller nor Ross, however, recalls any attempts being made to redraw a bubble during the afternoon.

Except for Chwastyk's testimony, no other evidence indicates that anyone in the control room realized on March 28 that there might have been a hydrogen explosion in the reactor building, or that Miller was aware of such a possibility. No evidence suggests that Met Ed management officials in the Observation Center or GPUSC officials in New Jersey were informed either about the pressure spike or about the possibility of any explosion. No evidence, either documents or testimony, establishes that NRC employees either at Region I Headquarters in King of Prussia, Pa., or in Washington were aware on Wednesday of the pressure spike or of the possibility that large amounts of hydrogen had probably been generated during the first 10 hours of the accident.

At the time the pressure spike occurred, at least two of the five NRC inspectors that had arrived at about 10:30 a.m., were in the area of the Unit 2 control room. They were James Higgins, a Reactor Operations Inspector, and Don Neely, a Health Physics expert. Two other inspectors who had come onto Three Mile Island, Charles Gallina and Ronald Nimitz, had gone to the Unit 1 control room. The fifth inspector, Karl Plumlee, was performing radiation surveys outside of the plant buildings. A second team, composed of an inspector and an investigator from Region I, Walter Baunack and Raymond Smith, arrived at TMI around noon, but did not get to the Unit 2 control room until approximately 3:00 p.m. or later.[113,114]

In sworn depositions, neither Higgins nor Neely recalled having been made aware of the pressure spike.[115,116] Higgins kept a spiral notebook of information to pass back to Region I, which had a direct open line to the Unit 2 control room during most of the afternoon, but his notes neither reflect the pressure spike or a possible pressure excursion in the reactor building, nor the actuation of the spray pump system. Nor have we discovered anyone at Region I or NRC Headquarters who recalls being made aware of the spike or the possibility that an explosion might have occurred.

However, quite a number of others in the control room recall that an inspector was standing in the control room and was in a position to observe the pressure spike directly and the ensuing response to it by control room operators and supervisors. For example, Zewe recalled that an NRC inspector was standing directly behind him when the spike occurred.[117]

The most specific testimony relating to this question was given by Mehler. Mehler recalls that when he came out of the shift supervisor's office, an NRC inspector followed him out of the office and "was behind us" when Mehler instructed the spray pumps turned off.[118] The inspector, according to Mehler, asked why he had given such an instruction, and Mehler explained to him that there had been a pressure spike but that the pressure had gone down, and that Mehler did not know what had caused the pressure increase. Mehler specifically recalls explaining to the inspector the coincident two-of-three logic of the spray pump system. According to Mehler's testimony, the inspector did not seem to understand what had happened, and did not make any further inquiry about it.[119]

Mehler could not identify the inspector, but testified that the individual was not Neely, whom he knows from the TMI postaccident recovery effort. He described the inspector as being medium height, with dark hair and a little gray around the sideburns, aged perhaps 30.[120] Mehler's description does not fit James Higgins, who is a tall (well over 6 feet), thin man in his midthirties. According to Mehler, he recalls that the individual he talked to was wearing a white hard-hat with "U.S. NRC" emblazoned on it, also suggesting that perhaps the inspector had only recently entered the control room from elsewhere in the plant. (Mehler testified that the only NRC inspector in the control room on the 28th whom he recognized was Donald Haverkamp, the Project Inspector for TMI.[121] Haverkamp was, in fact, in King of Prussia, Pa., on Wednesday and did not arrive at TMI until Thursday, March 29.)

Chwastyk also recalls that "there was an NRC inspector...standing behind Mehler when we shut down the spray pumps."[122] Chwastyk's recollection is that the individual was about Mehler's height (Mehler is about 5 feet, 8 inches tall), but somewhat heavier. Chwastyk did not know the names of any of the NRC personnel in the control room March 28, and does not think he could identify the individual he saw standing behind Mehler if he saw him today. Nor does he recall whether Mehler had a conversation with the inspector.

More important, Chwastyk testified that he had "some recollection of talking to someone from the NRC" about his conclusion that there might have been an explosion in the reactor building.[123] Chwastyk does not recall whether it was the same inspector he observed standing behind Mehler when the spray pumps were turned off, but he does recall the following:

> Relating to someone from the NRC that I think we may have had an explosion in the building, but I wasn't sure. And that was about it, and I was probably a little curt because I had other things to do.[124]

Neither Higgins nor Neely recalls any such conversation, nor do Higgins' notes record such information. It appears that the only other possibility is that Ronald Nimitz, who was stationed in the Unit I control room, may have been in the Unit 2 control room at this time and may have talked to Chwastyk and Mehler about the pressure spike. Nimitz was definitely in and out of the Unit 2 control room during the afternoon, according to his recollection. He does not recall learning about either the pressure spike or the possibility of an explosion, nor do his notes reflect such information. Nimitz is not a reactor operations inspector, but he has had nuclear engineering and reactor operators training, and he testified in a deposition taken by the SIG that had he been informed of the spray pumps actuating, such information would have been very significant to him and he would have recalled it.[125]

When Chwastyk was pressed as to whether he told anyone else about his conclusion that there might have been an explosion in the reactor building, and as to why that fact did not seem to have been common knowledge until late Thursday or Friday morning, Chwastyk responded that he thought he had reported to Miller and the NRC inspector, and that he "must have talked to other people in the control room," including his counterparts who relieved him late that night. But he could not recall anyone specifically with whom he had talked. He did not recall discussing the matter with Kunder, and was not sure about Mike Ross.[126] Chwastyk denied that he, or he and Mehler, made any decision to hide the possibility that an explosion had occurred, but admitted that they "didn't just make it general knowledge to everybody in the control room."[90] As for the NRC inspector, Chwastyk conceded that "maybe I should have explained more [to him] but I just didn't have the time. At least I didn't feel I had the time."[127] He recalled that his primary concern was dealing with the reactor coolant system.

What conclusions can be drawn, then, from this evidence as to whether Met Ed personnel willfully withheld significant information from the NRC? No evidence indicated that company management off the island was aware of the pressure spike or the possibility that an explosion had occurred on Wednesday, March 28. The top official on site, Gary Miller, the Station Manager, has consistently testified that he did not become aware of the spike or the possibility that an explosion had occurred until Friday morning. Testimony from more than one witness indicates that Miller was aware of the pressure surge on Wednesday, but this testimony is less than clearcut; some other testimony tends to corroborate Miller's account.

Even if Miller knew of the pressure spike, possibly he dismissed it or failed to recognize its significance, because other supervisory employees who were in the control room and their coworkers did not believe that the spike actually reflected a pressure increase. Such an interpretation of the spike appears to have been technically deficient: at least two supervisors recognized that the actuation of the spray pumps probably compelled the conclusion that there had actually been a pressure excursion in the building. On the other hand, in the minds of most or all of those present in the control room, serious consideration of the possibility that a hydrogen explosion had occurred probably would have contradicted all the assumptions under which they were proceeding to try to cope with the accident.

Only Chwastyk's testimony made Miller aware that an explosion might actually have occurred. Such testimony might give rise to an inference that Miller withheld such information from the NRC except that Chwastyk is not certain that he did indeed tell Miller, and Chwastyk also testified that he himself informed an NRC inspector present of this possibility. Chwastyk also testified that he explained the pressure spike and its significance to the same or another NRC inspector right after the event.

There is no dispute that at least two NRC inspectors were on hand in the control room observing plant operations, and that no effort was being made to restrict their freedom to move about and ask any questions they wished to ask. The virtually unanimous testimony of Met Ed witnesses is that an NRC inspector was standing directly behind the console when the pressure spike occurred and the spray pumps went on, and was in a position not only to observe these events but also to hear the discussion among operators and supervisors about what had happened. However, none of the three NRC inspectors who may have known or been told about the spike and possibly about its consequences around midafternoon on the 28th presently recalls having been so informed. Chwastyk's recollection, on the other hand, is that the inspector to whom he spoke did not really seem to have understood what was happening. In any event, none of the inspectors reported the event to Region 1 or to Headquarters in Bethesda.

Of course, if Chwastyk had really told an NRC inspector that a hydrogen explosion might have just occurred, and explained what that meant to him, it is hard to believe any inspector, or anyone else, would have taken such information lightly. Chwastyk was, in a de facto if not official sense, the shift supervisor in charge of the control room consoles. It could be argued that his failure to inform and alert responsible NRC officials of his conclusions and their implications represented a willful withholding of information from the NRC, that merely informing an inspector in the control room should not have been enough. However, it might also be argued that control room personnel can hardly be expected to double as NRC employees in the middle of an emergency, and that as long as NRC inspectors are present observing everything that happens, there can seldom be a "conscious withholding" of information "from the NRC."

Perhaps most important, it does not appear to us that the legal requirements placed on reactor licensees to report significant safety-related information to the NRC were ever intended as a tool to compel effective flow of information to the NRC in the midst of an accident or disaster situation. If control room supervisors had consciously decided not to tell NRC inspectors on site a significant piece of information because they were afraid of the consequences of doing so, the legal requirements might well have applicability in this situation. We did not find evidence indicating that that occurred here. Moreover, it is unclear what motive Met Ed personnel would have had to hide such information from the NRC, when control room personnel were at the same time encouraging the NRC representatives present to provide any ideas that occurred to them to help cope with the unstable reactor.

Summary and Conclusion

The pressure spike was only one of a number of important indicators that were ignored, misinterpreted, or disbelieved on March 28 by control room personnel. Each of these pieces of information, if believed and understood, could have given a crucial clue to what was happening (or what had happened) during the accident. When viewed together, in hindsight, they should have afforded compelling evidence of core uncovery.

We failed to adduce evidence showing that any of this information was willfully concealed to hide the seriousness of the accident. Yet the pattern of failure to communicate critical information is clear. A number of factors other than deliberate attempts to downgrade the seriousness of the situation could account for this failure. These factors include the inability to recognize and comprehend the full significance of the information, and certain psychological factors: the difficulty of accepting a completely unexpected situation, the fear of believing that the situation is as bad as the instruments suggest, and a strong desire to focus on getting the reactor stable again rather than dwelling on how bad the accident is, if indeed the situation is dire.

The failure to recognize and act on significant data, in our view, demonstrates a lack of technical competency by site employees to diagnose and cope with this accident. But neither lack of such a capability nor the psychological factors mentioned above amount, in our view, to an intentional withholding of information. Moreover, NRC and B&W employees in the control room also did not recognize or communicate critical information. Their offsite organizations did no better, and perhaps worse, than the utility's offsite engineers at GPU in New Jersey in demanding reporting of important information and in recognizing the significance of that information which they did receive. The fact that NRC and B&W did no better than Met Ed or GPU in reporting critical information up the management chain and acting upon it, tends to support our conclusion that there is no evidence to show willful withholding of information by Met Ed from the NRC.

e. Findings and Recommendations

Findings

- The evidence fails to establish that Met Ed management or other personnel willfully withheld information from the NRC.
- Information conveyed by Met Ed, B&W, and NRC personnel from the control rooms to their managements and offsite organizations was in many cases incomplete and delayed. On several occasions, interpretations of plant status that were incorrect were provided by personnel in the control room when the mere provision of instrument readings would likely have been more definitive and could have led to an earlier realization of the true plant status.
- NRC personnel both in the control room and off site were unfamiliar with plant systems and some did not have a basic understanding of plant operations, both of which interfered with the flow of information.
- Communications from NRC offsite emergency response centers to the control room were undisciplined in that several personnel were allowed to request information, no priority was established to identify the more important information requests, no followup was provided to ensure that the requested information was obtained or at least acknowledged as not available, and various inquiries about reactor status were uncoordinated and not focused to the NRC communicator in the Unit 2 control room.
- NRC personnel in the Unit 2 control room were too few to permit independent gathering of operations data, to respond to information requests, and to provide continuity in the flow of information.
- Some information was not obtained by the NRC because of the delay in establishing contact between Met Ed and the NRC regional office.

Recommendations

- The NRC should identify and qualify those NRC personnel relied upon to obtain or evaluate critical information during nuclear powerplant or radiological emergencies. The qualification should ensure that the personnel can recognize, diagnose, and properly evaluate abnormal conditions within their identified area of responsibility.
- The NRC should provide training, equipment, and guidance which ensure rapid, efficient, and comprehensive gathering of information by NRC personnel during nuclear powerplant or radiological emergencies. Training and guidance should ensure that predetermined basic information is obtained at the scene of the accident, and the equipment provided should be sufficient to ensure immediate and direct communication with the appropriate NRC emergency response centers.
- The NRC should determine the minimum staffing and composition of the initial NRC response teams, both on site and off site, for nuclear powerplant accidents and other foreseeable radiological emergencies. For purposes of obtaining plant operations information during nuclear powerplant accidents, no less than three personnel qualified in reactor operations should be assigned to the control room to obtain and communicate plant status information.

REFERENCES AND NOTES

[1]Chart, TMI-2, Recorder HP-UR-1901, March 28, 1979.

[2]Offsite Dose Calculation Sheet, TMI-2, March 28, 1979, 0744.

[3]Crawford Interview on May 22, 1979 (IE) at 3.

[4]Benson/Crawford Interview on May 3, 1979 (IE) at 8.

[5]Dubiel Interview on May 22, 1979 (IE) at 3.

[6]Miller Interview on April 12, 1979 (Met Ed) at 14.

[7]Offsite Dose Calculation Log, TMI-2, March 28, 1979.

[8]Reilly Interview on May 3, 1979 (IE) at 53-54.

[9]Region 1 Incident Response Center Transcripts, March 28, 1979.

[10]Arnold dep. (Sept. 24, 1979) at 5-6.

[11]Region 1 Incident Response Center Transcripts, March 28, 1979, Tape 17A at 8-9.

[12]Porter Interview on May 21, 1979 (IE) at 3-13.

[13]Miller dep. (Sept. 20, 1979) at 14-16.

[14]Porter dep. (Oct. 30, 1979) at 4.

[15]Porter Interview on May 21, 1979 (IE) at 9-17.

[16]*Id.* at 5.

[17]*Id.* at 18.

[18]Wright Interview on June 15, 1979 (IE) at 6-7.

[19]Porter dep. (Oct. 30, 1979) at 5, 11-13.

[20]Porter Interview on May 21, 1979 (IE) at 19-20.

[21]Porter dep. (Oct. 30, 1979) at 38.

[22]Miller dep. (Oct. 29, 1979) at 3-6.

[23]Porter dep. (Oct. 30, 1979) at 13.

[24]Miller dep. (Oct. 29, 1979) at 8-9.

[25]Yaeger Interview on June 20, 1979 (IE) at 14.

[26]*Id.* at 16.

[27]*Id.* at 18-19.

[28]Wright Interview on June 15, 1979 (IE) at 8, 14.

[29]*Id.* at 14, 19.

[30]*Id.* at 13.

[31]Bennett Interview on June 19, 1979 (IE) at 18.

[32]Wright Interview on June 15, 1979 (IE) at 11-12.

[33]Bennett Interview on June 19, 1979 (IE) at 13, 18.

[34]Porter dep. (Oct. 30, 1979) at 9-11, 18, 24.

[35]*Id.* at 18.

[36]Porter Interview on May 21, 1979 (IE) at 20.

[37]Porter dep. (Oct. 30, 1979) at 7-8.

[38]Porter dep. (Oct. 30, 1979) at 13, 24.

[39]Porter Interview on July 2, 1979 (IE) at 6.

[40]Miller dep. (Oct. 29, 1979) at 5-6.

[41]Wright Interview on June 15, 1979 (IE) at 24-25.

[42]Bennett Interview on June 19, 1979 (IE) at 17-18.

[43]Porter dep. (Oct. 30, 1979) at 14-17.

[44]Porter Interview on July 2, 1979 (IE) at 12.

[45]Wright Interview on June 15, 1979 (IE) at 9.

[46]Yaeger Interview on June 20, 1979 (IE) at 9-11, 14.

[47]Porter dep. (Oct. 30, 1979) at 5-6.

[48]Porter Interview on July 2, 1979 (IE) at 6-7.

[49]Porter dep. (Oct. 30, 1979) at 6-7.

[50]Miller dep. (Oct. 29, 1979) at 10-11.

[51]Herbein dep. at 16-17.

[52]Hq. IRC Day 1 Transcripts, Channel 2, Book 1, at 188.

[53]Region 1 IRC Transcripts, March 28, 1979, Tape 10 at 19.

[54]Hq. IRC Day 1 Transcripts, Channel 2, Book 2 at 325-339.

[55]Hitz dep. at 44-45.

[56]Stello dep. at 18-19.

[57]Hearings Before the Subcommittee on Energy and the Environment, 96th Cong., 1st Sess. (May 9-15, 1979) Part 1 at 12-13.

[58]Higgins dep. at 102-103.

[59]Lowe Interview Memo, December 4, 1979

[60]NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by the Office of Inspection and Enforcement," NUREG-0600 at I-4-49-51, August 1979.

[61]Logan Interview on May 9, 1979 (IE) at 35.

[62]Logan dep. at 2.

[63]Faust, Frederick, Scheimann, and Zewe dep. at 256-260.

[64]*Id.* at 257-258.

[65]Ross dep. (Oct. 30, 1979) at 8.

[66]Ross dep. (Sept. 18, 1979) at 42-44.

[67]Ross dep. (Oct. 30, 1979) at 8-9.

[68]Flint dep. (June 30, 1979) at 21-22 (Pres. Com.).

[69]Flint Interview on April 20, 1979 (Met Ed) at 4.

[70]Chwastyk dep. (Oct. 30, 1979) at 5-6.

[71]*Id.* at 6.

[72]Mehler dep. (Oct. 30, 1979) at 7.

[73]TMI Station, March 28, 1979 Incident, Statement by G. P. Miller, Station Manager, signed April 7, 1979 at 24.

[74]Miller Interview on May 7, 1979 (IE) at 70.

[75]Miller dep. (May 31, 1979) at 57 (Pres. Com.).

[76]Miller dep. (Sept. 20, 1979) at 31-32.

[77]Miller dep. (Oct. 29, 1979) at 19-22.

[78]Logan Interview on May 9, 1979 (IE) at 31-32.

[79]Rogers dep. at 47.

[80]Kunder dep. at 75-76.

[81]Chwastyk dep. (Oct. 30, 1979) at 5.

[82]Mehler dep. (Oct. 30, 1979) at 10.

[83]Mehler dep. (Oct. 11, 1979) at 15.

[84]Chwastyk dep. (Oct. 30, 1979) at 8, 14, 17-21.

[85]*Id.* at 15.

[86]*Id.* at 14.

[87]Mehler dep. (Oct. 11, 1979) at 14.

[88]Mehler dep. (Oct. 30, 1979) at 22-23.

[89]*Id.* at 11.

[90]Chwastyk dep. (Oct. 30, 1979) at 20.

[91]Mehler dep. (Oct. 30, 1979) at 17.

[92]*Id.* at 17-18.

[93]Chwastyk dep. (Oct. 11, 1979) at 18.

[94]*Id.* at 21-22.

[95]Chwastyk dep. (Oct. 30, 1979) at 17.

[96]*Id.* at 19-20.

[97]*Id.* at 17-21.

[98]These include all of the transcripts of taped interviews conducted by NRC's Inspection and Enforcement Office; all of the President's Commission depositions with Met Ed, B&W, and NRC personnel; and some additional records of interviews including some transcripts of taped interviews of Met Ed personnel by congressional committee investigators, provided to us by the witnesses themselves.

[99]Ross dep. (Sept. 18, 1979) at 42.

[100]Ross dep. (Oct. 30, 1979) at 10.

[101]Miller dep. (Oct. 29, 1979) at 24-28.

[102]*Id.* at 30-32.

[103]*Id.* at 19-22.

[104]Porter dep. (Oct. 30, 1979) at 27.

[105]Ross dep. (Oct. 30, 1979) at 13.

[106]Mehler dep. (Oct. 11, 1979) at 16, 25.

[107]Mehler dep. (Oct. 30, 1979) at 11-13.

[108]Mehler dep. (Oct. 11, 1979) at 25.

[109]In the interim, an October 21 front-page story in the *New York Times* reported that Mehler had told the Special Inquiry Group that such an instruction had been given on March 28. The story also referred to testimony by Mehler reflected in "notes" taken by a "Federal investigator" in July 1979. Since the notes (a copy of which the story said had been obtained by the *Times*) were not those of the staff of the SIG, an attempt was made to identify them in order to determine whether Mehler had made statements earlier than the October 11 interview regarding the date of an instruction not to start electrical equipment. However, the SIG has not discovered any earlier interview in which Mehler was asked about this subject, nor did Mehler recall ever having discussed it with any investigator before October 11.

[110]Mehler dep. (Oct. 30, 1979) at 15-16.

[111]Chwastyk dep. at 15-17.

[112]Miller dep. (Oct. 29, 1979) at 23-24.

[113]Smith dep. (Nov. 19, 1979).

[114]Baunack dep. at 7-8.

[115]Neely dep. at 16-17.

[116]Higgins dep. at 5-6.

[117]Faust, Frederick, Scheimann, and Zewe dep. at 259.

[118]Mehler dep. (Oct. 30, 1979) at 8.

[119]*Id.* at 8-10.

[120]*Id.* at 10, 21.

[121]*Id.* at 19.

[122]Chwastyk dep. (Oct. 30, 1979) at 18.

[123]*Id.* at 21.

[124]*Id.* at 22-23.

[125]Nimitz dep. at 21-23.

[126]Chwastyk dep. (Oct. 30, 1979) at 19.

[127]*Id.* at 23.

6. MANAGEMENT OVERVIEW OF THREE MILE ISLAND, UNIT 2 (TMI-2)

a. Organization

The Three Mile Island Generating Station near Middletown, Pa., has two units that use Babcock & Wilcox designed pressurized water reactors. The Unit 1 nuclear powerplant went into operation in 1974 and Unit 2 was started in 1978. Operation of these units is the responsibility of the Metropolitan Edison Company (Met Ed) which owns 50% of each unit. Met Ed has corporate offices in Reading, Pa., and is one of three operating utilities belonging to an investor-owned holding company. This holding company, the General Public Utilities Corporation (GPU) with offices in Parsippany, N.J., also owns the Pennsylvania Electric Company (Penelec) with offices in Johnstown, Pa.; the Jersey Central Power and Light Company (JCPL) with offices in Morristown, N.J., and the General Public Utilities Service Corporation (GPUSC) with offices in Mountain Lakes, N.J. Penelec and JCPL are operating utilities, and each owns 25% of each TMI unit. GPUSC is responsible for providing technical and managerial assistance to the operating utilities primarily in the area of fuel management and in the design, construction, and startup of new generating units.

Figure III-8 shows the corporate and line management relationships within GPU and Met Ed for the operation of TMI-2 as they existed on March 28, 1979.

Both GPU and GPUSC are headed by Herman Dieckamp who has been involved in the technical end of the nuclear industry for most of his 30-year professional career. He joined the corporation in 1973. Assisting Dieckamp at GPUSC is Robert Arnold, Vice President of Generation. Arnold received nuclear power training and operating experience as a commissioned officer in the U.S. Navy before joining Met Ed in 1969. He was involved in the startup and operation of Unit 1 and the construction and startup of Unit 2. He served as Vice President of Generation for Met Ed before advancing to GPUSC. On March 28, 1979, reporting to Dieckamp was Walter Creitz, then President of Met Ed. Creitz had been with the company for 31 years holding a variety of engineering and management positions before becoming president in 1972. His technical experience was primarily in non-nuclear work. Reporting to Creitz was John Herbein, Vice President of Generation for Met Ed. Herbein received nuclear power training as a commissioned officer in the U.S. Navy before joining Met Ed in 1967. He progressed through several management positions at TMI, including station superintendent, before moving to the corporate offices. Gary Miller, Station Manager, reported directly to Herbein. Miller graduated from the U.S. Merchant Marine Academy and had 8 years of nuclear construction and testing experience with U.S. Navy reactors before joining GPUSC in 1973. Miller became the superintendent of Unit 2 in 1974 while the plant was under construction and he moved to the site superintendent (later station manager) position in 1976. In this position, he was primarily concerned with administrative and managerial duties as opposed to directing the day-to-day operation of the reactors.

Both Dieckamp and Arnold worked at GPU corporate offices in New Jersey. Creitz and Herbein worked at the Met Ed corporate offices in Reading, Pa., about 50 miles from the TMI site, and Miller headed the Met Ed staff at the site.

Joseph Logan, Unit Superintendent, reported to Miller and was responsible for the overall operation of Unit 2. Logan graduated from the U.S. Naval Academy and had 20 years of nuclear power training and operating experience as a commissioned officer in the U.S. Navy before joining Met Ed in early 1978. He became unit superintendent after the plant began commercial operation in late December 1978. James Floyd, Supervisor of Operations, and George Kunder, Superintendent of Technical Support, were assisting Logan. Floyd graduated from Columbia University with a degree in chemical engineering and had a background of nuclear training and operations experience as an enlisted man in the U.S. Navy before joining Met Ed in 1968. Floyd had 3 years of experience as operations supervisor, in charge of operating personnel, at GPU's Saxton training facility and TMI-1 before his appointment as operations supervisor at Unit 2 in 1975. Kunder, on the other hand, graduated from Pennsylvania State University with a degree in mechanical engineering and joined Met Ed in 1968 where he received his nuclear training and operating experience. Kunder progressed through a variety of staff engineering assignments before his promotion to operations supervisor at Unit 1 in December 1977. In December 1978, Kunder became the Superintendent of Technical Support at Unit 2. James Seelinger held that position until he was promoted to Unit Superintendent at Unit 1 in December 1978. Seelinger is a graduate of the U.S. Naval Academy and served as a commissioned officer in the U.S. Navy. He had 6 years of training and experience in the operation of naval nuclear powerplants before joining Met Ed in 1974.

Several key Met Ed management personnel held an NRC senior reactor operator license at TMI at

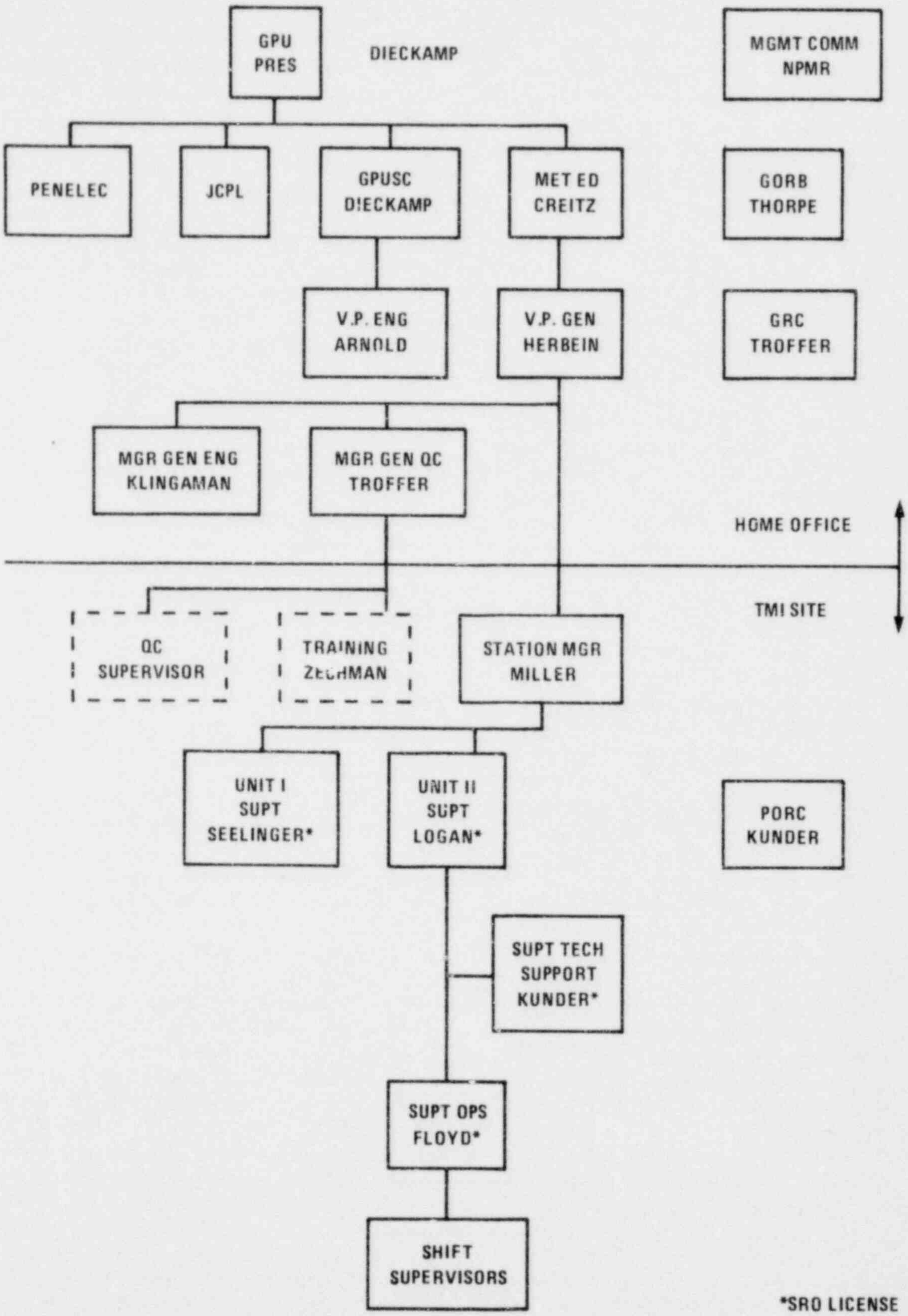


FIGURE III-8. GPU/Met Ed Organization as of March 28, 1979 some time in their career. Herbein was licensed for Unit 1 from February 1974 to February 1975; Miller held a license for 6 months in 1976 for Unit 1; Logan held a current license on Unit 2 which he received in December 1978; Floyd was cross-licensed for Unit 2 and has held a Unit 1 license since March 1974; Kunder held a current license for Unit 1 which he received in August 1975 and was in the process of being cross-licensed for Unit 2; Seelinger was cross-licensed for Unit 2 and had held a Unit 1 license since January 1977. (Personnel holding a current senior reactor operator license for Unit 1 were cross-licensed by the NRC as senior reactor operators at Unit 2 upon the request of Met Ed, provided that the candidates had successfully completed Met Ed's training program that stressed the differences between the two units.)

The NRC approved the management organization in February 1978 by issuing the operating license. Incumbents in key positions met the requirements of the industry standard ANSI N18.1-1971, "Selection and Training of Nuclear Power Plant Personnel." (Met Ed is permitted under the NRC license to replace personnel in key positions without prior approval or prior notification to the NRC, provided the replacements meet the requirements of industry standard N18.1 and any additional requirements listed in the technical specifications. Logan and Kunder met these requirements.)

The NRC staff involved in assessing the acceptability of utility operating staffs believed that qualifications of personnel in the home office were average, whereas those of employees in the plant were superior.[1]

Although several corporate officials were experienced in the nuclear field and plant management met current industry and NRC qualification requirements, key management personnel, Logan and Kunder, were inexperienced in Unit 2 operations. Because they were the first two management officials to arrive in the Unit 2 control room on March 28, 1979, and they arrived before any significant fuel damage had occurred, we believe that they could have played a major role in the diagnosis of the problem had they been better acquainted with plant operations.

Management control was set up through use of a traditional line organization. In addition to the normal advice and counsel exchanged between a manager and his staff, Creitz, Herbein, and Logan were advised on Unit 2 nuclear safety matters by formal review committees institutionalized by either corporate policy, NRC license conditions, or both. Additionally, a quality assurance group reported to Herbein. This group inspected and audited activities related to nuclear safety at the TMI Station.

b. Operating Experience of Key Management Personnel

TMI-2 was in commercial operation for only 3 months before the reactor accident took place on March 28, 1979. During 1977 and 1978, the unit underwent extensive preoperational and power testing directed by GPUSC personnel and performed by Met Ed site personnel.

During the preoperational and power testing phases Miller had a dual role as Site Manager and Unit 2 Superintendent. Although GPUSC was in charge of these testing programs, Seelinger, then superintendent of technical support at Unit 2, performed the day-to-day testing and operation management duties normally assigned to the unit superintendent. Miller apparently spent most of his time in his site manager role and delegated many of the unit superintendent functions and signature authority to Seelinger.[2,3] Logan, after joining Met Ed in early 1978, spent most of the remainder of the year in training to qualify for an NRC senior reactor operator license.[4]

Although Seelinger had unit superintendent signature authority and had signed plant procedures, safety reviews, test acceptances, and similar documents in the capacity of unit superintendent, he stated that he was not, nor was he acting as, the Unit 2 Superintendent.[2] Consequently, during these critical experience and learning periods—preoperational and power testing phases at Unit 2—the position of unit superintendent was in reality not staffed. The GPUSC startup and engineering personnel left the site as the testing and startup programs were completed and initial operations progressed. Seelinger then moved to a new position at Unit 1 in December 1978. This left Unit 2 with two of its three key management positions filled by personnel inexperienced in the plant's operation—Logan and Kunder.

Floyd, the most experienced member of Unit 2 management, was away for simulator retraining in Lynchburg, Va., on the day of the accident. During testimony after the accident, Logan and Kunder each stated that they lacked experience with the Unit 2 facility.[5,6]

Kunder admitted that this inexperience limited his ability to respond and diagnose the cause of the abnormal conditions that developed on March 28 as a result of the accident.[7] Miller also recognized his lack of detailed knowledge and called on Herbein, Seelinger, and the B&W Site Manager, Leland Rogers, to assist him on March 28. Miller, Logan, and Kunder were aware of the abnormal conditions encountered by the shift supervisor before any significant fuel damage occurred. Thus, they had the opportunity to prevent or limit core damage had they been able to properly diagnose the cause of the abnormal conditions.

The qualifications and training requirements for plant personnel were established by the NRC in the technical specifications included in the Unit 2 license. These requirements were in the form of an endorsement of the industry standard ANSI N18.1-1971, "Selection and Training of Nuclear Power Plant Personnel." This standard includes the minimum qualifications for plant managers and supervisors. However, the standard is not specific as to what experience is required with respect to each type of nuclear powerplant nor the plant at which the person will be working. The standard requires the plant manager to have a minimum of 10 years of "responsible" powerplant experience, 3 of which must be associated with nuclear powerplants and 4 of the remaining 7 may be fulfilled by academic training. Moreover, the plant manager (unit superintendent) has to acquire the training and experience required by the NRC to hold a senior reactor operator license, but he does not necessarily have to hold one. Met Ed, however, required the unit superintendent to hold a senior reactor operator license. Each of the aforementioned TMI-2 personnel exceeded the minimum qualifications required in ANSI 18.1.

c. Review Committees

Three review committees were established to advise key Met Ed managers on nuclear safety matters at Unit 2. These were the Plant Operations Review Committee (PORC), which advised Logan; the Generation Review Committee (GRC), which advised Herbein; and the General Office Review Board (GORB), which advised Creitz. Additionally, Dieckamp established a program for an annual review of the overall operation and status of each nuclear plant in the GPU system. These reviews were conducted by senior GPU management, including Dieckamp, Creitz, Herbein, and others, at the plant sites. Miller was not a member of the GRC or GORB but often attended GORB meetings.

During the critical testing phases of Unit 2 in 1977 and 1978, Miller had dual responsibilities as Site Superintendent and Unit Superintendent. The evidence suggests that much of Miller's time was devoted to his site superintendent duties. He rarely participated in PORC activities or the technical duties customarily performed by a unit superintendent. Likewise, Logan, the incoming Unit Superintendent, was in training for an NRC license and did not participate in PORC or unit superintendent activities until he assumed that position in late December 1978. Furthermore, in December 1978, Seelinger, who had performed much of the unit superintendent's work in 1977 and 1978, was promoted to Unit 1 Superintendent when Logan took over Unit 2. Kunder came to Unit 2 then to replace Seelinger as the Superintendent of Technical Support. Apparently, this staffing arrangement was made by upper management with no recognition of its weakening effect on the technical and plant knowledge strength of the Unit 2 site management.

We found no evidence that the safety committees recognized the weaknesses that were developing in the Unit 2 management structure. Rather, their attention was primarily focused on licensing and operating experience matters.

Plant Operations Review Committee

The Plant Operations Review Committee (PORC) is a requirement of the NRC license. This committee advises the unit superintendent on all matters related to nuclear safety. The PORC is primarily responsible for review of procedures that affect nuclear safety, review of proposed tests and experiments that affect nuclear safety, review of proposed changes of technical specifications, and review of proposed changes or modifications to unit systems or equipment that affect nuclear safety. In addition, it investigates violations of technical specifications, including the preparation and forwarding of reports on evaluation and recommendations to prevent recurrence. PORC also reviews unit operations to detect potential nuclear safety hazards, and performs special reviews, investigations or analyses as requested by the unit superintendent.

There are no NRC or industry qualifications for individual members of PORC. Both Seelinger and Kunder, who were chairmen during 1978 and 1979, possessed extensive education and experience in nuclear technology. The remainder of the PORC members had technical or engineering backgrounds.

A review of PORC meeting minutes indicated that the committee reviewed procedures, temporary changes, design change reports submitted to the NRC, and the other matters associated with their assignment. However, the meeting minutes do not contain details by which we could judge the extent to which the topics were discussed. We do know that some approved plant procedures were contrary to the technical specifications.[8]

For most of 1978, the position of Unit Superintendent was filled by Miller who also had to carry out his primary responsibility as Site Superintendent. The time Miller could devote to PORC was severely limited and Seelinger performed most of the activities customarily performed by a unit superintendent.

Logan, who took over as Unit 2 Superintendent at the end of December 1978, and Miller rarely attended the PORC meetings. Logan attended some PORC meetings after he became Unit Superintendent. Seelinger went to Unit 1 in late December 1978 and was, therefore, no longer a member of the Unit 2 PORC.

Generation Review Committee

The Generation Review Committee (GRC), the offsite safety committee, is a requirement of the NRC license. This committee advises the Met Ed Vice President of Generation and provides an independent review and audit of designated activities in the areas of nuclear unit operations, engineering, metallurgy, radiological safety, and quality assurance practices related to TMI-2.

The GRC is composed of at least five members, all appointed in writing by John Herbein. The committee, chaired by George Troffer, Manager of Quality Assurance, consisted generally of no more than nine members.

Again, there are no NRC or industry qualifications for members of GRC. The technical specifications describe only a general requirement to be satisfied by committee members. Troffer, who was chosen to be the GRC Chairman by Herbein, had 32 years of experience in the U.S. Navy. He served actively for over 12 years in various duties in the Navy Nuclear Program. Additionally, he had various assignments in engineering, repair, and quality assurance while serving as a commissioned officer. The members of the GRC had previous experience in design, some had experience in operating naval reactors, and all had engineering degrees. Three of the group worked directly under Troffer in his quality assurance organization.

One of the main responsibilities of the GRC was to overview the PORC activities. Whereas the position of Unit 2 superintendent for most of 1978 was filled by Miller, who also had the dual responsibility of station superintendent and, thus, had only a limited time to devote to PORC matters, this responsibility of GRC was a vital one. However, we found no evidence that the GRC was aware of or concerned about Miller's lack of presence and participation in PORC activities. We sampled the PORC activities carried out during June 5 to September 9, 1978 and found that of the 47 PORC sessions we reviewed, Miller attended 2 sessions and Logan, the incoming Unit Superintendent, attended none.

GRC was required to meet at least once per calendar quarter, according to technical specifications, but it met more frequently. Minutes of these meetings contain few details. There is no indication in the minutes that Herbein attended these meetings.

General Office Review Board

The General Office Review Board (GORB) was concerned with broader issues (rather than details) of nuclear safety. The responsibility of GORB was to (1) foresee potentially significant nuclear and radiation safety problems and to recommend to the President of Met Ed how they could be avoided, and (2) periodically review the Generation Division audit program to ensure that audits are being accomplished in accordance with requirements of technical specifications and ANSI 18.7-1976, "Standard for Administrative Controls and Quality Assurance for the Operational Phase Nuclear Power Plants."

GORB was established in accordance with requirements of TMI-1's technical specifications. It was not required by TMI-2's technical specifications; however, its review responsibilities included TMI-2.

The Chairman and Vice Chairman of GORB were appointed by Creitz. The Chairman, J. Thorpe of GPUSC, designated a minimum of four additional members. No more than a minority of the committee had line responsibility for day-to-day operation of the Three Mile Island Nuclear Station.

The members of GORB collectively possessed knowledge of and experience in nuclear powerplant design, construction and operations, nuclear plant management, industry organizations and practices, and B&W nuclear plant design and performance information. The majority of the members attended all the meetings held by GORB for Unit 2.

GORB met at least once per calendar quarter during the initial year of facility operation following fuel loading and at least once every 6 months thereafter. A quorum for informal meetings had no less than a majority of the principals or duly appointed alternates and included the Chairman or Vice Chairman. No more than a minority of the quorum held line responsibility for day-to-day operations at TMI.

GORB examined proposed changes in procedures and equipment, proposed changes in technical specifications, violations of the operating license (including technical specifications), operating abnormalities and deficiencies, and reportable occurrences. It also evaluated the adequacy of the Plant Operations Review Committee's and the Met Ed technical support staff's determinations concerning unreviewed safety questions. GORB meeting summaries do not indicate any review of the GRC functions as they do for the PORC.

The Committee Chairman is empowered to send a letter to Creitz, within 14 days following completion of a review that would accomplish one of the following:

- Recommend actions that should be taken on proposed changes to the operating license or technical specifications.
- Recommend actions that should be taken on proposed tests, facility changes, procedure changes, or operating abnormalities that the committee had reviewed.
- Recommend to the company President appropriate action to prevent recurrence of reportable occurrences or to improve the effectiveness of the plant and corporate organization.

However, meeting minutes indicate that there were never any recommended actions that required the attention of Creitz, nor did GORB express concern about the dual responsibilities placed on Miller or his lack of participation in PORC activities. Furthermore, we found no evidence of concern about the inexperience of two key individuals, Logan and Kunder, in Unit 2 activities.

Nuclear Plant Management Review Committee

The purpose of the Nuclear Plant Management Review Program was to provide senior management in the GPU system with a description of the overall operation and status of the generating station in order to annually assess the efficiency of the station's performance. GPU President Dieckamp set up this management review to ensure that the overall operation and status of each nuclear plant in the GPU system was reviewed annually by the Nuclear Plant Management Review Committee. The stated objectives of these reviews were the following:

- To increase management awareness of nuclear plant operational and safety problems.
- To promote intercompany communications on nuclear matters.
- To provide management awareness of key nuclear personnel and related problems.

> These objectives do not in any way reduce or replace the requirement of responsible line management to discharge their full responsibility for these nuclear plants, nor of organizations established to independently review nuclear plant safety-related issues.[8]

To help meet these objectives, onsite reviews were conducted of plant organization and manpower; operational history and status; reported incidents; NRC inspections; personnel exposure history; and problems, comments, and recommendations of the plant staff. Members of the review committee also participated in plant tours.

The Nuclear Plant Management Review Committee included Dieckamp, Creitz, Herbein, Arnold, and the company presidents and generation vice presidents from Penelec and JCPL. In preparation for the TMI-2 review, the plant staff prepared and distributed a package of material to each committee member containing information for each item on the agenda. This information included comments by plant staff about their perceptions of problems in various areas in addition to routinely distributed copies of key letters on inspections, incidents, and other significant plant-related issues.

The management review for TMI-2 took place on January 18, 1979. The information as outlined above was presented to management by the plant staff. The presentations appeared to be candid discussions of problems and suggested courses of action. The main area of concern to plant management was the lack of incentives to keep qualified personnel. Also, filling of vacancies in certain positions was administratively cumbersome. Arnold, who attended the meeting, recalled that two major decisions made were to provide for a new service building (provide centralized offices for plant staff) and authorization to hire 6 to 10 more engineers.[9]

d. Operational Quality Assurance Program

Another management overview tool was provided by the Operational Quality Assurance (OQA) Plan. Herbein, responsible for the implementation of this plan, appointed George Troffer to head the OQA program. Troffer was responsible for developing the detailed program, updating it as necessary, and monitoring all onsite and offsite activities required by the program to ensure compliance with its requirements. Troffer also was responsible for the training group at the TMI site.

Troffer coordinated his efforts with the GPUSC's Manager of Quality Assurance in developing the details of the OQA Program for the Three Mile Island Nuclear Station. This coordination was to ensure that all of the GPU companies had the same basic approach for their OQA Programs.

The TMI OQA Program is described in a quality assurance plan that was reviewed and accepted by the NRC. The purpose of the plan was to assign and define responsibilities for implementing the requirements of NRC Regulation 10 C.F.R. 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants," and the Met Ed policy statement regarding the OQA Program for TMI. Met Ed retained overall responsibility for all activities associated with this program, and the work was performed either by Met Ed personnel or by organizations or personnel performing services for Met Ed.

This program was primarily hardware and procedures oriented, and, although these features are important to nuclear safety, the program apparently provided no insight into the management weaknesses developing in the Unit 2 organization.

e. Summary of Findings and Recommendations

Findings

- In December 1978, utility management staffed the TMI-2 superintendent and superintendent of technical support positions with personnel having little experience at the TMI-2 facility. The incumbents met the standards established in ANSI N18.1-1971 and the requirements of the NRC.
- The qualifications and training requirements established by the NRC and industry standard N18.1-1971 for plant management personnel are inadequate.
- Utility management did not adequately staff the Unit 2 superintendent position during the preoperational and power test phases in 1977 to 1978. The incumbent had dual responsibilities as site superintendent and Unit 2 superintendent. This dual role was accepted by the NRC.
- The Unit 2 superintendent's participation (by both the incumbent and his designated replacement) in the workings of the Plant Operations Review Committee was infrequent during the critical preoperational and power test phases at TMI-2.
- The management overviews afforded by onsite and offsite safety review committees and the Operational Quality Assurance Program were not adequately attentive to the qualifications and training of the TMI-2 management staff.
- The offsite safety review committees should have discerned the weaknesses developing in the TMI-2 site management organization resulting from the organizational structure adopted during the preoperational and power test phases and the personnel changes effected at the start of commercial operation.
- Specific qualifications have not been established for persons participating in onsite and offsite safety review committees.

Recommendations

- Prompt action should be taken to upgrade the qualification and experience requirements for personnel managing and supervising activities at nuclear powerplants. This action should include establishing requirements for specific expertise in the activity being supervised as well as experience at the nuclear powerplant where the activity is performed. A suitable method of certification of the qualification and experience requirements should be established that will provide reasonable assurance that these personnel have and maintain the skills needed to meet the requirements of their position. These actions should be completed as soon as practicable but not later than January 1, 1982.
- The NRC should require that each key management position at a nuclear powerplant be staffed by a qualified person working full time in that position.
- The NRC should perform a timely evaluation of personnel changes in key plant management positions and changes in the plant organizational structure to ensure that adequate staffing is maintained.
- Offsite safety review committees, or equivalent, should include within the scope of their activities the evaluation of personnel changes in key management positions and the evaluation of changes in plant organizational structure.
- Qualifications for personnel participating on safety review committees should be established by the NRC.

REFERENCES AND NOTES

[1]Allenspach dep. at 86.

[2]Seelinger dep. at 15-16.

[3]G.P. Miller dep. (Aug. 7, 1979) at 54 (Pres. Com.).

[4]Logan dep. at 18 (Pres. Com.).

[5]Logan Interview Transcript at 28.

[6]Kunder dep. at 125-126.

[7]id. at 125-127.

[8]Memorandum from H.M. Dieckamp, GPU Services, to R.C. Arnold, S. Bartnoff, R.W. Conrad, W.M. Creitz, I.R. Finfrock, J.G. Herbein, W.A. Verrochi, March 21, 1978.

[9]Arnold dep. at 302-303 (Pres. Com.).

7. THE RADIATION EMERGENCY PLAN—DEVELOPMENT AND TRAINING

a. NRC Requirements and Met Ed's Plan

Met Ed's radiation emergency plan in effect on March 28, 1979, evolved from the emergency planning activities that began with the preparation of their Preliminary Safety Analysis Report (PSAR) for Unit 1. This report was docketed for review by the Atomic Energy Commission (AEC) on May 3, 1967. Publication of AEC requirements for emergency planning at nuclear powerplants first appeared in AEC's Notice of Proposed Rulemaking, Title 10 Code of Federal Regulations, Part 50 (10 C.F.R. 50), "Licensing of Production and Utilization Facilities," published in the Federal Register on April 15, 1955. Pursuant to Part 50.34, applicants for a license to construct and operate a nuclear powerplant were to submit the following:

> A description of plans or proposals in the event that acts or accidents occur which would create radioactive hazards. The description should relate the various operational procedures, the protective devices, and the pertinent features of the site to such happenings as operational mistakes, equipment or instrument failure or malfunction, fire, electric power failure, flood, earthquake, storm, strike and riot.

On August 16, 1966, the AEC published proposed amendments to 10 C.F.R. 50. The proposed changes included requirements for a "Safety Analysis Report" in place of a "Hazard Summary Report" and referenced a "Guide for the Organization and Contents of Safety Analysis Reports." Furthermore, applicants for nuclear powerplant construction permits would be required to submit a PSAR. A Final Safety Analysis Report (FSAR) would be required before issuance of a license to operate the plant. The FSAR would include "plans for coping with emergencies..."

On May 3, 1967, a PSAR was docketed for TMI-1. The facility was to be operated by the Metropolitan Edison Company. In a short paragraph in the PSAR, Met Ed stated that, (1) "...an emergency plan will be developed...," (2) the emergency plan would cover such emergencies as "fire, medical injury and illness, radiation, and contamination accidents, and other conditions that may result from nuclear and non-nuclear accidents," and (3) station personnel would be familiar with the emergency plan; practice drills would be conducted for training; and outside agencies included in the plan would be informed concerning their expected roles in an emergency.

On May 18, 1968, construction permit CPPR-40 was issued for the construction of TMI Unit 1. On December 17, 1968, the AEC published amendments to 10 C.F.R. 50 based on the proposed amendments to 10 C.F.R. 50 initially published August 16, 1966.

A PSAR for TMI Unit 2 was submitted to the AEC on March 10, 1969. The initial statement concerning "Emergency Drills" was identical to that submitted for TMI Unit 1, except for minor grammatical changes. Also included was an outline of the specific contents of the Radiation Emergency Plan which was to be prepared.

On November 4, 1969, construction permit CPPR-66 was issued by the AEC to authorize the construction of TMI Unit 2.

The Federal Register of May 21, 1970, reported that the AEC had under consideration amendments to 10 C.F.R. 50 that would require more information pertaining to emergency planning. These amendments were to expedite the licensing process and provide greater uniformity in plans submitted at the PSAR and FSAR stages. These amendments included Appendix E—Emergency Plans for Production and Utilization Facilities. The availability of a Guide for Emergency Planning to assist applicants in preparing the plans was also announced. Amendments to 10 C.F.R. 50.34, published December 24, 1970, required that the information presented in the PSAR and FSAR on emergency plans address the items specified in Appendix E, and incorporated Appendix E as part of 10 C.F.R. 50. The Guide to the Preparation of Emergency Plans for Production and Utilization Facilities was revised effective December 1970. With the amendment of 10 C.F.R. 50.34 to incorporate Appendix E and revision of the Guide, the final regulatory requirements affecting the TMI Unit 1 and 2 Emergency Plan were in place. These requirements were not subsequently amended prior to March 28, 1979.

The TMI Unit 1 FSAR was accepted for review on March 2, 1970. As a result of the staff's review, the FSAR for Unit 1 was amended substantially. The Unit 1 FSAR as finally amended included commitments from Met Ed to have a radiation emergency plan as outlined in Appendix 12A to the FSAR and to provide for coordination with local agencies for emergencies. The latter commitment addressed training and drills, emergency procedures, coordination with and training of outside agencies, and the availability of medical consultants.

The Unit 1 FSAR "Radiation Emergency Plan" (Appendix 12A) was a document of 23 pages and 5 appendices, with a total of 7 pages, which was responsive to NRC's requirements. This plan was developed from the initial commitment contained in the May 3, 1967, PSAR. Final revisions were approved by the then Assistant Superintendent and the Radiation Protection Supervisor. The former, J. Herbein, was to be Met Ed's Vice President of Generation at the time of the March 28, 1979, accident. The AEC staff reported in the July 1973 Safety Evaluation by the Directorate of Licensing that the emergency plan was "...in conformance with 10 C.F.R. 50 Appendix E, Emergency Planning Requirements, and concluded that it is acceptable."

The operating license for TMI Unit 1, DPR-50, was issued on April 19, 1974. Prior to the issuance of this license, the Commission's inspection staff found that Met Ed had satisfied the FSAR commitments for the development of emergency procedures. The Three Mile Island Radiation Emergency Plan for Unit 1 identified three categories of emergencies: local, site, and general. Included in the criteria for declaration of a site emergency were: radiation level at the site security fence of "125 mR/h"; loss of primary coolant pressure coincident with high reactor building pressure, high reactor building sump level, or both; and actuation of the reactor building high range gamma monitor alarm. The criteria for declaration of a general emergency category included a reactor building high range gamma monitor indication of 8 R/h and a radiation level at the site boundary of "$>$125 mR/hr."

b. Plan Changes from Licensing Unit 1 to March 28, 1979

The initial Unit 2 TMI Radiation Emergency Plan was patterned after the previous plan for Unit 1, except for minor word changes, an increased number of conditions resulting in a local emergency, and the change in concept from a single unit site to a multiunit site plan.

On May 30, 1975, Met Ed submitted to the NRC Amendment 28 to the Unit 2 FSAR in response to questions from the NRC staff. Amendment 28 identified that there would be one supervisor of the chemistry and health physics staff for Units 1 and 2, and that he or she would report to either the station or unit superintendent, whoever was in charge. This supervisor would be responsible for the chemistry and radiation protection programs on site. The amendment also contained as Appendix 13A a revised radiation emergency plan outline. The action levels for initiating a local, site, or general emergency remained unchanged from the Unit 1 FSAR, except for the addition of another condition for the declaration of a unit emergency.

In April 1974, the NRC's Regulatory Requirements Review Committee, also known as the RRRC or the "Ratchet Committee," held its first meeting. One function of the committee was to examine the necessity for backfitting of existing plants to NRC staff positions that were being developed on acceptable methods of meeting NRC regulations. Most of these positions were issued as regulatory guides. At Meeting No. 31 in July 1975, a listing of backfit categories was established: "*Category 1*—Clearly Forward Fit only...*Category 2*—Further staff consideration of the need for backfitting appears to be required ... and *Category 3*—Clearly backfit."[1] The RRRC meeting No. 34, August 1975, considered proposed Regulatory Guide 1.101 on emergency planning and characterized this guide as Category 3—Backfit required.[2] Decisions based on the recommendations of the RRRC were announced to applicants and licensees only through the implementation section of each regulatory guide. The findings of the RRRC were distributed widely within the NRC, particularly within the Office of Nuclear Reactor Regulation (NRR). The RRRC had no requirement for followup to ensure that their approved recommendations were implemented. In the case of the backfit requirement for Regulatory Guide 1.101, it was the decision of the NRR Branch Chief with the responsibility for emergency planning that, because of the workload involved in backfitting existing licensed plants and budgetary limitations, backfitting would be implemented on plants at the time of review for issuance of an operating license or, if already licensed for operation, at a time in the future when the licensee requested a change to the previously approved emergency plan.

Regulatory Guide 1.101 was issued in November 1975. Annex A, *Organization and Content of Emergency Plans for Nuclear Power Plants*, was used by the NRC staff during their evaluation of FSARs. Annex B, however, *Implementing Procedures for Emergency Plan*, was published for comment.

In September 1976, the NRC published the Safety Evaluation Report (SER) for TMI-2. With respect to emergency planning, the staff stated that "...the applicant has included plans for coping with emergencies in Appendix 13A of the Final Safety Analysis Report. We have reviewed this emergency plan, submitted in Amendment 28." The staff closed with the statement, "We conclude that it meets the requirements of 10 C.F.R. 50 Appendix E, is responsive to the specific requirements of the staff, and provides a basis for an acceptable state of emergency preparedness."

Revision 1 to Regulatory Guide 1.101 was published in March 1977. It incorporated certain changes and the following statement.

> [The] guide reflects current Nuclear Regulatory Commission practice. Therefore, except in those

> cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein is being and will continue to be used in the evaluation of Final Safety Analysis Reports.

Before an operating license was issued to TMI-2 a hearing was held before an Atomic Safety and Licensing Board (ASLB). The ASLB's findings were published on December 19, 1977. Two of the matters considered at that hearing concerned emergency planning. Contention 6 of that hearing stated that, "The environmental radioactivity monitoring program of the applicant's is inadequate to accurately measure the dose delivered to the public during normal and accident conditions. Only active, real-time detectors can determine what the actual dose rate is. Furthermore, an array of offsite detectors could greatly aid possible evacuation plans." The ASLB considered this as two separate contentions:

1. The actual radiation dose received by the public during normal and accident conditions can be properly measured only if offsite, real-time detectors are deployed.
2. The implementation of evacuating plans could be greatly aided by the deployment of such detectors.[3]

With respect to the contentions, the ASLB found that the current monitoring capabilities were adequate based on a review of Met Ed's monitoring capabilities, advantages, and disadvantages of active real-time detectors and the fact that Met Ed and the NRC staff were in agreement. Furthermore, the Board found that the environmental monitoring program was not intended for evacuation planning or implementation and that active, real-time detectors would be of little or no value. The Board specifically noted, "Instrumentation used to determine the severity of an accident, and the need for any offsite emergency action, is located on site and is monitored from the reactor control room." Furthermore, "In the event that accident conditions arose for which evacuation would be an effective protective measure, necessary measurements and corrective actions to mitigate the consequences, including notification of offsite emergency personnel, would be performed quickly, within 10–15 minutes of the incident."[4] The ASLB found the monitoring programs adequate and that active, real-time detectors would add nothing to the monitoring capability and would not aid or improve the emergency response capability.

In examining Contention 6, we believe the ASLB viewed too narrowly the potential use of offsite, real-time detectors. The TMI procedure that described response to a site emergency required the dispatch of onsite and offsite monitoring teams. When the accident occurred at the site at 6:55 a.m. and general emergencies were declared at 7:24 a.m. on March 28, the first onsite confirmatory measurement was reported at 7:46 a.m. The first offsite confirmatory survey results were reported from Goldsboro at 8:32 a.m. The elapsed time for confirmatory surveys was 51 minutes for an onsite location and 1 hour 37 minutes for Goldsboro. With the wind existing on the day of the accident, a gas cloud transport time to Goldsboro, about 1.4 miles away, was 20 to 40 minutes.

Margaret Reilly, Pennsylvania Bureau of Radiation Protection, was informed of a dose projection for Goldsboro of 10 R/h at about 7:45 a.m. Reilly advised the Pennsylvania Emergency Management Agency (PEMA) of the potential need for evacuation of Brunner Island and Goldsboro. Reilly recalled that it was not until about ½-hour later that confirmatory offsite measurements established that dose rates were near background levels in Goldsboro and, consequently, the evacuation alert terminated.

Only an offsite, real-time detector system could have provided the confirmation of offsite exposure rates at a relatively inaccessible location such as Goldsboro within the 10 to 15 minutes that the Board considered.

Contention 8 alleged that the warning and evacuation plans of the applicants and the Commonwealth of Pennsylvania were inadequate and unworkable. The applicant's staff presented information concerning accident detection and evacuation, and emergency plan training and drills. The ASLB also heard witnesses from State and local agencies and the NRC staff. The Board considered the availability of State and local officials, the appropriateness of the response of such officials and the appropriateness of the public response without prior tests or drills. The Board found that Contention 8 was without merit, that the staff had properly assessed the adequacy and workability of emergency response, and that the emergency and evacuation plans were both adequate and workable. We believe that the adequacy of State and local evacuation planning were found to contain serious flaws in the days immediately following the accident and that these flaws derived to a large extent from the belief that such an accident was, if not impossible, at least so unlikely as to be unworthy of consideration.

T. M. Gerusky, Director, Bureau of Radiation Protection, Commonwealth of Pennsylvania, stated the following in response to questions:

> Gerusky: I testified before the legislature trying to get funds for our program ever since I have been

> with the State to get a good emergency response capability including radios and communications and so forth.
>
> Question: This is communications, van, people...
>
> Gerusky: Equipment.
>
> Question: Portable iodine equipment?
>
> Gerusky: Right. And they look at you and say, 'For reactor accidents? No way!' Rasmussen came out and said that the probability was greater of getting killed by a meteorite. You haven't been killed by a meteorite.[5]

On February 8, 1978, License DPR-73 was issued to Met Ed for the operation of TMI, Unit 2. At this time the NRC-accepted emergency plan was identified as a part of Amendment 28 to the FSAR, dated May 30, 1975. Met Ed's Supervisor of Radiation Protection and Chemistry, Richard Dubiel, was the individual with overall responsibility for the radiation emergency plan.[6-8] Dubiel reported to the Station Manager, Gary Miller, in both the normal and emergency organizations. In the latter part of 1977, a health physics engineer was employed, reporting to Dubiel, who was assigned the principal task of revising and updating the existing emergency plan.[7] The engineer functioned as an emergency planning coordinator, a position which was not formalized prior to March 28, 1979. Working with a consultant, a revised emergency plan and procedures based on the requirements contained in Regulatory Guide 1.101 were developed. During the preoperational period, 1977-78, the NRC Region 1 inspection staff discussed with Met Ed representatives the content of the Radiation Emergency Plan and Procedures. The inspection staff was concerned that the plan outline in Appendix 13A to Amendment 28 of the FSAR was not state-of-the-art.[9] In January 1978, the newly revised emergency plan and procedures were discussed by Met Ed personnel with NRC Region 1 inspectors. Met Ed's emergency planning coordinator understood that the NRC inspector review of the emergency plan and procedures conformed to the guidance contained in Regulatory Guide 1.101. In January 1978, after review by Dubiel, the revised plan and procedures were submitted to the Plant Operations Review Committee (PORC). The revised emergency plan had been designated as the *Three Mile Island Emergency Plan 1004*, a plant procedure. The implementing procedures were designated as 1670 series procedures. At meeting No. 250, January 1978, PORC recommended that the unit superintendent approve the new and revised emergency plan and procedures.

Following the approval of the emergency plan and procedures, copies of the revised plan were provided by Met Ed to the General Public Utilities (GPU) licensing group that provided the licensing interface for Met Ed with the NRC. Consistent with the applicable regulations, 10 C.F.R. 50.59, GPU licensing did not believe that NRC staff approval was required prior to implementation of the revised plan. When the revised emergency plan was submitted to the NRC, it was identified as Amendment 65 to the TMI-Unit 2 FSAR, and was directed to the NRC licensing project manager with a letter dated May 11, 1978.[10] This submission was considered by GPU licensing to be for information and not a formal request for approval by the NRC.

Unknown to the licensee, the submission of an amendment to an FSAR-described emergency plan resulted in a review of the plan pursuant to the earlier NRC position to backfit the requirements of Regulatory Guide 1.101. When the staff received the revised emergency plan, they found that the plan did not fully conform to the staff position as stated in Regulatory Guide 1.101, Revision 1 and was, therefore, not acceptable. In a staff memorandum dated November 1, 1978, the NRC reviewer stated, "The licensee should be instructed to revise the submittal to conform to Regulatory Guide 1.101, Revision 1, and in the interim, to abide by the provisions of the emergency plan previously approved as stated in the Safety Evaluation Report for Three Mile Island Unit 2, dated September 1976."[11]

No action was taken by the NRC with respect to notifying Met Ed or GPU of the staff's position on the emergency plan with respect to Regulatory Guide 1.101. As of March 28, Met Ed, not having heard to the contrary, believed that the emergency plan in effect was that contained in Amendment 65 to the FSAR. It was this plan on which Met Ed based their response to the accident.

c. The Emergency Plan in Effect on March 28, 1979

Appendix 13A, Three Mile Island Site Emergency Plan, submitted as Amendment 65 to the FSAR, is organized substantially on the same format as Regulatory Guide 1.101, Annex B. Dubiel stated that Met Ed rewrote their emergency plan using Regulatory Guide 1.101 as a basis, and that they attempted to make the old and new plans compatible because of the training that had already been accomplished under the original plan. The review of the submittal by the Environmental Evaluation Branches, Division of Operating Reactors, Office of Nuclear Reactor Regulation, had identified areas where the discussion of certain elements of Regulatory Guide 1.101 was either deficient or missing. The NRC staff did not notify Met Ed or GPU of their findings. Some

NRC findings that were of significance during or following the accident of March 28 were:

- Your classification system does not include an Emergency Alert Class as described in Regulatory Guide 1.101 at Section 4.1.2. A site emergency includes a condition of 125 mR/h at the security fence. Such a dose rate must be the result of a serious incident requiring a General Emergency response.
- Your listing of a Spectrum of Postulated Accidents in Section 2.2 should include instrumentation capability for prompt detection and continued assessment and manpower needs in relation to the anticipated sequence and timing of events.
- Section 4.2, Assessment Actions, of your plan places emphasis on in-plant radiation monitors and on and offsite surveys, but makes no mention of process instrumentation. Section 4.1.5 of Regulatory Guide 1.101 states that 'emergency action levels and other criteria for declaring a General Emergency should be specified in terms of information readily available in the control room. Such information should include the status of engineered safeguards.' As backup to such installed instrumentation your plan should include estimated dose rates at a convenient location outside containment, e.g., opposite the equipment hatch or outside the personnel airlock, for the following:
    - (a) release of primary coolant activity into containment
    - (b) release of core gap activity into containment
    - (c) release of activity from 1% core melt into containment
    - (d) release of activity from 10% core melt into containment
- Activation criteria for declaration of emergencies should be defined in terms of control room instrument readings and should also be related to protective action guides incorporated in USEPA guidance. (Regulatory Guide 1.101, Section 4.1.4.)
- Sections 4.3.1 and 4.3.2 of your plan should be expanded to include the following information specified under Section 6.4 of Regulatory Guide 1.101:
    - (a) steps to provide visitors to the plant and to make available to occupants in the low population zone information concerning how the emergency plans provide for notification to them and how they can expect to be advised what to do.
    - (b) the means and the time required to warn or advise persons in the low population zone.
    - (c) protective actions including isolation and area access, control of agricultural and water supplies, and the criteria for such actions...[12]
- Section 4.4.2 states that first aid and decontamination facilities are maintained at the Unit #1 ECS (Emergency Control Station) and the two service buildings. Your plan should also describe provisions for first aid, monitoring and decontamination of personnel and of vehicles evacuating from the site.[11]

Certain other information identified as missing or incomplete was in Met Ed's possession but had not been included in the submittal.

An unannounced inspection of emergency planning was conducted at TMI-1 and TMI-2 by an NRC radiation specialist in July 1978. This inspection included an examination of revisions to emergency plan implementing procedures. The revisions were found to provide the same or higher degree of preparedness than the previous procedures. The licensee had satisfied the administrative requirements for procedure changes. Additionally, the licensee conducted several emergency plan drills during the latter part of 1978. One of these drills was observed by NRC inspectors. As a result of observations during the drill and discussions with the NRC inspectors, portions of the emergency procedures were revised early in 1979.[7] These revisions were subsequently reviewed and approved in accordance with the licensee's procedures.

Met Ed's radiation emergency plan in effect on March 28, 1979, was part of Station Administrative Procedure 1004. This procedure included guidance and procedures pertinent to the plan and defined three types of emergencies:

1. Personnel or Local Emergencies are accidents or incidents involving one or more individuals and/or protective evacuation of one or more buildings. A personnel emergency may require local offsite services such as fire, police, ambulance, or medical.
2. Site Emergencies are accidents or incidents with the potential for uncontrolled release of radioactivity to the immediate environment. Site evacuation by nonessential personnel may be required. This emergency constitutes a potential for offsite radiological exposures.
3. General Emergencies are accidents or incidents with potential serious radiological consequences for the health and safety of the general public. Coordination with offsite support agencies is initiated to provide for protective actions.

The plan contained the following:

1. A section on Organizational Control of Emergencies describes the onsite emergency organization, staffing and responsibilities, and provisions for augmentation of the onsite organization by various offsite groups.
2. A section on Emergency Measures describes the delegation of authority to declare an emergency and provides for notification of station personnel and state officials. The plant monitoring systems

and on- and offsite monitoring are described with respect to assessment actions. Protective actions, aid to affected personnel, emergency exposure criteria, first aid and decontamination, medical transportation, medical treatment, and backup medical treatment are also included.

3. A section on Emergency Facilities identifies the affected unit control room as the Unit 1 and 2 Emergency Control Centers. The unaffected unit control room is identified as the Alternate Emergency Control Center. The Emergency Control Station for either unit is located in the radiation protection laboratory of Unit 1 with an alternate location in the Unit 2 Shift Supervisor's office. The offsite Emergency Control Station is identified as the TMI Observation Center. Communications systems are identified, as are natural phenomena and radiological, nonradiological, and environmental monitoring equipment and systems. Damage control equipment is identified.
4. A section on Maintaining Emergency Preparedness identifies groups requiring specialized training and provides for training program administration and emergency plan drills as a means of testing equipment and personnel familiarity with assigned duties. Drill types, purpose and frequency are identified. Critiques are required following drills.
5. A section on Recovery and Reentry addresses general considerations on recovery, emergency exposure guidelines, and reentry.
6. A section on Written Agreements for the Coordination of Emergency Planning states that written agreements have been reached with various local, State and Federal agencies that ensure a clear understanding of responsibilities and proper coordination of activities, and identify the type of support to be provided.

The second volume of Met Ed's Station Administrative Procedure 1004 included a Radiation Emergency Checklist, an abbreviated instruction for use by plant personnel to ensure that required actions were completed; a procedure for Recall of Standby Personnel to Plant; and two procedures concerning the plant communications systems. The emergency plan implementing procedures developed by Met Ed addressed those topics identified in Annex B to Regulatory Guide 1.101.

Met Ed's administrative procedures and operational quality assurance plan provided a mechanism for procedure review and approval; specified a procedure review frequency; and provided for procedure revision, review, and approval. These administrative procedures were required by the plant technical specifications. Procedures in effect at the time of the accident had been reviewed and approved in accordance with Met Ed's procedures.

Revisions to procedures can be initiated by Met Ed supervisors on the TMI station staff but are subject to review by PORC. Prior to the accident, it was not required that revisions to radiation emergency plan procedures be referred to the acting emergency plan coordinator. They would have come to his attention only if he had been a member of the PORC when the revision was reviewed.[13]

d. Training Philosophy—Classroom vs. Drills

The section of the plan entitled "Maintaining Emergency Preparedness, Personnel with Emergency Responsibility" states:

> Members of the Three Mile Island staff having responsibilities in relation to the Emergency Plan will be required to participate in appropriate training programs or drills. Certain off-site agencies with emergency responsibilities will also be invited to participate in appropriate training programs and drills conducted at TMI.

The various training programs were to provide program participants with the necessary information to ensure continued effectiveness of the plan when combined with the required drills.

e. Training—Goals vs. Accomplishments

The members of the TMI staff assigned specific emergency roles required training appropriate to the assignments. The training programs were to be conducted annually. The supervisor of training was assigned the responsibility for scheduling, instructor assignments, and training documentation maintenance. The training department did not have qualified instructors in the areas of specialized instruction necessary and was dependent upon personnel from other onsite groups for the preparation of lesson plans and for instructors.

Procedure 1670.9, "Emergency Training and Emergency Drills," specified the employee classification that could be called upon to fill any of the specific categories in the emergency response organization. The procedure further specified that all members of the staff were required to be familiar with their duties and responsibilities. As originally issued, the procedure required training of all individuals who might be called upon to fill one of the emergency categories. Although the emergency training was offered annually, an individual who was trained and qualified one year retained that qualification throughout the following year. The training procedure was developed in response to Regulatory Guide 1.101. During 1978, Met Ed attempted to satisfy the training requirements contained in the procedure.

In early 1979, the procedure was revised to avoid a situation in which noncompliance for failure to follow procedures was inevitable. The change in procedures occurred after discussions with NRC inspectors who questioned the licensee's training accomplishments.[14,15] As originally prepared, the procedure called for 100% training of personnel that might be assigned to emergency response roles. The training department found, however, that their lack of authority to obtain the required lesson plans and to control trainee attendance made the goal unachievable. Correspondence from the training organization to various onsite organizations during the period April 1978 to February 1979 identified an increasing concern regarding the inability to accomplish the training.[16] As a result, in February 1979, Procedure 1670.9 was amended to remove the 100% training requirement and instead place a limitation on personnel assignments. This change stated that only those individuals who had received the appropriate training were to be assigned to the following emergency response categories:

Accident Assessment Personnel
Radiological Monitoring Team
Fire Brigade Team
Repair Party Team
First Aid Rescue Team

The imposition of this limitation on assignments required a plant roster that identified the emergency training each individual had received. Additional information not contained in the roster was located in training records. This information, as of March 1, 1979, is summarized in Table III-2.

Procedure 1670.9 also provided for training of offsite emergency personnel. On October 12, 1978, training was conducted for offsite agencies and organizations, including:

Porter-Gertz Consultants
Pennsylvania Bureau of Radiation Protection (BRP)
Pennsylvania State Council of Civil Defense (now PEMA)
Londonderry Fire Company
Goldsboro Fire Department
York Haven Police Department
Susquehanna-York Haven Fire Department
Dauphin County Office of Emergency Preparedness
Pennsylvania State Police (PSP)

On December 5, 1978, the annual training session for local fire companies was conducted. A total of 28 representatives attended, including representatives of Londonderry Fire Company, Union Hose Company No. 1, Rescue Hose Company No. 3, Bainbridge Fire Company, and Liberty Fire Company.

Judged on the basis of the early philosophy of 100% training, the licensee was not totally successful in his training of plant personnel. The failure was not numerically significant, except in the case of repair party team training. Met Ed's training personnel said that the repair party team training deficiency resulted from a misunderstanding. The personnel trained were mechanical maintenance personnel only; instruments and controls, and electrical maintenance personnel did not receive any training. The nature of the misunderstanding was communicated to G. Miller, Station Manager, in February 1979. However, corrective action had not been accomplished at the time of the accident. Additional repair party team training was conducted in January 1979, but the instructor was not familiar with the material presented and the training was, therefore, not credited.

The emergency plan stated that site or general emergency drills would be conducted annually, consistent with Regulatory Guide 1.101. The drill program conducted by the licensee in 1978 included seven drills. The seventh drill was observed by NRC inspectors. The drills were of varied scenarios and included situations which, while unbelievable during the drills, actually came to pass during the accident. Some of the staff believed the drills were unrealistic because of the simulated high radiation levels and other data with which they were provided during the drills. A frequent comment was that this belief disappeared on March 28.

During their inspection of the seventh drill, the NRC inspectors identified no noncompliance. However, they did discuss records of times at which radiological measurements were taken and the "use of existing procedures to project thyroid critical path doses prior to receipt of environmental air sample results."

f. Training Effectiveness

On the day of the accident some personnel were assigned to radiation monitoring and repair party teams who had not been trained for the duties to which they were assigned. In addition, certain of the training provided was inadequate. Radiation monitoring teams were required to use a gamma scintillation detector. dual-channel analyzer (Eberline Instrument Company, Stabilized Assay Meter SAM-2/RD-19) to measure the radioactivity in air samples. Several Met Ed rad chem techs expressed

TABLE III-2. Plant roster of emergency training received by Met Ed employees

Employee Position	Employee Category	Employees in Category	Category Employees Trained	Noncategory Employees Trained
Emergency Director	Station and Unit Supt., Unit Supt. - Tech. Support, Supervisor of Operations, Shift Supervisors, Shift Foremen	28	25	6
Accident Assessment Personnel	Group 1: Supervisor of Operations, Shift Supervisors, Shift Foremen, Control Room Operators	53	49	18 in Both Groups 1&2
	Group 2: Supervisor - Radiation Protection & Chemistry, Radiation Protection Foremen, Rad Chem Techs, Shift Supervisors, Nuclear Engineers	28	25	—
Radiation Monitoring Team	Rad Chem Techs, Auxiliary Operators "A"	51	45	42
Repair Party Team	Maintenance Shift Workers (designated by Supervisor of Maintenance)	40	19	—
Fire Brigade Team	Aux. Operators, Rad Chem Tech Jrs.	87	84	274
First Aid/Rescue Team	Rad Chem Techs, Auxiliary Operators "A"	51	50	168
Training Program for Operations Personnel (Emergency Plan)	Supervisor of Operations, Shift Supervisors, Shift Foremen, Control Room Operators, Aux. Operators	136	136	—
Training Program for Plant Security Personnel	Supervisor - Plant Security, Security Sargeants, Security Guards	48	45	—

concerns about the training prior to the accident. Although training was provided, the training and limited opportunity to become familiar with the SAM-2 instrument seemed inadequate. An individual experienced with instruments stated that an electronics technician in his employ became competent in the use of the instrument after "playing" with one for 40 to 50 hours.[17] Although probably extreme, this example tends to indicate that a demonstration or limited use during a short classroom session or drill is insufficient.

Notwithstanding the aforementioned shortcomings, we believe that the response of plant personnel to the radiation emergency resulting from the accident at TMI-2 was reasonably effective. Frequently during interviews, Met Ed personnel stated that the response to the radiological emergency had been good and that it had gone unrecognized. They attributed the success of the response to the drills.

The drills provided valuable training that resulted in speeding the dispatch of offsite teams, improved accountability, personnel familiarity with emergency roles, practice in unusual evolutions, personnel familiarity with the potential for high dose rates and airborne levels and, in general, improved ability to respond to an accident.

Had the licensee been content only to satisfy the requirements of Regulatory Guide 1.101 and of the TMI Emergency Plan for one site or general emergency drill each year, the licensee would have been less able to mount an effective response.

g. Offsite Agencies—Training and Interface

State and local agencies participated in training and drills conducted by the TMI staff. Reports of communications on March 28, 1979, between Margaret Reilly, Chief, Division of Environmental Radiation; and W. Dornsife, Nuclear Engineer, Bureau of Radiation Protection; K. Molloy, Director of Emergency Preparedness for Dauphin County; and R. Dubiel, Supervisor, Radiation Protection and Chemistry, TMI; show that the individuals knew one another and had knowledge of Met Ed's radiological emergency plan.

The following extract of a transcribed telephone conversation between Dubiel and Molloy during the morning of March 28 demonstrates the working relationship between the site and local agencies in the immediate area.

> Dubiel: Kevin — Dick Dubiel. Okay, we are in for real.
>
> Molloy: Okay.
>
> Dubiel: Okay, it looks like — we are not exactly sure. We've got the core covered right now. I don't think we've got a real big problem, but we've got some bad radiation readings that could, in fact, be erroneous, but we can't rely on that, okay. Uh, what I need is, I need to get Maggie Reilly [BRP], the foreman, back in touch with us.
>
> Molloy: Okay, ... we'll take care of it.[18]

Met Ed had conducted training and orientation programs and provided the opportunity for participation in drills to the State and local agencies. Met Ed had apparently satisfied any outstanding commitments to the State and local agencies in the area of radiological emergency response planning.

h. Summary of Findings and Recommendations

Findings

- The criteria included in the emergency plan for declaration of a site emergency were nonconservative and no emergency alert classification was included. These deficiencies were recognized by the NRC but were not communicated to Met Ed. These deficiencies could have delayed both the identification and declaration of the emergency.
- The possible value of active, real-time, on- and offsite monitors during an accident was an issue considered and rejected during the TMI Unit 2 prelicensing hearings.
- A training program that included seven emergency plan drills held shortly before the accident, and which also attempted to provide training for all personnel with emergency response assignments, significantly aided in the ability of the plant staff to respond to the accident.
- The importance assigned to emergency plan training by the TMI supervisory staff was less than warranted; furthermore, when training inadequacies were identified by plant staff members, corrective actions were only marginally effective.
- The present Regulatory Guide 1.101 position, which provides for one drill prior to initial fuel loading and annual drills thereafter, is not adequate to provide for the level of training and practical experience required to respond to a major accident.
- Inadequacies in the TMI emergency plan and preparations are attributable, in part, to the low priority placed on those subjects by the NRC.

Recommendations

- Regulatory Guide 1.101 should be revised to include a requirement that each nuclear utility employee with an emergency response assignment receive appropriate training and participate in at least one emergency plan drill each year.
- The NRC should expedite review and upgrading of existing emergency planning and preparation requirements.

REFERENCES AND NOTES

[1]Memorandum from E. G. Case, NRC, to L. V. Gossick, "Regulatory Requirements Review Committee Meeting No. 31," July 11, 1975.

[2]Memorandum from E. G. Case, NRC, to L. V. Gossick, "Regulatory Requirements Review Committee Meeting No. 34," August 22, 1975.

[3]E. Luton, E. O. Salo, and G. A. Linenberger, "Atomic Safety Licensing Board - 6 NRC 1185 (1979)," p. 1201, Docket 50-320, December 1977.

[4]*Id.* at 1202.

[5]Gerusky dep. at 42-43.

[6]Herbein dep. at 98-101.

[7]Landry Interview Memo at 1.

[8]Donaldson Interview Memo at 1.

[9]*Id.* at 3.

[10]Tsaggaris Interview Memo at 2.

[11]Memorandum (and attached report) from G. Knighton, NRC, to R. Reid, "Three Mile Island Revised Emergency Plan," November 1, 1978.

[12]*Id.* at Enclosure 1.

[13]Landry Interview Memo at 5.

[14]*Id.* at 4-5.

[15]McCormick Interview Memo at 1-2.

[16]Correspondence and records of telephone conversations from F. McCormick, TMI, to various members of the TMI staff, April 5, 1978 to February 14, 1979, concerning training.

[17]Jacobs Interview Memo at 3.

[18]Inspection and Enforcement: Telephone Call Transcript, R. Dubiel, TMI, to K. Molloy, Dauphin County; March 28, 1979, TMI tape No. 210.

B NRC RESPONSE

1. INTRODUCTION

This section of Volume II deals with the response of the Nuclear Regulatory Commission (NRC) to the accident at Three Mile Island (TMI). The section begins with a brief background of some of the agency's primary performers during the TMI emergency, outlining their roles in the NRC's organizational structure; then it considers the NRC's emergency response structure as described in agency documents when the accident began. A narrative account of selected aspects of the NRC's actual emergency response follows this introduction. The narrative account focuses primarily on the first 5 days of the accident. This account, designed as a vehicle for evaluating the quality of the agency's response, is immediately followed by the evaluation. A summary of recommendations concerning the agency's emergency response is provided in Section III.B.3.c.

This section does not focus on the NRC's relationship with the media during the accident at TMI. That subject is discussed in Section III.D.

The NRC's Principal Emergency Response Cast and Their Roles in the Daily Organization

The NRC is headed by five Commissioners—John Ahearne, Peter Bradford, Victor Gilinsky, Joseph Hendrie, and Richard Kennedy. Their offices are located on H Street in downtown Washington, D.C., 5 miles from most of the agency's staff personnel, who work in offices scattered throughout the Maryland suburbs (see Figure III-9). Each Commissioner has "equal responsibility and authority in all decisions and actions of the Commission."[1] The chairman of the five-member commission is "the principal executive officer" and exercises "all of the executive and administrative functions of the Commission."[2] Although the precise authority of the chairman when compared to the other four Commissioners seems unsettled, Commissioner Kennedy interprets it thus:

> I'm a 20 percent shareholder.... The 20 percent that I'm talking about is 20 percent of perhaps 90 percent. I have 20 percent of all of the substantive questions and issues that are the responsibility of the agency.
>
> But I don't have 20 percent of the execution responsibilities. Those things are a matter...for the Chairman to execute.[3]

Until recently, Joseph Hendrie served as Chairman of the NRC. Hendrie, unlike the other four Commissioners, previously held senior staff positions within the agency.[4] Hendrie has more substantial expertise concerning nuclear reactor systems than any other Commissioner. On the third day of the TMI accident, former Chairman Hendrie took an active role in managing the agency's emergency response and was a prime motivator of the NRC's efforts to determine whether the hydrogen bubble lodged in the reactor vessel was potentially explosive. The roles played by the other Commissioners during the TMI accident varied widely, but none of the other Commissioners were as directly involved as Hendrie in managing the NRC response.

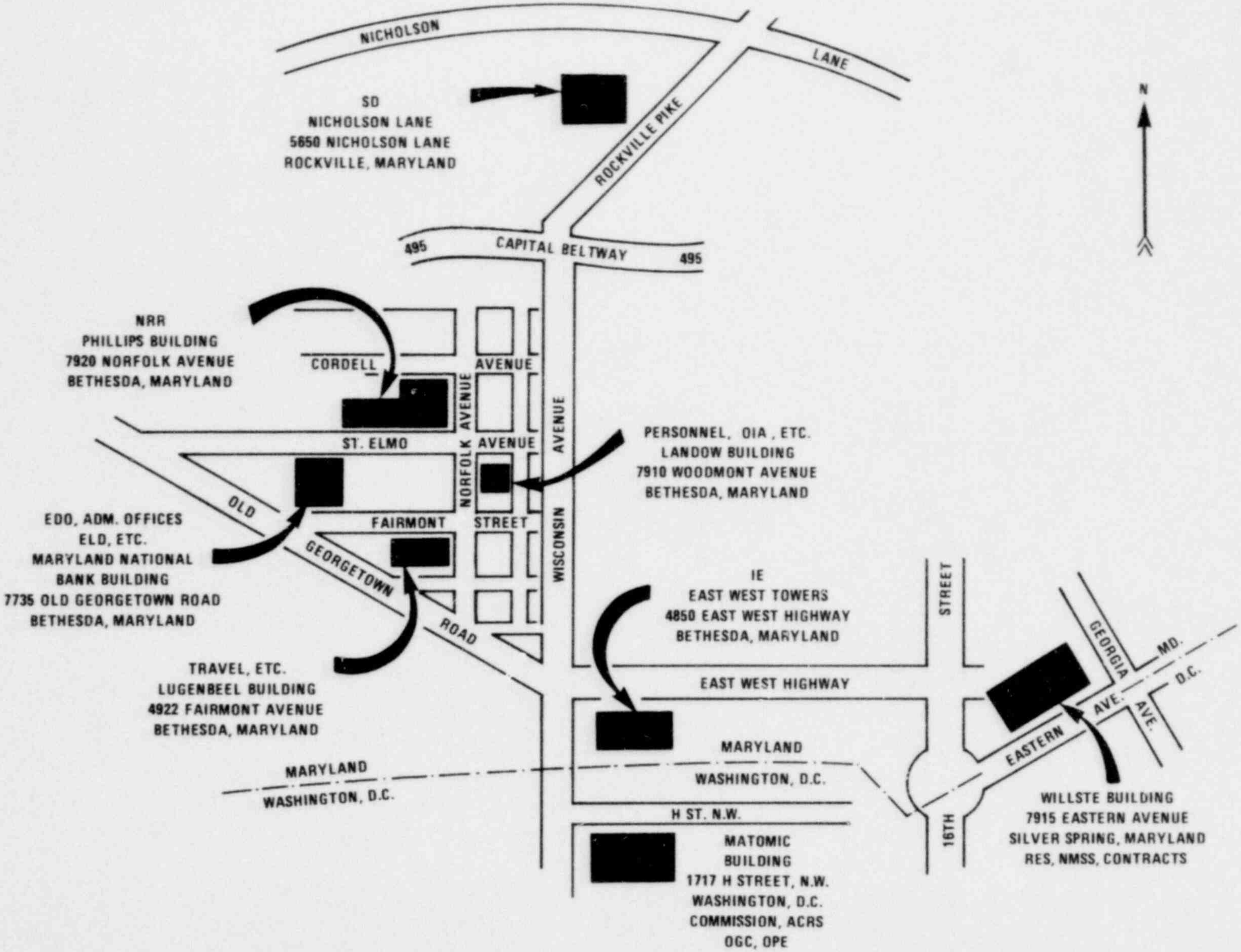


FIGURE III-9. NRC Headquarters Locations

The NRC's emergency response during the TMI accident involved many but not all of the agency's staff level offices. Figure III-10 displays the organizational structure of the NRC, truncated to show the staff offices that played a significant role in the response. Figure III-11 repeats this organizational display to show some of the principal emergency response personnel from NRC Headquarters in their normal organizational positions during the accident.[5] This discussion will focus principally on two staff offices—the Office of Nuclear Reactor Regulation and the Office of Inspection and Enforcement.

By statute, the Office of Nuclear Reactor Regulation (NRR) is responsible for licensing and regulating all facilities associated with the construction and operation of nuclear reactors. The NRR personnel are located in the Phillips Building in Bethesda, Md., about 20 to 25 minutes travel time from the Commissioners' Washington, D.C. offices. The NRR reviews the safety of all such facilities by "monitoring, testing, and recommending upgrading of systems to prevent substantial health or safety hazards."[6]

Harold Denton is the Director of the NRR and Edson Case is Denton's Deputy Director. During the TMI accident, Denton and Case each served at different times as a member of the Headquarters-based Executive Management Team (EMT), which was assigned responsibility for managing the agency's emergency response. On the third day, Denton was rushed to the site to take onsite command of the NRC's effort.

Of the four divisions within the NRR, the two of primary interest are the Division of Systems Safety and the Division of Operating Reactors. The Division of Systems Safety is responsible for reviewing and evaluating most of the engineering aspects of every application for a reactor construction permit or a reactor operating license. Roger Mattson is Director of this division within the NRR. Presumably because of his position, one newspaper reporting on the accident at TMI described Mattson as "the NRC's top safety expert."[7] Mattson had no assigned role at the beginning of the accident, but he soon became responsible for a wide range of the agency's technical support efforts, including its ill-fated attempt to determine the potential hazards of the hydrogen bubble.

The second division within the NRR, the Division of Operating Reactors, is responsible for reviewing and evaluating proposed design and operational changes at a reactor facility after the reactor is licensed. However, in the case of the TMI-2 reactor, which had been licensed for more than a year, the Division of Operating Reactors had not yet taken over this responsibility for administrative reasons. The Division of Operating Reactors also is responsible for analyzing operating events and ensuring that these experiences are taken into account in the licensing process.

On March 28, Victor Stello, Jr., was Director of this Division and Darrell Eisenhut was his Deputy Director. Both have principal expertise in reactor systems. During the first days of the TMI accident, Stello was a designated member of the Incident Response Action Coordination Team (IRACT), which was the principal supportive arm of the EMT. Stello generally supervised all NRR staff members who worked for IRACT during the beginning of the accident. Because of his expertise, however, Stello was more directly involved in IRACT's evaluation of reactor systems data.

At the time of the TMI accident, Richard Vollmer and Brian Grimes served as Assistant Directors under Stello and Eisenhut. Vollmer was chosen to lead the first team of NRC officials sent from Headquarters to the site on March 29. Grimes, a radiology specialist who had done a great deal of work in radiological emergency response planning, worked at Headquarters for IRACT. Grimes was assigned by Stello to take direct charge of the NRR members who were evaluating radiological data.

A second major office within NRC is the Office of Inspection and Enforcement (IE). IE personnel are located in the East-West Towers building in Bethesda, Md., which is approximately 1 mile from the NRR (Phillips Building). During the TMI accident, the Headquarters emergency response generally was managed from an Incident Response Center located in the East-West Towers building.

The IE's principal responsibilities are to inspect reactor facilities both during construction and after the facilities are completed and licensed to operate. The IE also ensures compliance with NRC licenses, rules, and regulations. The IE personnel spend more time "in the field" than NRR personnel because of inspection functions. When IE officials identify either a need to change the terms of a reactor operating license, or a problem in interpretation of the license, the matter is referred through IE officials at Headquarters to the NRR where final decisions concerning the license are made. Many NRR officials seem to consider themselves more technically talented than IE officials and in at least one respect NRR is treated as a more important office than IE. The Energy Reorganization Act of 1974, as amended, positions the director of NRR one executive grade level above the level of the IE director.[8]

On March 28, 1979, John Davis was Deputy Director of IE. The director's position was then vacant (and had been for about a year) so Davis also

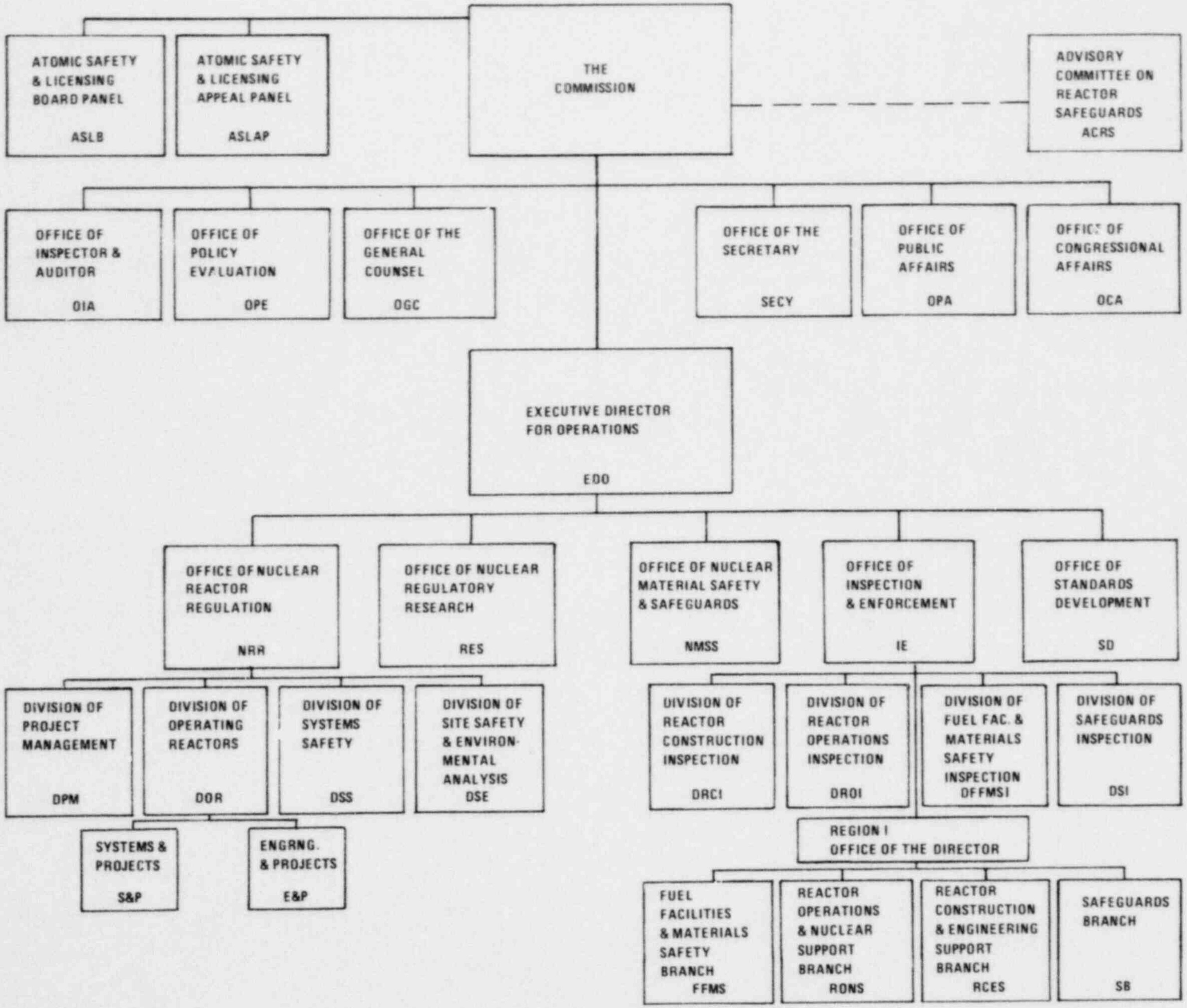


FIGURE III-10. Simplified NRC Organization Chart

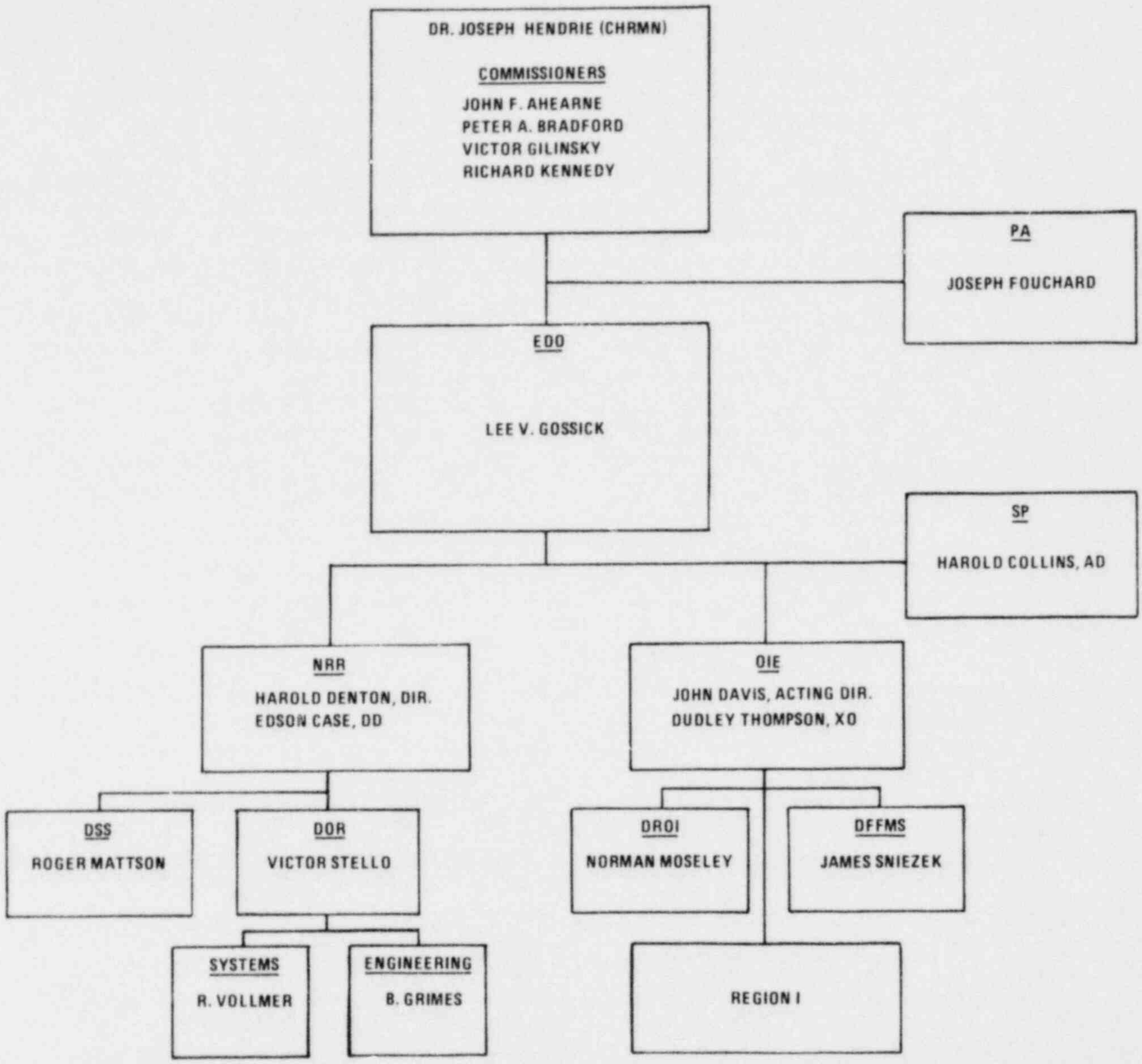


FIGURE III-11. Simplified NRC Organization Chart

served as Acting Director. (Since the TMI accident, Stello has been appointed Director of IE.) As Acting Director, Davis also was a member of the Headquarters-based EMT during the accident.

Four divisions exist within IE. Two are of interest, the Division of Reactor Operations Inspection and the Division of Fuel Facilities and Materials Safety Inspection.

The Division of Reactor Operations Inspection is responsible for inspecting reactor systems once they are licensed. This division is the IE counterpart of the NRR's Division of Operating Reactors. On March 28, 1979, Norman Moseley was Director. During the emergency, Moseley was designated to act as "Director" of the Headquarters-based IRACT, but as matters evolved, he divided his IRACT responsibilities with Stello. Moseley headed IE staff members involved in the Headquarters emergency response, and Stello was in charge of NRR personnel. Both Stello and Moseley have principal expertise in reactor systems, and during the TMI accident Moseley was involved more directly with IE personnel who worked on that aspect of the accident. The IE personnel principally gathered reactor systems information from the site and referred the information to NRR reactor specialists for evaluation.

The IE Division of Fuel Facilities and Materials Safety Inspection is responsible for conducting safety inspections of all reactor facilities. Most of the division's members specialize in health physics matters. James Sniezek is Director of this division. During the TMI emergency, Sniezek supervised IE personnel at Headquarters who worked for IRACT on the radiological aspects of the accident. Sniezek's personnel primarily gathered radiological survey data from the site and then referred this information to NRR members for calculations and evaluation.[9]

The Office of Inspection and Enforcement also includes five regional offices located throughout the United States. The Region I office sent the NRC's initial emergency response team to Three Mile Island. Figure III-12 displays pertinent parts of Region I's organizational structure to show some of the principal NRC emergency response personnel from Region I in their normal organizational position during the accident.

On March 28, 1979, the Director of Region I was Boyce Grier and James Allan was Grier's Deputy. As an IE staff member, Grier's communications with Headquarters during the TMI crisis were generally with IE officials such as Moseley and Davis rather than with NRR officials such as Stello or Denton. Grier had overall supervisory authority over the initial emergency response team sent to the accident, but he personally did not go to the site until midday Friday.

The Region I office has four branches. The duties and functions of these branches generally coincide with those of IE's four divisions at Headquarters. The two of interest are Region I's Fuel Facilities and Materials Safety Inspection Branch, the counterpart of Sniezek's Division at Headquarters, and Region I's Reactor Operations and Nuclear Support Branch, the counterpart of Moseley's Division at Headquarters. George Smith directs Region I's Fuel Facilities and Materials Safety Inspection Branch. Eldon Brunner supervises its Reactor Operations and Nuclear Support Branch. Neither Smith nor Brunner went to Three Mile Island until Friday, March 30, when Smith joined the onsite team. Instead, they remained at Region I "coordinating" the radiological and reactor operations efforts. As Figure III-12 shows, all of the Region I personnel who went to the site on Wednesday or Thursday normally worked under Brunner or Smith in Region I offices.

The daily affairs of the entire NRC staff are managed by an Executive Director for Operations (EDO). The EDO is appointed by and serves the Commission. As with the NRR and IE directors, the EDO works in a separate office building in Bethesda, Md., 5 miles from the office of the Commissioners. Although directors of major offices such as NRR and IE are required to keep the EDO "fully and currently informed" concerning communications with the Commission, these office directors report directly to the Commission, not to the EDO. Moreover, the Commission, not the EDO, has the power to hire and fire the major office directors. Lee Gossick, the present EDO, says that the function of this position is to ensure that the other offices are working in a coordinated fashion.[10] Gossick served as a member of the EMT during the accident and was by formal designation the EMT's "Director."

In the NRC's normal organizational configuration, a number of offices that are smaller than IE and NRR report directly to the EDO. One such office is the Office of State Programs, which is responsible for cooperating with the States on nuclear licensing and for assisting State and local authorities in the preparation of emergency plans. On the third day of the accident, when the EMT hastily decided to recommend evacuation from the area of the TMI plant, an official from the Office of State Programs, Harold Collins, was given the task of calling State officials to transmit the NRC's recommendation.

The preceding is not intended to be a complete description of the NRC organization and its functions.

The Agency's Written Emergency Response Plans

The NRC has a series of documents providing instructions on how the agency should respond to an emergency. Pertinent documents include (1) NRC Manual Chapter 0502, NRC Incident Response Program, which provides the foundation for all agency response planning; (2) a Headquarters Incident Response Plan, the most complete text dealing with the emergency response of NRC personnel at Headquarters; (3) various Incident Response Procedures, which are prepared by and for divisions within the Office of Inspection and Enforcement; and (4) a Region I Incident Response Plan, which is prepared by and for IE's Region I personnel. These documents are not always consistent, but the outline of the NRC's emergency response organization emerges from them. What follows is a discussion of this emergency organization as it was described in the documents when the accident at TMI began. For convenience, the Headquarters and the Region I components will be dealt with separately. (A more detailed discussion of the agency's emergency response planning, entitled "Background on NRC Planning for Its Response to Emergencies," may be found in Appendix III.1.)

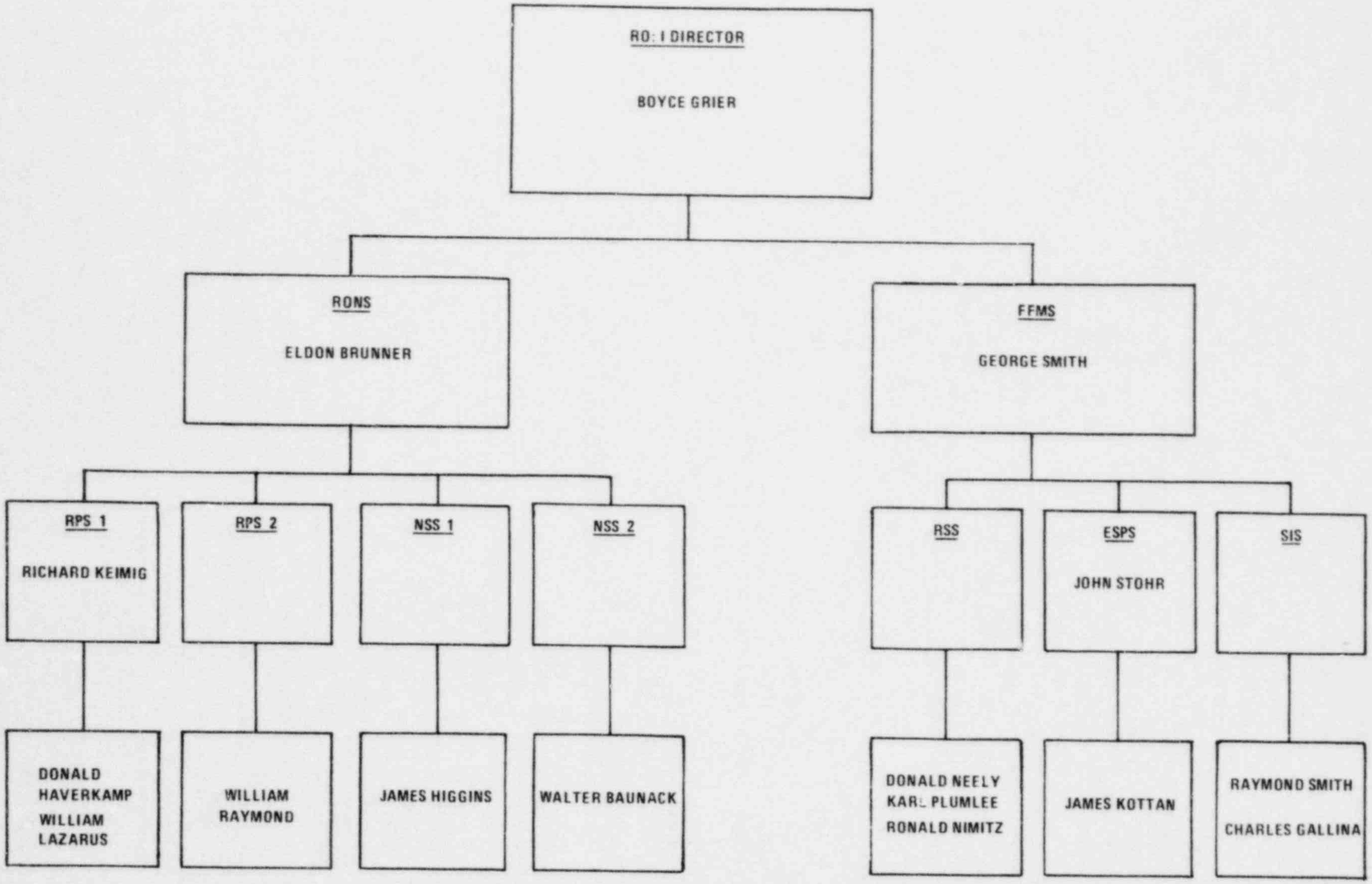


FIGURE III-12. Principals in NRC TMI Response, Region I

The Headquarters Organization

Primary responsibility for managing a major incident such as the TMI accident rests with senior NRC staff officials at Headquarters who in an emergency form an Executive Management Team (EMT).

According to the NRC Headquarters Incident Response Plan, the EMT's functions during an emergency include the following:[11]

- On the basis of Commission policy, provide guidance for determining [the] extent of NRC response to [a] particular incident.
- Make decisions concerning significant NRC actions during [an] incident, e.g., should NRC provide assistance or onsite direction?
- Approve specific NRC directives to the licensee during incident response.
- Coordinate policy with other agencies and resolve any conflicts between NRC and Federal, State, or local agencies.

Neither the Headquarters Incident Response Plan nor any other emergency response document discusses what type of "assistance or onsite direction" should be considered by the EMT or when. These documents also do not discuss important advice that may have to be given to a State, such as evacuation recommendations. (See Appendix III.1 for a discussion of the agency's long-standing hesitancy to define clearly its role in an accident vis-a-vis the licensee and the State.)

According to the pertinent emergency response documents, the only role of the Commission in an emergency is to provide "general policy which determines the overall course of action NRC takes in response to incidents."[12] As Commissioner Gilinsky has stated: "dealing with emergencies was delegated to a staff organization specifically set up for that purpose."[13] In his deposition, former Chairman Hendrie offered one possible explanation for why the EMT is delegated the task of managing a nuclear emergency:

> I really didn't expect [the Commissioners would] have much of a role because I anticipated that events would probably move fast enough so that there simply wouldn't be time to involve the Commission which, as a collegial body, is a very slow-moving animal in that kind of discussion.[14]

NRC Manual Chapter 0502 indicates that in every accident the EMT will consist of the EDO, the directors of IE and NRR, and the Director of the Office of Nuclear Material Safety and Safeguards (NMSS).[15] However, the director of NMSS did not serve on the EMT and played no significant role during the accident at TMI. Although no document clearly states this, participation by the NRR and NMSS directors apparently depends on the nature of the accident.

According to the emergency response documents, the EDO acts as "Director" of the EMT. The documents, however, fail to indicate the EMT director's distinct duties or authority. When the TMI accident began, Gossick interpreted his duties as EMT director as primarily requiring him to ensure that proper procedures were followed:

> [The director's role was] primarily to see that the staff was brought physically together in such a way as to respond in whatever way seemed appropriate or necessary in an event of this or any other kind, and to make sure that the overall operations of the staff... proceeded as we had more or less laid [it] out... and so forth.[16]

The emergency response documents do not indicate how the members of the EMT should make decisions. During the TMI accident, Gossick's view was that:

> In essence we were in a normal Staff configuration from an organizational standpoint. ... It was primarily the view that the Staff would make recommendations, and to me [sic], if I felt it was appropriate for us to go ahead and carry it out without any further reference to the Commission, we'd go ahead and do it.[17]

The EMT's principal assistance in an incident such as occurred at TMI is provided by an "Incident Response Action Coordination Team" (IRACT). The IRACT's duties include (1) ensuring that the Commission and other Federal agencies are notified of an incident, (2) overseeing the gathering and evaluation of information, (3) identifying problem areas and developing alternative solutions for the EMT, (4) keeping Commissioners and EMT members currently informed concerning the incident, and (5) implementing EMT decisions.[18] For reactor accidents, NRC Manual Chapter 0502 seems to indicate that the IRACT will consist of five members, the four division directors of IE and the director of NRR's Division of Operating Reactors.[19] During the TMI accident, however, only Moseley, the Director of IE's Division of Reactor Operations Inspection, and Stello, the Director of NRR's Division of Operating Reactors, clearly considered themselves IRACT members.[20] The other three IE division directors apparently viewed themselves as members of IRACT's support staff.[21]

According to the written instructions, Norman Moseley, as head of IE's Division of Reactor Operations Inspection, is designated to act as the "Director" of IRACT in reactor accidents. Once again, however, the emergency response documents do not indicate what particular responsibilities or authority are assigned to IRACT's "Director." In his deposition, Moseley provided a general description of the IRACT director's responsibilities that seemed no different from the responsibilities of all IRACT members:

> Q: What were your responsibilities as IRACT director?
>
> A: My responsibilities are to have the people assemble to establish communications with the site to collect information and to have the information reviewed to see if there is any action—to see first if the licensee is doing those things that we feel should be done and if not should make recommendations to EMT for any actions that should be taken by the NRC.[22]

According to the emergency response documents, the EMT and the IRACT are to be located in the Incident Response Center in two adjacent rooms in the East-West Towers building (see Figure III-13). Communication between the two "teams" should be conducted through an EMT/IRACT Liaison Officer. This single officer is expected to periodically brief the EMT on the status of an incident and identify both the "principal questions" being pursued and the actions being taken by IRACT. The EMT questions should be written and delivered to this liaison officer who maintains a record of the questions that are submitted. The EMT members are to "limit their intrusion into the Operations Room."[23] In providing information to the EMT through the liaison officer, IRACT is instructed to provide "evaluation of information acquired," not "unevaluated raw data."[24]

The IRACT's assigned responsibilities are performed by an "IRACT Support Staff." In a serious reactor accident, this support staff should include personnel from a number of distinct organizational components including NRR, IE, and the Office of State Programs. According to NRC Manual Chapter 0502, the work performed by an IRACT support staff member depends on the organizational component from which he or she is drawn. The NRR members of the IRACT support staff are to handle evaluation functions, such as considering the future course of the incident, possible corrective actions, the feasibility of assistance to the licensee, and the need for formal intervention by the NRC. The IE members of the support staff, on the other hand, are responsible for ensuring that personnel are dispatched to the site to "monitor the licensee's activities," gathering information concerning the incident "to assist in NRC's independent evaluation of effects of the incident," and performing "inspection and investigatory functions in the field required to assure the health and safety of the public and to provide information requested by EMT or IRACT." Office of State Program members are expected to identify State capabilities in an emergency, evaluate State actions, and advise IRACT of "alternatives available based on performance levels of State and local authorities."[25]

In "safety incidents" such as at TMI, the NRC Headquarters Incident Response Plan indicates that the IRACT support staff's work should be divided into three functional categories: (1) "situation evaluation" (evaluation of real or potential causes of the incident, and determination of whether the situation is under control and consideration of potential problems), (2) "offsite implications" (evaluation of real or potential impact upon public health and safety including consideration of real or potential radioactive releases and meteorology and the potentially affected population), and (3) "NRC field liaison" (communications among Headquarters, the affected regional office, NRC personnel at the site, and the licensee).[26] The Headquarters plan does not state how these three functions should be staffed. However, because the "situation evaluation" and "offsite implications" functions are evaluative, NRC Manual Chapter 0502 suggests that these functions should be performed by NRR personnel and, because the "NRC field liaison" function constitutes information-gathering work, the chapter suggests that this work should be performed by IE personnel.

Although the emergency response documents generally indicate what is to be done and who should do it, they do not state clearly how the support staff is to be organized and managed. Does the support staff divide into three groups based on function? If so, who is in charge of each? Does the IRACT director, who is from IE, directly manage NRR personnel working on "situation evaluation" or "offsite implications"? Or does he manage only IE personnel doing "field liaison" work? If they work separately, who coordinates the work of NRR personnel and IE personnel? These and other organizational questions are left unanswered. During the first few days of the TMI accident, the support staff separated into two general groups—situation evaluation (generally consisting of reactor specialists) and offsite implications (generally consisting of health physicists). Each of the two groups had two distinct subgroups one consisting of IE personnel who primarily gathered information and the other consisting of NRR personnel who evaluated information. IE officials supervised only IE personnel and NRR officials supervised only NRR personnel.

The Regional Organization

A licensee must report an incident by notifying the appropriate IE regional office, not NRC Head-

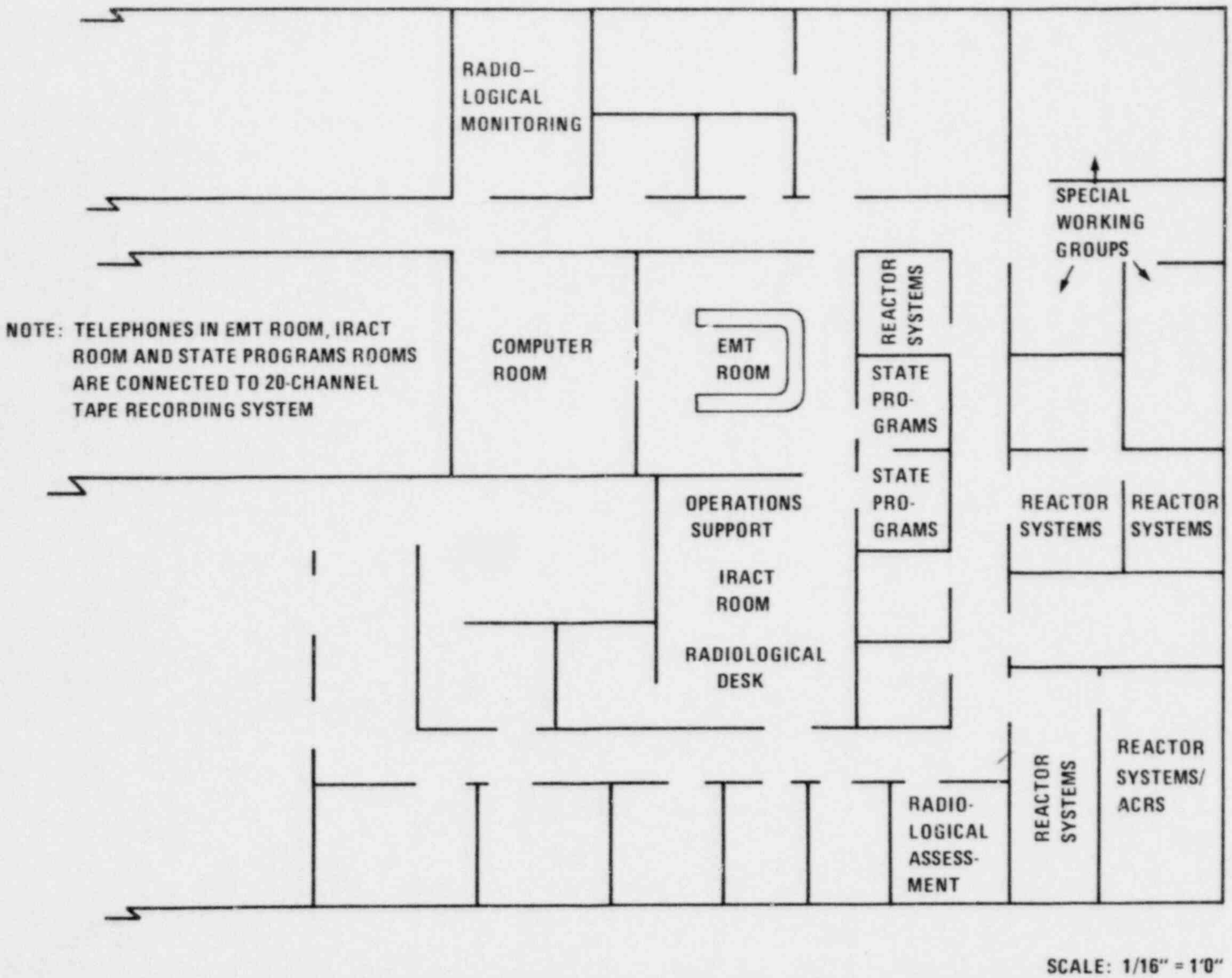


FIGURE III-13. Arrangement of NRC Incident Response Center in EW Towers quarters. It was Region I, then, that was responsible for sending the first team of NRC officials to Three Mile Island.

The stated "policy" of the Region I Incident Response Plan includes (1) sending inspectors to the site "to assure that actions are being taken to protect people, property, and the environment," (2) coordinating its effort with NRC Headquarters and other Federal agencies and "request[ing] their assistance, advice, and support, as appropriate," and (3) providing radiological assistance to licensees and other agencies.[27]

The Region I Plan provides for an incident response organization under the overall authority and supervision of the regional director. The organization consists principally of a Regional Incident Response Action Coordination Team (RIRACT) and an onsite inspection team. The RIRACT, headed by a Region I branch chief, is to receive and evaluate information from the site and provide continuous information updates to the Headquarters IRACT.

The Region I Plan states that the "primary" function of the onsite inspection team is "to serve in an investigative role... in order to gather factual information," although this function may "be subordinated to those of radiological assistance when the nature of the incident is such that health, safety, and property damage prevention measures are required."[28] The plan specifies in an underlined instruction that

> *Region I personnel at the scene must take care to limit their activities to that of objective observation, evaluation and investigation to avoid being directly involved in directing or ordering actions by the licensee or other agencies unless the licensee's organization significantly breaks down.*[29]

According to the plan, the onsite team "will normally consist of four persons" and the plant's project or resident inspector will have supervisory responsibility for the team. It adds, however, that members of the team "will depend on the nature of the incident, e.g., the Regional Director may be Team Leader for Level I [the most serious] response."[30] Region I's plan lists Donald Haverkamp and William Lazarus as the primary and alternate project inspectors for TMI-2, neither of whom went to the site on March 28.

Although the Region I plan refers to the need to coordinate efforts with Headquarters, its language implies that Region I officials, not Headquarters officials, must make the critical judgments:

> Inspectors will be sent to the scene of incidents... to assure that actions are being taken to protect people, property, and the environment...[31]

> The Regional Office... will notify [Headquarters and other Federal agencies] of incidents... and will request their assistance, advice and support, as appropriate.[32]

> [onsite team] members... determine the magnitude of the problem and the hazards to the public...[33]

Region I's plan gives no indication that a Headquarters-based EMT is charged with responsibility for making "major decisions affecting NRC's response actions."[34] Moreover, Region I's plan discusses evaluative work to be performed by regional personnel but does not mention the evaluative functions that are to be performed at Headquarters. Although Region I's plan warns onsite team members to "avoid being directly involved in directing or ordering actions... unless the licensee's organization significantly breaks down,"[35] the plan does not advise that the EMT at Headquarters must "make [the] decisions concerning significant NRC action" such as onsite direction.[36]

2. DESCRIPTION OF NRC EMERGENCY RESPONSE

a. Wednesday, March 28, 1979

The NRC is Notified of the Accident

The Three Mile Island (TMI) accident began at 4:00 a.m. with a loss of condensate and feedwater flow, which promptly led to a turbine trip and a reactor trip. Metropolitan Edison (Met Ed) was not required to notify the NRC of these particular events. By 7:00 a.m., however, the reactor core had been damaged and radioactive materials were being released. Because of the radioactivity, Met Ed declared a site emergency and notified the State of Pennsylvania and the NRC. A Met Ed employee called the NRC's Region I office in King of Prussia, Pennsylvania, at 7:10 a.m. and notified the agency that a site emergency had been declared. Because the regional office was closed at that time, the telephone answering service called the home of James Devlin, the NRC duty officer, and was informed that Devlin was en route to the office. The answering service then called the home of James Allan, the Region I Deputy Director, and discovered that Allan was also en route to the office. Devlin received a signal on his beeper, but, being near the office, decided to continue and answer the call from the office. NRC officials did not learn of the accident until the NRC Region I switchboard opened at 7:45 a.m.[37]

About 7:50 a.m., the Region I office called the TMI-2 control room. Region I was informed that a "site emergency" had been declared shortly before 7:00 a.m. and a "general emergency" had been declared at 7:24 a.m. "Site emergency" was defined in the TMI emergency plan as "the occurrence of an incident which could potentially result in an uncontrolled release of radioactivity." "General emergency" meant an "incident which has the potential for serious radiological consequences to the health and safety of the general public."

About 8:00 a.m., Boyce Grier, Director of Region I, telephoned John Davis, Acting Director of NRC's Office of Inspection and Enforcement, at his office in Bethesda, Md. to notify him of the event. Grier reported that TMI had had a turbine trip, an extraordinary primary system transient, and activation of the safety injection system. Grier reported that, "The loss of feedwater resulted in turbine trip which resulted in reactor trip. What caused the problem there, I don't know. They got safety injection."[38] The plant had lost pressurizer level and developed a bubble in the reactor coolant system; there was also evidence of failed fuel. High activity was reported in the secondary system along with a slight increase in the reactor building pressure.

Region I Initiates Its Emergency Response

Based on information received from Met Ed, Region I designated the accident as a Level I severity incident (the most severe classification),[39] and began to staff its incident response center and gather documents describing the TMI-2 plant. An open telephone line between the TMI-2 control room and the response center was established to enable NRC staff members to gather further details on the accident and the status of the plant.

The Region I officials quickly selected an inspection team of five people to go to the site to observe and report what was happening. Members of this initial team were Charles Gallina, an investigation specialist, who was also an alternate emergency planning officer; Donald Neely, a radiation specialist; Karl Plumlee, a radiation specialist; Ronald Nimitz, a radiation specialist; and James Higgins, a reactor operations inspector. Neely was apparently appointed as the team leader.[40] This team left the regional office for the Three Mile Island plant at about 8:40 a.m.

The Region I Incident Response Plan indicates that in a reactor emergency the project inspector will be sent to the site to act as the team leader. However, Donald Haverkamp, the project inspector for TMI-1 and TMI-2, was not sent to the site until the second day after the accident; he had been assigned to work in the regional incident response center as a communicator on Wednesday and part of Thursday. William Lazarus, the alternate project inspector for TMI-1 and TMI-2, had visited the TMI-2 plant only once during a familiarization visit about a year and a half earlier. He remained at the Region I office on Wednesday.

Shortly after the first team left, two more Region I staff members (Walter Baunack, a reactor operations inspector, and Raymond Smith, an investigation specialist) were dispatched to the site. Region I also summoned its mobile laboratory van to Three Mile Island. This van, which is equipped with air sampling equipment and radiation measuring instruments to make independent radiological measurements, was at the Millstone Nuclear Plant in Connecticut at the time. Appendix III.2 describes the deployment of NRC personnel and their management structure for the first few days of the emergency.

The Region I actions were initiated and carried out by a Regional Incident Response Action Coordination Team (RIRACT). The Region I director and deputy director directed the activities. The principal members of RIRACT were Eldon Brunner, who coordinated the reactor operations response activities, and George Smith, who coordinated the radiological and environmental activities. Other Region I staff members were designated to assist RIRACT by handling communications between the site and NRC Headquarters in Bethesda, Md. This staff also handled notifications of various State and Federal agencies. Region I contacted the Pennsylvania Bureau of Radiation Protection at 8:50 a.m. Region I also telephoned State officials in Delaware, New York, New Jersey, Maryland, and Connecticut commencing at 10:30 a.m. Calls were also made to the Department of Energy's Radiological Assistance Team at Brookhaven National Laboratory at about 8:45 a.m., the Federal Preparedness Agency Region II at 11:30 a.m., and the Environmental Protection Agency Region III at 12:04 p.m.

Headquarters Initiates Its Emergency Response

Beginning about 8:00 a.m., emergency response measures were initiated at NRC's Headquarters offices. At that time, Joseph Fouchard, Director of the NRC's Office of Public Affairs, called John Davis, Acting Director of the NRC's Office of Inspection and Enforcement (IE), and asked him if he knew anything of the happening at Three Mile Island. Fouchard had received a call from his Public Affairs Officer, Karl Abraham, in Region I. This was the first that Davis had heard of the accident. A few minutes later, Davis received a call from Boyce Grier, Director of Region I. Grier explained to Davis what he knew of the accident at that time.

After talking with Grier, Davis directed Dudley Thompson, the operations officer for an incident response, to activate the Headquarters Incident Response Center. Davis then went to the center and called Lee Gossick, NRC's Executive Director for Operations (EDO), at his office to recommend activation of the agency's Executive Management Team (EMT). Gossick, designated as the director of the EMT, agreed and left to go to the center. Davis, also a member of the EMT, proceeded to notify Harold Denton, Director, Office of Nuclear Reactor Regulation (NRR), a third member of the EMT for incidents involving nuclear powerplants. Denton was not immediately available, so Edson Case, NRR Deputy Director, went to the center in his place.

Notice of the accident was called to the NRC Commissioners starting at 8:53 a.m.[41] Joseph Hendrie, the Chairman of the NRC, was away from the office that morning. In his absence, Victor Gilinsky, the Commissioner with highest seniority, assumed the role of acting chairman. Upon being notified, Commissioner John Ahearne went directly to the response center as an "observer . . . monitoring what they were doing, trying to understand how did the NRC react in an emergency."[42]

As notifications went out to Commissioners, Dudley Thompson and other designated members of the emergency response staff began to set up the incident response center in accordance with the Headquarters Incident Response Plan. Moseley organized an Incident Response Action Coordination Team (IRACT) and a support staff. Moseley called Victor Stello, Director of the Division of Operating Reactors, designated as a member of the IRACT in the event of reactor incidents, to notify him of the incident. Moseley told Stello, however, that indications were that the reactor was all right, and that the problem was probably related to a radiological release inside the reactor containment system. Moseley also told Stello that he did not need to come to the response center, and instead suggested that Stello send someone from his division with radiological expertise.[43] Accordingly, Stello sent Brian Grimes to work with the IRACT. When Edson Case arrived at the incident response center, he requested that Stello come to the center immediately.

The responsibility for communicating with outside agencies was assigned to Bernard Weiss, the Operations Communication Officer. At 9:00 a.m., he notified the Department of Energy (DOE) at the DOE Emergency Operations Center in Germantown, Md., explaining that the NRC might be requesting aerial surveillance assistance shortly. The NRC's request for assistance was withheld until 11:00 a.m. The NRC dispatched a staff member to the DOE Emergency Operations Center in Germantown, shortly after 9:00 a.m. to act as NRC Headquarters coordinator with DOE. In addition to calling DOE, NRC Headquarters called the Environmental Protection Agency at 9:02 a.m.; NRC Congressional Oversight Committees and Pennsylvania Congressmen from 9:10 a.m. to 9:30 a.m.; and the White House Situation Room at 9:15 a.m.

Staff from the NRC Office of State Programs established Headquarters liaison with the Pennsylvania Bureau of Radiation Protection at 10:45 a.m. This staff also made calls to officials in surrounding states to inform them of the accident.

The NRC Incident Response Plan specified that the Director of the Division of Operations Inspection (Moseley) would direct the IRACT. The plan also specified that the Director of the Division of Operating Reactors (Stello) would be a member of the IRACT in cases of incidents at nuclear reactors. In actuality, Moseley did not act as Director of IRACT except during the initial activation and staffing of the response center. At other times, Moseley and Stello operated as joint leaders for reactor operational matters. James Sniezek, Director of IE's Division of Fuel Facility and Materials Safety Inspection, together with Brian Grimes, Assistant Director in NRR's Division of Operating Reactors, jointly coordinated radiological issues.

In accordance with the Headquarters Incident Response Plan procedures, communications between the IRACT and the EMT were initially handled by a liaison officer. He was supposed to carry written messages or requests for information back and forth between the two groups. Written communications, however, were only briefly used and no systematic record was kept of EMT requests for information or of IRACT answers. The procedure for coordinating communications between the EMT and IRACT through a liaison officer was quickly found to be too time consuming and consequently dropped. EMT members began to communicate directly with individual members of IRACT or its support staff. Communications developed along organizational lines; the NRR member of EMT tended to talk directly to the NRR support staff, and the IE member of EMT tended to talk directly with the IE staff members. Dudley Thompson informed us[44]

> [T]here was a great deal of difficulty on the part of both EMT members and IRACT members of disconnecting themselves from their organizational responsibilities and loyalties within the day-to-day NRC function and reestablishment of relationships specified in the incident response plan for the emergency condition.
>
> * * *
>
> [T]here was a substantial inclination on the part of EMT members to obtain information they felt was crucial to their decisionmaking process from their own home staffs, in many cases by physically leaving the EMT room and going to collar the individual from whom they wanted to obtain the information and questioning him face to face, rather than transmitting questions as was proposed in the response plan in written form through the liaison member of IRACT to get information back. At the same time, because of the evolutionary process of information coming into the center, there was a strong inclination on the part of the IRACT members, particularly senior IRACT members, to take what bits of information were available at a given moment in time and feed them directly to a representative on EMT, most frequently the representative with whom they were most familiar; that is, the man who was their boss in day-to-day activities.

Two groups were organized and located at separate tables in the IRACT room, one to deal with radiological issues and one to deal with reactor operations issues. At first, the two groups consisted primarily of IE staff members who gathered information. When NRR members came to the center to assist IRACT, they were stationed in satellite offices outside of the IRACT areas of the response center.

A field communicator was assigned to maintain an open telephone line to the Region I Incident Response Center and to transmit all requests and receive all information from that office. Initially, Headquarters had only one telephone line open to the Region I Incident Response Center; through this line, the Headquarters field communicator could ask the region for information and thereafter received whatever information the region had been able to obtain. Before the arrival of its onsite team, the region obtained its information by relaying the Headquarters' information requests to a Met Ed plant operator.

Before 10:00 a.m., the Met Ed operator was located in the TMI-2 control room. Shortly after 10:00 a.m., however, the operator was forced to evacuate the TMI-2 control room and the communications link with Region I had to be transferred to the TMI-1 control room.

On March 28, IRACT's radiological group bypassed the field communicator by calling Region I on a separate line. This resulted in a delay of the region's response to Headquarters' questions on operations matters, because the region had only one line to the site and all questions, both radiological and operational, had to be handled by the TMI plant operator. This was temporarily resolved when Stello asked the region to accept only requests for information that came through the field communicator.

During the morning of March 28, the Headquarters personnel responsible for operations had a second source of information about the status of the reactor at Three Mile Island. Before Stello left for the response center, he told his deputy, Darrell Eisenhut, to gather a staff team to provide additional technical assistance. Eisenhut did so immediately and found himself waiting for information from the response center. Eager to help, Eisenhut called Babcock and Wilcox (B&W), the company that had designed and fabricated the reactor, about 10:00 a.m. to find out what that company knew. Although B&W's information was incomplete, Eisenhut maintained communications with the company and exchanged information throughout the day.

The Region I Team Arrives On Site and Begins Work

Shortly after 10:00 a.m., the initial five-man team from the Region I office arrived at the site and entered the TMI-1 control room. The control room was already occupied by Met Ed as a center for gathering radiological data. Neely, who was acting as team leader, directed Gallina and Nimitz to establish a command center in the shift supervisor's office adjoining the control room. The team immediately called the Region I Incident Response Center to report its arrival at the site and to indicate it had established contact from a telephone in the TMI-1 shift supervisor's office. Except for an occasional loss of connection, this telephone link was held open to the region response center for days. Appendix III.3 describes the telephone communications used by the NRC in the first days of the emergency.

At the TMI-1 control room, the onsite team was briefed on the status of the plant by the Met Ed shift supervisor, James Seelinger, and other Met Ed officials.[45] Team members learned that the atmosphere in the TMI-2 control room was contaminated and entry would require protective face masks. Neely, who was the lead health physicist, and Higgins, who was the only NRC reactor inspector present at the time, entered the TMI-2 control room at about 11:00 a.m. They were the first NRC officials to enter TMI-2 following the accident. Later they established a communications link with Region I and remained in TMI-2 until about 7:30 p.m. Neely and Higgins followed the activities in TMI-2 and relayed information to other NRC officials.

About the same time Higgins and Neely left to go into the TMI-2 control room, Baunack and Smith arrived from Region I, bringing the total onsite NRC force to seven. At the request of G. Smith at the Region I Incident Response Center, one member, Plumlee, began conducting a radiation survey around the exterior of the facility. Nimitz, Baunack, R. Smith, and Gallina remained in the area of the TMI-1 control room and assisted in gathering information requested by the region over the TMI-1 telephone; Gallina took control of the telephone to the region.

Shortly after 1:00 p.m., airborne radioactivity in the TMI-1 control room necessitated the use of face masks by Nimitz and Gallina. Nimitz continued to act as intermediary between Gallina, who was manning the telephone, and the emergency control station in TMI-1 that was receiving survey data and wind speed directions. Baunack and Smith were unable to obtain face masks and consequently had to leave the area. They were not able to return until about 3:00 p.m. at which time they joined Higgins and Neely in the TMI-2 control room.

Communications with the Site—A Continuing Problem

As the morning passed, Headquarters personnel became dissatisfied with its indirect telephone link through Region I to the site. As a result, a tie-in was established between the TMI-1 line and Headquarters at about 12:30 p.m., permitting a three-way conversation between Region I, the TMI-1 control room, and Headquarters. However, Headquarters still lacked any direct communications link to NRC inspectors in TMI-2; the onsite information had to be passed through Region I to Headquarters. At approximately 4:30 p.m., a three-way telephone connection also was established between TMI-2, Headquarters, and the regional office. Concurrently, the TMI-1 line was changed to a two-way connection between TMI-1 and the regional office. Thereafter, the TMI-1 line was used for radiological information and the TMI-2 line was used for operational information.

Throughout Wednesday, Headquarters operations staff members were frustrated by the fact that they were talking to people at both the region and the site who neither had reactor operations background nor understood the questions being asked. Their direct tie to TMI-1 was manned by Gallina, who had a radiation protection (health physics) background; Gallina was assisted by Nimitz, who also had a health physics background.

Communications problems, however, were not attributable only to the NRC officials at the site. The Headquarters tape transcripts indicate that IRACT staff members tended to ask their questions in piecemeal fashion with little attempt to group questions together in a manner that would make it easier for onsite personnel to gather answers efficiently. Also, Headquarters did not explain why requested information was needed or what it was concerned about. As an onsite recipient of Headquarters' persistent requests for reactor information, Higgins' perspective was that:

> There didn't appear to be any filtering of the questions [by Headquarters] to determine which were important, which should be asked first, which shouldn't be asked; that type of thing.[46]
>
> * * *
>
> There were . . . investigative-type questions, questions on system design, questions for many, many parameters, a lot of which didn't really pertain to the particular situation at hand.[47]

Higgins felt he could communicate better with Region I than with Headquarters. He told us[48]

> I felt much better able to communicate my findings, my discussions, and so forth, with what was going on in the plant with the people that were in the Region, particularly Don Haverkamp, than to people in Washington.
>
> * * *
>
> Really, the people in Region I were, first of all, familiar with me, and that helped a little bit. Additionally, they were familiar with the types of things that go on in the plant, in a Control Room, much more so than the people in Washington. Whereas, when I discussed these things with them, they knew what I was talking about.
>
> Beyond that, the people in the Region had some familiarity with people, the positions of these people at Met Ed and the specifics of the Control Room that the people in Washington didn't have. They also appreciated a little more, I think, the types of

things I was going through on the site and were able to put a little bit of that into the questions they asked.

2:00 p.m. to 8:00 p.m.: Growing Concern at Headquarters

The limited data that NRC offices acquired during the day indicated continuing problems. First, bits of information received indicated that the reactor was not being fully depressurized. Second, additional information began to reflect an exceptional difference in the temperatures of the hot and cold legs (the reactor outlet and inlet pipes). By roughly 2:00 p.m., staffers from Headquarters were comparing the reported hot leg temperatures with the saturation temperature for the prevailing system pressure. Headquarters concluded that the steam bubbles in the system seemed to be in a superheated condition. The only heat source available for this superheating was the core itself, suggesting that at least part of the core was uncovered and being cooled only by steam.

Victor Stello, one of the prominent staff members at the Headquarters Incident Response Center, was worried about the status of the core. Shortly after 4:00 p.m., with information still too sparse to alleviate his concern, Stello tried to take matters into his own hands. He "impulsively" took the phone from the Headquarters field communicator and spoke directly to one of the Met Ed shift supervisors in the TMI-1 control room, Gregory Hitz. Stello told Hitz, "If you really have 550 degrees on that hot leg, it's clear that you're getting some superheat. If you're getting superheat, there's a chance the core could be uncovered."[49] Stello did not order Met Ed to do anything, but rather relayed his anxiety concerning core uncovering. Hitz immediately cited the reasons why the core was already adequately covered, but agreed to pass on the concern to TMI-2.

Shortly afterward, Stello reported the Hitz conversation and his concerns to Commissioner Gilinsky, the acting NRC Chairman. This conversation reflects not only Stello's concern about the core but also Headquarters' poor understanding of the situation at the site:

> Stello: And we're trying to understand why they haven't been willing to open the damn thing—the valves open and let the thing blow down so they can really get enough water in there. They've got bubbles, or whatever they've got to get rid of them.
>
> Gilinsky: Yeah.
>
> Stello: About a half hour or so—or 20 minutes I got on the phone and explained to them that if they really have that hot leg temperature as they've indicated, the only plausible explanation that I could see is superheating, and if they are superheating, they've got to find a way to get more water in their core.[50]
>
> * * *
>
> Gilinsky: Well let me understand what you're saying. You're saying that, in fact, the core may not be covered.
>
> Stello: Right.[51]
>
> * * *
>
> Stello: They're controlling at that pressure for a reason I don't understand, and I've never got an answer that I did understand.[52]
>
> * * *
>
> Gilinsky: And are these guys pretty adept technically?
>
> Stello: Vic, it's awful hard to understand. We're talking through two or three different people at the moment. We're talking through their general principal—one of the inspectors who is running from one control room to another and then relaying information back to—through us, and in some cases, through another man. So I don't really have any way of judging how well equipped they are from any given point of view there. I don't know.
>
> Gilinsky: Who is in charge?
>
> Stello: I don't know.[53]

The conversation also reflects a firm conviction by Headquarters that Met Ed, not the NRC, would be "in charge" of correcting the problems with the reactor:

> Gilinsky: Well is there anything we ought to do about that beyond having talked with this guy?
>
> Stello: The only thing I can think of doing is to use our minds and understanding and tell them what we think based on the facts we hear, and they must make the judgment. We cannot make the judgment here, because we're relying on information that's from too many different channels. I don't have enough information myself to decide what I would de [sic]. I can only react to the facts and raise question for them to consider.[54]
>
> * * *
>
> Gilinsky: We've got to be careful that, you know, they don't start asking us what to do and then....
>
> Stello: No. They're in charge, and we can only offer something that we thought of, but they are absolutely in charge. There can't be any question about that. And we don't want any confusion in anybody's mind, especially in their mind. I mean they are on top of the situation, and we're at the other end of the telephone.
>
> Gilinsky: That's right.[55]
>
> * * *
>
> Stello: We'll make it very clear to them that the decisions that are being made are theirs, and that the only thing we're doing is asking questions.[56]

The single 4:00 p.m. conversation between Stello and Hitz appears to be the only contact between NRC Headquarters and Met Ed. In spite of the frustrating lack of information and Stello's concerns about core cooling, Headquarters officials did not call the plant management directly. According to Stello, "It didn't occur to me to talk to anyone in the management of the plant beyond the individual I talked to."[57]

Nor, it appears, did Headquarters discuss Stello's concern about core cooling with one of the onsite reactor specialists from Region I. Higgins, for example, was in the TMI-2 control room throughout the afternoon, but was never informed of this problem. The following statements were made by Higgins in response to questions asked by the Special Inquiry Group:[58]

> Q: Do you recall any questions or suggestions coming in from Region I or from Bethesda relating to saturation conditions or relating to the core being uncovered?
>
> A: No.
>
> Q: Do you recall anybody over the phone saying, Hey, we think there's a core coverage problem?
>
> A: Definitely not.
>
> Q: You don't recall that?
>
> A: Definitely not, because there were discussions among the caucuses that went on as to Gary Miller saying the type of thing: Does anyone here feel we're not providing adequate core cooling or adequate core coverage? I didn't feel at that time there was a problem. I didn't have an indication the people on the other end of the phone in Washington felt that either.
>
> I guess I can add here some things I found out afterwards?
>
> Q: Sure.
>
> A: Afterwards, that Mr. Stello called the Unit 1 Control Room and talked to an operator there some time in the afternoon and asked that operator to pass on to their management the NRC's concerns about core coverage, which if that happened, it just never did get to the caucuses, never did get to the right people, and in fact was really not the right way to get it to the management because, first, coming from Mr. Stello at that point, that's certainly a significant comment because that represents some type of NRC caucus, I would think, some type of NRC consensus that had that feeling.
>
> If I had heard that, I would have certainly taken some steps to find out why they felt that and tried to communicate that to Met Ed.

Higgins testified that he believed Headquarters could have communicated with him in the TMI-2 control room on Wednesday most of the time during the afternoon.[59] No guidance was provided; only questions were asked by Headquarters.

Midafternoon: Headquarters Decides to Send Its Own Team from Headquarters

While concern mounted about the reactor core, the senior NRC staff at Headquarters discussed the need to send a post-recovery team to the site.[60] Existing license conditions (technical specifications) and procedures were no longer applicable to the plant in its then-existing accident condition. Realizing that new procedures would be needed in order to place the plant in a cold shutdown condition, Headquarters sent a seven-man team of licensing engineers to the site, headed by Richard Vollmer of NRR, presumably to review and approve the revised procedures that the licensee would be preparing. As Vollmer put it: "Well [our mission] was sort of open . . . we had to have a first hand knowledge of what was going on and also they wanted us to reconstruct . . . what had happened."[61]

2:00 p.m. to 8:00 p.m.: Activities at Region I and the Site

As the day progressed, it became clear that additional Region I officials would be needed. At about 1:00 p.m., William Raymond, a reactor operations inspector, was dispatched to the site to relieve either Baunack or Higgins, but he did not begin working until midnight. Raymond, having served as a startup engineer for Babcock and Wilcox at TMI-1, was the first reactor operations inspector with substantial previous experience at Three Mile Island to arrive on site.

At 4:00 p.m., Grier received a call from Norman Moseley at Headquarters who informed him that Headquarters was not getting much information from the site.[62] Grier does not recall what he did in response to the complaint,[63] but a three-way telephone connection was established at 4:34 p.m. between the TMI-2 control room, Region I, and Headquarters.

Moreover, about the same time, Grier directed Richard Keimig, a reactor projects section chief who knew something about the TMI-2 reactor, to go to the site as the senior onsite NRC official to better coordinate the NRC onsite effort. Keimig did not arrive at the site until some 5 hours later.

Shortly after 7:30 p.m., the NRC's mobile laboratory, recalled earlier in the day from the Millstone Plant in Connecticut, arrived at the plant with John (Phil) Stohr and James Kottan.

During this period, members of the onsite team were trying to obtain and evaluate reactor information while keeping Headquarters posted. The onsite team seemed to be fighting a losing battle as Higgins later testified:

> I think if we had a dozen people there getting answers to the questions we couldn't have gotten them all and still kept up with the on-going developing situation in the Control Room. So, I tried to give

> my first priority to keeping track of the situation as it was developing in the Control Room, keeping track of management plans for where they were going to go from there, and providing that information back to the region and Washington and picking up as many of the questions that I could and the ones that appeared to be more important to me and provided answers to those back to the region.[64]

In his testimony Higgins also noted:[65]

> I really got no direction as to where to put my priorities from anyone else; so, I set my own as to what I felt was most important.
>
> A lot of time was spent in participating in the caucuses that were held in the Shift Supervisor's office with the plant management there. At the time there were discussions how they were going, from a systems standpoint, go from where they were.
>
> * * *
>
> I was active but I really didn't have too much input. Whenever we had an input or comment, they were willing to listen to us. However, my level of experience with the plant was limited compared to what the plant operators had, and therefore as they got involved in a lot of technical-type discussions on systems and equipment, clearly their knowledge and their experience on how to handle particular things were better than ours. So, therefore, they carried the majority of the discussion for these reasons, and also with the Met Ed and the B&W people.
>
> * * *
>
> I feel if I had known the plant very thoroughly I would have been able to make a much more significant contribution than I did, yes, both to discussions or to helping to correct the on-going situation in the plant but also to be able to provide much better information, much better evaluations back to the Region and to Washington.
>
> Actually, throughout the first day I was on a learning process myself to update myself as to exactly what equipment they had, what parameters were measured where, what the significance of those parameters were.
>
> But by the end of the day I was able to answer a lot of the questions over the phones by going out and getting the information myself directly from the panels. When I first arrived I wasn't able to do that.

Evening Activities at Headquarters and On Site— The Worst Is Believed Over

In the early evening, Region I officials received word that State officials wanted to be briefed about the situation at Three Mile Island. Higgins, Neely, and Gallina were directed by Region I to go Wednesday evening to the State capitol (Harrisburg) to inform the Lieutenant Governor and Governor. Neely and Higgins left the TMI-2 control room at about 7:30 p.m. and were joined by Gallina. They were to go to the observation center and from there be driven in a State Police car to the Capitol. However, Neely's trousers were found to be contaminated, forcing him to remain. Consequently, Higgins and Gallina gave the briefing alone. These two individuals became the principal spokesmen for the NRC to State officials that day and continued in that role through most of the following day.

At about the same time these NRC officials left the site to brief the Lieutenant Governor and Governor, Met Ed was trying to repressurize the reactor and restore reactor coolant pump circulation. Improvement was achieved by 8:00 p.m. and the problem seemed to be under control. NRC officials appear to have played no role in Met Ed's decision to repressurize, but Headquarters personnel were nonetheless pleased. Lee Gossick in a conversation with Commissioner Kennedy late Wednesday night said:

> [E]arlier this evening, oh, in the neighborhood of 9:00 o'clock, things took a turn for the better as far as the reactor is concerned... it was apparent that we still had an air lock or steam binding.... They finally bumped it with the main recirculation pumps and got it cleared up, and now they're coming down in orderly fashion. We're a bit ways yet from a point where we can go on the heat removal system, but we are fairly relaxed now about the reactor itself.[66]

As Stello would later say:

> I had a sense of confidence that the core was being cooled and the worst of the accident was behind us when that pump was started. And I think that there was a general sense of a relaxed attitude at that point, that people felt that that was really the major milestone, getting that pump on and getting water circulating through the system.
>
> So there was a sense of relief and understanding what happened and know where to go from there. There was not a feeling of a great deal of pressure at that point. It was letting things come as they did. No feeling of real urgency that I recall following sometime Wednesday night or Thursday. That it looks like, you know, the biggest part of the problem is behind us. We now need to understand what we have before you can take the next step.[67]

The evening passed in a general atmosphere of relief. Communications were greatly improved, the plant appeared to be in a stabilized cooling mode, and responsible local officials were being briefed by NRC and other personnel on site. Shortly after midnight, NRC issued a press release stating that the plant was cooling, but a high level of radiation existed in the reactor building and some measurable radioactivity releases had occurred off site.

By the end of the day, a total of 11 NRC officials, all from Region I, had been sent to the site.

NRC Contacts with Federal Agencies and Congress

From the initial reporting of the accident, a great deal of interest was expressed by other Federal agencies, congressional oversight committees and congressmen whose districts included or surrounded Three Mile Island. For several days following the accident, the NRC received many calls, most of which were handled by designated NRC senior staff members who devoted practically full time to this effort. Some calls, however, were handled by the top NRC management staff who were directing NRC's emergency response activities. In all, considerable time and effort was involved in keeping Federal agencies and congressional offices informed throughout the emergency.

In late afternoon, NRC Headquarters was notified of the desire of the Subcommittee on Energy and the Environment of the House Committee on Interior and Insular Affairs to be briefed the next day. The NRC staff began preparing the briefing Wednesday night, and selected the senior staff members who would remain at the response center through the night and those who would give the briefings the next day. Darrell Eisenhut, Stello's deputy, and Edward Jordan, Moseley's assistant director, were designated to be the principal spokesmen at the briefings. Lee Gossick, the EMT Director, and Chairman Joseph Hendrie would accompany them.

b. Thursday, March 29, 1979

Activities at Headquarters—Briefing and Fact-Gathering

At 9:55 a.m. five staff members, including EMT members Gossick and Davis, briefed the assembled Commission in their Washington office. Stello's deputy director, Darrell Eisenhut, explained that the "sequence of events that occurred early yesterday morning is a little bit sketchy at this time"[68] and the information Headquarters had "is very preliminary".[69] He indicated, however, that the plant had "somewhat stabilized"[70] and the "primary goal right now is to get the plant down to a temperature configuration where it can switch to the RHR [decay heat removal system] mode."[71]

The briefing to the Commission did not specifically refer to Victor Stello's concern the day before that the existence of superheated steam conditions indicated that the core had been uncovered; this had been previously expressed to Commissioner Gilinsky. Eisenhut, when asked by Hendrie about large differences in hot- and cold-leg temperatures, said:

> Yes. We had some quite large hot-leg cold-leg temperature differentials yesterday of maybe 2- to 300 degrees F.
>
> Our only belief may be that it was associated with some steam binding, perhaps maybe not steam as much as a bubble somewhere in the system.[72]

In deposition, Eisenhut was asked why he did not specifically mention superheating. He responded by referring to the above statement and said:

> Well, I think it's there. I think where you get steam in a PWR is from superheat. Steam is not present in a PWR. It's clearly pointed out this is a PWR. That's why I read the next sentence. It's important to say that the next sentence points it out: "The system was not flowing by natural circulation. Because of that, the licensee elected to go on a path of bringing the system up solid, heating it up and bringing it back to pressure, to try to either collapse or do away with any bubbles in the system."[73]

What was clear to Eisenhut (an engineer) may not have been clear to the Commission. Regarding possible core damage, Eisenhut stated:

> We can't really say too much about the core, except we can make one inference from the activity. The activity levels that we have seen inside the containment would infer that we have had fuel failure. To the degree of fuel failure, it's just unclear. One radiation monitoring instrument located at the operating deck level indicated a radiation level of 10 roentgens per hour. Another monitor in the dome of this building indicated a level of several thousand roentgens per hour, but was suspected of not reading correctly.[74]

With regard to possible health effects, Moseley's assistant director, Edward Jordan, reported that:

> [T]he off-site measurements of radioactivity...indicated that there is no immediate threat to health and safety.... We believe that the off-site airborne radioactivity has resulted in minimal exposures to the public.[75]

Staff members informed the Commission of a "recovery operation" plan using an onsite group under Richard Vollmer. Lee Gossick reported that:

> [T]he team up there at present, of course, are the I&E people that are...following the events and communicating back with us. Mr. Vollmer's group, when they will arrive, will literally assume the responsibility for seeing that the state of the plant is kept in a safe condition; any changes to tech specs and all the things that have to be done to assure the continued safety of everything.[76]

Eisenhut went on to say:

> By that we don't mean taking the primary lead away from the licensee. Another way may be to say that when the incident center closes down at the point the event is in a stable mode, Dick Vollmer's team takes over as sort of incident center on the site.[76]

In response to a question concerning the relationship of NRC with the State and other Federal agencies, Gossick reported:

> My impression is that it has gone quite well. I think early on there may have been some misunderstanding as to what was actually going on. But

certainly, with all of the other federal agencies here it went very smoothly ... [Governor Thornburgh] seemed to be quite satisfied.[77]

While the Commissioners received their briefing, Headquarters officials continued to gather and assess the little information available. Staff members seemed satisfied that the situation was stabilized but remained concerned as to its seriousness. Roger Mattson recalls:[78]

> I recall receiving information that the core had been partially uncovered for several periods of time in the course of Wednesday. I recall receiving information that there were indications of high radioactivity in a number of places in the plant. I recall being told that the licensee's estimate was that the radiation could be explained by an iodine spike or a crud burst, which would be indications of much less severe damage than we came to recognize [later] on Thursday and Friday.
>
> I recall considerable dissatisfaction with that opinion on the part of the staff in general. That is, a tendency to believe that it was more serious than an iodine spike or a crud burst, but also a general feeling of frustration on the part of the technical people who had been involved at the time I was speaking to them, that they had very incomplete and oftentimes conflicting information as to what was going on at Three Mile Island.
>
> * * *
>
> And again there was skepticism—I recall a general feeling of skepticism on the part of the people I talked to in Mr. Eisenhut's office, that that explanation did not comport with all the information that was available from the site, that other information available from the site indicated much more damaging consequences to the fuel.

As the day progressed, the flow of incoming information to Headquarters improved, but did nothing to allay the staff's concerns. By this time, readings of the core exit thermocouples were conducted regularly and still showed superheated steam temperatures at the top of the core. Moreover, by later Thursday afternoon, Headquarters realized that Met Ed was not going into the decay heat removal system phase of cooldown. Edson Case would later recall:[79]

> I think there was, at least on my part, a growing feeling on Thursday that things were getting worse, that we had a rather unusual change to a very unusual situation on our hands. I don't recall any specific thinking on that point, but I also undoubtedly had a warm feeling knowing Vollmer was on the way and would be there shortly.
>
> * * *
>
> I think I perceived [the situation] improved in terms of factual information for sure, because we started getting all thermals and were plotting on those.
>
> As far as confidence in the quality of information, getting significant information from the licensee, I think it was deteriorating during Thursday. In other words, I think there was, at least on my part, a growing feeling that—of lack of confidence in the licensee's performance.

Preliminary results of a reactor coolant sample, taken Thursday afternoon, further heightened Headquarters' concern. Headquarters had been asking for a sample since Wednesday, but high levels of radiation in the auxiliary building had prevented Met Ed from obtaining the sample earlier. The reported radiation dose rate (1000 R/h from a 100 ml sample) brought new attention to the state of the reactor coolant and the reactor core. Stello testified that this "was starting to suggest that you had an awful lot of fission products in there beyond the kind of fission product inventory you might suggest from just a fuel rod failure."[80] Discussions through the evening included the estimate that 10% of the core's radioactive inventory had been released into the coolant.

By late evening, Headquarters had been notified that radioactive gas releases could be expected to continue. Furthermore, radiation readings outside the plant reflected that gas releases originated from the reactor coolant letdown and makeup system and not from spilled water on the auxiliary building floor as initially assumed.

Earlier Thursday afternoon, Chairman Hendrie and NRC senior officials briefed the House Committee on Interior and Insular Affairs, Subcommittee on Energy and the Environment. In the briefing, Eisenhut indicated he had "every reason to believe that the plant is in a stable condition and that the systems are performing in a way we think is well understood at this time."[81] The NRC staff indicated, however, that assessments were still being made concerning the seriousness of the accident and possible steps necessary to bring the reactor to a cold shutdown. When asked whether he was making a "best-case" presentation, Hendrie indicated he was not:

> What I was trying to do was to outline for you what seemed to me to be the most likely situation in view of the limited information we have on the nature of the fission product releases and the general magnitude. The releases that we have seen, the fact that it is limited, apparently, to noble gases, would suggest that there was not any melting. The magnitude suggests that perhaps about one percent of the fuel in the core might have been involved in the cladding cracks.
>
> So I do not know that I am trying to give you the most favorable picture; I am trying to give you the one that seems the most consistent with the other pieces of evidence we have at hand.[82]

The congressional briefing, like the Commission briefing, did not cover the issue concerning superheated steam conditions and possible core uncovering.

The Need to Dump Industrial Waste—Coordination Problems

Early Wednesday morning, Met Ed discontinued dumping industrial wastewater from toilets, showers, and drains into the Susquehanna River. The wastewater contained concentrations of radioactivity well below the NRC disposal limits.

By Thursday afternoon, some 400 000 gallons of water had been accumulated. At this time, Met Ed requested the permission of both the NRC and State officials to release the wastewater. Both State officials and NRC officials on site and in Region I consented provided that the contained radioactivity was below the applicable NRC limits. Dumping had already commenced when the NRC Commissioners were informed of it at 5:30 p.m. As a result, Chairman Hendrie called the NRC Incident Response Center and decided that the EMT and NRC staff had not received adequate information on the subject:[83]

> Hendrie: What's going on with this dump down at Three Mile into the Susquehanna?
>
> • • •
>
> I just got a report they'd released 400 000 gallons of slightly contaminated water into the river.
>
> • • •
>
> I thought they weren't going to do things like that without letting us know.
>
> • • •
>
> Edson Case: Well, they let—as I understand it, they let us know they were dumping the—they maintained, I gather, that it was in the licensed limits.
>
> • • •
>
> Hendrie: Now, it would be—if you—if Three Mile were operating normally then the licensee might find it within his license to go ahead and make this release, that would be all right. In the circumstances, why the impression everybody will have is that he's dumping the contaminated water into the river.
>
> Case: Bad PR, agreed.
>
> • • •
>
> Why don't we just call them up right now and tell them to stop if he hasn't stopped it?
>
> Hendrie: I think something like that would be use—be more useful if we had started a little earlier....

At the EMT's direction, Morris Howard, who was acting as a member of IRACT at the time, called the regional office and told George Smith that the releases should be stopped. Smith had been one of the people who previously indicated that the dumping would be permissible if within the existing NRC limitations. Smith relayed to Headquarters that the releases were within NRC technical specification limits and warned that if not dumped, overflow of the storage tank onto the turbine building floor could occur. Nonetheless, as directed, Smith terminated releases ½ hour later.

At about 8:30 p.m., Joseph Fouchard and Case informed Hendrie that the releases were within the Met Ed technical specification limits and that the State had earlier agreed it would not object as long as the NRC approved. Hendrie told Case that if the EMT had indicated it was "aboard on it" when talking with him earlier (5:30 p.m.) "that would have settled it. It just didn't sound that way when I talked to you."[84] A decision was made to tell the Governor's staff that NRC believed it permissible to release the water and to await the Governor's concurrence before advising Met Ed. Eventually the plant received permission to resume release of the wastewater at 12:15 a.m. Friday morning.

Evening at Headquarters—Identification of a Hydrogen Bubble Concern

By late Thursday evening, Roger Mattson, Thomas Novak, and other analysts at Headquarters had enough information to conclude that there was a large noncondensible bubble in the reactor coolant system. Efforts began to determine how much of this bubble was hydrogen and how to remove the bubble safely. At about 8:30 p.m., analysts at Headquarters called and requested Merrill (Mat) Taylor to estimate the possible radiolytic generation rate of hydrogen if the plant was taken to low pressure. Taylor called back about 10:00 p.m. with a rough estimate that 1 to 2 standard cubic feet of hydrogen would be generated per hour if the pressure of the system was near atmospheric pressure (Appendix III.4). Neither the question nor the answer dealt with the possibility of the system staying at high pressure with a bubble maintaining a hydrogen overpressure on the coolant.

Later Thursday night and into Friday morning, the NRC Headquarters group conversed with B&W personnel at Lynchburg, and discussed holding or depressurizing the reactor coolant system. Although no NRC notes or recollections confirm it, those of D. Nitti of B&W indicate that he told NRC that the generation of hydrogen and oxygen by radiolysis would not be a problem provided the system stayed at pressure with a hydrogen overpressure, which it apparently had.

Activities at the Site—As at Headquarters, the Emphasis Is on Briefing and Fact-Gathering

The NRC significantly increased the quantity of its onsite response force throughout Thursday. Region I dispatched additional inspectors while Vollmer's seven-man team traveled to Three Mile Island from Headquarters. By Thursday's end, there were 28 officials on site, 7 from Headquarters (Vollmer's team) and 21 from Region I.

Most of the day was spent gathering facts concerning the reactor and radiological release data. Operational data was relayed to both NRC Headquarters and Region I by way of a three-way phone connection with the TMI-2 control room. Radiological data was forwarded to Region I from the TMI-1 control room and the data was subsequently relayed to Headquarters. Included in the radiological data sent to the region were two reports of gaseous releases measured above the stack by helicopter. These readings were far higher than other readings reported on Thursday and equalled or exceeded a reading on Friday that eventually triggered a frenzy of action at Headquarters. The first reading on Thursday at 9:40 a.m. was 1200 mR/h (beta-gamma) and 120 mR/h (gamma);[85] the second reading at 2:10 p.m. showed 3000 mR/h (beta-gamma) and 400 mR/h (gamma).[86] Headquarters tape transcripts reflect that the morning reading was transmitted to the Headquarters Incident Response Center, and some circumstantial evidence indicates that the afternoon reading also was transmitted to Headquarters. However, the IRACT support staff members responsible for radiological matters appear to have no recollection of either hearing or seeing these Thursday readings.

James Higgins, the reactor inspector who had spent most of Wednesday in the TMI-2 control room, did not go directly to the plant early Thursday morning. Instead, he was instructed to wait at the motel for the arrival of Vollmer and his team. Upon their arrival, Higgins escorted them to the site and arrived there around noon. After he and Richard Keimig briefed Vollmer's team, Higgins returned to the TMI-2 control room. Less than an hour later, Higgins and Gallina were dispatched to rebrief the Governor and Lieutenant Governor. When Higgins and Gallina left the control room, they were not aware of the very high level of radioactivity in the reactor coolant system. Higgins learned of the highly radioactive sample after the Governor's press conference. After hearing about this sample, he called the Governor's office immediately to report this information.

Although the Vollmer team's general mission was to establish better communications between the site and the NRC staff at Headquarters, as well as better understand what had occurred the day before, instructions to the team were imprecise. With regard to his team activities on Thursday, Vollmer testified:

> I made assignments to the people in my group, as I said, with the radiological people to follow with the I&E operation, to see that they were satisfied that both the extent of the I&E surveys were adequate and that in their view the releases were not something that should be alarming from a public point of view, public safety, we should think about evacuation or anything like that.
>
> Secondly, I asked the systems people to try to get the information they could to start forming a scenario of what had happened to evaluate the systems that could be useful in keeping the reactor conditions in a stable condition in the next—then I think we were talking about the next few hours or few days.[87]

At the site, Vollmer discovered firsthand the difficulty in communicating with NRC Headquarters:

> Communications were very bad. At the observation center [across the river from the plant] there were a few phone lines. Even when the phone was available, some of the circuits were often busy.
>
> I can recall actually crawling under one of the tables to get away from the noise and the people and so on and actually trying to hold a phone conversation back to Bethesda. In one case I had to drive back to Middletown to call back because even the pay phone happened to be out of order at the response center, and there weren't any phones generally available. There were a few homes around there but I didn't feel I would burst in on people and use that. So I drove back to Middletown to make some phone calls.
>
> The communications really were all right after we got back to the motel.[88]

Vollmer felt he solved the communication problems after he returned to his motel Thursday evening and set up a "meeting room" for the team.[88] Nonetheless, Headquarters EMT member Harold Denton would later say:

> My recollection is that Mr. Vollmer's staff fell into an Einsteinian black hole, and communications were so poor that there was either the lack of good communication links with the site, or either Dick was busy doing things and didn't have time to call, but there sure was very little back from Vollmer for the 24 hours that he may have been there.[89]

Onsite officials spent a substantial amount of time attending to congressional delegations. Senator Gary Hart, the Chairman of the Senate Committee on Environmental and Public Works, Subcommittee on Nuclear Regulation, made a personal visit to the reactor site Thursday for a firsthand briefing concerning the accident and a tour of the reactor. Senator Hart was accompanied by several other Congressmen, including Senator John Heinz (R-Pa.) and Representative Allen Ertel (D-Pa.). Later that same afternoon, another congressional delegation, which included Senator Richard Schweiker (R-Pa.), Representative William Goodling (R-Pa.), and Representative Robert Walker (R-Pa.), visited the site for a briefing and tour. The visits by the two congressional delegations came at busy times for both the Met Ed and NRC staffs; nonetheless, all was put aside until the briefings and tours were finished. Richard Keimig, the top IE official on site, spent most of the day preparing for the delegations and escorting them around. Vollmer also spent time taking part in these briefings.

The NRC's Evacuation Discussions with the State

During Thursday, officials of the State of Pennsylvania received evacuation recommendations from private citizens and also, it appears, from Anthony Robbins, Director of the National Institute of Occupational Safety and Health of HEW.[90] Yet, there seems to have been only two fairly brief exchanges on this subject between officials of the State and the NRC. Thursday morning, Commissioner Gilinsky spoke to Lt. Gov. Scranton who asked whether children in nearby Goldsboro should stay indoors. Rather than offer his own view, Gilinsky offered to have an NRC staff member provide advice; shortly thereafter Harold Denton called Mark Knouse of Scranton's staff for that purpose. Denton told Knouse that there was fuel cladding damage but not core or fuel melting. He ascribed the gaseous releases to the spilled water in the auxiliary building and said it was mostly ^{133}Xe gas. When asked about taking precautions to protect school children from iodine activity, Denton said, "I don't think iodine should be the, the concern." Denton went on to address the issue of evacuating older people and the sick, saying "you wouldn't want to create any stress in the elderly," when these radiation levels are "a factor of a thousand or so below the EPA evacuation guidelines."[91] Denton had no further conversations with State officials about evacuation or other protective action during Thursday, nor have we found any indication that the IRACT or IRACT support staff gave serious attention to this subject before Friday morning.

At the Thursday meeting with the Governor, there was extensive discussion of whether to carry out an evacuation of people from areas surrounding the site. Among those present were Higgins and Karl Abraham, the NRC Public Affairs Officer from Region I who was also serving as a liaison with the Governor's office. Abraham suggested that State officials consider the greater sensitivity of certain people, such as pregnant women, to radiation. We could find no information to indicate that Abraham had discussed this view with NRC Headquarters either before or after he offered this suggestion to the Governor.

c. Friday, March 30, 1979

Friday Morning Activities at Headquarters—A Call for Evacuation

The plant had been operating since 8:00 p.m. Wednesday with only one reactor coolant pump providing core cooling flow. The Met Ed staff was carefully watching the core exit thermocouples. Many were still showing high readings, but the temperatures were falling. The plant was slowly cooling down. The plant staff knew that a large bubble of noncondensible gas, perhaps 1000 cubic feet, was trapped in the reactor coolant system. Operators were using the letdown and makeup system to draw reactor coolant and gas out of the system. Once depressurized, the reactor coolant, like open champagne, would free the excess noncondensible gas. The gas relieved was highly radioactive, and the plant staff was trying to hold it in the waste gas storage tanks. None of these operations was proceeding normally, and there was a leak from the piping used to transfer the gas to the waste gas storage tanks. Thus, there were occasional releases of radioactive gas, or burps, to the atmosphere.

Headquarters was receiving increasingly bad news on Thursday night and early Friday morning. There were reports of very high reactor coolant activity, confirmation that the reactor core had been uncovered, high reactor core thermocouple readings, large bubbles of gas in the system, and occasional releases of radioactive gas that were not completely understood. Beginning sometime Thursday, Lake Barrett, an NRR staff member helping the IRACT to evaluate offsite consequences, had become troubled about the potential for increased radioactivity releases to the air:[92]

> We were concerned about the gas that would be going to these tanks...we knew...that the gas entering the waste gas decay tanks was highly radioactive and we were concerned that these tanks had enough capacity to keep receiving this gas, that we would not have this gas being released directly to the environment.
>
> * * *
>
> We could never seem to get any firm information on the status of the waste gas decay tanks.

The EMT Hurriedly Considers Evacuation

About 9:00 a.m. the highest level NRC staff at Headquarters began to gather at the incident response center. Harold Denton had just returned from an appearance on the Today show and was receiving a concentrated briefing when an unfortunate series of events occurred.

According to a Region I message form, a report at 8:45 a.m. from James Higgins at the site read:[93]

> [S]eal return to makeup tank is causing excessive offgas in makeup tank which in turn is directed to waste gas tanks which are full. Waste tank being dumped to STACK which is causing a more considerable release rate. Civil Defense and State are being notified by licensee.

In his deposition, Higgins stated that he remembered passing on information regarding "different aspects of [the] release path in the makeup system and the vent system" to Region I, but it is unclear whether the Region I message form accurately reflects a report sent by Higgins that morning.[94] The substance of this message apparently was relayed to Barrett at Headquarters shortly before 9:00 a.m.[95] Barrett considered the message grave. Barrett had previously estimated that a release of 1 curie per second in the gas could produce an offsite dose rate of 20 mR/h. He concluded that, with the waste gas tanks full, there was no additional storage space for the gas being let down from the reactor coolant system to the makeup tank, so the gas would be released to the atmosphere through relief valves at the rate at which it was being let down. Barrett calculated that the release could be about 60 curies per second, giving an offsite dose rate of 1200 mR/h.

Barrett was just reporting his rough calculations to people assembled in the EMT room when a report was received that there had been "an uncontrolled release of airborne activity from a release point in one of the cooling towers" measuring 1200 mR/h.[96] The report came at 9:09 a.m. from Karl Abraham, the Region I Public Affairs Officer, who was at the Governor's office in Harrisburg. It was clearly a second-hand report. Abraham had been asked by the Governor's staff to verify it. Abraham reported that if the measurement was accurate, the Pennsylvania Emergency Management Agency would immediately start preparing for evacuation.

The designated members of the EMT were Gossick, Denton, and John Davis. Edson Case and others were present in the EMT room. With the reported measurement, those assembled fell into quick debate.

As Denton remembers it, the reported measurement was over the plant, and thus the expected dose rate at the nearest offsite boundary would be 100 to 200 mR/h.[97] But this amount was enough for Denton to conclude that evacuation was necessary. As Denton later explained it:

> [I]t was this uncertainty about what will be the next hour release, and it was just the beginning of leakage from direct opening in the containment.... I think I had had mounting concern about the status of the core from these inputs, and then the 1250 [sic], when that report came in, sort of was the final straw that says here's the beginning... and for all I knew the next hour would be 2000 mR over the plant.[98]

Case had a different understanding about the report. He believed the 1200-mR/h measurement was not an onsite reading at all; it was an offsite reading, one that confirmed Barrett's rough calculations.[99] Case also concluded that evacuation was necessary. With a 1200-mR/h offsite reading, he reasoned, "[Y]ou're in the range or getting close to the range where EPA [Protective Action Guidelines] says evacuate."[100]

Neither Case nor Denton took steps to confirm the accuracy of the reported reading, which each understood differently. According to Case:[101]

> I guess I assumed, rightly or wrongly, that getting the 1200 mR report from IRACT must have come from the Licensee.
>
> * * *
>
> Q: Why wasn't there a decision made to call the state simply to find out what they knew about the situation?
>
> A: Because I never in my wildest dreams would think they had better information than we did.
>
> * * *
>
> Q: And finally, what about a communication to Mr. Vollmer? I know you had indicated that was one person you knew [at the site] and felt comfortable being able to call. Was there an effort made to call him?
>
> A: No.
>
> * * *
>
> A: I guess it's fair to say that I also felt that taking much time at confirming was not the right thing to do, because the longer you took, the more—if indeed it were true—you were resulting in exposures to people while you were verifying it.

Like Case, Denton did not try to confirm the critical report. Denton testified:

> I felt sort of the obligation to make that recommendation without further checking or attempting to verify it, and sort of assumed that it had been verified accurately.[102]

Having determined that an evacuation was necessary, Denton felt that the Commissioners should be called "to get their concurrence"—not because this was required, but because that was "the way the system worked."[103] But when initial efforts to get the Commissioners failed, Denton decided to take action. Apparently unknown to both EMT Director Gossick, who was still trying to reach the Commissioners by telephone,[104] and EMT member Davis,[105] who was in and out of the EMT room, Denton told Harold Collins from the Office of State Programs to advise State officials immediately of the

EMT's evacuation recommendations. Denton gave Collins no specific instructions.[106] Instead, he relied upon Mr. Collins' judgment.

Why didn't Denton call State officials himself? Denton would later explain:

> I looked upon Mr. Collins as being the contact, and in fact I think State Programs had jealously guarded that role in the past, and that contacts with states was to be through State Programs. They were the ones who really knew who the contacts were.[107]

State Officials Are Advised To Evacuate

Collins contacted Col. Oran Henderson, the Director of the Pennsylvania Emergency Management Agency (PEMA), at 9:17 a.m., approximately 8 minutes after Abraham had called in the 1200-mR/h report. PEMA had previously been notified by Met Ed that the plant had had an uncontrolled release that measured 1200-mR/h at 600 ft. above the plant but only 14 mR/h at the site boundary (PEMA log). That report, relayed to the Governor's office, had been given to Abraham to verify.

When Collins reached Henderson, he asked whether PEMA had heard about the release, and Collins was told that PEMA had received a report of 1200 mR/h. With this "confirmation," Collins asked if Henderson had issued any evacuation orders and was told that PEMA was awaiting word from the plant. Although Denton would later say he had "leaned more toward 3 to 5 miles,"[107] Collins then told Henderson "we're recommending here that you go ahead and evacuate...people out to 10 miles from that plume, in the direction of the plume."

The State, however, had evacuation plans for 5 miles, but not 10. Accordingly, Henderson told Collins, "we'll start with 5 maybe."[108]

Henderson alerted his colleagues in PEMA that an evacuation order was imminent, and called the Governor's office to advise him of the recommendation. Meanwhile, Kevin Molloy, Director of the Dauphin County Office of Emergency Preparedness, went on the radio to notify the public that there was a possibility that they might have to evacuate. He went on to provide advice on evacuation preparations.

Why did Collins decide to call PEMA instead of the State of Pennsylvania Bureau of Radiation Protection? Collins testified:

> [T]here was a sense of urgency, such that, I think, people believed the [1200 mR/h] reading and they wanted to do something about it. So there wasn't too much time to do anything. If one was going to do anything to save dose off site, the proper agency to call was Pennsylvania Emergency Management Agency, not the Bureau [sic] of Radiological Health, because it was PEMA that had the responsibility to implement any protective actions; and I think that certainly was what was in my mind and in the minds of other people as well.[109]

The Commissioners Deliberate the Evacuation Question

Lee Gossick did not hold Denton's view on the EMT's authority. He believed that the Commissioners had to decide and act on the evacuation recommendation. Thus, Denton and Gossick were calling the Commissioners with different intentions, Denton to inform the Commission of a staff action, and Gossick to request Commission action. Commissioner Peter Bradford was the first one reached, but soon all the Commissioners were on the line. As the conversations with Commissioners proceeded, Denton indicated that "[w]e did advise the state police to evacuate out to five miles," but there was a clear impression that the Governor was awaiting word from the Commission.[110]

During the time when Denton and Gossick were calling the Commissioners, the State offices in Pennsylvania had reacted negatively to the NRC staff recommendation to evacuate. The recommendation was questioned by the State radiological health authorities who were in touch with the site and saw no technical reason to evacuate. In addition, the Governor questioned Collins' authority to speak for the NRC; he wanted to hear from the chairman of the NRC.

And so the NRC recommendation rested with the Commission. The Commission discussed the evacuation issue, but did not vote. It was clear that the chairman had to speak to Governor Thornburgh shortly with a recommendation. As the discussion went on, more information came in: The release had stopped, and the 1200-mR/h report was a local dose rate directly over the containment building, not an offsite location. Furthermore, the relief valve that had lifted was not a waste gas tank relief valve, but instead was another relief valve from another tank, the makeup tank.

Under questioning from Chairman Hendrie, Denton indicated that in light of new and different facts from the site members, he did not believe there was as much urgency to evacuate as before, but Denton still felt that a precautionary evacuation was in order due to the uncertainty of the situation. On the other hand, Brian Grimes, who was working with the IRACT support staff, told Hendrie the "most that should be done, in my view, is to tell people to stay inside this morning."[111] Of the Commissioners present, only Bradford suggested that the conservative approach was to confirm the staff's evacuation recommendation.[112] Hendrie realized that he had to call the Governor to clarify the NRC position—word had been passed that the State immediately needed to know what the Commission was recommending.

The NRC Chairman and the Governor Talk and an Advisory Is Issued

As the matter was being considered by the Commission, Thornburgh telephoned and was put through to Hendrie at 10:07 a.m. After a brief exchange, Hendrie stated, "it would be desirable to suggest that people out in that northeast quadrant within 5 miles of the plant stay indoors for the next half hour."[113] The conversation was interrupted to allow Hendrie to take information from the site received at the Bethesda response center. When the conversation resumed, Hendrie stated, "I think I would continue to recommend that people stay inside this morning. And as our information improves, hopefully it will, then we can see where we go from there."[114]

Paul Critchlow, with Governor Thornburgh, reported that Thomas Gerusky, Director of the Pennsylvania Bureau of Radiation Protection, had arrived in the Governor's office with radiological data. That data indicated a maximum offsite reading of 14 mR/hr, well below what Denton had expected earlier.[114] Gerusky had advised that the wind was picking up, the plume should be dissipating, and "it probably didn't make any difference now whether people stayed indoors or not."[115]

Thornburgh then asked if there could be any more of those releases. Hendrie told him: "we may very well get them again, I think."[116] Hendrie stated, however, that he trusted it would not happen again "without all of us knowing it in advance and being ready to anticipate what we need to do."[116] Thornburgh asked whether he should order a precautionary evacuation in anticipation of more releases. Hendrie replied, "it would be just as well to wait until we know that they are going to have to make some kind of a water transfer... and then at that time, go ahead and make a precautionary evacuation."[116] In this fashion, Hendrie in effect countermanded the recommendation for evacuation made to State officials earlier that morning.

After he talked with Hendrie, the Governor went on WHP radio at 10:25 a.m. to deal with the many evacuation rumors. He said that an evacuation was not required, but people should stay inside within a 10-mile radius of the plant. This broadcast for people to stay inside, close doors and windows, and shut down air conditioners followed, by 1 hour, Molloy's WHP broadcast for people within 5 miles of the plant to pack their bags and be prepared to evacuate.

Reaction of the NRC Onsite Staff

The NRC onsite staff heard of the radio announcements about evacuation from Met Ed staff. For 2 days, Gallina and Higgins had been the principal NRC spokesmen at the site who had periodically briefed the Governor and answered questions at press conferences; yet, no one had called to ask their opinions of whether NRC should recommend an evacuation of areas surrounding the plant. Both Gallina in TMI-1 and Higgins in TMI-2 immediately tried to call NRC officials offsite to find out what was happening. In Gallina's opinion, an evacuation recommendation by Headquarters

> [W]as just a total mistake. We were violating not only our procedures, we were violating the State's procedures. We were violating the Licensee's procedures by having a direct NRC Headquarters to the Governor's Office type—completely ignoring the technical people on site and the Commonwealth itself who were all saying—you know—'There is no need to evacuate.'[117]

White House Interest in the Accident

Around 10:45 a.m., President Carter called Hendrie. Hendrie reported the plant status at the time, his earlier conversation with Thornburgh, and the existing communications difficulties with the site. The President said he would have the White House communications group help out and added he wanted a "responsible senior official to go to take charge at the site on behalf of the Federal Government, and that he would regard such an officer as his direct contact at the site."

Hendrie responded he had already suggested to Denton that he go and that "[Denton] was the best person."[118] Jody Powell at a 1:36 p.m. press conference said the President had told Hendrie, "to be sure that if they [NRC official] erred, to err on the side of caution and safety and to make sure that if there was any perception of a need for additional assistance that we be informed of it immediately."[119]

Commissioners Reconsider the Need for Evacuation

The Commissioners and the staff continued to discuss Hendrie's advice to the Governor to stay indoors as well as the current uncertain conditions in the plant. Case noted "the information you will have within the next hour maybe [sic] as sketchy or less than you had the last time. The plant is in a tender state, not really knowing what they are doing and I have no confidence they will know come the next. . . ."[120]

After Hendrie had reported his conversation with the President to the Commissioners, further discussion concerning evacuation ensued. Commissioner Bradford brought up the subject of pregnant women, which he had discussed on Thursday with one of the members of his personal staff.[121] If no general evacuation was necessary, what about an evacuation advisory to those who might be particularly sensitive to radiation exposure or those who simply do not need to be in the area? According to Hendrie:

> [I]t boiled down to children and pregnant women where they reasonably could leave, had someplace to go, on the basis that those elements of the population are known to be sensitive to radiation exposure.[122]

Although there was no formal vote, Hendrie thought it was the sense of the Commissioners that it would be prudent to recommend to the Governor an advisory for pregnant women and children to leave the area. Hendrie thus believed the recommendation was in effect a collegial decision.[123]

Governor Issues an Advisory to Pregnant Women and Preschool Children

At 11:40 a.m., Hendrie called the Governor. Hendrie began the conversation with a description of plant status and noted the possibility of further releases. The Governor mentioned that Pennsylvania's Secretary of Health was concerned about the special sensitivity of pregnant women and children and asked for Hendrie's comment. According to Gerusky, who was present, Hendrie said "If my wife was pregnant and I had small children in the area, I would get them out because we don't know what is going to happen."[124] Hendrie and Thornburgh discussed how far out—1, 2, or 3 miles. Gerusky suggested 5 miles because the State had evacuation plans for 5 miles, and the matter was thus settled.

At 12:30 p.m. Governor Thornburgh held a press conference in which he announced:

> Based on advice of the Chairman of NRC and in the interests of taking every precaution, I am advising those who may be particularly susceptible to the effects of radiation, that is, pregnant women and preschool age children, to leave the area within a 5-mile radius of the Three Mile Island facility until further notice. We have also ordered the closing of any schools within this area. I repeat that this and other contingency measures are based on my belief that an excess of caution is best. Current readings are no higher than they were yesterday. However, the continued presence of radioactivity in the area and the possibility of further emissions lead me to exercise the utmost of caution.[125]

Headquarters—A Growing Hydrogen Bubble Concern

The bubble concern first arose late Thursday. Tests by the plant staff indicated that there existed about 1000 cubic feet of uncondensed gas in the reactor coolant system. Through Thursday night and Friday morning, the system analysts debated the meaning of this condition. Finally, the high core outlet temperature readings, the high radioactivity levels in the coolant, and the discovery on Friday of a containment pressure spike at 1:50 p.m. on Wednesday,[126] led to the conclusion that most of that 1000 cubic feet was hydrogen. It was believed to have been produced by massive overheating of the core.

Early on Friday morning, Roger Mattson and his staff, principally under Robert Tedesco, were trying to devise means to remove the bubble from the reactor coolant system. Staff members feared that the bubble could inhibit core cooling. There was also concern about a possible hydrogen burn in the containment building. Conservative calculations showed that releasing the bubble entirely to the containment building could raise the hydrogen concentration in the building by about 2% (Appendix III.4). If there was a total of 4% hydrogen in the building, a burn might be expected.

As Friday morning progressed, the bubble became an evacuation consideration. With news of uncontrolled releases from a full waste gas decay tank, Mattson worried that the plant staff would be forced to depressurize. If they did depressurize, the bubble would simply expand and uncover the core once again. Mattson's concern, first expressed to EMT members, came to a head shortly after noon on Friday when Mattson telephoned the Commissioners to describe the problem. Mattson had played little part in the 1200-mR/h evacuation debate, but he strongly believed the bubble problem justified evacuation. As he put it to the Commission:

> I'm not sure why you are not moving people. Got to say it. I have been saying it down here. I don't know what we are protecting at this point. I think we ought to be moving people.[127]

Hendrie was apparently not persuaded by Mattson's plea. He sent him back to work with an instruction to keep the Commission posted.

Although Mattson's prime concern was that the plant staff would depressurize, no one had passed on this concern to Met Ed officials. Mattson appears to have believed that it was up to the EMT members like Case to do so.[128] Case, however, "assumed" Mattson "was making those kind of contacts."[129]

By Friday evening, Hendrie was worried about the bubble. Earlier in the afternoon, Governor Thornburgh had asked Hendrie about the possibility of the bubble exploding. Hendrie's reply was: "There isn't any oxygen in there [reactor pressure vessel] to combine with that hydrogen so the answer as far as I know is pretty close to zero."[130] However, Hendrie was nagged by the suspicion that radiolysis would ionize the water and produce more free oxygen inside the reactor pressure vessel, oxygen that might combine with the hydrogen in the bubble (Appendix III.4).

Hendrie's concern led to a new direction for the bubble work—investigation of the accumulation of oxygen inside the vessel and the attendant risk of explosion. Previous efforts to calculate the generation of hydrogen and oxygen by radiolysis in a depressurized system like the containment building would now be paralleled by similar calculations for a system with a substantial hydrogen overpressure. The former calculations were focused on the buildup of hydrogen, the latter on the buildup of oxygen. Friday at midnight, Hendrie and Commissioners Gilinsky, Bradford, and Ahearne considered the problem. Hendrie was aware that an overpressure of hydrogen normally suppresses the radiolytic production of more hydrogen and oxygen in a system such as this, but this system was not normal; it was filled with water contaminated with fission products from a badly damaged core.

Interagency Involvement Mushrooms

In the aftermath of President Carter's call to Hendrie, White House officials began to take an active role in the TMI response. Jack Watson, Assistant to the President for Intergovernmental Affairs, was designated by the President to coordinate all Federal agency activities in the response. Watson immediately organized a Federal interagency planning meeting, which was held at 1:30 p.m. Friday afternoon in the White House Situation Room; it was attended by representatives of the White House, the Federal Disaster Assistance Administration, the Federal Preparedness Agency, the Defense Civil Preparedness Agency, the Department of Defense, the Department of Energy, and Chairman Hendrie representing the NRC. At this meeting, Hendrie briefed the attendees on the status of the damaged reactor. He speculated that it might conceivably be necessary to evacuate as far out as 20 miles. He selected this number from "distant recollections... of accident calculations" and not from NRC staff recommendations.[131]

During the remainder of the day, there were frequent conversations between the NRC, the White House, and Federal agencies concerning the situation at the plant. By the end of the day, the Environmental Protection Agency (EPA) and the Department of Health, Education, and Welfare (HEW) had sent representatives to NRC's operations center in Bethesda to facilitate the exchange of information.

At 5:00 p.m. Commissioners Gilinsky and Bradford went to brief EPA and HEW officials about the status of the reactor and radioactivity releases. At that meeting, they indicated that officials might have about 6 hours advance notice of a meltdown.[132]

An interagency meeting also was held Friday night at the Capital City Airport near the site. It was initiated by DOE officials who saw a need to better coordinate the environmental monitoring and data collection activities of the various government agencies working at Three Mile Island. The meeting was attended by representatives from the State, EPA, HEW, and the NRC.[133] At that meeting, DOE was designated to coordinate all of these activities and to ensure that all involved organizations were kept currently informed. DOE's Region I office carried out this responsibility.

Onsite Activities After the NRC's Evacuation Recommendations

At about 12:30 p.m. Friday, Boyce Grier, Director of NRC's Region I office, was told by Headquarters to go to the site to supervise IE personnel. Denton was also preparing to fly to the site from Headquarters; his helicopter arrived at the site at 2:00 p.m. By late afternoon, NRC had 83 people at the site—51 from the NRC's Office of Inspection and Enforcement, 25 from the Office of Nuclear Reactor Regulation, 4 from the Office of State Programs, and 3 from the Office of Public Affairs.

When Hendrie told Denton to go to Three Mile Island, he informed him simply "to take charge of NRC activities at the site," nothing more specific than that.[134] Thus, Denton's plans were only loosely defined. He would "take [my] normal role as head of the safety review of the plant and direct actions in that area."[135] When he left, Denton had not yet "addressed [the] issue" of whether he would have authority to make evacuation recommendations and indeed "if I had felt the need to make further recommendations once I arrived on the scene, I would have done so back through the Commission again." Nor did Denton go to the site with any "firmly defined view" regarding his relationship with the Headquarters EMT.[136] Denton had not had time to make organizational plans concerning the IE and NRR personnel over whom he would "take charge" at the site.[137] Nor had he had time to decide what working relationship to establish between the NRC team and the Met Ed personnel manning the control room.[138] All of these important matters would have to be worked out in the days that followed.

After he arrived at TMI and surveyed the situation, Denton's previous impressions changed in a number of respects. Denton found that he had previously underestimated the degree to which Met Ed personnel were anticipating and working to avoid potential problems. As Denton reported to the Commission Friday afternoon:

> I think one of the things that at least is encouraging, we kind of had the feeling this morning, back there [at Headquarters] that the licensee doesn't even recognize the problems that we're facing with regard to the bubble and damage and what might happen if we were to lose vacuum and so forth and the brief discussions we've had, they seem to comprehend the same sorts of problems and have preliminary plans to cope with it. This takes a little bit of the pressure off the immediacy of my concern this morning. Their people do seem to be quite aware of the same kind of problems that we were having this morning.[139]

Although he had favored evacuation Friday morning, Denton's onsite view was that evacuation was unnecessary. In his deposition, Denton explained why:[140]

> A: I rely heavily on a very competent professional staff. And I don't think they were—they weren't feeling all that comfortable Friday morning—when I talked to some of the same people that went with me. And after getting the people up to the site and having them look into their various areas that they're specialists in, and finding that they were much more convinced of the stability of the situation.
>
> * * *
>
> I was projecting the image that I was getting from my professional staff after having seen the patient themselves....
>
> Q: But had the patients' condition changed, in retrospect?
>
> A: No, I don't think the patients' condition had changed. But our perception of it certainly changed.

After arriving at the site, Denton also discovered that his personal role would be different from what he had expected. There were immediate pressures on him to talk to the press and brief Governor Thornburgh and, indeed, later that night he would participate in a major press conference with the Governor. Denton had expected to manage the NRC's onsite response activities. He and Stello had agreed that they would split this assignment, Denton working the day shift and Stello the night shift. Denton had not "even perceived of the coming press aspects. It had not even been discussed with me when I left."[141] But Denton soon found that he was spending almost all of his time acting as a spokesman and transmitting information:[142]

> Q: Am I correct in my understanding that the problem with that became that you were simply too busy....
>
> A: Yes.
>
> Q: [A]ttending to other things, so Vic Stello wound up having to be the boss in your place when you were going to be the boss?
>
> A: That's right. It quickly ended up with Vic [Stello] working around the clock. And we did subsequently modify the structure by bringing in, I think, Denny Ross and Dick Vollmer as sort of the nominal day-to-day, shift-to-shift coordinators and leaving Vic and Roger Mattson [who arrived Sunday] to be the normal decision making heads. And my role got to be the one of spokesman for the agency, after a few days.

Denton and a larger onsite NRC team brought about a major improvement in NRC's onsite evaluation activities. For one thing, NRC began to require Met Ed to describe in advance what actions it proposed to take in plant operations, before initiating them. For another, NRC could now effectively monitor and evaluate all proposed recovery operations. John Collins, who arrived with Denton at the site on Friday, said:

> [T]he program for NRC to review [procedures] was initiated at the time we arrived on site. That was part of the plan by which Mr. Denton and Mr. Stello and Mr. Vollmer, that we would be engaged in reviewing their emergency procedures.[143]

Collins believed this formalized procedure commenced sometime Friday. It took time, however, for the team to become properly organized to avoid unnecessary overlap and duplication. For example, at one time there were as many as 10 NRC people in the control room.[144]

d. Saturday, March 31, 1979

The NRC Onsite Organization and Activities

By early Saturday morning, the onsite strength of the NRC had grown to 51 people and would grow more. The outline of an onsite organization had begun to develop. Since his arrival on Friday, Denton was the designated leader of all NRC activities on site. Under him, Denton had two somewhat parallel teams, divided along NRC office lines—an IE team and NRR team. Boyce Grier, the Region I Director, was in charge of the IE team. Since Denton and Grier were old friends, Denton assumed from the outset: "[T]hat [Grier] and I would get along fine and that he would direct his staff in doing what he traditionally did, and that we would work out things as we went along."[145]

The IE personnel at the site, however, were never really integrated with NRR staff. According to Denton, the IE personnel on site:

> [R]emained under [Grier's] direction. We never did integrate the two [staffs] completely. But we would attend each other's staff meetings, as I recall, and whatever they wanted us to focus on, we would. And if we wanted some measurements from them on the environmental side, they would. But they functioned as a separate unit pretty much the whole time.[146]

As Grier recalls the relationship between NRR and IE onsite personnel, the NRR personnel took charge of all in-plant activities.[147] Although IE personnel remained in the control room, IE was relied upon "principally to provide environmental information and briefings. We supplied [Denton] regularly with briefing information either written or oral in terms of environmental status."[148]

In his deposition, Grier admitted that everything did not go smoothly:[149]

> Q: I get the impression from talking to you that maybe the IE/NRR interface of relative roles was never clearly defined at the site?
>
> A: That's correct. My feeling—when we arrived onsite on the Friday evening there was direction to set up the organization.... Now, there was some integration in terms of the IE people were working within prescribed groups but—also contain NRR people. I guess I had some difficulty in that I didn't feel their organization was ever clearly defined. And I didn't know how to fit my organization in with theirs. That is one factor.
>
> The other factor is that, of course, we have our traditional roles of NRR reviewing and approving procedures, if you will. And IE having the role of verifying. Now, it—in my view the organization could have been continued to be set up along those lines that—if those in charge had made use of the IE personnel in that role.
>
> * * *
>
> [But] I had the feeling that the use of the IE people was just not being done. I can understand the fact that you know your own people, you have confidence in them. You can rely on them. And that perhaps affects NRR action because they know what to expect of their people. And they don't know the IE people.

In his deposition, James Higgins provided a clear picture of the organizational difficulties from the perspective of an IE inspector in the control room:[150]

> [We] did have some difficulties with who was doing what, what IE was doing, what NRR was doing, who was doing the procedures, who was reviewing them, who was looking at the operational aspects, who we would talk to when we had a particular problem, what our role really was. I think almost every afternoon when the Inspectors who were in the Control Room, we went out to talk to our supervisors, we would say, okay, what are we really supposed to be doing here and what is our role and how are we supposed to treat these different aspects and we would discuss it with them.
>
> It was not a situation where we—we weren't getting told anything but it was a developing situation and it was very, very difficult, very tenuous. We were continually trying to determine where we stood vis-a-vis the licensee and NRR. It was really not clearly laid out.
>
> Q: Did there come a time when it was clearly laid out?
>
> A: No.
>
> Q: During the first week, let's say?
>
> A: No. I was there for two additional weeks in the end of May and even then it wasn't clearly laid out.

As time went on, Denton's relationship with the EMT at Bethesda began to take a more distinct shape. As Denton put it:

> I didn't have a firmly defined view on that topic when I left Bethesda. After I had gotten to the site, I did quickly come to believe that the important decision should be made at the site and that we should rely on the EMT to continue the transmittal of information aspects and do detailed calculations. But I found that I was in a much better position to understand and make recommendations about things once I was at the site and getting firsthand information than I was back in Bethesda, operating on fragmented information. So I think over the few days, maybe even a smaller time interval, my perception about the role of the EMT changed.[151]

In effect, many of the EMT's responsibilities were taken over by Denton at the site.

Many of the NRR onsite staff members worked through Friday night and Saturday thinking out different scenarios and situations, and considering alternative actions to cope with events should they occur. Personnel worked on how to reduce the size of the gas bubble in the core and how to install and operate a hydrogen recombiner to remove hydrogen from the air of the containment building. Another concern was the possibility of equipment failure due to prolonged exposure to high levels of radiation. Other staff members continued to oversee the actions taken by Met Ed to get the reactor safely to cold shutdown. The NRC had established that Met Ed would not undertake new initiatives without informing NRC and obtaining NRC's approval. Whereas Met Ed had expressed concern with the presence of too many NRC inspectors in the control room the day before, early on Saturday the plant superintendent asked that NRC presence not be reduced further.[152]

By noon Saturday, Met Ed apparently believed it had a way to transfer hydrogen gas out of the reactor coolant system into the reactor building air space. However, Denton was holding up use of that path until he had "a better handle on the hydrogen situation within the containment."[153] The plant was degassing slowly, and GPU and Met Ed apparently believed the bubble was shrinking, but some at NRC were doubting that. At midmorning the bubble had been reported to be about the same size as it had been before. New calculations by Met Ed at 2:40 p.m. indicated the bubble size had decreased somewhat to 880 cubic feet at 875 psig. At 4:20 p.m., the size was recalculated to be 621 cubic feet at 875 psig. An hour later at 5:35 p.m., the bubble was calculated to be larger in size—742 cubic feet. Continuing efforts were being made to reduce the size of the bubble by venting the pressurizer into the containment building atmosphere.

During a noon status report to the Commissioners back at Headquarters, Denton expressed concern that since Met Ed was spread very thin they might not be able to cope with new problems from a management perspective. He indicated that the utility's operation was basically a "fire fighting operation." William Kreger of Denton's staff had estimated that Met Ed needed perhaps 50 more technicians to operate effectively. Denton and the Commissioners apparently agreed that efforts should be made to encourage and to assist Met Ed in getting additional industry experts to the site.

Denton also explained that he then foresaw only two reasons for evacuation—loss of the existing cooling mode and resultant degradation of the situation, or a deliberate planned change in the cooling mode. Denton was aware of the concern that the hydrogen bubble might explode and was awaiting firmer analysis of it by Headquarters personnel. But he seemed less troubled about it because of the "lack of an ignition mechanism."[154]

The NRC staff continued to monitor plant conditions. Fuel temperatures were still coming down; all the core exit thermocouples were back on scale. (The highest recorded temperature was 890°.) A reactor coolant sample taken the day before was analyzed at the DOE's Bettis Laboratory. The results of the assay showed amounts of ^{89}Sr, ^{90}Sr, and ^{140}Ba in the sample to be characteristic of gas releases and not of significant fuel melt. The consensus following receipt of the assay results was that the core was not damaged as badly as had been feared.

A sample of containment building air that was analyzed Saturday morning showed concentrations of hydrogen (1.7%), oxygen (16.5%), and nitrogen (91.8%). A sample taken later at 3:00 p.m. measured 1.9% of hydrogen. Thus, the hydrogen concentration appeared to be increasing. Later, when the hydrogen recombiner was started, concern of a possible hydrogen fire or explosion in the containment building was alleviated.

Communications Between the Site and Headquarters

Communications between the site and Headquarters were significantly improved Saturday with the presence of Harold Denton and the additional NRC forces that had arrived at the site. It was now possible to assign more people to the tasks of gathering and evaluating information and of manning the telephones. The manning of phones by new team members also lightened the burden of those NRC staff members who were responsible for gathering or evaluating information. As Higgins put it:

> We essentially had a phone talker. So that they could take all the questions from Washington and come to me, and I could get the answers and I could be spending all my time with keeping up with the situation and discussing plant status with the superintendent and so forth in the Control Room, and I didn't have to spend fifteen minutes at a shot on the phone also. I could just do that through the person who was right there. That helped me out a lot.[155]

In addition, NRC Headquarters no longer called the site every 10 minutes when an information need arose; instead, Headquarters called at 1-hour intervals with consolidated requests. The installation of "dedicated" telephone lines by the White House also appeared to help matters. Nevertheless, communications problems still existed. For an hour at about noon, for example, communications between the site and NRC Headquarters were lost.

NRC Activities Off Site

At Headquarters, officials spent less time "managing" the accident and more time providing support and advice. Activities at the Headquarters response center included answering inquiries from the public, the White House, and Congress; considering ways of reducing the size of the hydrogen bubble within the core; analyzing the possibility of a hydrogen explosion in the core; arranging delivery of needed equipment to the site, including lead bricks to shield the hydrogen recombiner and a mechanical robot to enter high radiation areas; and contingency planning.

In response to a site request for lead bricks to shield the hydrogen recombiner, dozens of calls were made by Headquarters and Region I to obtain a large supply. As a result, some 200 tons of lead bricks were obtained from such places as NL Industries, Altoona, Pa.; the National Bureau of Standards, Gaithersburg, Md.; DOE's Bettis Laboratory, Pittsburgh, Pa.; DOE's Brookhaven National Laboratory, Long Island, N.Y.; National Naval Medical Center, Bethesda, Md.; Nine Mile Point Reactor, Oswego, N.Y.; and the Armed Forces Radiobiology Institute, Bethesda, Md. The bricks were located by the NRC staff and prompt arrangements were made for military transport of these to the site. In less than 18 hours after the need was identified, the required bricks were in place surrounding the hydrogen recombiner permitting it to be placed in operation.

In response to a site request for a mechanical robot to work in high radiation areas, two were located by the NRC staff. One was found in Oak Ridge, Tenn., at the Y-12 plant and one was at the Eglin Air Force Base in Florida. Arrangements were then made for their delivery to the TMI site.

In addition to activities directly related to TMI, the NRC staff had prepared and was discussing the content of orders to operators of five other Babcock and Wilcox plants to ensure their continued safe operation.

At 8:00 p.m. on Saturday, Commissioner Gilinsky brought a new request to the EMT staff. He asked Edson Case to prepare contingency evacuation plans and to give them to him in writing by 6:00 a.m. Sunday. Plans and criteria were to be established for different situations that might arise. Dr. Stephen Hanauer was chosen to head up a team and they worked through the night on this task.

According to Commissioner Gilinsky, on Friday night he feared that "we just didn't have a grip on what sort of evacuation we might be thinking about, if in fact it came to that."[156] As a result, he had "some old documents" pulled together "on the nature of releases and how far they would extend and so on, what the various profiles would be."[157] Saturday afternoon, the need for contingency evacuation plans was suggested at a White House meeting attended by Gilinsky; Jack Watson of the White House staff asked that some contingency evacuation plans be prepared by the NRC. It was this request that led to Gilinsky's 8:00 p.m. directive to the staff at Headquarters.

Analysis of the Bubble Continues

As the bubble analysis grew in complexity, more and more people were called in to work on it. Hendrie's nagging concern about possible oxygen accumulation and an explosion inside the reactor vessel led him to press a number of staff members to work on this. The work was divided as it grew in scope, with Dr. Mattson apparently viewed as the staff coordinator.[158] NRC officials on site were aware of Headquarters' concern about the potential explosiveness of the bubble, but attended to more immediate problems at the site.

About 2:00 a.m., Wayne Lanning of the NRC's Office of Nuclear Regulatory Research (Research) was put to work to determine the probable results of an explosion in the reactor vessel. Lanning asked L. Ybarrando of EG&G–Idaho to do the calculation; Lanning at this time was already deeply involved in special tests being run on the Semiscale facility in Idaho at NRC request, exploring ways to flush the gas bubble out through the pressurizer. B&W was keeping in touch with these tests and was also involved with the NRC's interest in the potential forces of an explosion inside the reactor pressure vessel. At 5:30 a.m., B&W gave Warren Minners the results of its analysis. The B&W analysis indicated an explosion could generate an internal pressure of 14 000 pounds per square inch (Appendix III.4). At about 7:00 a.m., various members of Research asked Idaho National Engineering Laboratory (INEL), Battelle–Columbus, and Sandia Laboratories to calculate the hydrogen burning and explosion potential.

At 10:50 a.m., Roger Mattson discussed the situation with Robert Tedesco and gave Tedesco the following list of questions to ask Westinghouse and General Electric–Knolls Atomic Power Laboratory (GE-KAPL).

1. What is the gas evolution rate?
2. How soon would a flammable concentration be reached?
3. Is oxygen stripping out of the coolant and going into the dome of the reactor pressure vessel, i.e., entering the bubble?
4. Is oxygen staying dissolved?
5. What does it mean as we go to the flammability limit?
6. How does flammablity change at high pressure?

As early as Saturday morning, some thought that explosion of the bubble might not be a problem because of a low oxygen evolution rate. During the morning, NRR's Warren Hazelton (who was working on the effects of hydrogen on the vessel's steel walls), convinced that others' estimates concerning the evolution of oxygen into the bubble were far too high, consulted two experts by phone. John Weeks of Brookhaven and Paul Cohen (ex-Westinghouse and Bettis, retired) confirmed Hazelton's view that hydrogen overpressure would greatly inhibit oxygen evolution. Hazelton passed on his information within the agency, but somehow his efforts led nowhere. Mattson never learned of Hazelton's opinion.

Investigation of the oxygen generation rate led INEL to consider data from two dissimilar systems, the Cooper plant (a BWR) and the Advanced Test Reactor (a low-pressure system). Although INEL's investigation indicated that oxygen would be generated, the experts emphasized to Headquarters personnel in Research that their conclusions were very conservative.

About midday, Saul Levine, Director of Research, spoke with Robert Ritzmann of SAI. According to Levine, Ritzmann advised that a person could calculate 1% oxygen generation per day without consideration of bubble back pressure but 1% was probably too high—the proper rate was probably one-tenth of 1% and could be zero. Levine says that he passed on Ritzmann's opinion, together with information obtained by Research from INEL, to Mattson. Mattson confirms talking to Levine at midday Saturday. Mattson's contemporaneous notes, however, suggest that what Mattson heard Levine say about Ritzmann's opinion differed materially from what Levine remembers telling. Mattson's notes read:

> Levine reports that Ritzmann . . . says 2% oxygen present now . . . (*the rate of production from gammas could be 10 times higher, but Ritzmann doesn't believe it*).
>
> Ritzmann also tells Levine that mixture ignition could occur at 8% to 9% oxygen, with detonation higher by a factor of 2 or 3. Levine also reports that Sid Cohen (INEL) says 5% oxygen in 4–5 days. . . . [Emphasis added.]

At approximately 2:15 p.m., Mattson relayed to Chairman Hendrie his understanding of Ritzmann's opinion, together with the preliminary advice received by NRR from Knolls Atomic Power Laboratory (KAPL). Hendrie was at that time preparing to conduct a press conference at Headquarters; this conference and its repercussions are discussed below.

By 2:30 p.m., NRR personnel at Headquarters also were getting some feedback from Westinghouse and GE-KAPL. KAPL advised that the recombination of hydrogen and oxygen in the bubble was not a strong possibility, and Westinghouse indicated that at low coolant temperatures recombination in the coolant was not likely. At this time, the bulk temperature of the reactor coolant was down to about 300°F. About 4:00 p.m., NRR personnel again talked with KAPL and, based on that conversation, NRR officials concluded that the bubble was nearing the lower range of flammability and that it would take about 2 weeks to reach the lower detonable limit. This was relayed to Mattson, together with KAPL's view that there was no evidence of self-ignition.

After Chairman Hendrie's 2:45 p.m. press conference, the Commission met in Bethesda to discuss the bubble problem with Mattson and others. Mattson reported the staff's concern about oxygen buildup in the bubble and, apparently using his notes of Ritzmann's figures, said that the bubble then held 2% to 3% oxygen and that the danger points were 8% to 9% for ignition or burning and 2 or 3 times higher for detonation or explosion. It would take about 5 days to reach 8%. Mattson indicated that his group was looking for a way to vent the gas bubble by heating a control rod pressure housing in order to crack it open, but they feared that the method would ignite the gas. There was, however, some encouraging news—three of the four reactor coolant pumps were now operable. Mattson's biggest concern, shared by Levine, was that the plant install additional decay heat removal equipment as quickly as possible. The hydrogen bubble problem was tolerable because of the belief that it was just approaching the flammability point and still some way from the detonation level. During the discussion of the hydrogen problem and how to cool down the plant, Mattson withdrew his previous recommendation to evacuate people from areas surrounding the plant. Mattson no longer perceived the near-term necessity to depressurize or to take other action that might expose the already damaged core.

Shortly after 6:00 p.m., experts at KAPL, believing that the back reaction would absorb the oxygen at those plant conditions, recommended holding the hydrogen bubble in the reactor coolant system and continuing to degas with the system pressure held high. Still, NRC personnel feared oxygen evolution and explosion.

The Public is Concerned About the Bubble

At 2:45 p.m., Hendrie held a news conference in Bethesda. He reported, among other things, that the bubble would need to be removed from the reactor, but it would be some time before there would be any possibility of a flammable condition. In answer to a question on evacuation, he indicated that evacuation was a possibility that would have to be kept in mind in considering the steps to be taken, that evacuation might turn out to be a prudent precautionary measure, and that evacuation would be considered for people within 20 miles of the site.

Later in the afternoon at 4:25 p.m., Hendrie called Governor Thornburgh about the evacuation question. At that time, he reassured the Governor that his remarks about a 10- to 20-mile evacuation were made in answer to questions about a situation he did not expect to develop. Hendrie said that "the assessment here is that the plant is stable" and that evacuation was not called for.[159] In answer to Thornburgh's question, Hendrie advised leaving in effect the advisory on pregnant women and preschool children, at least overnight.

Saturday night, the Associated Press issued a bulletin, which had been cleared with NRC Headquarters, concerning the bubble. However, many people interpreted the bulletin as saying that the bubble was unstable and could explode momentarily; near panic ensued near the site as people began to evacuate surrounding areas without awaiting notice from public officials.

At about 11:00 p.m., NRC's Karl Abraham called NRC Headquarters to report that the Governor's Press Secretary, Paul Critchlow, had just walked into his office and in a loud voice told him, "Carl, you'd better tell your people in Washington to keep their 'blankety blank' mouths shut because the Governor is getting pretty sick of it. You're causing a panic. . . ."[160]

At about the same time, Edson Case, who had confirmed the substance of the AP story before it went out,[161] was manning the EMT room when a White House official called to urge that Headquarters no longer handle any press inquiries. Case says he subsequently discussed the White House call by telephone with Chairman Hendrie.[162] Case insists that "we didn't take orders from the White House. I do what the Chairman and I thought we ought to do."[163] According to Case, he and Hendrie eventually decided to transfer all press calls to the site after Case indicated that he would "be glad to get rid of this headache. Let's go along with it."[164] Case did not confer with NRC officials at the site before this decision was made.[165]

NRC Contacts with Government Organizations

Harold Denton established a schedule of calling Governor Thornburgh with briefing reports every 2 hours. He also held a joint news conference with the Governor at 11:00 p.m. Saturday to answer questions concerning the possibility of a hydrogen explosion in the core.

Saturday night, Commissioners Gilinsky and Bradford attended a meeting with representatives of all involved Federal agencies, held in the White House Situation Room, to discuss the total Federal effort being applied in response to the accident. It was during this meeting that Watson asked Gilinsky to prepare contingency evacuation plans—a request that led to the staff's all-night efforts at Headquarters.

Throughout Saturday, NRC gave frequent status reports to congressional oversight committees, interested Congressmen, other Federal agencies, and interested State officials in surrounding States.

e. Sunday, April 1, 1979

Bubble Analysis at Headquarters

Early Sunday morning, the Headquarters Incident Response Center was crowded with people; Roger Mattson and Darrell Eisenhut at the center spoke with Denwood Ross at the site. They reported to Ross that it had been conservatively estimated that the oxygen content of the bubble was increasing by 1% per day. There was some discussion of blanketing the makeup water, which was pumped in during the degassing process, with inert gas to reduce the evolution of oxygen from the makeup water. Reviewing a host of problems, Mattson concluded that taking any steps to cool down would be more risky than the present condition.

At 8:00 a.m., Merrill Taylor at the site, in response to Victor Stello's request the night before, advised Stello that an explosion in the reactor vessel was an extremely remote possibility (Appendix III.4). Taylor, himself not a radiochemistry expert, based his opinion heavily on his knowledge of special work at Oak Ridge National Laboratory about 10 years before. Taylor believed there would be no net evolution of oxygen into the bubble and therefore little chance of explosion. However, a short time later, at the NRC Headquarters, a different view was formed.

At 9:15 a.m., Mattson had just returned to the response center and was preparing to leave for the site with Chairman Hendrie. Mattson was briefed by Saul Levine, Robert Budnitz, and Thomas Murley, all of whom had worked on the hydrogen explosion concern. As reflected in notes they made at the time, their consensus was that oxygen was increasing at 1% per day and had already reached about 5% in the bubble, the "realistic" flammability limit; 11% to 12% was the "realistic" detonation limit; and 900°F was the threshold for spontaneous combustion.

Mattson describes how these numbers were obtained:[166]

> I said, "Okay, I am going to be with the President of these damned United States in a few minutes, and it's time to stop this wishy-washy all over the place. What do we think?" Maybe I was feeling my oats. I had had some sleep.
>
> And people talked for a few minutes, and it was kind of all over the place that morning again. I said, "All right, I am going to write some numbers down, and you tell me what's wrong with these numbers." And I started down the list.
>
> * * *
>
> I will not characterize [the numbers] as whether they were conservative or a best-estimate. People I have talked to have talked to me with such vigor they have destroyed any personal recollection I have of them. Everybody in that room knew how the numbers were going to be used. They knew to whom I was going to carry them, and they knew the importance of them, and they agreed to those numbers.

Saul Levine, who had become convinced Saturday night that there was "no significant oxygen in the bubble," has a different perspective concerning these conversations:[167]

> I started to try to explain to [Mattson] the ins and the outs of the conversations that I had been having with Ritzmann that led us to the tenth of a percent per day.
>
> * * *
>
> He kept repeating he had to leave almost momentarily, because the Chairman and he were going to the site. The President was coming and the Chairman had to be there for the President.
>
> He said—he cut short my explanation and asked what is the worst possible that it could be.
>
> And I said, well, the worst possible is an increase of 1% per day.
>
> * * *
>
> [A]nd then he said, "Well, okay. Now, what's the flammability limit?"
>
> I said it's five percent at this pressure and temperature and the explosive limit is somewhere between ten and eleven percent and therefore we have a week or so before you get to the explosive limit as an upper bound. But I didn't—for upper bound purposes, yes, but I didn't believe that was reality.

At noon, Mattson and Hendrie arrived at the airport in Middletown and were met by Stello and Denton. Stello firmly believed that the Headquarters consensus was wrong, that the high hydrogen overpressure in the system was recombining the oxygen. When Denton and Stello briefed President Carter, they apparently told him that the staff had a serious concern about the hydrogen explosion problem, but that it would be "days or a week" before there was a threat of explosion.[168]

Meanwhile, back at Headquarters more consideration was being given to the problem, concentrating on the effects of a hydrogen explosion in the pressure vessel, not its likelihood. At 1:45 p.m., the Commission, minus the chairman, met in the response center to hear a briefing from Robert Budnitz on the problem. Budnitz dwelt on the possibilities of ignition and the effects; he gave little attention to the generation of oxygen. At this meeting, the Commissioners tried to determine how quickly the local authorities could begin an evacuation. They were told that the Pennsylvania National Guard and State Police were on a 4-hour alert status and that the Governor would not increase that level of alert. The consensus of the Commissioners was that the uncertainties about hydrogen explosion potential, combined with the alert status of the local authorities, was sufficient to warrant a precautionary evacuation. The Commissioners decided to contact Chairman Hendrie with this view. In effect, the Commission had decided to recommend evacuation to Hendrie, deferring to his presumably better knowledge of the situation at the site.

At 3:00 p.m., Commissioners Kennedy, Ahearne, and Bradford spoke to Hendrie from the Response Center. Hendrie told them for the first time that a hydrogen explosion was not a problem, inasmuch as the assumptions concerning oxygen evolution were wrong. Hendrie, persuaded by Stello, told them that he expected expert confirmation of this shortly from the naval reactors people. Stello, meanwhile, was vigorously seeking confirmation from DOE's Bettis Atomic Power Laboratory (a naval reactor laboratory) and GE-San Jose (BWR designers). Commissioner Kennedy told Hendrie that the Commissioners recommended he discuss the matter with the Governor and advised that the Governor call for a precautionary evacuation out to 2 miles from the site. In an ensuing discussion, Commissioner Bradford stated that evacuation was warranted by the general uncertainties, not just the hydrogen explosion problem. Hendrie agreed to call Gilinsky, who had gone to the White House.

Shortly after Stello called Bettis and GE-San Jose at about 3:00 p.m., both experts confirmed his view—little or no oxygen was being generated into the bubble. Mattson was present when Stello first called these experts and he offers one possible explanation for Stello's quick success:

> Well, I heard him ask the question, and it had something to do with the way the question was asked. He said, "We've got this question about

> whether oxygen can be generated and cause an explosion, and a lot of people have been working on it and they come up with an uncertain answer that oxygen could be generated quickly; well, I don't think it can; I think the hydrogen will suppress it; and we need to decide this difference of opinion very quickly; and I think in normal operations they have to suppress radiolysis; and I think the way they do it is with hydrogen; and so I want an answer and I want it within two hours and I want it firm and conclusive. I don't care who you have to have, you get them and you get me an answer."
>
> Okay. So what's he done? He's narrowed the problem considerably. He has articulated the views that had already been gathered pro and con on this question and he has said to them very forcefully, "This is the nub; get me the answer on the nub."[169]

Stello relayed the results of his efforts to Chairman Hendrie, who was convinced that Stello was right. With the bubble concern alleviated, the NRC did not recommend evacuation. Meanwhile, estimates of the bubble size continued to go down. At 8:21 p.m., the volume was calculated to be only 240 cubic feet.

NRC Interaction with Met Ed

The close problem-solving, working relationship that was established between Met Ed and NRC on Saturday continued on Sunday. The role of Met Ed continued to be one of describing proposed operations and that of NRC was reviewing, evaluating, questioning, and approving them.

Communications between the NRC onsite staff was still somewhat of a problem. In an early morning call, Denton asked Headquarters to have Stello's people who were on site to call him at the site. Moreover, Boyce Grier called occasionally during the day asking Headquarters for reports on the latest developments.

Visit by President Carter

At 2:09 a.m., Harold Denton called Edson Case for a briefing in order to prepare for an 8:00 a.m. visit by President Carter to the site. Denton expected to be the principal spokesman, but he urged Hendrie to come to the site to "show the flag."

Denton and the Governor accompanied the Presidential party, which included the President, Mrs. Carter, and Jack Watson, Assistant to the President for Intergovernmental Affairs, during the visit to the site. Denton had given President Carter a complete briefing on developments at the plant and an assessment of current conditions upon his arrival at the Harrisburg airport. We found no evidence that any of the NRC personnel considered it dangerous for President Carter to visit the site.

NRC Activities at the Site

As Sunday came to a close, the control of NRC activity was even more vested in the NRC staff at the site. On Sunday morning, Denton had decided to open a full press center in the Middletown Borough Hall. There, from the stage overlooking the gymnasium floor, Denton gave his daily press conferences. At the site, NRC personnel had set up a headquarters on Friday in a collection of trailers adjacent to the observation center, in the area that was called Trailer City. NRC even had a small press trailer at the entrance to Trailer City. Hendrie returned to Washington, but Mattson stayed on at the site to further reinforce the NRC presence there.

NRC Contacts with Other Government Organizations

Harold Denton continued to provide frequent status reports to Governor Thornburgh throughout the day.

Back in Washington, NRC consulted with HEW officials concerning possible evacuation plans in case conditions at the reactor should seriously worsen. This was done in connection with an evacuation options paper that NRC was preparing at the request of the White House. Work on this paper had been initiated by Commissioner Gilinsky on Saturday night and was completed by a team headed by Dr. Stephen Hanauer. It was decided that Chairman Hendrie would take the completed document to the site and give it, with explanation, to Governor Thornburgh. This document, entitled *NRC Procedures for Decision to Recommend Evacuation*, is contained in Appendix III.5.

As on Saturday, NRC gave periodic status reports to Congressmen, Federal agencies, and State governments.

f. The Aftermath

Persistent degassing finally removed the gas bubble sometime Sunday or Monday. There was much debate about whether and when the bubble was gone. Later, B&W showed calculations and noise monitor traces which agreed that the bubble was gone by 3:00 p.m. on Sunday, April 1. The NRC acknowledged it had gone on Tuesday, April 3.

During the first week of April, there were many discussions of when the Governor should lift his advisory for the evacuation of pregnant women and preschool children. Early that week, lifting the advisory became tied to getting the plant to cold shutdown. There is no clear definition of what cold shutdown is, and final cooldown depended on the tedious process of reviewing and then ins- ·lling the revised cooling method. Finally, on Monday, April 9, long after the low level releases had stopped, the advisory was lifted on the advice of the Commission and Harold Denton.

From the time of its arrival on Friday, Denton's team had been concerned about the technical strength of the Met Ed personnel onsite. Denton and others periodically discussed with Met Ed and GPU officials the need for additional technical support, initially from safety systems suppliers like B&W and later from other utilities such as Duke Power Company.[170] Calls for assistance were made to suppliers and utilities. Denton also spoke to the President, then to other White House officials about the need for further support from industry.[171] Perhaps because of the efforts of Denton's team and the White House, or perhaps because industry groups already had recognized the need to help at Three Mile Island, outside technical assistance began to arrive over the weekend. An industry advisory group was then formed at the site to assist Met Ed in making decisions.

The large NRC force on site worked closely with the owners and the industry advisory group to work out an acceptable way to cool the plant down without using the decay heat removal system in the auxiliary building. This method, based on the technique used for cooldown of naval reactors, would use cold water circulation through the steam side of the steam generators. Under close NRC review, the necessary changes were made to install this system, but it was not turned on. Instead, it was held as a backup system. Circulation pumped through and around the core with slow steaming on the secondary side of the steam generator continued to be the method for heat removal. On April 27, 1979, the operating reactor coolant pump was turned off, and the TMI-2 reactor went on natural circulation with the core heat removed by natural convection flow of the coolant from the core to the steam generator. As of this writing at the end of December 1979, the same cooling method is being employed.

On April 17, after 19 days at the site, Harold Denton returned to Washington. On May 18, after 40 days at the site, Victor Stello returned. However, a large number of NRC staff remained at the site, and are still there today, evaluating and approving the cleanup and decontamination activities undertaken by Met Ed.

3. EVALUATION OF THE NRC EMERGENCY RESPONSE

a. Management of the NRC Emergency Response—Analysis and Findings

This subsection of the report discusses in detail our evaluation of the management of the NRC's general response to the TMI-2 accident during the first 5 days of the emergency. Findings on specific matters considered in the evaluation are listed at the end of this subsection.

Notification Procedures

The Region I procedure for receiving prompt notification of an accident proved to be ineffective when it was used Wednesday morning, March 28. At that time, the procedure for handling emergency telephone calls during hours when the Region I office was closed was to have an answering service call the Region I duty officer at home or wherever he might be. The duty officer was required to carry an electronic signal device ("beeper") that could be activated by the answering service. When he received a signal from this "beeper," he was to call the answering service as quickly as possible. The answering service received the 7:10 a.m. call from Met Ed but was unable to reach the duty officer for that day, James Devlin. The NRC did not learn of the accident until about 35 minutes later when some staff members arrived at the Region I office to start their normal work day and the Region I switchboard opened.

NRC's Response Organizations at the Three Mile Island Site

Initial Region I Team

Most of the group initially sent to Three Mile Island as members of the onsite inspection team lacked substantial previous experience with the TMI-2 plant. Of the first seven team members sent to the site, only Karl Plumlee had substantial previous experience with or detailed knowledge of the plant. Plumlee had previously served as the principal or lead health physics inspector for the TMI facility. The other six team members had limited prior experience and knowledge of the TMI plant. The team lacked sufficient detailed knowledge of the plant to be able to observe, evaluate, and report on the plant status and activities in a sufficiently effective manner immediately upon arriving at the site. The Region I Incident Response Plan states that usually the project inspector will be sent to the site as the team leader. However, Donald Haverkamp, who was the project inspector for TMI-1 and TMI-2, and who had substantial experience with and detailed knowledge of the plant was not sent to the site until the second day of the incident. He was assigned to work in the Region I Incident Response Center as a communicator on Wednesday and part of Thursday. Haverkamp should have been sent to the site on Wednesday morning.

William Lazarus, the alternate project inspector for TMI-1 and TMI-2, as listed in the Region I Incident Response Plan, informed us in an interview[172] that he was not very familiar with either of the two units. He told us that he had visited the TMI-2 plant only once—and that was a familiarization visit at the time he was assigned as alternate, about 2 years ago. He also told us that he had inspected TMI-1 as a specialist inspector before that time. Lazarus did not go to the site but was instead assigned to work in the Region I Incident Response Center. Assignment of a person without detailed knowledge of a plant to serve as alternate project inspector was a serious defect in the region's emergency response capability.

The plan also states that the regional director and deputy director will provide overall guidance and direction to the onsite inspection team assessment and, as appropriate, go to the accident scene. Neither of them went to the site on Wednesday or Thursday. Either the Director, Boyce Grier, or his deputy, James Allan, should have gone to the site on Wednesday to supervise the NRC's response activities and interact with Met Ed management at the site. NRC Headquarters was remiss in not directing Grier or his deputy to go to the site as soon as the magnitude of the accident was recognized.

During depositions, some of the onsite inspection team members indicated that they were given few or no instructions by Region I management as to what to do when they arrived at the plant.[173] There was and still is some confusion about who the team leader was. George Smith, branch chief responsible for radiological matters, testified[174] that he designated Donald Neely as the team leader. Boyce Grier indicated in testimony[175] and in conversations taped in the Headquarters Incident Response Center[176] that he thought Charles Gallina was the team leader. James Higgins, one of the team members, indicated that he did not know who was assigned to be the team leader and was not sure who was supervisor of his activities at Three Mile Island.[177] The onsite inspection team was not adequately instructed. They did not know who the team leader was (the Region I management was also not informed of who the team leader was), what they should do when they arrived, what they should look for, what they should report, to whom they should report, from whom they would receive instructions, and with whom in the licensee's organization they should work.

In addition to the fact that the initial group of inspectors sent to the site lacked familiarity with the TMI plant, and lacked adequate instructions, the number of staff sent was insufficient to gather and communicate to the region and Headquarters the large amount of information that was needed early in the emergency.

Furthermore, the inspection team was inadequately equipped when it departed for the site from Region I. The station wagon did not contain a radiotelephone over which the team could discuss the evolving situation at Three Mile Island with the Region I Incident Response Center. If the site had been hours further from Region I, the radiotelephone would have been even more important. The team members did not have battery-powered air sampling devices (they had air samplers that required an alternating current power supply) so they could not take air samples in the field, and they did not have respiratory protective face masks for use in radioactive atmospheres.

The region's mobile laboratory was dispatched almost immediately to Three Mile Island from its location at the Millstone Nuclear Plant, but required 8 hours to travel to the TMI site. Shortly after it arrived at the site, one of the tires was found to be flat and another badly worn. The van was considered by the inspection team members to be unfit for roving environmental field survey activities.[178] Equipment needed for independent measurements by NRC inspectors at the scene of an accident should be available to them immediately upon their arrival at the site.

Vollmer's Team from Headquarters

From the information we received, the role of the team from Headquarters headed by Richard Vollmer was unclear when the team went to the site on Thursday following the accident. Apparently the team was given unclear instructions as to what it was to do or how it was to coordinate what it did with Met Ed and the inspection team that was already at the site. Vollmer recalled in an interview with the Special Inquiry Group that:[179] (a) it was Victor Stello who asked him to get people together to go to the site; (b) his mission or role was "sort of open"; (c) Stello and "we all" felt that there was a lack of adequate communication between the site and the groups that needed to know what was going on; (d) he was not told that his group would assist in recovery; and (e) "we went up without a real definitive charter in my view, but one of trying to establish communication and understand what was going on and reconstruct the sequences of prior in [sic] the past day sc that we could perhaps understand what might best be done in the next few days."

Transcripts of the Headquarters Incident Response Center tapes show that about 3:00 p.m. on Wednesday afternoon, Edson Case called Vollmer and told him:

> The Commission wants us to start setting up a post-accident and licensee monitoring team.... I think you ought to be the man to head it up. There will be tight liaison with IE [Office of Inspection and Enforcement] and probably—maybe a couple of IE guys on the team.... They're presumably going to wind up with the containment building with water in it, contaminated to some degree.... And there will be presumably changes needed in text specs [sic]. Remember the Browns Ferry situation where...your normal text specs [sic] just don't cover this kind of a situation.... And you'll have to work on that, and those kind of things.... I don't know when you'll be going up there but I would imagine it would be shortly within a day or so.[180]

Different members of the Executive Management Team (EMT) have subsequently expressed different views of what the Headquarters team role was to be.[181] In any event, after Vollmer arrived, there was no clear understanding on site as to who was in charge of the NRC onsite operations. In fact, Vollmer set up an organizational structure that was separate from that of the region's onsite team.

Denton's Team from Headquarters

Asked by the President on Friday morning to send a responsible senior official to the site to serve as the President's direct contact at the site and take charge on behalf of the Federal Government, Chairman Hendrie asked Harold Denton to go immediately to the site. This was a proper course of action as it put someone with authority to speak for the NRC at the site. Also, Denton was accompanied by a team of experts that increased the NRC technical staff at the site sufficiently to allow it to do more than retrieve data.

The proper place for the principal NRC evaluators and decisionmakers to be following an accident is at the site. In deposition, Denton and Stello echoed this opinion. The flow of requests should be from the site to Headquarters, rather than vice versa as was the case during the TMI accident until the Denton team arrived at the site. Headquarters should provide technical support as needed and requested by the principal team of investigators and evaluators located at the site. As noted previously, NRC Headquarters management was remiss in not sending appropriate management staff to the site on Wednesday, especially when there were such poor communications and such real concern about the effectiveness of Met Ed's action.

Headquarters Incident Response Center

The Headquarters Incident Response Plan worked well as a procedure for the Office of Inspection and Enforcement to activate the Headquarters Incident Response Center, staff it with an initial pool of IE personnel, establish communications links with the region, and provide required notifications to other Federal agencies. It did not, however, sufficiently address what happens when two or more separate staffs, such as NRR and IE, must work together in the Headquarters Incident Response Center. There was no prepared plan that explained or specified how the IE and NRR members of the Incident Response Action Coordination Team (IRACT) and their support staffs would interact or coordinate with one another.[182] The procedure that evolved was one wherein the IE IRACT members and support staff served principally as coordinators for communications and data gathering, and the NRR IRACT members and support staff served as analyzers and evaluators.

In addition, there was insufficient coordination in the Headquarters IRACT between the people working on radiological matters and those working on operational matters. There was also insufficient coordination of information between the IRACT and the EMT and among the EMT members. For instance, in a deposition, Edson Case informed us that he was not aware that Stello was concerned on Wednesday about superheated steam or that the core was uncovered at that time.[183] The general practice evolved wherein members of the EMT, the IRACT, and the support staff worked and communicated with one another principally along their normal office organizational lines. This was one of the principal causes of the poor coordination and communications between NRR and IE that continued throughout the incident.

Headquarters Communications with NRC Staff at Region I and the TMI Site

The physical communication systems (e.g., telephone lines) used by Headquarters to communicate between the site and the Region I and Headquarters Incident Response Centers and among the onsite inspection team members were unreliable and inadequate. In addition, poor framing of requests for information by Headquarters, and requests for many individual bits of data that saturated the communications system prevented the onsite team from effectively providing the information that was most needed early in the accident. In requesting information from the region and the onsite team, Headquarters failed to explain in general terms what it considered to be the problems it was trying to evaluate. Had this been done, Headquarters would probably have gotten much better results. It would have also been easier for the staff at the site to answer questions if Headquarters had attempted to group its questions rather than asking them in the piecemeal manner that it did.

Communications problems were exacerbated for a time on Wednesday morning by the uncoordinated use of separate telephone lines between Headquarters and the region for radiological and operational information.

Headquarters Coordination with Met Ed

There was no interaction between Headquarters management and Met Ed management until Denton was sent to the site on Friday. The discussion on Wednesday afternoon between Headquarters and a Met Ed TMI-1 shift supervisor, Greg Hitz, concerning superheated steam in the reactor vessel and the indications that the core was uncovered apparently never resulted in consideration of the issue by Met Ed plant management. We do not understand why Headquarters did not explain this concern to James Higgins, the NRC reactor inspector who was stationed inside the TMI-2 control room. Higgins stated in his deposition with the Special Inquiry Group[184] that he did not hear any discussions of this subject by Met Ed management located in the TMI-2 control room. Higgins also stated that if he had been informed of the Headquarters IRACT's concern, he was in a good position to and would have made sure that Met Ed management considered the matter. We also do not understand why, with all its frustrations and concerns about what action the licensee was taking, the EMT and the IRACT did not make any attempt to contact Met Ed management directly to find out what their plans were and to propose matters they wanted Met Ed to consider. Stello, in his deposition[185] stated that he does not know why he did not contact Met Ed management directly.

NRC Headquarters' failure to discuss its concerns with Higgins or have its concerns relayed to him, and its failure to contact Met Ed management directly on this subject shows poor judgment. NRC management should have contacted Met Ed management early on Wednesday and maintained this contact at frequent intervals to discuss the actions that Met Ed was planning and to offer any advice or recommendations it felt necessary.

Headquarters Management Coordination with Region Management

Coordination between the Headquarters management and the region management was poor. As noted earlier, Headquarters management did not explain in general terms what it was trying to evaluate. After Headquarters made its direct telephone linkup with the TMI-1 control room and subsequently with the TMI-2 control room, the region was largely bypassed by Headquarters in the direction of the onsite team with respect to operational matters. Through Sunday, the region was not informed of many of the matters that were of concern to Headquarters or of actions that Headquarters was planning. Because it was not consulted or informed, the region was not able to plan its activities as well as it should have. This lack of coordination with Region I management probably contributed to the difficulties that Headquarters was having in acquiring operational information on Wednesday and Thursday. This problem continued through Sunday inasmuch as the region management was not informed by Headquarters of the preparation of evacuation contingency plans over Saturday night and Sunday morning. Boyce Grier, Director of Region I, who was at the site, did not learn of this until he called John Davis at about 11:00 a.m. on Sunday to suggest that such planning be done.[186]

> Grier: Yeah somebody down there ought to be looking at the situation continuously as to what might happen ... and how much time we have got.
>
> Davis: Now I understand that's being done. Now you don't have all that information up there.
>
> Grier: No and I don't know where to get it.

Commission Involvement in the Response

At the time of the TMI accident, there was no specified role for the Commissioners in a nuclear emergency. Notwithstanding this lack of defined role in an emergency response, the Commission interjected itself into the agency's response activities on Wednesday and assumed an increasingly active role with each ensuing day through Sunday, April 1, 1979. On the first day of the accident, most of the Commissioners limited their activities to staying informed of the developments either from their offices in Washington, D.C., or through personal visits to the Headquarters Incident Response Center in Bethesda, Md. However, Commissioner Gilinsky, who was Acting Chairman due to Chairman Hendrie's absence from the office on Wednesday morning, took a visibly active role that included suggesting to the EMT that it assign someone to think about what to do with the radioactive water inside the containment;[187] requesting the EMT to ensure that measurement information from the NRC, the Department of Energy (DOE), and the State were coordinated;[188] contacting the White House; and communicating with the Pennsylvania Governor's office.

The Commission's role in directing the EMT activities, and its involvement in the accident response escalated daily. On Thursday, Chairman Hendrie involved himself in the staff's activities concerning surveillance of industrial water releases and was instrumental in promulgating an NRC order to the utility to stop a release of industrial wastewater. The order seemed to be motivated principally by a concern for public reaction to the releases and an apparent EMT lack of information about the releases. It appears that, in response to the chairman's concern, the EMT asked the IRACT to order the plant to stop the releases. The IRACT, without considering the region's reasons for continuing the dumping or discussing these reasons with the EMT, ordered that the region order the plant to stop dumping.

The handling of the industrial waste releases on Thursday and the EMT's failure, as discussed below, to check with the site before recommending evacuation on Friday morning illustrate serious failures of Headquarters officials to establish the facts surrounding an issue before making decisions and issuing orders.

Discussions of evacuation on Friday morning forced still greater involvement of the Commission in directing the NRC's response activities when the Commission assumed management of the NRC's evacuation-related activities. Its first action was to override the staff's earlier recommendation to the State to evacuate the surrounding area. When Governor Thornburgh asked Hendrie whether or not Harold Collins of NRC was correct in earlier recommending to the State that it evacuate, Hendrie told the Governor that he would check on it, but he never got back to the Governor on this subject and still could not respond when the Governor asked him again on Sunday.[189] We believe that this was one of several incidents where poor coordination and poor communications within the NRC fueled distrust of the NRC by State officials. In a similar instance, Hendrie could not confirm to the Governor that Gallina was NRC's contact man at the site.[190]

On Friday night, Hendrie personally asked the staff at the Headquarters Incident Response Center to consider the possibility that the hydrogen and oxygen concentrations in the reactor vessel might at some time reach proportions at which they might explode. This concern had not occurred to the staff. Headquarters diligently pursued this subject, getting assistance from a number of experts outside the NRC. The NRC staff at the site believed there could be no free oxygen present and hence no explosion. When Roger Mattson and Hendrie went to the site on Sunday with their estimates on the explosion potential, the NRC staff at the site convinced them that no explosion could occur. Headquarters apparently had failed to coordinate its efforts with the NRC staff at the site, with the result that until they went to the site on Sunday, Mattson and Hendrie believed the oxygen concentration could build up inside the reactor vessel to a level at which detonation of the hydrogen could occur.

As noted in the narrative, Commissioner Gilinsky, in response to a White House request, asked the staff on Saturday night to develop an emergency contingency plan. We believe that the EMT or Commission should have directed earlier that a contingency plan be developed. It seems that the White House made an important request for an action that the Commission or EMT should have been taking already.

It was a mistake for the Commission to interject itself only partially into the management of the NRC response. It should have either made it clear to the staff that it was assuming command of the NRC response or made it clear that the EMT was in complete command. The fact that it interjected itself partially caused some confusion among EMT members. Although none of the EMT members have told us so, we believe that the confusion led some of them to rely on the Commission for decisions or to assume that Commission approval was required before they acted on substantive issues; other EMT members did not appear to believe they required Commission approval.

Coordination with Federal and State Agencies Responding to the Accident

When NRC Headquarters first notified the DOE of the accident Wednesday morning, March 28, it alerted DOE that aerial surveillance support might be needed but then delayed making the request for assistance until almost 11:00 a.m. As a result, the requested DOE aerial surveillance did not arrive at the site until about 1:30 p.m. We believe that DOE aerial surveillance support should have been requested during the first call. A general emergency, involving extremely high levels of gaseous radioactivity in the reactor containment building and uncertain plant status, as existed in the TMI-2 accident, in our opinion, called for more than an alert. DOE aerial surveillance should have been requested immediately.

The Pennsylvania Bureau of Radiation Protection requested monitoring assistance from the DOE Radiological Assistance Team (RAT) at Brookhaven Laboratory. Met Ed, the NRC, the State, the DOE Aerial Measurement System/Nuclear Emergency Search Team from Andrews Air Force Base, and the Brookhaven RAT were all monitoring the radiation doses and gathering radiological data in the area surrounding the plant.

As noted previously, Commissioner Gilinsky requested the EMT on Wednesday to ensure that measurement information from the NRC, DOE, and the State were coordinated. Notwithstanding this request, there were coordination problems during the first few days. The NRC had difficulty obtaining some of the ground measurements that the Brookhaven RAT had made. The Brookhaven RAT would only give its data to the State, apparently because the State had requested its assistance. In addition, some of the other Federal agencies were expressing the view that they were not appropriately informed or involved in the activity. These problems were discussed at an interagency meeting held at the DOE site headquarters at the Capital City Airport on Friday night. At that meeting, the DOE was assigned to coordinate all of the data.

Informing the State, Congress, Other Federal Agencies, and the Media

Throughout the accident, senior NRC officials at Headquarters and at the site who were most familiar with the facts were selected to act as spokesmen to State, Congressional, and Federal officials and to the media. In many instances, these designated spokesmen were actively involved in responding to the emergency, and the time they spent acting as spokesmen impaired the agency's emergency response effort. The agency failed to anticipate the need for these spokesmen and to specifically assign officials who were not actively involved in responding to the emergency to perform those duties. Pulling the onsite inspectors, Gallina and Higgins, away from the plant on Wednesday evening and again on Thursday afternoon to brief the Pennsylvania Governor and Lieutenant Governor and to participate in press conferences, diminished the effectiveness of the NRC in assessing the situation and reporting plant status and other information to the region and to Headquarters. On Thursday, key NRC staff members were pulled away from their jobs associated with the NRC's response to the accident to brief a congressional committee in Washington, D.C., and to brief two separate congressional groups that went to the Three Mile Island site to observe firsthand what was happening. On Friday, Harold Denton was sent to the site to manage the agency's response and to serve as the agency spokesman there. Instead of actively managing the activities, it turned out that he had to spend much of his time in briefings.

In all, hundreds of personal conversations were held with government officials to keep them informed of developments throughout the accident. This required a great deal of effort by NRC's top management staff. Although some effort was made by the NRC to prerecord information, the recorded information was not kept current and consequently was of little value to callers.

In addition to telephone calls and personal briefings, NRC used preliminary notification documents prepared by NRC's Office of Inspection and Enforcement to keep people informed. A reading of these documents concerning the TMI accident, which were used to inform other governmental offices, reveals that these documents may not have been fully understandable to the lay reader. The NRC needs to improve the understandability of preliminary notification documents by using nontechnical terms to the greatest extent possible and by explaining the significance of all reported information.

The Role the NRC Should Take in Emergency Response

The Commisson's stated policy with respect to emergency response indicated that the NRC would evaluate the adequacy of the licensee's actions in response to an accident and, if necessary, could intervene to direct the licensee's actions. However, there was no specific guidance or planning to ensure adequate sources of data from which to make such assessments, to ensure careful integration of the various elements of evaluation to provide a comprehensive overall assessment, or to ensure coordination of NRC assessments with those of the licensee's technical staff to determine the nature of and adequacy of ongoing and planned actions by the licensee. Thus, the broad "objectives" of the NRC policy had no preplanned substance. We believe this lack of planning and uncertainty about the agency's role in emergency response pervaded the NRC's actions in the TMI emergency. The difficulty was intensified by confusion about the respective roles of the staff members and the Commission.

As part of this inquiry, we have considered what the role of the NRC should be in an emergency. In addition, we contracted with the National Academy of Public Administration (NAPA) to study alternatives for government action in nuclear crisis management. NAPA used a panel of experts with a broad spectrum of government experience to advise and direct the NAPA staff. The products of the NAPA work are a staff report and a panel report. They are published together as NUREG/CR-1225. The NAPA panel report and a list of the panelists is in Appendix III.6. We find that the NAPA recommendations are generally consistent with our own about the proper role of the principal parties in a nuclear emergency.

Operating the Plant

Even before the TMI accident, the NRC required that an operator undergo extensive training and demonstration of qualifications before being authorized to operate a nuclear plant. After the TMI accident, it is obvious that even more operator expertise is required. With this in mind, we do not consider it reasonable that NRC maintain a separate staff of operators, prepared to step in to take over the operation of any afflicted plant. The number of expert operators needed would be very large; they would have to be unusually expert to step in during an accident; and the boredom of their ordinary work, waiting for an accident, would be a serious problem.

Realism prompts us to recommend that the NRC not take over the plant in a crisis, but the NRC does have a continuing obligation to monitor closely the emergency response of the operators and to exert what regulatory authority is necessary to protect the public. To do this, we envision the NRC working in close coordination with the licensee's technical and management staff to gather information, evaluate the situation, recommend possible actions to licensee management, review and approve needed license changes, and review and concur in proposed major licensee actions. This is essentially the role the NRC exercised at Three Mile Island after the Denton team went to the site. We also envision that the NRC will intervene at times to countermand some order by the plant management or to give some order regarding plant emergency operations.

We believe the NRC's present legal authority is sufficient for such on-the-spot orders (see Appendix III.1), but we believe it would be useful to clarify this, at least with public dialogue in emergency planning, preferably with clearer statutory authority as well.

Evaluating Licensee Operation of Plant

During the first few days following the TMI accident, the NRC managed its response from Headquarters in Bethesda, Md. It used its onsite team of inspectors principally as data gatherers and performed all its evaluations at Headquarters. Due to poor communications channels between Headquarters and the site, poor framing of questions by Headquarters, and poor coordination of information within the Headquarters Incident Response Center, the management of the response was ineffective. Headquarters did not feel that it had sufficient knowledge of what was going on at the site to accurately evaluate the situation and give orders to the licensee when it was concerned about the core being uncovered on Wednesday. And on Friday morning, when Headquarters did take a positive action and recommended evacuation to the State, it did so on the basis of an inaccurate understanding of what was happening at the site. Although the NRC team at the site on Wednesday and Thursday was better informed about what was happening at the plant than Headquarters, the team was not sufficient in size or technical expertise to effectively evaluate the complex situation at the plant.

When Denton's team went to the site on Friday, the NRC had, for the first time, a staff at the site sufficient in number and technical expertise to effectively monitor and evaluate the situation. It also had the authority to approve license changes and to order the licensee to take or to stop actions as it saw fit. Denton was the authorized and recognized spokesman for the agency with respect to the accident and as such was able to work effectively with the Met Ed management and with Governor Thornburgh.

Management of the agency's response from Headquarters was not effective following the TMI accident, but management of the response from the site, after Denton's arrival, was effective. We believe that the NRC should send an emergency response team sufficient in size, technical expertise, and management capability to the site of an accident, and move the management of its emergency response to the site as soon as possible following the accident. Headquarters should provide technical assistance as requested by the response team at the site.

We believe that with careful preselection of personnel and adequate training, the team sent to the site can be drawn from the regional office. It should be headed by the regional office director or his deputy whenever possible. The director is well known to the plant operators and to many local authorities as the principal NRC manager responsible for the plant. Through careful advance endorsement, he can be identified as the chief NRC spokesman on the scene. The director can draw from his own office the technical expertise he needs for the job at the site. Where necessary, specialists might be drawn from other locations. Working principally out of the regional office, the site team can develop and refine its procedures and equipment and even drill in conjunction with its normal activities.

However, as long as the regional office is an IE office without licensing authority of its own, it will be difficult for the regional office director to give orders to the operators when necessary. Therefore, the NRC should delegate to the site team director in advance plenary authority for all agency actions with respect to the emergency. The delegation of this authority should be carefully explained to the operators and to State and local officials in advance. No governor should ever have to ask for the credentials of the NRC spokesman.

We considered the alternative of having the emergency response team to the site drawn principally from Headquarters rather than from the regional office. We rejected this alternative for four principal reasons. First, the Headquarters staff has far less day-to-day familiarity with the facility and local officials involved. A Headquarters staff cannot possibly hope to develop complete familiarity with every facility and every critical official throughout the United States. Second, the regional office is typically closer to the facility and should be able to reach it sooner. Third, the regional office is already equipped for supplementary radiological monitoring and its staff is practiced in the use of this equipment. Fourth, if Headquarters staff took the lead in the onsite team, they would almost certainly have to also include a substantial number of regional office people. One dramatic lesson of the accident at Three Mile Island is that emergency response team members, whether at the site or in Bethesda, tend to work in their regular chain of command. Special emergency chains of command, superimposed on a temporary group, are likely to cause great difficulties.

We recognize, of course, that the present regional office staffs may need reinforcement and training to be able to meet this emergency responsibility. But that, we submit, is preferable to trying to create a "special" team at Headquarters ready to fly anywhere in the country at a moment's notice. It may be perfectly appropriate to have technical specialists and public information assistants from Headquarters trained and ready to be called upon in an emergency. However, the region's onsite team, not Headquarters, should have responsibility for deciding what support to request so that these additional specialists and assistants enhance rather than diminish the onsite team's effectiveness.

The region's team may need at least several hours to reach the site, even with careful planning. In the meantime, the Headquarters duty officer, and then the IE director or his designee, when he arrives at the Headquarters Incident Response Center, should be the sole spokesman, responsible for NRC's recommendations and response actions and vested with all agency authority regarding the accident situation. We believe that to serve in this capacity, a person so remote as one at NRC Headquarters should be provided with directly transmitted plant and environmental information sufficient to assess the situation. A separate study should be made promptly to identify plant parameters, equipment status, and environmental information that should be transmitted to Headquarters on call whenever a plant has a serious emergency. We do not consider it practical for high-level officials of the NRC such as the chairman or office directors to serve as Headquarters duty officers. The responsibility for NRC emergency actions should be given to technically competent intermediate level managers who are assigned as duty officers and then to the IE director or his designee, and left with them except for the transfer of lead responsibility from Headquarters to the site team when the team director has arrived. We believe it would be reasonable for the NRC site team director to work from a central emergency response center close to the site provided that it has at least as much data directly available to it as we expect to be available to NRC Headquarters, and provided that the site team works directly at the site to the degree necessary.

Findings

1. The Region I system for receiving prompt notification of an accident proved to be ineffective when it was used Wednesday morning.
2. Most of the group initially sent to Three Mile Island as members of the onsite inspection team lacked substantial previous experience with the TMI-2 plant and lacked sufficient detailed knowledge of the plant to observe, evaluate, and report on the plant status and activities in an effective manner immediately upon arriving at the site.
3. It was a mistake that Donald Haverkamp, the NRC project inspector for TMI-1 and TMI-2, was not sent to the site on Wednesday morning, and that Boyce Grier or his deputy did not go to the site on Wednesday to supervise the NRC's activities and interact with Met Ed management at the site. Headquarters was remiss in not directing Grier or his deputy to go to the site as soon as the magnitude of the accident was recognized.
4. Assignment of an individual without training and experience with the TMI plants to serve as the alternate project inspector was a serious defect in the region's emergency response capability.
5. The onsite inspection team was not adequately informed as to who the team leader was (the Region I management also was not informed of this), what they should do when they arrived, what they should look for, what they should report, to whom they should report, from whom they would receive information, and with whom in the licensee's organization they should work.
6. The onsite inspection team was inadequately equipped when it departed for the site from Region I. Equipment needed by the NRC inspectors for independent measurements at the scene of the accident was not available to them immediately upon their arrival at the site.
7. There was no prepared plan that explained or specified how the IE and NRR members of IRACT and the IRACT support staff would interact or coordinate with one another.
8. In the absence of prepared plans, IE and NRR staff members who were part of the EMT, IRACT, and IRACT support staff at Headquarters tended to function along organizational lines, each individual dealing most frequently and effectively with those individuals with whom he usually worked. This tendency also was in evidence among members of the agency's onsite organization after Denton and his team of technical experts arrived at the site on Friday to supplement the work of personnel from Region I. There was insufficient coordination in the Headquarters IRACT between the people working on radiological matters and those working on operational matters, between the IRACT and the EMT, and among EMT members.
9. The physical communication systems (e.g., telephone lines) used to communicate between the site and the region and Headquarters response centers and among onsite inspection team members were unreliable and inadequate.
10. Poor framing of requests for information by Headquarters and requests for many individual bits of data saturated the communications system and prevented the onsite team from effectively providing the information that was most needed early in the accident.
11. When Headquarters asked for information, it did not explain adequately in general terms to the region or the onsite team the problems it was trying to evaluate.
12. An insufficient number of staff members were sent initially to the site on Wednesday morning to respond to the almost continuous flow of information requests from Headquarters. NRC personnel on site did not have a single command center at Three Mile Island, which increased the difficulty of ensuring a coordinated response by onsite personnel.
13. The NRC did not have one individual on site with the competence and authority necessary to give essential orders until Harold Denton was well established at the site.
14. When the Denton team went to the site on Friday, the NRC had, for the first time, a staff at the site sufficient in number and technical expertise to effectively monitor and evaluate the situation. It also had the authority to approve license changes and to order the licensee to take or to stop actions as it saw fit. Denton was the authorized and recognized spokesman for the agency with respect to the accident and as such was able to work effectively with the Met Ed management and with Governor Thornburgh.
15. Management of the agency's response from Headquarters was not effective following the TMI accident, but management of the response from the site, as was done after Denton's arrival, was effective.
16. NRC coordination with Met Ed was deficient in that NRC management did not contact Met Ed management early on March 28, 1979, and

maintain this contact at frequent intervals to discuss the actions that Met Ed was planning to take, to make any recommendations it felt necessary, and to bring any information or thoughts it felt appropriate to Met Ed's attention.

17. Coordination between the Headquarters management and the region management was poor in that Boyce Grier was not kept informed of Headquarters' concerns about the plant or what Headquarters was planning to do.
18. The NRC staff and the Commission were uncertain of their roles in the TMI response.
19. As the accident progressed, the Commission, most particularly Chairman Hendrie, took an increasingly active role in the management of the NRC's emergency response despite the fact that the Commission had no specifically defined role to play according to the agency's emergency response planning documents.
20. It was a mistake for the Commission to interject itself partially into the management of the NRC response without either making clear to the staff that it was assuming command of the NRC response or making it clear the extent to which EMT was in command.
21. There was no NRC planning to perform a comprehensive assessment of the adequacy of the licensee's recovery action taken at the plant.
22. There was no NRC planning for NRC intervention to approve or to direct the licensee's actions in response to the accident.
23. The NRC's coordination with the DOE, with the State, and with other Federal agencies, was inadequate to ensure that needed data was being developed and that the State, the DOE, the NRC, and other Federal agencies were getting all of the information they needed.
24. Key members of the NRC technical staff were pulled away from important emergency response activities to brief State officials, the Congress, and the media.
25. NRC preliminary notification documents that were used as a basis for informing other governmental offices about the accident were not sufficiently understandable to the lay reader.

b. Evacuation Issues—Analysis and Findings

The Three Mile Island experience showed that the NRC was and will be deeply involved in actions to protect the public from the consequences of a nuclear accident. Therefore we present our evaluation of this important aspect of the NRC's response separately.

When the NRC was first notified of the TMI emergency at 7:45 a.m. on March 28, 1979, the plant operators had already established close contact with the Pennsylvania Bureau of Radiation Protection (BRP). Met Ed was doing what it was required to do by the emergency plan. The plan held the licensee responsible for directly contacting the State radiological authorities to report the situation and to recommend evacuation or other protective measures when necessary.

The plan did not assign a voice to the NRC in that dialogue. There was no clear NRC policy that provided guidance concerning whether NRC should make evacuation recommendations to State officials, under what conditions it should make them, who should make them, and to which State officials they should be addressed. In our investigation, we found that the NRC inspection team, upon reaching the site, verified that this channel between Met Ed and the State was functioning for the reporting and evaluation of evacuation-related information. However, this plan like many others had a fundamental flaw. It conditioned the participants to think of protective measures being taken only on the basis of actual plant conditions and releases, not on the basis of deterioration in the situation. Although radioactive releases were quite low on Wednesday, there was great uncertainty about the ability of Met Ed to control the cooldown of the plant and the releases. This uncertainty should have been considered on Wednesday as a possible basis for evacuation. The NRC staff at the site and at the Region I and NRC Headquarters failed to consider *possible* offsite releases as a basis for evacuation; they obviously confined their attention to the measured offsite dose rates. They should have made regular appraisals of the plant conditions or status and provided explicit advice to the local authorities based on that appraisal.

Who Speaks for the NRC?

From Wednesday evening through Thursday afternoon, the situation remained essentially the same, with onsite NRC personnel monitoring the "evacuation interface" between Met Ed and the State. However, starting Wednesday evening, the Governor and Lieutenant Governor asked two of the NRC inspectors, Charles Gallina and James Higgins, to report the plant status and the possible need for protective measures. These inspectors were put in the unenviable position of having to: (1) perform a major inspection effort at the site; (2) act as the principal channels for communicating information to the NRC Region I and Headquarters offices; and (3) act as the NRC's spokesmen to the most senior local officials and the public. Gallina and Higgins were called to this last task Wednesday evening and again on Thursday afternoon, with the knowledge and concurrence of the NRC management.

The only evidence that the NRC management conferred with these men before they had to meet with the Governor and the press on either day was an exhortation to Gallina before the first meeting from his regional office director that he "be open and tell it like it was."[191] We believe that it was wrong to leave the responsibility for this high-level contact to these two individuals on both days, especially without consultation. We find it remarkable that on Friday morning, after the name was given to him by Governor Thornburgh, Chairman Hendrie asked the IRC, "Do we have a man named Gallina down there?"[192] Thus, when Gallina and Higgins discussed evacuation matters with the Governor, they had no benefit of higher level consultation.

On Thursday morning, Lt. Gov. Scranton asked Commissioner Gilinsky whether the children in nearby Goldsboro should stay indoors as a radiological protection measure. Gilinsky did not answer the question but had Harold Denton call Mark Knouse of Scranton's office on the matter. Denton made what might be called a negative recommendation by explaining to Knouse why he felt protective measures were not necessary.[193] We found no evidence that Denton was describing a previously reached negative recommendation. Denton's answer appears to be an on-the-spot response to Scranton's question. Denton's evaluation was consistent with the knowledge of the plant status at the time. It is interesting to note that the State authorities thereby opened a new channel for evaluation and recommendations regarding protective action. They began with technical contact with Met Ed, added the contact with Gallina and Higgins, and now opened higher level contact at the Commission and office director level. There was an opportunity here for the NRC management structure to decide who should be the evacuation spokesman to the State officials and at what level the contact would be made. That opportunity was missed and a great deal of confusion occurred the very next day because of it.

On Thursday, many had heard that Dr. Ernest Sternglass had recommended evacuation of pregnant women and small children from areas around Three Mile Island. At the Thursday afternoon meeting of Gallina and Higgins with Governor Thornburgh, there was extensive discussion of evacuation.[194] At that meeting Karl Abraham, a public affairs officer, suggested consideration of more radiation sensitive people such as pregnant women. The Governor has since related that he lost faith in the local NRC spokesmen when Gallina said to the press after this meeting that the danger was over for people offsite.[195] We believe the NRC was beginning to pay a price for leaving the burden of this important task on the shoulders of relatively junior people at the site without useful assistance. We have found no evidence that the Governor related this dissatisfaction to anyone at the NRC at this time.

The Friday Morning Fiasco

The greatest problems with evacuation evaluation and recommendations started Friday morning. Through Thursday evening and the early hours of Friday, the NRC was learning ominous things about the condition of the plant. This information was channeled to the EMT in the Incident Response Center. The evaluation process was greatly perturbed by the fortuitous combination and coincidence of Lake Barrett's offsite dose rate estimate with Karl Abraham's request from Harrisburg for verification of a reported over-the-plant dose rate measurement. The record shows that the EMT did not evaluate the information in an orderly way, did not reach a decision in an orderly way, and did not identify and follow a clear course of consequent action. In sum, the EMT evacuation decision made just after 9:00 a.m. on Friday, March 30, was bad on all counts: evaluation, decision, and action.

The analysis that produced a serious offsite dose estimate was based on a recent (8:45 a.m.) report that the waste gas tanks were full.[196] Although there appeared to be serious ramifications of this change in plant status, we found no record of any attempt to verify it. Later inquiry has shown that the report was erroneous; the tanks were not full.

The report of a 1200-mR/h gaseous release from someplace "in one of the cooling towers" was obviously garbled because cooling towers don't emit radioactive gases, and was clearly tendered with a request for verification.[197] Both factors were sufficient reason to verify the report; the EMT did not. The error was even compounded by treating the dose rate as if it represented an offsite ground level dose. We believe these failures by the NRC are dramatic examples of the need to verify facts that are crucial to a major decision.

The EMT decision process was also faulty. The EMT was a group under the direction of the NRC's Executive Director for Operations, Lee Gossick. The decision process as reported by Lake Barrett[198] does not reflect a clearly led group. Harold Denton seems to have made a decision to recommend evacuation of the area around Three Mile Island. The actions that followed further confused the matter. Denton did not turn to Gossick, the EMT director, to notify the State officials. Instead, Denton himself instructed Harold Collins of the NRC State Programs office to transmit to the State this grave recommendation to evacuate. Collins chose to transmit the recommendation to Col. Oran Henderson of the Pennsylvania Emergency Management Agency, and he did so in an uncertain way, first asking Henderson what they were told about the release.[199]

This EMT decision and action was defective in many ways. The decision was not made through the designated decision structure. It was made abruptly with little or no deliberation, although there was nothing in the information at hand or this situation that suggested such precipitous action. A sense of the confusion in this abrupt decision can be gained from Denton's and Gossick's later recollections. Denton told us that he felt the EMT had to act because the Commissioners were not readily available.[200] Gossick told us that he turned to the Commission for this decision because they were available.[201] The first phone call to a Commissioner (Bradford) was completed by Denton only 11 minutes after Karl Abraham's call.

The NRC EMT, with its battery of telephones and dozens of staff assistants in Bethesda and at the site, was not up to the evacuation decision. The ill-founded recommendation to evacuate was challenged almost immediately because it did not match the situation at the site. The EMT turned to the Commission to affirm the recommendation. The Commission had more authority but it certainly had less information, relying almost entirely on information passed to it by the EMT. If the EMT's decision to recommend evacuation had been a good one, we believe that the Commission could and would have affirmed it promptly. But the EMT calls that brought the matter to the attention of the Commission contained information that showed no need to evacuate. It is difficult to fault the chairman for not affirming the staff recommendation because of this.

From our investigation we believe that the Commissioners discussed the matter of protective action advice collegially but there is no evidence that the Commission took any formal vote to reach a position. The chairman seems to have heard the views of the others and then acted in accordance with his best judgment. We believe the Commission acted sensibly to depart from the voting process under these circumstances. Chairman Hendrie had had extensive training and experience in the field of nuclear safety and was therefore capable of evaluating the situation and making correct decisions and recommendations. However, we would not expect that every chairman would be as well qualified to make the agency's decisions related to nuclear accidents. Therefore, we recommend that the Chairman of the Commission should not make decisions of this sort for the agency during an emergency. A cadre of qualified intermediate level managers should be identified and *trained* for this decision-making role, and the agency should make clear to all that the one on duty during an emergency will speak with competence and full authority for the NRC. Such a person would represent the peak combination of technical competence, training, and authority for the agency. We presume that higher level authorities in the agency will be available usually and, of course, concerned about the situation and the agency's actions. If the responsibility is clearly held by the designated action manager then no loss of effectiveness will come from periodic consultations between this manager and higher level authorities as time permits. However, there must be no expectation that this manager will clear his decisions with the higher authorities, or the agency will be right back to the TMI difficulties. It should be clearly understood by local authorities and by other Federal authorities (such as FEMA, EPA, DOE) that this emergency duty officer speaks for the NRC.

The ultimate decision coming from the Friday morning evacuation uproar was endorsement of an advisory from the Governor that pregnant women and preschool children leave the area of the plant. We are unable to endorse this decision as a reasonable one except as a compromise for the false alarms that preceded it. By the time of the advisory decision, the release had stopped but could start again and repeat periodically. It was known that offsite dose rates were low, only occasionally going up to 10 or 20 mR/h. At those dose rates, it would take 50 to 100 hours of continuous exposure to bring a sensitive person such as a pregnant woman to the EPA Protective Action Guide level of 1000 mR. With the intermittent character of the releases, the time required was much longer. However, it is difficult to fault Governor Thornburgh and Chairman Hendrie for it, because they were both confronted with confusing information, and the situation was complicated by the actions of others—the EMT recommendation of total evacuation and Kevin Molloy's radio broadcast that the public should get ready for an evacuation order.

The Governor and the Chairman would have been helped greatly if they had a simple decisionmaking matrix before them on Friday morning such as the one that was prepared for Sunday (see Appendix III.5 to this section). Documents such as Appendix III.5 should not be prepared from scratch during an accident. As part of the emergency planning, matrices of this type should be prepared for a wide range of events, including serious core melt scenarios. These documents should present the basic scenario, time sequence, and offsite consequences (for a reference meteorology condition) for each of the events based on realistic analyses. The analyses could include corrections that would apply for different levels of decay heat. These tables would then be in the possession of the principals during an accident. Then expert advisors, whether from the NRC or the plant operators, could give their advice on a common basis needing only to correct for current meteorology and relying on their expert judgment for the selection of an appropriate likelihood of suffering a specific scenario. Ideally, nuclear experts should be seeking to give local officials advice as understandable as that which is available for better understood hazards. We can all understand it when an expert from the National Weather Service describes the size and intensity of a hurricane and then tells the governor of a coastal state that there is a 90% probability that the hurricane will cross the coast on a certain path at noon tomorrow. The governor has what he needs to make that difficult evacuation decision—the probability, the timetable, and the severity of the hazard. In a nuclear plant crisis, the nuclear experts should give him equivalent advice.

How Dangerous was the Bubble?

Shortly after Chairman Hendrie endorsed Governor Thornburgh's advisory, he heard from Roger Mattson the first intense concern about the bubble of gas in the reactor coolant system.[202] The concern at first was that the bubble, estimated to be 1000 cubic feet in volume, could expand and again uncover the core. Mattson recommended a general evacuation. We recognize that Mattson's concern was genuine and that there was a possibility that depressurization would uncover and melt the core. The record does not show an orderly evaluation of this concern. What was the likelihood of deliberate depressurization from all causes? What might the sequences of events be? At this time after cooldown, how long would it take for the core to melt? We believe that an emergency planning matrix of the type described above, somewhat like Appendix III.5 would be invaluable for the evaluation needed. In retrospect, we believe that an orderly evaluation of this problem would have reduced the concern and been useful for identifying the most important contingency plans needed.

The bubble concern began with fear of its volume displacing cooling water in the core. Later on Friday it became fear that, if the operators could successfully vent the bubble to the containment atmosphere, it might add enough hydrogen to cause an explosion. There was the additional concern that, once the plant vented into the building, radiolysis in the core might generate still more hydrogen to add to the problem. This concern led to the first estimates of the hydrogen, and oxygen, generation rates. Later, when the concern shifted to flammability of the bubble still in the reactor system, we believe there was a natural tendency to carry over these estimated radiolysis rates. As the NRC staff pursued the evolving bubble concerns, staff members from different parts of the agency were drawn to work on it. Each group seemed to turn to a different outside consultant. The result was a chaos of poorly related questions and answers. in the carefully reconstructed chronology in Appendix III.4, one sees a confusing array of questions going out and answers or opinions coming back in no pattern. Important opinions were not heard by the right people. In one example of this, Warren Hazelton, an NRC staff member of considerable expertise in reactor chemistry, was analyzing the metallurgical effects of all that hydrogen on the reactor vessel steel. Hazelton heard that others were worried about the oxygen generation rate and felt they were neglecting the reverse reaction. Hazelton raised an objection, but in the confusion he gave his opinion to Robert Ritzman, a consultant working with another group.[203] It was as if the focal point for the issue was this person outside the NRC staff. Later, Roger Mattson told us, "Had I been aware that Hazelton had an opinion, it probably would have caused me to go to Hazelton, whom I know to have some physical chemistry capabilities and some metallurgical capabilities.... I might have talked to him directly and grown to understand that he did have knowledge in this field that could be relied upon...."[204] Just as the Governor was forced to determine the credentials of those who advised local officials to evacuate, Mattson was trying to determine the credentials of consultants and advisors as the problem was being analyzed.

The most notable feature of all this is that the NRC staff had no recognized group that had the expertise to answer questions of reactor chemistry. We believe that having such a clear center of expertise within the staff would have made it the logical focal point for these questions and would probably have ensured a prompt, accurate appraisal of the bubble's explosion potential, which we know now was negligible. We suspect that the lack of this center of expertise in the NRC staff indicates that little attention was given to this area in the NRC's safety review. Therefore, we recommend that NRC establish a group within the staff with concentrated expertise in reactor chemistry matters.

The lack of a center of expertise for the hydrogen bubble problem illustrates a need to choose in advance the consulting experts who will be called upon in an emergency. At a minimum, the NRC staff should establish an index of names of staff experts who should be called on, organized by their technical specialty. These staff members should be able to provide sound advice promptly or be a logical channel to obtain such advice from others.

The Final Call for Evacuation

Late Saturday, at the behest of Jack Watson of the White House staff, Commissioner Gilinsky asked the NRC staff to prepare contingency evacuation plans.[205] The result of the staff effort was the document reproduced in Appendix III.5 to this section. Here, for the first time in the TMI accident, the NRC had put down its best evaluation of plant contingencies in a way that could be useful to the evacuation decisionmaker. The document was sent to the site with Chairman Hendrie. The four remaining Commissioners met in Bethesda and reviewed the contingency analysis. The information that the Governor did not want to increase the state of the alert[206] was a significant factor in the Commissioners' decision that precautionary evacuation was warranted. To their credit, they did not make it a Commission vote but presented their consensus to the Chairman at the site. As Commissioner Kennedy, who called Hendrie, told us:

> We were not telling him as a collegial body, you have just been given an instruction by a majority of your peers. We were telling him, the majority of your peers, from its own perception, sees it this way, but recognizes that there may well be factors which it doesn't know or comprehend in the same way as you do on the ground there. That just seems to me simple, straightforward common sense.[207]

We believe that this was a sensible way for the Commissioners to interact with the Chairman in such an emergency. We believe that this use of methodological contingency analyses and orderly consultation is good procedure for future emergencies facing the NRC.

Should the NRC Have Recommended Evacuation?

After reviewing the events at Three Mile Island and especially the confusion about evacuation, it is natural to ask whether the NRC should have recommended evacuation. This is second-guessing; we do enjoy the greater clarity that always comes with hindsight. We want to address this question here, not to find fault with past decisions, but to gain insight for making such decisions in the future. Our analysis will not be based on additional facts gained from months of investigation and evaluation. Instead, we will use only the information and insight that was available at the time. We will consider the need for evacuation in four different situations:

1. In the TMI-2 Control Room at 9:00 a.m. on Wednesday, March 28
2. In the NRC Headquarters IRC at 9:15 a.m. on Friday, March 30
3. In the NRC H-Street Commission offices at 10:00 a.m. Friday, March 30
4. With the Commission in the NRC Headquarters at 3:00 p.m. Sunday, April 1

Situation 1: In the TMI-2 Control Room at 9:00 a.m. on Wednesday, March 28

This first situation is at a time and place where no NRC person was present. The first NRC inspectors reached the TMI-2 control room about two hours later, at 11:00 a.m. We chose this situation time, 9:00 a.m., because of the state of the plant and the information that was then available. We postulate the presence of a competent monitor, whether from the NRC or from the utility, who has been present since early in the event and has been privy to the information passed to the plant management.

Information Available

1. Total loss of feedwater caused high pressure reactor trip.
2. Power-operated relief valve (PORV) lifted.
3. Pressurizer level dropped and then started to increase.
4. Low reactor coolant system (RCS) pressure caused emergency core cooling system (ECCS) to come on; two makeup or high pressure injection (HPI) pumps were operating.
5. Operators bypassed HPI controls and reduced HPI flow to prevent overfilling the system.
6. Pressurizer level went offscale high but system pressure was low.
7. Blockage of the auxiliary feedwater system was discovered and corrected; effect on decay heat removal unknown.

8. Pressure rise detected in reactor building.
9. Reactor coolant pumps not delivering rated flow; operators began to shut some down; finally all were shut down.
10. Reactor coolant system hot- and cold-leg temperatures began to diverge widely; hot-leg temperature went offscale high at about 6:00 a.m.
11. Block valve to PORV was closed at about 6:20 a.m.; RCS pressure began to rise.
12. High radiation alarms were received from the sample station, the letdown line, and other areas; a general emergency was declared.
13. Reactor coolant pumps could not be restarted, appeared to be vapor bound.
14. Reactor coolant system appeared to be filled with steam bubbles, superheat conditions were seen.
15. Radiation reading in the containment building was high and increasing.
16. Hot-leg temperatures went offscale high with system pressure usually at 1200–1500 psig.
17. Core exit thermocouples were measured directly; some showed temperatures over 2000°F.
18. Containment dome monitor reached 200R/h reading.

Actions That Appear Warranted

1. Advise or order plant that core appears to have been uncovered and thereby damaged. Maximum HPI flow should be provided to recover the core, open PORV block valve for maximum relief flow.
2. Advise State officials that the core has been badly damaged and has released a substantial amount of radioactivity. The plant is now in a condition not previously analyzed for cooling system performance. Presuming that full HPI flow is turned on, advise the State that if the cooling systems do not function adequately, portions of the core could begin to melt which could lead to significant offsite releases in a few hours. If the cooling systems are successful, evidence of that success should be available in a few hours. Recommend to State officials that they begin a precautionary evacuation of the first few miles around the plant with an alert for a larger radius (10 miles) evacuation that may follow. Evacuees from the inner zone of few miles' radius should be moved to locations at least 20 miles distant.

Discussion—In this case, the NRC could give better advice to the local authorities if there were better analyses done in advance, something similar to the decision matrix developed by the NRC on Saturday night, March 31 (see Appendix III.5). Core melt scenarios and offsite consequences could be more accurately predicted then. Without such advance calculation, only the few people most familiar with these specialized analyses could give a relatively precise timetable estimate for a core melt scenario and judge whether the offsite doses would reach Protective Action Guide levels. Presuming the absence of such advance calculations for a basis, we have had our postulated "well trained authority" offer the local authorities advice in terms of "a few hours" and "a few miles," admittedly imprecise terms. The outer radius of 10 miles is based on the latest thinking published at the time of the TMI accident,[208] which arrived at a 10-mile radius for evacuation planning for core melt scenarios. We are, of course, assuming that the postulated monitor has read this important document on emergency planning, which was published only 3 months before.

The difficult question in this situation is whether to advise precautionary evacuation of the nearby population or to advise only an alert for possible evacuation. The recommendation to evacuate is consistent with what we think would then be the case, a prudent doubt that the core-cooling passages were still sufficient for cooldown. In addition, the containment building was now filling with intensely radioactive gas and vapors, leaving the nearby public protected by only one remaining barrier, the containment, a barrier with a known leak rate that needed only internal pressure to drive the leakage. We presume the monitor would explain this to the governor or other official and thus help that official make an intelligent decision—which might not be to evacuate immediately.

Situation 2: In the NRC Headquarters at 9:15 a.m. on Friday, March 30

Information Available

1. The core is badly damaged from the events of Wednesday.
2. The cladding apparently underwent a massive metal-water reaction that released a large amount of hydrogen and radioactive gas into the reactor coolant system and in the containment building.
3. Since Wednesday night, the circulation provided by operating one reactor coolant pump was ap-

parently cooling the core; all temperature monitors indicate a cooling trend.

4. The pressurizer heaters and the reactor coolant pump, needed for this cooling mode, are both supplied by offsite power only and are vulnerable to its loss.
5. The gas bubbles in the system are large enough to be a threat to the ability to cool the core.
6. The system is being degassed as rapidly as possible, stripping hydrogen and radioactive gas out into the systems in the auxiliary building. It is not known yet whether degassing is removing the bubble.
7. The waste gas storage tanks in the auxiliary building have just been reported to be full. This means there is no more holding capacity for the radioactive gas being stripped.
8. There has just been an unconfirmed report of an uncontrolled 1200 mR/h gaseous release from "a point in one of the cooling towers." The location of the measurement is unknown.

Actions That Appear Warranted

1. Contact NRC inspectors in the plant to verify that the waste gas tanks are full and to confirm the facts related to the reported 1200 mR/h gaseous release.
2. Contact the Met Ed plant management directly to obtain their evaluation.

Discussion— The evacuation recommendation that was put out by the EMT under these circumstances was clearly a precipitous action. The report that the waste gas tanks were full, a significant development when radioactive gas is being stripped into them, was sent from the site without remarks about consequent actions. At the least, this indicated that whoever reported it didn't understand what was going on. A direct check would have discovered that the tanks were not full.

Even without an EMT request to verify the 1200 mR/h release, some of the facts came in quickly—offsite doses were on the order of 10 mR/h and the release had stopped. There was clearly plenty of time available to determine the facts and choose a course of action.

We believe that there need not have been a recommendation to evacuate at 9:15 a.m. Friday, and we feel that there should have been such a decision on Wednesday at 9:00 a.m. What of the time between, as NRC learned little by little how bad the accident was? There is no simple answer to that question because, as the NRC slowly learned of the severe damage, it was also slowly obtaining evidence that the cooling flow, restored Wednesday night, was successfully cooling the core.

Situation 3: In the NRC H-Street Commission offices at 10:00 a.m. on Friday, March 30

Information Available

1. There were intermittent releases of radioactive gas from the plant. There is little knowledge of the period or pattern of the releases, but they appear to be hours apart. Offsite doses associated with these releases are about 10 mR/h.
2. The NRC Headquarters staff has recommended evacuation to the State, but apparently with no effect. Local authorities are challenging the recommendation, and the staff sounds uncertain about reaffirming their recommendation.
3. The staff is getting more information from the site, but only in a piecemeal fashion.
4. The Governor is asking for the Commission to affirm or deny the recommendation to evacuate.

Actions That Appear Warranted

1. Order the Headquarters staff to check all reports with NRC personnel on site and with the Met Ed plant management.
2. Notify the Governor that the previous evacuation recommendation may have been unjustified.
3. Share all information gained with the Governor.

Discussion—It seems clear that if these procedures had been followed the NRC and the Governor would have had a clear basis for making their respective decisions. From a technical point of view, there was no apparent need to recommend evacuation. The plant was still in a relatively stable cooldown and the gaseous releases were not large. There was still great uncertainty about the final cooldown of the plant, but the situation was not significantly different from the night before. Presumably, if there was no need to evacuate then, there would be no need to Friday morning. Nevertheless, the Governor might have weighed all the facts at the beginning of the weekend and considered it prudent to remove many of the more radiation sensitive people by issuing an advisory. Later, if an evacuation were needed, the more sensitive population would for the most part be gone, which would simplify the evacuation.

Situation 4: With the Commission in the NRC Headquarters at 3:00 p.m. Sunday, April 1

Information Available

1. The plant is still cooling down very slowly.
2. There are mixed reports on whether the bubble is being removed from the reactor coolant system.
3. The oxygen content of the bubble may be increasing steadily. The gas composition may be

at or very close to the threshold of ignition. All available expertise is being applied to evaluate the gas problems.

4. Spontaneous ignition on sharp metal edges is possible.
5. The NRC staff in a prepared contingency plan has recommended a precautionary evacuation to at least 2-miles radius if the gas mixture is in the flammable range.
6. The contingency plan notes that an explosion leading to a core meltdown (4-hour warning) or even a breach of containment (24 hours to failure) would warrant even more extensive evacuation.
7. The local authorities are in a state of readiness that requires 4 hours call-up notice before fully effective action can proceed. The Governor will not change this state of readiness.

Actions That Appear Warranted

1. Continue working on the gas problem with all available resources.
2. Advise the Governor that the 4-hour state of readiness for local emergency forces is incompatible with the best estimated deterioration times available to the NRC.
3. Advise the Governor to increase the state of readiness or to begin a precautionary evacuation of the area near the plant.

Discussion—We now know that the concern Sunday about an ignitable bubble was unnecessary and was based on overly conservative analysis of the situation. Nevertheless, that was the best analysis based on information available to the Commission at the time. By Sunday the staff had prepared, at White House and Commission request, a procedure for evaluating and recommending evacuation (Appendix III.5). The Commission was right in following this procedure. Its recommendation, passed through the Chairman at the site, was blocked when Stello persuaded Hendrie that the gas bubble did not contain oxygen. Although all parties now seem to agree that Stello was right on April 1, we believe the four Commissioners acted correctly, basing their judgment on the evidence available to them.

Insights From Reconsidering Past Decisions

Reconsidering the Three Mile Island evacuation decisions can give us some valuable insights. For one, we see the obvious value of having the decisionmaker well informed. The Friday decisions were flawed because of the lack of accurate information. The factors surrounding decisions made on Friday and in situation no. 1 at 9:00 a.m. on Wednesday demonstrate a need for immediate surveillance of important plant parameters, either by a competent monitor in the control room or through a data link to such a monitor at a central location. Perhaps both methods of surveillance should be used.

A second insight of value is the importance of believing the best available information if it tells you that something is wrong. Verify it wherever possible, but be willing to believe it. The temperature instruments said the core was uncovered; they weren't believed and they should have been. You won't always be right if you believe the best reports available to you, witness the hydrogen bubble scare, but it is the proper course of action. The NRC's experience with the hydrogen bubble concern is a dramatic example of a problem that regularly is encountered in safety regulation. How conservative or pessimistic should you be? The NRC's worry about the bubble caused great public concern. The NRC's concern was later shown to be essentially unfounded, bringing great embarrassment to the agency and some of its principal staff. In retrospect we are all relieved that the NRC was wrong and, at least in this one respect, there was no danger to the public. But if these same officials are called to serve in another emergency, how pessimistic or conservative will they be? How conservative do we want them to be? Surely all of us would want them to be as realistic as possible, but where doubt exists, be conservative.

A third important insight is the value of having good contingency and emergency plans prepared. If there has been good preparation, then the NRC advisor and the State authorities can both have before them simple, understandable descriptions of possible events that entail the need for protective action. The interpretation of actual plant events and the intelligent evaluation of protective actions would be thereby greatly helped. Without a prepared system, these interpretations and evaluations are very vulnerable to gaps in the personal knowledge of the participants.

Findings

Based on the facts set forth in the narrative and the evaluation of NRC's actions on evacuation issues, we make the following findings:

1. The first NRC inspectors to arrive on site confirmed that the emergency operations contacts with the State were proceeding as planned.
2. Present emergency plans are inadequate because they do not provide a clear requirement to evaluate the need for protective actions based on deterioration of plant conditions.

3. There was no clear NRC policy that provided guidance to the NRC concerning evacuation recommendations to State officials.
4. The NRC did not promptly and regularly consider its obligation to give local authorities evacuation advice based on the condition of the plant.
5. The NRC management did not make a clear and orderly decision about who in the NRC should be the spokesman on evacuation and other protective measures, and to whom the spokesman should make his recommendations.
6. The NRC staff failed to verify facts significant to protective action decisionmaking before making decisions to recommend such actions.
7. The NRC did not analyze and present hazard data in an orderly way until Sunday, April 1.
8. The NRC consideration of evacuation based on fear that bubble expansion would uncover the core was not done carefully or completely.
9. Using the services of too many different groups without proper coordination, the NRC made a poor evaluation of the explosion potential of the hydrogen bubble.

c. Summary of Recommendations for NRC Emergency Response

Based on the evaluation and findings presented in the preceding sections, we make the following recommendations regarding NRC emergency response:

NRC's Emergency Response Organization at the Site

In an emergency of predetermined severity, the NRC should send an emergency response team to the site. The team should be drawn principally from personnel in the appropriate regional office, not from Headquarters. What is presently termed a "Level 1" emergency should always require the activation of this team. Through planning, the NRC should set standards determining the extent to which a "Level 2" emergency will require the activation of the emergency response team.

Whenever this team is activated and sent to the site, its leader should be the regional director or the regional official who, in the absence of the director, normally would become the acting regional director of the organization.

The onsite team leader should have the delegated authority to manage and direct the NRC's entire emergency response, and to be the agency's spokesman concerning the emergency response from the time of the team's arrival.

This authority should include the power to require the licensee to take such action as the onsite team leader deems appropriate to ensure adequate protection of the public's health and safety. Also included should be the authority to make a final recommendation to State and local officials on behalf of the NRC about the appropriateness of various protective actions, including evacuation.

The onsite team leader's authority should be made known through preplanned notification procedures to all NRC officials, officers and employees of the licensee, and appropriate Federal, State, and local officials.

The functions of the onsite team should include the following: (1) observing, evaluating, and reporting on operational and radiological status and activities; (2) giving advice or orders to the licensee regarding accident recovery; and (3) advising State and local authorities on public protection actions. A program plan should be prepared in each region ensuring that, to perform these functions, the onsite team will consist of a sufficient number of individuals with substantive training, experience, and a detailed understanding of the particular plant involved.

Regional project inspectors or, where applicable, resident inspectors should be part of the onsite team. These managers and inspectors must all have extensive exposure to the plant and good knowledge of its design, layout, operating procedures, and other essential information.

Procedures should be prepared that explain in detail the role of the onsite team. Team members should be adequately instructed as to who is team leader, what they should do upon arriving at the site, what to look for and report, to whom to report, and from whom they will receive further instructions.

The procedures should describe the emergency response structure that will be organized by the licensee during an emergency. These procedures should include the names and emergency telephone numbers of individuals given direct supervisory authority over the licensee's overall emergency response, and over operational and onsite radiological matters.

The procedures should describe State and local officials and offices that may play a role during the emergency, including the names and emergency telephone numbers of those officials who may have to be contacted and what their role will be in an emergency.

Upon arriving at the site, the onsite team should set up an operations center at a predesignated location, to which all available information concerning plant and offsite conditions will be transmitted. The licensee should set up a similar operations center at the same location. NUREG-0578 proposes that every licensee set up an "onsite operational support center." This center would be the logical location for the regional onsite team's operations center in an emergency.

Upon arriving at the site, the onsite team should immediately establish and maintain telephone contact with those individuals whom the licensee has designated to have direct supervisory authority.

Recognizing the onsite team leader's obligations as agency spokesman, the onsite team should be organized so that the team leader's deputies and principal managers in the everyday organizational structure are designated and prepared to assume primary responsibility for supervising the work of all NRC personnel at the site. These deputies and principal managers should be able to establish immediate verbal contact with the onsite leader at all times.

NRC Headquarters

When the NRC is first notified of an emergency requiring activation of an onsite team, NRC Headquarters officials should manage and direct the agency's emergency response until the onsite team arrives at the site. Once the onsite team leader notifies Headquarters of his arrival, however, full authority must pass to the onsite team leader and his team.

A duty officer should be available at the Headquarters Incident Response Center on a round-the-clock shift basis. When notified of an emergency requiring activation of an onsite team, the duty officer should supervise activation of the Headquarters' center. He also should notify the director of IE, or an individual previously designated by the IE director, to come to the incident response center as soon as possible. The duty officer, and then the IE director or his designee, should be responsible for managing and directing the NRC's emergency response until the onsite team leader assumes command.

Immediately upon notification of an emergency requiring activation of an onsite team, the Headquarters duty officer should establish telephone contact with individuals to whom the licensee has delegated direct supervisory authority. (At the beginning of an emergency, the licensee's designated individuals, like the Headquarters duty officer, may have only interim authority pending the arrival of other licensee officials.) Headquarters should maintain telephone contact until the arrival of the region's onsite team, which will then assume control.

Once the onsite team leader takes command, the function of the personnel at the Headquarters Incident Response Center should be to provide support and advice to the onsite team when and as requested by the onsite team leader. Headquarters should no longer manage or direct the NRC's response.

The Headquarters Incident Response Plan should describe the support and advisory functions that may have to be performed in any given emergency, and should specify which component office at Headquarters will be responsible for providing each such function. The plan should also describe the management structure each office will use in discharging an assigned function, as well as the structure that will be used to coordinate the work of all component offices. One individual from each component office should be designated ultimate responsibility for, and authority over, the work of the office. Similarly, one designated individual should command and be ultimately responsible for the coordinated work of all of the offices involved. This person should preferably be someone in the NRC's everyday organization, such as the EDO or a Commissioner, who has authority over the component offices.

Except for the command function at the incident response center just discussed, the Commission should not interject itself into the management's response to an emergency. The predesignated emergency response organization should be relied on. We expect that individual Commissioners will keep closely informed and act as spokesmen within the government.

Communications and Equipment

Automatic data retrieval systems should be developed to telemeter important plant data to the onsite response team's operations center, as well as to the affected region office and the Headquarters Incident Response Center.

Permanently open communication pathways should be maintained between each site and the region and Headquarters response centers. These communication lines should be backed up by alternative means of communication resistant to loss from possible environmental conditions (tornado, earthquake, and hurricane). The number of such permanent pathways should be determined on the basis of the data transmittal needs. As a minimum, separate pathways for operating and radiological information should be provided. Following an accident, each end of the permanent communication line should be continuously manned as soon as possible by NRC personnel who have been trained to ensure the adequacy and completeness of the information transmitted.

In an emergency, the oral communication of information among the onsite team, the regional office, and Headquarters, should be the responsibilities of individuals specifically assigned only to this task. They should have technical familiarity with the type of information being requested and transmitted, and should be trained to ensure the adequacy and completeness of the information transmitted.

The oral communication of information should be transmitted by the most direct means possible to the party having the principal need for the information. Thus, to the extent possible, emergency plans should establish communications priorities concerning the different categories of information. For example, the operations center of the region's onsite team should have first priority regarding all operations data. With respect to offsite radiological data, communications priorities should be established among the State, the region's onsite teams, or others who may have need in an emergency.

Each region should have available what has previously been determined to be the emergency equipment required to perform all necessary independent measurements, and to enable the NRC emergency response team to fulfill its mission. All such emergency equipment should be carried to the site by the onsite inspection team, or otherwise made available to them immediately upon arrival. The equipment should include portable communications equipment, portable air sampling devices, and protective equipment required for working in contaminated areas. Capabilities for quickly analyzing fission-product contaminated air and reactor coolant samples should be provided.

Notification Procedures

The region and Headquarters' incident response centers all should have duty officers available on a round-the-clock basis to immediately receive the licensee's notification of an accident.

The Role of the Agency

The NRC should prepare and publish a policy statement concerning its role in responses to nuclear accidents. This statement should describe the extent to which the NRC will independently collect and evaluate data relating to reactor safety systems and environmental releases following a nuclear accident.

The NRC's present policy referred to in paragraph 024 of Manual Chapter 0502, "NRC Incident Response Program," should be clarified. The NRC should prepare and publish a policy statement concerning whether and under what conditions the NRC will intervene to direct recovery actions following an accident. The statement should clarify the responsibilities of licensee management unless and until these are preempted by the NRC.

The NRC should consider in advance the assistance that will be needed by the State, the licensee, the NRC, and other Federal agencies in any nuclear accident. A determination of what will be needed and what party can and will satisfy the need should also be made. Agreements should be established between the NRC, the DOE, and other agencies as to what each will do in an emergency, and how and by whom the activities will be coordinated to ensure that all assistance and information needed by each of the parties is provided.

Protective Action Evaluation

The region's onsite team and the Headquarters' support team should each include a distinct group of officials whose assigned function is to evaluate contingencies. The group must be prepared to evaluate the chance of various contingencies actually occurring; the estimated type, magnitude, and timing of radiological releases in the event a contingency occurs; the likely exposure pathways resulting from such releases; and other matters weighing in favor of evacuation or other protective action.

The NRC support team at Headquarters should be organized in advance to identify centers of expertise for different technical areas. Based on the bad experience in one particular area during the TMI response, the NRC should establish within the staff an organization with concentrated expertise in reactor chemistry matters.

The contingency group should appraise the need for public protective measures as soon as possible after responding to an emergency. This appraisal should explicitly consider both the known state of the plant and possible deterioration in the plant's condition. The appraisal should be repeated whenever there is a significant change in the situation. The results of the appraisals should be communicated promptly to predesignated State and local officials.

The NRC should have a clearly identified single spokesman for making recommendations on protective actions. There should be advance knowledge on the part of State and local officials as to who this NRC spokesman is, with whom he will consult, and to whom he will make his recommendations. The spokesman for NRC should be the onsite team leader.

The NRC should prepare multiple plant accident and offsite hazard descriptions for each plant using realistic analyses and reference meteorology conditions. These descriptions should cover a wide range of serious accidents, including core melt sequences. They should be made a part of the emergency plan documentation so that all parties may refer to them readily during an accident.

Informing the State, Congress, Other Federal Agencies, the Media, and Others

The NRC should develop a policy about dealing with briefing requests from State and local officials, Congress, other Federal officials, the media, and others during emergencies. The policy should require that a special onsite team having no other role in the response activities, be made available to gather the latest facts and to brief the requesting agencies and individuals at frequent intervals. At least one such spokesman should be a senior NRC official. Members of this team who are responsible for transmitting information to people lacking technical expertise must have previously demonstrated an ability to explain technical information accurately in layman's terms.

The NRC should advise all other response team members—at Headquarters, the regional office, and at the site—to defer to the special team with respect to media briefings or discussions. A single location at or near the site for all media briefings should be considered. The NRC should provide guidance on what type of information is to be made available to the public to ensure they are kept informed of factual information, but are not panicked by rumors and unfounded or highly speculative information.

The informaton policy should be issued, along with an implementing procedure, as part of the emergency response plan. The NRC should inform the States, the Congress, the media, and the public of this policy, and request that they work only with this special information group. The NRC should be prepared to request that all State and Federal officials, including those from Congress, refrain from visiting the site of an accident or requesting hearings or formal briefings if such visits will interfere with the NRC's ability to fulfill its primary responsibility for the health and safety of the public.

The NRC should intensify its efforts to keep up-to-date information on nuclear accidents available on a prerecorded tape accessible to the public by direct dial phone.

Individuals who write preliminary notification documents (PN's) should be properly trained and instructed to prepare PN's for nontechnical readers. Highly technical terms should be avoided to the extent possible, and the significance of reported information should be explained.

The NRC should prepare and be able to provide to government officials and others appropriate documents to assist them in understanding technical explanations provided by the NRC staff during or after a nuclear accident. These documents should include primers on reactor operation, biological effects of radiation, and radiation protection terminology and concepts. Schematic drawings of plant systems and plot drawings that show how reactor systems interact and where the site is located in relation to nearby communities and environment monitoring stations should be available.

REFERENCES AND NOTES

[1]42 U.S.C. 5841, Sec. 201(a)(1).

[2]42 U.S.C. 5841, Sec. 201(a)(2).

[3]Kennedy dep. at 215.

[4]Hendrie actually held these positions in the NRC's predecessor organization, the Atomic Energy Commission.

[5]"Headquarters" as used in this section refers generally to the NRC offices in Washington, D.C. and the Maryland suburbs.

[6]42 U.S.C. 5843. Sec. 203(b)(1) and (2).

[7]"Early TMI Reports Sounded Like 'China Syndrome,'" p. 25, *The Washington Star*, June 11, 1979.

[8]Energy Reorganization Act of 1974, Pub. L. No. 93-438, Sec. 310, 88 Stat. 1253 (amending 5 U.S.C. Secs. 5315-5316).

[9]Sniezek dep. at 9, 21.

[10]Gossick dep. at 10-11 (Pres. Com.).

[11]NRC, "NRC Headquarters Incident Response Plan" at 4.1.2.

[12]*Id.* at Appendix II.C.

[13]Gilinsky dep. at 19.

[14]Hendrie dep. at 21.

[15]NRC, "NRC Incident Response Plan," Appendix I.B.1-4 and II.D.1.

[16]Gossick dep. (Sept. 28, 1979) at 15-16.

[17]*Id.* at 17.

[18]NRC, "NRC Headquarters Incident Response Plan," Appendix II.E.2.

[19]*Id.* at Appendix II.D.2.

[20]Moseley dep. (Sept. 25, 1979) at 11; Stello dep. at 87.

[21]Sniezek dep. at 6; H. Thornburg dep. at 9; J. Davis dep. (Sept. 11, 1979) at 18-22.

[22]Moseley dep. (Sept. 25, 1979) at 11.

[23]NRC, "NRC Headquarters Incident Response Plan," at 4.1.1, 4.2.1, 4.2.3.

[24]*Id.* at 4.2.1.

[25]*Id.* at Appendix II.E.3.

[26]*Id.* at 4.2.2.2.1.

[27]NRC, "Office of Inspection and Enforcement, Region I Incident Response Plan" at 1.2(b)-(d).

[28]*Id.* at 1.0(c).

[29]*Id.* at 8.1.15.

[30]*Id.* at 1.0(a).

[31]*Id.* at 1.2.b.

[32]*Id.* at 1.2.c.

[33]*Id.* at RIP-6.

[34]NRC, "NRC Headquarters Incident Response Plan," Appendix II.E.1.c.

[35]NRC, "Office of Inspection and Enforcement, Region I Incident Response Plan" at 8.1.15.

[36]NRC, "NRC Headquarters Incident Response Plan" at 4.1.2.

[37]NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," Investigative Report no. 50-320/79-10 (NUREG-0600), August 1979 at I-3-39.

[38]Hq. IRC Day 1 Transcript 01-115-CH4/22-EG-3.

[39]NRC Manual Chapter 0502, "NRC Incident Response Program," identifies three levels of incidents based on severity as follows:

Level I—There is an actual or imminent serious threat or hazard presented; activation of the NRC Incident Response Program required.

Level II—There is a potential serious threat or hazard, activation of the NRC Incident Response Program recommended.

Level III—There is no immediate potential threat or hazard, or there are relatively insignificant effects; Level III incident response is under the purview of the appropriate line office.

[40]Neely dep. at 5; Gallina dep. at 8.

[41]Hq. IRC Day 1 Transcript 01-258-CH7/25-EH-4.

[42]Ahearne dep. at 15.

[43]Hq. IRC Day 1 Transcript 01-066-CH3/21-PD-2.

[44]Thompson dep. at 159, 160.

[45]Neely dep. at 6; Gallina dep. at 12; Higgins dep. at 15.

[46]Higgins dep. at 26.

[47]*Id.* at 28.

[48]*Id.* at 38, 39.

[49]Hq. IRC Day 1 Tape 01-033. The conversation is transcribed with errors and omissions at Transcript 01-033-CH2/20MEM-6.

[50]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR-6.

[51]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR-8.

[52]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR-9.

[53]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR-10.

[54]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR-11 and -12.

[55]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR-14 and -15.

[56]Hq. IRC Day 1 Transcript 01-226-CH6/24-LFR 15.

[57]Stello dep. at 24.

[58]Higgins dep. at 51, 52.

[59]*Id.* at 17.

[60]Hq. IRC Day 1 Transcript 01-222-CH6/24-LFR-10 and -11; Transcript 01-223-CH6/24-LFR-1, -2, and -3.

[61]Vollmer dep. at 12.

[62]Hq. IRC Day 1 Transcript 01-126-CH4/22-HF-1.

[63]Grier dep. (Oct. 12, 1979) at 8.

[64]Higgins dep. at 26.

[65]*Id.* at 28, 29, 30.

[66]Hq. IRC Day 1 Transcript 01-01287-CH7/25-EH-1 and -2.

[67]Stello dep. at 71.

[68]NRC Commission Meeting Transcripts (March 29, 1979) at 7.

[69]*Id.* at 10.

[70]*Id.* at 20.

[71]*Id.* at 21.

[72]*Id.* at 23.

[73]Eisenhut dep. at 76.

[74]NRC Commission Meeting Transcripts (March 29, 1979) at 25.

[75] *Id.* at 13.

[76] *Id.* at 32.

[77] *Id.* at 33, 34.

[78] Mattson dep. (Sept. 24, 1979) at 31, 32, 33.

[79] Case dep. at 72, 74.

[80] Stello dep. at 69.

[81] Hearing before the Subcommittee on Energy and the Environment of the House Committee on Interior and Insular Affairs, 96th Cong., 1st Sess. at 31 of transcript (March 29, 1979).

[82] *Id.* at 49–50.

[83] Hq. IRC Day 2 Transcript 02-228-CH6-Kd-2, -3, and -4.

[84] Hq. IRC Day 2 Transcript 02-234-CH6-DC-5.

[85] Hq. IRC Day 2 Tape 02-073. The conversation is transcribed with errors and omissions at Transcript 02-073-CH3/21-SAC-2.

[86] NRC, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," Investigative Report no. 50-320/79-10 (NUREG-0600), August 1979, Appendix II-A at II-A-58.

[87] Vollmer dep. at 22.

[88] *Id.* at 31, 32.

[89] Denton dep. (Oct. 4, 1979) at 92, 93.

[90] President's Commission, "Report of the Office of Chief Counsel on Emergency Response," October 30, 1979 at 30–31.

[91] Hq. IRC Day 2 Transcript 02-212-CH6-CLB-5 and -6.

[92] Barrett dep. at 42, 43 (Pres. Com.).

[93] NRC Region I Incident Message Form, Control no. C-56.

[94] Higgins dep. at 80–89.

[95] Barrett dep. at 45, 46 (Pres. Com.).

[96] Hq. IRC Day 3 Transcript 03-259-CH7/25-PD-2.

[97] Denton dep. (Oct. 4, 1979) at 73, 74, 80, 81.

[98] *Id.* at 86.

[99] Case dep. at 100–101 and Exhibit 5092.

[100] Case dep., Exhibit 5182 at 70.

[101] Case dep. at 107–109.

[102] Denton dep. (Oct. 4, 1979) at 92.

[103] *Id.* at 105.

[104] Gossick dep. (Sept. 28, 1979) at 110.

[105] J. Davis dep. at 165, 166.

[106] Denton dep. (Oct. 4, 1979) at 88.

[107] *Id.* at 111.

[108] Hq. IRC Day 3 Transcript 03-019-CH2/20-sw-10 and -11.

[109] H. Collins dep. at 33.

[110] NRC Commission Meeting Transcripts (March 30, 1979), tape 1, side 1 at 5 and 6.

[111] *Id.* at 16.

[112] Bradford dep. at 122–25.

[113] NRC Commission Meeting Transcripts (March 30, 1979), tape 1, side 1 at 19.

[114] NRC Commission Meeting Transcripts (March 30, 1979), tape 2, side 1 at 3.

[115] *Id.* at 4.

[116] *Id.* at 7.

[117] Gallina dep. at 57.

[118] Hendrie dep. at 86.

[119] This statement is quoted in "Meltdown Looms as a Threat," p. 6, *New York Daily News*, March 31, 1979.

[120] NRC Commission Meeting Transcripts (March 30, 1979), tape 5, side 1 at 6.

[121] Bradford dep. at 105, 106.

[122] Hendrie dep. at 94.

[123] *Id.* at 95.

[124] Gerusky dep. at 64 (Pres. Com.).

[125] Transcript of Governor's press conference, March 30, 1979.

[126] Hq. IRC Day 3 Transcript 03-215-CH6/24-ab-1 and -2.

[127] NRC Commission Meeting Transcripts (March 30, 1979), tape 6, side 1 at 5.

[128] Mattson dep. (Oct. 17, 1979), at 83–84.

[129] Case dep. at 117.

[130] NRC Commission Meeting Transcripts (March 30, 1979), tape 12, side 2 at 10.

[131] Hendrie dep. at 156.

[132] Memorandum from J. A. Califano, Jr., HEW, to J. Watson, White House Aide, "Three Mile Island Nuclear Power Plant Accident," dated March 31, 1979.

[133] Hq. IRC Day 4 Transcript 04-099-CH4/22-sw-6.

[134] Denton dep. (Oct. 23, 1979) at 11.

[135] Denton dep., Exhibit 5090 at 8.

[136] Denton dep. (Oct. 23, 1979) at 12.

[137] *Id.* at 15.

[138] *Id.* at 13.

[139] NRC Commission Meeting Transcripts (March 30, 1979), beginning tape 10, side 1 at 13.

[140] Denton dep. (Oct. 23, 1979) at 29.

[141] Denton dep., Exhibit 5090 at 8.

[142] Denton dep. (Oct. 23, 1979) at 19.

[143] J. Collins dep. at 29, 30.

[144] *Id.* at 124.

[145] Denton dep. (Oct. 23, 1979) at 15.

[146] *Id.* at 15, 16.

[147] Grier dep. (Oct. 12, 1979) at 12, 13.

[148] *Id.* at 13.

[149] *Id.* at 13–15.

[150] Higgins dep. at 78.

[151] Denton dep. (Oct. 23, 1979) at 12.

[152] Hq. IRC Day 4 Tape 04-198. The conversation is transcribed with errors and omissions as Transcript 04-198-CH6/24-LFR-6.

[153] NRC Commission Meeting Transcripts (March 31, 1979), continuation of meeting at 12:00 noon at 4.

[154] *Id.* at 15.

[155] Higgins dep. at 93 and 94.

[156] Gilinsky dep. at 81.

[157] *Id.* at 82.

[158] Hendrie dep. at 150.

[159] NRC Commission Meeting Transcripts (March 31, 1979) tape 3-A at 3.

[160]Hq. IRC Day 4 Transcript 04-092-CH3/21-sw-4.

[161]Case dep. at 147-160.

[162]Case dep., Exhibit 5182 (Cassette 2) at 33-37, 44-45.

[163]*Id.* at 44 (Cassette 2).

[164]*Id.* at 45 (Cassette 2).

[165]Case dep. at 172.

[166]Mattson dep. (Sept. 24, 1979) at 254-256.

[167]Levine dep. at 62, 63.

[168]Denton dep. (Oct. 23, 1979) at 85.

[169]Mattson dep. (Oct. 17, 1979) at 66, 67.

[170]Denton dep. (Oct. 23, 1979) at 33-41.

[171]*Id.* at 42-48.

[172]Lazarus dep. at 4-5.

[173]Neely dep. at 5; Gallina dep. at 8-9; Higgins dep. at 9-10.

[174]George Smith dep. at 6-7.

[175]Grier dep. (Sept. 28, 1979) at 5-6.

[176]Hq. IRC Day 1 Transcript 01-850-CH19/2030-SW-5-6.

[177]Higgins dep. at 9.

[178]Plumlee and Nimitz Interview on May 30, 1979 (IE) at 23.

[179]Vollmer dep. at 12-16.

[180]Hq. IRC Day 1 Transcript 01-223-CH6/24-LFR-1-2.

[181]Case dep. at 66-71; John Davis dep. (Sept. 11, 1979) at 149.

[182]Moseley dep. (Sept. 25, 1979) at 21-23.

[183]Case dep. at 10-18.

[184]Higgins dep. at 51-55.

[185]Stello dep. at 34-35.

[186]Hq. IRC Day 5 Transcript 05-215-CH6/24-1-4; Grier dep. (Oct. 12, 1979) at 9.

[187]Hq. IRC Day 1 Transcript 01-222-CH6/24-LFR-3-5.

[188]Hq. IRC Day 1 Transcript 01-225-CH6/24-LFR-5-9.

[189]President's Commission, "Report of the Office of Chief Counsel on Emergency Response," October 30, 1979 at 54, 134.

[190]NRC Commission Meeting Transcripts (March 30, 1979) at 31-32.

[191]Grier dep. (Sept. 28, 1979) at 25.

[192]NRC Commission Meeting Transcripts (March 30, 1979) at 31-32.

[193]Hq. IRC Day 2 Transcript 02-212-CH6/CLB-1-7.

[194]Higgins dep. at 67.

[195]R. Thornburgh dep. at 39-40 (Pres. Com.).

[196]NRC Region I Incident Message Form, Control no. C-56.

[197]Hq. IRC Day 3 Transcript 03-259-CH7/25-Pd-1-2.

[198]Barrett dep. at 50-74 (Pres. Com.).

[199]Hq. IRC Day 3 Transcript 03-019-CH2/20-Sw-8-11.

[200]Denton dep. (Oct. 4, 1979) at 105.

[201]Gossick dep. (Sept. 28, 1979) at 115.

[202]NRC Commission Meeting Transcripts (March 30, 1979) at 57 *et. seq.*

[203]Appendix III.4 of this report.

[204]Mattson dep. (Oct. 17, 1979) at 36.

[205]Gilinsky dep. at 81.

[206]NRC Commission Meeting Transcripts (April 1, 1979) at 120.

[207]Kennedy dep. at 40.

[208]"Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," NUREG-0396, at 24, December 1978.

C RESPONSE OF STATE AND FEDERAL AGENCIES (EXCEPT THE NRC)

1. INTRODUCTION

Whatever can be done to prevent or mitigate the consequences of nuclear powerplant accidents or to protect public health and safety or property after an accident, one cannot preclude the possibility that accidents having serious offsite consequences will occur. Therefore, to minimize the effects of such accidents on public health and safety and on property, effective emergency response should seek to:

- Prevent minor reactor accidents from becoming accidents with significant onsite or offsite radiological consequences.
- Reduce the duration and magnitude of radiological releases from any accident through appropriate plant-related actions.
- Reduce the offsite effects of any radiological releases by assessing radiological hazards and implementing appropriate protective measures which must include disseminating unambiguous and easily understood information and instructions pertaining to the releases.

During the accident at Three Mile Island, the NRC and the utility were primarily charged with tasks arising from the first two of these objectives. Achievement of the last of these, and some aspects of the second, lay within the domain of other Federal and State agencies.

The TMI accident initiated an institutional and public response that was unprecedented in the history of nuclear power in the United States. Two dozen Federal agencies, a dozen agencies of the State and 27 counties of the Commonwealth of Pennsylvania, innumerable local jurisdictions and public and private organizations, four bordering States, and several national, quasi-Federal organizations participated substantially in the response to this accident.

These institutions provided many kinds of support services: to Metropolitan Edison in evaluating the status of the plant and in bringing the plant to a safe shutdown condition; and to the Commonwealth in evaluating the extent of public hazards, in preparing for possible evacuation, and in considering or preparing for the implementation of other protective actions. A State is the principal governmental entity responsible for protection of its citizens. Although the NRC clearly has Federal jurisdiction over events like those at TMI, it has no authority over offsite activities and can only make recommendations to a State regarding such activities. Other Federal agencies have no jurisdiction over plant activities and little or no jurisdiction over offsite activities, thus their role basically is to provide assistance to a State and to the NRC.

Because of the scope and complexity of the response, we chose to identify and evaluate the effectiveness of the integrated response, as opposed to performing a more laborious, time-consuming, and almost impossible detailed assessment of each agency's response. The rationale is that an accident such as the one at TMI will result in a similar multiagency response, and there is much more interest in the overall success of the response than in an agency-by-agency report card. Under this approach, the possible weakness of one agency's response could be offset by the strength of another agency's response in performing the same or a similar function. Such a weakness would not be critical and would not be underscored in our analysis. If it were critical, this fact would become apparent during the analysis of the total response.

Our analysis also would not likely highlight areas where response was excessive, or where unnecessary duplication of effort occurred; it attempts to assess only the adequacy of response, i.e., success versus failure. Furthermore, as in the case of most inquiries, we have given more attention to failure than to success.

We have divided the response into several different functions, and each function is discussed in a separate section of this report. We have tolerated some repetition of chronology in order that a reader primarily interested in only one of the response functions will find the story easier to understand.

The first section provides a recitation of the highlights of the "Emergency Response Chronology." This is provided to give the reader a general temporal impression of the type and magnitude of response, keyed to various changes or perceived changes in plant status and to other events, and is presented in narrative form. Appendix III.8 furnishes the reader with a more detailed portrayal of day-by-day events.

The next section provides an overview of "Federal and State Authorities and Responsibilities," together with an analysis of the status of the overall coordination and command structures (or lack thereof) in place at the time of the TMI accident. This section also necessarily highlights the important roles in coordination played by the White House and the Governor's office during the first week of the accident.

Detailed accounts of "Sheltering and Evacuation Advisories," "Evacuation Planning Before and During the Accident," including an assessment of evacuation capabilities, and "Other Protective Actions" considered or implemented to provide protection against radiological exposures, such as the possible use of potassium iodide, are then discussed. These stories are told in chronological form with sufficient commentary to give the reader some feeling for the pressures that existed during the accident and for the amount and quality of information that was (or was not) available, information upon which decisions had to be made.

The section on "Radiological Monitoring Efforts" provides a discussion of the institutional response to provide adequate radiological monitoring of the environment and to assess the anticipated radiation doses to people. A more detailed technical accounting of the physical measurements made and the assessments performed is provided in the previous Section II.B, entitled "Radiological Releases."

A section on "Institutional Communications During the Accident" is also included. Although integral to the effectiveness of all other emergency response functions, we believe that this subject is of such fundamental importance to effective response that it deserves to be discussed in a separate section, even at the expense of some repetition. The discussion treats the adequacy of communications networks and the effectiveness of human communications, once established.

A brief account of the "Technical Support for the Plant" provided by government agencies is discussed. Although much of this support was provided by the NRC, Metropolitan Edison, Babcock & Wilcox, and a host of other industry organizations and consultants, many services and much equipment were provided to the plant by other Federal agencies and their contractors.

The last section provides a "Summary of the Findings and Recommendations" contained in this portion of the report. It represents a synthesis of the findings and conclusions provided in each of the analytical sections. The interested reader is encouraged to examine the additional details available in these sections to gain a fuller understanding of the intent of and need for the summarized recommendations.

There are two appendices other than the one providing detailed chronology (III.8). Appendix III.7 provides an agency-by-agency summary of authorities and responsibilities for emergency response, tells in detail how each agency first became involved in the TMI accident response, and describes what each did. Appendix III.9 provides a brief summary of Federal legislation and executive actions related to emergency response that, as of December 6, 1979, has occurred since March 28, 1979.

2. EMERGENCY RESPONSE CHRONOLOGY

a. Introduction

During the early morning hours of Wednesday, March 28, 1979, the Three Mile Island Unit 2 (TMI-2) facility of the Metropolitan Edison Company (Met Ed) was operating normally, generating about 870 megawatts of electricity. At about 4:00 a.m., the plant suddenly experienced a total loss of the feedwater supply to the steam generators, resulting in an almost simultaneous shutdown or "trip" of the main steam turbine. With no feedwater supply to the steam generators, heat was no longer being removed from the reactor, and the reactor coolant system temperature and pressure began to increase. Approximately 3 seconds later, the pilot-operated relief valve opened at its setpoint pressure of 2255 pounds per square inch, absolute (psia), to relieve the excess pressure in the reactor coolant system. About 8 seconds after the turbine trip, upon receiving a high pressure signal from the reactor coolant system, the reactor protection system dropped the control rods into the core to shut down the reactor. This was the beginning of the TMI-2 accident.

During the ensuing 2¾ hours, the plant operators attempted unsuccessfully to bring the plant under control.[1] At 6:55 a.m., on the basis of high radiation alarms received from process and area radiation monitors, the TMI-2 Shift Supervisor declared a Site Emergency.

The Shift Supervisor's declaration of a Site Emergency triggered a series of responsive actions by various Federal, State, local, and other agencies. These actions were aimed, broadly, at controlling the technological consequences of the accident at TMI and protecting the local populace. This section of the report provides a brief chronological summary of the actions comprising the official emergency response efforts of the State and Federal agencies, except the NRC. Appendix III.8 provides an itemized chronological listing of the response actions in more detail.

b. Emergency Notifications

In accordance with the NRC-approved plant emergency plan, the Shift Supervisor, after declaring a Site Emergency,[2] began notifying offsite agencies. Within 15 minutes the plant had called the duty officer of the Pennsylvania Emergency Management Agency (PEMA); the Radiological Assistance Program (RAP) office of the Department of Energy (DOE) at the Brookhaven National Laboratory on Long Island, New York; the Emergency Management Agency of Dauphin County, where the TMI plant is located; the Pennsylvania State Police; and the answering service of the NRC Region I office in King of Prussia, Pennsylvania. The PEMA duty officer, in turn, contacted the Pennsylvania Bureau of Radiation Protection (BRP) and the emergency management offices of the three counties within 5 miles of the plant—Dauphin, York, and Lancaster.

At 7:24 a.m. the reactor building dome monitor alarm sounded, indicating a radiation reading of greater than 8 R/h at the top of the reactor building. (Because the dome monitor is shielded, it was expected to read about a factor of 100 less than the actual radiation level. Thus, the reading of 8 R/h implied an actual radiation level of 800 R/h.) Since this high reading indicated that there could be substantial offsite consequences in the event of a containment leak, Gary Miller, the Station Manager, who had arrived on site about 15 minutes earlier in response to a directive from Jack Herbein, Met Ed Vice President for Generation, declared a General Emergency.[2] His declaration triggered a second round of notifications, whereby plant personnel again called the officials they had first alerted less than half an hour earlier. Meanwhile, Thomas Gerusky of the BRP had called the Unit 2 control room at 7:25 a.m. to confirm the earlier notification BRP had received from PEMA; he was advised that the situation had escalated to a General Emergency. The telephone line between the control room and BRP that had carried Gerusky's call was held open over the next 2 weeks. It served as the principal communications link between the utility and the State for the duration of the accident.

In addition to the above notifications, PEMA called Pennsylvania's Governor Thornburgh, Lt. Governor Scranton, and the State agency members of the Pennsylvania Emergency Management Council. PEMA also alerted the Region 2 office of the Defense Civil Preparedness Agency in Olney, Maryland. The Brookhaven Area Office of the Department of Energy alerted the Emergency Operations Center at DOE Headquarters in Germantown, Maryland, which, in turn, notified various DOE subgroups, the National Military Command Center in the Pentagon, and the Joint Nuclear Accident Coordinating Center[3] in Albuquerque, New Mexico. At 10:00 a.m., the DOE Emergency Operations Center placed its

Aerial Measurement System/Nuclear Emergency Search Team (AMS/NEST) at Andrews Air Force Base in Maryland on standby alert.

A telephone call from the NRC Region I office to the TMI Unit 2 control room at 7:50 a.m. provided the first notice of the plant emergency to the NRC. The Region I office immediately activated its Incident Response Center and called the NRC Headquarters in Bethesda, Maryland. The NRC Headquarters activated its Incident Response Center at 8:05 a.m. and then spent about one hour alerting the NRC Commissioners and various staff members about the accident. By 9:30 a.m. the NRC had alerted the White House Situation Room and appropriate House and Senate staffs.[4]

At 9:02 a.m. the Associated Press released a national bulletin stating there had been an accident at Three Mile Island and that a General Emergency had been declared, but that no details were available. This was the first public notification of the accident.

Meanwhile, for a brief period between 7:45 a.m. and 8:20 a.m. on Wednesday morning, PEMA placed the residents of Brunner Island and Goldsboro, in York County downwind from the plant, on evacuation alert. PEMA cancelled the alert at 8:20 after plant personnel had determined that no radioactivity was escaping from the plant buildings and BRP had concluded there was little or no potential for radiation leakage from the plant.

The NRC Region I office sent two teams of inspectors to the TMI site. These teams both arrived at the Unit 1 control room by 11:00 a.m. on Wednesday morning.

Beginning at about 10:20 a.m. on Wednesday, radiation monitoring teams from the plant began detecting increased radiation levels on the Three Mile Island site outside the plant buildings. These radiation levels continued to increase during the day. Offsite readings downwind from the plant remained low. In response to these radiation readings and because there was a likelihood that small radioactive releases from the plant would continue, the NRC requested DOE to move the AMS/NEST from Andrews AFB to the site area, and the State BRP requested the assistance of a RAP team from Brookhaven.

c. Initial Emergency Response

The NRC issued a press release at about 10:30 a.m. on March 28 confirming reports of an emergency situation at the TMI site. The press release stated that primary coolant water had been released into the containment building and that there had been a release of radioactivity to the containment building, but that no radioactivity had been detected off site. At 10:55 a.m., after the NRC announcement, Pennsylvania Lt. Governor Scranton held a press conference based upon preliminary information he had obtained on the accident from Gary Miller at the TMI Unit 2 control room. He announced that the State had been informed of an "incident" at TMI-2, but that "everything is under control" and "there is and was no danger to public health and safety." He mentioned that there had been "a small release of radiation to the environment."[5]

The AMS/NEST from Andrews AFB arrived at the Capital City Airport near Harrisburg at 1:30 p.m. and established an operations center in the airport manager's office. The team's aerial radiation measurement equipment arrived later, enabling the team to start making aerial surveys of radiation levels in the area around the plant that afternoon. A Coast Guard helicopter brought the RAP team from Brookhaven, landing at the Capital City Airport at 2:30 p.m.

After the initial flurry of notifications and reactions, and based upon the sketchy information obtained from the plant, the State and Federal agencies seemed to reflect that the situation at the TMI plant was under control, or soon would be, and that there was no real danger to the local populace. Other than those immediately involved (that is, the NRC and DOE among the Federal agencies, and the PEMA and BRP among the State agencies) government agencies adopted passive observer roles.

As the day wore on, it became increasingly apparent that the core had suffered much more damage than the plant operators had originally thought. Difficulties in putting the plant into a cold shutdown condition were being encountered. Moreover, radiation releases continued; these were believed to be caused primarily by radioactive gases escaping from spilled water on the floor of the auxiliary building.

During Wednesday afternoon, press conferences held by Jack Herbein of Met Ed at 1:15 p.m. and by Lt. Governor Scranton at 4:30 p.m., as well as a press release issued by the NRC Headquarters at 5:00 p.m., all indicated that the reactor was under control and, while some radioactivity had been released off site, it posed no real hazard to the local populace. However, State officials had become suspicious that Met Ed was not telling them the complete story. Lt. Governor Scranton told the reporters at his press conference that Met Ed had "given you and us conflicting information."[6]

This technical situation continued through all of Thursday, March 29. During the day, DOE sent additional RAP teams from the Pittsburgh Naval Reactors Office and an AMS/NEST from Las Vegas to the site to assist in the radiological monitoring effort. A team of technicians from the NRC Headquarters also arrived on site during the day. Offsite radiation monitoring efforts revealed radiation levels only slightly above the natural background level.

Thursday evening Governor Thornburgh held a press conference during which he stated his belief that there was no cause for alarm, no danger to public health, and no reason to disrupt daily routines. However, he noted the conflicting information that had been received, and stated that the situation appeared to be under control, but it was important for people to remain alert and informed.

d. Expanded Response After Friday, March 30

During Thursday night and early Friday morning, plant operators conducted several brief venting operations to relieve the pressure in the reactor coolant makeup tanks by transferring the gases in them to the waste gas decay tanks. Leaks in the piping system connecting these tanks allowed some of the radioactive gases to escape, however, causing bursts of radioactivity to be released to the atmosphere during each venting operation. By approximately 7:00 a.m. on Friday morning, pressure in the makeup tanks had again increased and, at 7:10 a.m., the unit Operations Chief and the Shift Supervisor jointly ordered resumption of the gas transfer from the makeup tanks to the waste gas decay tanks; they instructed the operators to leave the transfer piping line open to allow for a continuing gas transfer. They also ordered a helicopter aloft to make a radiation survey over the plant during the gas transfer operation.

At 8:01 a.m. the team in the helicopter measured a radiation level of 1200 mR/h at an altitude of 600 feet above sea level, 130 feet above the Unit 2 auxiliary building vent stack. The helicopter then flew lower in an attempt to better define the source of the measured radiation. The radiation level decreased to 600 mR/h as the helicopter descended and, when the helicopter returned to the original altitude of 600 feet, the team found no further high radiation readings.

Plant personnel reported the 1200-mR/h reading to both PEMA and the NRC. This set off a chain of events, described in detail in the "Sheltering and Evacuation Advisories" section, that culminated in a sheltering advisory issued by the Governor at 10:25 a.m. for all persons within 10 miles of TMI, and an evacuation advisory by the Governor at 12:30 p.m. for pregnant women and young children within 5 miles of TMI. These advisories were issued after consultations between the Governor and NRC Chairman Hendrie, as well as many other individuals. The Governor had even discussed the partial evacuation with President Carter.

The President requested that Harold Denton go to the site immediately to act as a central point of contact and as the President's personal representative with regard to technical matters concerning the plant status and the potential for radiological releases.

That afternoon, at 2:00 p.m., a meeting of all the key Federal agencies[7] was held in the White House Situation Room. Jack Watson, Assistant to the President for Intergovernmental Affairs, chaired the meeting and assumed the lead role for the White House in directing the Federal agency response effort. During the meeting, a decision was made to send two people to the site: Robert Adamcik, the Philadelphia Regional Director of the Federal Disaster Assistance Administration (FDAA), to coordinate the logistical aspects of the Federal agency response efforts; and John McConnell, Assistant Director for Plans and Operations of the Defense Civil Preparendess Agency, to assist the State with evacuation planning. Following the meeting, Jack Watson called Governor Thornburgh to advise him that Adamcik and McConnell were coming in addition to Denton. Watson assured the Governor that there would be no Federal takeover and that Federal personnel would maintain a low profile.

Denton and his staff arrived on site by Presidential helicopter from Bethesda at approximately 2:00 p.m. on Friday afternoon. McConnell arrived in Harrisburg from Washington at about 5:30 p.m. Adamcik and his staff arrived in Harrisburg from Philadelphia at about 11:00 p.m.

At 12:40 p.m. on Friday, Roger Mattson at the NRC office in Bethesda called Chairman Hendrie to report that the staff estimated that there was a 1000-cubic-foot hydrogen bubble in the reactor vessel, at a pressure of 1000 pounds per square inch. Because of the uncertain and unanalyzed status of the reactor, Mattson recommended that people within a 10-mile radius be evacuated. Chairman Hendrie discussed the reported hydrogen bubble during the 2:00 p.m. meeting in the White House Situation Room and stated that an evacuation of up to 20 miles from the plant might be necessary while the plant technicians coped with the problem. At about 3:45 p.m. Chairman Hendrie called Governor Thornburgh and suggested that in view of the hydrogen bubble problem, the Governor should place the State emergency plan officials on alert status. At 4:00 p.m. a UPI wire quoted Dudley Thompson of the NRC in Bethesda as saying that a core meltdown could occur within a few days. At about the same time, McConnell of DCPA called Henderson of PEMA to advise him that he (McConnell) was coming to Harrisburg. Based on what he had heard from Chairman Hendrie during the earlier White House meeting, McConnell recommended that PEMA start working on plans for evacuation of the area within 20 miles of TMI.

At approximately 10:00 p.m. Friday, Governor Thornburgh and Denton held a joint press conference. On the basis of information obtained from Denton, the Governor announced his decisions that: (1) no evacuation order was necessary at that time; (2) his earlier recommendation that pregnant women and preschool-age children leave the area within 5 miles of the plant would remain in effect at least until Saturday, March 31; and (3) his recommendation that people within 10 miles of the plant take shelter would expire at midnight Friday.[8]

The Federal agency response swung into high gear on Friday following the agency meeting at the White House. The DCPA sent planning personnel and operators with radios to assist the State and the counties with evacuation planning. Adamcik and his FDAA staff went to Harrisburg to coordinate the Federal agency response effort. The DOE significantly increased the radiological monitoring efforts it had begun Wednesday. HEW sent personnel to participate in the radiological monitoring and arranged for procurement of potassium iodide, a thyroid blocking agent. EPA initiated a comprehensive environmental monitoring program in the area around the TMI plant. The DoD provided air and highway transportation services to move special equipment to the site in support of the TMI plant operations and, in conjunction with the Red Cross, began planning for furnishing and equipping mass care facilities and for providing special transportation for the evacuation. The DOT acted as a consultant in arranging for transportation for potential evacuees.

The Boise Interagency Fire Center of Boise, Idaho, at the request of the NRC, furnished communications equipment and radio operators to assist in the radiation monitoring efforts. The U.S. Postal Service identified vehicles to be available to assist in the evacuation. The National Oceanic and Atmospheric Administration provided routine weather forecasts and moved specialized teams and equipment to the site to provide improved meteorological data to DOE. The Consolidated Rail Corporation (CONRAIL) arranged for special trains to handle evacuees. At the request of the NRC, the National Bureau of Standards furnished lead bricks for use at the plant and provided data to help analyze the hydrogen bubble problem, and the National Aeronautics and Space Administration furnished the services of a consultant to help Met Ed solve the problem. The U.S. Department of Agriculture, on its own initiative, ordered all Federal meat and poultry packing plants within 5 miles of TMI to cease receiving and shipping produce.

Also at the State level, emergency response actions went into high gear on Friday, March 30. The PEMA Emergency Response Center began operations on Friday morning; emergency response teams from concerned State agencies were in attendance. The Pennsylvania State Police installed a portable radio base station at the TMI observation center to provide a radio link with PEMA in Harrisburg. Later Friday afternoon the State Police set up a mobile command post near the observation center and increased their patrols that evening to prevent looting of evacuated dwellings. The National Guard called selected officers to State active duty on Friday and began preparing plans to assist in a full-scale evacuation. The Pennsylvania Department of Transportation began planning to assist in evacuations. The Pennsylvania Department of Agriculture issued a recommendation through the Governor's press office that farmers get their animals indoors and put them on stored, protected feed.

The American Red Cross in Washington decided that the possible evacuation would be beyond the capabilities of its local chapters, so it designated its Eastern Field Office to coordinate planning for the mass care facilities that would be required.

Before March 28 emergency planning covered a 5-mile area around Three Mile Island and involved three counties: Dauphin, York, and Lancaster; prior to the accident, each county had already prepared emergency plans for its area within 5 miles of the plant. On Friday, however, following the NRC recommendation of a 10-mile evacuation, PEMA requested evacuation planning for a 10-mile radius, which concerned four counties. Later that day, after Denton had briefed the Governor, PEMA expanded the evacuation planning radius to 20 miles and late Friday and early Saturday issued instructions to this effect to the six counties affected by the change.

These decisions to extend evacuation from a 5-mile zone to a 10-mile zone, and then to a 20-mile zone introduced entirely new dimensions to the counties' emergency planning operations. The existing 5-mile evacuation plans could not simply be expanded to become 20-mile plans because more people and more institutions were affected and counties that were outside the 5-mile zone were included in the 20-mile zone. As a result, the affected counties had to initiate the 20-mile planning almost from scratch. A frantic planning effort took place during the 2-day period from early Saturday morning to early Monday morning, April 2. Several State and Federal agencies provided significant assistance to the counties during this planning effort. PEMA, DCPA, the State Police, the National Guard, the State Department of Health, and the State Department of Transportation offered valuable assistance. After the hydrogen bubble had been identified in the reactor vessel on Friday, Met Ed began operating the plant in a manner designed to allow the hydrogen gas to escape from the reactor vessel into the containment building. By Saturday morning, at a press conference in the American Legion Hall in Middletown, Jack Herbein of Met Ed was able to announce that efforts to reduce the size of the bubble were apparently meeting with success. He conveyed the impression that plant conditions were stable and that the plant was being brought under control. Almost immediately after Met Ed's press conference, near noon on Saturday, Denton independently held a press conference in the Middletown Borough Hall. He suggested that, contrary to Herbein's assessment, the crisis was not over and would not be over until the reactor was completely shut down. He affirmed his belief, however, that the hydrogen bubble presented no immediate danger of an explosion. He could not confirm the bubble shrinkage claimed by Met Ed, inasmuch as the NRC staff in Bethesda were still examining the data.

At this point, however, there was considerable concern among the NRC staff that oxygen as well as hydrogen was being generated within the reactor vessel and that, in time, an explosive mixture of hydrogen and oxygen would be attained. The staff attempted to calculate when an explosive condition might be reached. During a 2:45 p.m. press conference in Bethesda, Chairman Hendrie admitted that evacuation from around the site might have to be considered as a prudent precautionary measure, but he stated his belief that it would be some time before there was any possibility of a flammable condition.

Saturday night, at 8:23 p.m., Stan Benjamin of the Associated Press put out a bulletin, cleared by NRC officials in Washington, that warned that the hydrogen bubble showed signs of becoming potentially explosive. He followed this shortly with a second bulletin attributing to an unnamed NRC source a statement that the bubble could explode within 2 days.

Those press releases caused a near panic in the area around the plant. At 9:00 p.m. Saturday Denton held an impromptu press briefing in Harrisburg in response to the bulletins. He said that the hydrogen bubble would not become explosive for from 9 to 12 days and that there was ample time to correct the problem. He stated his belief that there was no imminent danger. At a later joint press conference on Saturday night, both Governor Thornburgh and Denton attempted to allay public fears about a hydrogen explosion.

On Sunday afternoon at about 1:00 p.m., the President and Mrs. Carter arrived at the Harrisburg airport enroute to visit the TMI site. Denton briefed the President's party at the airport. At the time, Denton was still receiving conflicting advice about the hydrogen bubble from his staff. Some persisted in their belief that an explosion was possible, while others argued that it could not occur. The President's party toured the plant and the President later held a brief press conference during which he avoided characterizing the prognosis of the accident, since the seriousness of the hydrogen explosion problem was not known. The President also did not discuss the possibility of an evacuation, but he did emphasize that the crisis was not over and he urged people to remain alert. Though the President was unable to report that the crisis was past, his visit to the site did much to abate public fears of imminent catastrophe.

Later Sunday, on the basis of its own calculations and the advice of experts around the county, the NRC staff in Bethesda concluded that oxygen could not accumulate in the reactor vessel. Thus, a flammable mixture of hydrogen and oxygen could not be present in the reactor vessel and there was no danger of an explosion. This conclusion was not transmitted to the Governor or to the public until Tuesday afternoon, although late Monday morning Denton indicated that the oxygen buildup in the bubble was based on very conservative calculations. The people in the area of TMI-2 went to bed Sunday evening with the feeling that catastrophe, if not imminent, was still possible although, in view of the President's visit, perhaps the danger was not as real as it had seemed.

e. Events After Sunday, April 1

By Monday morning, April 2, the emergency coordinators in the six "risk" counties had reasonably well-detailed evacuation plans laid out; refinement of the plans continued for the next few days. They had planned evacuation routes and had phased the evacuation to avoid congestion. The risk county officials had coordinated evacuation plans, at least minimally, with designated host county officials, and the host counties were well along in obtaining potential mass care facilities. Host county officials, with Red Cross assistance, developed plans to staff and stock the mass care facilities. The risk county officials had arranged for special transportation assistance (from military ambulances, for example) to assist in evacuating hospitals and nursing homes. Five National Guard battalions and a headquarters unit were ready for call-up to State active duty; they stood by to assist local authorities in the evacuation efforts and to provide security for the evacuated area.

At 11:15 a.m. Denton held a press conference in Middletown to announce that fuel temperatures continued to drop and that the hydrogen bubble had dramatically decreased in size (although the NRC technical support staff was still checking the calculations). He acknowledged that earlier reports regarding a possible hydrogen explosion inside the reactor vessel had been based on assumptions that were "too conservative" regarding the oxygen generation rate. Finally, he stated that the plant was about to start using the hydrogen recombiner to reduce hydrogen concentration in the containment building. By Tuesday afternoon at 2:40 p.m., Denton was able to announce at a press conference that he no longer considered a hydrogen explosion to be a significant problem because of the too-conservative numbers that had been used to calculate oxygen generation rates, because the hydrogen bubble had been eliminated from the reactor vessel, and because the hydrogen recombiner was reducing the hydrogen concentrations in the reactor containment building.

Federal agency response to the accident continued. On Monday DCPA sent additional staff members to Pennsylvania to assist the host counties in planning for care of evacuees. DCPA also shipped 6000 low-range dosimeters, capable of measuring radiation doses in the millirem range, to Pennsylvania for use by emergency workers in the plant area.

On Sunday FDAA had begun to hold daily coordination meetings with the participating Federal agencies. These meetings, held in Harrisburg, served as the clearinghouse for planning protection and evacuation of the populace. In addition, FDAA's Adamcik became the principal contact point for the NRC personnel on site in obtaining materials and equipment needed to support the technical operations at TMI. Adamcik provided daily reports to the White House, through FDAA Headquarters, summarizing the activities of all Federal agencies. DOE had begun to hold meetings of State and Federal monitoring teams each day at 5:00 p.m., starting on Friday, March 30, to consolidate the radiological measurement data accumulated during the day and to plan the next day's activities. These meetings were held throughout the period during which DOE coordinated the radiological monitoring data for the State.

The reactor remained relatively stable during the week; temperatures in the fuel element channels slowly decreased. On Saturday, April 7, at about 1:25 p.m., the reactor coolant pump that had been circulating the water through the reactor primary system stopped operating and had to be replaced with a sister pump, which was started and in operation within 2 minutes. Other than causing a slight shift in the pattern of thermocouple readings for fuel element channels, the change of pumps did not affect the cooling operation.

Denton held additional press conferences during the week, but they grew more and more routine. Finally, on Monday, April 9, at 3:00 p.m., 13 days after the accident began, Governor Thornburgh held a final press conference regarding the TMI accident. Thornburgh stated that he had spoken with Chairman Hendrie and that he had met with Denton, Adamcik, Lt. Governor Scranton, and other State officials. On the basis of the information and advice of these persons, he had decided to end all previous recommendations, advisories, and directives: pregnant women and preschool-age children could safely return to their homes; schools in the TMI area would reopen on Tuesday, April 10; State offices would return to business as usual; and emergency preparedness forces could shift from their full alert to an on-call status. Governor Thornburgh announced that he had been assured by State Department of Environmental Resources and State Health officials that the milk and drinking water of central Pennsylvania posed no residual threat to public health. The emergency was over.

f. Long Term Recovery Phase

Following the Governor's press conference on April 9, activities at and around Three Mile Island entered a long term recovery phase.

The plant has operated with natural circulation of coolant since April 27. Eventually the cleanup crews will have to enter the containment building and remove the damaged fuel elements from the reactor. Such activity, however, is months in the future. In the meanwhile, Met Ed has undertaken cleanup operations of the auxiliary and fuel handling buildings and other plant facilities that became contaminated during the accident. Final cleanup and restoration of the plant to commercial service are estimated to be several years away and will cost several hundreds of millions of dollars. At the time this report is issued, no decision has been announced as to the ultimate plans for the TMI-2 facility.

On April 13, 1979, Jack Watson sent a memorandum from the White House to the Secretaries of Health, Education, and Welfare (Califano) and Energy (Schlesinger) and to the Administrator of the Environmental Protection Agency (Costle), designating the Environmental Protection Agency as the lead Federal agency to continue the environmental radiological monitoring effort in the TMI vicinity during the final stages of plant shutdown and the start of the cleanup effort. He requested that HEW and DOE continue some of their radiation monitoring efforts and furnish the data obtained to the EPA operations center for inclusion in a report to be prepared by EPA for submission to the President's Commission on TMI. Federal monitoring activities around the plant will continue until cleanup of the damaged reactor is completed.

On April 19, 1979, Jack Watson sent a memorandum from the White House announcing that he had designated Thomas C. Maloney, Chairman of the Mid-Atlantic Federal Regional Council, to serve as the lead Federal official responsible for coordinating Federal response to the TMI accident.[9] In the memorandum, Watson confirmed that the NRC would "continue to have full on-site responsibility at Three Mile Island," and that EPA would "continue to have the lead for all direct federal activities pertaining to environmental monitoring." Watson assigned specific responsibilities to Maloney, including "...assuring effective communication within the Federal government and with the Governor and State officials, identification of problems requiring federal assistance, and monitoring the effectiveness and quality of federal responses."

On April 27, A. Vernon Weaver, Jr., Administrator of the Small Business Administration (SBA), approved the request of Governor Thornburgh to declare the five-county area including Cumberland, Dauphin, Lancaster, Lebanon, and York Counties an economic dislocation area. The SBA established special offices in Harrisburg, Lancaster, York, and Middletown to handle claims from local businesses. The program was designed to run through December 1979, but the SBA closed the Middletown office about the end of June and the other offices in October because of the small number of claims submitted.

Due to the fact that any damage to human health would first be discernible in newborn or stillborn infants, HEW's Region III office funded a State Department of Health study beginning immediate data collection on pregnancy outcomes. The Federal Center for Disease Control in Atlanta, Georgia, and the National Institutes of Health authorized the State Department of Health to incur up to $300 000 in costs to complete a detailed population census of all persons within 5 miles of TMI. Federal personnel, especially from the Center for Disease Control and the Public Health Service, provided extensive onsite technical assistance to the State Department of Health for this effort. Data collection for the census was virtually complete by July 15, 1979. This census registry will be used for any future health studies of the population. The National Institute of Mental Health has designed and is now funding a mental health survey to study the psychological impacts of the TMI crisis.

The Defense Civil Preparedness Agency, now a part of the Federal Emergency Management Agency (FEMA),[10] and the Nuclear Regulatory Commission designed a joint survey to study emergency response and behavior of the population affected by the TMI accident. Federal emergency agencies have been reviewing the adequacy of their own preparedness and working with State and local officials to improve the emergency planning and preparedness at the State and local levels.

Several Federal agencies (Department of Commerce (DOC), HUD, DOE, and the Community Services Administration) are funding a comprehensive study by the Governor's Office of State Planning and Development of the socioeconomic impacts of TMI. The Commonwealth's socioeconomic study focuses on the impacts of TMI in the following areas: commercial and industrial production and employment, agricultural production and commodity consumption, food processing industries, tourism and travel, new residential and commercial construction, residential real estate activity, community development, local governmental budgets, State and local revenues, and insurance claims associated with the accident.

The Mid-Atlantic Federal Regional Council has coordinated Federal assistance relative to the economic impacts of TMI in the Harrisburg area and is prepared to take action to mitigate adverse economic impacts if necessary.

3. FEDERAL AND STATE AUTHORITIES AND RESPONSIBILITIES

a. Introduction

Statutes, formal agreement, and tradition govern the response of Federal, State, and local government organizations to a peacetime nuclear emergency such as that presented at Three Mile Island. This subsection of our report explores this composite framework of government as it stood on March 28, 1979. In so doing, we wish to provide the background necessary to understand how government agencies came to perform critical official response functions during the emergency and how the weaknesses and strengths of the framework affected the response to the accident. The details of the Federal and State responses to the accident and the expanded evacuation planning which took place during the accident appear in other parts of this Section III.C.

By vesting in the President the executive power of the Federal Government and naming him Commander-in-Chief, Article II of the United States Constitution authorizes the President to command the Nation during peacetime civil emergencies as well as in times of military crisis abroad. A similar executive power to lead a State in times of domestic crisis resides in the Governor of each State of the Union and receives formal recognition in each State's constitution. The President and the Governors have at their disposal numerous organizations, equipment, and expertise to aid them in responding to an emergency.

At the same time, tradition dictates that local communities, from town to county, retain primary responsibility for planning emergency procedures and for carrying out those procedures in an actual crisis. The premise is that an evacuation team comprised of local citizens will better know whom to aid and by what route to evacuate, for example, than will a team of strangers to the stricken region. Between these extremes of power and capability lie many official responsibilities and authorities for managing an emergency. These manifold duties independently create a further responsibility: coordination of Federal, State, and local roles in responding to a crisis.

This subsection outlines the Federal and State authorities and responsibilities as they stood on March 28, 1979, for responding to an accident at a fixed nuclear facility. It describes how these authorities and responsibilities were documented prior to the accident, and how they affected the response to the accident.

b. Federal Authorities and Responsibilities

As stated, the President derives his broad power and responsibility to lead the Nation during a domestic nuclear crisis from Article II of the United States Constitution. Congress has enacted several statutes to enable the President to perform his role.

In 1950 Congress passed the Federal Civil Defense Act, 50 U.S.C. Sections 2251 *et seq.*, under which the Defense Civil Preparedness Agency (DCPA)[11] was established as part of the Defense Department. Though this Act was designed to cope with emergencies arising from an enemy attack, and though the section of this Act that provided DCPA with emergency powers during a civil defense emergency has lapsed, the Act nonetheless establishes an emergency management mechanism available for executive use during a domestic nuclear accident. As will be explained below, the President is authorized to use the DCPA in any kind of civil emergency.

More recently Congress passed the Disaster Relief Act of 1974, 42 U.S.C. Sections 5121 *et seq.*, which places a broad array of emergency measures at the disposal of the President and the Federal agencies to supplement State operations. The Act makes access to these measures contingent upon a Governor's request and the President's subsequent declaration that a major disaster has occurred. The Act circularly defines a "major disaster" as "any hurricane, tornado, . . . fire, explosion, or other catastrophe in any part of the United States which, in the determination of the President, causes damage of sufficient severity and magnitude to warrant major disaster assistance under the Act. . . ."[12] Though many of the measures authorized by the Act are oriented toward the type of disasters enumerated in the definition quoted above, i.e., a severe tornado or fire, the measures would be appropriate also in the event of a severe nuclear accident.

The Disaster Relief Act provides, for example, that agencies may loan or donate equipment, supplies, and personnel to a stricken area during an emergency,[13] or may make contributions to State and local governments to help rebuild an area after an accident.[14] The Act authorizes the President generally to provide a disaster-torn area with such other assistance under the Act as he deems appropriate;[15] to this end, it explicitly licenses the President to use the services of the DCPA.

The Disaster Relief Act of 1974 also permits the development of contingency plans for dealing with nuclear catastrophes, including an accident at a nuclear powerplant.[16] Toward this end the President has issued three Executive Orders (Executive Orders 11051, 11490, and 11725) which require the Federal Preparedness Agency (FPA), an emergency planning agency within the General Services Administration, to (1) coordinate and develop policy for emergency planning and preparedness among Federal departments and agencies, (2) prepare nonmilitary plans and preparedness programs within the Federal Government, (3) stimulate State and local participation in emergency preparedness, and (4) coordinate Federal and State involvement in emergency preparedness. The Executive Orders also require Federal agencies to develop peacetime nuclear emergency operational response plans.

FPA initiated the Federal planning effort for peacetime nuclear emergencies called for by these Executive Orders in April 1977, by issuing a document entitled "Federal Response Plan for Peacetime Nuclear Emergencies (Interim Guidance)" (FRPPNE). FRPPNE, as issued in April 1977, was not a response plan but was intended to accomplish four objectives: (1) provide policy and interim guidance to Federal agencies for the development, review, and maintenance of Federal plans and capabilities for responding to peacetime nuclear emergencies; (2) facilitate complete and coordinated Federal planning for all peacetime nuclear emergencies; (3) provide a basis for compatibility between Federal and State plans; and (4) identify responsibility for implementing and coordinating the efforts of Federal agencies responding to peacetime nuclear emergencies.[17]

The FRPPNE Interim Guidance directed the Nuclear Regulatory Commission, the Department of Energy, the Federal Disaster Assistance Administration, the Defense Civil Preparedness Agency, and (for incidents of domestic terrorism) the Department of Justice, to prepare operational response plans for specific types of nuclear emergencies. More than twenty other Federal agencies were designated to provide planning and operational support to these five primary agencies. The FPA encouraged the agencies to make maximum use of existing response plans in preparing the plans required by the April 1977 guidance. The FPA was responsible for overall coordination and direction of the FRPPNE planning effort.

In March of 1979, neither FRPPNE in its final form nor the five operational response plans called for under the April 1977 Interim Guidance had been completed. However, one Federal response plan for peacetime nuclear emergencies, the Interagency Radiological Assistance Plan (IRAP), in existence when FPA issued its Interim Guidance, continued in effect at the time of the accident at TMI.

IRAP is a Federal interagency agreement developed in 1961 to provide a means for using Federal resources for radiological assistance in the event of a peacetime nuclear emergency. Thirteen Federal agencies participate in the agreement. IRAP is intended to optimize the use of existing Federal facilities and capabilities and to encourage development of State and local plans and capabilities to cope with radiological incidents. It obligates its signatory agencies to make available their resources for development of an integrated Federal radiological assistance capability and for responding to a radiological emergency, subject to prior commitments to fulfill the agencies' primary responsibilities. It also obligates the Federal agencies to make their radiological response training capabilities available to State and local authorities. IRAP anticipates Federal, State, and local cooperation, and reciprocity with State and local governments during an emergency.

The Department of Energy (DOE) is assigned responsibility in IRAP for administration, coordination, and implementation of the radiological response efforts covered by the Plan. In support of IRAP, as well as its other responsibilities, DOE maintains a national Emergency Operations Center at Germantown, Maryland, and eight Regional Coordinating Offices. Typically, requests for assistance under IRAP are made by a State or local agency to a DOE Regional Coordinating Office. That office then calls upon the services of another agency, or dispatches a Radiological Assistance Plan (RAP) team, a DOE capability, to the locality, depending on the nature and extent of the request. Prior to March 28, 1979, DOE had responded to many minor radiological incidents, mostly transportation accidents involving radioactive materials, which did not require assistance from more than one signatory agency. At the time of the TMI accident, the interagency coordination aspects of IRAP had never been tested.

IRAP is not a plan, but a general inventory of radiological monitoring capabilities, both national and regional, of the 13 participating Federal agencies and is also a compilation of useful operational data, such as the locations and telephone numbers of the DOE Regional Coordinating Offices. IRAP defines neither the conditions under which its agency obligations will be activated nor who will bear the financial responsibility for the resulting response.

c. Implementation of Federal Authorities and Responsibilities During the TMI Accident

During the first 2 days of the accident at TMI, DOE was the only Federal agency, other than the NRC, to respond officially to the accident. DOE's radiological assistance to the NRC was not requested specifically under IRAP, although the NRC was aware of IRAP and of DOE's lead agency role under that agreement. The DOE support of the NRC was carried out under the interagency agreement between the two agencies developed following the creation of the NRC ("Agreement Between the U.S. Energy Research and Development Administration and the U.S. Nuclear Regulatory Commission for Planning, Preparedness and Response to Emergencies," March 8, 1977). The DOE support of the Commonwealth of Pennsylvania was automatically under the aegis of IRAP. Because DOE was the only Federal agency responding at that time and because DOE's relationships with both the NRC and the State were clear, there was no requirement for Federal interagency coordination.

With the perceived escalation of the emergency on Friday morning, March 30, several additional Federal agencies, notably the Environmental Protection Agency and the Department of Health, Education, and Welfare, initiated their own involvement in TMI. Because FRPPNE had not been completed, the functions that these other agencies should have performed and the mechanism for coordinating the overall Federal response was not clear. As a result, each agency independently initiated the radiological monitoring or other assistance programs that each was capable of providing. IRAP was not used to coordinate the Federal radiological monitoring activities because the assistance of the other signatory agencies that responded was not requested by DOE, the NRC, or the State under IRAP. Though IRAP was not fully invoked during the accident, the individual responses of the IRAP signatory agencies were largely consistent with the commitments they had made in IRAP.

The lack of clear mechanisms for coordinating the Federal response under FRPPNE or IRAP and the fact that the State had not requested a disaster declaration resulted in White House intervention on Friday afternoon, March 30. The White House did not undertake a command function; it did not direct the Federal response to the accident. It did attempt to coordinate the Federal response and ensure Federal and State coordination by arranging meetings of the involved Federal agencies to discuss what was being done. The White House also designated a lead Federal official for the TMI offsite response: Robert Adamcik, the Director of the Federal Disaster Assistance Administration's Philadelphia Regional Office. John McConnell of the Defense Civil Preparedness Agency was designated to assist the State in evacuation planning, and Harold Denton of the NRC as the President's personal technical representative on site.

Adamcik's responsibilities did not extend to coordination of the extensive Federal radiological monitoring effort that had begun in the area by Friday evening.[18] This gap was filled Friday night during a meeting in the Harrisburg area that was attended by the NRC, DOE, EPA, HEW, and State BRP officials, a meeting at which Thomas Gerusky, the Director of BRP, asked DOE to coordinate all State and Federal radiological monitoring.

Because Governor Thornburgh had not requested that the President make a disaster declaration for TMI, the Federal response authorized under the Disaster Relief Act of 1974 could not officially be made available to the State. The evidence indicates that no disaster declaration was requested by the Governor to avoid unnecessarily escalating the concerns of the people in the TMI area over the accident. The Governor has stated, however, that he withheld requesting the President to make such a declaration because he had been assured by the White House that Pennsylvania would receive the same level of Federal assistance, both during and after the incident, without a disaster declaration as they would have received if a disaster had been declared.[19] We believe that the Governor would have requested a disaster declaration had the Federal assistance not been satisfactory or had the situation at the plant deteriorated.

It is unclear what effect, if any, the absence of a disaster declaration had on the Federal response. Such a declaration would have clarified the authority under which certain actions were taken and would have made Federal funds available to the State, after the emergency, to pay for certain extraordinary expenses which were incurred. We uncovered no evidence, however, that the Federal response would have been significantly different with a disaster declaration. A disaster declaration probably would not have resulted in an earlier Federal response because events on Wednesday and Thursday did not lead State officials to believe that a situation necessitating a request for such a declaration had occurred or was likely to occur. Also, the actions by the White House on Friday accomplished the same Federal coordination and response as a disaster declaration would have.

On April 13, after the emergency was over, the White House took steps to coordinate the long term radiological monitoring in the TMI area by designating the EPA as lead agency for these efforts, to be assisted by HEW and DOE.[20]

d. State, County, and Local Authorities and Responsibilities

Legislation and Statewide Powers

The response plans that the Commonwealth of Pennsylvania had in place on March 28 assigned initial responsibility for directing emergency actions to local communities and envisioned that communities would call upon county and State agencies as their needs required. The State's plans acknowledged State responsibility for coordinating response efforts involving two or more counties and for seeking Federal assistance when appropriate.

As of March 28 the Commonwealth of Pennsylvania had in effect a Disaster Operations Plan that had been issued in accordance with the Federal Civil Defense Act of 1950, discussed earlier, under the authority vested in the Governor by Pennsylvania's State Council of Civil Defense Act of 1951.[21] The Disaster Operations Plan established certain fundamental principles, local responsibility preeminent among them, which were to govern the subsidiary programs that the Plan required. It also sought to provide a "common basis for joint State and County/local government operations in natural disaster...situations."[22] The plan charged the State Council of Civil Defense with the responsibility for putting the plan into effect.

In November 1978 the State legislature enacted the Emergency Management Services Code,[23] repealing the State Council of Civil Defense Act of 1951 and other related acts and adding certain provisions relating to emergency management. The Code established, among other things, the following emergency responsibilities within the State. First, it articulated the Governor's ultimate responsibility "for meeting the dangers to this Commonwealth and people presented by disasters,"[24] and gave him broad legal powers, apparently contingent upon his proclamation of a disaster.[25] Second, the Code established the Pennsylvania Emergency Management Council, which consists of 16 high ranking State officials, including the Governor and the Lieutenant Governor, to supersede the State Council of Civil Defense. The Governor has appointed the Lieutenant Governor Chairman of the Council. Under the Code, the Council was to employ an individual to direct the Pennsylvania Emergency Management Agency (PEMA), which superseded the staff office under the State Council of Civil Defense. It specifically assigned PEMA a new responsibility for responding to peacetime nuclear emergencies and directed PEMA to prepare an emergency plan for the State, to provide technical assistance to State agencies and political subdivisions, to monitor the status of local emergency plans, and to "provide emergency direction and control of Commonwealth and local emergency operations."[26]

Third, the Code directed and authorized each political subdivision of the Commonwealth to establish a local emergency organization in accordance with PEMA's overall plan and program and gave each subdivision the responsibility for local emergency management and recovery and the power to declare a "local disaster emergency."[27] Each local emergency management organization was to be headed by a coordinator and was to prepare, maintain, and keep current a disaster emergency management plan; establish, equip, and staff an emergency operations center; and provide prompt and accurate information regarding local disaster emergencies to appropriate Commonwealth officials and to the general public. Fourth, the Code provided immunity from civil liability, except in cases of gross negligence or willful misconduct, for persons engaged in disaster service activities in compliance with the Code. Finally, it imposed monetary penalties on persons violating its provisions and gave the Council power to halt Federal personnel and administrative funding of any political subdivision found to have violated the Code.

PEMA and BRP Plans

At the time the Commonwealth's Disaster Operations Plan was developed, the Department of Environmental Resources (DER), not the State Council of Civil Defense, PEMA's predecessor, was responsible for emergency planning for nuclear powerplants in Pennsylvania.[28] However, in July 1977, because DER had not completed a State-wide plan for responding to nuclear emergencies, PEMA included Annex E, entitled "Nuclear Incidents (Fixed Facility)" in the Disaster Operations Plan. This was intended as a stopgap measure until DER finished its plan. At about the same time, the Director of PEMA and the Secretary of DER entered into an agreement which provided that DER would continue to be the lead State agency in fixed nuclear facility planning.[29]

Annex E addressed in vague terms the relationship of local, county, State, and Federal governments in emergency response; the responsibilities of county and local governments; the roles of BRP, PEMA, and other State agencies during a nuclear emergency; the Federal assistance available to a State emergency response effort; and listed certain "protective action guides" for use in a nuclear emergency.[30]

In September 1977, 2 months after the appearance of Annex E, BRP issued a "Plan for Nuclear Power Generating Station Incidents." In this plan BRP addressed in greater detail the issues raised by PEMA in Annex E, and added discussions of accident assessment procedures and protective action options available during a nuclear accident. BRP's plan was largely consistent with Annex E.

According to these plans, which were both in effect on March 28, 1979, a utility was to give initial notification of an accident to PEMA. PEMA would first alert BRP, and then notify other State departments and agencies of the accident. If an emergency were officially declared—and, as we have observed, no emergency was declared during the TMI accident—PEMA was responsible for several tasks: (1) coordinating State, county, and local emergency operations; (2) coordinating technical and other assistance extended by Federal and private organizations; (3) relaying information to the counties; (4) operating the State's emergency operations center; and (5) maintaining emergency communications facilities. BRP's tasks were to: (1) establish and maintain contact with the facility for accident assessment purposes; (2) conduct environmental sampling and analysis; (3) advise State, county, and local agencies, through PEMA's information network, to take appropriate protective actions; and (4) request radiological monitoring assistance from Federal agencies, as needed.

These plans also assigned responsibility for particular response efforts during a nuclear emergency to other State agencies, including the Departments of Agriculture, Justice, Transportation, Health, and Military Affairs; the Fish and Game Commissions; and the State Police. The plans did not, however, provide for liaison between BRP and the Department of Health or provide for the Department of Health to be consulted by BRP regarding the need for protective actions during radiological emergencies.

In 1978 Dauphin, York, and Lancaster Counties, on the advice of PEMA, had developed emergency plans for accidents at TMI, including plans for a 5-mile evacuation. While these plans differed greatly in detail, each generally described public notification and evacuation procedures to be used in the event of an accident. None of the localities within 5 miles of TMI had emergency plans specifically for accidents at TMI, although the county directors had encouraged development of the plans before the accident. At the time of the accident, the three counties within 5 miles of TMI had full-time emergency management directors and all but two of the localities within the 5-mile area had appointed emergency management coordinators.

Only the notification and communications aspects of the State plans had been tested prior to the accident. Though the county plans had not been formally tested, the three counties within 5 miles of TMI had conducted limited evacuations in the past because of flooding of the Susquehanna River and therefore had some emergency management experience.

e. Implementation of State, County, and Local Authorities and Responsibilities During the TMI Accident

During Wednesday and Thursday, March 28 and 29, the State response to TMI consisted primarily of PEMA and BRP carrying out their responsibilities according to the existing plans. Lieutenant Governor Scranton, in his capacity as Chairman of the Pennsylvania Emergency Management Council, served as spokesman for the State and senior State official handling TMI during those 2 days.

The events of Friday morning heightened concern within the State over the seriousness of the accident and resulted in Governor Thornburgh taking charge of the State response to the accident. Although this action was not contemplated in State plans, it was not inconsistent with the Governor's authority and responsibility under the Pennsylvania Emergency Management Services Code. This action had major effects in the areas of decisionmaking and communications.

The events on Friday also resulted in officials within PEMA and many other State agencies and in the counties planning furiously for an expanded evacuation, in the middle of the crisis. This action obviously had not and could not have been anticipated in the State's preaccident planning efforts, particularly since the NRC had only stressed the need for such planning in the Low Population Zone—a distance for TMI of only about 2 miles.

Throughout the crisis, BRP continued to operate according to its plan, although on Friday BRP officials found that the expanded Federal presence had resulted in significantly more radiological monitoring activities in the area than they had requested. As was noted before, on Friday evening BRP requested that DOE coordinate all Federal and State radiological monitoring programs for the State. Although the BRP plan did not provide for liaison and consultation with the Department of Health, effective liaison between the Director of BRP and the Deputy Secretary of Health for Administration took place during the accident because the Deputy Secretary of Health had previously worked in DER and knew the Director of BRP.

During the TMI accident, Governor Thornburgh did not declare a disaster emergency under the Pennsylvania Emergency Management Services Code. However, on Friday afternoon the Pennsylvania Emergency Management Council was convened. At least part of the reason for this meeting appears to have been the requirement of Section 7312(d) of the Emergency Management Services

Code that when a disaster is determined actually or likely to exist, the Chairman of the Council shall call the Council into session within 48 hours. Although we are not aware that such a determination was officially made, the escalation of events that morning could have led the Governor or Lieutenant Governor, or both, to believe that a disaster situation was likely to exist.

Finally, though the Emergency Management Services Code attempts to protect Commonwealth personnel from civil liability in carrying out emergency functions, the constitutionality of this law was being challenged at the time of our inquiry, though not in a TMI-related lawsuit. The question of liability could be an important one and could enter into the thinking of a decisionmaker, particularly when considering precautionary protective measures that are costly to the public and that may prove in retrospect to have been unnecessary. Howe er, Governor Thornburgh has stated that the cos of evacuation or the question of liability never er tered his mind during the entire time the possibil y of evacuation existed.[31]

f. Findings and Recommend tions

The preceding narrative describes the Federal and State authorities for responding to peacetime nuclear emergencies and the status of planning for these emergencies as of March 28, 1979. It also briefly describes how these authorities and the existence or lack of plans influenced the Federal and State response to the accident. Since the accident, changes in both the Federal and State planning and response programs for peacetime nuclear emergencies have taken place or have been proposed. Because our recommendations build upon these changes, several of them will be briefly introduced in the detailed recommendations which follow. Greater details on the Federal changes are presented in Appendix III.9.

The findings of this section are:

1. In general, while there existed a reasonable understanding of Federal emergency response authorities and responsibilities in the event of a nuclear powerplant accident, there was no effective, coordinated emergency response plan in which the operational mechanism and responsibilities of interagency response, coordination, and command were clearly spelled out. The lack of Federal response plans for peacetime nuclear emergencies probably delayed the Federal response somewhat and resulted in some confusion and coordination problems as the Federal response expanded Friday. However, it is clear that improved Federal plans, in and of themselves, would not have resulted in a substantial increase in protection of public health and safety in the accident at TMI. This is not to say that such plans might not be extremely important in a fast-moving accident with greater offsite consequences.
2. The TMI accident clearly revealed implementation and coordination deficiencies in IRAP, the only complete Federal response document at the time of the accident. These inadequacies could have been revealed either by a pragmatic review of the agreement or through appropriate testing.
3. FRPPNE did not provide a guide for Federal agency response or a mechanism to coordinate the Federal response because it had never been completed.
4. The Governor's decision not to request the President to make a disaster declaration did not substantially affect either the State or Federal response. In the absence of a declared disaster, the actions taken by the Governor and the White House on Friday, March 30, assured adequate Federal and State coordination.
5. The State plans did not formally provide for liaison between BRP and Health authorities or for BRP's consultation with Health authorities on protective action recommendations. However, effective liaison between these two organizations was accomplished during the accident. One reason for this effectiveness was a prior professional relationship of the top officials in each organization.
6. There may be a substantive conflict between the State law (which charges PEMA with "direction and control of local emergency operations") and the philosophy of State response as described in the Disaster Operations Plan (which charges the local jurisdictions with the basic responsibility for protection of health and safety). This potential conflict should be carefully reviewed, and the authority to command and responsibility for protection of citizens in the State should be clearly documented.

Specific detailed recommendations relating to the development of State, county, and local emergency plans are included in Sections III.C.4 and 5.

The detailed recommendations of this section regarding overall authorities and responsibilities are as follows:

1. On September 16, 1978, Federal Reorganization Plan No. 3 established the Federal Emergency

Management Agency (FEMA) as the agency responsible for centralized overall planning and coordination for Federal agency response to emergencies, including nuclear reactor accidents. We endorse this action. We believe it is appropriate for FEMA to be the lead Federal agency for emergency planning and operations for fixed nuclear facilities because:

a. Many of the elements of the emergency response are common to both nuclear and nonnuclear emergencies, and FEMA, through its predecessors, has had lead responsibility for most emergency response planning and operations. However, FEMA can and must delegate specific technical aspects of planning and response functions to other Federal agencies such as the NRC, the EPA, DOE, and HEW, while retaining overall responsibility and authority.

b. Through its many responses to other man-made and natural disasters, FEMA has a normal operating role that will keep its emergency response capabilities sharp, whereas another agency like the NRC would have more difficulty maintaining its proficiency.

c. The emergency response role should not involve an emotional or philosophical conflict with the normal activities of the organization.

d. To the extent practicable, duplication of Federal resources should not be encouraged by the assignment of the same emergency response authorities or responsibilities to more than one Federal agency.

We caution, however, that in the interim, while FEMA is in the process of developing its capabilities, FEMA must make optimal use of the work that the NRC has done and is presently doing in providing guidance to the States and in reviewing existing State plans.

2. To handle planning and coordination FEMA must have sufficient authority to generate a timely response from other Federal, State, and local agencies. Such authority must recognize the following:

a. The NRC has authority over the regulated nuclear industry and has associated responsibilities, including the approval of the utility licensee's emergency plan and concurrence in certain aspects of the State's plan. A memorandum of understanding should be prepared between the NRC and FEMA outlining their respective responsibilities.

b. Many of the general needs and requirements for offsite emergency response to nuclear powerplant accidents are similar to those needs and requirements for other kinds of disasters and should be appropriately meshed with plans for those other disasters. The only unique planning aspects that must also be incorporated are the development of radiological protective action guidelines, criteria as to when these guidelines should be implemented, the requirements for radiological monitoring and assessment, and the need for technical assessments and forecasting of plant status.

c. The State and local agencies have authority over their citizens and have associated responsibilities.

d. The utility has the basic responsibility for the safe operation of the licensed nuclear powerplant.

3. FEMA must develop a comprehensive Federal response plan for peacetime nuclear emergencies. (At the time of our inquiry, Congress was proposing in the NRC's fiscal 1980 appropriations bill (S. 562) the development of a more explicit description of Federal and State authorities, responsibilities, and coordination. This bill would require that within 120 days of enactment the President, through FEMA, develop a National Contingency Plan, and that within 6 months the NRC develop an agency plan.) We recommend that the national plan developed by FEMA must include the following, as a minimum.

a. Upgrading of the Federal Response Plan for Peacetime Nuclear Emergencies (FRPPNE).

b. Upgrading and better coordination with FRPPNE of the Interagency Radiological Assistance Plan (IRAP) and the various agency plans, such as DOE's Radiological Assistance Plan (RAP).

c. A better description of the resources that could be expected on a temporal basis from the various agencies (e.g., ARAC at LLL, aerial surveillance capabilities, field laboratories, monitoring equipment, communications equipment, transportation facilities, personnel, etc.).

d. A clearly established command and coordination relationship among the various Federal agencies.

e. A category of response short of a declared disaster which activates appropriate response authorities and responsibilities.

4. The proposed NRC appropriations bill (S. 562) requires that an NRC emergency plan be

developed that provides appropriate details for rapid agency response to reported incidents at nuclear facilities. Some of these provisions are in the area of NRC interface with other Federal agencies. Therefore, the following important factors must be considered in the development of this plan.

a. The principal focus of NRC emergency planning efforts must be: (1) establishment of appropriate accident and consequence scenarios with attendant probabilities; (2) development of protective action guidelines and criteria for implementation; and (3) preparation for effective, independent technical evaluation and forecasting of plant status and likely radiological releases. These factors need to be coordinated with FEMA, EPA, HEW, and DOE.

b. The NRC must not plan for independent, extensive radiological monitoring and assessment capabilities. This is a function of DOE, EPA, the State, the licensee, and other Federal agencies, as appropriate. In particular, DOE is already equipped for prompt, large-scale emergency response and has the built-in advantage of more frequent operational testing of the personnel and equipment in its day-to-day operations. Therefore, duplicative Federal resources would be avoided and a more effective response likely provided if DOE were formally assigned this function. (The current version of S. 562 assigns EPA the responsibility for radiation monitoring outside the facility boundaries, a substantial duplication of Federal resources. EPA should, however, be the lead agency for the long term assessment of radiological effects, and should, therefore, have a role in planning for routine and emergency monitoring. HEW should have the role of determining the resultant radiological health effects on the population.)

5. Regarding State and local authorities and responsibilities, there could be a substantive conflict between elements of the State law that authorize PEMA to exert command control over local emergency actions and the portions of the law (and the underlying basic philosophy) that charges the local jurisdictions with the responsibility for protection of the health and safety of their citizens. This possible problem should be carefully considered by the Commonwealth (and other States), and the emergency plan must clearly describe the command functions to be discharged by PEMA, the circumstances under which they would become effective, and the operational aspects of discharging them.

4. SHELTERING AND EVACUATION ADVISORIES

During the first week of the nuclear accident at Three Mile Island (TMI), a number of official decisions were made to protect the health and safety of the people living near Metropolitan Edison's (Met Ed) Unit 2 reactor. These decisions affected almost three quarters of a million people within 20 miles of the plant. They included issuing an advisory to "stay indoors," an advisory to evacuate pregnant women and preschool children within 5 miles of the plant, and decisions at various times not to order a general evacuation. Since the State is the political entity that must order its citizens to take protective actions, most of the following is a discussion of events as seen from the vantage of the State.

a. Background

By definition, protective actions in a nuclear accident are actions taken to avoid or reduce a population's exposure to radiation after a reactor accident. The greater a population's exposure, the greater the number of damaging health effects, such as cancer, that can be expected within that population. Accordingly, to decrease the number of radiation-caused health effects resulting from an accident, government officials may either recommend or direct that various protective actions be taken.

In planning for emergency response to a reactor accident, State and Federal officials commonly consider ordering or advising a population to take the following protective actions: (1) "evacuation," in which all or selected categories of persons leave and stay out of a specified area surrounding the plant; (2) "taking shelter," in which persons remain inside a building to minimize their radiation exposure (persons remaining inside receive less radiation than those remaining outside); (3) "thyroid blocking," in which a drug is administered to prevent the thyroid gland from absorbing radioactive iodine released from the plant or contained in contaminated food or water, thus reducing the radiation dose to the thyroid; and (4) food or water interdiction, in which contaminated food or water is prohibited from human consumption. (The last two forms of protective action will be discussed in more detail in a subsequent section.)

Following the accident on March 28 much official effort was devoted to measuring the levels of radiation and radioactivity in the TMI area. Radiological monitoring teams made measurements close to the plant, at distances 15 or 20 miles or more from the plant, and at many points in between. The results of these measurements were used by government officials to estimate the risk to persons in the area and to decide which, if any, protective actions should be advised or ordered to reduce the estimated risk of exposure.

As an aid in deciding when to take these protective actions, in September 1977 the Pennsylvania Emergency Management Agency (PEMA) issued the Pennsylvania Disaster Operations Plan which included certain Protective Action Guides (PAGs). Other official bodies such as the Federal Environmental Protection Agency and the Food and Drug Administration have also adopted the PAG approach. The various PAG systems are not identical, but they do provide sufficiently consistent guidance to avoid confusion when attempting to apply them. These PAGs are recommendations keyed to the doses of radiation that a population is anticipated to receive after an accident if the population takes no protective actions. For example, the PAG system recommends considering a take-shelter advisory or order when the expected dose to a member of the general population exceeds 1000 millirem. (A millirem is one thousandth of a rem, a unit used to express the amount of radiation dose). While the PAGs are meant to serve as planning guides, the intent is that the State should require that some protective action be taken when anticipated doses approach the PAGs.

The Plan for Nuclear Power Generating Station Incidents, issued by the Pennsylvania Bureau of Radiation Protection in 1977 significantly expanded the PEMA plan's treatment of PAGs.

Applying these protective action guides requires considerable judgment. Although each protective action option can effectively reduce a population's radiation exposure, each also imposes certain costs. For example, while evacuation of an area where significant levels of radiation are going to occur would reduce the population's exposure to radiation, such an evacuation would impose the serious financial cost of moving and caring for evacuees, interrupting business and employment, disrupting social and educational activities, and causing health risks from traffic accidents and moving critically ill persons from hospitals. Thus, before deciding to order an evacuation, the State must weigh and balance the likelihood of occurrence of significant radiation levels, the likely reduction in exposures, and the costs of evacuation against the effectiveness of other protective measures such as sheltering.

As suggested above, a decision to take a protective action depends in part on existing and anticipated radiation levels. If forecasting radiation levels is impeded by uncertainty about further releases of radioactivity from the reactor, one approach is to assume the worst and simply to proceed with the appropriate protective actions. However, the framework of the PAGs is built around the concept that the exposures are likely to occur unless protective actions are taken. In the emergency response to TMI, the likely releases were very low compared to the PAGs. However, there was a small chance of very large releases which, if they occurred, would result in exposures that would far exceed the evacuation PAGs. This uncertainty about predicting further releases from the reactor contributed mightily to many individuals' opinions about the need to take protective actions at particular points in time.

b. Consideration of Sheltering and Evacuation

The first serious consideration of ordering an evacuation occurred early Wednesday morning, 3 hours and 45 minutes into the accident. An evacuation alert was sounded when, based on radiological calculations supplied by Met Ed through BRP,[32] PEMA advised York County Civil Defense to be prepared to evacuate the area of Goldsboro and Brunner Island,[33] west of TMI. Governor Thornburgh was immediately informed of this alert. Thirty minutes later, at 8:15 a.m., the evacuation alert was called off by PEMA[34] when BRP advised PEMA that the results of onsite and offsite radiation monitoring did not confirm the calculations;[35] i.e., there had been no major radiological releases.

As events proceeded over the next 24 hours, Pennsylvania's Lt. Governor Scranton, head of the Pennsylvania Emergency Management Council, carefully followed the course of the accident and provided State leadership. During this time the situation at the reactor appeared to be stable and perhaps improving. But as radioactive releases continued, it became clearer that there had been substantial core damage, and there obviously were obstacles to achieving a cold shutdown. Therefore, concern about the actual status of the plant began to build.

During a phone conversation on Thursday morning, Lt. Governor Scranton asked NRC Commissioner Victor Gilinsky whether school children in the Goldsboro area should stay indoors. Gilinsky did not reply, but in a return call to Mark Knouse, a

Scranton staff member, Harold Denton, NRC, advised that it was not necessary for children to stay indoors. When asked about sick and elderly persons, Denton also said he didn't think sheltering was necessary. He based his position on the fact that the radiation readings at TMI were well below EPA protective action guidelines.[36] This was the first time since the Wednesday morning evacuation alert that the question of precautionary protective measures was raised by people in the Governor's office with people outside the State offices.

Early Thursday afternoon Pennsylvania Secretary of Health Dr. Gordon MacLeod placed a conference call to Dr. Niel Wald, Chairman of the Department of Radiation Health in the University of Pittsburgh's Graduate School of Public Health. MacLeod sought to reinforce the State's knowledge of radiation health. The call was placed from the Governor's office in Harrisburg, where the Governor, the Lt. Governor, and members of their staffs were gathered, and concerned the effects of radiation exposure, particularly at high levels. There was no mention of evacuation.[37]

Later Thursday MacLeod discussed the evacuation of pregnant women and young children with BRP's Gerusky, PEMA's Henderson, a representative from the Lt. Governor's office, and Mr. Welch, the Deputy Secretary of Health.[38] The consensus of the group was that such action was not warranted.

Later that afternoon MacLeod received a phone call from Dr. Anthony Robbins, the Director of the National Institute of Occupational Safety and Health (NIOSH) of HEW in Washington. MacLeod reported later that Robbins expressed serious concern about the accident because of "the inability . . . to shutdown the reactors [sic]," and recommended that the State "consider evacuation of the population surrounding Three Mile Island."[39] According to MacLeod, Robbins added that he was making his recommendation after consultation with the Bureau of Radiological Health of the Federal Food and Drug Administration. Robbins has said that the phone call was an "informal contact" and denied he made any recommendations about evacuation.[40]

Following this phone conversation, MacLeod placed a conference call to PEMA Director Henderson, Gerusky, Governor's aide John Pierce, and Deputy Health Secretary Welch, to transmit Robbins' concern and recommendation. Again, the group felt that radiation levels were "not sufficiently high to warrant evacuation" and that there was not sufficient information about the ability to shut down the reactor to make a decision about evacuation. It was agreed when the plant moved into "an experimental mode . . . with respect to the shutdown process," that they "would be back in touch with respect to possibility of evacuation." Also during the same conference call, MacLeod focused attention on the greater sensitivity of the fetus and younger children. Again the group by poll unanimously took the position that there was no reason at that time to evacuate pregnant women and children under the age of 2.[41]

MacLeod later heard about the plant's discharge of contaminated wastewater and interpreted the action to be a result of human error. This, combined with his evaluation that events on Wednesday were caused by similar technical errors, led him to believe the situation at the plant was unstable. On Friday morning he instructed his deputy to attend all meetings with the Governor that day and to recommend strongly that the Governor consider advising pregnant women and children under the age of 2 to leave the area.[42] This was the situation in the Governor's office on Friday morning.

Early Friday morning, events at the plant resulted in the release of radioactive materials to the atmosphere. Floyd, the Supervisor of Operations at TMI-2, independently decided that he personally would alert PEMA to the possibility of a need "to evacuate people downwind of the plant."[43] He was not able to get through to PEMA, but he did reach the Dauphin County Civil Defense Office and asked that they have someone from PEMA call him. Before Dauphin County could relay the message, Floyd called PEMA at 8:40 a.m. and spoke to Carl Kuehn. Floyd told Kuehn that the plant had an "uncontrolled release," that the plant might evacuate noncritical personnel, and that PEMA should be prepared to evacuate people downwind. Floyd then asked Kuehn to tell BRP that he, Floyd, "may need help."[44] At the same time, the plant Emergency Control Station was on another line telling PEMA's Jim Cassidy about the 1200-mR/h reading taken 600 feet above the plant and the 14m-R/h reading at the site boundary, but not mentioning the possibility of evacuation on site or off.[45] Earlier, the plant Emergency Control Station had reported to BRP about the "planned but uncontrolled release," and had stated that "the first release would have been the highest amount of radiation and that levels should decrease significantly over the next few hours back down to where they were the day before."[46] PEMA's Lamison called BRP's Reilly at Floyd's request, and Reilly said she had received similar information from the plant and would send radiological monitors to the area.

Lamison then reported both Cassidy's and Kuehn's information to PEMA Director Oran

Henderson, noting as well Kuehn's description that Floyd was extremely excited.[47] Henderson immediately so informed the Lt. Governor, who reported the 1200-mR/h reading to the Governor's office. Paul Critchlow, the Governor's press secretary, walked to the next office where the NRC's Region I press officer, Karl Abraham, was located, to seek verification of the report. Abraham said he would check with the NRC Headquarters.

At about 9:15 a.m. Collins, at the NRC Headquarters, called Henderson and asked whether PEMA had heard about the releases. He was told PEMA had received a report of 1200 mR/h. PEMA's information would of course have been similar to the NRC's, since it had come full circle from Floyd to PEMA to Critchlow to Abraham to the NRC's Emergency Management Team to Collins and back to PEMA's Henderson. Collins asked if Henderson had issued any evacuation orders and was told PEMA was awaiting word from the plant. Collins then recommended that PEMA go ahead and evacuate people out to 10 miles from the plant in the direction of the plume. Henderson responded that PEMA would consider ordering a 5-mile evacuation all around the plant because there were no plans for a 10-mile evacuation and the wind direction was too unstable to predict the plume's path. On receiving NRC's recommendation to evacuate, Henderson immediately notified the Lt. Governor.[48]

Thus, within 15 minutes, senior NRC officials in Bethesda had made and communicated an evacuation decision to the State, beginning a chain of events that significantly heightened the anxiety of the people living around TMI. Like the first evacuation alert on Wednesday morning, Friday's event began with a projection of possible radiation exposure to the population. However, unlike Wednesday's alert, the NRC's Emergency Management Team decided on an evacuation without verifying the reported plant status and offsite radiation readings; nor had PEMA's Henderson received such an evaluation from BRP.

Henderson's deputy, Craig Williamson, informed Gerusky of Collins' call and of the NRC's urgent recommendation. Gerusky responded that BRP had no information to justify an evacuation but would check and get back to PEMA. Gerusky also questioned why Collins had made his recommendation to PEMA instead of BRP. The answer was that Collins had worked with BRP for a long time and that he knew "what we [BRP] were supposed to do, and [knew] that we had the responsibility for making the recommendation."[49]

As the Lt. Governor was briefing the Governor, Henderson told the Dauphin County Director of the Office of Emergency Preparedness, Kevin Molloy, to be prepared for a possible evacuation and to expect an order in 5 minutes, because Henderson was 90% sure of such an order from the Governor.

Following Dauphin County's emergency plans, Molloy made all the appropriate notifications within the county and then went on WHP radio, the primary emergency broadcast station in the vicinity, to advise that, as stated later, "there was a possibility we might have to evacuate, and if we did, that this is what the people should take with them, and basically this is where they should go."[50]

Meanwhile, BRP had been trying to check the basis for Collins' recommendation. BRP nuclear engineer William Dornsife spoke to NRC Investigator Charles Gallina at TMI. Gallina could not believe the evacuation recommendation since he saw no reason for it. BRP's Margaret Reilly made it quite clear to Collins that BRP also saw no reason to order an evacuation and cited Dornsife's conversation with Gallina. Collins said he was following orders and that NRC Chairman Hendrie would soon call the Governor. At 9:45 a.m. Governor Thornburgh called Henderson, asked about Collins, and was told that Collins was not known personally to Henderson, but that Collins enjoyed a good reputation among BRP staff and was considered reliable. BRP personnel completed data checks with the NRC staff in Bethesda and on site and were convinced that evacuation was not necessary. BRP was not able to make phone connections with the Governor's office or with PEMA, however. The phone system was overloaded with reaction to Molloy's broadcast alerting the population to the possibility of evacuation. Dornsife rushed to the PEMA office and Gerusky to the Governor's office to present personally their opposition to evacuation.[51]

At about 10:00 a.m. a siren was sounded in Harrisburg. Apparently it was not the county civil defense siren; it was perhaps located on State property. Other sirens went off twice in the city of Harrisburg, further increasing tensions in the area.[52]

At 9:59 a.m. Thornburgh called Hendrie, who advised after a brief exchange that "it would be desirable to suggest that people out in the northeast quadrant within 5 miles of the plant stay indoors for the next half hour." Their conversation was interrupted to allow Hendrie to receive information transmitted from the site to the NRC's Incident Response Center in Bethesda. When they resumed their conversation, Gerusky had arrived in the Governor's office with current radiation readings. The men compared these numbers, and while NRC's readings were higher than BRP's, they were both substantially lower than the 1200 mR/h that had been registered earlier.

Hendrie repeated that it would be prudent to have people within a 5-mile radius stay indoors that morning until "our information improves, hopefully it will, then we can see where we go from there." Gerusky said the wind was picking up and the plume should dissipate, thus, as he stated later, "it probably didn't make any difference now whether people stayed indoors or not." Hendrie felt Gerusky's comment was not a bad judgment, but explained that the NRC's suggestion about people staying indoors was more of a "precautionary one, from a feeling that the material is there." Thornburgh then asked if there could be any more of these releases and was told "we may very well get them again, I think." Hendrie added that he hoped the NRC would know from the plant "in advance" of such a situation and would be "ready to anticipate what we may need to do." Thornburgh asked whether he should order a precautionary evacuation in anticipation of more releases. Hendrie said: "It would be just as well to wait until we know that they are going to have to make some kind of a water transfer . . . and then at that time, go ahead and make a precautionary evacuation." In this fashion, Hendrie in effect countermanded Collins' and the NRC's Emergency Management Team's recommendation for evacuation.[53]

After he talked with Hendrie, the Governor, at 10:25 a.m., made a live broadcast on WHP radio to attempt to deal with the many evacuation rumors.[54] At the same time, Critchlow briefed newsmen about the Governor's talk with Hendrie, the 1200-mR/h reading over the plant and that 25 mR/h was the highest reading recorded off site, and that there was no need for evacuation. However, he advised people within a 10-mile radius of the plant to stay indoors.[55] Instead of the 36 000 people within the 5-mile radius suggested by Hendrie, the 10-mile radius encompassed 135 000 persons. (Critchlow said it had been his mistake, and that he had misheard Hendrie.) This broadcast advising people to stay inside, close the doors and windows, and shut down air conditioners followed by only 1 hour Molloy's WHP broadcast directing people within 5 miles of TMI to pack their bags and be prepared to evacuate. The Governor did not end his take shelter advisory until midnight Friday,[56,57] although PEMA mistakenly notified the affected counties at noon that it had been lifted.[58]

President Carter called Hendrie at 10:45 a.m. Friday for a plant status update. During this call it was decided to send Harold Denton to the site to serve as the President's direct contact and responsible senior official regarding plant matters. Following his talk with Hendrie at 11:15 a.m., President Carter called Governor Thornburgh. The President said he would be sending Harold Denton to be the President's representative on site, that Jessica Tuchman Mathews would be the State's contact point in the White House, and that the President would provide communications systems to link the site with the Governor's office, the NRC, and the White House. Thornburgh later described his talk with the President in his 12:30 p.m. press conference:

> Based upon the evidence and best technical advice available, the President concurred with me that there continues, at present readings, no reason for panic or implementation of emergency measures. . . The President has dispatched . . . Harold Denton . . . to assist me and work with our experts, on the scene, to monitor the situation and keep me, and through me the public, fully advised.

In response to a newsman's question, Thornburgh elaborated that the President was concerned that there be no panic and that "there be appropriate communication of the best estimate of the situation to the people."[59]

At 11:40 a.m. Hendrie called the Governor. Hendrie began the conversation with a description of the plant's technical status and noted the possibility of further releases. The Governor mentioned his Secretary of Health's concern about the special sensitivity of pregnant women and young children, soliciting Hendrie's comment about the proposed evacuation. According to Thornburgh, Hendrie "agreed at that time that this would be a prudent step to take as a precautionary move."[60] They discussed what evacuation zone the advisory should define—1, 2, or 3 miles. Gerusky, in the room with the Governor, volunteered "5 miles," since the State had evacuation plans for 5 miles, and the matter was settled. Upon the conclusion of the phone conversation, State officials discussed how best to implement the "young children" advisory; they agreed to draw the line at preschool-age children. PEMA's Deputy Director Craig Williamson had arrived in the Governor's office earlier and was able to identify possible mass care centers and describe the school situation. It was appreciated that mothers with both preschool-age and school-age children would want to take the latter along, and it was therefore decided to close schools as well. At his 12:30 p.m. press conference Governor Thornburgh announced:[61]

> Based on advice of the Chairman of NRC and in the interests of taking every precaution, I am advising those who may be particularly susceptible to the effects of radiation, that is, pregnant women and preschool-age children, to leave the area within a 5-mile radius of the Three Mile Island facility until further notice. We have also ordered the closing of any schools within this area. I repeat that this and

> other contingency measures are based on my beliefs that an excess of caution is best. Current readings are no higher than they were yesterday. However, the continued presence of radioactivity in the area and the possibility of further emissions lead me to exercise the utmost caution.

This was the only evacuation ordered as a result of the accident at TMI, and it was merely a precautionary advisory. However, the question of evacuation was still seriously considered for the next several days. The existence of a hydrogen bubble had been determined on Thursday night, and concerns regarding core cooling and an explosion of the hydrogen bubble continued through Sunday.

Friday afternoon, Jay Waldman, the Governor's Executive Assistant, and Paul Critchlow, also in the Governor's office, established phone contact with Watson, Mathews, and Eidenberg in the White House. Sometime after 1:00 p.m. Mathews briefed Waldman on the hydrogen situation. The briefing was based on the information she had received earlier from Gilinsky and on Hendrie's briefing in the Situation Room.[62] The foreboding news was passed on to the Governor, who interrupted the phone call to obtain a direct briefing from Mathews. The Governor explained to Mathews his problem with two information sources in the NRC, one at the site, another in Washington; he was getting inconsistent information. He desperately needed a reliable central source. Denton, who had arrived at the site but was not yet in direct contact with the Governor, would now assume that role. When Hendrie called the Governor at 3:41 p.m., Thornburgh already had a pretty good idea about the bubble problem. Hendrie described the situation and said Met Ed, Babcock & Wilcox, and the NRC then agreed that core damage was "considerably more extensive than we had thought yesterday." He added that the situation was fairly stable at the moment, should continue that way for several days, and, meanwhile, Met Ed and the NRC were "working hard figuring how to come down out of this situation." In response to a question, Hendrie said it might be prudent to evacuate out to 20 miles "if we suspected getting a fairly husky release." When asked, "What are the potentials for an explosion that would rupture the core? Rupture the vessel?" Hendrie replied, "There isn't any oxygen in there to combine with that hydrogen, so the answer as far as I know is pretty close to zero."[63]

The first bubble scare—that the bubble would cause a core meltdown—was born as UPI passed on a story stating that the TMI accident posed the ultimate risk of meltdown. This shattered the calm in the Harrisburg area: the Governor had 4 hours earlier reported to the people that, based on his talks with President Carter and NRC Chairman Hendrie, "There continues [to be] no need for panic or implementation of emergency measures."[64] To try to put the UPI story in perspective, the NRC Commissioners in Washington struggled to compose a press release downplaying the presence of a large condensible bubble in the top of the vessel which could present the possibility of interrupting coolant flow. At his press conference at 5:00 p.m., Jody Powell indicated that meltdown was speculative.[65] Later that night, at 10:00 p.m., Governor Thornburgh, Lt. Governor Scranton, and Harold Denton held a press conference. In a further effort to calm the situation, the Governor reported that he had just spent an hour and a half with Denton, whom he described as being assigned by the President to Pennsylvania "for the duration." Thornburgh went on to announce their belief that "no evacuation order was necessary at the time." At the press conference, Denton put the meltdown story to rest by saying its possibility "was very remote."[66]

The notion of a bubble explosion again became a public concern when, at his Saturday afternoon press conference, Hendrie was asked about the chances of an explosion. He responded:

> Okay the bubble, with regard to the bubble in the vessel, there is ... that is a problem which is of course and which we are working on very intensively a the moment. As long as the bubble has hydrogen, steam, fission product gas composition, why it's not flammable. But if enough oxygen over a longer period of time were evolved, why it could become a flammable mixture. Now, it's a fairly high pressure 1000 pound per square inch and contained in the vessel dome; in fact at the moment a little too well contained for our purpose; so that there aren't ignition sources at hand, and the indicators out of staff calculations and other calculations are being done for us by other experts around the country. This preliminary indication from that is that we are some time from any possibility of a flammable condition. But that is a preliminary result, and it is a concern, and we are working very hard on that.[67]

Earlier that day Hendrie had called Denton at the site to ask him to be sure the Governor had a sense of the risk that oxygen presented and its implications for an evacuation decision. Denton talked to the Governor by phone to explain the estimated likelihood of flammability and explosiveness.

Following his press conference, Hendrie called the Governor to say, "We've had some returns from the technical groups around the country that are working on the problem, and it appears that it's at least not near term, not something that we have to deal with here immediately."[68]

Later that evening Stan Benjamin, an AP reporter, following up on Hendrie's statements about the oxygen problem, prepared a story and confirmed it with NRC Assistant Press Officer Frank Ingram and with Edson Case. Around 8:30 p.m. Benjamin filed an editorial advisory: "Urgent (with Nuclear) The NRC now says gas bubble atop the nuclear reactor at Three Mile Island shows signs of becoming potentially explosive. A story upcoming."[69] The Governor received a copy of the wire story advisory. He asked Critchlow to call Denton, who said the danger was hypothetical. Denton was asked to stop by the capitol newsroom on his way over to the Governor's office to put the story to rest. Denton told the newsmen that the bubble would not be explosive for from 9 to 12 days, there was plenty of time to correct the problem, and there was no danger at that time. Denton then proceeded to meet with the Governor and his staff. They held a joint press conference at 11:00 p.m. at which the Governor again tried to reassure the people with the following opening remarks:

> Good evening. I have just completed a routine briefing from Mr. Denton. These briefings have been held by phone since his arrival here and he has joined us last night and this evening for a detailed review of the day's events.
>
> There have been a number of erroneous or distorted reports during the day about occurrences possible difficulties at the facility on Three Mile Island and this briefing this evening was of particular significance in that respect.
>
> Mr. Denton in our discussion assured me and will be available to answer your questions that there is no imminent catastrophic event foreseeable at the Three Mile Island facility and I appeal to those who may have reacted or overreacted to reports to the contrary today, to listen carefully to his characterization of the current status of the situation. I appeal to all Pennsylvanians to display an appropriate degree of calm and resolve and patience in dealing with this situation.

Thornburgh added that President Carter would be coming to the area to make a personal onsite visit and urged that this was "an important vote of confidence in the kind of work that is proceeding there and a further refutation in the kind of alarmist reaction that has set in in some quarters."[70]

The news stories about possible massive evacuation and the bubble possibly exploding had taken their toll. County officials were receiving numerous requests for information, but all the county had were two PEMA teletype messages reporting no change in plant conditions. Not only were they unable to respond intelligently to the concerned public, but they felt they were unable to anticipate what they were expected to do. State Senator Gekas, who happened to be in the Dauphin County emergency operations center at the time, witnessed this frustration. When he learned that Dauphin County was unable to reach the Governor to request more information, the Senator himself tried to make contact, to no avail. He finally told the Lt. Governor's office that if they did not get in touch with Dauphin County with a little more information, Dauphin County would be performing its own evacuation at 9:00 a.m. the next morning.[71]

Early Sunday morning Lt. Governor Scranton and Dr. Robert Wilburn met with Senator Gekas and Dauphin County civil defense officials to attempt to address the serious county-level concerns. In these discussions Scranton assured the county officials that he would try to correct the situation. Molloy said the Lt. Governor was "surprised, extremely, I think. I don't think that he was fully aware of some of the problems that we were facing at our particular level...."[72]

At noon Governor Thornburgh left Harrisburg to meet President Carter, who arrived in Middletown at 1:00 p.m. After his briefing from Denton, the President toured the TMI plant, including the Unit 2 control room, accompanied by Thornburgh and Denton. At 2:00 p.m. the President made a statement to the people of Middletown, Pennsylvania, 3 miles from the plant. He explained that the reactor was stable, but that certain actions might have to be taken to bring the reactor to cold shutdown. In that event the Governor, he said, might ask the people in the area to take certain precautionary action. The President continued by asking the people to carry out the Governor's instructions "calmly and exactly."[73]

By late Sunday night it was clear that the bubble no longer posed a substantial problem from a core cooling standpoint and that there never had been a chance it might explode. While precautionary planning for evacuation continued, the spectre of evacuation no longer loomed large.

In retrospect, the levels of radiation and radioactivity measured in the environment around TMI did not require protective actions by any established standard. The maximum radiation dose estimated to have been received by any one member of the general population was less than 100 millirem; the average dose to an individual in the population within a 50-mile radius of the plant was 1.4 millirem. For comparison, the natural background radiation in Pennsylvania is about 100 millirem per year for each individual. The collective dose to the total population within a 50-mile radius of the plant has been estimated to be in the range of 1600 to 3300 person-rem. (A person-rem is a unit used to express the cumulative radiation dose per 1000 people; e.g., 1 000 000 people exposed to an average of 2 millirem each would result in a total exposure of 2000 person-rem). The number of excess fatal cancers projected to occur because of this dose over the remaining lifetime of the population within 50 miles of TMI is less than one, and had the accident not occurred, the number of fatal cancers that would be normally expected in this size population over its remaining lifetime is estimated to be 325 000. The projected total number of excess health effects, including all cases of cancer (fatal and nonfatal) and genetic ill health to all future generations, is less than two.[74]

This analysis does not support the conclusion that evacuation advisories should not have been made, however. It demonstrates that these advisories were issued because of uncertainty about the status of the plant and not because of actual or likely radioactive releases which would result in exposures that would approach the established PAGs. This points up the need for better and more prompt information regarding plant status in an emergency situation in order to avoid as much of this uncertainty as possible. For, while uncertainty about the chance of a postulated release may justifiably provide the basis for a decision to evacuate, a 5% chance should weigh lighter in the balance than a 30% chance.

c. Aftermath of the Advisories

Based on an extensive survey taken by an NRC contractor after the accident,[75] approximately 144 000 of the 370 000 people living within 15 miles of TMI evacuated the area between Wednesday and Sunday. Details of this evacuation and of the resultant socioeconomic impacts are provided in Section IV of this volume and are summarized below.

1. Approximately 39% of the people living within 15 miles of TMI evacuated. This ranged from about 60% of the people living within 5 miles to about 32% of those living 10 to 15 miles away.
2. Approximately 14% of the total number who evacuated did so before Friday. More than 50% evacuated on Friday.
3. Of those households within 15 miles of TMI that had evacuees, about 36% had a pregnant woman or a young child; fewer than 5% had a pregnant woman or a young child and also resided within 5 miles of TMI.
4. Approximately 65% of the pregnant women and young children living within 15 miles of TMI evacuated. This ranged from about 93% of those living within 5 miles, to about 57% of those living 10 to 15 miles away.
5. The median length of time evacuees remained out of the area was 5 days.
6. Most evacuees stayed with friends or relatives.
7. Evacuees traveled an average distance of 100 miles.

Immediately following the 12:30 p.m. advisory by the Governor on Friday, two mass care centers were established for the evacuees: York County opened one in its Central High School in York, Pa.,[76] and Dauphin County operated the second in the Hershey Arena in Hershey, Pa.[77] Though operation of these mass care centers was a county responsibility, the American Red Cross provided substantial assistance to the counties by providing personnel and supplies.[78]

On Saturday morning, when the evacuation scare was almost at its peak, the total number of evacuees at the two shelters was only about 185.[79] On Sunday, April 1, the York County Center was closed because few evacuees had come to this shelter and all evacuees went to the homes of friends or relatives.[80] During the next several days the number of people at the Dauphin County Center dropped as people either returned to the evacuated area, went to stay with friends or relatives, or used advance insurance payments from the utility's insurance underwriters to move into motels.[81] The Governor did not officially lift the evacuation advisory until 3:00 p.m. on April 9;[82] however, on April 7, 1979, the Dauphin County Center was closed and the 17 remaining displaced persons were moved to motels.[83]

d. Lifting the Evacuation Advisory

The evacuation advisory for pregnant women and young children and the school closings remained in effect from Friday, March 30, until Monday, April 9. During this entire period, the situation at the plant remained stable, but radiation releases continued at a very low level, and the plant never achieved a cold shutdown.

Therefore, Governor Thornburgh could point to no single, major event as demonstrating to the public such an improvement as would justify bringing people back into the evacuated area.

The basic problem was that on March 30 there was no clear and demonstrable physical fact that served as a basis for issuing the advisory: the basis was one of uncertainty as to the future status of the reactor, since unlikely but possible future events at the reactor could release large quantities of radioactivity that would greatly exceed the population exposures specified in the PAGs. There was much concern about the plant status on Friday, but by all estimates there was no immediate hazard. While radioactivity was released on Friday, it was not continuous, and the maximum exposures measured off site were almost a factor of 100 below the protective action guidelines. We will never know the precise influence that the following events had on the collegial decision (between the Governor's Office and the NRC) to evacuate.

1. The emergency call between Floyd of Met Ed and Kuehn of PEMA during which Floyd allegedly recommended evacuation in an excited voice.
2. The NRC's recommendation through Collins to PEMA to evacuate downwind for 10 miles.
3. Henderson's advisory to Dauphin County to get ready for an evacuation "in 5 minutes" and his recommendation to the Governor to evacuate out to 5 miles (both done without BRP concurrence).
4. Dauphin County's subsequent public announcement over the radio for the citizens to get ready for an evacuation announcement.
5. The sounding of civil defense sirens.
6. The 10:25 a.m. advisory by the Governor for people within a 10-mile radius to stay indoors.
7. The flood of telephone calls from the public, sufficient to jam the telephone exchanges.

The NRC and the Governor's office pondered for several days over the criteria for lifting the advisory. Finally, on Monday, April 9, Governor Thornburgh lifted the advisory. Denton stated that he recommended this action to Thornburgh because (1) the core was much cooler and all hydrogen gas had been removed; (2) the containment was at negative pressure; (3) offsite exposures were very low; (4) iodine releases were under control; and (5) there had been no liquid releases in excess of those that would be permitted during normal operations.[84]

e. Findings and Recommendations

The preceding narrative describes the events leading to the decisions regarding the take-shelter and evacuation advisories issued by the Governor and the results of these advisories. We draw a number of findings from the preceding description. Some of these findings lead to the recommendations presented in this section; others lend support to recommendations made in other sections. The findings of this section are:

1. Uncertainty of information regarding plant status and the potential for large releases of radioactivity were the principal causes of the concerns and fears of Government officials and the public and for the decisions to advise taking shelter within a 10-mile radius and to advise that pregnant women and preschool-age children evacuate from within a 5-mile radius. This uncertainty arose from lack of information, the existence of incorrect and conflicting information, poor or inaccurate communication of information, and improper assessment or evaluation of information.
2. Radiation exposures projected on the basis of measured or likely releases were a factor of 10 to 50 lower than any protective action guidelines for taking shelter or evacuating.
3. The Governor of Pennsylvania acted responsibly in his actions to verify the recommendation to evacuate made by Harold Collins of NRC; however, in a fast-moving accident with serious offsite consequences, taking the time required for such verification might have serious public health and safety consequences. The TMI accident was not a fast-moving accident and, had it been, we believe it highly probable that the verification process would also have been more rapid (e.g., Gerusky would likely have recommended evacuation also, under such a postulated situation, since he was aware of the plant status).
4. The TMI accident and the ensuing advisory for a partial evacuation resulted in about 144,000 evacuees, at least 20 times more than the number of pregnant women and young children (and their families) living within 5 miles of TMI.
5. Whereas the Governor testified that the liability for, and economic impacts of, an evacuation never entered his mind when deciding whether to evacuate,[85] and while no evidence was uncovered to the contrary, such considerations could be of importance to a future decisionmaker. This question of economic disincentives to evacuation in its broadest context (i.e., economic impacts on citizenry as well as on the State and Federal Governments) has not been well thought out or studied. For example, officials in the Pennsylvania Department of Agriculture told us that there is a need to eliminate economic disincentives for farmers to evacuate. They noted that a farmer would be reluctant to evacuate and leave his livestock unless it was clear to him that he would not be financially destroyed if his livestock died while he was away. They suggested that if farmers knew they would be financially indemnified against such losses, they would be more inclined to comply with an evacuation order.
6. Protective actions cannot be effectively recommended from Washington unless substantially improved communications are provided and information is verified by onsite personnel. However, we believe it preferable that such recommendations not be made by persons far removed from the accident.

7. The decisionmakers suffered from a lack of understanding of the protective action guides and the usefulness of various protective actions.

Based on the above, the detailed recommendations of this section are:

1. Official channels for the transmittal of protective action recommendations to the responsible decision authority must be set up in advance and understood by all parties. All participants in this process should be predesignated to the extent possible.
2. Procedures must be established in advance by the decision authority for verifying protective action recommendations and their bases. These procedures must provide for timely verification, according to the temporal nature of the public hazard.
3. The NRC, in cooperation with HEW and EPA, must develop clear and commonly acceptable protective action guidelines (PAGs) that are understood by decisionmakers and can be applied in a relatively unambiguous manner. Consistency between 10 C.F.R Part 140, and EPA and FDA protective action guidelines should be achieved. Projected dose calculations associated with PAGs should be based on the following:
   a. Forecasts of likely radiological releases, including reasonable assumptions regarding present and future plant status.
   b. Likely meteorological conditions.
   c. Existing demographic and topographic characteristics.
4. The NRC, in cooperation with EPA, HEW, and FEMA, must evaluate the array of protective actions available in the event that PAGs may be exceeded and develop recommendations for action accordingly. These recommendations must be based upon consideration of the following:
   a. The effectiveness of various protective actions (e.g., precautionary evacuation, partial evacuation, sheltering, use of thyroid blocking agents, food interdiction). Particular attention should be given to sheltering and the conditions under which it should be recommended; e.g., the increased shielding effectiveness against low-energy radiations, such as from xenon, must be considered in evaluating the sheltering alternative.
   b. The time required to implement various protective actions compared to the likely timespan of the emergency.
   c. The area surrounding the nuclear facility, within which specific effective actions must be appropriately planned. In this regard, the EPA-NRC proposal for 10-mile evacuation planning and the NRC estimates during TMI of up to a 10-mile evacuation for possible TMI scenarios suggest that the formal planning should extend to that distance; planners must recognize, however, that substantial voluntary evacuation will extend to much larger distances.
   d. The adverse health, safety, social, and economic impacts of various protective actions.
5. FEMA must study and, to the extent reasonable, lower possible economic barriers to protective actions such as evacuation. Although one cannot reduce the overall costs of an evacuation, one can determine whether the participants in the evacuation decision and in the evacuation itself should be made more immune to the economic consequences; i.e., should these costs be borne by a larger segment of society through insurance or the use of Federal or State revenues. FEMA must resolve the following questions.
   a. Who bears liability for private loss resulting from evacuation? Are Government officials personally liable for loss resulting from such decisions? Is any indemnity available?
   b. Who bears the risk if a loss is incurred as a result of either an ordered or "advised" protective action, and the radiological threat does not materialize?
   c. Will a farmer or a businessman with perishable stock or capital investment evacuate as ordered or advised?

5. EVACUATION PLANNING BEFORE AND DURING THE ACCIDENT

a. Introduction

In July 1977 the predecessor to the Pennsylvania Emergency Management Agency (PEMA) added Annex E, entitled "Nuclear Incidents (Fixed Facility)" to the Commonwealth Disaster Operations Plan.[86] Annex E generally describes State, county, and local responsibilities during a nuclear emergency and assigned primary responsibility for responding to a nuclear emergency to county and local governments. The PEMA plan had never been formally given to the NRC for concurrence.

In 1978, at PEMA's suggestion, the three counties within a 5-mile radius of Three Mile Island (Dauphin, Lancaster, and York) developed emergency plans for accidents at TMI, including 5-mile evacuation plans. Each of the three county plans differed greatly in detail, although each described individuals or organizations responsible for carrying out specific portions of an evacuation, described official communications channels, identified the location of mass care facilities, and made provisions for informing the public. None of the localities within 5 miles of the plant had such emergency plans.

PEMA established a planning zone of 5 miles around TMI and all other powerplants in Pennsylvania to standardize planning within the State. The distance of 5 miles was selected because the largest Low Population Zone (LPZ) specified by the NRC for any nuclear powerplant in the State was about 5 miles. The LPZ for TMI was about 2 miles. At the time of the accident, PEMA believed the 5-mile planning zone was adequate and saw no need for more extensive planning. During the first 2 days of the accident, PEMA reviewed the 3 counties' emergency plans, which were on file in PEMA's offices. The county emergency management directors of the three affected counties were also reviewing their emergency plans and their county resource inventories, which list all the personnel and equipment resources available within the counties. By Thursday evening PEMA officials and the county directors believed the situation at TMI had significantly improved, the emergency would soon be over, and their plans would not be called into service.[87]

This situation changed on Friday, March 30, following the NRC's recommendation to Oran Henderson, the Director of PEMA, to carry out a 10-mile evacuation downwind of the plant. The extent of the NRC recommended evacuation made Henderson doubt the adequacy of the existing 5-mile plans and prompted his decision on Friday morning to expand the emergency planning zone to 10 miles. Later the same day, while briefing Governor Thornburgh on plant status, Harold Denton stated that 20-mile evacuation planning would be prudent. Early Saturday morning, Henderson called the emergency management directors of the 6 counties within 20 miles of TMI and instructed them to begin planning for the evacuation of all residents within 20 miles of TMI.

b. State, County, and Local Planning

Expanding the planning zone from 5 to 10 and from 10 to 20 miles significantly complicated evacuation planning and affected the ability of the counties to carry out an evacuation without outside assistance. The 5-mile zone previously planned for included about 38 000 people, only a few nursing homes that required special handling and transportation for their residents, and no hospitals or prisons. In addition, evacuees from each of the three affected counties could have been sheltered within their own county; that is, no outside counties would have been required to provide mass care centers.

As the planning zone increased to 10 miles, it encompassed portions of Cumberland County, and the affected population increased to about 165 000. The 10-mile zone included several additional nursing homes and three hospitals.

The 20-mile zone covered portions of two more counties (Lebanon and Perry) and more than 600 000 people, 13 hospitals, a major prison, and a large number of nursing homes. To handle the overflow of evacuees, 21 host counties would have been required to provide mass care shelters.

By Saturday morning, March 31, the emergency management officials in each of the six counties within 20 miles of TMI had begun planning for a 20-mile evacuation. While the detailed planning process differed among the counties, the first step generally was to call to the county emergency operations center (EOC) those people in the county who were knowledgeable concerning evacuations. As these people arrived in the county EOC, they were assigned specific sections of the plan to begin drafting. The local American Red Cross officials began calculating the number of mass care centers needed for the evacuees, attempting to identify and make arrangements for the use of suitable facilities. County fire and rescue officials began determining the number of ambulances needed to transport hospital patients and invalids and began locating additional ambulances both within and outside the county. Other groups were identifying evacuation routes, locating assembly points and arranging transportation for persons without their own, planning the evacuation of hospitals and nursing homes, and preparing public announcements for use under precautionary and emergency evacuation orders.

As the plans were developed, county emergency management directors met with local evacuation-zone emergency management directors to inform them of their responsibilities. In five of these six counties, the evacuation planning was largely centralized at the county level, and local directors were primarily responsible in three areas: (1) providing information to the county on needs for equipment, such as ambulances, or on problems with which they needed assistance; (2) informing local residents of the evacuation plans; and (3) carrying out the evacuation when ordered. The sixth county, Cumberland County, gave planning responsibility, with the exception of planning for evacuation of hospitals and other institutions, to the local directors, reasoning that the local directors could best plan for their localities and could best carry out a plan they had developed themselves. The Cumberland County Emergency Management Director assisted the local directors and coordinated their plans. County directors also met with officials from unaffected portions of their counties and from other counties to identify areas in which they could provide assistance, particularly in establishing mass care shelters.

As the groups in each county completed the various segments of their plans, the county emergency management directors reviewed and consolidated them. By late Saturday night each of the county directors believed that he could have successfully carried out a 20-mile evacuation even though detailed plans were not complete. Throughout Sunday and Monday the counties completed and refined their plans, and each of the six county plans was formally printed and issued during the next week.

Several Commonwealth agencies assisted the counties in preparing their 10- and 20-mile evacuation plans. On Saturday representatives from PEMA, the Pennsylvania Department of Transportation, the Pennsylvania State Police, the National Guard, and the Department of Health went to each county to assist in preparing the plans. PEMA headquarters staff in Harrisburg had the overall responsibility to assist the counties in developing plans and to assure coordination of the plans among the counties. One major function carried out by PEMA, in cooperation with the Pennsylvania Department of Transportation, was coordination of major evacuation routes among the counties to avoid situations where two counties, working independently, would plan to use the same road and thereby exceed the road's capacity. PEMA also sought to prevent two counties from planning to use the same road to send evacuees in opposite directions.

On Saturday, March 31, PEMA distributed suggested evacuation routes to each of the six risk counties for their use in developing plans. The routes suggested by PEMA were selected on the basis of the general direction each county's evacuees would be moving, the population density of the areas the roads served, and the road capacities. With the assistance of the Pennsylvania Department of Transportation, the State Police, and National Guard representatives in each county, the counties could use the PEMA suggestions to complete their detailed plans, including a procedure for getting evacuees on and off the major evacuation routes. Throughout the next several days, PEMA officials, working primarily through State representatives in the counties, coordinated the county evacuation routes, and on April 4 they prepared a map showing the specific evacuation routes that would be used by each county. Each county had determined its evacuation routes before the map was prepared, but the map provided a coordinated document so that traffic control agencies such as the State Police could estimate traffic density expected along specific routes.

The Department of Health representative assigned to each county assisted in planning the evacuation of hospitals and nursing homes. As the counties identified mass care centers for their evacuees, the Department of Environmental Resources inspected the proposed mass care facilities and sampled the water supply of each for impurities. The Department of Agriculture was prepared to advise farmers in the evacuation zone that before leaving they should shelter their livestock, reduce food available to cows to slow milk production, and have water available for the livestock. If the evacuation lasted for an extended period of time, Agriculture was also prepared to work with BRP to try to safely return farmers to their farms long enough to care for their livestock. Agriculture was ready to issue sheltering instructions to farmers who chose not to evacuate. No plans to evacuate livestock were developed by either the counties or the State.

c. Federal and Other Planning Assistance

At the Federal level, the Federal Disaster Assistance Administration (FDAA), an agency within the Department of Housing and Urban Development, and the Defense Civil Preparedness Agency (DCPA), an agency within the Department of Defense, assisted the State and counties in evacuation planning. On March 30, 1979, Jack Watson in the White House designated Robert Adamcik, the Director of FDAA's Philadelphia Regional Office, as Lead Federal Official at TMI and assigned John McConnell of DCPA to assist the State with evacuation planning. Throughout the accident, Adamcik served as the Federal onsite coordinator with the State for planning for the protection and evacuation of the populace.

The FDAA provided major support to the State in locating out-of-state emergency equipment, supplies, and personnel needed for the evacuation. Were it necessary, the FDAA would also have helped obtain such support. Had a 10- or 20-mile evacuation been ordered, most resources needed by the State and counties were available within the

Commonwealth, but certain shortages existed. On April 2, PEMA's Henderson gave Adamcik a list of the State's "unmet needs," which included 440 ambulances, 35 doctors, 200 nurses, 1 fixed-wing aircraft, 183 200 blankets, 183 200 cots, and 40 incubators for newborn babies. By April 3 the FDAA, with assistance from the American Red Cross, had located sources for most of these needs, although FDAA daily reports to the White House indicated that problems were encountered in obtaining sufficient numbers of blankets and cots.[88,89]

On March 28, 2 days before McConnell was sent to help the State, a DCPA Regional Field Officer, who was already in the Harrisburg area to assist PEMA with a training program scheduled for that day, went to the PEMA Emergency Operations Center to work with the PEMA staff. On the morning of Friday, March 30, at the request of Oran Henderson, and also before McConnell was dispatched, DCPA sent two-person teams to Dauphin, York, Lancaster, and Cumberland Counties to assist in evacuation planning. At the same time, DCPA detailed communications operators with radio equipment to both York and Lancaster Counties to provide a communications link with the State Emergency Operations Center. On Saturday, March 31, as the evacuation planning zone grew to 20 miles, DCPA assigned communications operators with radios to the four other affected counties. The actual role of the DCPA representatives in the counties ranged from assisting the county director in preparing the plan to actually writing the plan based on input from the various planning groups within the county.

On Monday, April 2, at Henderson's request, DCPA assigned an additional 19 persons to 19 host counties in Pennsylvania to assist in developing plans for reception areas, from which evacuees would be assigned to mass care centers, and for the care, feeding, and sheltering of evacuees.

From the start of the accident, local chapters of the American Red Cross in each county monitored the events and provided assistance to the county directors. On Friday, March 30, officials in the American Red Cross National Headquarters in Washington realized that the expanded evacuation under consideration would be beyond the capabilities of the local Red Cross Chapters. As a result, Daniel Prewitt, the Assistant Director for Disaster Services in the Red Cross Eastern Field Office in Alexandria, Virginia, went to Harrisburg on Friday to coordinate the Red Cross response, which was oriented toward planning for mass care centers. The following day, at Prewitt's request, the Red Cross sent 35 trained mass care planners to the TMI area, where Prewitt assigned them to the designated host counties to help plan for mass care facilities.

d. Assessment of Preparedness

If a general evacuation had been ordered, the county and local governments would have had primary responsibility for carrying it out, although PEMA and the Federal Government would have assisted in specific functional areas. Traffic control was to be handled by local police with assistance from the Pennsylvania State Police and the National Guard, in cooperation with the Pennsylvania Department of Transportation. Security for the evacuated area was to be maintained by the Pennsylvania National Guard. The operation of the mass care centers in most instances was to be the responsibility of the American Red Cross working with the counties. The exception was Perry County, whose evacuees were to remain within the county borders in mass care centers which were to be operated by the county school systems and which required outside assistance only for food after about 48 hours. Within the counties, planning for the evacuation was essentially completed by Sunday; details of the plans were completed and the plans formalized shortly thereafter.

Throughout the incident, State and Federal officials were concerned with the length of time required to carry out a "controlled" evacuation. A controlled evacuation is one in which advance notice that evacuation will be needed allows positioning of support forces, such as the National Guard and the State Police, before the populace is actually told to leave. Precautionary evacuations are controlled. This contrasts with an emergency evacuation, in which the immediate need for people to leave an area does not allow time to position support forces before the populace begins to evacuate. While the time required to actually move people in an emergency evacuation will probably be longer than in a controlled evacuation, it is unclear how large an evacuation must be before the time required to position support forces will result in a shorter total evacuation time.

Kevin Molloy, the Dauphin County Emergency Management Director, estimated that a 5-mile evacuation in Dauphin County on Wednesday morning would have required 6 hours.[90] Oran Henderson generally agreed with Molloy's estimate and added that since Dauphin County had the largest population of the 3 affected counties in the 5-mile zone, it probably would have taken the longest time to evacuate.[91] Craig Williamson, Henderson's deputy, told us that based on his judgment, a 20-mile controlled evacuation on Friday night, March 30, would have required about 20 hours.[92] Thomas Blosser, the Cumberland County Emergency Management Director, estimated that if a 20-mile evacuation had been ordered Saturday evening, it would have taken 24 hours to complete in that county. He estimated that by Sunday evening more complete planning would have enabled a controlled 20-mile evacuation in Cumberland County to be completed in 12 hours, of which about 8 hours were required for positioning evacuation forces such as the National Guard.[93]

Several county directors we spoke to were reluctant to provide any estimates of evacuation times. Henderson told us that he too was reluctant to estimate times, explaining that evacuation times would have depended on many factors. He noted, for example, that an evacuation on the weekend could have taken less time than one on Monday because most people do not work on weekends, many volunteer police and fire and rescue personnel were in their stations ready to move, and National Guard personnel were readily available.[94] In addition, Henderson told us he still does not know how long it would have taken to evacuate a hospital.[95] York County emergency management officials hesitated to estimate times but told us that evacuation of homebound invalids would have taken more time than the rest of the evacuation.[96]

The Pennsylvania Department of Transportation performed the most analytical estimate of evacuation times. On Sunday, April 1, as the counties were finalizing their evacuation routes, the Department of Transportation used this information to estimate the time required to move the evacuation traffic along these routes. The Transportation calculations assumed a precautionary evacuation of the total population within the evacuation area, with three persons in each car, moving at 35 miles per hour. The calculations were intended only to estimate traffic movement times and did not include the times required by government organizations to get personnel and equipment in place prior to the order for people to move. This process produced estimates of 7 hours to evacuate a 10-mile area and 10 hours to evacuate a 20-mile area. PEMA officials recognized that actual traffic movement times would have been longer had an evacuation been ordered without warning because all preparations would not have been completed when it began. At the same time, since a substantial number of persons had already voluntarily evacuated the area, PEMA officials believed the time estimates could have been high.[97]

The Governor's office was concerned about the ability of the State and counties to carry out an evacuation if one were ordered. On Wednesday and Thursday, the Governor had been assured by Oran Henderson, the Director of PEMA, that a 5-mile evacuation could be successfully carried out. After the planning zone increased, Governor Thornburgh directed Robert Wilburn, the Secretary of Budget and Administration, on Saturday, March 31, to independently review the existing plans for a 5-mile evacuation and the plans being developed for the 10- and 20-mile evacuations. Wilburn's review included discussion of the evacuation plans with Henderson and his deputy, Craig Williamson, and frequent discussions with officials in the various State agencies involved in the planning. He obtained information regarding the counties' ongoing planning efforts from the National Guard representatives assigned to the counties. Wilburn's review showed that, while the individual county plans differed in degree of specificity, the plans were reasonably good. Further, Wilburn concluded that PEMA and the other State agencies involved were adequately addressing problem areas within their jurisdictions.

By Saturday night Secretary Wilburn was able to assure Governor Thornburgh that a 5-mile evacuation could be successfully carried out and that a 10-mile evacuation could be carried out with a reasonable degree of success and minimal personal and property loss. Wilburn's review of the 20-mile planning efforts continued through Saturday and into Sunday. According to Wilburn, by Sunday afternoon, Governor Thornburgh and his staff, largely on the basis of information obtained from Harold Denton and Niel Wald, a consultant to the State, had concluded that there was little use in planning for a 20-mile evacuation because no accident scenario that would require a 20-mile evacuation had been determined.[98] This decision was confirmed by Chairman Hendrie of the NRC during a meeting with Governor Thornburgh on Sunday evening. Attention within the Governor's office was therefore focused on what Wilburn described as the 10-mile plans with 20-mile consequences: if a 10-mile evacuation had been ordered, hospitals and other institutions located within the 10- to 20-mile zone might also have had to be evacuated, since many of the personnel necessary to run those institutions either lived within the evacuation zone or would leave voluntarily and thus would not be available to operate them.[99] Staffing in many hospitals in the area was already low because of voluntary evacuations by staff members.

At PEMA and in the counties, planning for a 20-mile evacuation continued after Sunday, primarily because of the uncertainty about what area would have to be evacuated, as well as because a 10-mile evacuation would likely have resulted in voluntary evacuation of many people out to 20 miles. The frustration of the counties at this point is reflected in the statement by the Director of the York County Emergency Management Agency that so many changes were made in the planning zone that eventually officials of that county decided to disregard all statements made by the State and plan exclusively for 20 miles.[100]

In addition to Wilburn's review, Lt. Governor Scranton requested that Robert Adamcik of the FDAA also independently assess the adequacy of the county planning efforts. John McConnell of the DCPA carried out this evaluation for Adamcik on March 31 and April 1 when he visited the Dauphin, Cumberland, York, and Lancaster County EOC's, observing and discussing the planning process with county officials. McConnell said that although the county directors were encountering some problems, the difficulties were being satisfactorily resolved. McConnell felt that, based on his review, the counties he visited had good overall civil defense setups.[101]

e. The Mississauga Evacuation

There are several important questions to consider regarding the effectiveness of evacuation as a protective action, all of which are important to the planner. These questions are:

1. How quickly can an evacuation be performed?
2. To what extent does population density and the existence of facilities such as hospitals, prisons, and nursing homes affect the effectiveness of evacuation?
3. What is the importance of a good plan, and what degree of detail should be provided?

The Special Inquiry was unable to provide clear answers to these questions, but the preceding section does offer informed judgments regarding some of them, at least with regard to TMI. To provide a further basis for judgment, the Special Inquiry gathered information about the evacuation of 240 000 people from Mississauga, Ontario, Canada's 10th largest city.

Shortly before midnight on Saturday, November 10, 1979, a Canadian Pacific Railroad (CPR) train derailed in Mississauga, a suburb of Toronto. The site of the wreck was a light industrial district about 14 miles from downtown Toronto and about 7 miles from the Toronto airport. A total of 24 cars of the 106-car CPR train piled up at the wreck site, and fire broke out immediately. The light from the flaming wreckage gave the first alert of the accident to the central dispatcher of the Mississauga Fire Department, and the first firefighting equipment was at the crash scene about 2 minutes later.

Of the 24 wrecked cars, 2 were boxcars containing insulation and the rest were tank cars: 11 contained propane, 1 contained chlorine, 3 contained styrene, 4 contained caustic soda, and 3 contained toluene. At 12:10 a.m. a tank car exploded; this was followed by a second explosion about 5 minutes later. The second explosion hurled the tank car about 2200 feet to the northeast. A third explosion about 5 to 10 minutes later blew a portion of a tank car 200 feet to the south. The explosions shattered windows within half a mile, and shrapnel from the explosion set fire to a number of buildings near the site of the wreck.

Mississauga Fire Chief Gordon Bentley obtained a copy of the train manifest from the caboose, but it was an illegible copy. By about 1:30 a.m. he had obtained a readable copy from CPR headquarters in Toronto and confirmed that one of the cars contained chlorine. Upon Chief Bentley's recommendation, Police Chief Douglas Burrows ordered an evacuation of people living within about 2000 feet of the site in the downwind direction. At 2:10 a.m. about 8000 people living south and west of the crash site began evacuating to a shopping center mall located about 1½ miles northeast of the site.

At 4:00 a.m., following another series of explosions, Police Chief Burrows ordered the evacuated area expanded to about 10 square miles around the wreck. By this time personnel from the Chlorine Institute were at the site to offer expert advice. The Provincial Ambulance Coordinating Centre had been notified and was assembling ambulances; by 8:00 a.m., 139 ambulances and 300 ambulance workers had arrived in the area.

Chlorine gas was escaping from the ruptured tank car, but most of it was swept upward in the flames of the burning propane. The continuing fire and explosions prohibited attempts to seal the leaking chlorine car. Firefighting personnel and equipment from surrounding cities, including a foam pumper from the Toronto airport, came to the assistance of the Mississauga Fire Department. The Peel Region Police Department (Mississauga is in the Peel Region) was augmented by police officers from the Metro Toronto Police, the Ontario Provincial Police, and the Royal Canadian Mounted Police.

By early morning Solicitor General Roy McMurtry, who is the Provincial Minister responsible for coordinating Provincial emergency measures, Mayor Hazel McCallion of Mississauga, and Chairman Frank Bean of the Peel Regional Council were at the scene. These individuals plus Police Chief Burrows and Fire Chief Bentley formed an ad hoc Emergency

Operations Control Group (EOCG) at the site command post, under the direction of McMurtry. When the fires continued and the chlorine leak could not be stemmed, additional evacuation became the only real alternative.

The emergency plan in effect at the time was a local Peel Region evacuation plan prepared about 18 months earlier after a serious fire at a refinery. It had been used once before in a limited evacuation following a plane crash near the Toronto airport. In addition, the police forces relied on a standard disaster manual.

Shortly after 9:00 a.m., in consultation with other members of the EOCG and in view of expert advice obtained from personnel from the Chlorine Institute and the Ministry of the Environment, Police Chief Burrows ordered the evacuation of Mississauga General Hospital (450 patients) and two nursing homes (539 persons). The patients were transferred to Toronto and to surrounding area hospitals and nursing homes in accordance with the Ambulance Disaster and Hospital Disaster Plans. The transfer was completed by 1:15 that afternoon. After this move was completed, Queensway General Hospital (280 patients) and three more nursing homes (322 persons) were evacuated.

At 12:30 p.m. on Sunday, the first reception center at the Square One shopping mall, 1½ miles northeast of the site, had to be evacuated. The evacuated area was expanded three more times during the afternoon, as unpredictable winds carried the threat to other areas. In each case, except the emergency evacuation in the morning, police cars with public address systems were able to alert area residents prior to the actual evacuation orders. Local radio and television stations gave full-time coverage to the accident. Buses from municipal transit companies and schoolbuses were used to evacuate people who had no transportation of their own. Most evacuees merely checked in at the designated reception center and then went on to stay with friends or relatives or in hotels and motels outside the evacuated area. The reception centers never had more than about 3000 people on hand. The main reception center had to be relocated twice after it was initially established.

At 7:00 that evening the Mayor of Oakville, a neighboring city, decided to evacuate the Oakville-Trafalgar Hospital and the Oakville Extendicare Nursing Home (468 patients). This operation was completed by midnight.

By day's end more than 2000 persons had been evacuated from hospitals and nursing homes, and about 240 000 residents out of a total population of 276 000 had been evacuated from the city of Mississauga. The bulk of this evacuation had been carried out by 6:00 p.m.; it was accomplished in stages as the winds shifted, endangering additional areas around the site of the wreck. The evacuated area covered about 60 square miles. No serious injuries or mishaps were reported.

Police cordoned off the evacuated area, and only three cases of looting were reported during the evacuation. The propane fires were allowed to burn out, and the last flames died out by 2:30 a.m. on Tuesday, November 13. By 8:30 a.m. Tuesday morning, the leak in the chlorine car was sealed, but by this time 70 tons out of the 90 tons carried by the car had escaped. By late evening on Tuesday, 110 000 evacuees had been allowed to return home. However, problems were experienced with the seal on the chlorine car, and it was Friday night before the remaining evacuees were allowed to return home.

The Canadian Federal Government is making a formal inquiry into the train wreck and into the subsequent evacuation. The study is being conducted by the Federal Ministry of Transportation and will probably result in the publication of a White Paper. In view of the worldwide interest in the details surrounding the accident and evacuation, the Canadians plan to hold a seminar during the summer or early fall of 1980 to make available the details of the lessons learned about the state of planning and preparedness, complicating factors such as hospitals, and effects of the evacuation.

The Province will prepare an emergency evacuation plan next year that can be used for any general natural or manmade emergency. The radiation emergency plan which is already in place will probably serve as a model for this work.

f. Findings and Recommendations

The preceding narrative discusses the efforts of the State, county, and local governments and the assistance provided by Federal agencies and other organizations in planning for 10- and 20-mile evacuations during the TMI accident. The findings of this section are:

1. The ability to carry out any evacuation around a nuclear powerplant depends more on the existence of adequate county and local emergency plans than on the existence of an NRC-approved State plan. As Oran Henderson, the Director of PEMA, told us:

> I could prepare you the most beautiful State plan that I assure you NRC would approve, but if that

> plan isn't disseminated and the subordinate county and local municipal plans prepared that dovetail [with the State plan] and take the guidance in the state plan, you still don't have anything. It's the local government and the county government that are going to have the capability to execute any evacuation, if evacuation were necessary.[102]

2. All levels of government were largely unprepared to respond to the accident at TMI.
3. The NRC's requirement that evacuation of the Low Population Zone (LPZ) be feasible led State officials to believe that the planning zone around TMI was sufficient because it exceeded the LPZ specified by the NRC.
4. Local emergency plans for TMI did not exist. While we cannot be sure why localities did not prepare such plans, the probable reasons include: (1) nuclear accidents were perceived as low probability events for which the localities were not highly motivated to divert planning funds and effort, away from higher probability risks in the area; (2) other major types of disasters (such as floods) to which the localities were subject gave sufficient advance warning that detailed planning had not really been required before; and (3) other types of emergencies, such as fires or transportation accidents, required only a more limited response, for which local agencies were highly trained and experienced, thus decreasing the need for formal planning.
5. There was no general agreement during the early days of the accident about the size of the area around TMI that might have to be evacuated. This caused confusion within State and county planning organizations and necessitated a massive effort by them to prepare 10-and 20-mile evacuation plans in the middle of the crisis.
6. Evacuation of institutions such as hospitals and prisons, evacuation of homebound invalids, and the time required for support forces such as the National Guard to position themselves are likely to be critical factors in determining the time required to complete an evacuation.
7. An order to evacuate a specified area around a nuclear powerplant is likely to have consequences extending well beyond that area.
8. We have uncovered no evidence that several hundred thousand people cannot be evacuated quickly and safely. Although the 10- and 20-mile evacuation plans developed during the accident at TMI were not tested, there was a general consensus within the State and counties, after the fact, that the plans could have been carried out. We concur in the estimate that, following the preparation of detailed evacuation plans, evacuation of the area within 10 miles of the plant could have been accomplished in about 10 hours. Certainly the time required to complete a 10- or 20-mile evacuation would have been significantly higher on Friday than on Sunday because little, if any, planning would have preceded the evacuation order. Had it been necessary, the evacuation could and would have been completed. The success of the evacuation in Mississauga further supports this finding.
9. The plans that existed at the time of the accident were adequate to carry out a 5-mile evacuation. Detailed plans were less necessary at TMI for a 5-mile evacuation than for 10- or 20-mile evacuations because of the small number of people, the few nursing homes, and the absence of hospitals and prisons within the 5-mile area. We believe Molloy's estimate that the 5-mile area could have been evacuated in 6 hours was reasonable. It should be noted that conditions such as adverse weather, which were not factors at TMI, could have affected the counties' ability to carry out a 5-mile evacuation in that time. An evacuation of a 10- or 20-mile area would have presented many more problems requiring detailed planning, as a result of the significantly larger number of people and institutions involved.

The recommendations of this section are:

1. Each Federal, State, county, and local organization involved in emergency response must develop complete, integrated emergency response plans which prescribe the organization's functions, its emergency organization, and its modus operandi and which assure that proper information will be obtained and disseminated by the agency so that it can discharge its responsibilities. Factors important to the development of these plans include the following:
   a. The NRC must provide a sufficiently wide range of accident scenarios so that different types of responses can be developed accordingly. These scenarios must include the range of types and amounts of radioactive materials likely to be released.
   b. The response planned by each organization should be based on realistic appraisal of the problems that are likely to be encountered and the resources that will be needed and available to carry out the necessary response.
   c. Federal agencies must have the authority to respond without a State's invitation, based on the agency's evaluation of whether explicit,

preestablished criteria have been met, and funding must be explicitly provided for such responses. Clear procedures must also be established for States to request Federal assistance.

d. A system which provides, when time permits, for a series of alerts should be considered.

e. Hospitals, nursing homes, and other institutions (such as prisons) require a tremendous effort in both evacuation planning and operations. They call for many special resources, and the time for evacuating an area is significantly extended if such institutions are involved. All State and local agencies must recognize these and other special situations in developing emergency plans.

f. Emergency plans must routinely be tested to: (1) exercise all notification channels; (2) simulate the level and temporal response of all support resources; (3) exercise communication channels during the simulated response phase, including plant communications traffic and simulated media and public traffic; (4) simulate the evacuation routes and times required to move people; and (5) drill decision-makers in realistic, unannounced, and difficult decision situations.

2. State, county, and local plans for response to nuclear plant accidents must include the following:

   a. It must be clearly stated that Federal agencies do not have the authority to order an evacuation—this is a State, county, and local authority.

   b. The division of authorities and responsibilities between State, county, and local governments, as well as between the various State agencies such as Radiation Protection, the Health Department, the Agriculture Department, and Civil Defense, must be clearly spelled out.

   c. Federal, State, and local relationships must be clearly defined and the resources that each agency could provide must be predetermined.

   d. Local jurisdictions (those lower than county level) must develop emergency plans in such detail as will assure that their responsibilities are understood. They must demonstrate their awareness of the practical demands of an evacuation and the resources that would likely be required and available. It is likely that most local and county plans need more detail than they now contain. Matters requiring detailed planning include the size of planning zones, evacuation routes, designation of host areas, communications procedures so that plant personnel can provide specific information concerning the extent of the hazard to State, county, and local government officials, coordination of public information releases, and tests and drills.

   e. Funding is required for establishing and maintaining county and local emergency preparedness. We believe funding assistance to county and local governments for nuclear facility emergency planning is necessary for four reasons. First, many counties near nuclear power facilities are rural in nature, have a small tax base, and have limited capabilities to develop meaningful plans. Most localities in Pennsylvania provided no funds for emergency management. Second, accidents at nuclear facilities are low probability occurrences that likely would not command priority attention compared to funding for planning for higher probability emergencies. Third, the response to nuclear emergencies requires more detailed advance planning than responses to other types of emergencies. Fourth, it is not clear that such planning would be performed in a meaningful manner unless funding is provided.

      Such funds could come from the NRC, FEMA, the State, or the utility. We believe the utility should fund the county and local effort necessary for effective nuclear emergency planning. Because such detailed planning likely would not be required for types of disasters other than nuclear, the plans would have a limited specific use related only to the nuclear powerplant. Also, the people who benefit directly from the existence of the nuclear plant are the utility's stockholders and the users of electricity produced by the plant. Because the hazards and degree of planning are unique, the beneficiaries are clearly identifiable, and the beneficiaries are not restricted to the people at risk during an accident, we do not believe the Federal or State Government, i.e., the taxpayers, should be required to fund the necessary planning.

   f. Training of State, county, and local emergency response personnel must be provided by the utility in areas such as basic plant operations and the site emergency plans.

   g. FEMA, in consultation with the NRC and other appropriate Federal agencies, should offer assistance to the States in establishing and carrying out, if necessary, training programs for State, county, and local officials having emergency management planning and response responsibilities.

h. Considering that a large Federal and utility technical support response will occur in any emergency that has potential for serious offsite consequences, the State, county, and local plans must consider the resultant impacts on transportation, food, shelter, and communications, as well as the need for various primary and alternate command centers.

3. FEMA and the NRC should study the Mississauga evacuation as well as other evacuations of populated areas to determine:
   a. The extent to which prior planning can improve the effectiveness of an evacuation.
   b. The impact of population density and other factors on the effectiveness of evacuation.
4. FEMA should be required to certify the status of State emergency planning prior to the issuance of an NRC license, but FEMA's certification must have NRC input and concurrence and should not be treated as a separate major Federal action having significant environmental impact under NEPA (i.e., while contentions regarding the certification must be permitted in the NRC's adjudicatory proceeding, a separate environmental impact statement and decisional process should not be established for this certification).

6. OTHER PROTECTIVE ACTIONS CONSIDERED BY OFFICIALS

a. Introduction

In the event significant amounts of radioactive materials are released during an accident at a nuclear powerplant, two protective action options other than evacuation or sheltering are available to government decisionmakers to reduce a population's exposure to radiation. First, if the population is likely to be exposed to significant amounts of radioactive iodine, persons can be given a drug called a "blocking agent" to reduce radiation injury to their thyroid glands. Potassium iodide is one such blocking agent.[103] Second, if food or water in the area become contaminated with radioactive material, action can be taken to prevent their consumption.

The following discussion covers the actions taken or considered by the responsible Federal and State agencies with regard to these possible protective actions during the TMI accident.

b. Potassium Iodide

Among the radionuclides that may be released during a reactor accident are the radioactive iodines. These are of particular concern from the radiation safety standpoint because they are readily absorbed by human bodies and accumulate in the thyroid gland. If a person breathes air containing radioactive iodine or ingests milk or other food products containing radioactive iodine, the body normally absorbs the iodine, and a significant fraction of it ends up in the thyroid. Radioactive iodine in the thyroid can result in benign thyroid nodules or thyroid cancer.

Accumulation of radioactive iodine by the thyroid can be reduced by use of potassium iodide. Simply stated, when ingested, the nonradioactive potassium iodide saturates the thyroid with iodine, so that when radioactive iodine arrives at the thyroid most of it is rejected and quickly eliminated from the body. Potassium iodide provides optimal protection if taken before or immediately after exposure to radioiodine (within about 3 to 4 hours), although some limited protection will be provided even if it is taken as long as 10 to 12 hours after exposure.

Potassium iodide has been used medically in doses much larger than those required for thyroid blocking, in the treatment of asthma and other bronchial conditions, for many years, with few if any side effects. There is, however, some risk of side effects associated with taking any drug. For potassium iodide potential side effects include affecting the functioning of the thyroid; nonthyroid-related effects include swelling of joints, skin rashes, and gastric upset. The side effects can be eliminated by discontinuing use of the drug.[104]

In August 1977 the National Council on Radiation Protection and Measurements (NCRP)[105] recommended that potassium iodide be considered for use during radiation emergencies as a thyroid blocking agent.[106] The NCRP also noted that the drug could be stocked at nuclear facilities, firehouses, police stations, and at similar locations for ease of distribution in the event of a radiation emergency.[107] The NRC failed to follow up on this recommendation; it did not require that potassium iodide be available for the general population near reactors. Therefore, drug manufacturers saw no market for potassium iodide and did not seek approval from the Food and Drug Administration (FDA) to manufacture the drug. On December 15, 1978, partially because of the NCRP recommendation, the FDA requested drug manufacturers to submit new drug applications (NDAs) seeking approval to make potassium iodide in oral dosage forms for thyroid blocking during radiation emergencies.[108] This action was unusual for the FDA since normally the FDA does not solicit NDAs from drug manufacturers.

At the time of the accident at TMI, the FDA had received no requests for NDAs for potassium iodide for thyroid blocking; therefore, the drug was not available in large quantities. Had the NRC required that potassium iodide be available for the general population prior to the accident, drug manufacturers would have had a market for the drug, the potassium iodide probably would have been manufactured, and, as a result, available during the emergency. In November 1979 the FDA approved two NDAs from Wallace Laboratories Division of Carter-Wallace, Inc., of Cranbury, N.J, for the manufacture of potassium iodide, one in tablet and one in solution form, for use as a blocking agent during radiation emergencies.

Shortly after the start of the accident at TMI on March 28, 1979, Dr. Donald Frederickson, Director of the National Institutes of Health, after conferring with his staff, advised Secretary of Health, Education, and Welfare Califano that as a precautionary measure supplies of potassium iodide should be available in the Harrisburg area. On Friday evening, March 30, Secretary Califano directed the FDA to initiate steps to make the drug available to the Commonwealth of Pennsylvania as soon as possible.

Toward this end, John Villforth, the Director of the Bureau of Radiological Health in the FDA, called Thomas Gerusky, the Director of Pennsylvania's Bureau of Radiation Protection (BRP), during the early morning hours of Saturday, March 31, to determine if the State wanted the FDA to arrange with a drug manufacturer to make potassium iodide for the State. Gerusky has stated that before the accident at TMI, the Commonwealth of Pennsylvania had attempted to obtain potassium iodide for use in the event of an accident. BRP found, however, that potassium iodide for use as a blocking agent was not manufactured in this country. (Another blocking agent, potassium iodate, is manufactured in Great Britain as a thyroid blocking agent.)[109] Because of Pennsylvania's prior interest in obtaining potassium iodide, the fact that trace amounts of radioiodine had been reported in the TMI area, and the uncertainty about future events at the reactor, Gerusky immediately accepted Villforth's offer.

FDA quickly discovered that local pharmacies did not have enough potassium iodide on hand to meet Pennsylvania's needs. As a result, FDA arranged with the Mallinckrodt Corporation to begin emergency production of the drug.

Immediately after the Mallinckrodt Corporation agreed to manufacture the potassium iodide, it called in about 50 employees at its Decatur, Ill., plant to begin production. Mallinckrodt turned sufficient quantities of potassium iodide salt into solution and bottled more than 100 000 ounces to meet the State's needs. An additional 100 000 ounces were sent to Parke Davis Company in Detroit for bottling. Because Mallinckrodt did not have bottles with droppers, FDA purchased the medicine droppers separately from Dougherty Brothers of Buena, N.J. The cost to the FDA for the potassium iodide was about $400 000.

Later Saturday, Gerusky and the Secretary of the Department of Environmental Resources, Clifford Jones, discussed the potassium iodide decision with Gordon MacLeod, the Secretary of Health, Emmett Welch, the Deputy Secretary of Health for Administration, and Oran Henderson, the Director of PEMA. All agreed that the Department of Health would be responsible for storing the potassium iodide and, if necessary, for its distribution.

By 8:00 p.m. Saturday the first 11 000 1-ounce bottles of potassium iodide solution, ready for administering, were loaded onto an Air Force cargo jet for delivery to Harrisburg International Airport. The first shipment was received by the Department of Health at about 1:30 a.m. Sunday, April 1. Six more shipments arrived by Wednesday morning. The Commonwealth received a total of 237 000 1-ounce bottles of potassium iodide, enough for 10 daily doses for more than 10 000 000 people.[110]

The FDA developed, printed, and delivered to the State 250 000 copies of an informational insert, "Patient Information Use of Saturated Solution of Potassium Iodide (SSKI) for Thyroid Blocking," for distribution with the potassium iodide. This package insert described who could take potassium iodide, advised users to begin and stop taking the drug when told to so do, and identified the side effects that the drug's users might expect.

On March 31 the Department of Health also printed patient information material entitled "Emergency Advisory for Protection of the Thyroid Gland from Radioactive Iodine (I-131)" for distribution with the potassium iodide. The Department of Health instructions provided general information on sheltering, the purpose for taking potassium iodide, when to begin taking it, how much to take, and how long to take it. The Department of Health insert did not offer explicit directions for use of the drug, however. For example, it directed readers to begin taking potassium iodide "at the time of announcement of the imminent likelihood of significant radiation exposure." This required the user's knowledge and judgment about what a significant radiation exposure was. Also, it advised the user to "drink dosage recommended for appropriate age once a day for ten (10) to twenty (20) days (the latter advised by Department of Health, Education, and Welfare)," which required the user to exercise judgment in deciding when to stop taking it.

Problems began to develop almost immediately after the Department of Health received the potassium iodide. Inspectors for the Department discovered that many of the bottles in the first shipment contained hairlike filamentous material and other particulate matter which indicated the possible use of unwashed bottles, poor filtration, or both.[111] In addition, the white metal cap liners on the bottles in the first shipment provided an inadequate seal and were absorbing the fluid, causing some leakage. Part of the first shipment arrived unlabeled and was accompanied by various size medicine droppers that did not fit the bottles for which they were procured. Furthermore, the droppers yielded only about half the dosage that had been recommended by the NCRP.[112]

Jack Ogun, Director of the Division of Drugs, Devices and Cosmetics in the Department of Health, to whom MacLeod had assigned responsibility for inspecting the drug, immediately discussed these problems with representatives of the FDA. Ogun and the FDA officials concluded that, while the medicine's quality was not in full compliance with FDA standards, it could be effectively administered with no health hazards resulting from the deficiencies.

Throughout the next week, Secretary of Health MacLeod was faced with deciding whether the potassium iodide should be distributed to the populace or whether the Department should place the potassium iodide in strategic locations in anticipation of future needs. After discussions with the Governor, the Lieutenant Governor, Harold Denton, and Dr. Niel Wald (Professor and Chairman of the Department of Radiation Health of the University of Pittsburgh, who served as a consultant to the Department of Health), MacLeod decided that the potassium iodide should be placed in strategic stockpiles and not dispensed immediately. According to a document prepared by the Department of Health following the emergency, MacLeod's decision was based on several factors.[113]

First, the National Council on Radiation Protection and Measurements had recommended that potassium iodide be administered if the anticipated thyroid dose due to radioiodines exceeds 10,000 millirem. At the time of MacLeod's decision, the highest cumulative dose projected for any individual within a 5-mile radius of the plant from all types of radiation was only 80 millirem.

Second, the general level of anxiety among the citizens in the TMI area was extremely high. MacLeod felt that this anxiety (prompted by misinterpretation of announcements that extremely low levels of radioactive iodine had been found in milk in the TMI area) created a danger that individuals would unnecessarily take the drug.

Third, by Monday, April 2, the danger of an explosion from the accumulation of gases within the reactor's containment vessel essentially disappeared, and the possibility of a high level release of radioactivity was diminishing each hour. The NRC's Harold Denton offered the Governor assurances that the likelihood of an imminent meltdown had decreased and that the leadtime before a release of radioactive material continued to increase as the days went on. As a result, the public's need to have the potassium iodide actually in hand decreased.

Fourth, the Department of Health report refers to a National Council on Radiation Protection and Measurements suggestion that after 10 days of taking potassium iodide a so-called "escape effect" occurs and prevents the thyroid from taking on further doses of potassium iodide. A hiatus of several days must then take place before potassium iodide can be effectively readministered.[114] MacLeod reasoned that, if the radiation hazards, particularly to workers on the island who could not be evacuated, continued for a period of weeks or months, the workers would conceivably have had to go through several cycles of protection versus no protection as they ingested, discontinued, then reingested the medication. Since no one could predict the onset of a high radiation accident, it seemed more prudent simply to have the potassium iodide available where it could be administered within 30 minutes of a substantial release.

Fifth, as was mentioned before, ingestion of potassium iodide carries with it the small possibility of side effects such as skin rashes, swelling of salivary glands, metallic taste in the mouth, soreness of teeth and gums, gastric upset, shortness of breath, and goiter. Though the risk of serious health effects was small, the potential for public health problems encouraged caution in the decision whether to administer the potassium iodide. Since MacLeod believed that potassium iodide could be placed in everyone's hands in a matter of hours, and well within the leadtime estimated to be available, it seemed unnecessary to risk even one serious or fatal complication resulting from the drug itself.

Finally, the inappropriate dropper sizes and the compromised quality of the solution of potassium iodide also discouraged MacLeod from deciding to distribute the drug after its arrival.

As the potassium iodide was received, the Department of Health placed it in a State warehouse a few blocks from the capitol in Harrisburg. The Department then began developing a program for distributing it to the general populace, should the need arise. Two plans for handling the potassium iodide were set forth: (1) for use under emergency evacuation conditions, when it would be distributed to the general populace at evacuation receiving points; and (2) for use in a precautionary evacuation situation, when it would be positioned for distribution but not actually distributed to the populace.

On Tuesday, April 3, 1979, a week after the emergency began, the Governor received a recommendation from the Surgeon General, through HEW Secretary Califano and Jack Watson at the White House, that the potassium iodide should be administered to site workers and made available to the populace within a radius of about 10 miles from the plant. The Director of the National Institutes of Health (and three of his staff), the Commissioner of the FDA (and three of his staff), and the Director of the National Cancer Institute had concurred in the Surgeon General's recommendation. The Surgeon General's recommendation was based on these officials' conclusion that for those close to the site the benefits of administering potassium iodide clearly outweighed the risks of side effects, because they would have insufficient time to anticipate exposure. In closing, the memorandum from Califano to Jack Watson that transmitted the Surgeon General's recommendation noted: "Those in immediate touch with the local situation should assess these recommendations in light of knowledge about current risks and about the likelihood of advance warning of releases."[115] Neither John Villforth, the Director of FDA's Bureau of Radiological Health (who was appointed by Secretary Califano as overall HEW coordinator), nor the HEW representative in MacLeod's office participated in the recommendations or were aware of them when they were made.

The HEW recommendation, transmitted by Watson, caused Secretary MacLeod and Wald considerable concern because they believed the "recommendations" were couched more in the language of a directive,[116] even though Califano's memorandum urged local assessment of the situation. They believed the recommendations contained only minimal leeway to accommodate the judgment of health and nuclear officials at the site, who were in the best position to evaluate the dangers. After receiving this recommendation, Secretary MacLeod, Niel Wald, and Harold Denton reconsidered and reaffirmed their original decision not to administer potassium iodide to anyone, the Federal recommendation notwithstanding.

Wald documented his advice to MacLeod in a memorandum dated April 3, 1979, which stated that administration of potassium iodide should be considered for site workers prior to any plant operation likely to produce an accidental release of radioactive iodine that could result in an absorbed dose of 10 rads or more to the thyroid. Wald advised that potassium iodide for the general population should be located at distribution points, from which it could be given to the populace for administration within a few hours after a release sufficient to warrant its use. He noted that the 20-day duration of potassium iodide treatment proposed by Secretary Califano was not consistent with the 10-day upper limit referred to by the National Council on Radiation Protection and Measurements. Wald also expressed concern that, based on the trace amounts of radioiodine reportedly found in local milk, the populace could misinterpret the need for taking potassium iodide. Wald's memo provided the final justification for MacLeod's rejection of the HEW recommendation.[117]

The Department of Health never distributed potassium iodide to anyone. State officials did discuss with Harold Denton shortly after his arrival at TMI the need to distribute potassium iodide to Federal officials on site. Denton indicated that he believed there was no need for such action. Thomas Gerusky of BRP requested potassium iodide from the Department of Health for use by DER personnel in the event of a general evacuation, reasoning that DER personnel would not be able to evacuate because of their radiological monitoring responsibilities. The Department of Health rejected Gerusky's request on the theory that if the potassium iodide was made available to DER, it would have to be given to everyone. Department of Health officials assured Gerusky that if use of potassium iodide became necessary, it would be given to DER.

In spite of MacLeod's conclusion and Dr. Wald's recommendation that the potassium iodide should be decentrally positioned to speed its distribution, the entire stock of potassium iodide was kept in the State warehouse in Harrisburg throughout the emergency. Emmett Welch, the Deputy Secretary of Health for Administration, told us that by the time the potassium iodide was received by the State, the need for the potassium iodide had passed and the Department no longer saw a need to position it in decentralized locations.[118]

While the State was obtaining potassium iodide, the drug was already available for Metropolitan Edison employees on site. Radiation Management Corporation (RMC), a consultant and contractor to Metropolitan Edison for the TMI Radiation Protection Department (and consultant to many other nuclear powerplants in the East and Midwest United States), provides Lugol's Solution, a potassium iodide solution, for emergency thyroid blockage of workers at these nuclear facilities, as part of the ongoing emergency medical assistance program. The solution would be administered, if necessary, under the supervision of a licensed medical doctor.

RMC also indicates to its customers that potassium iodide tablets in the form of expectorants, are available on the market as prescription drugs. Although the therapeutic dose as an expectorant is twice (or more) than necessary for thyroid blockage, this form is also suitable for emergency use, and is available from pharmacies for approximately $21.00 per thousand.

Some of the Federal officials and Metropolitan Edison contractors responding to the emergency had supplies of thyroid blocking agents. One of Metropolitan Edison's contractors had a supply of 10,000 potassium iodate tablets in packets of 10 each—a 10-day regimen for thyroid blockage for 1000 workers. These tablets were available for emergency distribution under appropriate medical direction from about April 1. On April 1 FDA headquarters officials had seven 1-ounce bottles of potassium iodide solution made up under prescription at a pharmacy near FDA's Rockville, Md., offices. This potassium iodide was hand carried to senior FDA officials in the TMI area with instructions to take it only when directed to do so by an HEW official or a competent medical authority on site and then to share it with others in the area who did not have potassium iodide. Some NRC personnel on site also had limited potassium iodide supplies.

c. Food Interdiction

Milk

In a reactor incident during which there is a release of radioactive material, milk and other human foods may be contaminated. A principal concern is that radioactive iodine might be deposited on pastures, taken up by grazing cows, and passed on in milk to humans. Under the BRP plan,[119] protective actions relating to milk should be initiated if actual or expected radioiodine levels reach 8300 picocuries per liter (pCi/l) of milk,[120] which corresponds to a 1-rem dose to an infant's thryoid. The FDA recommends that protective actions be taken if actual or expected iodine levels reach 12 000 pCi/l of milk, which corresponds to a 1.5-rem dose to an infant's thyroid.[121] At no time were levels of radioactivity found that would necessitate protective actions under either the BRP or the FDA guides; the maximum concentration found in any milk sample was 41 pCi/l, reported by Met Ed from a sample of goat's milk.[122]

Beginning with the evening milkings on March 28, 1979, the Pennsylvania Department of Agriculture, at the request of BRP, began taking milk samples directly from farms in the TMI area. This milk sampling program was carried out on a daily basis at between 7 and 10 farms during the 4-week period following the accident. As of November 1979 a milk sampling program is continuing, though the samples are of packaged pasteurized milk from six dairies in the area. Agriculture also took forage samples from TMI area farms.

The highest radioactive iodine concentration found in any milk sample taken by the Commonwealth was 29 pCi/l. This was found in only one sample and is well below the levels at which both the FDA and BRP recommend taking protective actions. As a precautionary measure, however, on March 30 the Pennsylvania Department of Agriculture recommended to dairy farmers in the TMI area that they put their cows under shelter, away from stream water, and that the cows be fed protected stored feed. Because it was late March and forage grass had not yet begun to grow, most cattle were already consuming only stored feed, and farmers had adequate supplies of stored feed available in silos.[123] This advisory was lifted about 1 month later when all agreed that the danger was past.

Neighboring States closely monitored milk coming into their States from the TMI area. The State of Maryland Department of Health and Hygiene carried out a milk sampling program at 23 farms in northern Maryland and central Pennsylvania, beginning March 29 and continuing for 2 weeks following the accident. The farms in Pennsylvania, some of which were only 3 miles from TMI, held permits to ship milk into Maryland. The Department of Health and Hygiene also sampled some pasteurized milk from Pennsylvania dairies sold in Maryland retail outlets. All of Maryland's milk samples were analyzed in the Maryland Department of Health and Hygiene laboratory in Baltimore. No radioiodine was detected in any samples taken by Maryland above the 20 pCi/l minimum detectable level established.[124]

The New York Bureau of Radiological Health and the New Jersey Bureau of Radiation Protection also tested Pennsylvania milk coming into their States and milk from the cows within their own States. Although there was a press report that the New York Bureau of Radiological Health detected radioactivity in milk, additional analysis of the samples showed this to be in error. During this inquiry we heard allegations that several States had taken action to prohibit milk from Pennsylvania from entering their States. Discussions with officials in each of these States indicated that none of these allegations was true. Our inquiry did not reveal any adverse actions taken by any State against milk from Pennsylvania.

The FDA actively participated in milk monitoring. The FDA checked 760 milk samples from TMI area farms and found trace amounts of radioiodine in 49 samples. The levels ranged from 13 to 36 pCi/l, far below the 12 000-pCi/l level of concentration at which FDA recommends that cows be removed from contaminated pastures.

The Pennsylvania Department of Agriculture received very few reports of adverse actions being taken against milk from area farms by milk wholesalers and dairies in the TMI area. They could confirm only one report of a milk wholesaler's refusing to pick up milk from a local farmer. According to the Department of Agriculture, the refusal was caused by the farmer's statement to the media that he thought his milk was contaminated with radiation. The wholesaler refused to pick up milk from this farmer until his milk could be sampled. After analysis showed no radioiodine in the milk, the wholesaler again accepted milk from this farmer. The delay, however, required the farmer to dump one milking because his milk storage tanks were filled.

There were also unconfirmed reports that wholesalers had diverted some milk from normal retail use as fresh fluid milk to use in processed milk products such as cheese and powdered milk. If this happened, it had no effect on the farmer, since he would not receive a lower price for milk because it was diverted to other uses.

Other Foods

Because the accident occurred before food crops in the area had begun to grow, contamination of food products other than milk was not of great concern. The FDA did sample some food products in the TMI area, however, on Friday, March 30, and analyzed samples of candy, bread, cheese, pastries, and ice cream obtained from retail food stores within a 20-mile radius of the plant. None of the samples collected revealed any detectable amounts of radioactivity. If significant levels of radioactivity had been found, the food simply could have been removed from the marketplace and further investigation for contaminated products could have continued.

At noon on Friday, March 30, 1979, the U.S. Department of Agriculture ordered the six federally regulated meatpacking plants within 5 miles of TMI to cease slaughtering and shipping meats to avoid possible radioactive contamination from that source. Agriculture took this action because there was a great deal of confusion and uncertainty over the extent of the danger of radioactive contamination. On Monday morning, April 2, the Department of Agriculture permitted the meatpacking plants in the 5-mile area to resume production based on information from the Pennsylvania Bureau of Radiation Protection that there had been no surface deposits of radioactivity in the 5-mile area and that radiation levels outside the immediate plant area had been negligible.

d. Water Supplies

Several hundred thousand gallons of radioactively contaminated water were generated by the TMI plant early in the incident, and more was generated in the following days while technicians brought the reactor to a cold shutdown. State and local authorities were concerned that this water might find its way into the Susquehanna River and pose a threat to downstream cities and towns that relied on the Susquehanna River for their drinking water. They were also concerned that airborne radioactive material from the reactor might be deposited on the ground, and, either with or without rain, contaminate nearby private and public water supplies.

On Thursday, March 29, at about 2:30 p.m., Richard Dubiel, the Supervisor of Radiation Protection and Chemistry at TMI, called Margaret Reilly of BRP and told her that the plant urgently needed to discharge industrial wastewater containing "small" amounts of xenon, because its wastewater holding tanks were almost full. Dubiel stated that if the water was not dumped in a controlled manner the tanks would overflow, dumping the untreated water through storm drains into the river. Dubiel told Reilly the amount of xenon in the water was below concentrations that would be allowable under proposals by the NRC for new plants. There were no existing discharge standards for xenon for TMI, so Reilly asked Dubiel if the NRC had approved the discharge and was told they had.

Reilly approved the dumping, reasoning that when the water got to the river the xenon would dissipate into the air or be diluted by river water and would not create a health hazard. Reilly advised Gerusky that the discharge was being made, but neither notified downstream localities.

This discharge began at about 2:30 p.m., but was stopped at about 6:00 p.m. by Boyce Grier, the Director of the NRC Region I office on direction of NRC officials at the Bethesda Incident Response Center. By about 8:00 p.m. that evening, NRC officials in Bethesda were satisfied that the State did not object to the discharge and that the water contained only xenon. By this time BRP had also advised the State of Maryland and downstream municipal users that there was no cause for concern over the discharge.

Meanwhile, Governor Thornburgh had become involved in the problem, and NRC officials believed he wanted to approve the restart of the discharge. In fact, the Governor did not know if he had authority to approve the discharge, and he did not learn that he had no such authority until about 9:30 that evening when (according to Paul Critchlow, the Governor's Press Secretary) he was so advised by Karl Abraham, the NRC Region I Public Information Officer, who was working in the capitol. For the next several hours, Critchlow and Abraham argued over which organization—the NRC or the State—should issue the press release announcing the restart of the water discharge. Finally, David Milne, the DER press secretary, drafted a press statement from Clifford Jones, the Secretary of DER, which was released shortly after midnight. It stated that Met Ed and the NRC informed the State of an urgent need to dump wastewater containing small amounts of xenon and that the DER had "reluctantly" agreed the action was necessary.[125]

Shortly after the March 28 accident, the Environmental Protection Agency, in cooperation with DER, identified more than 100 sources of drinking water within 20 miles of TMI. The State of Pennsylvania, the Environmental Protection Agency, and the Food and Drug Administration developed and implemented a program for sampling these water sources, including locations on the Susquehanna River where local communities drew drinking water. At no time were significant concentrations of radioactive material detected.

If, for example, excessive concentrations of radioactive material had been found in the Susquehanna River, persons normally drawing their drinking water from the river would have had to rely on other sources. Soon after the accident the State of Maryland began taking samples from the river because several Maryland municipalities draw drinking water from the river. By Thursday afternoon, March 29, the Maryland Department of Health and Hygiene had notified all affected Maryland municipalities to fill their storage tanks and to keep them full in case it became necessary to cut off water from the Susquehanna. The municipalities were also advised to locate possible secondary water sources for use in the event the Susquehanna was unavailable for an extended period. Continued and extensive testing by the State of Maryland showed the Susquehanna River water to be acceptable for use.

Testing of water in the Delaware River by New Jersey State personnel also indicated that no airborne radioactivity had been deposited in that watershed and transported as far as the sampling station at Trenton.

e. Findings and Recommendations

The preceding narrative describes the protective actions other than take-shelter or evacuation that were implemented or considered by officials during the TMI accident.

The findings in the preceding section on "Sheltering and Evacuation Advisories," relating to making protective action recommendations from Washington and decisionmakers' lack of understanding of protective action guides and options, generally apply to this section also. The additional findings of this section are:

1. Radiation exposures projected on the basis of measured or likely releases were a factor of 10 to 200 lower than any protective action guidelines.
2. Adequate quantities of potassium iodide for large-scale thyroid blocking treatment were not available in the United States at the time of the TMI accident. Had large quantities of radioiodine been released from the TMI-2 plant prior to the arrival of the potassium iodide in Harrisburg, this protective action would not have been available to State decisionmakers.
3. State and Federal health officials disagreed on the length of time potassium iodide could be effectively administered as a blocking agent.
4. The State Secretary of Health acted reasonably in not distributing potassium iodide to individuals in the vicinity of TMI despite the HEW recommendation. However, the potassium iodide should probably have been prepositioned in decentralized locations to speed its distribution to the populace had the need arisen.
5. The confusion and Federal and State conflicts which resulted from HEW's recommendation to administer potassium iodide to site workers and persons near the reactor were precipitated by the lack of clear criteria for administering the drug.
6. BRP and FDA protective action guides for milk are dissimilar and could have resulted in some small degree of confusion and conflicts over the need to take protective actions regarding milk.

7. The package inserts prepared by the Pennsylvania Department of Health for distribution with the potassium iodide would have required the public to use their own judgment in determining when to begin taking the drug and how long to take it.
8. Uncertainty regarding plant status and the potential for large releases of radioactivity were the principal contributors to the concerns and fears of the public and governmental decisionmakers, and led to unwarranted recommendations or decisions to administer potassium iodide, close meatpacking plants, and take cows off of pasture.
9. The prohibition on Thursday afternoon and evening regarding Met Ed's dumping of industrial wastewater into the Susquehanna River was not warranted, resulted from a lack of communications between and within the NRC and the State, and caused a jurisdictional dispute between the NRC and the State over restarting the discharge.
10. There was substantial concern regarding the radioactive contamination of milk, even though the highest measured levels of radioiodine were a factor of 200 lower than the protective action guide.

Recommendations 3 and 4 of the section on "Sheltering and Evacuation Advisories," which relate to the development of clear and commonly acceptable protective action guides (PAGs) and the evaluation of possible actions in the event PAGs are likely to be exceeded, are supported by the findings of this section. The additional recommendations of this section are:

1. The NRC in cooperation with FEMA and HEW must establish criteria for the storage and distribution of a thyroid blocking agent such as potassium iodide. Specifically consistent guidance needs to be developed for the use of potassium iodide in the total context of nuclear hazards, including nuclear attack as well as reactor accidents; however, prompt attention should be given to the population at risk in the vicinity of nuclear plants.
2. The utility must fund the purchase and storage of potassium iodide based on the same rationale that supports our recommendation to require utility funding of the development of local emergency plans. (See recommendation 2 of "Recommendations and Findings" under subsection 5, above.)
3. Each State must develop specific criteria and procedures governing the storage, distribution, and use of potassium iodide that are consistent with Federal guidance and storage requirements.
4. Unlike evacuation, which requires substantial time to implement, other protective actions should be strongly considered only if radiation levels or doses are likely to approach protective action guides. Such guides are conservatively set to begin with and generally can be quickly implemented (even after the fact in many cases) so as to provide adequate protection of public health and safety. There are also alternatives. For example, if cows are not fed stored feed and water quickly enough, the milk can be either dumped or processed for use at a much later time, after the radioactive iodine has decayed. Therefore, uncertainty regarding plant status and future possible radiological releases should play only a minor role in recommending these other actions, whereas it may play a major role in the decision to recommend evacuation. The role that plant uncertainty should play in the distribution of potassium iodide depends largely on its availability near the site and the time required to distribute it to the population at risk.

7. RADIOLOGICAL MONITORING EFFORTS

a. Introduction

On Wednesday, March 28, 1979, at 6:50 a.m., Met Ed announced to all persons at the TMI plant that there was a radiation problem on site and at 7:24 a.m. announced a general emergency, signifying that there had been or might be an extraordinary release of radioactivity off site. In accordance with established and practiced procedures, both of these announcements were promptly telephoned to Pennsylvania State radiation specialists and to an emergency response team of radiation experts at Brookhaven National Laboratory (BNL), a U.S. Department of Energy facility in New York about 150 miles from TMI. Those two calls, plus calls to the NRC and detection later in the morning of above normal radiation levels in areas away from the plant property led to extensive efforts by Met Ed and Federal and State agencies to determine the extent of the radiation hazard to persons in the vicinity of TMI.

These efforts required the measurement of radiation levels and concentrations of radioactive material in air, water, milk, and other food products in an area extending more than 20 miles in all directions around TMI. In Pennsylvania, thousands of radiation measurements were made at nearby Goldsboro and

Middletown, and at York, Lebanon, Hershey, Carlisle, and many points in between. The neighboring States of Maryland, New Jersey, and New York examined the possibility that TMI-produced radioactivity would end up within their respective borders. Detailed information on these radiological monitoring activities and their results are presented in the section on "Radiological Releases" and in Appendix III.7 of this report. The following provides an overview of the agencies involved, describes generally what kind of measurements were made, and offers several findings and recommendations based on Government agencies' responses to the TMI accident.

b. Overview of Agency Participation

A wide spectrum of organizations with various responsibilities performed radiological monitoring functions during the TMI accident. Under its reactor operating license, Met Ed is charged with determining offsite consequences of radioactive releases so that it can recommend protective actions to the State and local governments. The NRC supported the utility in this task and strove to meet its own statutory obligation to assure protection of the public's health and safety.

The Commonwealth of Pennsylvania, having direct responsibility for the protection of its citizens, had previously assigned to its Bureau of Radiation Protection (BRP) the task of obtaining and evaluating radiological data and recommending required protective actions. Most of BRP's 19 professional staff members were involved full time in response to the TMI accident. BRP relied heavily on information and analyses on monitoring provided by Met Ed, the NRC, the U.S. Department of Energy, the Department of Health, Education, and Welfare, the U.S. Environmental Protection Agency, and the State of Maryland. It also obtained information from its own sampling and measuring activities, analyzed many of the milk and environmental samples in its own laboratory facilities, and maintained a comprehensive awareness of the plant's status, the radiological releases, and the potential radiological effects of the accident. The neighboring States of Maryland, New Jersey, and New York, having responsibilities for protection of their own citizens, monitored the environment within their respective boundaries and sampled milk from Pennsylvania that was intended for consumption in those States.

Agencies of the Federal Government took extensive part in the radiological monitoring effort. The Department of Energy (DOE) provided the earliest and greatest radiological response. Initially, the DOE Region I office provided a Radiological Assistance Program (RAP) team, along with technical members from BNL, in support of the Commonwealth of Pennsylvania. This support was provided in accordance with the DOE program for implementation of the Interagency Radiological Assistance Plan (IRAP) and the interagency agreement between DOE and the NRC. At the peak of DOE's radiological activities at TMI, there were RAP teams from three of the eight DOE Regions, along with technical members from seven contractors, involved in making measurements.[126] DOE also provided aerial monitoring and meteorological assistance.

The Environmental Protection Agency (EPA) and the Department of Health, Education, and Welfare (HEW) were also major Federal participants. DOE's assistance at TMI had been requested by BRP and the NRC. The involvement of EPA and HEW was largely at their own initiative. They responded later than DOE, and their participation stemmed from a combination of their own health and safety responsibilities under their enabling statutes and encouragement by the White House.[127] By Sunday following the Wednesday accident, those three Federal agencies (DOE, EPA, and HEW) had moved nearly 170 trained professionals into the TMI area to perform radiological monitoring. The buildup and decline of these resources is illustrated in Figure III-14.

Other agencies played important support roles. Pennsylvania's Department of Agriculture collected milk samples from farms near the damaged reactor. A U.S. Coast Guard helicopter moved monitoring personnel and equipment from Brookhaven National Laboratory on Long Island, N.Y., to the TMI area. The U.S. Department of the Interior diverted communications equipment normally used in fighting forest fires to use at TMI. More than 200 portable two-way radios were flown in from the firefighting center in Boise, Idaho, for use by monitoring personnel so that the results of measurements taken anywhere in the area could be rapidly sent to a command center for compilation, providing a current composite view of the TMI radiological environment at all times.

c. Brief Description of Offsite Radiological Monitoring

Early on Wednesday morning a high radiation level was detected by the radiation measuring instrument at the top of the TMI-2 reactor building. A calculation, based on that radiation level and an assumption about how fast radioactive gases were

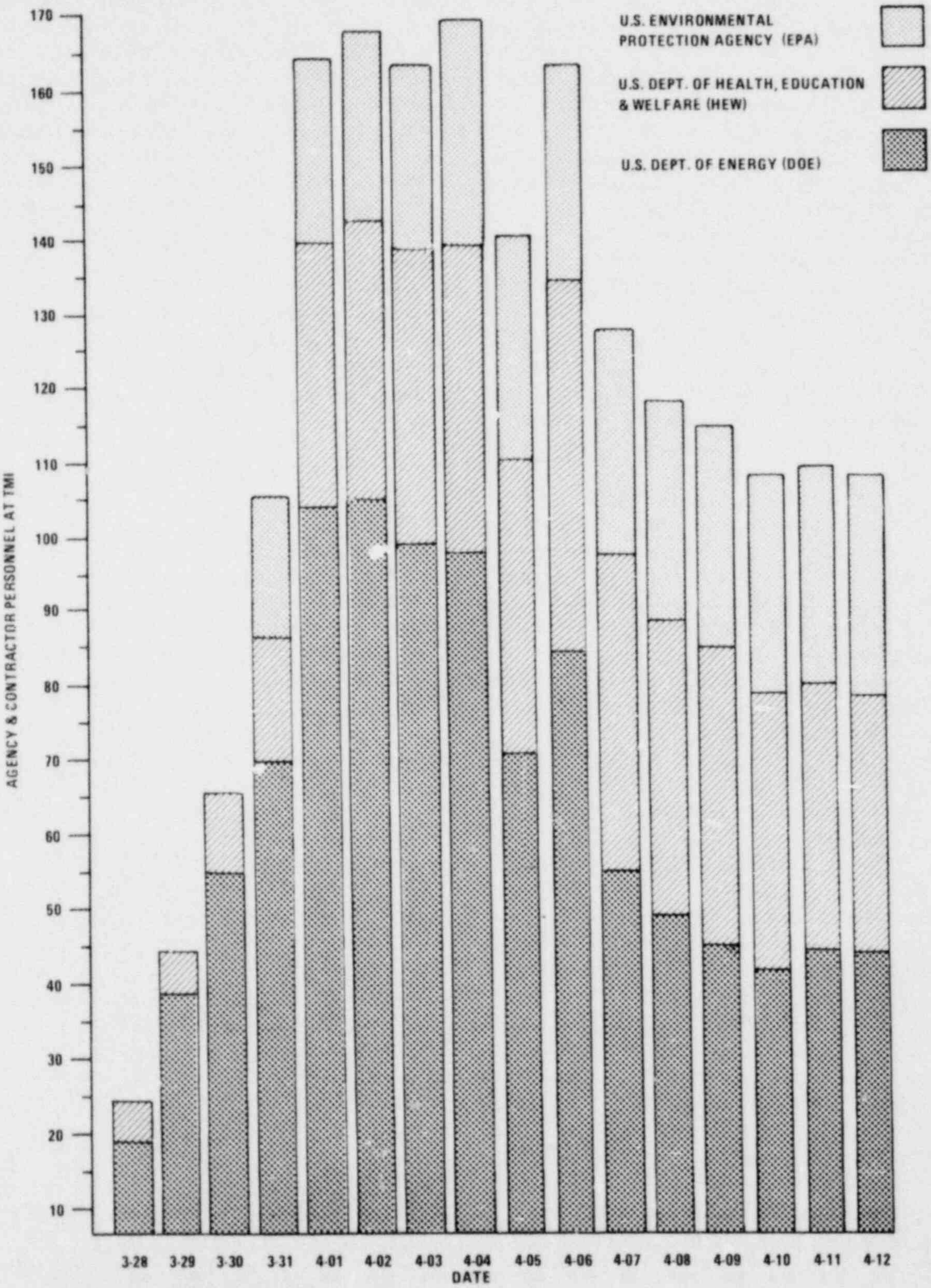


FIGURE III-14. TMI Radiological Monitoring Personnel (DOE, HEW, and EPA) leaking from the reactor building, indicated that the 576 residents of the village of Goldsboro, about a mile away, were being exposed to a radiation level of 10 rem (10 000 millirem) per hour. If that was the radiation level, and if it remained constant for 30 minutes, people in Goldsboro would receive 5 rem, or 5000 millirem, a dose which under the protective action guide established by Pennsylvania would require their evacuation. Because of the high radiation level that had been calculated, an evacuation alert was called. In view of the uncertainty about the assumptions used in the calculation however, Gary Miller, TMI Station Manager, requested a State Police helicopter to take a pair of Met Ed monitoring technicians across the river to Goldsboro. In fact, the technicians took a longer route to Goldsboro by car. Another group made radiation measurements at the west side of the island. All teams made radiation measurements and found nothing unusual at that time.

A couple of hours later, however, at about 10:30 a.m., the Met Ed monitoring personnel found low levels of radiation (about 3 millirem per hour) near Goldsboro. That positive indication of a release of radioactive material from the damaged reactor triggered extensive efforts to find out just how much radiation people in the area were receiving and to decide what actions, if any, should be taken to protect those people.

Earlier in the morning the BNL RAP team had been placed on standby alert, but at 11:18 a.m. BRP's Reilly requested BNL's Charles Meinhold to send the team from New York to the site.[128] This seven-person team flew by Coast Guard helicopter to the TMI area, arriving at about 2:30 p.m., and promptly began collecting air, soil, and vegetation samples and making field radiation measurements. A second BNL RAP team of five persons arrived in Harrisburg at about 1:30 a.m. on Thursday morning, primarily to serve as a relief team. Initially the RAP teams worked out of Gerusky's BRP offices in downtown Harrisburg, but on Thursday the RAP teams moved their base of operations to the Capital City Airport, joining with other DOE personnel to form a DOE Command Post. The airport was closer to TMI and the decision to locate at the airport helped improve communications between persons in the field and persons at the base.

Both the BRP and the NRC fielded their first environmental monitoring teams late Wednesday morning. Until that time, Met Ed personnel had done essentially all of the field monitoring. The total effort by Met Ed, BRP, and the NRC on Wednesday was carried out by about a dozen persons.

Participation by other Federal agencies during the first 2 days was only modest. The EPA, for example, took daily instead of its usual weekly air samples in Harrisburg, Pa., Wilmington, Del., and Washington, D.C. The EPA also took water samples from the Chesapeake Bay and the lower Susquehanna River. HEW developed a strategy for food and water sampling and began actually sampling and measuring on March 29.

During these first 2 days a total of up to about 40 DOE specialists using many sophisticated radiation measuring instruments, meteorological instruments, computers, helicopters, fixed-wing aircraft, aerial photographic cameras, two-way radios, and surface vehicles participated in evaluating radiation and radioactivity levels out to many miles from TMI. The strategy for the offsite radiation monitoring was simple: Find the radioactive material, measure it, and then compile and evaluate the measurement data.

The task of finding the radioactive material at ground level was simplified considerably by having good guidance on where to look. That guidance came at the arrival early Wednesday afternoon of a U.S. Department of Energy Aerial Measurement System/Nuclear Emergency Search Team (AMS/NEST) from Andrews Air Force Base near Washington, D.C. The team's helicopter, and a second helicopter that arrived from Las Vegas early on Thursday, were equipped with radiation measuring instruments. This AMS/NEST group had been mapping normal levels of radiation near nuclear power reactors for several years. The same group also assisted Canadian authorities in 1978 in locating a highly radioactive Russian satellite that fell in a remote area of Canada.

From the period of March 28 through April 15, the AMS/NEST unit made 72 flights at TMI. The team was particularly useful in tracking and locating the boundaries of the "clouds," or plumes of invisible radioactive gases emitted from the plant through the use of their radiation monitoring equipment. On occasion, when meteorological conditions were right, the teams were able to track the radioactive plume out to 20 miles from TMI because their monitoring equipment was very sensitive and could measure very low levels of radiation.

With the heightened concerns on March 30, the level of effort by all of the Federal agencies involved in the radiological monitoring effort increased substantially (refer to Figure III-14). The NRC requested and obtained additional DOE support for its land survey teams, EPA brought in a monitoring team and laboratory analysis staff to work closely with the State, DOE support of the Commonwealth of

Pennsylvania was increased, and HEW increased its personnel in the area dramatically.

Incoming teams were equipped with radiation measuring instruments, including those to be used in measuring exposures to team members. Such instruments, called personnel dosimeters, were also available locally for use by the National Guard and others. Many of the National Guard's personnel dosimeters, however, were designed for measurement of the high levels of radiation associated with nuclear warfare and were of no value for indicating the TMI low level radiation encountered by individuals.

With the increase in numbers of persons and agencies participating, there was a need to coordinate the monitoring efforts. Gerusky of BRP asked DOE to take the lead in this effort. Beginning Friday evening, representatives of the agencies performing monitoring met daily at 5:00 p.m. at the DOE Command Center at the Capital City Airport to pool their data and plan the next day's activities. DOE undertook the task of compiling and summarizing the data into a form that was useful to decisionmakers. The information developed was given to the Commonwealth of Pennsylvania, the NRC, and other interested parties, and was used by the NRC, DOE, EPA, and HEW to estimate the maximum individual exposure among the public, the cumulative population exposure, and the health effects resulting from the TMI accident.

By Monday, DOE, EPA, and HEW radiation specialists were at TMI en masse. Radiation measurements were being made in all directions out to 20 miles and more from the reactor. HEW had more than 200 radiation measuring devices carefully located on a grid pattern within the 20-mile radius. The NRC, Met Ed, EPA, and BRP had measuring devices at selected locations. EPA had used aerial photography to identify 465 dairies within 25 miles and had selected 9 dairy farms from which to obtain samples to complement milk sampling programs already underway by BRP, HEW, and the State of Maryland. Water supplies were being analyzed by the NRC, BRP, HEW, EPA, DOE and neighboring States. Air sampling instruments and external radiation measuring instruments were located in concentric circles of from 3 miles to 6 and 7 miles from the plant and in nearby towns. Teams of radiation specialists with portable instruments and two-way radios were in contact with the DOE central command post at the Capital City Airport where monitoring data was displayed using transparent overlays on large maps of the area. To sum up, this effort certainly resulted in a comprehensive radiological monitoring program. Once in place it could have adequately responded to higher offsite radiation levels and to much larger releases of radioactive material than were experienced at TMI.

Buildup of the radiological monitoring efforts was extensive during the first weekend following the accident. Intensive efforts continued at a high level for about a week and then rapidly diminished following Governor Thornburgh's announcement on April 9 that pregnant women and preschool-age children could safely return to the area.

On April 13, the White House designated EPA the lead Federal agency for long term radiation monitoring at TMI. EPA had the responsibility for collecting, collating, and maintaining all the various radiation monitoring data that were developed by the NRC, DOE, EPA, HEW, and others. It was recognized that these data were critical to understanding not only what had happened at TMI, but also its environmental effects and its consequences for public health. EPA, as opposed to DOE, was selected for the task in recognition of its statutory mandate to protect air and water quality and in recognition of the public's awareness of EPA's principal mission of controlling environmental pollution. The public, on the other hand, identified DOE with energy development. White House staffer Eidenberg has explained that selection of EPA as lead Federal agency for long term radiation monitoring did not reflect a lack of confidence in the technical competence of DOE and HEW.[129] Long term monitoring by EPA, with limited assistance from DOE, is underway and is expected to continue through the TMI cleanup process.

d. Findings and Recommendations

The preceding narrative has described the nature and the extent of the participation of each of the agencies involved in the radiological monitoring effort. The findings of this section are as follows:

1. Because of the high radiation levels in the reactor building, it was clear by 8:00 a.m. on March 28 that there had been a radiological accident of serious potential consequences at TMI. Yet the DOE AMS/NEST was not requested by the NRC until 11:00 a.m., and the DOE RAP team was not requested by BRP until after 11:00 a.m.
2. The radiological response effort was more than adequate and likely would have been adequate for an accident of much larger offsite consequences.
3. There was recognition in Washington that a single Federal agency should be assigned the lead for long term radiological monitoring and EPA

was eventually given this assignment. This assignment was consistent with EPA's statutory responsibilities to protect the environment and with the public's perception of normal EPA activities.

4. There was a lack in the TMI area of immediately accessible personnel monitoring devices able to indicate radiation doses below one rem. This could have affected the emergency response actions of the State Police and the National Guard had radiological releases necessitated an evacuation.
5. While not substantially affecting the radiological response, there was some initial duplication of effort in radiological assessments and there were some early delays in obtaining results because suitable locations for radiological monitoring and radio relay stations had not been designated prior to the accident.

Consideration of the TMI radiological response suggests that the following recommendations would lead to a more effective and efficient operation in the event of a reactor accident with substantial offsite radiological consequences:

1. DOE must be the lead agency for coordination and implementation of a prompt, large-scale emergency radiological monitoring response because it is already operationally equipped for such a function. However, the EPA should be the lead agency for long term, low level, followup monitoring; HEW, with its broad responsibilities for protecting public health, should be the lead agency for determining the long term health effects of the accident.
2. FEMA must assure that personnel dosimetry equipment capable of measuring and indicating both low and high radiation exposures is available for those involved in conducting evacuations and securing the evacuated areas. These include the State Police, fire personnel, and the National Guard. FEMA must also assure that training is provided in the use of this equipment.
3. RAP and AMS/NEST units must be promptly dispatched by DOE at the onset of a potentially serious radiological incident, even without waiting for an invitation or request from the State or the NRC.
4. Radiological monitoring and radio relay positions must be preplanned by the utility in cooperation with the NRC, DOE, and the State, and should be based on land use, terrain, accessibility, and other considerations.

8. INSTITUTIONAL COMMUNICATIONS

a. Introduction

This discussion addresses three elements of the communication process (information selection, transmission, and assimilation) in the context of the TMI accident, with emphasis on interagency communications. In so doing, it attempts to analyze the effectiveness of institutional communications during the course of the emergency response to the TMI accident.

b. Notifications

Metropolitan Edison Company's emergency procedures for TMI-2 required plant operations personnel to notify the Pennsylvania Emergency Management Agency (PEMA) and, "as necessary," the NRC Region I office in King of Prussia, Pa., the Dauphin County Office of Emergency Preparedness, the Department of Energy (DOE) Region I Radiological Assistance Program (RAP) at Brookhaven National Laboratory in New York, various utility management representatives, and the Hershey Medical Center, in Hershey, Pa.[130] These notifications, both of a site emergency and of the subsequent general emergency, were easily made over commercial telephone lines on Wednesday morning soon after the accident. However, the NRC Region I answering service was unable to promptly contact the NRC Region I Duty Officer or the Deputy Region Director.[131] One organization on the utility call list, the Hershey Medical Center, was deliberately not contacted.

Clarence Deller, the PEMA duty officer, who was automatically notified by PEMA of Met Ed's call, phoned the duty officer of the Bureau of Radiation Protection, William Dornsife, at his home at 7:05 a.m. Deller also attempted to contact the Emergency Management Agencies (EMAs) of the three counties within 5 miles of TMI (Dauphin, York, and Lancaster), other State Agencies, and nearby States to inform them of the site emergency. Deller was not able to reach the York County EMA by phone and asked the Lancaster County Director to relay the information to York by teletype, since, in addition to commercial telephone connections through county courthouse switchboards, county EMAs have permanent teletype connections with PEMA and with each other. This message reached the York County EMA at 7:27 a.m.[132]

BRP duty officer Dornsife called Margaret Reilly, Chief of the Division of Environmental Radiation, who in turn called Thomas Gerusky, the Director of the Bureau of Radiation Protection, with word of the accident. In accordance with the BRP emergency plan, Dornsife then established contact with the TMI-2 control room. Gerusky was the first BRP employee to arrive at work that morning, getting there at about 7:25 a.m., and, again following the BRP emergency plan, he recontacted the TMI-2 control room. This line remained open for about 2 weeks and became the primary direct means of communication between the Commonwealth and the utility.[133]

Soon after the NRC Region I switchboard was opened at 7:45 a.m., a telephone line was established between the TMI-2 control room and the NRC Region I office. This line was also kept open continuously. The NRC Region I staff contacted the NRC Headquarters and established a relay for information between the plant and Bethesda. The NRC Headquarters staff notified many other Federal agencies in accordance with an emergency call list that had been developed.

During this preliminary notification process each of the elements of the communications process was simple and, with the exception of the problem in reaching the NRC Region I office, the process worked quite well. The information selected for transmission was very limited, but it was sufficient to alert government officials to the problem as perceived at the plant. Oran K. Henderson, the Director of the Pennsylvania Emergency Management Agency, for example, noted at the time that, "They give us the bare minimum, and that's what we want."[134] These transmissions were made almost entirely over the commercial telephone system, which functioned very satisfactorily. Assimilation of the information and initiation of actions on the basis of that information were prompt.

c. Technical Communication Between Agencies

After the initial notifications, interagency communications became highly technical. In a nuclear powerplant, as in any large facility of such complexity, a very specialized vocabulary develops to identify rapidly and unambiguously any component of the system. Even a technically sophisticated individual normally requires substantial explanation of terms in common use at the plant. In the emergency communication chains established at TMI, where characteristically there were several intermediaries between the source of the information and its user, the opportunities for misunderstanding were numerous. The selection of information to be transmitted and the significance given to it by the receiver were markedly influenced by the previous experience, training, and expectations of the individual. For example, plant operating staff did not communicate indicative temperature and pressure data to the NRC because either they did not appreciate the significance of the information or they believed the data invalid.

For 2 days the open telephone lines from the plant to the BRP, the NRC Region I office, the NRC Headquarters in Bethesda, and the utility headquarters functioned as the principal channels of communications. A response team from the NRC Region I office, arriving at the plant on Wednesday morning, was soon manning the telephones from the plant to the NRC Region I office, and the NRC Headquarters. Communication with the plant became physically more difficult when control room radiation necessitated the use of respirators. The telephone communications between the plant and the State were supplemented by offsite briefings of State officials by both utility and NRC staffers.

The DOE Radiological Assistance Program (RAP) team, which was aiding the State in its radiological monitoring efforts, established its base of operations with the State's Bureau of Radiation Protection in Harrisburg, so contact with the BRP was person-to-person rather than by phone. The AMS/NEST group that had been requested by the NRC located its headquarters at the Capital City Airport in New Cumberland, Pa. and used the manager's office, where there was an adequate number of telephones available, for its center of operations. After the telephone company installed telephone lines and equipment, the team moved on Thursday to the State hangar at the airport, where DOE also established its local command post. The AMS/NEST continued to use the telephone to relay its data to the NRC, to DOE Headquarters, and to the RAP team in Harrisburg.

During the 2-day interval from Wednesday to Friday, the principal means of communication among all organizations remained commercial telephone lines. There were, of course, face-to-face communications between utility personnel and NRC representatives at the plant; between the DOE RAP team and the BRP in the BRP office; and among the utility, the NRC, DOE, the Governor, and other State officials at the State Capitol. At both the NRC Headquarters in Bethesda and at the State Capitol in Harrisburg, however, the insufficient and varying data they were receiving gave rise to concern that the right information was not getting to them.

d. Particular Communications Problems Encountered

Every element of the communication process encountered difficulties during the course of the accident. Because of the limited number of telephone lines into the TMI plant, it was sometimes difficult to contact plant personnel. Babcock & Wilcox (B&W, the reactor vendor), for example, was unable to contact the plant for extended periods on Wednesday.[135] Occasionally, unattended lines which were supposed to remain open were disconnected;[136] reestablishing the connection could be both time consuming and frustrating.

Too, the circumstances surrounding Thursday's discharge of the slightly contaminated industrial wastewater into the Susquehanna River illustrate both a lack of complete information and failure to assimilate and recognize the significance of the information. Both problems resulted from poor communications and both providing clear examples of human failures, not mechanical ones.

The protracted nature of the accident, the lack of confidence in the utility, and the general perception that the plant's control of radioactive releases had substantially improved set the stage for the Friday morning release of radioactivity into the atmosphere. Shift Supervisor Floyd's description to PEMA of the release as "uncontrolled" was soon followed by an NRC recommendation for evacuation. This recommendation was subsequently reversed, but not before the public was informed of the evacuation possibility.

The concern and confusion related to these events produced such a volume of telephone traffic that the local exchanges were overloaded,[137] and most of the lines being used for the TMI response were connected through these local exchanges. The consequent loss of key telephone connections created a great deal of consternation among Government officials participating in the response effort because it effectively isolated those response organizations which had not established dedicated telephone lines or were not maintaining open lines. While some radio communications were used during this chaotic Friday morning, they were ineffective, not only because there were too few radios, but also because, in some instances, terrain and buildings interfered with transmission.

The details of the events leading to the evacuation advisory for pregnant women and young children are provided in the previous section, "Sheltering and Evacuation." One aspect of this story, however, seems strongly influenced by communications problems. At 9:15 a.m. on Friday morning, PEMA's Henderson received a telephone call from the NRC's Collins in Bethesda recommending evacuation out to 10 miles. Henderson then notified BRP's Gerusky of Collins' call. Gerusky responded that BRP was not aware of any information that would justify an evacuation and said that he would look into the matter and get back in touch with PEMA.[138] Before getting confirmation or advice from BRP, however, Henderson notified Molloy, Dauphin County Coordinator, of the strong possibility of a 5-mile evacuation order within the next 5 minutes. Molloy immediately made a radio announcement alerting the public to the evacuation possibility, causing distress and confusion which might have been averted, either by improved communications channels and information flow from the plant to the NRC Headquarters or by improved communications between BRP and PEMA, as by the presence of a senior BRP official at the PEMA Emergency Operations Center.

It should be said that, although the emergency communications at the PEMA center were activated on Wednesday morning, emergency teams from the various State departments were not physically present at the center until late Friday morning. Even at that time, the Department of Environmental Resources representative at the center was not an official from BRP and did not have nuclear training.)

e. Communications Improve After Friday

A number of organizational and operational actions that altered the communications process for the remainder of the emergency response were taken or at least begun on Friday.

Coordination

- The President assigned coordination of the Federal response to Jack Watson of the White House staff.[139]
- A senior NRC task force headed by Harold Denton established a base of operations at the plant site; Denton represented the President and served as official NRC spokesman.
- Governor Thornburgh assumed direct control of emergency response and public information in Pennsylvania.[140]

Hardware

- Direct phone lines were installed connecting the plant, the NRC, the Governor's office, and the White House.[141]

- DOE moved its mobile field communication system from Nevada and provided additional communicators and field personnel.[142]
- Dedicated telephone lines connecting PEMA directly with the EMAs in the six risk counties were ordered.[143]
- DCPA installed radio equipment in the six counties to provide backup communications among the emergency management agencies.[144]

Personal Communications

- DCPA and FDAA staff were brought in to work directly with State and local emergency management personnel in planning 10-mile and 20-mile evacuations.[145]
- DOE conducted daily radiological monitoring coordination meetings at the Capital City Airport for all governmental agencies involved in monitoring.[146]
- At least two of the counties set up rumor control phones with special numbers.[147,148]
- The State, assisted by the FDAA, established its rumor control center during the following week.[149]

These actions ultimately produced a substantial change in institutional communications. Direct communications between the information sources and the evaluators became more common, and basic data became available to decisionmakers. The potential for error in data communications shrank since the key communicators were now more broadly knowledgeable people. Improved interagency communications narrowed the divergence of purported facts.

All official pronouncements eventually were centralized through Governor Thornburgh, Harold Denton, or the White House and the rampant production of unsupported rumors was tamed. Unfortunately, the decision to implement this centralized information process also served to close the normal official communication channels to the local areas which, as a result, became almost totally dependent on the news media for information.

The counties were unable to get information from the State throughout much of the accident. PEMA issued situation reports to the counties but communicated little if any substantive information about plant status.

This situation was aggravated by two factors. First, before Friday, and as required by the State emergency plan, BRP had routinely provided plant status and radiological monitoring information to PEMA, which in turn passed the information on to the counties and to others. These reports largely reflected "no change" in previous status reports, because radiological releases were not large and the plant status was not well understood. After Friday morning, however, the Governor stated that he would be the sole spokesman within the State. PEMA interpreted this statement to mean that nothing other than planning information was to be communicated to the counties by PEMA, and so confusion about releases and the plant's stability escalated. The county organizations, bombarded with reports of what had been heard on radio or television, deluged with questions about the information's validity, and cut off from official information sources, were unable to respond effectively.

The additional telephone and radio communications equipment installed as a result of Friday's difficulties and, perhaps more significantly, the assignment of PEMA and DCPA personnel to the counties to assist county emergency coordinators in developing detailed 20-mile evacuation plans, constituted a framework for some effective communication between the State and local agencies. In the area of evacuation planning, that framework appears to have supported very effective communications; in the area of plant status, it did not.

Within the State, technical information generally flowed upward from its source to the Governor's office. Little information moved laterally from agency to agency. The BRP supplied neither liaison personnel nor meaningful status reports to PEMA. The NRC provided "preliminary notifications of events or unusual occurrences," called PNOs, to the press and to the Governor's office; PEMA, however, was unaware of them for the first week of the emergency, and the PNOs were not sent to the counties until after PEMA began to receive them.

After Friday the NRC provided essentially all information about plant status to the Federal and State Governments and to the public. This information reflected the caution and pessimism properly associated with a regulatory environment, but it is not clear that such deliberately pessimistic information should dominate public information in an emergency. After Friday, however, there were no alternate sources from which a different perspective could be obtained.

Confirmation that the bubble was diminishing and the visit of the President and Mrs. Carter to the plant on Sunday marked the beginning of a calmer but still very cautious period. Ample communications equipment was available so the extensive contingency planning for evacuation and for plant support could be continued with minimal difficulty.

Isolation of county governments from technical information, however, continued, but a gradually reduced level of public apprehension made this isolation less important as time went on.

f. Aftermath

During the long term recovery period, available means of communication reverted to preaccident status. By the end of April the additional communications systems, such as the dedicated telephone lines between PEMA and the county emergency management agencies, the DCPA radio links with the counties, etc., had been withdrawn.[150, 151]

Actions have been taken since the accident to make permanent improvements. The NRC, for example, has required the nationwide installation of dedicated lines from each licensed nuclear reactor plant control room to the NRC Headquarters. It is providing each NRC regional office with a small short-range portable field radio communications system for use by its emergency response team. Headquarters and regional emergency operations are staffed 24 hours a day.

g. Findings and Recommendations

The preceding discussion has illustrated the types of communications problems which were encountered during the TMI emergency response. The findings of this section are listed below.

Communications Systems

1. The commercial telephone system functioned satisfactorily during the initial notifications.
2. The commercial telephone system using dial-up connections was not satisfactory for continuing technical communication during the emergency.
3. The telephone companies functioned well in response to numerous requests for installation of lines and equipment, but there was no coordinated planning for either telephone or radio requirements. Such planning could have accelerated the process of making communication equipment operational.
4. In times of public confusion and concern, overloading of local telephone exchanges and agency switchboards should be expected.
5. Though there were no other natural or manmade interruptions to telephone communications during the TMI response, such problems are encountered frequently enough that an independent backup channel for critical communications would be prudent.
6. Radio communications between some locations were inhibited by terrain or intervening structures.

The Act or Process of Communicating

7. During the first few days of the response, the divergent descriptions provided by different organizations reflected a variety of interpretations of the same information. This is to be expected in an accident situation. In order to minimize the problem, it is essential to ensure that all evaluations are based on consistent and, to the extent possible, accurate information.
8. Communications between PEMA and BRP were incomplete and, therefore, ineffective.
9. The flow of official information from the State to the counties regarding plant status and radiological matters was virtually nonexistent. This presented a major problem to the county and to local jurisdictions.
10. The need for rapid and accurate transmittal of essentially identical information to several recipients was not satisfactorily met. There were too many independent sequential transmissions and there were too many intermediaries.
11. The rumor control center was established by the State after the period of greatest need was over.

The recommendations of this section are the following:

1. PEMA must carefully evaluate communications systems to determine if the preassigned authorities and responsibilities of the various Federal, State, and local agencies and the utility can be carried out effectively during an emergency situation. This evaluation should include at least the following:
   a. The assumption that switchboards and local exchanges will sometimes be overloaded by public and media calls.
   b. Assuming overloaded telephone lines, simulation of necessary communications traffic among the utility, utility support organizations (such as the vendor and architect-engineer), the NRC, other Federal agencies, the Governor's office, various State agencies, the counties, local agencies and elected officials, and other States.

c. Experimental determination of adequate transmission from predesignated command posts, monitoring stations, and control points when radio communications are to be used.

d. Consideration of planned primary and alternate locations of the various command posts involved in the emergency response.

e. Consideration of techniques that would permit simultaneous transmittal of information to many recipients, information such as radiological assessments, plant status, etc.

f. Consideration of any backup equipment needed for critical communications channels.

g. Rapid establishment of rumor control telephones.

h. Encouragement to State radiological health organizations to maximize staff involvement with other governmental agencies, especially within the State, both before and during an emergency. Such involvement is critical to the effective communication of the actual and potential radiological hazards and recommended appropriate protective actions. Plans must be in place to draw upon sufficient Federal agency support to augment the essential field and laboratory radiological measurements that this State staff would normally perform, freeing some of this staff to perform the critical communications function.

i. The education of persons apt to be involved in response to an accident (including plant control room personnel and auxiliary operators) regarding the type of information needed during an incident (e.g., off-normal critical parameters, radiological release pathways, etc.) so that management personnel and response teams can better perform their functions. In relaying technical data, the source, units, date, and time for which the data are valid need to be transmitted. Standard data recording forms should be used. Also, in responding to requests for information, emergency personnel must keep in mind that the person making the request may not have a firm understanding of what is needed, and should ask questions in order to clarify the request.

j. The State must take steps to assure that nearby States are promptly informed of and then kept up to date on the accident.

k. Where dedicated telephone lines are necessary, they should preferably be fully operational, if they can also be useful in normal operations all the time, or they should at least be fully installed. Standby instructions to the various telephone companies to ensure very prompt hookup in the event of need should be readily available.

l. Where radio networks are necessary, the equipment should be routinely tested for operability, and suitable arrangements must be made for any necessary patching. Where such systems would be borrowed from other agencies (a good cost-effective solution), suitable planning and testing must be performed to assure their availability on a timely basis, their operability, and their effective integration into the overall communications network.

2. Necessary information regarding the status of the emergency must be transmitted routinely and consistently by all parties to all appropriate Federal, State, county, and local government agencies. The State must not rely exclusively on the media to pass information to county and local jurisdictions and to the public. The State must make use of its existing institutional channels as efficiently as possible so that local officials, who get many questions from the public, will have the latest official information available.

9. TECHNICAL SUPPORT FOR THE PLANT

a. Agency Response

In addition to the many emergency response efforts aimed at protecting the public, the government agencies made significant efforts in support of technical activities at the Three Mile Island plant. These efforts were undertaken either in response to direct requests from the utility or in response to requests from the NRC. On March 30 the White House designated the FDAA's Robert Adamcik to serve as lead Federal official for TMI with responsibility to coordinate the technical support tasks performed by Federal agencies other than the NRC.

The Department of Energy, through its Pittsburgh Naval Reactors Office, made the initial agency efforts (aside from the NRC's) in support of the TMI-2 plant. In response to an NRC request, DOE's Bettis Laboratory, near Pittsburgh, undertook a detailed determination of the radioisotopic composition of a highly radioactive primary coolant sample that was obtained from the plant on March 29. In addition, samples of the containment building atmosphere and of the contents of the TMI-2 waste gas storage tanks were analyzed at Bettis during the first week of the emergency response. Bettis later performed a less elaborate analysis of primary coolant activity from a sample taken on April 10. The primary coolant analysis effort was also extended on April 10, and involved three other DOE Laboratories: Oak Ridge National Laboratory in Tennessee, Savannah River Laboratory in South Carolina, and Idaho National Engineering Laboratory (INEL).

The Department of Defense provided air transport of the highly radioactive samples, which could not be shipped on commercial aircraft, and billed the costs to the utility. This same billing arrangement was used for the large items discussed in the remainder of this section and for the large mine safety filters obtained from the Washington Public Power System and transported from Pasco, Wash., to Harrisburg, Pa. State agencies including the Air National Guard and the State Police expedited the transfer and delivery of materiel to the site.

Beginning on March 30 the escalation of concerns and the consequent expansion of contingency preparation encompassed a number of plant-related activities. Lead bricks, required for shielding a recombiner being installed outside the containment, were needed. The recombiner was to be used to mix, in a controlled manner, the hydrogen in the containment atmosphere with oxygen. Thus more than 85 tons of lead were obtained during the weekend from Brookhaven National Laboratory, the GSA stockpile, the National Bureau of Standards, the DOE Pittsburgh Naval Reactors Office, and the Armed Forces Radiobiology Institute. Delivery to the TMI site was completed on Sunday, April 1.

Concern over the hydrogen bubble spawned a great many analytic, experimental, and consultative support activities. NRC safety research programs in progress at DOE laboratories such as INEL, and the Sandia Laboratory in Albuquerque and the Los Alamos Scientific Laboratory in New Mexico, were diverted to support these activities. Other DOE capabilities such as Bettis Laboratory and Knolls Atomic Power Laboratory, near Schenectady, N.Y., made their experience and expertise available to the NRC.

NASA sent W. A. Riehl from the Marshall Space Flight Center to TMI to advise the utility on hydrogen technology. The National Bureau of Standards provided technical data. The NRC independently solicited the advice of a number of university and industry experts.

On March 30 the NRC requested remote manipulation capability at the plant. The initial response was from Oak Ridge National Laboratory. Their mobile manipulator, nicknamed "Herman," arrived at TMI on March 31 with its operating crew. Operating procedures for use of the manipulator in obtaining primary coolant samples were developed and tested. A second manipulator, owned by MBA Associates, a private concern, arrived at the site from Eglin Air Force Base in Florida on April 1. Like many contingency preparations, these devices were never actually used.

Waste management and decontamination efforts started early and developed into a major long term effort. Oak Ridge and INEL supplied both knowledge and onsite manpower in support of the recovery effort. A number of other DOE laboratories, including Argonne, Sandia, and Savannah River, provided laboratory services. The Department of Transportation later contributed to this activity by assisting in locating potentially available railroad tank cars and then putting the utility in contact with the owners.

The problem of conducting operations at a contaminated plant, particularly in a contaminated atmosphere, was a continuing concern. Savannah River provided the plant with supplementary supplied-air respiratory equipment, including 140 plastic suit jackets with air distribution systems. The Hanford Engineering Development Laboratory, in Richland, Wash., provided two breathing-air distribution manifolds. The Mine Safety and Health Administration of the Department of Labor supplied 18 Draeger oxygen breathing systems as well as a staff to train personnel in using them.

A miscellany of other support activities were carried out by various DOE laboratory groups. For example, Oak Ridge performed noise measurements and analysis to detect coolant boiling; Argonne performed analyses related to fuel damage; Sandia prepared a preliminary design of a containment vent-filter system that might be used in the event of a core meltdown; and Oak Ridge provided instrumentation expertise, which was used to evaluate the reliability of existing instruments and to modify and improve instruments that were accessible and in need of modification.

b. Findings and Recommendations

The cooperation of the Federal agencies in responding to the needs expressed by the utility or the NRC in preparing to deal with a variety of possible recovery scenarios, and their success in meeting these needs, was commendable. The effort was mounted and executed on an ad hoc basis, and was, therefore, somewhat less efficiently executed than would have been possible if the effort had been very carefully preplanned. Since such preparation for a wide spectrum of possible accidents would be very expensive, we have not been able to conclude that the benefits of such specific preplanning would outweigh the costs.

There are no recommendations.

Bibliography

This section is based on the following sources:

1. Memorandum from H. G. Rickover, DOE Division of Naval Reactors to Robert Ferguson, DOE Office of Nuclear Energy Programs, Subject: Assistance Provided by DOE Division of Naval Reactors, Pittsburgh Naval Reactors Office, Schenectady Naval Reactors Office, Bettis Atomic Power Laboratory and the Knolls Atomic Power Laboratory, dated May 24, 1979.
2. Memorandum from Joseph A. Lenhard, DOE Oak Ridge Operations Office, to Robert Ferguson, DOE Office of Nuclear Energy Programs, Subject: Assistance provided by Oak Ridge Operations and Oak Ridge National Laboratory, dated 5/25/79.
3. Memoranda from N. Stetson, DOE Savannah River Operations, to Robert Ferguson, DOE Office of Nuclear Energy Programs, Subject: Assistance provided by Savannah River Laboratory and Savannah River Plant of E. I. duPont de Nemours and Company, dated 5/25/79 and 4/25/79.
4. Memorandum from Charles E. Williams, DOE Idaho Operations Office, to Robert Ferguson, DOE Office of Nuclear Energy Programs, Subject: Information Requested by the President's Commission on Three Mile Island, dated 5/29/79.
5. Memorandum from Gil E. Cordova, DOE Albuquerque Operations, Sandia Area Office, to Robert Ferguson, DOE Office of Nuclear Energy Programs, Subject: Three Mile Island Accident, dated 5/22/79.
6. Memorandum from Robert H. Bauer, DOE Chicago Operations, to Robert Ferguson, DOE Office of Nuclear Energy Programs, Subject: Information Requested by the President's Commission on Three Mile Island, dated 6/6/79.
7. Memorandum from F. R. Standerfer, DOE Richland Operations Office, to R. L. Ferguson, DOE Office of Nuclear Energy Programs, Subject: Information Requested by the President's Commission on Three Mile Island, dated 5/25/79.
8. List of titles of TMI-related activities at Los Alamos Scientific Laboratory (LASL) and Sandia supplied by DOE Albuquerque Operations Office.
9. Memorandum for the President from Jack Watson, Subject: "Federal Contingency Plans, Three Mile Nuclear Facility," dated March 30, 1979.
10. Note to Mr. Schivinghamer from W. A. Riehl, Subject: "Technical Support to Three Mile Island Nuclear Power Plant Incident," dated April 5, 1979.
11. Letter to E. K. Cornell from James P. Wade, Jr., Assistant to the Secretary of Defense (Atomic Energy), October 10, 1979.

10. SUMMARY OF FINDINGS AND RECOMMENDATIONS

A summary of our findings and recommendations regarding the response of Federal (except the NRC) and State agencies to the TMI accident is provided below. These findings identify a number of specific inadequacies regarding the emergency planning and response of the various agencies. The reader is cautioned to refer to the preceding sections for detailed findings regarding inadequacies of response and for detailed recommendations of corrective actions. A reasonable understanding of the importance and scope of many of the general findings summarized below cannot be fully achieved without familiarity with the supporting detail.

a. Root Cause

Finding

The principal finding is that the root cause of most of the inadequacies in governmental emergency response, and a contributory cause of all of the inadequacies was the NRC's failure to promote an awareness that nuclear powerplant accidents with substantial offsite consequences are possible and must be planned for. The NRC did not sufficiently emphasize emergency planning, nor did the NRC require an adequate State emergency plan as a condition for operation of a reactor. On Friday, March 30, the NRC recommended that evacuation be planned for areas within 10 and 20 miles of the plant; before March 28 they suggested State and local planning only for evacuation of the applicable low population zone, a distance of only 2 miles for the TMI reactors.

We believe that the NRC's use of the word credible in describing the classes of accidents used in the design basis (and its implication thereby that other accidents are "incredible") contributed significantly to the general attitude that serious emergency planning was not important. The attitude has been reinforced in two ways:

1. The NRC has judged the so-called Class 9 accidents (accidents with consequences greater than the design basis accidents) to have a likelihood of occurrence so low that no specific consideration of these accidents is required in the design review process. If the NRC did consider these Class 9 accidents in planning emergency response, it would probably be criticized for planning for them while neither requiring reactors to be designed to preclude their occurrence nor requiring reactors to be sited in such a manner as to reduce offsite consequences should such an unlikely accident happen. The result is that, while the NRC clearly acknowledges the remote possibility of Class 9 accidents, it so effectively downplays such accidents that no emergency response planning for them takes place.
2. The NRC evaluates credible accidents in a conservative manner. The analysis is based on almost "worst case" assumptions of plant failure, release of radioactive materials, and possible exposure to persons off site. Because of this conservative analysis, the NRC's attitude has become one of not really believing that even the so-called "credible" accident will have much likelihood of occurring, or at least not with offsite consequences as great as calculated. This tends to downgrade the importance that the NRC (and through the NRC, the State and the public) places on emergency planning, even for low population zones.

Recommendation

The NRC must adopt a policy that requires reasonable offsite emergency planning, and such planning must consider emergency response to low probability accidents having offsite consequences greater than those analyzed as credible in the design review. This policy is an important aspect of the NRC's defense-in-depth concept, which deserves strong reemphasis.

b. Siting

Finding

Characteristics of an area, such as population density, road networks, and the existence of nearby prisons or large hospitals can substantially influence the effectiveness of evacuation.

Recommendation

The NRC must establish the areas for which evacuation planning is required and the maximum times within which evacuation of the areas must be conducted. To the extent possible, these criteria should establish siting limits based on demographic and other characteristics that substantially influence the effectiveness of evacuation. However, such criteria must have a reasonable basis. Unnecessarily restrictive criteria could result in a substantial loss in siting options for a nuclear powerplant without a commensurate improvement in the effectiveness of emergency response. A substantial loss in siting options would unreasonably limit consideration of other important safety and environmental siting characteristics such as water availability and use, land use, seismicity, flooding, ecological impacts, community impacts, and aesthetics.

c. Overall Institutional Coordination

Finding

Federal and State officials generally understood and implemented their respective legal authorities and responsibilities; for example, DOE's initial radiological response was in accordance with its prior agreements with the NRC and the Commonwealth of Pennsylvania. However, the Federal response effort beginning on Friday was not coordinated, principally because neither FRPPNE nor IRAP provides an adequate response plan. Although FRPPNE provides a lengthy treatise on Federal authorities and responsibilities, and IRAP provides a resource inventory and a reasonable basis for interagency coordination of radiological monitoring and assessment functions, neither of them establishes a clear plan for overall effective Federal coordination and response. This resulted in some confusion on Friday and made it necessary for the White House to intervene and to take strong actions to assure Federal coordination. While this inadequate coordination had little effect on the TMI response, it is possible that under similar circumstances the response to a fast-moving accident would have been unnecessarily impaired.

At the State level, it is not clear how PEMA would have discharged its command function as required by State law had a prompt emergency evacuation been required. Emergency command and control duties and procedures had not been clearly established for PEMA, and the statutory command function appears to fly in the face of the established autonomy of the local and county jurisdictions. However, it is likely that PEMA would not have attempted to assert control but would have discharged its characteristic coordination role. Thus, a confrontation of command (with its accompanying confusion and possible loss of efficiency) would have been unlikely.

Recommendation

Clear and explicit Federal and State emergency response coordination and command roles must be established and understood by all parties. The basic institutional framework for emergency response provided in formal, understandable plans must contain the following:

1. The utility licensee must be fully responsible for the safe operation of the reactor and appropriate emergency response, and should make recommendations for protective action guides to offsite Federal and State authorities.
2. The NRC must be responsible for all regulatory activities concerning the safe operation of the plant, independent assessments of plant status and operations, and recommendations regarding protective actions that might be warranted to reduce radiological exposures. This latter responsibility is also shared to some extent by EPA and HEW and thus must be well coordinated.
3. FEMA must be responsible for ascertaining that adequate Federal, State, and local emergency plans exist and are properly maintained and tested, assuring that NRC concurrence is received on those portions of the plans that are unique to the hazards and emergency response actions peculiar to nuclear reactors. Further, FEMA should provide appropriate coordinated Federal response to State and local agencies following reactor accidents that have a potential for substantial offsite radiological consequences. However, regarding the adequacy of State and local emergency plans, FEMA must make optimal use of the work that the NRC has done and is presently doing in the areas of providing guidance and reviewing existing plans.
4. DOE is basically responsible for providing radiological monitoring support to the State. Under IRAP, other Federal agencies might share in these responsibilities, but such responsibilities as interagency coordination and the triggering mechanism for IRAP need to be better defined.
5. EPA should be responsible for long term radiological monitoring and assessments after an accident, and HEW should be responsible for assessing the health effects on persons in the area.
6. Local and county jurisdictions should retain basic responsibility for the immediate protection of the health and safety of their citizens.
7. State governments should retain responsibility for the overall health and safety of citizens and for providing effective and coordinated assistance to local and county jurisdictions in any emergency situation.

d. Overall Emergency Planning

Finding

Effective emergency response begins with adequate operational plans at the local level and requires the development of integrated, functional, and testable emergency plans at the county, State, and Federal levels. The plans should further be suitably meshed with the utility's emergency plan. At the time of the TMI accident:

1. No local plans existed, although local authorities appeared to be reasonably familiar with the resources available to them to implement protective actions.
2. County plans appeared to be reasonably adequate for a 5-mile evacuation, but no plans for evacuations out to 10 or 20 miles existed.
3. Because of the added complexities of larger populations, more extensive road networks, and the inclusion of hospitals and a prison in the 20-mile area around TMI, the development of an effective evacuation plan out to that distance required much more detail and much better coordination among the various local and county jurisdictions than was required for effective 5-mile plans. While it was subsequently determined that a 20-mile evacuation was not needed, the State continued 20-mile planning because spontaneous evacuation out to 20 miles was likely to occur in the wake of a 10-mile evacuation order.
4. The State emergency plan appeared adequate to support the rapid evacuation of a 5-mile area.
5. The DOE had an effective radiological response plan, which, however, lacked suitable criteria to trigger its response. The plan required a request from another agency, and, at TMI, this request was not timely.

Recommendation

Appropriate emergency plans, suitably meshed with the utility's plan, must be developed and routinely tested at all levels of government. These plans must include sufficient detail to facilitate a reasonably prompt and effective 10-mile evacuation. The utility should in some manner provide the funding appropriate for the development and testing of local emergency plans. While NRC rules should require the existence of a federally approved State plan prior to licensing, they should not require the existence of a federally approved local plan. The State plan, however, must require the preparation of local plans, and the utility, in addition to providing funding for local planning, must be required to conduct effective training sessions in local jurisdictions and must cooperate in comprehensive testing of the plans, though not to include actual evacuations.

e. Evacuation

Finding

We find that existing local plans likely would have been adequate to conduct a 5-mile evacuation in about 6 hours, and that the detailed planning during the weekend of March 30 to April 1 likely would have permitted a 10-mile controlled evacuation in about 10 hours. (A controlled evacuation is one in which emergency response resources, such as buses and traffic-control police, are assembled prior to the public notification to evacuate.) We also find that precautionary evacuation advisories for selected members of the population cannot be issued after a nuclear powerplant accident without anticipating that substantially greater numbers of people will evacuate. The recommendation that pregnant women and preschool-age children within 5 miles of TMI evacuate led to the voluntary evacuation of [illegible] times that number of people from a region extending out to 15 miles from the plant. Because of the low levels of radioactivity experienced and anticipated, and the large numbers of volunteer evacuations, we believe that the appropriateness of the selective evacuation of pregnant women and children is questionable. It is likely that the uncertainty of information regarding plant status played the major role in this decision. In spite of this, we found little to fault the Governor's decision, considering the events of March 30. Also, we commend the Governor for his insistence on establishing a meaningful verification process for recommendations concerning various protective actions.

Recommendation

Evacuation plans must be prepared based on the expectancy that the evacuation of selected persons will result in the voluntary evacuation of many more people than specified, and that many people living at least twice as far as specified from the reactor will also evacuate. The evacuation plans must establish channels through which recommendations should flow to the decisionmaker and must establish processes for the verification of substantial information and all recommendations.

Criteria for recommending evacuations and other protective actions must be clearly established and must take into consideration the role that will be played by the uncertainty of information regarding plant status.

The benefits and costs of all protective actions must be evaluated in the establishment of these criteria, and these benefits and costs must be clearly articulated to enhance public understanding as to the actual hazards of radiation and the purpose and appropriateness of various protective actions. Also, the results of other evacuations (such as at Mississauga) should be studied to identify the degree of planning useful for an effective evacuation and to identify those characteristics that greatly impair the effectiveness of evacuation, i.e., that might prohibit an effective evacuation or greatly increase the time required to conduct such an evacuation.

f. Other Protective Actions

Finding

During the TMI accident, protective actions other than evacuation were either taken or considered, though the actual and expected levels of radioactivity in the environment ranged from as little as .5% to 10% of published protective action guides or radiological discharge limits. Such actions included: (1) prohibiting the plant from discharging wastewater on Thursday afternoon and night, (2) closing meatpacking plants on Friday, (3) putting cows on stored feed and water, (4) recommending the distribution and use of potassium iodide, and (5) issuing a take-shelter advisory on Friday morning.

The advisability of such protective actions is constantly in the forefront of officials' thoughts and is assessed and reassessed in light of changing information. The first three actions listed above were not warranted by the facts of the accident at TMI; all five are subject to question as to their appropriateness. Unlike evacuation, the above actions should be seriously considered only if anticipated radiation levels or doses approach published radiation limits or protective action guides. This is so because such limits and guides are conservatively set, and these actions can be quickly and usefully implemented, even after a release in many cases. Uncertainty concerning the forecasts of radiological exposure should play a minor role in decisions to implement such protective actions, though uncertainty legitimately plays a major role in decisions to evacuate.

We find that some inadequacies in managing the protective actions listed above stemmed from confusion caused by inadequate information and by attempts to manage the response from Washington. Also, potassium iodide for use as a thyroid blocking agent was not readily available in the United States, in large part because the NRC had not promulgated requirements for stockpiling it.

Recommendation

The NRC, in cooperation with HEW and the EPA, must establish mutually agreeable, uniform protective action guides. It must clearly define the purpose of these guides and must prescribe criteria for their application in decisions regarding various protective actions. Such criteria must set forth the costs and benefits of each protective action so that a decisionmaker has full knowledge of all aspects of protective actions and their alternatives before he makes a decision. Promulgation of such guides would also help stem the NRC's demonstrated inclination to manage the emergency response decisions from Washington.

The NRC must also develop criteria for the storage and distribution of potassium iodide so that it can be reasonably available to the public if needed.

g. Radiological Monitoring Efforts

Finding

The radiological response to the releases experienced during the TMI accident was more than adequate and would have been adequate for much larger releases. However, there was some unnecessary delay on Wednesday in requesting DOE aid when the high radiation levels measured in the containment building should have triggered such a request. In addition, there was some confusion about the responsibility for coordinating radiological data and assessments on Friday. And, there were too few personnel monitoring devices of appropriate range, a situation which could have affected the emergency response actions of the State Police and the National Guard had radiological releases necessitated an evacuation.

Recommendation

A DOE Radiological Assistance Team must be automatically dispatched whenever there is a clearly abnormal radiological situation at a nuclear powerplant; formal procedures to this effect must be instituted.

DOE should be the lead agency with regard to the collection and assessment of radiological monitoring data in any multiagency emergency response. Also, appropriate radiation monitoring equipment must be readily available to every nuclear plant, and arrangements must be made for training of emergency personnel in its use.

h. Physical Communications

Finding

Commercial telephone systems are not satisfactory for communicating detailed technical information during an emergency. In times of a serious emergency it must be expected that the public response will quickly overload existing telephone exchanges, effectively prohibiting use of the commercial system even for nontechnical emergency instructions and information. A system of dedicated telephone lines must therefore be in place before an accident occurs.

Recommendation

FEMA must carefully evaluate communications linking all participants in emergency response systems to assure that the systems are adequate for emergency communications. Such an evaluation should consider the availability of backup systems as appropriate, communications from alternate command posts, and the use of automated data transmission.

i. The Act of Communicating

Finding

A major contributor to concerns and fears of officials and the public was the absence of adequate, accurate, and confirmatory information. To some extent this failure of information is unavoidable, but the failure at TMI could have been mitigated by a better choice of information to be communicated, the use of better informed and more knowledgeable communicators, and by increased attention to the overall problem of effective human communications about a complex subject in the face of an emergency.

Recommendation

All organizations involved in emergency response must assess their information needs to assure the effective and timely communication of all necessary information during an emergency. This assessment must not only include evaluation of the information needs of each organization and the manner in which the information will be communicated to them, but it must also include a policy regarding the flow of information to the media and in response to public inquiry.

j. Comparison with the Conclusions of the President's Commission

We are in general agreement with the findings and recommendations of the President's Commission in the areas discussed in this section. We find, however, that for some of the topics, the findings of the Kemeny Commission are incomplete and are, therefore, susceptible to misinterpretation. Some examples which illustrate this observation are given below.

1. On page 16 of the Kemeny Report the text implies that there could have been an extremely dangerous situation at TMI because of the lack of local emergency plans. We have found that, in general, county and local jurisdictions understood the resources available to them well enough to have conducted a successful 5-mile evacuation even in the absence of detailed, formal plans. However, because of the added complexities of evacuating areas 10 or 20 miles around TMI, we believe the more formal plans would substantially have reduced the time required to conduct a controlled evacuation of the larger areas.
2. On page 37 of the Kemeny Report the Commission finds that the State public health officials and health care providers in the TMI area "did not have sufficient resources to respond to the potentially serious health consequences of the accident at TMI." We believe that this finding is literally correct, but should not serve as a basis for concluding that major new State capabilities are required. Because of the substantial personnel and equipment resources required to respond to a radiological emergency with potentially serious health consequences, we believe it inappropriate and uneconomical for State agencies to maintain sufficient resources to respond effectively to such unlikely accidents. Such resources must be made available to the States from appropriate Federal agencies, however, on a preplanned, expedited basis.

REFERENCES AND NOTES

[1]Details of the plant status chronology and operator actions are presented in Section II.A. of this report.

[2]The Emergency Plan for Three Mile Island defines three different action levels for emergencies.

a. A Local Emergency exists upon the discovery of any condition(s) which could affect the safety of personnel or equipment and involves only areas within a unit.

b. A Unit Emergency (Site Emergency) exists on occurrence of a major accident which could potentially result in the release of radioactive material to the immediate environment.

c. A General Emergency is an incident which involves areas external to the station boundary.

[3]The Joint Nuclear Accident Coordinating Center, staffed jointly by the Department of Energy (DOE) and the Department of Defense (DoD), serves as the clearinghouse for information relating to response to emergencies involving radioactive materials under the jurisdiction of the DOE and DoD.

[4]The Office of Congressional Affairs, in the NRC, called the majority and minority staffs of the House Committee on Energy and Environment, and the Senate Subcommittee on Nuclear Regulation, as well as Senators Schweiker and Heinz and Representatives Walker and Ertel, all of Pennsylvania.

[5]Transcription, Press Conference, Lieutenant Governor William W. Scranton, 3rd, incident at Three Mile Island, March 28, 1979. Identification number 321-D79.

[6]Transcription, Press Conference, Lieutenant Governor William W. Scranton, 3rd, Incident at Three Mile Island, March 28, 1979, 4:30 p.m., Identification number 322-D.

[7]The Federal agencies participating in the Friday meeting were the Nuclear Regulatory Commission (NRC), the Defense Civil Preparedness Agency (DCPA), the Federal Disaster Assistance Administration (FDAA), the Federal Preparedness Agency (FPA), the Department of Energy (DOE), and the Department of Defense (DoD).

[8]PEMA had officially lifted the take-cover advisory at noon on Friday. It is unclear why this mix-up occurred.

[9]Memorandum from Jack Watson to multiple addressees, subject: "Coordination of Federal Response to Three Mile Island and Designation of Thomas C. Maloney as Lead Federal Official," The White House, April 19, 1979.

[10]On July 15, 1979, the Federal Emergency Management Agency (FEMA) assimilated the personnel and the responsibilities that had previously been assigned to the Defense Civil Preparedness Agency (DCPA), under the Department of Defense; the Federal Preparedness Agency (FPA), under the General Services Administration; and the Federal Disaster Assistance Administration (FDAA), under the Department of Housing and Urban Development.

[11]Reorganization Plan No. 3 of 1978, approved by Congress on September 16, 1978, established the Federal Emergency Management Agency. In July 1979, the Defense Civil Preparedness Agency, the Federal Disaster Assistance Administration, and the Federal Preparedness Agency were placed under FEMA by Executive Order 12148.

[12]Disaster Relief Act of 1974, Pub. L. No. 93-288, Sec. 102(b).

[13]*Id.*, Sec. 306(a).

[14]*Id.*, Sec. 402.

[15]*Id.*, Sec. 305(c).

[16]Federal Response Plan for Peacetime Nuclear Emergencies (Interim Guidance) Annex II, "An Analysis of Legal Authorities in Support of the Federal Response Plan for Peacetime Nuclear Emergencies," dated April 1977, at 8.

[17]Federal Response Plan for Peacetime Nuclear Emergencies (Interim Guidance) at 4, dated April 1977.

[18]Adamcik Interview Transcript at 8-9.

[19]Pres. Com. Hearing (Aug. 21, 1979) at 13-14.

[20]Memorandum from Jack Watson, White House Staff, to J. Califano, HEW; J. Schlesinger, DOE; D. Costle, EPA; "Long Term Environmental Radiation Monitoring at Three Mile Island," April 13, 1979.

[21]Commonwealth of Pennsylvania Disaster Operations Plan, Annex E, "Nuclear Incidents (Fixed Facility)," dated July 12, 1977, at 1.

[22]Cover letter by M. J. Shapp, Governor, for the Commonwealth of Pennsylvania Disaster Operations Plan, dated July 12, 1977.

[23]*Penn. Consol. Stat.*, Tit. 35 (1978).

[24]*Id.*, Chap. 73, Sec. 7301(a).

[25]Section 7301(d) of the Pennsylvania Consolidated Statutes Title 35 (1978) provides that: "Activation of disaster response. - An executive order or proclamation of a state of disaster emergency shall activate the disaster response and recovery aspects of the Commonwealth and local disaster emergency plans applicable to the political subdivision or area in question and shall be authority for the deployment and use of any forces to which the plan or plans apply and for use or distribution of any supplies, equipment and materials and facilities assembled, stockpiled or arranged to be made available pursuant to this part or any other provision of law relating to disaster emergencies."

[26]*Penn. Consol. Stat.*, Tit. 35, Chap. 73, Sec. 7313(7) (1978).

[27]*Penn. Consol. Stat.*, Tit. 35, Chap. 75, Sec. 7501(b) (1978).

[28]Henderson dep. at 18-19.

[29]*Id.* at 20.

[30]Protective action guides are discussed in Sections III.C.4 and 6.

[31]Pres. Com. Hearing (August 21, 1979) at 64.

[32]Letter from T. M. Gerusky, Director of Bureau of Radiation Protection, to D. T. Lunden, PC Staff Director, Subject: Activities During Three Mile Island Accident, dated June 18, 1979.

[33]Pennsylvania Emergency Management Agency Log, Message 29, time 0752, dated March 28, 1979.

[34]Pennsylvania Emergency Management Agency Log, Message 44, time 0818, dated March 28, 1979.

[35]Letter from T. M. Gerusky, Director of Bureau of Radiation Protection, to B. T. Lunden, PC Staff Director, Subject: Activities During Three Mile Island Accident, dated June 18, 1979.

[36]Transcript of IRC Tape, Number 02-212-CH6-CLB4 through 6, dated March 29, 1979.

[37]Pres. Com. Hearing (August 2, 1979) at 136.

[38]*Id.* at 140-141.

[39]*Id.* at 137-140.

[40]Robbins dep. at 36-37 (Pres. Com).

[41]Pres. Com. Hearing (August 2, 1979) at 139-140.

[42]Id. at 143-145.

[43]Floyd dep. at 226 (Pres. Com).

[44]Kuehn dep. at 20.

[45]Pennsylvania Emergency Management Agency Log Message 14, time 0840, dated March 30, 1979.

[46]Pres. Com. Hearing (August 2, 1979) at 94.

[47]Lamison dep. at 40.

[48]Pres. Com. Hearing (August 2, 1979) at 41-42.

[49]*Id.* at 96.

[50]*Id.* at 10.

[51]*Id.* at 44.

[52]Molloy dep. at 46.

[53]NRC Commission Meeting Transcripts (March 30, 1979) at 73-78.

[54]Memorandum of Telephone Conversation with Martha Lester, WHP, from F. Herr, NRC/SIG Task Group 6, to M. Ernst, Task Group Leader, "Governor's Stay Indoors Advisory," November 8, 1979.

[55]Report of the Office of Chief Counsel on Emergency Response to the President's Commission on the Accident at Three Mile Island, dated October 31, 1979, at 55.

[56]Transcript of Governor's Press Conference dated March 30, 1979, time 12:30 p.m., at 4.

[57]Transcript of Governor's Press Conference, dated March 30, 1979, time 10:00 p.m., at 1.

[58]Pennsylvania Emergency Management Agency Log, Message 42, time 1240, dated March 30, 1979.

[59]Transcript of Governor's Press Conference, dated March 30, 1979, time 12:30 p.m., at 1.

[60]Hearing Before the Subcommittee on Nuclear Regulation of the Committee on Environmental and Public Works, 96th Congress, 1st Sess. 240 (April 23, 1979).

[61]Transcript of Governor's Press Conference, dated March 30, 1979, time 12:30 p.m., at 1.

[62]Office of the Governor Chronology, dated March 30, 1979.

[63]NRC Commission Meeting Transcripts (March 30, 1979) at 122-129.

[64]Transcript of Governor's Press Conference, dated March 30, 1979, time 12:30 p.m., at 1.

[65]Transcript of White House Press Secretary's Press Conference, dated March 30, 1979, time 5:00 p.m.

[66]Transcript of Governor's Press Conference, dated March 30, 1979, time 10:00 p.m., at 1.

[67]Transcript of NRC Chairman's Press Conference, dated March 31, 1979, time 2:45 p.m., at 14-15.

[68]NRC Commission Meeting Transcripts (March 31, 1979) Section 3, at 8.

[69]AP Press Release, time 8:25 p.m., dated March 31, 1979.

[70]Transcript of Governor's Press Conference, dated March 31, 1979, time 11:00 p.m., at 1.

[71]Molloy dep. at 55.

[72]Molloy dep. at 16 (Pres. Com.).

[73]Report of the Office of Chief Counsel on Emergency Response to the President's Commission on the Accident at Three Mile Island, dated October 31, 1979, at 126.

[74]U.S. Nuclear Regulatory Commission, "Population Dose and Health Impact of the Accident at Three Mile Island Nuclear Station," NUREG-0558, May 1979.

[75]Three Mile Island Telephone Survey, NUREG/CR-1093, October 1979.

[76]York County Log of Events Pertaining to Three Mile Island, dated March 30, 1979, at 1.

[77]W. D. Lentz, American Red Cross, "Mass Care Report D.R.-014," April 10, 1979, at 1.

[78]*Id.*at 1

[79]Pennsylvania Emergency Management Agency Log, Message 14, time 0520, dated March 31, 1979.

[80]Leslie Jackson, York County Emergency Preparedness Office, Supplement to SIG interview.

[81]Prewitt Interview Memo at 5.

[82]Governor's Press Release, dated April 9, 1979, at 1.

[83]Pennsylvania Emergency Management Agency Log, Message 639, time 1035, dated April 7, 1979.

[84]Transcript of Governor's Press Conference, dated April 9, 1979, time 3:00 p.m., at 2.

[85]Pres. Com. Hearing (August 21, 1979) at 64.

[86]Commonwealth of Pennsylvania Disaster Operations Plan, Annex E, "Nuclear Incidents (Fixed Facility)," dated July 12, 1977.

[87]NRC Office of State Programs Meeting with Pennsylvania State Officials on July 11, 1979, Transcript (Harrisburg, Pa.), at 39-40, dated July 27, 1979.

[88]Memorandum from W. H. Wilcox, FDAA, to J. Watson, Assistant to the President, "Report No. 4, Three Mile Island Incident," at 2-3, April 2, 1979.

[89]Memorandum from W. H. Wilcox, FDAA, to J. Watson, Assistant to the President, "Report No. 5, Three Mile Island Incident," at 3, April 3, 1979.

[90]Pres. Com. Hearing (August 2, 1979) at 30.

[91]Henderson dep. at 52.

[92]Williamson dep. at 16, 19.

[93]Blosser Interview Memo at 3.

[94]Henderson dep. at 48-49.

[95]*Id.* at 50.

[96]Jackson Interview Memo at 4.

[97]Crowe dep. at 11-14.

[98]Wilburn dep. at 17.

[99]*Id.* at 14-17.

[100]Jackson Interview Memo at 4.

[101]John McConnell Interview Memo at 4.

[102]Henderson dep. at 81.

[103]There are other drugs that can be effectively used as blocking agents. Problems with these other drugs such as toxicity, expense, or too little experience with the drug led the NCRP to conclude that potassium iodide was the best drug to use.

[104]National Council on Radiation Protection Measurements, "Protection of the Thyroid Gland in the Event of Releases of Radioiodine," NCRP Report No. 55 at 26, paragraph 4.5.7, dated August 1, 1977.

[105]The National Council on Radiation Protection and Measurements is a nonprofit corporation chartered by the Congress in 1964 to collect, analyze, develop, and disseminate information and recommendations about radiation protection. The Council is made up of 56 scientific committees composed of experts having detailed knowledge and competence in the particular area of the committee's interest.

[106]National Council on Radiation Protection and Measurements, "Protection of the Thyroid Gland in the Event of Releases of Radioiodine," NCRP Report No. 55, at 32, dated August 1, 1977.

[107]*Id.* at 33.

[108]Department of Health, Education and Welfare, Food and Drug Administration, "Potassium Iodide as a Thyroid Blocking Agent During a Radiation Emergency," Federal Register, Vol. 43, No. 242, dated December 15, 1978.

[109]National Council on Radiation Protection and Measurements, "Protection of the Thyroid Gland in the Event of Releases of Radioiodine," NCRP Report No. 55 at 23, dated August 1, 1977.

[110]Each 1-ounce bottle contained enough potassium iodide for 45 people for 10 days.

[111]G. K. MacLeod, M.D., FACP, Secretary of Health, Commonwealth of Pennsylvania, "The Decision to Withhold Distribution of Potassium Iodide During the Three Mile Island Event: Internal Working Document," at 5, undated.

[112]*Id.* at 6.

[113]*Id.* at 16-19.

[114]*Id.* at 9, 18.

[115]Memorandum from J. A. Califano, Jr. to J. Watson, "Recommendations of the Surgeon General with Respect to Thyroid Blocking," at 2, dated April 3, 1979.

[116]G. K. MacLeod, M.D., FACP, Secretary of Health, Commonwealth of Pennsylvania, "The Decision to Withhold Distribution of Potassium Iodide During the Three Mile Island Event: Internal Working Document," at 21, undated.

[117]*Id.* at 21-22.

[118]The potassium iodide was returned to the FDA in July 1979 and is now being stored by the Department of Health, Education and Welfare at the National Center for Toxicological Research in Jefferson, Ark.

[119]Department of Environmental Resources, Bureau of Radiological Health, "Plan for Nuclear Power Generating Station Incidents," September 1977.

[120]A picocurie is a very small unit (one trillionth of a curie) used to express the radioactivity of a material.

[121]The protective action options available as preventive measures to decisionmakers include removing cows from pastures and feeding them on stored feeds. If significant levels of radioiodine have already been found in milk, two options are available; the choice is made depending on the level of contamination. At low levels the milk can be diverted from use as fresh fluid milk to use as processed milk products, such as powdered milk and cheese, which can be stored until the radioactivity decays to acceptable levels. At higher levels, the milk would be condemned and subsequently destroyed.

[122]The process for detecting radioactive iodine in milk involves placing the sample under a counting device; the length of time the sample is counted is a major determinant of the level of radioactive iodine detectable. Detection and measurement of low levels of radioactivity in milk can also be accomplished by removing the water from the milk in order to concentrate the radioactive portions. The minimum detectable levels established by various political jurisdictions during the TMI event were generally in the 20- to 30-pCi/l range because it was believed the benefits to be derived from establishing lower detection levels did not justify the costs involved in longer counting times or processing.

[123]The Pennsylvania Department of Agriculture had located alternate feed supplies in the event farms ran out of feed or feed supplies in the TMI area became contaminated.

[124]The Maryland Department of Health and Hygiene processed several samples of milk and counted them for 1,000 minutes, lowering the minimum detectable level to .3 pCi/l. No radioiodine was detected in these samples.

[125]Transcript of Press Statement by the Secretary of the Department of Environmental Resources (the Governor's Press Office, 318R) dated March 29, 1979.

[126]DOE's RAP teams are experienced and equipped to respond to requests for radiological assistance. For the period of July 1958 through December 1978, DOE (and before the DOE, the AEC) sent out RAP team members on 683 occasions. On 259 of these, a single individual was sent and, on 424, a team responded. Teams are composed of health physicists and technicians from DOE contractor facilities and may be accompanied by a DOE employee. Figure III-15 shows DOE's radiological assistance experience for 1958-1978.

[127]For example, about 2 weeks after the accident, the White House charged the EPA with full responsibility for long term radiological monitoring.

[128]Brookhaven Area Office Communications Log, Appendix B, "DOE Region I Radiological Assistance Program (RAP) Response to the Incident at Three Mile Island: March 28-April 18, 1979," at 2.

[129]Eidenberg dep. at 147-153.

[130]Three Mile Island Station, Radiological Emergency Procedure 1670.2, Figure 4, Revision 9, November 22, 1978.

[131]J. L. Tew, "Technical Staff Analysis Report to President's Commission on the Accident at Three Mile Island on the Catalog of Events," at 31 and 46, October 1979.

[132]York County Log of Events Pertaining to Three Mile Island, dated March 28, 1979, at 1.

[133]NRC's Office of State Programs Meeting with Pennsylvania State Officials on July 11, 1979, Transcript (Harrisburg, Pa.), at 10.

[134]*Id.* at 19.

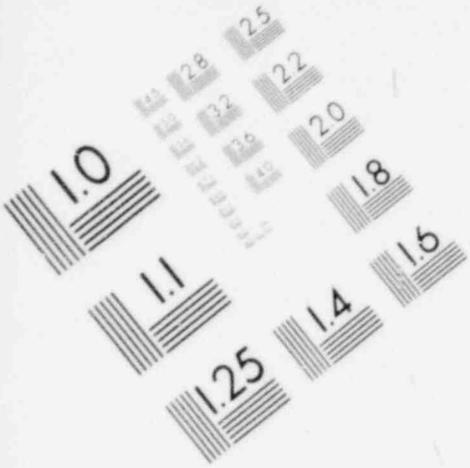
[135]Deddens dep. at 37, 41.

[136]Baunack dep. at 22.

[137]Letter from D. J. Culkin, AT&T, to Dr. Larry F. Darby, FCC, Subject: Report on Telephone Industry's Response to the TMI Accident, at 3, dated April 27, 1979.

[138]Pennsylvania Emergency Management Agency Action Log, Message 21, time 0922, dated March 28, 1979.

[139]Watson dep. at 13 (Pres. Com.).



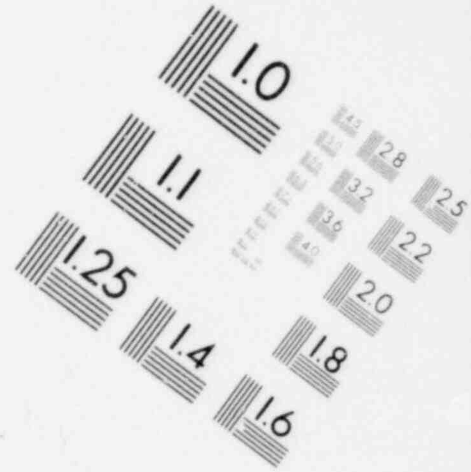
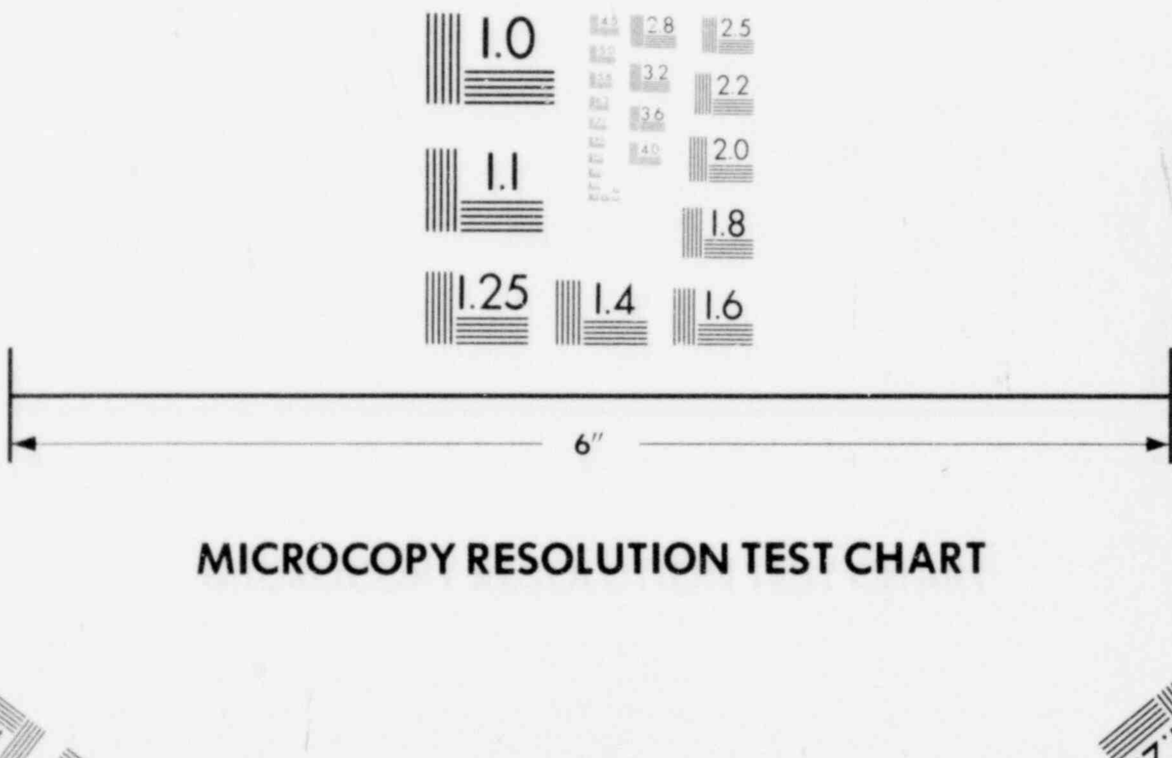
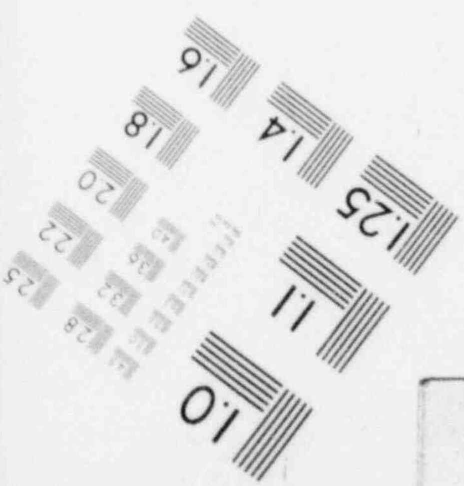
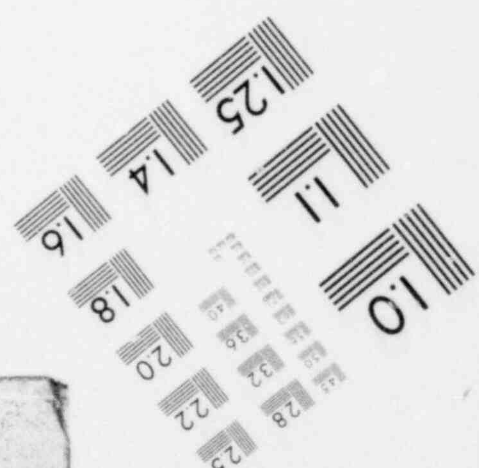


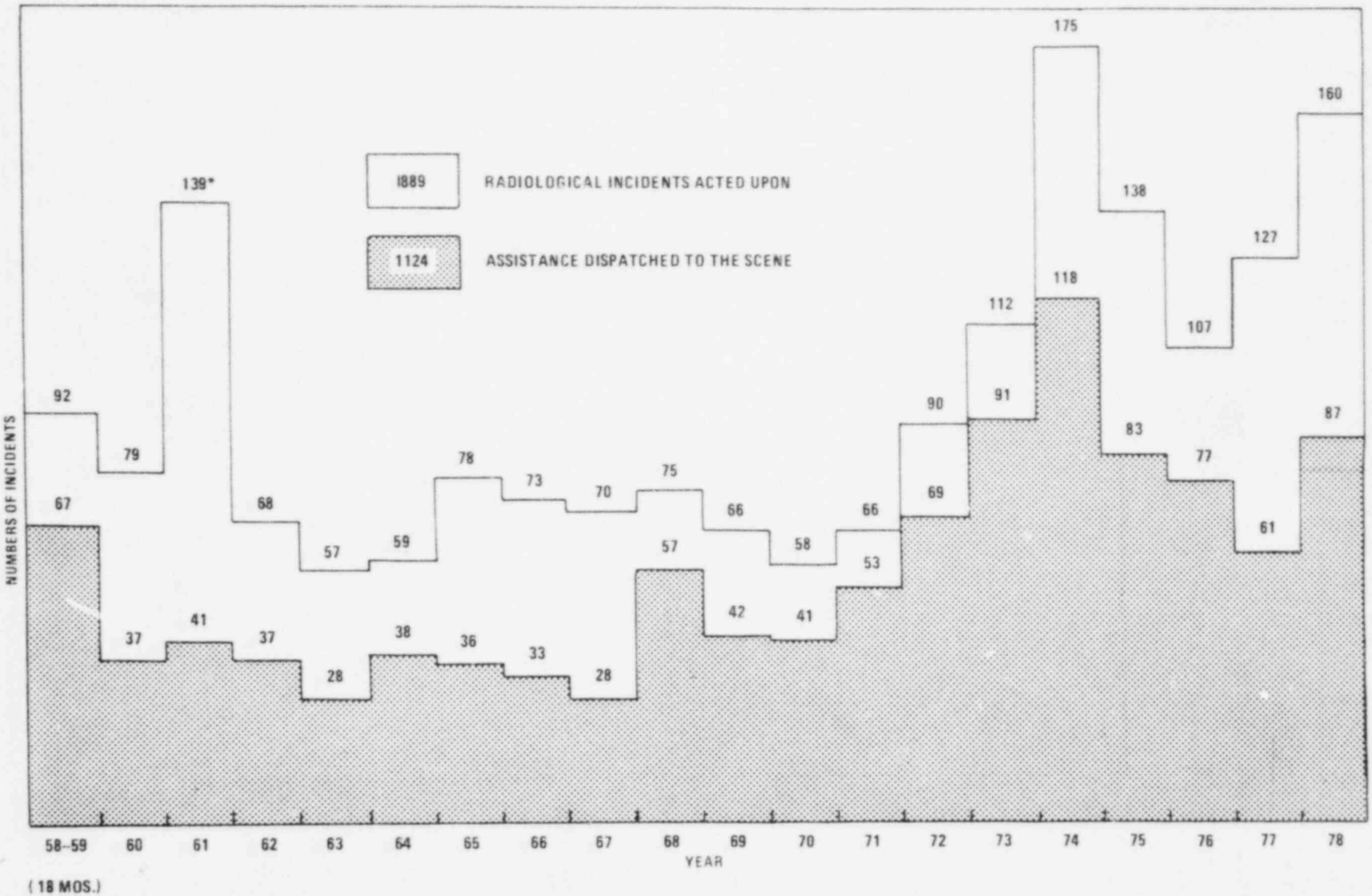
IMAGE EVALUATION TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART







* INCLUDES REQUEST FOR INFORMATION ON RADIATION HAZARDS REPORTED AS ASSISTANCE REQUESTS.

FIGURE III-15. DOE Radiological Assistance Incident Experience, July 1958-December 1978

[140]"Report of the Public's Right to Information Task Force to the President's Commission on the Accident at Three Mile Island," dated October 31, 1979.

[141]Memorandum from L. P. Crocker, NRC, to M. L. Ernst, "White House Communications Agency," November 19, 1979.

[142]Deal Interview Memo at 2 and 4.

[143]Kuehn dep. at 4-5.

[144]Henderson dep. at 43.

[145]Adamcik Interview Memo at 5.

[146]Deal Interview Memo at 2, 3.

[147]Molloy dep. at 38-39.

[148]Jackson Interview Memo at 2.

[149]Memorandum from Robert Adamcik, FDAA, to W. Wilcox, "Three Mile Island Incident," at 1, April 7, 1979.

[150]Kuehn dep. at 12, 13.

[151]John McConnell Interview Memo at 8.

D INFORMATION PROVIDED TO THE NEWS MEDIA AT THREE MILE ISLAND

1. INTRODUCTION

This section addresses and evaluates State, NRC, and Met Ed interactions with the news media during the TMI accident and presents a chronological narrative of the first 6 days following the accident. It discusses the views of national wire service and television network representatives, as well as the feelings of Met Ed officials on why the utility lost its credibility with the news media. Additionally, it presents commentary from the news media on factors which affected the performance and credibility of the NRC in its dealings with the news media.

It will then examine the impact of the many sources of information that existed during the first 4 days of the accident and, finally, presents our findings on how well these organizations informed the public during the course of the accident and our recommendations for improving the flow of information to the public in the event of another accident.

Press conferences and public announcements were the principal vehicles of public information. Met Ed and the State depended on one or two daily press conferences, while the NRC depended solely on public announcements for the first 2 days. Both Met Ed and the NRC appointed public affairs offices to handle phone inquiries, and both organizations later discontinued these operations and established news centers near the site.

Key State individuals involved in media relations included Lt. Governor William Scranton, who acted as spokesman, until this position was taken over by Governor Richard Thornburgh when he held his first press conference on Thursday, March 29. The Governor was assisted by Press Secretary Paul Critchlow.

The key NRC individuals involved in the NRC's relations with the news media include: Harold Denton, who became the NRC's principal spokesman after he arrived at the site on Friday, March 30; Joseph Fouchard, the NRC's chief public affairs officer, who served as Denton's liaison with the news media; Karl Abraham, regional assistant to Fouchard, who was initially the NRC's media contact in Harrisburg and who later assisted Fouchard in Middletown; Frank Ingram, assistant to Fouchard, who served as liaison with the news media at the NRC Headquarters; Chairman Joseph Hendrie, who held a news conference at the NRC Headquarters on Saturday, March 31; and Dudley Thompson, who participated in a news conference held at the NRC Headquarters on Friday, March 30.

There were a number of key Met Ed individuals who met with the news media: Jack Herbein, Met Ed Vice President for Generation, became the principal spokesman for the company; Walter Creitz, Met Ed President, appeared on two nationwide television programs on Thursday morning and later made the decision to discontinue Met Ed's standup news briefings; Blaine Fabian, Met Ed Manager of Communications Services, was in charge of the Reading operation and later the Hershey News Center; and George Troffer, Met Ed Manager of Quality Assurance, acted as the principal technical adviser to the utility's Reading Communications Department and later to the news center staff.

Herbein relied on two plant officials, George Kunder, Superintendent of Technical Support of TMI-2, and Gary Miller, Station Manager, to provide up-to-date information on the status of the plant. Kunder, who was the officer on call Wednesday morning, arrived at the plant at about 4:45 a.m. to observe plant recovery from a transient induced shutdown. He found the plant in an unusual condition. The primary coolant system appeared to contain too much water, yet system pressure was low. Kunder had been taught that a full primary coolant system was always associated with a high pressure condition.

Miller, who was preparing to go to a meeting in New Jersey, had been notified of the reactor trip shortly after 4:00 a.m. and was advised that no conditions out of the ordinary existed. At about 5:15 a.m., Miller placed a call to Kunder, and Kunder explained the unusual plant conditions. Miller then directed additional personnel to the plant to assist. He next set up a conference call to discuss the morning's events with Kunder, Herbein (who was in Philadelphia for naval reserve training), and Lee Rogers, Babcock & Wilcox's onsite technical representative. The information conveyed to Herbein in this conversation would provide the information base for Met Ed's first public statement.

2. CHRONOLOGY

Wednesday, March 28

Met Ed's Jack Herbein first learned of the trip at TMI-2 during the conference call discussed above. Herbein, under the impression that the plant situation was stable, placed a call to Blaine Fabian in Reading, Pa., at approximately 7:15 a.m. The purpose of his call was to prepare Fabian for handling inquiries from the press and from the general public concerning the reactor trip. Fabian drafted a short public statement which advised simply that the reactor had tripped because of a feedwater malfunction and would be out of service for about a week. According to Fabian, the statement was kept brief because information concerning plant status was still preliminary. The purpose of the statement was primarily to advise the public that, first, a problem existed and, second, that the utility was working to solve it. Shortly after the statement was drafted, Fabian was notified, probably by Herbein, that a general emergency had been declared. He did not include this information in the initial public statement, however, because the draft statement had already been agreed upon.[1]

Shortly after 8:00 a.m., Fabian met with members of his professional and clerical staff to discuss the morning's events. They had begun discussing the need to have background information on the TMI units available, for the purpose of answering media inquiries, when the telephones began ringing. Fabian released his three available professional communicators to respond to the calls and instructed his staff to respond to inquiries by reading the public statement and providing background information on the TMI plant.

Meanwhile, a reporter from a Waynesboro, Pa., newspaper was making a routine morning check with the State Police and learned there had been a problem at TMI and that a general emergency had been declared. This information was passed on to the Associated Press (AP) Philadelphia Bureau and then to the Harrisburg Bureau. A reporter from the Harrisburg Bureau attempted to confirm the information with Met Ed in Reading, but was unable to reach a spokesman. The reporter then called the Pennsylvania State Police, who confirmed the report but could not say what constituted a general emergency. At 9:02 a.m., AP put a national bulletin over the wires stating there had been an accident at TMI, that no radiation had been released, and that a general emergency had been declared; no details were as yet known, and a company spokesman was not available. This was the nation's first notification that there had been an accident at TMI.

Shortly after 8:30 a.m., Fabian went to Walter Creitz's office and assisted Creitz in answering calls from the media and from Government officials. It was during this period that Fabian learned that conflicting reports were circulating that radiation releases to the environment had been detected.

Fabian then requested George Troffer, who had been enlisted by Fabian to act as technical advisor to communication services, to determine whether there had been any such releases.

Troffer contacted Gary Miller at about 9:30 a.m., and was advised by Miller that there had been no known releases to the environment. Miller also told Troffer that reactor coolant had been released to the reactor building floor and that there might have been some fuel pin leakage, but that there was no indication of melted fuel. Miller also said a general emergency had been declared because plant instrumentation indicated high levels of radiation in the reactor containment building dome area, but that no releases were expected. Miller added that no one had been overexposed, but that in the actions necessary to reach cold shutdown someone might be. Finally, he noted that efforts were still being made to bring the plant under complete control.[2] Based on Troffer's conversation with Gary Miller, Fabian and Creitz drafted an updated statement by 10:00 a.m. This statement advised that the general emergency plan had been implemented because radioactive water had been released inside the containment building, but that monitoring had detected no external radiation releases and no such releases were expected. The 10:00 a.m. statement was provided to the communication services personnel, who would not confirm releases to the environment.

The small communication services staff was overwhelmed by the large number of incoming phone calls and was unable to return calls. As soon as one call was completed, another incoming call would have to be accepted. As an indication of the seriousness of the problem, the AP Harrisburg Bureau did not receive a call from Met Ed on Met Ed's initial 7:30 a.m. statement until shortly before 10:00 a.m. In order to cope with the high volume of incoming calls, communication services clerical and administrative personnel, as well as volunteers and individuals recruited throughout the company, began answering phone calls. Many of these individuals were unable to provide any other information than that contained in the public statement.

Although the NRC was notified of the accident by Met Ed at 7:45 a.m., it was not until after AP broke the story that reporters began flooding the NRC with calls. Some of these calls were directed to the NRC Regional Office in King of Prussia, Pa., which had inspection responsibility for the plant. Others were directed to various NRC Headquarters offices located in Washington, D.C., and Montgomery County, Md. Since reporters did not initially know who in the NRC to call for information concerning the accident, inquiries were made to several different offices. This hampered the NRC's ability to handle the incoming calls and to assure that information on the accident was consistent.

The NRC did not issue a public announcement concerning the accident until 10:30 a.m. This announcement stated that the NRC had received preliminary information that there had been a release of radioactivity inside the reactor containment building. It also stated that measurements to determine whether there had been an offsite release were being made, that some reactor coolant water had been released into the containment building, that the emergency core cooling system was being used to provide water to the reactor, and that the reactor had been shut down. Apparently, the announcement could have been released much earlier. It was delayed, however, while the NRC attempted to obtain additional details on the accident. It appears too that the release was delayed by the time-consuming process of obtaining staff and Commission concurrence on what should be said.

At 7:02 a.m. Met Ed notified the Pennsylvania Emergency Management Agency (PEMA) about the site emergency declaration and requested that PEMA notify the State Bureau of Radiation Protection (BRP). Upon learning of a general emergency declaration, PEMA notified Governor Thornburgh at 7:50 a.m. Lt. Governor Scranton was informed of the situation when he arrived at his office at 8:20 a.m.

Scranton called the TMI-2 control room shortly after 9:00 a.m., and was briefed on plant status by Gary Miller. Miller provided Scranton with essentially the same information, but in less detail, that Miller would discuss with Met Ed's George Troffer in their 9:30 a.m. conversation.

Based on this information, the Lt. Governor held a press conference at 10:55 a.m., and announced that the State had been informed of an incident at TMI-2, but that he had been advised that everything was under control and that there was no danger to public health and safety. He stated that Met Ed had been monitoring near the plant and that no increase in normal radiation levels had been detected. He also reported that PEMA had notified the counties in the vicinity of the plant, although there was no need for evacuation. Available to answer questions with the Lt. Governor were: William Dornsife, BRP; Oran Henderson, PEMA; Senator Jim Ross, a member of the Emergency Management Council; Bob Laughlin of the Governor's Science Advisory Committee; and Ray Holst, Energy Liaison Officer. Questions following the Lt. Governor's prepared remarks concerned the cause of the accident, its seriousness, whether any employees had been exposed, whether there were dangers due to offsite radiation, and why there had been a 3-hour delay from the initiation of the incident to notification of State agencies. Because of the limited information available about the accident, the Lt. Governor was forced continually to respond to reporters' questions by explaining that the State did not yet have any details regarding the incident. During the question and answer session, however, Dornsife reported that small amounts of radioiodine had been detected by the monitoring teams, information that had not been provided to the Lt. Governor prior to the briefing. This information later proved to be false and only added to the morning's confusion.

At 11:45 a.m. Troffer notified Creitz and Fabian that above background radiation levels had been detected at the observation center and at the site boundary. Based on this information, Fabian and Henry Robidoux, Vice President of Operations, drafted Met Ed's third public statement, a statement approved by Creitz. Far from acknowledging readings above background, Met Ed's statement read that "there had been no recordings of any significant levels of radiation and none were expected outside the plant." The statement also advised that no evacuation of the local population was needed at that time.[3]

Shortly before noon, Herbein arrived at the observation center where members of the news media, including television crews from the national networks, had been anxiously awaiting the appearance of a Met Ed spokesperson. Herbein and Creitz discussed what should be done with respect to the media. They agreed that Herbein would hold an impromptu news conference. Herbein also was instructed to go to the State Capital when he was finished talking to the press to brief the Lt. Governor. After he received an update on the status of TMI-2 from plant personnel, Herbein briefed a group of about 30 reporters outside on lawn at the observation center. Herbein briefly described the accident sequence, indicated that no one had been injured, and related that radiation measuring only 10% of the general emergency level was being monitored at the site boundary. He also described the conditions in the reactor building that led to the site emergency declaration and stated that there was possibly a small amount of damaged fuel. The briefing, which began at 1:15 p.m., lasted about 40 minutes.

Herbein did not mention during the briefing that steam had been vented to the atmosphere in an effort to cool down the plant but that just prior to the briefing he had ordered the venting stopped because he wasn't sure whether or not the steam was radioactive. Met Ed apparently did not tell State officials of the steam venting until after the fact, nor did Herbein volunteer this information until it was requested during his briefing of the Lt. Governor at 2:30 p.m. State officials, who believed the steam was the source of offsite radiation, were extremely upset, and believed that Met Ed was deliberately holding back information that the State needed to evaluate the accident's impact on public health and safety. This perception by the State was aired publicly during a 4:30 p.m. press conference held by Scranton. In attendance were Dornsife of BRP, Henderson of PEMA, and Gerusky of BRP.

The Lt. Governor's prepared remarks stated that the situation at TMI was more complex than the State had been led to believe originally, but that State officials believed there still was no danger to public health. The Lt. Governor stated that Met Ed had given misleading information to the State and to the public, but that he had just met with company officials and hoped that the press conference would clear up any questions. He stated that radiation had been released from about 11:00 a.m. until 1:30 p.m. while the plant was venting steam as part of the emergency cooling process. Apparently, he reported, a leak in the primary system had allowed radioactivity to get into the steam. (This was not correct; there had been no radioactivity in the steam, but since radiation was measured after steam venting had been started, a connection between the steam venting and the radioactivity release was presumed to exist.) Scranton stated that the State had not been aware of the release until near the time it was halted, but that Met Ed had promised to notify the State in the event further steam discharge was necessary. He stated that radiation levels were below any existing or proposed emergency action levels, but that the State was concerned because any increased exposure constitutes a danger to health. Scranton said that teams from the State Department of Environmental Resources (DER), the NRC, and the Department of Energy (DOE) were in the area conducting measurements, and that reports indicated that radiation levels had been decreasing throughout the afternoon.

During the question and answer session, State officials went on to say that Met Ed had advised them that the company had followed normal procedures in its initial notification of State officials concerning the accident, that a chest X-ray is equivalent to 20-100 milliroentgens, that radioactivity leakage had decreased since the steam venting had stopped, that there was no potential for high radioactivity releases to the environment, and that the plant could be shut down for a matter of weeks.

On Wednesday afternoon Creitz, at Fabian's urging, agreed to hold a press conference on Thursday morning. They also agreed that Herbein, despite his limited public relations experience, should be the principal spokesman because his technical background would enable him to respond in detail to questions posed by the media. The Hershey Convention Center was selected as the site for the press conference because of the availability of telephones for the press and the overall adequacy of the facility. Fabian had worked out the logistics for the press conference by 4:30 p.m. Fabian later stated that he advised Karl Abraham, the NRC Region I Public Information Officer, of the plan and then asked Abraham to participate. Abraham called Joe Fouchard, the NRC Public Relations Director, and was instructed not to take part in any news conference held by Met Ed because the NRC wanted to stay in the "investigative mode."[4] This was the first of three occasions on which the NRC rebuffed requests by Met Ed for joint press ventures. The NRC's position on this subject was a major contributor to the problem created by multiple sources of information, a problem discussed later in this report.

The number of phone calls from the media had reached the point that Met Ed communicators found it impossible to draft additional public statements. Staff answering phone inquiries were updated verbally by technical personnel who were in contact with the plant and the observation center. Information on plant status, however, was still sketchy.

The NRC was also experiencing problems with the huge influx of phone calls from reporters and others during the first several days of the accident. Inquiries were mostly answered by the NRC's senior public affairs personnel and by designated technical staff. Some calls, however, were answered by the NRC's senior management staff in the Incident Response Center, who had to stop other important work for this purpose. While most calls requested updated reports on the accident, some requested television and radio appearances by NRC staffers. A number of these requests were honored, but others were refused in an effort to limit the number of agency spokespersons.

Met Ed was also receiving requests for television appearances by company spokespersons. Late on Wednesday afternoon, Creitz and Fabian discussed with GPU management the feasibility of having Creitz appear on Thursday morning on the "Good Morning America" and "Today" shows. GPU management agreed that Creitz should appear. After the discussion, Fabian made arrangements for manning the telephones Wednesday night. Communicators were moved to a location with centralized phones and facilities for communicating directly with news media representatives if necessary. Three communicators were directed to call the news media to advise them of the news conference scheduled for 10:00 a.m. Thursday in Hershey. Arrangements were also made for an all-night operator, who was told to read the public statement to callers and advise them of the Thursday press conference.

The NRC issued a second public announcement at 5:00 p.m. It stated that low levels of radiation had been measured offsite, but that these levels of radiation were believed to be prinicipally attributable to direct radiation coming from the containment building rather than from the release of radioactive materials into the environment. The announcement stated that the sequence of events which led to the release of radioactivity into the containment building had not been determined. In retrospect, this announcement substantially understated the significance of the accident and was in error regarding the source of the radiation levels detected off site. It is apparent that the NRC officials were not at that time fully aware of plant conditions. Had the NRC officials known that core temperatures above 2000 degrees had been measured that morning and that a hydrogen burn had occurred in the reactor building that afternoon, their perception of the seriousness of the accident would have been substantially different.

Additionally, the offsite radiation levels were not the result of direct radiation from the reactor building. The source of these radiation levels was radioactive gas being emitted from the plant into the air of surrounding communities. The inadequacies of this press release can be attributed to the poor quality of information flowing from the site to the NRC Headquarters on the first day of the accident.

The small team of NRC inspectors on site at Three Mile Island Wednesday and Thursday was so busy collecting data and manning telephones that they could not communicate needed information to the outside. Also, telephone lines were so tied up that phone connections between inspectors and offsite NRC staff were frequently not possible for long periods of time. These problems resulted in considerable confusion and would later cause people to question the reliability of certain information given out by the NRC.

At 8:45 p.m. Charles Gallina and James Higgins of NRC Region I and Bob Friess of the DOE met with Lt. Governor Scranton and other State officials to discuss the plant status. At 10:00 p.m., following this meeting, the Lt. Governor held the State's third press conference. Gallina, Higgins, and Friess attended. Scranton announced that he had been advised that there currently was no radioactive leakage from the reactor containment; however, there was radioactivity in the auxiliary building, and there was some dispersion of this material into the atmosphere when the auxiliary building was vented. This information directly contradicted the NRC's 5:00 p.m. press release. Scranton further stated that there were some high, but not critical, levels of radioactivity on site, but that no critical levels of radioactivity had been detected off site. He then opened the floor for questioning of the NRC representatives.

Reporters were told that there was no permanent damage to the plant, there appeared to have been a primary system to secondary system leak, there was no indication of human error, there had been some damage to the fuel but it didn't appear to be severe, and that the reactor was stable.

Region I's Karl Abraham, who had earlier informed Joe Fouchard that he, Abraham, could be more effective at the site, listened to a radio broadcast of this press conference as he drove to Harrisburg. Finding the observation center virtually without phone communications, Abraham set up shop in Paul Critchlow's office there. Circumstances were to dictate that he was not to play an instrumental role in the NRC's interaction with the news media. He found himself virtually isolated from NRC activities at TMI-2, a situation illustrated by the fact that Abraham was not notified of the arrival of the NRC Headquarters team on site. Consequently, Abraham was unable to use the team as a source of information on Thursday, and on Friday he assumed the task of funn ing information from the NRC Headquarters to th Governor's office and, later, of handling the logistic for setting up the NRC press center. Thus, he was stripped of any responsibility for acting as a public spokesperson.

As the first day of the accident came to a close, Creitz arrived at the observation center to be briefed for his Thursday morning television appearances on "Good Morning America" and the "Today" shows. Creitz was briefed a second time prior to his appearances by George Kunder and Joseph Logan, the TMI-2 Superintendent. As midnight approached, Creitz held a short, general briefing for the reporters still on the observation center lawn, and after the briefing he left the observation center.

Thursday, March 29

The NRC issued its third public announcement shortly after midnight. It stated that reactor temperatures had continued to drop, but not far enough to activate the normal decay heat removal system. The statement further indicated that a radiation level of thousands of roentgens per hour existed inside the containment dome and that there had been a continuing release of radioactive gases to the atmosphere, releases said to have come from water that had been pumped over from the containment building to the floor of the auxiliary building. Radiation measurements were reported to be 1/3 milliroentgen per hour in the air over the Harrisburg area and 12 milliroentgens per hour at ground level at the Harrisburg airport. The announcement went on to say that these radiation levels were far below the level at which the Environmental Protection Agency (EPA) recommended protective action. Eight Met Ed workers were reported to have received radiation doses of up to 1 rem during the day's activities. The reference to EPA Protective Action Guides was somewhat confusing because the announcement implied that the guides are based on dose rates, i.e., milliroentgens per hour, when in fact they are based on accumulated radiation doses, i.e., total milliroentgens. To avoid confusing the public, the NRC's statement should have explained the significance of all reported information. This public announcement was the last the NRC would issue for 42 hours.

Although Met Ed management believed the plant was fully under control, the core was not cooling down as rapidly as expected. The reasons for the slow cooldown were the physical disarrangement of the core and the presence of steam and hydrogen gas in the reactor coolant system. This situation was not generally known by the plant staff. The staff was also unaware that radioactive gas was beginning to accumulate in the makeup tanks.

At 5:00 a.m. Creitz taped his appearance for "Good Morning America" at the WTPA studio in Harrisburg. ABC news correspondent Bettina Gregory was with Creitz in Harrisburg, and David Hartman, host of the show, and Daniel Ford, Executive Director of the Union of Concerned Scientists, were in ABC's New York studio participated in the taping. This segment of the show was aired at 7:15 a.m. During the broadcast, Creitz stated that radiation levels outside the plant were low, that no Met Ed employee or member of the public had been exposed to radiation levels considered dangerous, and that radiation releases had been substantially reduced. The plant was safely shut down, he said, and was under control; radiation levels in the containment building were high, but Met Ed would not be able to evaluate the seriousness of the problem without further study.

At 7:47 a.m. Creitz and Ford appeared with Tom Brokaw, NBC news correspondent, on the "Today" show, and Creitz reiterated essentially the same information he had discussed earlier on "Good Morning America."

At about the same time, Herbein appeared on CBS's "Thursday Morning," as previously agreed with Creitz and Fabian. CBS news correspondents Gary Shepherd and Bob Schieffer participated in the broadcast, which was conducted at WHP studios in Harrisburg and went on the air at 7:30 a.m. During the broadcast, Herbein advised that the plant was stable. Plans were to switch to decay heat removal later that day, at which point the plant would be in the cold shutdown condition. He said that trace amounts of radiation were still leaving the site boundary and there were high levels of radiation in the reactor building, although one monitor was believed to be giving an erroneous reading. There were 2 to 3 feet of water on the reactor building floor, action was being taken to reduce the trace amounts of radiation escaping from the water on the floor of the auxiliary building, and there had been some fuel failure. Safety systems functioned as designed, and it was hoped that releases to the environment would be over in about two days.

Met Ed held its first formal press conference in the Aztec Room of the Hershey Convention Center at 10:00 a.m. Thursday morning. The large turnout of media representatives, over 100, had not been anticipated by the utility and was described by Met Ed officials as overwhelming.

Creitz, after making a brief opening statement, turned the press conference over to Herbein for the substantive briefing. Herbein made a few optimistic comments on plant status and then opened the floor to questions. In keeping with a generally optimistic tone, he provided a relatively detailed sequence of the accident and stated that the utility hadn't ruled out the possibility of human error in the accident. Most of the paths leaking radiation from the auxiliary building, he said, would be closed off by the day's end. Perhaps .5% to 1% of the fuel rods had melted somewhat, and Met Ed was not certain of the period of time the core had been uncovered. The plant would be in a cold shutdown condition by late that night or by the next morning. Toward the end of the press conference, both Herbein and the reporters were somewhat irritable. Under intense questioning on the dangers of radiation, Herbein responded, "I can tell you that we didn't injure anybody in this accident, we didn't overexpose anybody and we certainly didn't kill a single soul ...."[5] Observers of the news conference felt that reporters were frustrated by Herbein's use of technical jargon that they were unable to understand and by his inability to provide complete answers to their questions. The press conference lasted about 90 minutes.

On Thursday afternoon Fabian discussed future media relations with Bill Murray, GPU Vice President of Communications, and Richard Hyde. Hyde, a Vice President of Hill and Knowlton, a large New York-based public relations firm, had volunteered his services to Met Ed. They decided to set up a news center in the Hershey Convention Center to handle day-to-day inquiries from the media and from the general public. They also agreed to hold future press conferences at the American Legion Hall in Middletown.

Earlier in the day, Lt. Governor Scranton had toured TMI-2. Based upon information gained by Scranton, Governor Thornburgh held a press conference at about 5:15 p.m. The Lt. Governor, Gerusky, Higgins, Gallina, and Henderson were in attendance. The Governor stated his belief that there was no cause for alarm, no danger to public health, and no reason to disrupt daily routines. He noted the conflicting information that had been received and stated that Lt. Governor Scranton had visited the plant to obtain a layman's impression of the situation. He stated that, though the situation appeared to be under control, it was important to remain alert and informed.

In response to reporters' questions, Higgins and Gallina, from the NRC, stated that the plant was approaching cold shutdown, radiation levels had been greatly reduced, a preliminary evaluation had shown no human error (contradicting an earlier report from the NRC Headquarters), and that the danger was over for people off site. This last remark later resulted in criticism of the NRC by State officials and the media.

Unknown to NRC participants at this press conference, the potential danger for people off site was far from over. By this time, plant personnel had realized that a noncondensible gas bubble in the reactor coolant system was impeding the flow of coolant to the core. This bubble would prove to be the source of much public confusion and alarm over the next 2 days.

About midnight, in a press release issued by Clifford Jones, DER Secretary, the discharge by Met Ed of industrial wastewater containing small concentrations of xenon into the Susquehanna River was announced. The press release stressed that the discharge did not add harmful radioactive pollution to the river. The discharge, the report stated, also ended a half-day effort on the part of the utility to dump the wastewater. It also ended a protracted dispute between the NRC and the State over who would take public responsibility for authorizing the discharge.

Friday, March 30

Although plant status did not change significantly from Thursday night, pressure resulting from noncondensible gases in the primary coolant system had built up in the makeup tanks. In an effort to relieve this pressure Met Ed's James Floyd ordered the gas transferred to another tank. Primarily because of leaks in the transfer system, however, this operation resulted in a continuous release of gas to the atmosphere, beginning about 7:30 a.m. A helicopter monitoring the release recorded a spike measurement of 1200 milliroentgens at about 8:00 a.m. This measurement was reported to the State, to the NRC, and eventually to the press, none of whom had been notified in advance of the venting operation. The news of this release dramatically altered the perceptions of the news media and the public concerning the seriousness of the accident.

The information about the release was misinterpreted by the NRC Headquarters, and Chairman Hendrie advised the Governor that people within 5 miles of the plant in the downwind direction should be told to stay indoors. The Governor made this announcement in a live broadcast on WHP radio at 10:25 a.m., altering Hendrie's recommendation and suggesting that people within a 10-mile radius of the plant stay indoors and keep their windows closed.

Shortly after this broadcast President Carter conferred with Hendrie. Subsequently, because the President wanted a responsible senior official to take charge on behalf of the Federal Government and to be his direct contact, Harold Denton was sent to the site to represent him. Then, in an 11:15 a.m. conversation with the President, Governor Thornburgh complained he was being given diverse information about what was happening at the plant. Carter advised Thornburgh that Denton was going to the site to be the President's representative and that Denton would be the primary source of information on reactor status for the President and for the Governor. It was never intended that Denton would have a public information role. This would quickly change.

Following Denton's Friday night briefing of the Governor, the Governor asked Denton to join him at a press conference to field questions about the plant. Because there were conflicting reports about plant status, the White House, with State urging, evolved a press policy by which Denton would be spokesman for all information on plant status. In addition, Jody Powell would be the sole spokesman regarding Federal emergency assistance and the Governor would be the only public spokesman on matters of evacuation and emergency response.

Met Ed held its second press conference at 11:00 a.m. on Friday morning, and Herbein again was principal spokesman. Reporters were concerned and were openly skeptical of Herbein because of the dramatic change in the public's perception of the accident, a change caused by the reported radiation releases earlier that morning and the advisory from the Governor. Herbein, who had just spoken to the control room, explained the planned venting procedure which led to the release and said that the release was measured at between 300 and 350 milliroentgens per hour. Herbein was unable to respond to reporters' contentions that plant officials told State officials that the release had been uncontrolled. He also maintained that he had not heard of the 1200-milliroentgen measurement cited by the State and the NRC, but did not dispute the reading. Herbein informed reporters that the venting would probably need to be repeated over the next 5 days.

The atmosphere at the press conference grew increasingly heated. The confusion caused by conflicting reports on the day's events and by reporters who had just arrived on site and were still catching up on basic information irritated reporters who had been at the site since Wednesday and were already familiar with the accident. Shouting matches for Herbein's attention ensued. The situation was intensified when Herbein, responding to a question on why the press hadn't been notified of the wastewater discharge to the Susquehanna River, remarked, "I don't know why we need to tell you each and everything that we do ...."[6] This statement was interpreted by some reporters as a refusal by Met Ed to volunteer information concerning the health and safety of the public. As an engineer, Herbein probably viewed the discharge of the wastewater as a part of normal plant operations and totally separate from the accident, thus not newsworthy. In fact, the radioactivity was well below regulatory limits for routine discharge to the river.

It is notable that Met Ed did not make available an experienced public relations official to be with Herbein at the company's press briefings. Such an official could have explained Herbein's probable rationale for the remark, thus minimizing its adverse impact.

Herbein advised reporters that cold shutdown could not be achieved for 5 days because of high temperatures in five fuel assemblies. After the question and answer session, Herbein explained the accident sequence by use of charts and graphs.

At about 12:30 p.m. Governor Thornburgh, after conferring a second time with Chairman Hendrie, held a press conference at the capital. Lt. Governor Scranton, Gerusky, and Craig Williamson of PEMA were also present. The Governor announced that he had been in contact with the President and with the Chairman of the NRC. He stated that the President concurred in the Governor's views that there was no reason for panic or implementation of emergency measures, and that the President should dispatch Harold Denton to the site as his personal representative. The Governor also announced that, based on the advice of the NRC Chairman and in the interest of taking every precaution, he was advising that pregnant women and preschool-age children within 5 miles of the plant leave the area. He also ordered the closing of schools within the 5-mile radius. During the questioning following the prepared remarks, he extended the earlier "stay indoors" advisory to "until further notice." (It should be noted that PEMA had already sent a teletype to the counties lifting the first advisory.) In response to reporters' questions concerning evacuation planning, the Governor said that though evacuation plans were ready he was not declaring an alert. Reporters and State officials spent the remainder of the press conference discussing the significance of radiation readings and cumulative doses.

By noon on Friday the Met Ed news center in the Hershey Convention Center was operational. The news center had six phone lines, one of which was reserved for outgoing calls. The news center staff comprised professional, technical, and clerical personnel from GPU Corp. and its three subsidiary utilities. Richard Hyde acted in an advisory capacity. The purposes of the news center were to confirm known factual information, provide technical explanations (technical calls were to be referred to technical advisors), and provide background information on normal TMI operations. Reporters, however, were sometimes successful in wheedling individual views on events from members of the staff. Updated information was to be provided to the staff by the technical advisors, who were in contact with the observation center. This approach did not prove entirely effective because personnel in the observation center were often too busy to speak to the news center staff. Too, the rapidly changing plant status quickly made information obsolete.

At about this time, in Bethesda, the NRC was setting up a press center in the East-West Towers Building directly over the Incident Response Center. Commissioner Gilinsky had received a suggestion from Jody Powell that a press center be established, and directed Frank Ingram to handle the matter. (One TV network executive reported that he had been requesting since Thursday that the NRC and the White House set up a press center.)

The NRC held its first briefing at the press center shortly after it became operational. It was during this briefing that a member of the NRC senior technical staff, Dudley Thompson, in response to a reporter's question, suggested that, although there was no imminent possibility of a meltdown, it could happen if conditions worsened.

Thompson's statement was carried as the lead in many national stories, often neither qualified nor put in its proper context, thus causing a great deal of alarm among the public. The Met Ed news center received a flood of calls after Thompson first publicly raised the possibility of a meltdown. The staff at the news center advised callers that based on current plant parameters the possibility of a meltdown was extremely remote. The news center continued to handle inquiries until about 1:00 a.m. on Saturday, when calls abated.

Early Friday afternoon Denton, accompanied by Joe Fouchard, arrived at TMI-2. Shortly thereafter Denton was approached by Met Ed officials and was asked to concur in a joint NRC–Met Ed press release. Fouchard felt the proposed release portrayed too optimistic a picture of plant status, and refused the request.

At 6:30 p.m. NRC issued its first public announcement on the accident since shortly after midnight on Thursday morning. It stated that Chairman Hendrie had said there was no imminent danger of a core melt. The announcement reported also that additional NRC technical experts, headed by Harold Denton, had reached the site earlier in the day. Some further information informed that reactor fuel temperatures were coming down so slowly that final depressurization of the reactor vessel had been delayed. There was evidence of severe fuel damage, samples of primary coolant indicated high levels of radioiodine, and a large bubble of noncondensible gas was present in the top of the reactor vessel. The announcement went on to say that if the pressure were further decreased and the gases were allowed to expand, there was a possibility that the flow of reactor coolant might have to be interrupted. If this were to occur, there could be some additional fuel damage. Several options were under consideration for reaching a final safe state for the fuel. Radiation levels in the immediate vicinity of the plant were reported to be 20 to 25 milliroentgens per hour while offsite levels were reported as a few milliroentgens per hour.

Subsequently, information was provided by the NRC primarily through news conferences or on a personal request basis. Some information was also recorded for playback on special phone lines, but this system was not widely used and did not satisfy many callers.

At 8:30 p.m. Denton met with the Governor to give him a status report. Following this meeting, at about 10:00 p.m., they held a joint press conference. The Governor announced that he had decided, based upon information he had obtained from Denton, that no evacuation order was necessary, though his earlier recommendation regarding pregnant women or preschool-age children staying out of the 5-mile area around the plant would remain in effect at least until Saturday. His earlier advice that people stay indoors within 10 miles of the plant would expire at midnight. Denton, responding to reporters' questions, provided the reporters with his evaluation of the plant status, the problems Met Ed and the NRC were facing, and tentative plans for the future. He stressed that there was no possibility of an explosion in the reactor vessel and that he considered the possibility of a core meltdown very remote.

Saturday, March 31

Plant staff were continuing the procedures for removal of the hydrogen from the reactor and related systems. During the morning Met Ed and GPU officials discussed the problem of conflicting reports, a problem created by spokespersons' making differing statements at different times. In an attempt to eliminate this problem, Creitz asked Fouchard to participate in a joint press conference, but Fouchard again refused to join with Met Ed. Creitz then decided that Met Ed would discontinue its daily news briefings, and he notified the NRC of his decision.[7]

Creitz began Met Ed's 11:00 a.m. Saturday news conference with an announcement to that effect and said that further public information would be provided by the NRC. The conference was again held in the American Legion Hall, which was jammed with reporters. Following Creitz's opening remarks, Herbein provided a briefing on plant status and told reporters the utility had attempted, to the best of its ability, to provide the press with whatever information was available at all times. During the question and answer session Herbein stated that he personally felt that the crisis was over.[8] Only an hour later Harold Denton told reporters the crisis was not over.

These two statements, widely contrasted by the media, brought down severe criticism on the utility for being unduly optimistic.

Herbein also commented during the question and answer period that the hydrogen bubble had been reduced by a third since Friday, a statement also later disputed by Denton. Herbein went on to say that offsite radiation readings were only 3 to 5 milliroentgens per hour, the core was severely damaged, and four workers had been overexposed.

Shortly after Met Ed's press conference, Denton held his first briefing in the NRC news center at the Middletown Borough Hall, a center hurriedly established with assistance from Congressman Allen Ertel. Equipping the center was substantially facilitated by the availability of communications equipment provided by the White House. It was during this press conference that Denton refuted Herbein's earlier statement that the crisis was over. He said the crisis would not be over until the reactor was in a cold shutdown condition, but indicated that he did not think the hydrogen bubble posed an explosion problem at that time.

Shortly after the NRC news conference in Middletown, Chairman Hendrie held a news conference at 2:45 p.m. in Bethesda. He reported that the reactor was stable and the fuel was continuing to cool, that the gas bubble would have to be removed from the reactor, and that small releases of noble gas fission-product activity were continuing. In answer to a question on evacuation, he indicated that evacuation was a possibility that would have to be kept in mind in considering the steps to be taken, that evacuation might turn out to be a prudent precautionary measure, and that evacuation would be considered as far out as 20 miles. Regarding the bubble, Hendrie stated it would be some time before any possibility of a flammable condition existed. Hendrie was also asked to confirm Herbein's earlier statement that the bubble had decreased in size by a third. He responded that Herbein had been talking not about the bubble in the reactor but about another bubble, which was in the pressurizer. Hendrie's statement further confused the bubble story because Herbein had, in fact, been talking about the bubble in the reactor vessel.[9]

Chairman Hendrie's news conference bothered some of the reporters at the site. They wondered why a second news conference in Bethesda was scheduled when Denton had presumably said all there was to say at his earlier news conference. One hypothesis was that perhaps Chairman Hendrie would announce bad news which, for obvious reasons, should come from the NRC Headquarters.

Following discussions with Denton and Hendrie, Governor Thornburgh issued a press release at about 5:00 p.m. The release stated that the evacuation advisory for pregnant women and preschool-age children would remain in effect for at least another night. It also related that wider evacuations were unnecessary, that decisions regarding school closings and leave policy for State employees would be announced on Sunday, and that there was no threat to public health in either milk or drinking water.

The Middletown area was calm until around 8:20 p.m., when the AP, in a bulletin cleared by the NRC, warned that the hydrogen bubble showed signs of becoming potentially explosive. Soon, a second bulletin announced that an unnamed source at the NRC had related that the bubble could explode in a couple of days. The AP story created a near panic in the Harrisburg area. State Police officers in the area were flooded with calls from anxious residents asking what they should do. Fearing an explosion was imminent, some people left the area.

After the AP story, telephone calls to the NRC, heavy all along, hit their peak when a TV station in New York urged listeners to call the NRC if they had questions about the accident. In an effort to assist callers, the station gave out the NRC phone number. As a result, the NRC was deluged with calls, many from viewers who wanted to know if they might have to evacuate their homes in New York or New Jersey. A physician in New York City called to say that he had been hearing from his patients, who were concerned for their safety. One call to the NRC asked, "how far do we have to get away to survive?"[10]

A large number of people offered ideas and assistance, some even came from terminally ill people who offered to enter potentially dangerous high radiation areas. Other calls came from technically trained people who had ideas concerning the elimination of the hydrogen bubble or the provision of increased protection.

Over time, the NRC public affairs spokespersons were exhausted by the volume of calls. They had worked 12 hours a day from Wednesday through Saturday, and some of them had worked much longer. By Saturday night, when incoming calls significantly increased, many on the staff were so exhausted that their ability to deal with the callers was greatly reduced.

In Hershey, technical personnel in the Met Ed news center were giving out an explanation on the steps Met Ed was taking to reduce the hydrogen bubble. These technical advisors openly disagreed with the NRC, and were stating that the bubble could not explode because there was neither oxygen generation nor source of ignition.

The NRC onsite technical personnel also did not believe the bubble was explosive. When they heard that the NRC Headquarters had approved the bubble story, they were surprised, and they openly disagreed. They voiced this disagreement in a phone call to the NRC Headquarters and again through a joint news conference held by Governor Thornburgh and Denton later that night. Governor Thornburgh also expressed deep concern to the White House and, as a result, the White House suggested that the NRC Headquarters stop dealing with the news media. From then on, all calls from the news media were directed to Denton and his staff in Pennsylvania.

The near panic created by the conflicting reports on the status of the hydrogen bubble and the resulting AP story prompted White House aide Jack Watson to call Herman Dieckamp, GPU President, and suggest that all future press conferences be held by the NRC. Although Met Ed had announced earlier that they would no longer hold press briefings, the utility was still giving out information on plant status from the Hershey news center.[11,12]

After learning of Watson's call, Fabian called Ken McKee of GPU at about 10:00 p.m. and told him an agreement had been reached whereby the NRC would provide all information on plant status. Calls on plant status received by the news center were to be referred to the NRC, and the news center staff was to continue only to provide background information on TMI and confirm existing public statements made by Met Ed and the NRC. One of the technical advisors in the news center, however, believes he continued to provide the Met Ed position on the bubble when requested. Met Ed's news center operated on this basis until Monday.

At about 11:00 p.m. Governor Thornburgh and Harold Denton held their second joint press conference in an attempt to alleviate some of the confusion on plant status. The Governor stated that there had been a number of erroneous or distorted reports during the day regarding the TMI plant and that during his briefings with Denton he had been assured that no imminent catastrophe was foreseeable. Thornburgh appealed to those who had reacted or overreacted to the day's reports to listen carefully to what Denton had to say about the current status. Denton opened his portion of the press conference by stating that there was no near term possibility of a hydrogen explosion in either the containment or the reactor vessel. Reporters questioned the differences between Denton's views and those of the NRC Washington offices on the possibility of a hydrogen explosion in the reactor and the necessity of evacuating an area out to 20 miles from the plant when removal of the gas from the reactor was attempted. Denton stated that he had been in touch with the Washington offices and that there was essential agreement on the plant status and the courses of action open. He indicated, in reference to the differences, that reporters were overplaying minor contradictions, and that he didn't know how to solve the problem, except by issuing statements from only one point. In answer to a straightforward question regarding the danger of a hydrogen explosion, he stated, "There is no physical possibility of it"[13] in the immediate future. Denton discussed the procedures being used for hydrogen control and talked about shipments of special equipment to the site.

Sunday, April 1

At about 1:00 p.m. President Carter arrived in Middletown with Mrs. Carter and Jack Watson. Carter toured the plant and later gave a brief speech in the gymnasium adjacent to the Middletown Borough Hall. Carter's visit had a reassuring effect on local residents. One Middletown resident remarked that Carter's presence, "has helped morale tremendously up here—they think if it's safe for the President of the United States to come up, it's not too bad."[14] After Carter's visit, near panic in the Harrisburg area subsided, and the news media and the public caught its breath from the events of the previous 2 days. Meetings with the press also slowed; Denton held the day's only press conference. During a briefing at 2:00 p.m., Denton repeated his belief that evacuation was unnecessary. Steps were being taken, he said, to eliminate the bubble, and core temperatures were steady.

Although technical personnel shared a more optimistic outlook regarding TMI-2 by that evening, Governor Thornburgh still wanted to be cautious. In a 7:00 p.m. press release, Thornburgh directed State offices to open as usual on Monday, April 2, but he extended the advisory made to pregnant women and mothers with preschool-age children to stay out of the area within 5 miles of the plant. He also recommended that schools within the same area remain closed until further notice. He noted that schools elsewhere had taken independent action regarding closing, but emphasized that there was no evidence of hazards to health or safety that would require such action.

Monday, April 2

By morning the bubble was gone and the crisis at TMI was over. Later, AP reporters placed a call to George Troffer at the Met Ed news center. Troffer, believing the crisis was over, advised that the bubble had disappeared and no obstacles to cold shutdown existed. But, he retracted his statement when he learned the NRC was upset with his announcement. After this, Troffer, with the concurrence of Fabian, closed down the news center because, for all intents and purposes, there was no further need to "calm the public."[15]

Just before noon Denton held a news conference in Middletown. He announced that the bubble had been reduced in size enough so that it was no longer considered a problem. Denton, however, did not tell reporters the NRC had been wrong in its assumptions about the possible explosiveness of the bubble. He said only that the staff had been very conservative in their calculations. And, although the emergency was over, the NRC continued to hold regularly scheduled news conferences for weeks afterward, in order to keep the media informed of recovery developments.

Later in the day the NRC made technical staff available in the news center to explain plant status information to reporters. Members of the media welcomed the presence of technical personnel (for the first time), but were critical of the NRC for not having made them available sooner.

Still later, Hyde discussed Met Ed's communication problems with Met Ed officials. On April 4, the company retained the firm of Hill and Knowlton to reestablish good relations with their employees, the community, and the news media.

3. THE CREDIBILITY ISSUE

Met Ed's Saturday, March 31, announcement that all future information on plant status would be presented publicly by the NRC was rather anticlimactic. It was apparent by then that the utility had lost its credibility with the news media and was no longer considered a reliable source of information. This loss is best illustrated by the fact that none of the representatives from the two wire services or from the major television networks interviewed in this inquiry raised any objection to having Met Ed virtually eliminated as a source of public information on the accident. It is further emphasized by the fact that while only one media representative we interviewed felt Met Ed deliberately held back information, the media in general felt that Met Ed was unduly optimistic in the information it made public and was, therefore, not a credible source. Media representatives consistently used the term "downplayed" when describing Met Ed's presentation of information to the public, and intimated that, as information developed over the course of the accident, it became evident to them that Met Ed's early statements were overly optimistic. Reporters discounted statements by the utility and sought sources of information viewed as more credible, usually the NRC. Some of the reasons why the news media mistrusted the utility are listed here:

- Met Ed continually discounted the seriousness of radiation releases during the accident.
- The utility continually had to revise upward its estimate of core damage.
- The utility continually changed its mind as to when cold shutdown could be achieved.
- Initial statements were made by the utility that no plant workers had been overexposed.

Other events which in the view of the media were adverse to the credibility of Met Ed include:

- Lt. Governor Scranton's statements at his Wednesday afternoon news conference that Met Ed had given the media and the State conflicting information and that the situation was more complex than the utility first led the State to believe.
- Herbein's remarks at Met Ed's Friday news conference concerning the wastewater discharge into the Susquehanna River.
- Herbein's statements at the same press conference that Friday morning's release was controlled and planned, and measured 350 milliroentgens per hour, even though plant personnel reportedly told State and NRC personnel that the release was uncontrolled and measured 1200 milliroentgens per hour.
- The perception that plant workers would not talk to reporters because of company directive.
- The general unavailability of Met Ed spokespersons, both in Reading and at the observation center, during the first few days of the accident.

Company officials who were involved in the dissemination of public information during the accident gave a variety of reasons why Met Ed wasn't viewed as a credible source of information. The reasons given include the following:

- The public relations official in a recently released movie, *The China Syndrome*, conveyed a negative impression.
- Local news stories prior to the accident described a serious hypothetical accident.
- The news media was left with the impression that Met Ed knew all along that the accident was of much greater magnitude but wasn't telling the public when, after Met Ed issued optimistic statements on Thursday, the situation worsened on Friday.
- Herbein's statement on Friday that, "I don't see why we need to tell you each and everything that we do," alienated the media.
- Because of poor physical communications, primarily phone lines, Met Ed was difficult to reach and was unable to return phone calls. This created the impression that the utility was hiding from the press.
- Cognizant technical personnel, principally Herbein, were tied up with the accident and not available as company spokespersons.
- Met Ed could not obtain and give out complete information early in the accident because of the rapidly changing status of the plant.
- A feeling prevailed among company officials that they had seen this type of transient before, full recovery had been achieved, and, therefore, that was what would happen again. This feeling led to an overly optimistic view of the accident during the first day.
- The utility failed to notify the news media before the Friday morning release of radioactivity—a mistake that was compounded by Herbein's later statements that the release was planned and controlled.
- The media believed that Met Ed would only tell the truth when forced to do so, a belief based on the delay in making information public.
- The press believed that Met Ed knew the plant inside and out and thus must have known exactly what was going on at any time with respect to the accident.
- The press overstated the conflicting statements made by Met Ed and the NRC.
- The media perceived that because Met Ed had a vested interest in the plant, they would not give out negative information.
- Because security guards kept reporters away from trailers where technical personnel were working, the press felt that Met Ed wanted to operate in secrecy.

The NRC, unlike Met Ed, was not as severely criticized by the media for one primary reason—Harold Denton. While media representatives we interviewed gave Denton high marks, they generally criticized the NRC Headquarters. Reporters were particularly critical of the NRC delay in providing onsite spokespersons and technical advisors. Some of the comments are as follows:

- The NRC should have had a technical briefer available on site immediately, not 6 days after the accident.
- The NRC got involved with the media on site too late.
- Prior to Denton's arrival on site, the NRC's visibility was too low, probably because the NRC did

not recognize the seriousness of the accident early enough.

Other comments concerning the NRC Headquarters' performance are as follows:

- The NRC Commissioners were more concerned with looking good and protecting the industry than in assuring public safety.
- The NRC Commissioners had no real concept of what the news media people were doing at TMI; their one thought, apparently, was that the press was against them.
- It was obvious that the NRC and its public relations staff had given no advance thought to how to handle the news media in the event of a major accident. The NRC was not equipped to handle TMI.
- The NRC's communications among its Headquarters, onsite personnel, and the King of Prussia office were poor.
- Information coming from the NRC Headquarters was possibly too conservative. Headquarters should have let Denton act as sole spokesman because he was more familiar with plant status.

Typical impressions of Harold Denton as conveyed by news media representatives we interviewed included the following:

- Our team placed more trust in Denton than Herbein. Denton was more responsive, more in control, and more communicative.
- Denton was accessible and informally gave out information to reporters when requested to do so.
- We never got the impression that Denton was giving out misinformation.
- Denton did a good job of appearing to take command when he arrived on site Friday.
- We were initially suspicious of Denton because he was not known, but he quickly established his credibility, credibility helped by the fact that Governor Thornburgh showed a good deal of faith in Denton.

4. THE MULTIPLE NEWS SOURCES

The TMI accident was one of the major news stories of 1979. As many as 400 news people covered the story in the TMI and Harrisburg areas, while another group worked at the White House and at the NRC in Washington. Their reports and commentary impacted directly and immediately on the lives of three quarters of a million people living near the reactor at TMI. For those outside the area, throughout the Nation and the world, the accident was perceived as life threatening to those near the plant, and held serious implications about the safety of nuclear power reactors. For the utility, the State, the NRC, and the media, it was a difficult story to tell. It was a "first," and the accident continued for days. The words and actions of the participants as reported by the media scared many of the people around TMI, made the management of response to the accident more difficult, and raised the level of anxiety about the future of nuclear power.

Each of the participants recognized the responsibility to meet the public's right to know. Met Ed President Walter Creitz said it was a long standing company policy "to communicate openly and completely with our various publics."[16] Creitz added that during the accident Met Ed tried to tell the public as well as the State and the NRC about "significant events as they occurred."[17] In fact, Met Ed's emergency plan calls for the station superintendent, in conjunction with the Commonwealth of Pennsylvania, to make a decision concerning notification to the "general public that an abnormal operating condition exists at the TMI nuclear station."[18] The NRC's policy was likewise designed to ensure that the public would be kept informed of actual and potential hazards to health and safety. Moreover, it was the NRC's policy to encourage "the licensee to take the lead in information activities related to the accident occurring at their facilities."[19]

This task was further defined in Region I's Incident Response Plan by instructions to the Public Affairs Office to request the licensee to release information regarding the incident, "its cause, effect, consequences, injuries involved, action being taken, etc."[20] The Governor, who had ultimate responsibility for the health and safety of the people around the plant, also felt it important to apprise "the public in an event like this, which is so unprecedented, of every bit of factual material there is."[21] Thornburgh told the Hart Subcommittee that the State regarded the public credibility of the Governor's office as essential to the effort to avoid panic as well as to implement, if necessary, an orderly evacuation.

In carrying out their public information policies, Met Ed, the State, and the NRC failed to coordinate public information to such a degree that the public was unnecessarily confused and alarmed. The main culprits were Met Ed and the NRC, but the State was not blameless. The first instance was conflicting information coming from within Met Ed itself, and later between Met Ed and the NRC during the first 2 days of the accident. These reports pertained to the levels and source of radiation. This conflict led first to Lt. Governor Scranton's public charge that

Met Ed was providing conflicting information to the State and the media, and finally to Met Ed's virtual loss of credibility with the media and the public. The second major example was the conflict between Met Ed and the NRC Headquarters over the hydrogen bubble in the reactor vessel dome. The failure to coordinate information on this subject resulted in the silencing of multiple sources in favor of a single voice speaking on plant status. The media acquiesced to this restriction.

During the first day of the accident, the main concern of the public around TMI was possible radiation exposures from the plant. Initially, the worry was not over how much radiation there was, but whether there was any at all. The conflicting reports issued by Met Ed and the NRC, and repeated by the State during the course of the first 2 days, led to confusion and mistrust. The problem was compounded further by the use of different terms in describing the level of radiation monitored, by the various explanations of how it got out to the atmosphere, and by the disagreements on what it all meant to the health and safety of the public. Met Ed's first statement, at 7:30 a.m. Wednesday, made no mention of a "General Emergency" to signify potential offsite radiation. Met Ed's second statement said that "no external radioactive releases" had been found and that "none were expected."[22] The NRC's first statement, at 10:30 a.m., said that there had been a release of radioactivity inside the reactor containment and that measurements to determine offsite releases were being taken. At his first press conference, at 10:55 a.m., Lt. Governor Scranton said there was a "small release of radiation to the environment,"[23] but that he couldn't say how much because it was not detectable in the atmosphere. BRP's William Dornsife described the level as being less than 1 milliroentgen per hour. At noon, Met Ed told the public there had been "no recording of any significant levels of radiation and none are expected outside the plant." Herbein, in an impromptu press conference shortly after 1:00 p.m., said radiation at the site boundary was being monitored and was "a tenth of the general emergency level."[24] Around 3:00 p.m. Creitz said radiation readings at the plant boundary were around 2 to 3 milliroentgens per hour. At 4:30 p.m., during his second press conference, Scranton announced:

> The company has informed us that from about 11:00 a.m. until 1:30 p.m., TMI discharged into the air, steam that contained detectable amounts of radiation. The discharge was a part of the normal reactor emergency cooling process. It was done to relieve potentially dangerous pressure in the reactor chamber. Because of an apparent leak in the primary cooling system, radioactive material was discharged into the air along with the steam. Pennsylvania's DER was not notified of the releases until about the time it was halted. The company has said that further discharges may be necessary and has promised to notify us in that event.[25]

It was at this press conference that Scranton told the media that "Met Ed has given you and us conflicting information," and that the situation was "more complex than the company first led us to believe."[26] Scranton added in response to a question on whether he was being misled by Met Ed: "I think there is a great deal of disappointment from our side that the company did not tell us that they were venting radioactivity, particularly when statements were represented that they made, that they said there was no radioactivity being put out in the atmosphere."[27] The reporters at the site were beginning to show their instinctive distrust of the utility by asking whether the Lt. Governor was depending solely on what the utility told him. As discussed earlier in this report, Scranton's irritation stemmed from Met Ed's failure to volunteer information on the so-called "steam dump" that was suspected to have contained radioactivity but in fact did not. It is ironic that this act of caution initiated the slide of Met Ed's credibility.

The first conflicting reports between Met Ed and the NRC came with the Wednesday, 5:00 p.m., NRC press release that stated that low levels of radiation had been measured off site, levels principally attributed to direct radiation coming from the containment building. NRC press spokesman Fouchard went on to say, "the accident sent radiation beaming up to a mile away through the 4-foot-thick walls of the power plant."[28] He cautioned, however, that the amount of radiation was relatively small. Additionally, Edson Case, Denton's deputy, said the radiation level inside the containment building was 1000 times normal, but when a reporter checked with Met Ed's George Troffer, he was told that the 1000 figure was too high and that the level was perhaps 10 times normal. At the Lt. Governor's third press conference, at 10:30 p.m., he cleared up the confusion on the source of releases by describing what he had reported to the Governor based on briefings from NRC inspectors Higgins and Gallina:

> There is currently no radioactive leakage from the primary building or the reactor itself, there is radioactive material currently in the auxiliary building which is being ventilated and, due to that ventilation, there is some dispersion into the atmosphere. There have not been, and they have taken samples, any critical levels found offsite. There are high, but not yet critical, levels found onsite.[29]

By midnight, NRC Headquarters caught up with the situation and in its press statement said the releases to the atmosphere resulted from water pumped over from the containment building and lying on the floor of the auxiliary building.

Herbein, in his CBS appearance on Thursday morning, took slight issue with the NRC statement about radiation levels in the containment and said that at least one monitor may have been giving erroneous readings. He further stated that actions were being taken to reduce the radiation from the water on the auxiliary building floor. Another problem grew out of the NRC Headquarters' briefing of the Hart Subcommittee, a briefing which indicated human error was involved in the accident. Herbein took exception, saying human error had yet to be established. The NRC inspectors on site supported Herbein and said, "preliminary evaluation indicated no operator error occurred."[30] By Thursday night the people around the plant were confused. Governor Thornburgh, in his first press conference, took note of the conflicting reports:

> I realize that you are being subjected to a conflicting array of information from a wide variety of sources. So am I. I spent virtually the entire 36 hours trying to separate fact from fiction about this situation. I feel that we have succeeded on the more important questions.[31]

By this time the populace was confused by strange sounding terms: releases, emissions, venting, ventilation, millirems, paths of leaking radiation, site emergency, and general emergency. On Friday morning the populace was exposed to a more disturbing set of words: unplanned and uncontrolled releases or emissions. Around 9:45 a.m. Paul Critchlow, referring to Thornburgh's conversation with Chairman Hendrie, told the press that there had been an unplanned and uncontrolled burst of 1200 milliroentgens per hour above the the TMI-2 stack. Herbein, in his 11:00 a.m. press conference, said the release was not uncontrolled, as stated by the NRC, but was made on purpose, in order to relieve pressure in an effort to reduce contamination danger. He insisted he understood the release measured 350, not 1200, milliroentgens per hour. At the Governor's noon press conference, Gerusky said he was told by Met Ed prior to 8:00 a.m. that they had had an uncontrolled, unplanned release of radioactive material. Met Ed's credibility dropped to near zero as the media began to view Met Ed's statements with a jaundiced eye. In an accident situation, the public is certain to view any utility statements as self-serving, but Met Ed compounded their credibility problems by being overly optimistic and by downplaying radiation data.

On Friday afternoon, the NRC opened its press center in the East-West Towers in Bethesda. The purpose of the center was to make technical advisors available to assist reporters in understanding the technical situation at the TMI plant. It was this center and its link with the Incident Response Center that created major problems for the State of Pennsylvania. Thornburgh, appearing before the President's Commission on August 21, singled out two news events which made his task more difficult. He cited "a report on Friday afternoon, relating to a supposed imminence of a meltdown and a report on Saturday evening relating to supposed incidence of an explosion."[32] Both of these stories, he said, were at best distorted and caused a good deal of concern among the general public. A special effort was required by the Governor and by Harold Denton at the site to put to rest the alarming nature of these stories. Chairman Hendrie, in a press conference on Saturday afternoon, added to the Governor's problems by mentioning the possible need for a 20-mile evacuation radius. This jumped the affected public from 136 000 to over 600 000 people, and the phones rang off their hooks in government offices in Pennsylvania.

Each time such a story hit the streets, Thornburgh's aides called the White House to check their accuracy as well as to note their adverse impact on the State's attempts to manage the emergency. This, in turn, triggered a series of calls among White House officials, the NRC officials at the site, and the NRC Headquarters. Eventually, the press center at East-West Towers in Bethesda was closed down, and it was announced that an NRC press center would be opened in Middletown. Early Saturday morning Met Ed had announced it would no longer hold press conferences and that the NRC would henceforth speak for plant status. At this final press conference, Herbein said the hydrogen bubble had been reduced to two-thirds of its Friday size, and stated that the crisis was over. Denton took issue immediately, and said the crisis was not over and would not be over until cold shutdown had been achieved. Denton would not accept Met Ed's figures on bubble size. Throughout Saturday afternoon Met Ed's news center in Hershey continued to respond to questions about the size of the bubble, and took issue with the view of the NRC office in Bethesda on the possibility of an explosion. Later that evening Jack Watson called Herman Dieckamp and discussed the problem of conflicting reports. Met Ed then instructed its news center to refer all questions on plant status to the NRC and to limit its responses to background information on TMI.

Early on in the accident Pennsylvania's BRP had referred all press queries to DER. By Friday, PEMA and DER had deferred to the Governor's Press

Secretary. On Friday, Jody Powell in the White House had assumed responsibility for all press statements concerning Federal emergency support to Pennsylvania. With the events of Saturday, public sources of information had been reduced to Denton for information on plant status, Powell for Federal emergency assistance, and Thornburgh for evacuation and emergency response. No one, however, provided details on radiation monitoring around the plant. At the time, the press accepted the limitation on news sources, but since has questioned the wisdom of accepting such limitations.

Met Ed did not provide full and complete information at the outset, but Met Ed spokespersons did not have all the facts at the time. The NRC did not, early on, assure that Met Ed provided complete information and, by refusing to work with Met Ed in the public information area, contributed to the conflicting reports. Abraham rebuffed Met Ed's invitation to participate in a press conference. Denton refused an offer from Creitz to issue a joint press statement on plant status on Friday afternoon. To preserve his credibility, Thornburgh refused to have any contact with Met Ed. There were good reasons for the standoff posture of the NRC and the State, but as a result of the extent of their posture, cooperation was inhibited and distrust resulted.

One other aspect of this overall problem should be noted. Late Wednesday night NRC Inspector Gallina was asked by a reporter what would happen if the core did not cool off. He responded, "That is not the situation we have here and I prefer not to hypothesize for what we don't really have."[33] Whether he was aware of it or not, Gallina at the time was following the Region I guidance: "Avoid speculation! The spokesman should avoid commenting on hypothetical situations. Answering what would have happened if ... questions tends to aid misunderstanding."[34] The hydrogen bubble scare, involving the possibility of a meltdown as well as an explosion, was created by the NRC because it failed to adhere to that guidance.

5. SUMMARY OF FINDINGS AND RECOMMENDATIONS

General Findings

- Information provided to the news media by Met Ed, the NRC, and in some cases the State during the accident was often incomplete, untimely, or inaccurate. We found that these failures were caused primarily by the lack of preparation on the part of Met Ed and the NRC to be ready to inform the media adequately in this kind of an event. Other reasons include: poor communications, the existence of multiple sources of information, and the fact that spokespersons often did not receive accurate, up-to-date information from their respective organizations. The problem was further compounded by the NRC's refusal, after Harold Denton's team arrived on site Friday, to work with Met Ed in trying to provide a single, credible account of the reactor's status and of potential dangers to the public. The State, which relied upon Met Ed and the NRC for its information, could only report what it was told. We did not develop evidence to establish that any of these parties willfully provided false information to the media during the accident.

Findings—Metropolitan Edison

- During the first 2 days of the accident, Met Ed consistently emphasized optimistic aspects of the situation and avoided any statements it feared might alarm or panic the public. Moreover, Met Ed spokesmen demonstrated a reluctance to provide the public with detailed information on radiation releases. However, we found that Met Ed spokesmen themselves were not aware of the seriousness of the accident during those first 2 days and that they did not willfully distort the information available to them in order to mislead the press. After the first 2 days, Met Ed consistently provided accurate information to the media, but by that time the company's credibility had been destroyed.
- The sporadic accessibility of onsite Met Ed officials to the news media, the rapidly changing and worsening events of the accident, and the limited information available to Met Ed spokespersons early in the accident all contributed to the utility's inability to provide full and complete information on the accident.
- The limited public relations experience of Met Ed principal spokesman Jack Herbein, compounded by the limited nuclear background of reporters covering the story, adversely affected the flow of information between the utility and the media.
- Met Ed's public information office was not adequately staffed nor was it prepared to effectively interface with the news media during the TMI accident.

Findings—NRC

- NRC public affairs planning did not take into account the likelihood of an accident of the type that occurred at TMI-2 and that, as a result, the NRC was not prepared to properly interface with the news media during the course of the accident.

- The NRC sent too few personnel to the TMI site to obtain and provide the information needed by the NRC's offsite spokespersons. This problem was further compounded by the inadequacy of the existing telephone system.
- Confusion created by conflicting statements between the NRC spokespersons at Headquarters in the Washington, D.C., area and those near the site was partially attributable to a tendency on the part of Headquarters spokespersons to release information without awaiting confirmation.
- The NRC demonstrated a willingness to speculate on possible developments and to answer "what if" questions, a willingness that resulted in agency staff contributing to several alarming reports during the accident.
- There was no advance planning for a local facility where the NRC could expeditiously establish an onsite news center able to deal with large numbers of reporters. Such a facility was needed at the onset of the accident.
- The NRC erred significantly in not providing the news media with a technical briefer on site until 6 days after the accident began.
- Reporters' understanding of matters discussed at the NRC press briefings was hampered by the lack of basic information on radiation releases and protection and on reactor design and operation.
- Overall, Harold Denton, the NRC's principal spokesman, was found by the media to be responsive, credible, and reassuring, but at times he lapsed into technical jargon that was difficult for lay people to understand. In retrospect, Denton, due to erroneous staff input, did not provide the media with completely accurate information on the analyses associated with the hydrogen bubble.
- The NRC waited too long to issue its initial public announcement on the first day of the accident and did not issue announcements frequently enough thereafter to keep the media fully and properly informed.
- NRC announcements were also not as informative as they should have been; some lacked clarity because the NRC did not discuss the significance of the information reported (especially with respect to radiation releases). Too, the NRC did not indicate the source of all reported information or explain that information might change over time as a result either of new developments or investigation by the NRC.
- Delays in issuing public announcements appeared to be attributable in part, to an unnecessary and time-consuming process of obtaining concurrences from both of the staff offices as well as the Commissioners.
- The Public Affairs Office did not have adequate staff to properly work with the media nor did it have adequate technical personnel to provide explanations on the radiological and operational aspects of the accident. This situation resulted in distracting phone calls to the technical staff in the Incident Response Center.

Findings—The State of Pennsylvania

- The State of Pennsylvania did a commendable job under trying circumstances in providing credible information to the public about the TMI accident and about potential hazards to public health and safety. The State, as a result, minimized panic and ensured that the implementation of emergency action, if necessary, could have been carried out with a minimum of confusion.
- The State of Pennsylvania exerted subtle pressure on the White House and the NRC to eliminate many of the separate sources of information available to the news media. This approach served the State very well by reducing confusion and the level of anxiety, but, in hindsight, few people thought it was a good idea to restrict the public's right to know in this fashion.

Recommendations

- All utilities operating nuclear powerplants should designate a place equipped to serve as a communications center in the event of an accident that requires extensive work with the news media. Such a facility must be near the site.
- A senior NRC official on site or near the site should be the principal spokesperson at press conferences during an accident at a nuclear plant. A utility spokesperson should be present at such press conferences to provide any differing views or additional information the utility feels is necessary to keep the public properly informed. A cognizant State official also should be present at these press conferences and should have sole jurisdiction for public information concerning evacuation and related planning. The utility should still maintain responsibility for initial public statements until the NRC can establish an onsite or near-site capability for media interface. Press briefings should be held at least three times a day, depending on the situation.
- Each utility operating nuclear powerplants should ensure that a member of its public relations staff has extensive experience in dealing with the local media and that he or she has a detailed under-

standing of the operating and radiological aspects of the utility's reactor plants and can participate effectively at the press conferences.

- Each utility operating nuclear powerplants should prepare a standard briefing package, for each plant, which provides background information about the plant and which can be disseminated to the media as required. This briefing package should be approved by the NRC, and the NRC should have verbatim copies at Headquarters and at regional offices for emergency response purposes.
- The NRC should establish requirements that will ensure prompt notification of the news media when a nuclear facility experiences an event that could impact on the public's health and safety. Such requirements should ensure that this early notification is made by an informed individual.
- The NRC nuclear accident response teams should include at least two technical individuals, one with a background in health physics and the other in reactor design and operations. The primary mission of these two would be to gather onsite information concerning the cause of the accident, to monitor the changing status of the plant, to assess the radiological risk to the public, and to communicate this information to the NRC public affairs staff and spokespersons, who could then keep the media fully and currently informed. Another response team member should be designated to establish and maintain open channels of communication to offsite centers involved in media interface activities. The NRC Headquarters should designate specific personnel to communicate with their onsite counterparts for purposes of exchanging information.
- The NRC should choose and train members of the technical staff to serve as technical advisors to the media following any future nuclear accident. This staff should be chosen in part because of their technical knowledge of particular licensed operations and in part because of their ability to effectively communicate technical concepts to a lay audience. No calls from the media should be taken by or referred to members of the staff involved in managing the NRC's emergency response activities.
- The NRC should develop a standard format for press releases to ensure inclusion of basic information concerning a nuclear accident: dates, times, radiation levels, and type of accident. Press releases should also include the source of the information (the NRC official, State official, licensee spokesperson) and should clearly indicate that the events described therein are subject to change with the passage of time. This format should be accompanied by example press releases written in lay terms. This information should be made available to all utilities operating nuclear powerplants.
- The NRC should establish a clear policy of issuing prompt public announcements concerning nuclear accidents. Such a policy should include delegation of responsibility to the Director of the Office of Public Affairs for issuing press releases without the concurrence of any NRC Commissioner. Concurrence should only be obtained from the cognizant licensing office.
- The NRC should take the lead in working with responsible State agencies to develop a public information program to educate the general public (and more importantly the populace in the immediate area of an operating reactor) on nuclear power and its consequences. Such a program should include information on reactor operation and the potential hazards of radiation both in the case of normal operation and in the event of an accident. In conjunction with establishing these programs, the NRC should develop simplified literature on the subjects and disseminate this literature to State and local agencies.

REFERENCES AND NOTES

[1]Fabian Interview Memo (August 28, 1979) at 2.

[2]Transcript of telephone conversation between G. P. Miller and G. Troffer, March 28, 1979 at i-5.

[3]Public statement by Met Ed, March 28, 1979, 12:00 noon.

[4]Hq. IRC Day 1 Transcript 01-135-CH4/22-WH-2.

[5]Transcript of Met Ed press conference, March 17, 1979 at 14.

[6]Transcript of Met Ed press conference, March 30, 1979 at 6.

[7]Creitz dep. at 36-40.

[8]Transcript of Met Ed press conference, March 31, 1979 at 4.

[9]Transcript of Met Ed press conference, March 31, 1979 at 5-6.

[10]Hq. IRC Day 4 Transcript 04-768-CH17/203C-DC-6.

[11]Memo from J. Watson, White House Aide, to the President, Subject: Status Report — Three Mile Island Nuclear Facility, Report #3, dated March 31, 1979.

[12]Dieckamp dep. at 43-44.

[13]Transcript of State press conference, Part 1, March 31, 1979, 11:00 p.m. at 6.

[14]"Crisis: Three Mile Island," Chapter 10, p. 2, *The Washington Post*, (undated).

[15]Troffer Interview Memo at 6.

[16]Creitz dep. at 5 (Pres. Com.).

[17]*Id.*

[18]Met Ed Emergency Plan, Section 5.5, at 12A-10.

[19]U.S. Nuclear Regulatory Commission Manual, Chapter 0502, "NRC Incident Response Program," Sec. 8b., at 4.

[20]U.S. Nuclear Regulatory Commission, Region I Incident Response Plan, Appendix D, at I.

[21]Thornburgh dep. at 47 (Pres. Com.).

[22]Public statement by Met Ed, March 28, 1979, 10:00 a.m.

[23]Transcript of March 28, 1979, 10:55 a.m., State press conference at 1.

[24]Herbein Interview on May 10, 1979 (IE) at 9.

[25]Transcript of State press conference, March 28, 1979, 4:30 p.m. at 1-2.

[26]Transcript of State press conference, March 28, 1979, 4:30 p.m. at 1.

[27]Transcript of State press conference, Part 2, March 28, 1979, 4:30 p.m. at 6A.

[28]AP Wire Service release, Time 12:25 a.m., dated March 29, 1979.

[29]Transcript of State press conference, March 28, 1979, 10:00 p.m. at 1.

[30]Transcript of State press conference, March 29, 1979, 10:20 p.m. at 6.

[31]Transcript of State press conference, March 29, 1979, 10:20 p.m. at 1.

[32]Thornburgh dep. at 45 (Pres. Com.).

[33]Transcript of State press conference, March 28, 1979, 10:00 p.m. at 9.

[34]U.S. Nuclear Regulatory Commission, Region I Incident Response Plan, Appendix D at 2.

APPENDIX III.1

BACKGROUND ON NRC PLANNING FOR EMERGENCY RESPONSE

Summary

Before the accident at TMI the NRC's perception of its role as an agency in connection with emergency response to a serious nuclear accident at a power reactor was a rather ambiguous third party role—one of backup support to primary roles played by the licensee and State and local emergency authorities, with some vague sense of the need to do something if the licensee failed in its primary role.

There was also a role of coordinating response actions of other Federal agencies in bringing Federal resources to bear in the State's response to an emergency. Section III.C of Volume II and NUREG/CR-1225 (entitled "Major Alternatives for Government Policies, Organizational Structures, and Actions in Civilian Nuclear Reactor Emergency Management in the United States"), as well as the "Report on Emergency Preparedness by the Office of the General Counsel of the President's Commission on Three Mile Island," among other studies, discuss this role and its background. This report focuses on the NRC's emergency response planning in relation to the licensee and the State.

It is difficult to identify a specific basis for this third party perception by the NRC, because little in materials that discuss emergency response to a serious nuclear accident deals explicitly with specific functions that should be carried out by the NRC. However, from those that do, there appears a constellation of separate but related concepts that together tend to suggest little need for an active NRC response role in nuclear emergencies. Apparently, these concepts contributed to the ambiguous status that characterized the NRC plans for its own participation in emergency response. These plans, while overflowing with objectives, did not come to grips with necessary organizational structure and related communications needs that would enable the agency to achieve its objectives under accident conditions involving significant uncertainty about the nature of the damage, about the ongoing risk, and about the character and adequacy of actions taken in response to the accident.

1. BACKGROUND

a. Statutory Basis

The Atomic Energy Act[1] does not describe any specific role for the NRC in the event of a serious accident at a licensed nuclear powerplant;[2] nor does there appear to have been any definitive legal analysis of the statutory authority of the NRC in connection with response to nuclear emergencies.[3]

With respect to the regulatory activities that were transferred to the NRC by the Energy Reorganization Act, the Atomic Energy Act is principally cast in regulatory terms:

- It imposes obligations on persons to "possess" facilities and materials in order to obtain a license;
- It imposes obligations to obey the Act, the Commission's regulations, and the license;
- It authorizes the Commission to issue licenses and to impose standards and regulations governing "possession" of facilities and materials.

The Act deals with emergency situations explicitly in two instances in three sections. These sections are directed principally toward the recapture by the Commission of facilities in order to continue operation, rather than toward recapture for the purposes of safe shutdown.

Under Section 108, should the Congress declare a national emergency, the Commission can suspend licenses, order recapture of special nuclear materials, order operation of the facility, and order entry to operate. It is unclear whether this was intended to apply when the operation of the facility itself, or an emergency at the facility, constituted the "national emergency."

Under Section 188, in cases of license revocation, if the Commission finds that "public convenience and necessity" or production programs[4] require continued operation of the facility, the Commission may, after consulting with appropriate State regulatory agencies, order that the facility be taken over and operated. Under Section 186, in revocation cases involving operations of extreme importance to the national defense or to the health and safety of the public, the Commission may recapture and operate the facility even before completing administrative procedures provided under the Administrative Procedures Act (APA). It is unlikely that this was intended to apply if the facility became a threat to health and safety; the only operations intended to be performed by the NRC were those leading to safe shutdown. Nevertheless, Section 186 appears broad enough to encompass a condition of extreme importance to public health and safety and permits the issuance of an immediate order to enter and operate a facility in order to shut it down and render it safe while the APA notice and hearings on the revocation are completed. A condition precedent to such action is an immediately effective revocation of the applicable licenses.

The existence of these sections dealing explicitly with certain circumstances does not detract from the application by the Commission of other broad regulatory authority in emergency situations; that is, the NRC may use any other regulatory authority it has in an emergency situation, including section 161i, which grants the power to "prescribe such . . . orders as it may deem necessary . . . to govern any activity authorized pursuant to this Act . . . protect health and minimize danger . . . ."

Although the Act provides the Commission with broad, nonspecific regulatory authority to impose requirements on licensees to protect health and safety and to minimize danger (103, 161i, 161b, etc.), the statute does not impose on the Commission an obligation to take any specific role or action in the event of a serious accident; nor, on the other hand, does the statute restrict the role the Commission may play in exercising its broad regulatory powers over the licensee.[5]

The Act does not provide the NRC with authority to use police powers in the vicinity of private nuclear power reactors. Thus, to the extent that police powers are required to effect needed offsite protective measures in the event of an emergency, participation by State or local authorities vested with police power will be essential. Although this leads to ascribing an important role to the States, it does not restrict the NRC from taking an active, even dominant, role in assessing the danger posed by a serious nuclear accident, nor in determining the need for specific actions and requesting State police power assistance. Though the statute could define a clearer role for the NRC, the statute does not limit the NRC's role, except to the extent that the actual exercise of any needed police powers would require the participation of State and local authorities.

b. NRC Role Concepts

Rather than reflecting some statutory limitation, apparently the NRC's view of its role in serious nuclear emergencies prior to the TMI accident was shaped by, or at least corresponded to, certain concepts concerning the nature of potential nuclear accidents and the nature of responses needed in such events. These concepts appeared to leave little of value that could be contributed by a distant organization not intimately familiar with the specific nuts and bolts of the reactor in which the accident occurred.[6]

Limits on Accident Planning

Before the development of NUREG-0396,[7] the bulk of the AEC–NRC expressions concerning emergency planning was clearly directed toward consideration only within the scope of large design basis accidents. Although the consequences of such accidents are significant, they are limited rather sharply by the design of the plant and would provide a known upper bound to the severity of the accident—a bo nd of fairly local immediate impact.[8] There were indications in some nuclear emergency planning documents that emergency plans should cover a range of incidents up to events involving severe damage and widespread contamination. These generally were contained in documents making overall recommendations that there be disaster planning covering a wide range of incidents and events, including sabotage, weapons events, and reactor and materials accidents. NUREG-0396 states on page III-4: "NRC and other Federal agency planning guidance has perhaps been misinterpreted as reflecting a position that no consideration should be given to so-called Class 9 accidents for emergency planning purposes."

This misunderstanding is natural in light of the low profile given to reactor accidents in the broad emergency planning guidance in the documents cited by NUREG-0396[9] when contrasted to the emphasis given to design basis accidents.[10] The same is true concerning the heavy emphasis in NRC regulatory guidance on planning for the limited area of the low population zone (LPZ).[11]

In recent years, since the draft promulgation of EPA's Protective Action Guides (PAGs) at levels substantially lower than the values set forth in 10 C.F.R. Part 100,[12] the guidance that limits planning consideration to the LPZ has been under revision. More recent guidance has suggested that planning should be extended beyond the LPZ. In general, though, this guidance seemed clearly related to providing protection for projected exposures down to the PAG levels rather than protecting against accidents more severe than design basis accidents.[13]

The attitude of excluding accidents larger than design basis accidents began to shift after the Reactor Safety Study, WASH-1400. With the development of NUREG-0396, the NRC provided explicit consideration of planning for accidents more severe than design basis accidents. It did not, however, except for specifying two planning zones (one out to 10 miles and one out to 50 miles), come to grips with the implication of this guidance on details of planning,[14] nor did it come to grips with the broad implications in studies showing a range of core melt accident probabilities with very high radiation doses substantially beyond 10 miles from the plant.[15]

The Commission's recent Statement of Policy adopting the 10-mile airborne emergency planning zone and the 50-mile zone for contaminated foods[16] also skirts the inconsistency implicit in its acceptance of a 10-mile planning zone, and, at the same time, stating as a policy that emergency plans should take into consideration "a spectrum of design basis and core melt accidents." NUREG 0396, the document referenced by the Commission's policy statement, shows a specific portion of the spectrum of core melt accidents (some 30% on Figure 1-11, 10% on Figure 1-15, and 90% on Figure 1-16), with whole-body doses in excess of 5 rem at 10 miles. Figure 1-15 shows high doses for substantial distances be ond 10 miles for some portion of the spectrum of core melt accidents. For probability values at the traditional "one in a million" or 10^{-6} per reactor year level,[17] doses in excess of 50 rem whole body are shown in Figure 1-15 beyond 30 miles.

It may be that the estimates of large distances must be used with caution,[18] but the implications of these estimates deserve more consideration than the ssertion in the Commission's policy statement that the 10-mile airborne exposure and the 50-mile contaminated food zone distances "are considered large enough to provide a response base which would support activity outside the planning zone should this ever be needed."

Accident Types Considered

Although there is some mention of the potential for slowly developing accident sequences,[19] a large number of accident discussions in pre-TMI material concentrate on short accident sequences,[20] those which impose the most strain on communications and on State and local response resources. Related to this concept of short accident sequences was the emphasis on dealing with well defined events of readily identified characteristics—and lack of consideration of uncertainties.[21] In the main, the situations discussed in various background documents dealt with well defined events[22] or suggested that the nature of the accident events can and will be identified rather promptly.[23]

The concentration on these short accident scenarios and rapid decisionmaking emphasized the need for close coordination between the licensee, who has the most direct knowledge of plant conditions, and local authorities, who may have to undertake prompt protective measures.[24] This, in turn, relegated the NRC—a distant agency—to a secondary role. Although it may be an important support role, it is still secondary.[25]

Reliance on Licensees

The NRC's perception of its role in responding to a serious accident at a licensed nuclear reactor was based on the concept that the plant operating organization has great technical competence combined with an intimate knowledge of the design, layout, and operational idiosyncrasies of its plant. This combination would put the licensee in the best position to judge the choice and usefulness of whatever actions could or should be taken in dealing with an accident or unstable condition that results from transients, failures, or errors during operations.[26]

In such circumstances, persons or organizations with a more remote ability, which may be very useful in performing an advisory function, may very well hesitate to intervene in the "hands-on" response to the accident.[27]

Responsibility of States in Emergencies

Another concept which appears in various documents and which may have contributed to an NRC view of its role as "secondary," was one that expressed in jurisdictional terms that the "primary" responsibility for responding to emergencies is with State and local governments.[28] This concept appeared to be accepted as a truism related to the States' authority to regulate matters of public health and safety.[29] However, it is not clear how these traditional jurisdictional concepts are affected by the nontraditional structure applicable to nuclear reactor regulation in which there has been Federal preemption of regulatory authority with respect to radiological health and safety.[30]

Both the Federal and State Governments have important responsibilities in connection with response to a serious nuclear accident. Federal agencies have primary regulatory authority over the basic activities. The State is the principal source of police powers that may be needed to carry out protective measures. But there appears to have been little recognition of the importance of both of these sets of responsibilities in connection with emergency response to a serious nuclear accident. Rather, there was mainly only the overly simplified assertion that, "the responsibility for protection of the public in the environs [sic] a nuclear power plant rests with the Governor of the state in which the plant is located."[31]

c. Experience

These concepts concerning the nature of nuclear accidents and the responses needed in such events were not challenged seriously by accidents that took place prior to TMI. Four will be used as examples.

SL-1

On January 3, 1961, at 9:00 p.m., a serious nuclear accident occurred at a small military power reactor at the AEC Idaho Testing Station. The accident involved a power excursion during planned maintenance and work on the core. Three operators were killed. The Station was an AEC contract operation, with substantial technical operating capability. The local AEC Health and Safety Division supervised overall health and safety activities at the site. Promptly after the alarms were sounded, AEC fire and security teams, with technical support from various contractor personnel, undertook lifesaving and radiological control. Events appeared to have stabilized sufficiently within 12 hours to permit reopening of a nearby highway, although there remained some uncertainty over an extended period of time as to how to proceed with the recovery program.[32]

Although a Commissioner, the AEC's General Manager, and other Headquarters officials were at the site on the following day, overall operational control was apparently exercised by the AEC Idaho Operations Office; radiological control was carried out by the local AEC Health and Safety Division. The report of the AEC investigation into the accident appears to be mildly critical of the early presence at the accident site of so many outside officials and other personnel.[33]

Fermi 1

At 3:10 p.m., October 5, 1966, there was an accident involving flow blockage by a loose piece of zirconium plate resulting in the melting of two fuel elements. The reactor was scrammed on abnormal instrument behavior about 10 minutes after initial indications of a problem. By 6:30 p.m., a meeting of important technical management and others with long and close association with the development of the design of the reactor was convened.[34] At the meeting, it was concluded that all rods had been inserted, that there was no sodium leakage, and that radiation leakage was local and confined; no additional measures were needed to protect public safety.

The AEC was notified of the event after this meeting and a local newspaper was informed. The AEC inspector arrived the next day and concluded that there was no hazard.[35] The AEC did not issue a report on this event.

Browns Ferry

At approximately 12:30 p.m., March 22, 1975, a workman using a candle to test for leaks started an extensive fire that damaged electrical control systems for both Units 1 and 2. Both units were scrammed within about 30 minutes, but the fire continued until about 7:45 p.m., resulting in the loss of a number of Unit 1 decay heat cooling systems. The local fire department was called at around 1:00 p.m. and quickly responded. The licensee activated its offsite emergency centers between 2:30 and 3:00 p.m., then notified the State and the NRC at around 3:30 p.m. The fire was put out by about 7:45 p.m. NRC inspectors arrived on site very late that night.

There was subsequent criticism of the licensee's failure to use water on the fire earlier. A local fire chief had recommended at about 2:00 p.m. and again later that water be used, but nothing was done until around 7:00–7:20 p.m. There is no indication that the NRC made a recommendation to use water, although there are indications that the NRC communicated with the licensee's emergency center.[36]

Ft. St. Vrain

On January 23, 1978, at about 9:00 a.m., an instrument malfunction led to a release of primary coolant helium to containment, a release containing about 4 curies of noble gas fission products and about 5 microcuries of iodine. The licensee initially misinterpreted the stack monitor as indicating all iodine, and thus made a very large overestimate of the offsite doses. The plant was evacuated by nonessential personnel at approximately 10:00 a.m., and roads in the area were blocked. The county and State were notified at about 10:15 a.m.; the NRC at about 10:30 a.m. Radiological assistance teams were notified at about 11:00 a.m., but were never used. The releases from the primary system were stopped by approximately 11:20 a.m., and personnel returned to the plant at 2:30 p.m. NRC inspectors arrived at 6:00 p.m. There is little indication of any specific NRC recommendation for action by plant operators.[37]

d. Overall NRC Attitude Toward Emergency Planning

Concepts derived from all of the above formed a framework for emergency response to nuclear accidents in which the following circumstances were envisioned:

- An accident, if one should occur:
  - a. would develop very rapidly,
  - b. would be readily diagnosed by the licensee, and
  - c. would have offsite consequences limited to the vicinity near the reactor.
- The licensee would rapidly diagnose the event and then would quickly and competently respond to the event, taking appropriate action to minimize offsite consequences. Browns Ferry raised the spectre of a licensee not responding quickly and correctly; however, the crisis stage of imminent danger was over within four hours after the NRC was first notified and before any NRC personnel reached the site.
- State and local authorities would be promptly informed. Protective actions, if any, would be needed only in very limited areas.

Given this framework, it is not surprising that the concept of emergency planning as a component of adequate public health and safety protection did not develop within the NRC. Rather, this component was viewed as an "add-on," providing something extra over the "adequate" safety provided by siting features and design characteristics.[38]

It is against this background that the NRC developed its agency plans for response to nuclear emergencies, plans characterized principally by ambiguity in the role to be performed by the NRC.

2. PLANNING FOR NRC RESPONSE TO EMERGENCIES

a. 1975–1976 Initial Planning

General

The initial NRC plan for its role in emergency response[39] was similar to the AEC plan for response to emergencies at non-AEC facilities. Although the plan sets forth as an objective, "To assure that proper actions are taken to protect health and safety... from the consequences of incidents which occur as a result of NRC-licensed activities, ..."[40] the plan did not come to grips with how this was to be accomplished by the NRC—a distant regulatory body with little of the operational capability of the AEC and its contract organization, an organization that had been transferred to ERDA. Except for general directives to various officials on the NRC staff to take appropriate action,[41] the principal NRC emergency responses covered by the initial incident response plan were to gather information, notify others within the agency and outside the NRC, request assistance from ERDA, and coordinate Federal and State agency actions.[42] In addition, the plan mentioned certain planning activities and after-incident investigations and measures to prevent recurrences.[43]

The plan identified no role for the Commission, and limited the role of the Executive Director for Operations (EDO) to determining whether an event should be reviewed by a special incident review committee chaired by the EDO's Technical Assistant.[44] Indeed, the entire response function was vested in the Director of IE and an Incident Response Action Coordination Team (IRACT),[45] in cooperation with the Regional Office.[46] The Directors of NRR and NMSS, in addition to having a general duty to provide staff for IRACT,[47] were assigned responsibility[48] for imposing notification requirements on licensees, for seeing to the preparation of after-incident reports to determine if additional safety evaluations or changes were needed, and for after-incident calculations of "corrective actions proposed by the licensee as a result of the incident."

The NRC incident response plan was implemented by IE Manual Chapter 1300.[49] This Manual Chapter went into greater detail on specifics regarding the actions of IE and the Regional Offices in response to emergencies.

The IE plan called for the IRACT (under the Director of IE, assisted by the Deputy Director and IE Division Directors) to coordinate the IE Headquarters and Regional Office responses. The plan further provided that IRACT was to be supported by "staff members" from NRR, RES, NMSS, etc., but did not ascribe to particular offices any specific response.[50] It provided guidance on the initial information to be obtained and the initial notifications to be made,[51] although specific phone lists were not included in the IE Manual.

The plan provided general guidance concerning public information activities. Though NRC press releases were to be made in certain instances, licensees were encouraged to take the lead. It required that NRC press releases "be factual and must report accurately the licensee's position or statements about the incident" as well as provide "a statement of actions taken by NRC ...."[52] The IE Manual repeated this guidance for Regional Directors, but went on to identify the types of incidents for which press releases should be issued.[53]

The IE Manual also called for Regional Office response under the direction of the Regional Office Director.[54] It provided guidance for classifying incidents on the basis of severity, directives to notify Headquarters promptly and to dispatch an inspector or team to the scene of serious (Level I or II) events, guidance regarding the information to be obtained by the Onsite Team, and guidance on regional notification of other Federal agencies[55] although, again, specific phone lists were not included.

The overall organizational structure under the initial plan was rather straightforward. All response action functions were vested in the Director of IE and an IRACT composed of the IE Director, Deputy Director, and Division Directors. Similarly, the regional response was to be carried out under the Regional Director.

Function of the NRC Response

While the organization was straightforward, the plans provided no sense of what, if anything, the NRC was to do in the event of an accident, other than to gather information and notify a number of persons and organizations. For security threats, the plan was fairly explicit: the FBI had lead responsibility, with the NRC gathering information, notifying the FBI, and, along with ERDA, providing technical assessment and other assistance.[56]

For operational incidents, the initial plan stated that the NRC's objective was: "To assure that proper actions are taken to protect health and safety...." Yet no guidance was provided as to what the NRC staff and the Director of IE should do or how they should provide such assurance. The directives to take appropriate action,[57] coupled with the potential sweep of this objective, are broad enough to encompass a wide-ranging intervention in the licensee's actions by the NRC in response to an accident, to direct such actions, and to supersede the licensee's actions, if necessary, so that it would be the NRC itself which assures "that proper actions are taken to protect health and safety...." This, however, was not the tone set elsewhere in the NRC emergency planning documents, nor was it the understanding reflected by senior NRC officials.

The initial response action called for by this incident response plan was the dispatch of inspectors to the scene.[58] These inspectors were to assess "the threat and magnitude of the incident by direct observation, and by discussion with the licensee and local authorities . . . ," and were to provide information to the Region and to Headquarters.[59] Rather than actively intervening to "assure that proper actions are taken to protect health and safety . . . ," the onsite inspectors were admonished in the Region I Emergency Plan[60] to limit their involvement to "objective observation, evaluation and investigation and avoid being directly involved in directing and ordering actions by the licensee or other agencies . . . ." This posture of limited involvement was to be maintained "unless the licensee's organization significantly breaks down."[61]

A provision in the IE Manual Chapter, and in the Regional Plan, strikes a similar note. Although calling for NRC evaluation of the licensee's actions "to assure safe conditions," it states that if options to provide further assurance of protection are identified by the NRC, the NRC was to "notify the authority or agency responsible for taking appropriate action."[62] This suggests a role for NRC of "notifying" (or at most recommending) that someone else, presumably including the licensee, may have an available option that can further assure safety. Nowhere did the initial plan or the IE Manual mention the stronger role of instructing or directing the licensee to take any action.[63]

Similarly, at least three regional directors, on three very different occasions, have expressed very like thoughts indicating that the NRC's function was not to direct or manage response actions.[64] These views are consistent with others expressed on occasion by the NRC. For example, in a memo to E. Volgenau, Director of IE, dated May 26, 1976, B. Rusche, Director of NRR, stated: "We must avoid the idea that we can substitute for the licensee but we must be capable of confirming that he has done his job and that others (States, local governments, etc.) have done them. We must be in a position to detect obvious deficiencies and suggest corrective actions."[65] If the focus is on those instances when the licensee does respond correctly to the accident, then these views of the NRC's functions vis-a-vis the licensee are compatible with the ringing statement of good intentions in the initial plan: It is the NRC's objective to assure "that proper actions are taken to protect health." In these cases, it is sufficient for the NRC to confirm "that he has done his job . . . ." However, there were no plans, and little consideration of the planning necessary, to deal with situations when the licensee is not correctly responding to the incident. There was only the vague objective of assuring "that proper actions are taken to protect health."

b. Reassessment After Browns Ferry

After the Browns Ferry fire, there were a number of actions taken relating to emergency response. Three in particular have bearing on the NRC's response to emergencies: the Browns Ferry Special Review Group report, an internal study of NRC emergency response culminating in a revision to the NRC Manual Chapter 0502, and a study by the MITRE Corporation to analyze NRC incident communications needs. Each of these studies was affected also by the availability of the information developed by the Reactor Safety Study (WASH-1400).

The Browns Ferry Fire Special Review Group Report

After the Browns Ferry fire, a special internal NRC review group was appointed to review the accident and to make recommendations.[66] The report discussed the event in some detail, focusing on fire prevention, and provided a number of recommendations. The report also touched on the problems of communications and the difficulties such problems could have caused if offsite action had been required[67] and discussed the need for improved emergency response communications for the NRC.[68]

With respect to the role of the NRC in emergency response, the report admonished:

> The NRC is responsible for assuring the health and safety of the public and the safe operation of Browns Ferry and all other reactors. NRC provides this assurance of public safety through the establishment of safety standards, evaluation of the safety of plants, and inspection and enforcement programs. The licensee, TVA, has the responsibility for the safe design, construction, and operation of its plant within the framework of the NRC regulatory program. If the NRC were to become too closely involved in the licensee's operations, this might have an adverse effect on the licensee's view of his safety responsibilities. In other words, it is the licensee's responsibility to operate the reactor safely, and it is NRC's responsibility to assure that he does so. (p. 7.)

Again, the report did not touch on the function of the NRC in "assuring" that the licensee does his job in cases when it is unclear whether the licensee is responding correctly or incorrectly to an accident.[69]

Grimes-Bryan Study

Although the Special Review Group warned against becoming too closely involved, another internal study by B. K. Grimes of NRR and S. E.

Bryan of IE[70] addressed explicitly an "independent" role for the NRC in response to an accident.

> Although a final judgment has not been made on the precise role that the NRC should seek to play in the event of a serious incident, the following overall goal has been assumed for the purpose of this discussion paper as reflecting current staff opinion and providing a broad framework for discussion of various alternatives: *The goal of NRC incident response is to obtain and evaluate information in order to have the capability to make independent judgments with regard to the impact of licensee and other agency actions on the public health and safety and the common defense and security and to have the capability to assist the licensee and other agencies where possible and direct the licensee if required.*[71]
>
> A design basis accident which followed its expected course would involve only information gathering and evaluation by the NRC to confirm that adequate actions were being taken by the licensee and other responsible agencies. It should also be noted that the need for active NRC involvement in an incident is predicated on the failure of preplanned utility and State actions either because an event different than planned for has occurred or because of a breakdown in the execution of the preplanned actions ....[72]

On the other hand, the report acknowledged that, for many accident sequences, the time available for response by the NRC, made it impossible for the NRC to take action to alter the course of events. Further, the report pointed out the importance of the operating staff's intimate knowledge of the facility.[73]

The NRC's role as reflected in this report was more active than that suggested by existing NRC plans and underlying material discussed above. The report suggested a much more active evaluation of the licensee's actions to determine adequacy and even suggested active intervention, such as giving advice or providing technical assistance. It went so far as to explicitly recognize that there may be circumstances that warrant formal intervention by order, or "in the extreme, could, theoretically involve onsite direction of actions." Yet, in terms of departure in intent, the report was not considered significant.[74] Testimony indicates that the draft report expressed the generally held consensus of senior management on the NRC's role in emergency response.[75]

The remainder of the report made a number of observations and recommendations and included an extensive list of potential accident scenarios and time estimates for such events.[76] Recommendation was made that a senior management team be available to advise the IRACT on incident response direction. This Management Advisory Team (MAT) was to be similar in composition to the EMT eventually created, except that it did not include the EDO. However, there was an important functional distinction—the MAT was to be advisory to the IRACT; the IRACT was to be the group responsible for carrying out the emergency response under the Director of IE who was to serve both as head of the MAT and as head of the IRACT.[77]

The report recommended that the Directors of the Operating Reactors Division, the Safeguards Division, and the Fuel Cycle and Materials Safety Division be added to the IRACT for incidents in their area of licensing responsibility.[78]

The report mentioned but did not discuss at any length the need for communications systems improvements, such as a system that "does not rely on the telephone network."[79] It included a list of parameters needed for incident assessment[80] and indicated, "One possibility for transmittal of the information to the IMC would be through a direct hookup from an IMC computer to all plant computers. The feasibility of this type of hookup should be evaluated. However, an immediate problem of equipment compatibility arises and this method of data collection may not be feasible for plant information ...."[81]

This draft report was never finalized, but the overall objectives of NRC incident response as set forth on pages 3 through 5 are used essentially verbatim in revised Manual Chapter 0502.

The MITRE Contract

Toward the end of 1975, staff discussions concerning communications improvements for NRC Headquarters in the event of emergencies, including safeguards emergencies, were begun. By June 1976, work statements and preliminary estimates were completed; MITRE Corporation was selected as "sole source" for a contract to assist the NRC "in designing command and communications procedures for the IE Incident Management Center."[82]

The MITRE Corporation report[83] discussed elements of communications arrangements for responding to nuclear incidents, basing those arrangements on characteristics derived from a set of hypothesized incidents together with a premise "responsibility" on the part of the NRC. The report outlined three concepts:

1. A monitoring concept in which the "NRC's involvement would be limited to monitoring the activities of the various response units and coordinating Federal information exchange." It notes that, "Although advice could be provided, delays should be expected ...."[84]
2. An advisory concept in which the source of data and the source of requests for advice would be the licensee's management.[85]

3. An advisory concept in which data are independently available to the NRC via telemetered sensor information. In this case, the NRC could advise the licensee concerning matters not yet considered by the licensee.[86] The report notes that this capability "provides NRC the information base required to intervene in the licensee response if it should ever be necessary."

The NRC selected the second of these concepts (advisory with dependent data) for planning, but indicated that such plans should not preclude upgrading the system to an independent data source concept.[87]

The report was principally devoted to discussion of communications arrangements, and although its discussion of NRC responsibility is overly abrupt,[88] the report makes this salient point:

> There appears to be little doubt that the public will hold the NRC ultimately accountable for any hazards, regardless of any responsibilities formally delegated to the licensee....[89]

With this premise of NRC obligation, and with incident characteristics based upon a set of hypothesized incidents, the report made a number of communications recommendations:

1. In order to enable onsite plant staffs to concentrate on coping with the situation facing them, the report recommended that licensees set up an offsite operations center (LOC) for offsite management. The LOC would serve as the single point of communications for the licensees' onsite staff. The LOC would also serve as the single point of contact between the licensee's management and the NRC, which would act as the point of contact for Federal reponse; the State police, acting as the point of contact for local authorities; and one or two other points of contact with State authorities. The report recommended that this center be staffed at all hours, and emphasized the importance of this central point of control and contact away from the midst of the crisis response.[90]
2. The report recommended an automatic or semiautomatic early alarm to promptly notify both the NRC and licensee management. It also recommended 24-hour operation of the NRC response center.[91]
3. The report pointed out that a communications system should generally reinforce the normal functional relationships, including chains of command, among its users. Otherwise, the system may inadvertently generate competition between authorities or, alternately, it may keep information from the authority who really needs it.[92]

In addition to the various recommendations, the report linked the communications system (the availability of information) to the ability to respond in a particular fashion. This point was made explicitly in discussing the concept finally selected by the NRC for further development (option 2, above), the NRC advisory, data-dependent role. The report notes: "The most obvious limitation is that the NRC must depend on the licensee for details of the incident. If the LOC doesn't anticipate a problem the NRC-OC is unlikely to have enough information to sense it, either."[93]

A principal shortcoming of the report was the short shrift given to the communication and control relationships between the NRC Headquarters and the Regional Office and the role of the resident inspector in those relationships. This was particularly true in light of the point noted in the draft that a communications system should reinforce normal functional relationships to avoid the inadvertent generation of competition between authorities. Yet the report showed communication from a distant NRC Headquarters filtered through the licensee's management to the site, and another chain from Headquarters through Regional IE to the onsite inspector (and perhaps a three-way tie-in among Headquarters, Regional Office, and onsite inspectors). It is unclear how this system was expected to reinforce the normal lines of authority in regard to the onsite inspector and the Regional Office.

Another shortcoming, perhaps inherent in the nature of the contract to study the NRC's communications needs, was the failure to identify the communications needs of the licensee's operations center, needs that are basic to its ability to fulfill the vital role ascribed to it in the overall arrangement that the report envisions. The need for such centers to have independent sources of data (independent readout) and the necessary staff to fulfill its role as "center" for emergency response information are only touched upon. Yet, this center was the linchpin of the planning arrangements recommended.

Follow-up of the report focused mainly on the NRC's end of the communication systems; e.g., purchase of a telephone taping system for IRC, layout of IRC, arrangements for "satchel" radios and NEST assistance for fieldwork (transportation accidents, scripting, and review of IRC information gathering).

Revision of Manual Chapter 0502

The activities mentioned above led to the need to revise Manual Chapter 0502. The 1977 early drafts were fairly simple modifications of existing 0502, but reflected a new organization, with an Executive

Management Team (EMT), including the EDO, functioning in the overall decisionmaking role. This was different from the advisory role recommended in the Grimes-Bryan study. An IRACT with additional members, as suggested in that study, was also proposed.

The response role of the NRC reflected in the Grimes-Bryan study was not reflected in the early proposed revisions to 0502. However, a draft dated August 8, 1977, extensively revised the prior format of 0502 to reflect not only the changed organization for emergency response, but also to reflect the objectives of evaluation, assistance, and direction articulated in the Grimes-Bryan study.

After a number of additional drafts and comments by the various offices and divisions, principally relating to organizational structure and details, the revised Manual Chapter 0502 was adopted on February 6, 1978. There is no indication in these various comments and revisions of any particular emphasis on the significance of formally expressing as the objectives of the NRC, in connection with response to incidents at licensed facilities, that the NRC would:

- evaluate information gathered to determine whether the actions taken up to that point by the licensee and others will assure that effects on public health and safety are minimized.
- determine what assistance to the licensee and others is useful and provide assistance in the form of opinions, advice, and technical expertise.
- determine whether the situation warrants formal intervention by order or by onsite direction of action.

3. PLANS IN EFFECT MARCH 28, 1979

a. Headquarters Plan

General

In order to accomplish the objectives discussed above, the NRC Incident Response Plan[94] created an incident response organization. This organization consists of an Executive Management Team (EMT), which "transforms" general policy provided by the Commission into "specific guidance for the response organization and makes major decisions affecting NRC's response actions," and an Incident Response Action Coordination Team, IRACT, which "executes EMT decisions by directing activities of the IRACT support staff," and which "provides information to EMT." The IRACT was also to identify significant problem areas, develop alternate solutions, and present alternatives to the EMT for decision.[95]

The EMT is constituted by the Executive Director for Operations, who served as Director, the Director of IE, the Director of NRR, and the Director of NMSS. For reactor accidents, the four Division Directors of IE and the Director of Operating Reactors of NRR constituted the IRACT, with the IE Director of Reactor Operations Inspection as Director of IRACT.[96]

There was also to be an "IRACT Support Staff."[97] While admonishing that detailed actions to be taken by the IRACT Support Staff are incident-specific, the Manual nevertheless specified certain functions assigned to NRR, others to IE, still others to State Programs, and others to Public Affairs. The NRR staff was assigned the functions of evaluating information on the likely future course of the incident, evaluating the corrective actions proposed and taken, evaluating the feasibility of assistance to the licensee, and evaluating the need for formal intervention by the NRC. The IE staff was assigned the functions of assuring that personnel are dispatched to the site to "monitor licensee activities," gathering information concerning the incident "to assist in NRC's independent evaluation of effects of the incident," and performing "inspection and investigatory functions in the field required to assure the health and safety of the public and to provide information requested by EMT or IRACT."[98]

Procedures to implement the broad program outlines of the Manual were developed by IE.[99] These procedures, set forth in the NRC Headquarters Plan, covered:

- call lists and communications with other agencies, whether State, local, DOE, DCPA, EPA (and White House, DD, FDA, and others as needed);
- handling initial notifications through various potential channels, during and after duty hours, including a form covering certain basic information;
- activating the Incident Response Center, including identification of certain initial steps to be taken by various staff members;
- emergency communications assistance;
- emergency transportation arrangements;
- general organization of the EMT;
- general functions of the IRACT;
- EMT-IRACT interaction;
- general description of duties of certain staff members;
- a directive to contact specified members of OELD in the event that EMT determines an order may be needed.

Apart from its emphasis on "encouraging licensees to take the lead in information activities related to incidents,"[100] the 1978 Manual Chapter, unlike the 1976 version, provided little discussion of public information procedures. Rather, the Manual Chapter called for an implementing procedure to be developed covering public information.[101] However, the entire implementing procedure consisted of the statement:

> Any request for information from members of the public will be referred to the Office of Public Affairs representative in the IRC. Obtain requestor's name and the phone number where he may be reached. The Office of Public Affairs will be informed; a return call will be made by PA staff.[102]

The procedures in the plan of the IE Division of Reactor Operations Inspection identified specific staff functions such as "Technical Coordinator" and "Field Communicator," and made specific personnel assignments for the various functions.

Organization Interrelationships

With the Commission—The NRC Incident Response Plan contained no role for the Commission in emergency response. Other than references to assuring notification of the Commission in the event of an emergency, the Commissioners were seldom mentioned in the NRC Incident Response Plan. The Commission was shown as the top box on the Incident Response Organization Chart,[103] and the provision for postaccident investigations indicated that the Commission may prescribe a different organization for carrying out investigative activities after an accident.[104] The discussion of the "Concept of Operations"[105] stated, "The Commission provides general policy which determines the overall course of action NRC takes in response to incidents . . . ."

Though the Commission could interject to "provide general policy" guidance in the midst of an accident, and indeed could modify the response plan set forth in the Manual if necessary, it is obvious that the plan was designed to be carried out without direction from the Commissioners and without a specific role assigned to them. The responsibilities for carrying out the plan and for taking any required action were vested in the EMT.[106]

Between EMT and IRACT—The role of EMT in the plan was that of "major" decisionmaker, with IRACT actually supervising the gathering of the information upon which such "major decisions" were to be based and actually supervising the myriad tasks to be performed by the staff in carrying out such "major decisions."

The implementing procedures along with the physical layout reinforced this confined role for EMT—dedicated to "major decisions," apart from the hurly-burly of information gathering.

EMT was located in a room adjacent to, but separate from, the IRACT room.[107] Communications between EMT and the IRACT Operations Room was through an EMT-IRACT liaison officer who was to periodically brief EMT on current status and to identify "principal questions" being pursued and actions being taken by IRACT. If EMT had any questions, they were to be posed in writing to the liaison officer who was then to keep track of all questions submitted. EMT members were admonished to "limit their intrusion into the Operations Room."[108] IRACT was to provide "adequate" information to EMT; however, it was directed to provide an evaluation of information—not unevaluated raw data.[109]

NRR and IE formally agreed on March 21, 1977, that IE would manage the incident response "until the Executive Management Team is available," and that EMT, when available, "will assume full management of NRC incident response activities."[110] However, no further organizational plans or arrangements for the management of the incident by EMT were established, despite the fact that the formal agreement among Office Directors was at odds with the then existing arrangements under Manual Chapter 0502 of 1976 and IE Manual Chapter 1300.[111] When the Manual Chapter and the Headquarters plan were modified in 1978 to reflect EMT, the role turned out to be as described above, that of "major" decisionmaker, rather than one of "full management."

Between IRACT and Staffing—The NRC plan did not identify how the IRACT was to function; that is, whether it was to function as a body, or whether individual members were to supervise specific components of the support staff, or whether the IRACT members were to be assigned supervisory roles as necessary. Nor did the plan discuss how the support staff was to be supervised by the IRACT. In this regard, it should be noted that, though four out of five members of the IRACT were to be from IE, the bulk of the evaluation was assigned to NRR, with IE assigned principally an information gathering role. Similarly, the implementing procedures did not discuss how the five-member IRACT was to function in order to discharge its supervisory role. The procedures simply lumped together the IRACT support staff functions without dealing with how the functions assigned by the Manual to separate divisions were to be organized and supervised by the IRACT.

Specific role assignments for reactor accidents were provided in the plan only for the IE Division of Reactor Operations Inspection. These role assignments, which provided for complete staffing of all roles by IE personnel, were intended to apply only when the IE Division of Reactor Operations Inspection was the sole or principal responding organization.[112] They were not intended to govern the situation after NRR undertook participation in the response to a serious incident. However, they appear to have been the only set of written, preplanned role assignments for reactor accidents.

There were, in short, no preplanned organizational arrangements or role assignments for carrying out the vital assessment functions along the divisional lines outlined in the Manual Chapter. The NRC's plan for incident response simply did not deal with organization of people not used to working with each other, people from different divisions within the agency—divisions between which historically there has been some sense of rivalry and friction.

b. Regional Plan

The Regional Plan, in contrast to the Headquarters Plan, was organizationally straightforward. It provided both general policy guidance and areas of fairly specific guidance and instructions. There were, however, two important areas of ambiguity in the Regional Plan when viewed in connection with the overall NRC plan. One was the relationship between the Region and Headquarters; the second concerned the NRC's function in the event that (and criteria for determining when), the NRC's response should transcend "the investigative role." These are discussed separately below.

The Regional Plan was initially developed in August 1977, and was very similar in general approach to IE Manual Chapter 1300. However, as noted above, this IE Manual Chapter was developed in connection with the initial 1976 NRC incident response plan. Although the Regional Plan had been modified to reflect the newer organization of the current Headquarters Plan, consideration of further modifications to more closely reflect the new Headquarters Plan had begun only recently.[113] The Regional Plan specifically provided for an incident response organization under the overall authority and supervision of the Regional Director or the Deputy Director. The organization consisted of a Regional Incident Response Action Coordination Team (RIRACT), headed by the affected branch chief,[114] and an Onsite Inspection Team (OIT).[115]

The RIRACT was responsible for the overall coordination and control of Regional response.[116] It was to select the team and its leaders to be dispatched to the site.[117] The RIRACT was also responsible for assessing any incident characterized as, "collectively the responsibility of the Director, Deputy Director, and responsible Branch and Section Chiefs . . . ."[118]

An OIT was to be dispatched to all significant incidents to gather information concerning the incident and to observe and evaluate the licensee's efforts to respond to the emergency.[119] The team was directed to provide radiological assistance to the licensee or to others until relieved by other agencies.[120]

In circumstances of life or death, or in those directly affecting the public health and safety, the plan indicated that radiological responsibilities supersede normal regulatory functions until the situation is under control.[121]

In addition to overall policy guidance and general organizational instructions, the plan also contained fairly specific guidance and instructions concerning response actions by various regional participants.[122] These included specific notification procedures, guidance on the specific data to be obtained after notification of an incident, guidance for classifying the severity of incidents, guidance on specific information to be obtained by RIRACT, guidance on specific information to be obtained by OIT, plans for drills, lists of equipment to be available, guidance as to emergency radiation exposure, projected dose guidance for protective actions off site, guidance concerning public information statements, lists of consultants and other agency contacts, and lists of licensees.

The Regional Plan guidance was far more specific than that in the Headquarters Plan concerning public information procedures. The Regional Plan gave as its objective making the facts known "so that possible health hazards and precautions will be understood, undue public alarm will be avoided and scare stories written in the absence of facts will be at a minimum." It emphasized the need to authenticate facts and to avoid speculation.[123] Though specifically indicating that public announcements normally were to be issued by the licensee, the Regional Plan went on to state that the licensee was not to be used as spokesperson for NRC activities.[124]

c. The Relationship Between Headquarters and the Region

Each plan imposes very similar responsibilities on different groups, though little was said about their interrelationship aside from essentially hortatory guidance to "coordinate."

The Regional Plan contained a number of references to coordination with the Headquarters IRACT, and the organizational chart shows the Headquarters IRACT in a box above that of the Regional Director. However, the language used throughout the Regional Plan to discuss responsibilities suggested that it was the responsibility of the Regional officials to carry out the various response functions.[125] The plan called for Regional officials and the onsite team, as the first line, to determine the particulars of the incident, assess the magnitude of the hazard to the public, and determine whether adequate protective and corrective actions were being taken. These functions entail the exercise of a significant degree of technical judgment.

The overall NRC plan, however, delegated these same judgment functions to other components of the NRC staff; the Headquarters Plan called for NRR to evaluate the likely future course of the accident and the corrective actions being taken in response to the incident. NRR was also responsible for evaluating the need to provide assistance to the licensee or the need for formal NRC intervention.[126]

On the other hand, the NRC Headquarters Plan assigned to IE the functions of monitoring the licensee's activities, gathering information for the NRC's independent evaluation (presumably the evaluations assigned to NRR), and providing information requested by EMT and IRACT. But this plan, too, contributed to the conflict by also specifying th.t IE "performs inspection and investigatory functions in the field required to assure health and safety of the public...." This function, during an ongoing event, is broad enough to encompass any and all the activities then underway to stabilize an unstable situation and to prevent or mitigate serious potential releases.

These overlapping organizational functions may be of little significance in a fairly well defined situation. However, in a situation with substantial uncertainty and with the potential for serious danger, the scene is set for conflicting perceptions between people on site and those at Headquarters who may be receiving information from sources other than the site or from people with a wider range of background. These conflicting perceptions can lead to conflicting priorities regarding information to be gathered or action to be taken. To cope with this potential, the Regional Plan simply called for "coordination" with Headquarters; the Headquarters Plan did not do that much.

d. Difference in Role Played by the NRC

Although it can be argued that the overall NRC role reflected in the Regional Plan was essentially the same as that reflected in the Headquarters Plan, the basic thrust of these two plans was very different, just as the basic thrust of the NRC's role reflected in the NRC's initial plan was significantly different from that reflected in the current plan.

The role depicted in the Regional Plan is somewhat easier to describe, although it too has complex characteristics. Essentially, the role described for NRC response to an incident was "investigatory,"[127] with the additional responsibility for providing radiological assistance until such time as NRC personnel could be relieved.[128] In circumstances of life or death, or when public health and safety are affected directly, the radiological responsibilities were to supersede normal regulatory functions.

Even for the radiological assistance role, the function was essentially a backup one to be terminated when "other groups with this specific responsibility (e.g., DOE-RAP)" arrive, or "when the situation is in control."[129]

While the Regional Plan called for the onsite team to "assure that actions are being taken to protect people...," to "determine the magnitude of the problem and the hazards to the public," and to "determine what actions the licensee is taking to assure safe conditions...,"[130] the plan makes it clear that Region I personnel at the scene were to be careful to limit their involvement to "objective observation, evaluation and investigation and avoid being directly involved in directing or ordering actions by the licensee or other agencies unless the licensee's organization significantly breaks down."[131]

The Region I plan did not mention this situation again. Thus, it provided no criterion for judgment, except as inherent in the rather drastic phrase, "significantly breaks down," which suggests a fairly severe degree of inability to cope with the situation.[132] Except for the "radiological assistance" role as needed, there is little if any mention of the NRC's providing recommendations or advice to the licensee on how to cope with a situation he may be facing.

The Headquarters Plan suggested a much more active role. The determination of whether to intercede by providing advice or formal direction of operations entails a very active involvement in evaluating the situation and the actions being taken by the licensee. Moreover, the placement of this responsibility with offsite Headquarters NRR staff, rather than with the onsite inspector, tended to make this judgment independent of (or isolated from, depending on one's point of view) direct influence from the licensee's personnel. Yet, in the absence of an independent source of information, the independence of judgment may be illusory, and isolation from the actual situation on site may be dominant.

Although the Headquarters Plan expressed the concept that it may be necessary for the NRC to intercede in the licensee's response to an emergency, the absence of any preplanned criterion for such intervention left the situation as ambiguous as the Regional Plan's use of the phrase, "unless the licensee's organization significantly breaks down." However, in the case of the Regional Plan, the judgment of when such an event takes place was in the hands of the onsite inspection team. It is unclear who decides what to do thereafter. In the case of the Headquarters Plan, the judgment of when to intercede and what to do was in the hands of the senior-most staff of the agency, but based on information filtered through a Headquarters staff which itself, at best, had secondhand information of perhaps undefined quality.

4. CONCLUSIONS

a. Role Perceived by the NRC

Prior to the TMI accident, the NRC's concept of its role as an agency in the event of a serious nuclear accident was an ambiguous "third-party" role—one of backup support of the primary roles to be played by the licensee and the State—with some vague sense of the need to do something if the licensee failed in its primary role.

This backup role is not one imposed by the Atomic Energy Act. The Act does not define a specific role for the NRC in an emergency. Because the NRC is not provided with police powers that may be needed to effectuate offsite protective actions, State and local authorities must play a vital role. However, this does not restrict the NRC from taking an active role in determining the need for, and taking the lead in, marshalling crisis response actions.

The backup role appears to be based on, or at least coincides with, a series of concepts about the character of accidents. The result was a framework in which reactor accidents were envisioned to be well understood, rapidly diagnosed events calling for prompt plant actions by the licensee. The licensee was thought to have the most complete, most current information, as well as an intimate knowledge of all aspects of the facility. Such accidents also called for prompt decisions on offsite protective actions and, thus, for close communication between the licensee and State and local authorities. However, such offsite actions, if needed, would be required only in limited areas very near the site. Against this framework, the principal role for the NRC, in response to the crisis stage of an accident, would logically seem to be one of support to the licensee and the State:

- Providing technical assistance to the licensee, if needed, such as technical suggestions and evaluations of alternatives proposed by the licensee, to alleviate some of the burden on the licensee in his efforts to cope with the problem;
- Providing the State with monitoring and radiation assessment assistance, contributing to IRAP support, and assisting the State to obtain any needed resources available from the Federal Government;
- Providing the important supportive role of communicating information to the public and to government officials.

After the Browns Ferry fire, and the subsequent publication of WASH-1400, some of these concepts began to change. The NRC explicitly expressed a role for itself as potential overseer of the licensee's response: evaluating the actions the licensee is taking, providing technical advice to the licensee and thus influencing actions, and possibly (in what are characterized as highly unlikely circumstances) deciding that the licensee is not doing what needs to be done and, so, stepping in to direct actions.

b. Overall NRC Organization Planning

While these objectives were expressed in the NRC's plan for incident response, the agency's preparations were not at a stage where such objectives could reasonably be fulfilled.

Although an NRC study of communications made a number of recommendations for a necessary overall communications structure to accomplish these functions, only a few recommendations relating to specific items had yet been implemented. Thus, at the time of TMI, the NRC's communications systems were highly dependent on information supplied by the licensee: there were no arrangements for early notification of the NRC, and there were no arrangements for direct communications between licensee management and the NRC. Indeed, there were no NRC-induced arrangements for early marshalling of the licensee's management and offsite resources for prompt support of the onsite operating staff.

Moreover, the NRC's internal organization had not been coordinated to fulfill these goals. The overall NRC incident response plan had been changed from an IE operation (with assistance from other offices) to one in which there was a major role for the NRR component, without any specific planning for how the efforts of this component were to be directed and coordinated in the overall response. Nor was there any clear assessment of how these changes would affect interrelationships with the Region and the field team of regional inspectors dispatched to the site. Confusion about the role of the field response personnel was inevitable. The Regional Plan suggested that the field personnel were responsible for assuring that things were being done properly to protect public health and safety, a responsibility that carries with it the exercise of professional technical judgment. The Headquarters Plan, however, separated the information-gathering function of the IE component from the assessment function of the NRR component, thus leading to treatment of field personnel as sources of nuggets of information to be put together by Headquarters evaluators.

Telephone communication in a crisis situation, particularly in relaying complex concepts, is difficult enough under the best of circumstances. When the people on opposite ends of the phone have different understandings of their respective roles, the situation is destined to result in misunderstanding.

REFERENCES AND NOTES

[1]Atomic Energy Act of 1954, as amended (The Atomic Energy Act or "the Act") 42 U.S.C 2011 *et seq.*, as amended by the Energy Reorganization Act of 1974, as amended (The Energy Reorganization Act), 42 U.S.C. 5801 *et seq.*

[2]Although such a serious accident is postulated as the premise of the Price-Anderson financial protection provisions of the Act (Sec. 170), the Act does not deal explicitly with any other aspect of response to serious nuclear accidents except as encompassed by the broad grants of regulatory authority to the NRC over safety issues; e.g., to establish by rule "such standards ... to govern the possession of [materials] as the Commission may deem necessary ... to protect health or to minimize danger ..." (161b).

[3]A legal analysis was carried out by the Federal Preparedness Agency (GSA), in April 1977, as part of its study, "Federal Response Plan for Peacetime Nuclear Emergencies (Interim Guidance)." This analysis, Annex II, concludes very broadly that, "there appears to be no lack of legal authority to respond to Category I emergencies [defined as minor and localized] and, to the contrary there is a legal obligation imposed upon the NRC and ERDA to take prompt and effective corrective measures ..." (p. 4). It also concludes, for Category II accidents (defined as having the potential for widespread contamination and encompassing a major accident at a power reactor) that, "The authority of the President and the Federal agencies involved to respond to such an emergency appears clear with no lack of legal authority to respond to the needs of this contingency ..." (p. 9).

This analysis weaves its discussion of agency and presidential powers over a range of circumstances covering both accidents and deliberate acts. Broad conclusions, supported only in part by the references, are reached. With respect to the NRC, the statutory citations are to the general regulatory provisions of the Atomic Energy Act, Secs. 11, 41, 53, 57, 62, 81, 92, 101, 170, 183, 274, and to the criminal violations provisions, Secs. 221, 222, 223.

In commenting on the draft of this report, the Office of the Executive Legal Director stated that, "none of this authority [the authority cited by the author of the report], standing alone, has any direct bearing on the subject under consideration, i.e., the responsibility and the extent of NRC's authority to *respond* to a nuclear emergency *during* the time the emergency exists. On that subject, it would be far more appropriate, for example, to discuss Section 108, which is the only provision giving NRC clear authority to act directly, and then only pursuant to a *Congressional* declaration of war or national emergency ...." It recommended that, "the references to the provisions of the Atomic Energy Act and Energy Reorganization Act as they relate to NRC be deleted in their entirety, and that there be substituted a legal analysis which will be relevant to the matters under consideration."

This comment was forwarded to the Federal Preparedness Agency by Harold Collins of the NRC on January 11, 1977; however, the final report does not appear to have changed in this respect.

[4]ERDA-DOE function under the Energy Reorganization Act.

[5]The Commission has often appeared to describe this as a limitation on its authority in the field of emergency planning, in that it has no authority to direct the States to provide emergency planning. This disregards the rather plenary scope of its authority over licensees to assure adequate safety. In the event of inadequate emergency planning or inadequate emergency response ability on the part of State or local authorities, the Commission may simply assess the safety of the facility design for its intended use at a location at which there is inadequate State and local emergency response capability. The Commission may require extensive additional safety precautions (or a lower acceptable probabilistic risk goal), if these are capable of compensating for inadequate emergency planning. If not, it may deny or suspend authority to build or to operate the facility.

[6]These concepts are seen in a wide range of NRC material and in material produced by other Federal agencies that have worked with the NRC on various aspects of guidance concerning emergency planning.

[7]"Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," USNRC and USEPA Task Force on Emergency Planning, December 1978, NUREG-0396, EPA 520/1-78 016.

[8]For example, "based on past experience ... a distance of 3 miles to the outer boundary of the low population zone is usually adequate" (Reg. Guide 4.7, Sec. C.3). Even if the 25 rem thyroid dose PAG is considered (a dose that is significantly lower than the 300 rem thyroid dose value of Part 100), the techniques used in NUREG-0396 indicate that, following a DBA-LOCA, such doses will be within a radius of two to five miles (see pp. I-27 to I-30).

A greater distance is required for actions that may be necessary to avoid dose through the milk pathway. This distance may be required even for an incident limited to a design basis loss of coolant accident (NUREG-0396, p. I-35). However, a greater period of time is available before human exposure occurs (NUREG-0396, p. 14).

[9]NUREG-0396 follows the quoted sentence with the statement: "The Task Force, after considering the published guidance and available documentation ..., concluded that Class 9 accidents have been given some consideration in emergency planning." The sentence refers to four documents:

1. "Radiological Incident Emergency Response Planning Fixed Facilities and Transportation: Interagency Responsibilities," Federal Preparedness Agency, General Services Administration, Federal Register Notice, Vol. 40, No. 248, December 24, 1975.
2. "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants" (NUREG-75/014), October 1975, WASH-1400, USNRC.
3. "Disaster Operations, A Handbook for Local Governments" (CPG 1-6), July 1972, and "Change No. 1," June 1974, Defense Civil Preparedness Agency.
4. "Federal Response Plan for Peacetime Nuclear Emergencies (Interim Guidance)" April 1977, Federal Preparedness Agency, General Services Administration.

The third reference recommends that there be plans for dealing with incidents "affecting a substantial area outside the facility site" (p. 68b). The fourth reference recommends plans for dealing with incidents ranging up to "situations in which, despite all preventive . . . efforts . . . widespread contamination, shall have occurred . . ." (p. 17).

The discussion in the fourth reference concerning serious events (Categories II, III, and IV), though mentioning reactor accidents as a source of such events, heavily emphasizes sabotage and threats of deliberate acts, as well as weapons events (see pp. 15–16, 18, and Annex I, pp. 6–7, 29–31, 43–47).

Although the second reference, in part, considers the effect of protective actions such as evacuation in mitigating the consequences of severe core melt accidents, it cannot be characterized as recommending the need for extensive evacuation plans for each operating reactor.

[10]See Reg. Guide 1.101, Annex A, 4.1.5: "An acceptable planning basis [for General Emergency plans] is the most serious design basis accident analyzed for siting purposes."

See also "Guide and Checklist for Development and Evaluation of State and Local Government Radiological Emergency Response Plans in Support of Fixed Nuclear Facilities," USNRC, Office of International and State Programs, Revision 12/1/74, NUREG 75/111: "The AEC considers that it is reasonable, for purposes of emergency planning relative to nuclear facilities, to prepare for the potential consequences of accidents of severity up to and including the most serious design basis accident analyzed for siting purposes. . . . The AEC recognizes that accidents with more severe potential consequences than design basis accidents can be hypothesized. However, the probability of such accidents is exceedingly low. Emergency plans properly designed to cope with design basis accidents would also provide significant protection against more severe accidents, since such plans provide for all of the major elements and functions of emergency preparedness . . ." (p. 4).

See also Standard Review Plan, Sec. 13.3: "The planning should reflect, in particular, commitments to the following: (a) For an accident of the type postulated pursuant to 10 CFR Part 100, the initial assessment measures should assure a capability for prompt notification to offsite authorities, i.e., within approximately fifteen minutes of detection of the initiating event."

See also the following AEC and NRC licensing cases in which emergency planning adequacy is assessed in terms of design basis accidents or the requirements of 10 C.F.R. Part 100: Midland 6AEC331, Catawba 7AEC861, Limerick 7AEC1098, San Onofre 8AEC957, Seabrook 1NRC613, 3NRC857, and 5NRC733, Marble Hill 6NRC1101, Jamesport 7NRC826, Three Mile Island-2 8NRC9.

In Jamesport, specifically, the Board assessed emergency plans in terms of the DBA, but went on to hear evidence to assure itself that, "in the remote possibility of an accident more severe than a design basis accident, no insurmountable difficulties to evacuation were posed by the Jamesport location . . . ." However, the Board "did not require . . . that Applicant devise . . . definitive plans . . . since such mandate rests with [the County] and the State . . ." (7NRC854). In short, while looking at the "remote possibility" of an accident greater than the DBA, the Board did not consider as part of its finding of "reasonable assurance" that such plans be required as conditions of the license. Moreover, it found as fact that the county could take adequate steps when the county argued that such steps were not feasible (7NRC856).

In Seabrook 3NRC857, the Licensing Board "recognizes that the potential consequences of such [Class 9] accidents form, at least in substantial part, the basis for State and local radiological emergency plans." However, the Board goes on to conclude that, under the NRC requirements, the licensee need not consider evacuation or other protective measures outside the LPZ (3NRC926). Again the Licensing Board does not consider as part of its findings of "reasonable assurance" that plans to deal with events greater than design basis accidents should be assessed or required as part of the conditions of the license.

The Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, USEPA Office of Radiation Programs, September 1975 (Draft?), indicates on page 1.9 that, in the absence of available information during the course of an accident, "default values should be available from planning efforts. These values could be based on scenarios from WASH-1400, design basis accidents evaluated in the NRC safety evaluation reports for individual facilities, or other scenarios . . . ." The enormous potential difference in response to uncertain events that would be associated with assumptions based on WASH-1400, as distinguished from those based on the DBA assumptions, is not mentioned. In fact, after again referring to WASH-1400 as indicating that, "there is an extremely wide spectrum of different kinds of possible releases to the atmosphere depending on the severity and the exact sequence of the failure modes . . ." (p. 5.2), the Manual goes on to state that it is usually conservative to assume a fission product release based on NRC guidance for DBA assessment and states that, "[In] the absence of more accurate information regarding release composition, it would be conservative to assume that this composition is released . . . at the design leak rate" (p. 5.3).

[11]See Reg. Guide 1.101 C.: "Planning and implementation of measures to cope with plant-related emergencies outside the site boundary with particular emphasis on the low population zone should be a coordinated effort. . . ."

See also Reg. Guide 1.101, Annex A, Sec. 4.1.5: "Although the likelihood of occurrence of such an event is extremely low, emergency plans should include a General Emergency class which provides for early warning of the public and prompt initiation of protective actions within the low population zone . . . ."

See also 1970 Guide to the Preparation of Emergency Plans: "The licensee should give particular attention to protective measures that may be necessary for individuals within the low population zone . . ." (Sec. IV).

See also cases cited in 10, above, and Point Beach 4AEC689, and Shearon Harris 7NRC92. See especially Seabrook 5NRC733 in which the NRC staff argued that emergency evacuation planning requirements should, in that case, extend beyond the LPZ. The Appeal Board held that, "we adhere to our uniform prior holdings that, under the Commission's regulations in their present form, consideration is not to be given in a licensing proceeding to the feasibility of devising an emergency plan for the protection (in the event of an accident) of persons located outside the low population zone . . ." (p. 747).

[12]The values selected in the EPA Manual of Protective Action Guides, note 10, above, are: For airborne exposure: 1 to 5 rem whole body and 5 to 25 rem thyroid (pp. 2.3 and 2.5). The Part 100 values are, for different purposes: 25 rem whole body and 300 rem thyroid.

[13]See Reg. Guide 1.101, Annex A, Sec. 6.4.3.2: "Protective actions planned for the low population zone with provisions for extending such actions to areas farther from the site boundary, if necessary, should be described...."

See also Reg. Guide 1.101, Annex A, Sec. 4.1.5: "Provision should also be made for modification or expansion of protective actions, based on conditions prevailing at the time of an accident, to include areas in which projected doses to individuals would be likely to exceed the upper limits of protective action guides."

See also Standard Review Plan, Section 13.3: "If supported by an assessment of the specific plant and site situation, this region [the region for which emergency planning should be provided] should be extended beyond the LPZ. The principal criteria to be employed in this regard include...and (b) a comparison of projected doses from postulated releases with Federal guidance on those protective action criteria which might mandate the initiation of an evacuation, i.e., upper limit values where ranges are given."

The staff argument in Seabrook 5NRC733 was directed toward protection against the lower exposure levels (5NRC748, but see 5NRC752).

The Commission ruling in response to the Appeal Board Seabrook decision similarly appears to be directed principally toward planning beyond the LPZ, "taking into account the emergency protective action criteria developed by appropriate Federal authorities and by appropriate State and local governmental authorities in cooperation with the Commission" (43FR37473, August 23, 1978). However, the statement of considerations also contains the concept of optionally providing protection above that called for by 10 C.F.R. Part 100: "Particular attention is to be given to the foregoing as they affect the effectiveness of taking protective actions within the LPZ established pursuant to the Commission's siting criteria of 10 C.F.R. Part 100. This should not, however, preclude the consideration of utilizing emergency plans to provide additional protective benefit to persons beyond a LPZ as a matter of reasonable and prudent risk management, to assure protection beyond that afforded by safety design features and the siting of facilities in accordance with 10 C.F.R. Part 100."

[14]See, for example, comments on the draft of NUREG-0396 by M. Reilly, Chief, Division of Environmental Protection, Pennsylvania Bureau of Radiological Health, dated August 11, 1978, to D. Snellings, Jr., Director, Division of Radiological Health, State of Arkansas, copy provided to NRC-OSP. Reilly indicates:

"5. The added feature of substantial particulates and the concept of doses to the order of 200 Rad at 10 miles cannot be offered cavalierly. Those who believe that planning for this consequence would not be burdensome have no idea what is involved in treating one let alone hundreds of casualties of 200 Rad (and more) exposures. It is a lot beyond putting them up in armories and passing around cookies and milk."

[15]*Id.* Reilly (see 14, above) goes on in his comments to say:

"6. Regarding the matter of planning for accidents yielding 200 Rad at 10 miles it is not difficult to estimate that doses at one mile would approximate 6K Rad and 23K Rad at a quarter mile. If, indeed, this scenario is believed to be of sufficient probability to require planning, it becomes the duty of the CRCPD [Conference of Radiation Control Program Directors] to reject this technology."

See also comments dated March 1979 on NUREG-0396 by the Citizens Committee for a Better Environment: "A second basis given for the 10 mile EPZ comes from analysis using RSS methodology. The model is no where described; the results are presented with orthodox RSS inscrutability. It appears that, for a core melt accident (given the numbers in the RSS and some ill-defined meteorology) doses of the order of the PAG of 5 rem whole body radiation are moderately probable up to 100 miles away; massive doses (greater than 200 rem) are possible around the reactor, but their probability drops off sharply beyond 10 miles or so. At this point all ideas of responding to to PAG levels are dropped, since it is clearly impossible to prepare for emergencies up to 100 miles away from the reactor. However, since short-term lethal doses are only found within about 10 miles, this is taken as confirmation of the 10-mile EPZ concept" (p. 4).

[16]44 FR 61123, October 23, 1979.

[17]Compare this to testimony by Chairman Hendrie at the Hearing on Radiation Protection-Emergency Planning Before Subcommittee on Energy, Nuclear Proliferation and Federal Services, Committee on Governmental Affairs, U.S. Senate, May 9, 1979: "To take an extreme case, it would not be useful to provide for an evacuation that was 99.9999 likely never to happen" (p. 117). This is more like 10^{-6} per reactor lifetime or 10^{-7} per reactor year.

[18]NUREG-0396, p. I-45.

[19]NUREG-0396 cites the Reactor Safety Study, WASH-1400, as indicating that major releases may begin in the range of ½ hour to as much as 30 hours after the initiating event (p. 18). See also Grimes-Bryan study (note 70, below), Appendix A.

[20]See Grimes-Bryan study (note 70, below), Appendix A. Of 17 scenario outlines for large break LOCAs, five for small break LOCAs, and four for reactor transients, 12 mention decision points for evacuation within 1½ hours of the onset of the event. Five more that do not mention decision points have very large releases within 200 minutes after the event begins. Four do not have severe offsite consequences.

See also NUREG-0396: "The time available for action is strongly related to the time consumed in notification that conditions exist that could cause a major release or that a major release is occurring. Development and periodic testing of procedures for rapid notification are encouraged" (p. 19).

"Throughout both of the intervals from 0 to 10 miles, the importance of a rapid and efficient implementation of either evacuation or sheltering is evident (small delay times for evacuation, small ground exposure times for sheltering)" (pp. I-49 to I-50).

"Note that evacuation (i.e., removal of population from hazardous area) with delay times of 1 hour or less will reduce the projected number of early public health effects to roughly 0 in any radial interval, and will always be the most effective response measure for a severe accident, if it can be achieved."

See also NUREG-75/111: "In some situations, there could be a need for protective measures within short time intervals a half hour or perhaps even less after determination that a hazard exists. For this reason, emergency planners should recognize the importance of prompt accident assessment at or near the source" (p. 3).

See also 10, above: "Within the general framework of providing maximum health protection for an endangered public, the public official charged with response to a hazardous situation may be faced with a number of decisions which must be made in a short time.... The efforts of planning activities can usually be based on the need for immediate response" (p. 1.2).

"Release Assumptions... Significant releases of radioactivity may occur within 1½ to 2½ hours of the initiating cause of the incident; therefore, if protective actions are to be effective, they must be taken promptly" (p. 5.2).

The most vivid displays of the concentration on very short, very well defined and understood scenarios are the descriptions used to evaluate the adequacy of emergency planning in the Jamesport case and in the TMI-2 case.

In Jamesport 7NRC826 the sequence of events is described as: "Based on a step-by-step analysis of the evacuation process, LILCO has estimated a maximum of 5 minutes for the plant operator to assess the extent of an accident from control room instrumentation, a maximum of 10 minutes for estimation of possible offsite doses, and 5 minutes to notify local authorities, and that the entire LPZ could be cleared within 2 hours after an order is given to begin notification for evacuation. Removal of people from any single 45° sector within the LPZ could be completed in much shorter time..." (7NRC at 853).

In TMI-2 8NRC9, the sequence of events is described as: "Stated in an extremely simplified way, the sequence of activities following an accident or incident, or other cause of radioactive release, would be as follows. The occurrence of the event would be detected, and its severity assessed, by means of instruments located onsite and monitored in the control room (and confirmed and augmented by portable equipment).... Thereupon, the applicants would notify first the State Council of Civil Defense duty officer (who is available at all times) and then (as necessary) the State Police, a nearby medical center and NRC.... In the event of the most serious type of incident, the occurrence would become known in seconds, and the duty officer would be notified within 5 minutes.... That officer in turn would notify the county civil defense organization... which is also manned without interruption... and the BRH duty officer. BRH would confirm the notification by recontacting the applicants..." (8NRC at 15).

[21]But see 10, above: "The decision to initiate a protective action may be a complex process with the benefits of taking the action being weighed against the risks and constraints involved in taking the action. In addition, the decision will likely be made under difficult emergency conditions, probably with little detailed information available..." (p. 1.8). See also p. 1.2.

However, the uncertainty touched upon here appears to concern the amount of release rather than the nature of the event: "The amounts and types of radionuclides available for release should be immediately calculable by site personnel. What is actually being released to the environment can be estimated but may not be confirmed by some time after the incident. The magnitude and duration of the release may be estimated by site personnel from plant conditions or from knowledge of the type of incident that has occurred. However, the estimate may be highly uncertain and must be updated on the basis of onsite and offsite monitoring observations and operational status of engineered safeguards. If source term information is not available immediately, default values should be available from planning efforts. These values could be based on accident scenarios from WASH-1400, design basis accidents evaluated in the NRC safety evaluation report for individual facilities, or other scenarios appropriate for a specific facility" (p. 1.9).

[22]WASH-1400 and Appendix G of Grimes-Bryan study (note 70, below), are evaluations based on postulated or defined scenarios. The examples given in the Jamesport and TMI-2 cases in note 20 above also reflect very rapid and well defined events. Similarly, all the cases identified in notes 10 and 11, above, are discussed in terms of well defined events.

The MITRE Report 7618, discussed at note 83, below, sets forth eight well defined scenarios as, "intended to demonstrate the full range of incidents to which NRC might have to respond" (p. 1, Vol. II).

[23]See note 10, above: "Nuclear facility operators have the initial responsibility for accident assessment. This includes prompt action necessary to evaluate public health and safety both onsite and offsite.... Ideally, this notification should occur as soon as conditions in the facility are such that an impending accidental release potential exists. While such notification could lead to false alarms on rare occasions, they could also permit more timely protective actions than postponing the notification until a release has occurred... Immediately upon becoming aware that an incident has occurred that may result in exposure of the offsite population, a preliminary evaluation should be made by the facility operator to determine the nature and potential magnitude of the incident. This evaluation, if possible, should determine potential exposure pathways, population at risk, and projected doses..." (p. 1.20).

However, the underpinning of the guidance on protective actions is projected dose (see EPA Manual of Protective Action Guides, referenced in NRC guidance in Reg. Guide 1.101, NUREG-0396, and 43FR37473.) The guidance for projecting such doses tends to be in terms of information available from control room instrumentation (Reg. Guide 1.101, Annex A, 4.1.3, 4.1.4, 4.1.5; 1970 Guide, p. 4; NUREG-0396, p. 3) or other preplanned scenarios (e.g., EPA Manual Section 5). While these preplanned relationships are extremely important, the relationship between specific control room readings and projected doses may not be valid for accident sequences not postulated. Yet there is no discussion of this limitation or the potential implications for confusion in the event of an accident different from those postulated.

This problem is exacerbated by conflicting approaches to the making of dose projections for protective action decisions. For example, one portion of the TMI Emergency Plan Procedures, 1670.4, calls for prompt calculation from control room instruments of projected doses and spells out a procedure for making such calculations. It indicates that these calculations are the basis of any (prompt) decision on emergency protective measures, with field measurements, when made, used to correct the projected dose (Sec. 4.6.4). On the other hand, Procedure 1670.7, Sec. 4, and Procedure 1670.3, Sec. 4.1.5, indicate that evacuation of the public off site is to be based upon (and will therefore await) offsite measurements.

[24]See Reg. Guide 1.101: "Although Federal agencies can and will respond to emergencies arising from nuclear power plants activities if necessary, such response should be regarded primarily as supportive of, and not as a substitute for, responsible action by licensees and State and local governments. The development of an effective interface between the licensee and the State and local governments in radiological response planning is therefore necessary . . ." (pp. 1.102-2).

See also NUREG-75/III: "An additional emergency measure for which facility operators have a primary responsibility is accident assessment. This includes prompt action to evaluate any potential risk to the public health and safety, both onsite and offsite, and timely recommendations to State and local governments concerning protective measures" (p. 3).

See also note 70, below: "All action within such a short timeframe must be taken by those with the best information, the best knowledge of the facility, and the best chance to influence the outcome of sequence of events—the onsite plant operating staff" (p. 10).

See also: note 9, above, p. 68C; and note 10, above, pp. 1.20-1.21, and 5.9.

[25]Compare this to Grimes-Bryan study (note 70, below), at p. 12, and Appeal Board Decision TMI-2, 8NRC, pp. 20-22.

[26]See note 70, below, pp. 10-12. See also the memo from Rusche to Volgenau dated May 26, 1976, quoted in the discussion under text Subsection 2.a., of the "Function of NRC Response" in the 1975-1976 initial planning.

See also note 83, below: "Power reactors—personnel are onsite at all times who are technically trained and well qualified to help assess most problems" (Vol. I, p. 7), and "The licensee has the responsibility for his facility and the persons working there and would have the most thorough knowledge of a problem and actions which might be underway to alleviate it" (Vol. II, p. 10).

[27]Stello dep., pp. 44-49. See also Mattson dep., October 17, 1979, pp. 81-84. Cf. Eisenhut dep., at 137-141, 145, Mattson dep., October 17, 1979, pp. 200-207.

[28]See Regulatory Guide 1.101: "This policy is based on the recognition that State and local governments have the necessary authority to implement protective measures for the public in their jurisdictions. Although Federal agencies can and will respond to emergencies arising from nuclear power plant activities if necessary, such response should be regarded primarily as supportive of, and not as a substitute for, responsible action by licensees and State and local governments" (p. 1.101-2).

See also FRPPNE, Annex I: "This plan provides guidance to Federal agencies to assure that a coherent and comprehensive approach to Federal response activities to nuclear emergencies is developed. Most importantly, it recognizes that, under our constitutional form of government, those emergencies, unless they occur in federally controlled areas or involve federally owned material or equipment, are in the first instance, a matter of concern to State and local authority" (p. 1).

[29]FRPPNE, Annex I, pp. 11-12.

[30]*Northern States Power Co.* v. *Minnesota*, 447 F.2d1143 (8th Cir. 1971), aff. mem. 405 U.S.1035 (1972); *Pacific Legal Foundation et al.* v. *State Energy Resources Conservation and Development Commission et al.*, Cir. No. 78-711E (S.D. Cal. March 6, 1979) (on appeal).

[31]Answer to question 1, Enclosure 1, from C. Kammerer, NRC, to M. Udall, Chairman, Subcommittee on Energy and the Environment, Committee on Interior and Insular Affairs, U.S. House of Representatives, dated May 8, 1979, Hearings on Nuclear Regulatory Commission Authorizations for Fiscal Year 1980, Before Committee on Interior and Insular Affairs, House of Representatives, 96th Congress, 1st session, February 22 and March 2, 1979, pp. 502 *et seq.*

[32]Information derived from Nucleonics, February 1961, pp. 17-18; Nucleonics, December 1961, pp. 43-46; SL-1 Accident, Atomic Energy Commission Investigation Board Report, printed by Joint Committee on Atomic Energy, Cong. of U.S., 86th Cong., 1st Session., June 1961.

[33]See note 32, above: "We suggest that the effectiveness of the Operations Office in conducting recovery and investigatory operations may have been impaired by the early presence of so many outside personnel. It is noted that within 24 hours of the incident there were present an AEC Commissioner, the General Manager, the Director of the Operating Division and several other members of the Division, the Board of Investigation and its consultants and advisers, representatives from several other AEC sites and several other Federal agencies, and the press" (p. x).

[34]The management meeting included McCarthy, Amorosi, Wilber, Jens, Olson, and Johnson. This group consisted of people who had long and close association with the engineering design and development of the Fermi reactor and were associated with its operation. McCarthy had been Assistant General Manager of PRDC for a number of years and, before that, had been head of nuclear engineering for APDA. Amorosi had been the long time technical director of APDA. Wilber was a licensed reactor operator and had long been associated with the Fermi project and with the design of its instrumentation and control systems.

The list of people at the meeting was taken from *We Almost Lost Detroit*, John Fuller, Readers Digest Press, T. Y. Crowell Company, New York, 1975, p. 202. Backgrounds taken from Fermi-1, New Age for Nuclear Power, Alexanderson, Ed., American Nuclear Society, LaGrange Park, Ill., 1979, Chapters 4, 5, 11 and Appendix C.

[35]*Id.* at 230.

[36]Information derived from Hearings before Joint Committee on Atomic Energy, U.S. Cong., on Browns Ferry Nuclear Plant Fire, 94th Cong., 1st Sess., September 16, 1975.

[37]Information derived from memorandum from Higginbotham and Thornburg, NRC, to Volgenau, NRC, dated March 8, 1978.

[38]In response to a GAO report critical of NRC efforts to obtain better State and local emergency preparedness around nuclear facilities, the NRC Executive Director responded: "I would like to comment briefly on each of the key conclusions of your report:

"1. *NRC should approve license applications for nuclear facilities only in States that have concurred-in plans.* "NRC protects public health and safety by giving primary consideration to site characteristics and design features of nuclear facilities. Once we are satisfied that these meet an adequate measure of safety, we evaluate the emergency plans for the facility. From this point of view, State and local emergency plans provide an added margin of protection for the public in the vicinity of a nuclear facility in which we believe that an adequate measure of safety *already exists*. The Commission's licensing decision process is structured to take into account a wide variety of standards and criteria in the evaluation of proposed or existing nuclear power plants to the end that substantial conservatisms exist in design and operating safety margins. To the extent that proposed or existing plants fail to meet these standards, NRC would not license them or permit them to continue to operate. In this context, State and local plans while related to the facilities undergoing the licensing process, and to applicant's emergency plans, are not essential in determining whether the plant can be operated without undue risk to public health and safety."

See also Report to Congress by the Controller General, "Areas Around Nuclear Facilities Should be Better Prepared for Radiological Emergencies," EMD-78-110, March 30, 1979. The response by the NRC Executive Director for Operations is set forth as Appendix VII, pp. 67–77.

Similarly, see testimony of Chairman Hendrie in which he outlined the various elements of the regulatory process that contribute to assurance of public health and safety. The emphasis is on design considerations and there is no mention of emergency planning. See oversight Hearing Before the Subcommittee on Energy and Environment, Committee on Interior and Insular Affairs, House of Representatives on Reactor Safety Study Review, 96th Cong., Ist Sess., February 26, 1979, pp. 90 *et seq.*

[39]See Manual Chapter 0502 adopted May 4, 1976, which was superseded by a revised Manual Chapter 0502 on February 6, 1978, in effect at the time of the TMI accident. To distinguish between these two revisions, the 1976 version will be referred to as the "initial plan" or "0502(1976)." The 1978 version will be referred to as the "current plan" or "0502(1978)."

[40]0502(1976), Sec. 02.

[41]0502(1976),0502(1976), Sec. 032: The Director, IE, "Evaluates reports of incidents and determines and initiates the initial required response, including where appropriate, requesting radiological assistance from ... (ERDA)....

"Advises the Commission ... and senior NRC management on questions connected with an incident relating to the operational aspect of shutting down or placing licensed facilities in a safe condition."

The Director of the Regional Office "initiates appropriate response actions required by contingency plans.... Investigators ... will be sent to the incident scene if appropriate ... response actions may be raised or lowered ... if ... information is obtained which warrants such an action" (App. p. 1).

The IRACT "will direct and coordinate the initial actions taken in response to Level I incidents which have particularly significant health and safety ... or public interest aspects" (App. p. 2).

The Office of Inspection and Enforcement "Evaluates reports ... to determine the initial response actions required and initiates the response actions, including the dispatch of inspectors to the scene when appropriate" (App. p. 3).

[42]0502(1976), Secs. 02, 032, 037, 0310, 0311, and App. pp. 1–5, 7.

[43]0502(1976), Secs. 02, 032, 034, 035, 036, 037, and App. p. 2.

[44]The Commission and EDO are to be notified by the Director of IE of the occurrence of incidents and are to be advised by the Director of IE "on questions connected with an incident relating to the operational aspects of shutting down or placing licensed facilities in a safe condition" (0502(1976)-032).

[45]The NRC Manual did not specify the composition of IRACT, but IE Manual Chapter 1300 identifies IRACT as composed of the Director and Deputy Director of IE and the Directors of three IE Divisions—Reactor Inspection, Materials Inspection, and Field Operations. IE Manual Chapter 1300, p. 1300-2.

[46]0502(1976), 032, App. p. 1–3.

[47]0502(1976), 035, 036, and 046.

[48]0502(1976), 035, 036. The Director of NMSS is also given responsibilities for developing plans for security threats.

[49]Although the IE Manual is dated December 11, 1975, earlier than the May 4, 1976, date of the NRC Manual Chapter, they were in process during the same period.

[50]Unlike 0502(1978).

[51]IE Manual Chapter 1300, App. 1320.

[52]0502(1976), App. p. 7.

[53]IE Manual Chapter 1300, App. p. 1300-AII-1.

[54]IE Manual Chapter 1310.

[55]IE Manual Chapter 1300, App. 1300; IE Manual Chapter 1310.

[56]0502(1976), App. p. 5; IE Manual Chapter 1310, Chapter 1320, App. 1320, Enclosure 2.

[57]See note 41, above.

[58]0502(1976), App. p. 1.

[59]IE Manual 1310-AI-1.

[60]The Regional Plan, Davis Ex. 5012, was developed in 1977. It is similar to and apparently based in large measure on IE Manual Chapter 1300.

[61]Regional Plan, p. 15. Onsite inspectors are also given radiological assistance and lifesaving responsibilities discussed below.

[62]IE Manual Chapter 1300, p. 1300-1; Regional Plan, p. 2.

[63]An early draft of the Initial Plan, attached to a memo dated June 30, 1975, from L. Higginbotham to J. G. Davis, *et al.*, specifically would have disclaimed authority to intervene in a licensee's actions in response to an emergency. "The licensee has primary responsibility for assuring safe conditions in his operation ... and for taking preplanned actions to protect health and safety ... from the consequences of incidents which may occur directly as a result of his operation. The NRC will respond to significant incidents and emergencies which involve licensees by sending its personnel to the scene; however, the arrival and presence of NRC personnel at the scene does not relieve the licensee of his responsibility. NRC personnel have no authority to direct, nor assist in the direction of, the licensee's actions or operations."

B. Rusche, then Director of NRR, commenting on this section, stated in a memo dated July 24, 1975, to D. Knuth: "The first paragraph should be qualified somewhat to reflect our responsibilities and authority under our regulations, the Atomic Energy Act, and Energy Reorganization Act. In particular, the term 'responsible authorities' needs definition and clarification. NRC's authority to issue orders for the protection of the public should be discussed here and also in Section 0XXX-04, 031g. on pp. 4–5."

A subsequent version of the draft, in a memo from Higginbotham to Carter, *et al.*, dated October, 1975, appears without this disclaimer, but also without reference to the NRC's authority to issue orders.

[64]An undated letter signed for B. Grier, Director of Region I, contained as part of the Met Ed Emergency Plan for the Three Mile Island reactor, states: "The primary role of the NRC during a radiation emergency is that of conducting investigative activities associated with the incident and verifying that emergency plans have been implemented and proper agencies notified. In addition, however, if NRC personnel are dispatched to the scene, they will, as needed, assist in coordination with the Energy Research and Development Administration Radiological Assistance Team and provide to State and local agencies advisory assistance associated with investigating and assessing hazards to the public."

Similarly, in 1976, N. Moseley, then Director of Region II, in a memo to D. Thompson, dated September 3, 1976, discussing certain information needed from the regional offices to support the Headquarters Plan, stated: "I question the necessity for this detail in information since it strongly implies that we envision managing the incident. We are not prepared in any way to manage incidents. I strongly doubt that we could prepare ourselves to manage large incidents. A significant manpower commitment would be needed. Further, a detailed knowledge of each facility much in excess of that we now have is required for effective incident management. We have no mechanism to obtain rapid information about the incident upon which to base operational decisions."

Subsequently, after the Three Mile Island accident, R. Engelken, Director of Region V, in a memo to B. Grier, dated May 21, 1979, discussed his concerns over what appeared to be the sharing of responsibility for plant operations between the NRC and the licensee some three weeks after the initial accident during efforts to achieve a long term stabilization of the cooling mode, stated: "This arrangement apparently in effect since early after NRC arrived at the site in force, conflicted rather sharply within NRC's longstanding philosophy of operations, i.e., that the licensee has the primary responsibility for the safety of operations and the NRC assures that the licensee is meeting that responsibility."

He goes on to say: "The emergency mode of operations and its lack of definition of how responsibility and authority were to be shared during that emergency mode, left it pretty much to the man in charge to decide for himself just what his authority and responsibility were. While this may have been unavoidable during the early NRC response to the incident, I felt that by the time that I arrived at the site there should have been better definition of how the NRC was to interface with the licensee during recovery operations."

[65]He also states: "We kid ourselves to think we can do much in less than one or a few hours...."

[66]"Recommendations Related to Browns Ferry Fire," Report by Special Review Group, USNRC, NUREG-0050, February 1976.

[67]*Id.* at 7.

[68]*Id.* at 58.

[69]There were criticisms of TVA's failure to use water to extinguish the fire for some seven hours. See Hearings on Browns Ferry Nuclear Plant Fire (note 36, above), pp. 13, 45, 817. However, the fire was extinguished at 7:45 p.m., before the NRC inspectors arrived.

[70]NRC Incident Response, B. K. Grimes and S. E. Bryan, Draft #2, dated July 23, 1976, Grimes Exhibit 5029; See Grimes dep. at p. 21.

[71]*Id.* at 2.

[72]*Id.* at 9.

[73]*Id.* at 10–12: "All action within such a short timeframe must be taken by those with the best information, the best knowledge of the facility, and the best chance to influence the outcome of a sequence of events—the onsite plant operating staff. Even if it were possible to arrive at specific action plans for response to a large number of accident scenarios which would theoretically allow remote direction of an incident, the best use of these action plans would be to make them available to all operating plants for incorporating into their emergency procedures.

"Despite the impracticality of obtaining and adequately evaluating plant and site information immediately after initiation of an incident, there are a number of scenarios where action taken many hours after initiation of an incident are of high significance.... Even in these cases, however, an intimate knowledge of the facility by the operating staff would have to be combined with any additional evaluative resources that the IMC may be able to bring to bear to implement actions within the facility. The IMC plant-related activities are therefore expected to be at most advisory in nature. It would be an extremely unusual situation where directives would need to be issued with regard to specific plant actions in response to incidents. A somewhat better case can be made for IMC direction of offsite actions, mainly because of the additional time available.... Even for offsite actions, however, the IMC role would be much more likely to be advisory than directive."

The IMC referred to in the quote is the "Incident Management Center," the location to be used by NRC Headquarters personnel in connection with Headquarters incident response. The name was later changed to the "Incident Response Center," or IRC.

[74]Grimes, dep., p. 27; Thornburg dep. p., 59.

[75]Grimes, dep., pp. 23, 27; Thornburg dep., pp. 46–48, 52, 53, 55.

[76]Grimes-Bryan Study, Appendix A.

[77]Grimes-Bryan Study, p. 14.

[78]*Id.* at 16.

[79]*Id.* at 19.

[80]*Id.* at 23–25.

[81]*Id.* at 27.

[82]Memo, Cobb, NRC, to Halman, NRC, dated June 8, 1976. Initially, the proposed contract scope was quite broad, encompassing as part of its purpose to define the "command control and communication procedures for managing incidents." It mentioned as a policy issue to be considered, "the extent of NRC's responsibility to 'manage' a licensee incident...." Subsequently, the planned scope of work was reduced to identifying communication relationships and developing alternative command and control concepts (see memo, Thornburg to Halman, dated September 23, 1976). The contract was executed on March 9, 1977 (NRC-05-77-044), and has been modified to add tasks from time to time, including

the development and conduct of tests of the incident response systems and the survey and specification of equipment. (See, for example, "Request for Procurement," OIE-77-044 6/30/78; Amendment #6 Contract OIE-77-044 5/11/78). Additional tasks were under discussion toward the end of 1978 and in early 1979, including that of providing certain advice to states and a study of the psychological aspects of crisis management (draft of memo, Himes, MITRE Corp., to Ryan, NRC, dated October 12, 1978; letter, E. Stewart to B. Weiss, NRC, dated February 28, 1979).

[83]MITRE Technical Report 7618, in two volumes, *Communications and Control to Support Incident Management*, Himes, Lopez, Sandy, November 1977.

[84]*Id.*, Vol. I, p. 13; See also Vol. II., p. 16.

[85]*Id.*, Vol. I, p. 14, and Vol. II, p. 18.

[86]*Id.*, Vol. I, p. 14; see also Vol. II, p. 21.

[87]*Id.*, Vol. I, p. 15; see also: Letter, Jordan, NRC, to Sanders, MITRE Corp., dated July 20, 1977.

[88]The report discussion, Vol. I, starts with a paraphrase of the statement from the Browns Ferry Fire Special Review Group Report quoted in the text: "[I]t is the licensee's responsibility to operate safely within the NRC's regulatory program and the NRC's responsibility to assure that he does so" (p. 5). Then, as if it followed *a fortiori*, the report states: "When an incident occurs the NRC is ultimately responsible for:

Minimizing the public risk by assuring that the incident is terminated with as little damage and as few subsequent problems as possible.
Disseminating factual information in the proper context to the public and to official bodies.
Preserving adequate information for later review, education and feedback into the regulatory process.

"While any of these functions may be partially delegated to the licensee, the NRC must continually evaluate the licensee's response and ensure that the functions are being properly executed."

This is in contrast to the position expressed in the draft report dated June 10, 1977 (MITRE Working Paper WP 12413:

"An incident requires action to mitigate its consequences, investigation to discover its cause, and dissemination of information to the public (and other authorities). These latter two functions are the sole responsibility of the NRC, and no agency is uniquely charged with the first" (p. 6).

[89]MITRE Report, Vol. I, p. 5.

[90]*Id.*, Vol. I, pp. x, 22; Vol. II, pp. 12, 13, 25; Draft WP 12413, p. 22.

[91]*Id.*, Vol. I, pp. x, xi, 22; Vol. II, pp. 14, 22, 25.

[92]Draft Report WP 12413, p. 23. The final report has similar but briefer expression; see MITRE Report, Vol. I, p. 10.

[93]MITRE Report, Vol. II, p. 20; also Vol. I, p. 14. The impact of this point tends to be softened by the belief reflected in the report that, "The licensee has the responsibility for his facility and the persons working there and would have the most thorough knowledge of a problem and actions which might be underway to alleviate it" (Vol. II, p. 10).

[94]The Plan consists of a set of documents, principally NRC Manual Chapter 0502, "NRC Incident Response Program," and a three-part Appendix thereto, an "NRC Headquarters Incident Response Plan" which incorporates Manual Chapter 0502 and its Appendix; the Headquarters Response Plan also incorporates the Incident Response Procedure of the IE Division of Reactor Operations Inspection. They are collectively identified as Davis Exhibit 5011. The Manual Chapter basically outlines the overall objectives and the overall organization. The Headquarters Plan provides certain duty rosters, notification lists, and some operating procedures. It also outlines certain "National Level Emergency Procedures" for carrying out agency functions in National emergencies. The Division of Reactor Operations Inspection Procedure provides specific duty assignments for members of that Division with some operating procedures for such personnel.

[95]0502(1978), App. pp. 7, 9, 11. The Plan also creates, for safeguards threats, an Information Assessment Team to assess the seriousness of threats (pp. 7, 14).

[96]0502(1978), App. pp. 7, 8, 9.

[97]Its composition is not specified, but all Division Directors are directed to provide IRACT support staff if called upon to do so by EMT or IRACT 0502(1978), App. p. 5. The initial duties of the IRACT Director include selection of "a nucleus of staff members for IRACT support staff" (NRC Headquarters Plan, Sec. 3.5). In practice, this amounts to calling Division Directors or Assistant Directors to identify the kinds of backgrounds needed. The specific personnel are selected by the Division Director or Assistant Director.

[98]0502(1978), App. pp. 11-13

[99]Such procedures are called for by 0502(1978), App. p. 14.

[100]0502(1978), App. 0502, p. 4.

[101]0502(1978), App. 0502, p. 15.

[102]NRC Headquarters Plan, Sec. 4.4.

[103]0502(1978), App. p. 8.

[104]0502(1978), App. p. 19.

[105]0502(1978), App. p. 7.

[106]0502 (1978), Sec. 044: The EMT is "responsible for . . . making decisions, and managing NRC's response to accidents." 0502(1978), App. p. 7: The EMT "makes major decisions affecting NRC's response actions; IRACT executes EMT decisions by directing activities of IRACT support staff . . . ." 0502(1978), App. pp. 10, 11: EMT "Makes major decisions affecting NRC's response actions." IRACT "Directs action of IRACT Support Staff to implement EMT decisions . . ." and "Performs actions required by IRACT Implementing Procedures in order to carry out information, evaluation, assistance direction and coordination functions." (See also NRC Headquarters Plan, 4.2.2.1.)

[107]See NRC Headquarters Plan, figures follow Sec. 3.6.4.

[108]NRC Headquarters Plan, Secs. 4.1.1, 4.2.1, and 4.2.3.

[109]NRC Headquarters Plan, Sec. 4.2.1.

[110]Memo, B. Rusche, Director, Office of NRR, and E. Volgenau, Director, Office of IE, to L. Gossick, dated March 21, 1977.

[111]See discussion of 1975-1976 Initial Planning in text Subsection 2.a.

[112]Moseley dep., September, 25, 1979, pp. 10-30.

[113]Grier dep., October 12, 1979, pp. 3-5.

[114]The affected branch chiefs (Reactor Incident, Radiological Incident, and Security Incident) are specified. They are to act as Coordinator of the Regional Incident Response Center. The Emergency Planning Coordinator serves as data recorder, and other identified officials serve specified roles. It also appears that all branch chiefs and section leaders are to function as members of RIRACT as needed. Regional Plan, pp. 10, 12, 19, IRIP 1-2, IRIP 2-1, IRIP 3-1.

[115]Regional Plan, pp. 3, 5, 11, 19, IRIP-6.

[116]Regional Plan, p. 10.

[117]Regional Plan, p. 10; but usually the leader is to be the principal or resident inspector, pp. 3, 11, IRIP 6-1.

[118]Regional Plan, p. 9.

[119]Regional Plan, pp. 1, 2, 3, 5, 11, 15, IRIP 6-1.

[120]Regional Plan, pp. 2, 11, IRIP 6-1.

[121]Regional Plan, p. 11, IRIP 6-1.

[122]These are in the portions identified as IRIP, SP, and Appendices.

[123]Regional Plan, Appendix D.

[124]Regional Plan, p. 17.

[125]Regional Plan: "The Regional staff, supplemented by consultants and other federal agencies ... is qualified to perform all actions necessary to implement this Incident Response Plan..." (p. 9).

"Inspectors will be sent to the scene of incidents ... to assure that actions are being taken to protect people..." (p. 1).

"The Regional Office will provide radiological assistance to licensees and other agencies.... In matters of life and death or those which directly affect the public health and safety, radiological responsibilities will supersede normal regulatory functions" (p. 1).

"The Region I Office ... objectives ... are to: Establish the nature, extent and particulars of the incident.... Evaluate the licensee's actions to correct problems ... to assure safe conditions.... Determine if adequate protective and corrective actions are being taken..." (p. 1).

"OIT members... Determine the magnitude of the problem and the hazards to the public..." (p. IRIP 6-3).

[126]0502(1978), App. pp. 11, 12.

[127]Regional Plan IRIP 6-1; see the guidance as to how to perform investigations, pp. IRIP 6-4 to 6-6.

[128]Regional Plan, pp. 1, IRIP 6-1, 6-3.

[129]Regional Plan, pp. 1, IRIP 6-1.

[130]Regional Plan, pp. 1, IRIP 6-3, 6-7.

[131]Regional Plan, p. 15.

[132]Also, by not mentioning this situation again, the plan provides no picture of what the onsite inspector is to do in such an event, other than that he no longer needs to "avoid being directly involved in directing or ordering actions by the licensee and other agencies...."

APPENDIX III.2

DEPLOYMENT OF NRC PERSONNEL AND MANAGEMENT STRUCTURE

This appendix contains a detailed description of the deployment of NRC staff in response to the TMI emergency and the changing emergency management structures under which they operated. The material presented covers the first 3 days of the emergency, March 28 through March 30, 1979. The description is subdivided to cover activities at the site, at the NRC Headquarters and at the NRC Region I office (RO:I), in the following sequence.

March 28, 1979

On Site
Headquarters Incident Response Center
Region I IRC

March 29, 1979

On site
Headquarters IRC

March 30, 1979

On site

On Site

March 28, 1979— The first onsite inspection team (OIT) departed the NRC's Region I office in an emergency vehicle and arrived on site at the TMI Nuclear Power Plant by 10:15 a.m. Included in this team were five RO:I inspectors: Donald R. Neely, Team Leader (TL) and Lead Health Physicist (H/P);[1,2,3] Charles O. Gallina, Investigator (I) and Emergency Planning Officer (EPO);[4] James C. Higgins, Operations Reactor Inspector (ORI);[5] Karl E. Plumlee, H/P; and Ronald L. Nimitz, H/P.[6]

Initially, all five members of the first Region I contingent on site reported to the Shift Supervisor's office in the TMI-1 (U 1) Control Room,[7] which had been designated the Emergency Control Station (ECS) by the plant management.[8,9] From there, under the direction of the team leader, members of the OIT deployed and performed various duties around the plant.[10,11]

Neely, with assistance from Higgins,[12] went to the TMI-2 (U 2) Control Room, where they collected data and attempted to evaluate the situation.

Staying in U 1, Gallina,[13] with assistance from Nimitz and Plumlee, established a Command Post (CP) in the Shift Supervisor's office. From there they collected utility data and received updated information from U 2. Through a mutual agreement with Metropolitan Edison (Met Ed) personnel in U 1, they took over communications previously established by Met Ed, an open telephone line between RO:I and U 1 and communicated their findings to the IRC.

Soon after this system of communication was established, and as a result of a direct request from George Smith of the RO:I IRC Incident Response Action Coordination Team (IRACT) management at the Incident Response Center (IRC), Plumlee departed U 1 and went outside to monitor on site and around the exterior of the reactor facility.[14]

Within an hour, a second team departed RO:I in a private vehicle and arrived on site. Included in this car were two RO:I Inspection and Enforcement (IE) inspectors: Walter F. Baunack, Operations Reactor Inspector, and Raymond H. Smith, Investigator.

Upon arrival at the site, the second RO:I contingent (Smith and Baunack) reported to the TMI-1 CP. Shortly after their arrival, because of high airborne activity in the Control Room and the nonavailability of respirators, they departed the plant for the Observation Center, where they remained until late that afternoon.[15]

By 5:00 p.m. they were back on site in TMI-2 with Higgins.[16,17] There, Smith assumed the role of communicator and manned an open telephone line between U 2 and the RO:I IRC, thereby establishing a CP in U 2. Like their counterparts in the U 1 CP, they observed the situation, collected data and other available information, and communicated their findings to the RO:I IRC.

By early evening, with two CPs in operation at the TMI site, the U 1 CP became the center for radiological data collected and communicated to the RO:I IRC, while the U 2 CP became the focal point for all operations-related data collected and communicated to the Headquarters (HQ) IRC through the RO:I IRC.[18,19]

Of the first seven OIT members, Higgins and Baunack were the only two operations-oriented inspectors. Nimitz, Neely, and Plumlee were all Health Physicists, and Smith and Gallina, even though assigned as investigators, also had backgrounds as health physicists.[20,21]

By as early as 12:00 noon the NRC organization on site was in place, and the individual roles were defined. App. Figure III-1 shows the organizational structure of the NRC presence on site that remained in place until early in the evening.

As a function of time, the following schedule reflects the deployment of NRC personnel throughout the plant and off site:

11:00 a.m.-12:00 Noon

U 2

D. Neely, TL, Lead H/P
J. Higgins, ORI

U 1 ECS

C. Gallina, OIT EPO, I, U 1 TL
R. Nimitz, H/P
W. Baunack, RI
R. Smith, I

Onsite Outside Monitoring

K. Plumlee, H/P

By 1:00 p.m., William Raymond, Operations Reactor Inspector, was dispatched from the RO:I IRC and arrived on site by late that afternoon. There he prepared to go on shift later that night to relieve the NRC RIs who worked that day.

12:00 Noon-5:00 p.m.

U 2

D. Neely, TL, H/P
J. Higgins, RI

Observation Center

W. Baunack, RI
R. Smith, I
W. Raymond, RI

U 1

C. Gallina, EPO, I
R. Nimitz, H/P

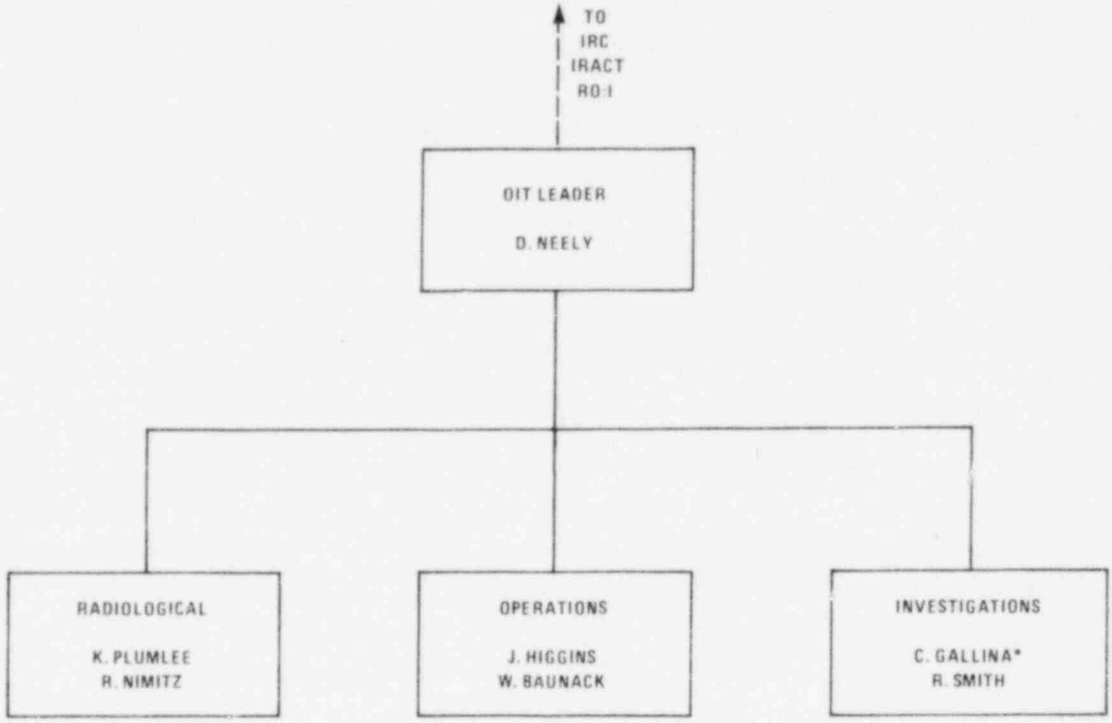
Offsite Monitoring

K. Plumlee, H/P

5:00 p.m.

U 2

D. Neely, H/P
J. Higgins, RI



*Dr. Gallina was the Emergency Planning Officer (EPO) and investigator assigned to the initial OIT. As such, he assumed the job of making sure the team arrived onsite with the proper equipment, and that the emergency aspects of the plan operated smoothly. Subsequent to the team leader's departure from U 1 to U 2, Gallina assumed the duties of team leader for Unit 1.[22]

APP. FIGURE III-1. NRC Onsite Organization on March 28, 1979

W. Baunack, RI
R. Smith, I

Observation Center

W. Raymond, RI

U 1

C. Gallina, I
R. Nimitz, H/P

Offsite Monitoring

K. Plumlee, H/P

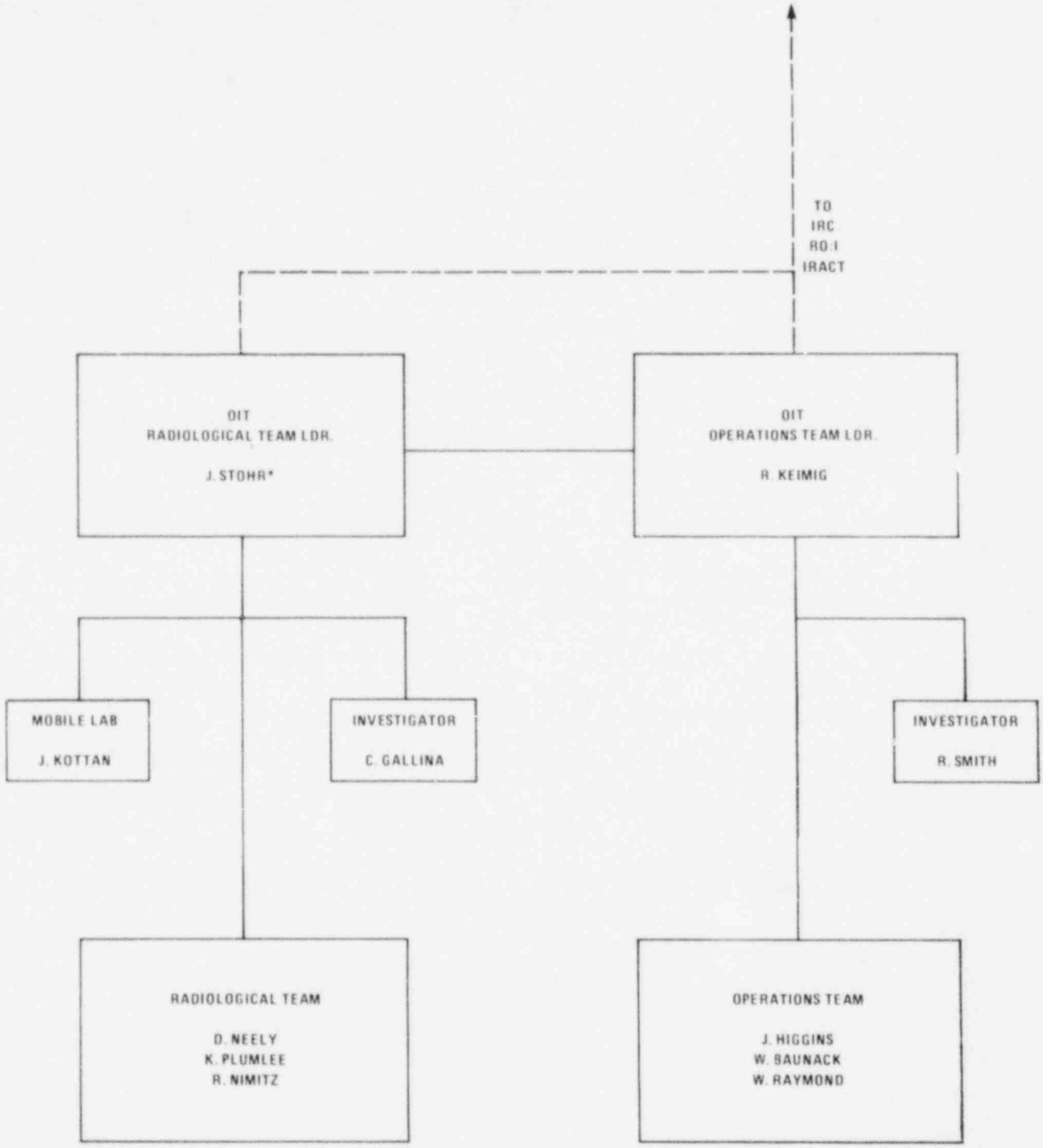
Early in the evening, John Stohr, Chief, Environmental and Special Projects Section, and James Kottan, Radiation Specialist, arrived at the Observation Center in the RO:I radiological monitoring van. They had been called back by the RO:I IRC management from an inspection at the Millstone site in Connecticut. After a quick briefing at RO:I, they departed for TMI.

On his arrival, Stohr was the senior NRC official on site and as such took charge of the OIT. In this capacity, he contacted the team members, checked on the organization and placement of the team, put the mobile laboratory into operation, and established communications with the RO:I IRC.[23]

Later that evening, Richard Keimig, Chief, Reactor Operations Section, arrived on site and shared the management responsibilities with Stohr, taking charge of the operations side of the OIT. Keimig was now the senior NRC person on site and as such also took charge of the OIT.[24-27]

By the end of the day a formal organization and management structure had evolved. The NRC's presence on site had grown from the initial five inspectors to nine inspectors (two investigators, three operations, four health physics), two managers (one operations and one health physics), and a mobile laboratory. All personnel and equipment were from Region I; a total of 11 NRC personnel were at TMI.

App. Figure III-2 shows NRC's organization on site and in place Wednesday night through Thursday afternoon.



*Reported to Keimig; Maintained the Lead in the H/P area; Communicated with RO:I IRC Directly.

APP. FIGURE III-2. Management and Organization of NRC Force, End of Day, March 28, 1979

Deployment of NRC personnel on site and off site at the end of Wednesday, March 28, 1979, was as follows:

Observation Center

J. Stohr, Radiological TL
R. Keimig, Operations TL

Mobile Lab

J. Kottan, Radiation Specialist

U 1 ECS

C. Gallina, EPO, I

U 2

D. Neely, Lead H/P
J. Higgins, RI
W. Baunack, RI
R. Smith, I
W. Raymond, RI

Offsite Monitoring

K. Plumlee, H/P
R. Nimitz, H/P

Headquarters Incident Response Center, Bethesda, Maryland

March 28, 1979— Early in the morning, the NRC Headquarters Executive Management Team (EMT) was notified of the accident at TMI and rapidly started to assemble in the Incident Response Center (IRC) at Bethesda, Md. Concurrently, the emergency management procedures in the Bethesda NRC HQ IRC, also known as the Operations Center (OC), were activated.

In accordance with the criteria (Appendix 0502 of the NRC Manual), groups from NRC HQ would respond through the IRC.

EMT

Pursuant to the criteria stated, the EMT formed. According to the stipulations within its charter, the EMT would be the principal entity exercising the NRC's authority in the case of an accident.

Initially, the team consisted of Lee V. Gossick, Executive Director for Operations (EDO); Edson G. Case, Deputy Director, Office of Nuclear Reactor Regulation (NRR); and John G. Davis, Acting Director, Office of Inspection and Enforcement (IE).

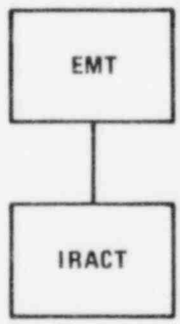
Harold Denton, Director of NRR, who was planning to leave town, originally sent Case to the EMT. It was not until late in the afternoon that Denton arrived at the HQ IRC.

IRACT

With the formation of the EMT, the Incident Response Action Coordination Team (IRACT) started to take shape. Under the direction of Norman C. Moseley, Director (D), Division of Reactor Operations Inspection (DROI), IE, the IRACT drew substantially on NRC HQ staff, principally from IE and NRR, and grew rapidly. On hand at the outset was Victor Stello, Director, Division of Operating Reactors (DOR), NRR.

Eventually, eight additional members of NRC's top IE–NRR management became part of the team. Included were: Dudley Thompson, Executive Officer for Operations (EOO), IE; Harold D. Thornburg, Director, Division of Reactor Construction Inspection (DRCI), IE; James H. Sniezek, Director, Division of Fuel Facilities and Materials Safety Inspection (DFFMS), IE; Elbert M. Howard, Director, Division of Safeguards Inspection (DSI), IE; Samuel E. Bryan, Assistant Director (AD) for Field Coordination, IE; Leo B. Higginbotham, Jr., Assistant Director for DFFMS, IE; Edward L. Jordan, Assistant Director for Technical Programs, IE; and Roger W. Woodruff, Senior Reactor Inspection Specialist, IE.

With the EMT and IRACT in place, the infrastructure of the HQ response was formed. The following chart and schedule reflects the relationship between the two groups, and the people involved in them.



EMT

L. V. Gossick, Director, EMT, EDO
H. R. Denton, Director, NRR
E. G. Case, Deputy Director, NRR
J. G. Davis, Acting Director, IE

IRACT

N. C. Moseley, Director, IRACT, DROI, IE
V. Stello, Director, DOR, NRR
H. D. Thornburg, DRCI, IE

E. M. Howard, DSI, IE
J. H. Sniezek, D/DFFMS, IE
L. B. Higginbotham, A/D DFFMS, IE
D. Thompson, EOO, IE
S. E. Bryan, A/D Field Coordination, IE
E. L. Jordan, A/D Technical Programs, IE
R. W. Woodruff, Senior Reactor Inspection Specialist, IE

Balance of Staff

EMT Support

Forming as rapidly as the EMT and IRACT, other NRC groups were assembled to assist with the accident.

Reporting to the HQ IRC to support the EMT from the Office of Public Affairs came J. J. Fouchard, Director, and F. Ingram, Assistant to the Director. From the Office of State Programs came: R. G. Ryan, Director; R. T. Jaske, Technical Advisor to the Director; B. DeFayette, Reactor Safety Engineering (Emergency Planning); and H. Gaut, Emergency Preparedness Specialist. From the Office of International Programs came R. S. Senseney, International Programs Assistant. From the Antitrust and Indemnity Group within NRR came J. D. Saltzman, Chief, and Ira P. Dinitz, Indemnity Specialist. Arriving from the Division of Operating Reactors, NRR: D. K. Davis, Chief, Systematic Evaluation Program Branch (SEPB).

Meanwhile, at RO:V, R. F. Fish, Jr., Radiation Specialist, and J. Hanchett, Public Affairs Officer, together served a public affairs role, as did Karl Abraham, Public Affairs Officer in RO:I.

Figure III-3 shows the relationship of the EMT support groups with the EMT and IRACT:

The following schedule reflects the NRC personnel as a function of the emergency response, and their relationship with the EMT support staff, EMT, and IRACT.

EMT

L. V. Gossick, Director, EMT, and EDO
H. R. Denton, Director, NRR
E. G. Case, Deputy Director, NRR
J. G. Davis, Acting Director, IE

Liaison/Coordinator

B. DeFayette, Reactor Safety Engineer (Emergency Planning)
H. Gaut, Emergency Preparedness Specialist
D. Davis, Chief, SEPB, NRR

Public Affairs HQ

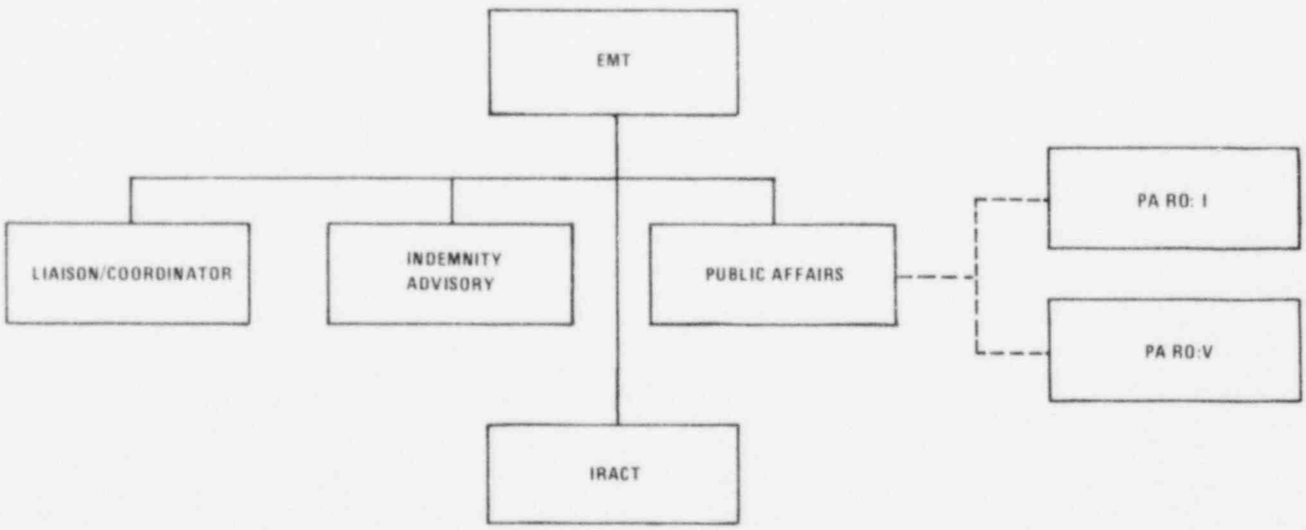
J. Fouchard, Director, PA
F. Ingram, Assistant to the Director, PA
R. Ryan, Director, SP
R. Jaske, Technical Advisor to SP Director
R. Senseney, International Programs Assistant, IP

RO:I

K. Abraham, PA Officer

RO:V

R. Fish, Radiation Specialist
J. Hanchett, PA Officer



APP. FIGURE III-3. EMT and Support Groups

IRACT Support

During Wednesday, personnel resources from within NRC responded to the IRC to assist the IRACT in its mission.

From IE, for operations support, came: B. Weiss, Senior Technical Operations Specialist; R. Paulus, Senior Health Physicist; J. Hegner, Incident and Operations Coordinator Intern; W. Ward, Investigation Specialist; S. Morales, Engineering Aide (Co-Op); T. W. Brockett, Jr., and G. Barber, Enforcement Specialists; and K. Jackson and C. Deliso, Secretaries.

From the Division of Operating Reactors, NRR, came: Darrell Eisenhut, Deputy Director; Brian Grimes, A/D for Engineering and Projects; George Knighton, Chief, Environmental Evaluation Branch; S. Block, Senior Health Physicist, EEB; D. Davis, Chief, Systems Evaluation Program Branch; Lake Barrett, Environmental Evaluation Branch; P. Shemanski, Senior Systems Analyst; M. Mendonca, Reactor Engineer; T. Marsh, Nuclear Engineer; E. Wenzinger, and J. Bland, Radiological Engineer.

From the Division of Systems Safety, NRR, came: Leo Beltracchi, Principal Reactor Engineer (Instrumentation); Reactor Engineers F. Orr and E. Throm; and Senior Reactor Engineer, J. Watt.

From the Division of Site Safety and Environmental Analysis, NRR, came: R. P. Denise, A/D for Site Technology; L. Soffer, Section Leader, Accident Analysis Branch; Robert E. Jackson, Jr., Section Leader, Geology-Seismology Section; Reactor Safety Engineer J. A. Martin; and Geophysicist Phyllis A. Sobel.

From the Division of Project Management, NRR, came H. Silver, Senior Project Manager for Light Water Reactors.

From the Division of Reactor Safety Research, Office of Nuclear Regulatory Research, came Thomas Murley.

From the Division of Fuel Facility and Materials Safety Inspection, IE, came Senior H/P L. Cunningham and H/P L. Cohen.

From the Executive Office for Management and Analysis, IE, came Steven Showe, Chief, PWR Technology Section; and Nuclear Engineers (Instructors) Paul Harmon, Paul Bemis, and Arthur Oxfurth.

From the Division of Reactor Operations Inspection, IE, came Nuclear Engineer Donald C. Kirkpatrick.

From the Division of Reactor Construction Inspection, IE, came Kermit W. Whitt, Chief, Performance Appraisal Branch.

From the Division of Reactor Operations Inspection, IE, came Senior Reactor Inspection Specialists John I. Riesland, Howard A. Wilber, and G. Klingler; and Reactor Inspection Specialist James C. Stone.

James Gagliardo, Inspection Specialist, Performance Appraisal Team, IE, from RO:IV, was in HQ at the time of the accident and contributed his skills to the emergency.

By the end of March 28, the HQ IRC had evolved, and HQ NRC had 71 people directly involved from throughout the agency. From NRR there were 24 people; from IE 35 people; from other groups, 12 people.

Figure 4 and the following schedule of NRC personnel reflects the HQ incident response as an organization and identifies the NRC personnel that responded, their areas of expertise, and the functions they performed.

Personnel Deployment

End of 3/28/79

EMT

H. Denton
E. Case
L. Gossick
J. Davis

IRACT

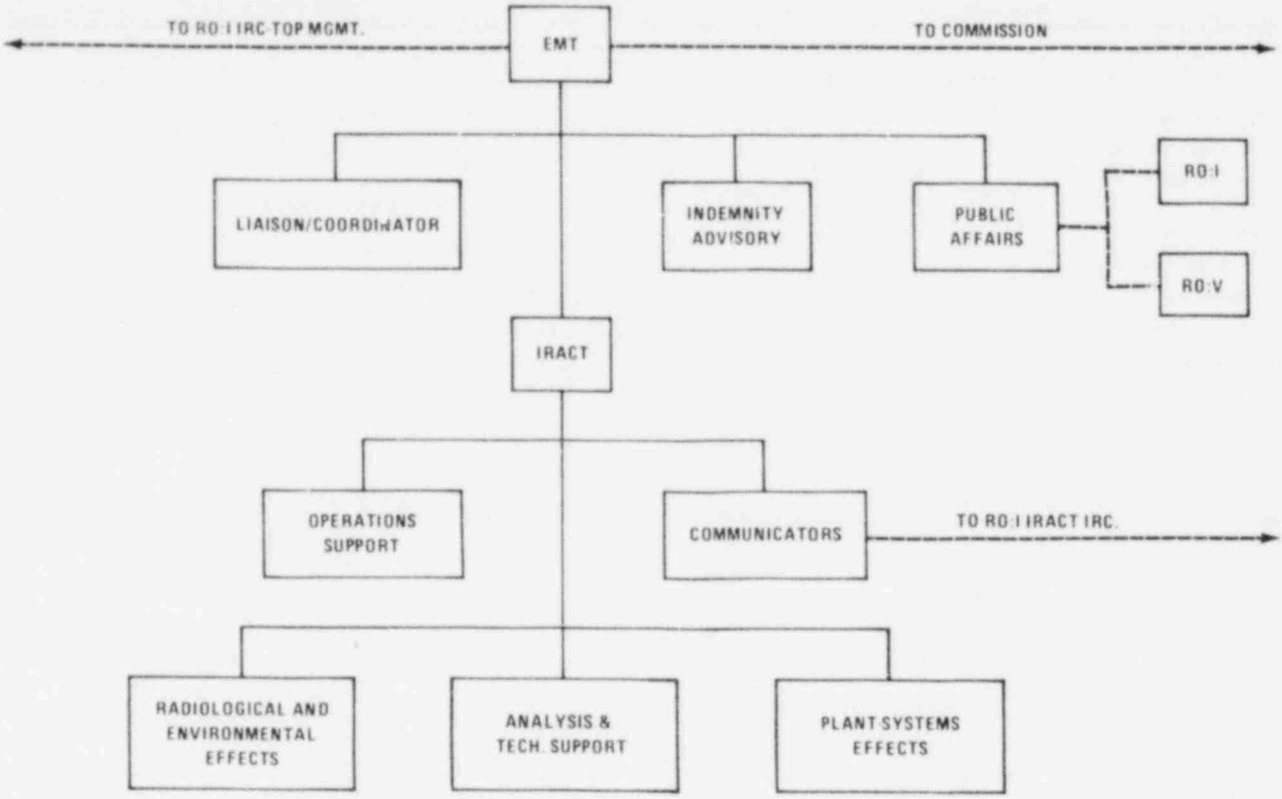
N. C. Moseley, DROI, IE
H. D. Thornburg, DROI, IE
E. M. Howard, DSI, IE
J. H. Sniezek, DFFMS, IE
V. Stello, DOR, NRR
S. E. Bryan, IE
E. L. Jordan, DROI IE
L. Higginbotham, DFFMSI, IE
R. W. Woodruff, IE
D. Thompson, IE

EMT-Indemnity Advisory

J. Saltzman, AIG
I. Dinitz, AIG

EMT-Public Affairs

J. J. Fouchard, PA
F. Ingram, PA
K. Abraham, RO:I
R. T. Jaske, SP
R. G. Ryan, SP
R. S. Senseney, IP



APP. FIGURE III-4. Management Organization and Structure, End of Day, March 28, 1979, at HQ, IRC

RO:V

J. G. Hanchett
R. Fish

EMT-Liaison

B. DeFayette, SP
H. Gaut, SP
D. K. Davis, NRR

IRACT: Operations Support Staff

B. H. Weiss
R. C. Paulus
J. Hegner
W. Ward
S. Morales
T. Brockett
G. Barber
C. Deliso
K. Jackson
D. Eisenhut

IRACT: Communications

K. W. Whitt, Chief, Performance Appraisal, IE
J. I. Riesland, IE
H. A. Wilber, Senior Reactor Inspection Specialist, IE
J. Stone, IE
G. Klingler, IE
J. Gagliardo, IE, RO:V

Analysis-Technical Support

E. Throm, DSS, NRR
T. E. Murley, RSR, RES
J. J. Watt, Senior Reactor Engineer, DSS, NRR
R. P. Denise, DSE, NRR
R. E. Jackson, DSE, NRR
P. A. Sobel, DSE, NRR
T. Marsh, Nuclear Engineer, NRR
A. Oxfurth, Nuclear Engineer, Instructor, IE
P. Shemanski, Senior Engineering Systems Analyst, NRR, DOR, PSYB
M. M. Mendonca, NRR, DOR
F. Orr, DSS, NRR
E. C. Wenzinger, NRR, DOR

IRACT: Plant Systems Effects Group

J. A. Beltracchi, DSS, NRR
H. Silver, DPM, NRR
D. Kirkpatrick, Nuclear Engineer, IE
S. Showe, Nuclear Engineer, IE

P. Harmon, Nuclear Engineer, IE
P. Bemis, Nuclear Engineer, IE
D. Davis, Chief, Systems Evaluation Program Branch, NRR, DOR

IRACT: Radiological and Environmental Effects Group

J. A. Martin, Reactor Safety Engineer, DSE, NRR
L. Soffer, Section Leader, Accident Analysis Branch, DSE, NRR
L. Barrett, DOR, EEB, NRR
J. Bland, DOR, EEB, NRR
G. Knighton, Chief, EEB, NRR
S. Block, EEB, NRR
B. Grimes, AD E&P, NRR, DOR
L. Cunningham, Senior H/P, IE
L. Cohen, H/P, IE

Commission

On March 28, 1979, the Chairman of the agency, Dr. Joseph Hendrie, was not initially available. In his absence, Commissioner Victor Gilinsky acted in his stead. Throughout the day, individual Commissioners and staff members of the Commission tracked the events closely and visited the IRC in Bethesda, Md. From the Commission at the IRC for periods throughout the day were: John Ahearne, Commissioner; Peter Bradford, Commissioner; J. Guibert, Technical Assistant to Commissioner Richard Kennedy; Hugh Thompson, Technical Assistant to Commissioner Peter Bradford; and Vickie Harding, Legal Assistant to Commissioner John Ahearne.

The following schedule of personnel and App. Figure III-5 reflect the Commission involvement and role as it related to the emergency response on March 28, 1979.

Commissioners

J. Hendrie, Chairman
P. Bradford
V. Gilinsky
J. Ahearne
R. Kennedy

Staff

J. Guibert, Technical Assistant to R. Kennedy
V. Harding, Legal Assistant to J. Ahearne
H. Thompson, Technical Assistant to P. Bradford

Region I, King of Prussia, Pennsylvania

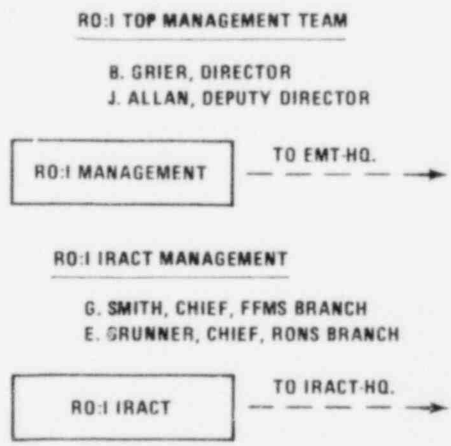
March 28, 1979—On Wednesday, March 28, 1979, at 7:45 a.m., a telephone call was taken in the NRC RO:I office from the TMI nuclear power plant notifying the NRC of the incident at TMI-2. Based on the nature of the call and the substance of the conversation, the NRC RO:I Incident Response Center (also known as the RO:I Operations Center) was activated.

George Smith, Chief, Fuel Facility and Materials Safety (FFMS) Branch, RO:I, assumed the leadership and directed the activities of the RO:I Operations Center and the Incident Response Action Coordination Team (RO:I IRACT) within the Center. Assisting Smith, and serving as a member of the RO:I IRACT, was Eldon Brunner, Chief, Reactor Operations and Nuclear Support (RONS) Branch.

Overseeing and managing the response activities was the RO:I top management: Boyce Grier, Director, RO:I, and James Allen, Deputy Director, RO:I. By virtue of their authority to act during an emergency, and under their direction, the basic structure of the RO:I response was formed.

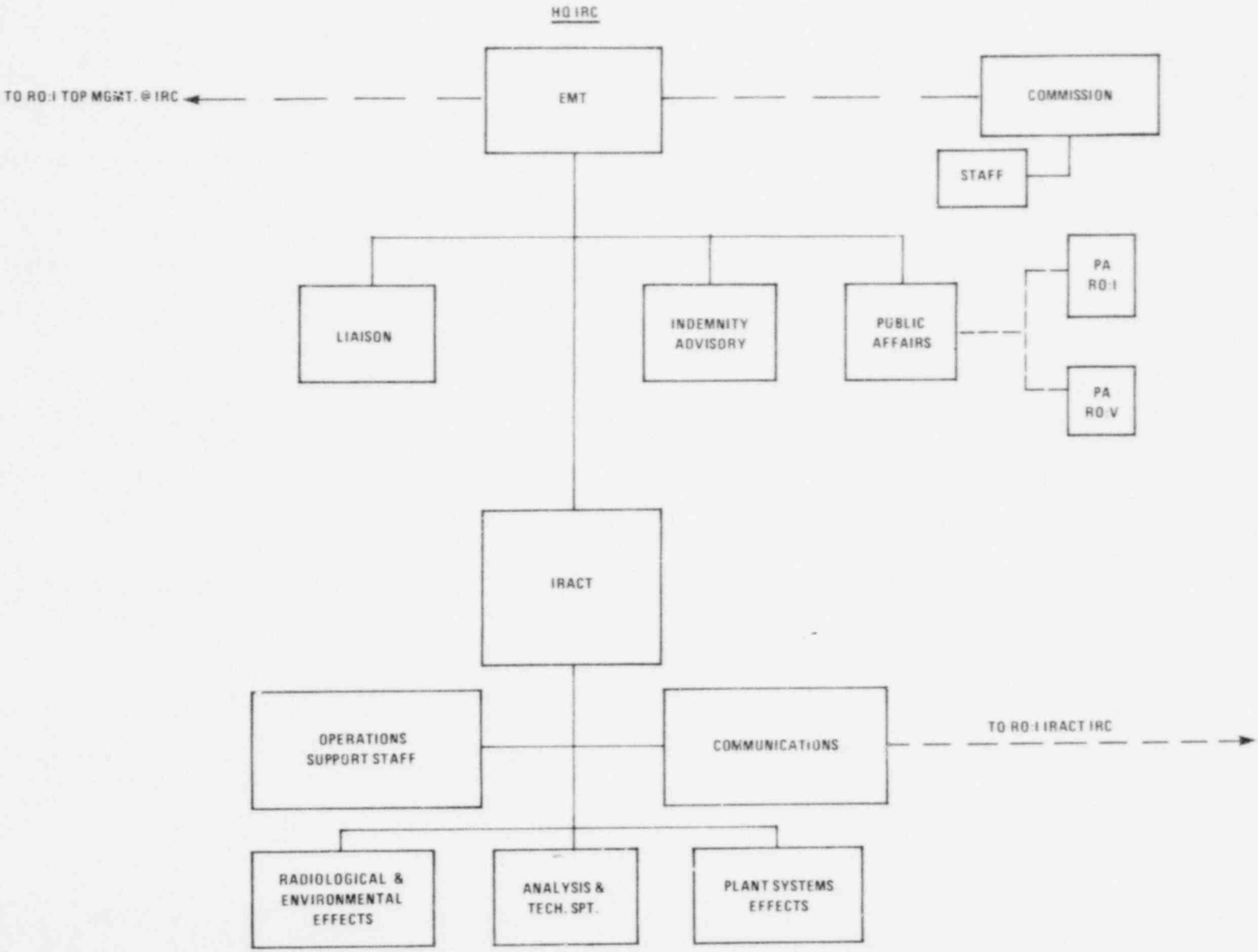
The onsite inspection team (OIT) was assembled and dispatched to the site to gather information and relay it to RO:I. Concurrently, a command post within the RO:I IRC was set up at RO:I and manned with round-the-clock staffing. A system of communications was established between the site and RO:I.

In summary, the following chart and schedule of personnel reflects the early RO:I response.



Under the direction of RO:I, IRACT management, duties, and responsibilities were delegated to the Regional staff.

Directed to notify, coordinate, and act as the liaison between other Federal and State agencies responding to the accident was Dr. Robert Bores, Radiation Specialist, Environmental and Special Projects Section, FFMS. Assisting Bores in this role and serving as the liaison with State agencies was Thomas Elsasser, a Region I-assigned State Liaison Officer.[29]



APP. FIGURE III-5. Management and Organization Structure of Headquarters IRC and NRC, End of Day, March 28, 1979

As directed by George Smith (through Hilbert W. Crocker, Chief, Fuel Facility Projects Section), Donald R. Neely, Radiation Specialist and Senior H/P in RO:I, formed the RO:I Emergency Response Team and was named the team leader by Smith.[30,31]

Assigned as radiological members to the team were: Karl Plumlee, Radiation Specialist and the lead H/P for TMI, Charles Gallina, Investigation Specialist (with an H/P background), and Ronald Nimitz, Radiation Specialist Intern.

Under the direction of Brunner, members were assigned to the OIT. James C. Higgins, Reactor Inspector, was assigned to the initial OIT (through Harry B. Kister, Chief, Nuclear Support Section #2); Walter F. Baunack was assigned to the second NRC RO:I contingent deployed to the TMI site,[32] as was Raymond H. Smith, Investigator Specialist.

In anticipation of the public response to the incident, as is common with most incidents, an office of Public Affairs was established. Initially, Karl Abraham, the assigned Public Affairs Officer from RO:I, handled this function.

As the day went on, and the public's awareness of the incident increased through the news media, the RO:I office was flooded with calls. Compounding the problem was the fact that little information was available in RO:I to accurately assess the situation at TMI. Eventually, more people were called in to assist with the Public Affairs function. One of the people responding was James Joyner, Chief, Nuclear Materials Control Support Section.

The administrative staff provided active support from the very beginning. Telephone communications were established, tape recorders were installed, and communicators manned the phones as the staff obtained key data relayed from the site.

Serving the functions of communicator were Donald L. Caphton, Chief, Nuclear Support Section, and Richard R. Keimig, Chief, Reactor Projects Section (who left for TMI later in the day). Both of these were with the RO:I Reactor Operations and Nuclear Support Branch (RONS). Also serving in this capacity were Nuclear Reactor Inspectors with the RONS Branch William J. Raymond, who also went to TMI later day, and L. H. Bettenhausen and Donald R. Haverkamp (who was also Project Inspector (P/I) for TMI). Joining them from the Fuel Facilities and Materials Safety Branch (FFMS) were John R. White and Lee H. Thonus, both Radiation Specialists.

Supporting the RO:I IRACT in assessing the radiological aspects were Hilbert W. Crocker, Chief, Fuel Facilities and Projects Section, and Gregory P. Yuhas, Radiation Specialist, FFMS.

Supporting the RO:I IRACT in assessing the operational aspects was Ebe C. McCabe, Chief, Reactor Projects Section, RONS.

App. Figure III-6 shows the NRC's organization at Region I and in place throughout the day. Following is a schedule of RO:I personnel that reflects their relationship with the Emergency Response Team.

Personnel Deployment

3/28/79 RO:I IRC

RO:I Top Management

B. Grier
J. Allan

RO:I IRACT Management

G. Smith
E. Brunner

State and Federal Liaison

R. Bores
J. Joyner
T. Elsasser

Administrative Support

(Administrative staff)

Communicators and Records

D. Caphton
R. Keimig
W. Raymond
L. Bettenhausen
D. Haverkamp
J. White
L. Thonus

Operations Assessment Staff

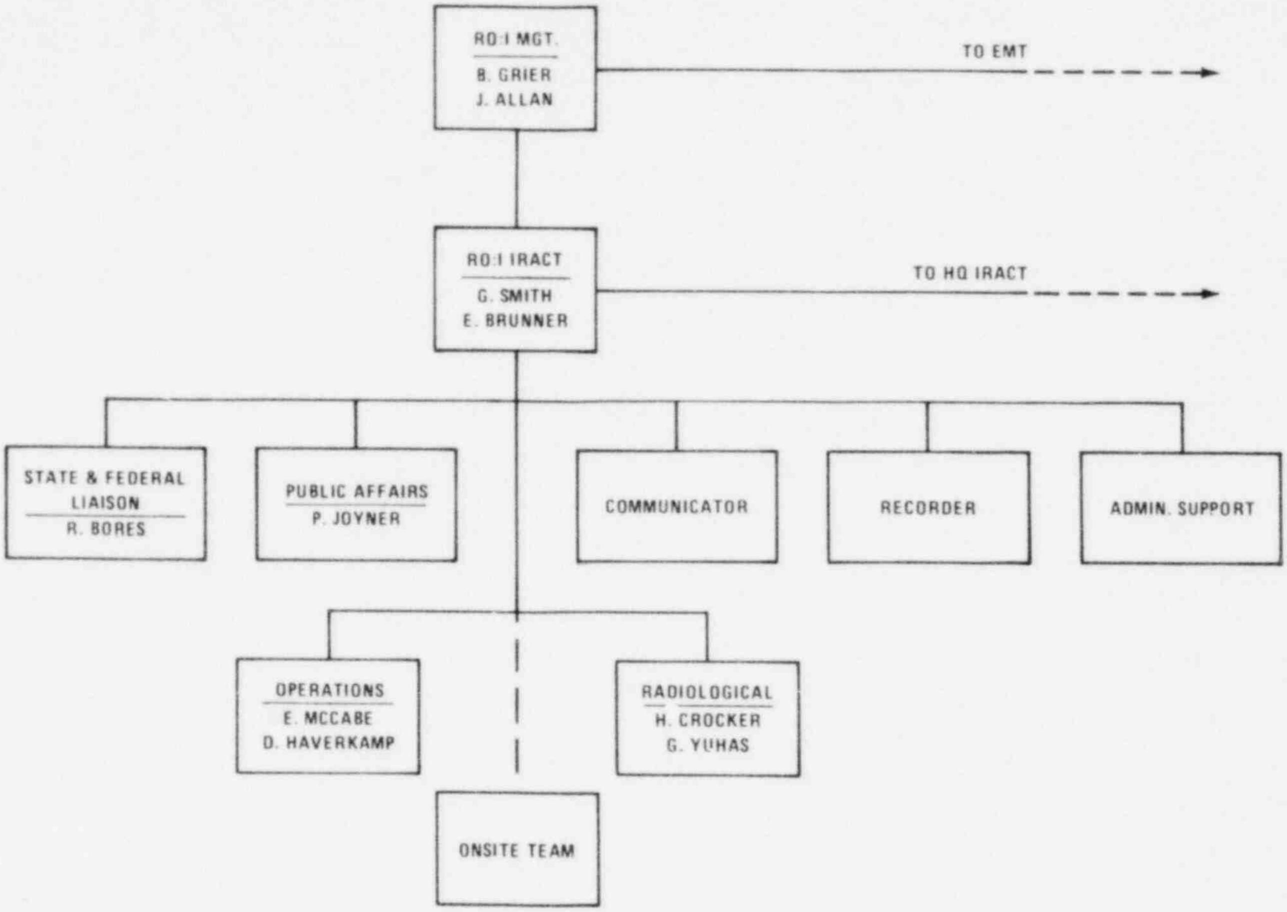
E. McCabe

Radiological Assessment Staff

H. Crocker

On Site

March 29, 1979—As Thursday morning passed, the NRC presence on site grew and became more organized and better defined.



APP. FIGURE III-6. Management and Organization Structure, RO:I Incident Response Center on March 28, 1979

By noon a group of Fuel Facility and Materials Safety (FFMS) inspectors dispatched from RO:I arrived on site. Members of this contingent included F. Costello, T. Jackson, J. Serabian, and B. O'Neill (all FFMS inspectors).

From Headquarters, a licensing and "clean-up" crew was dispatched and arrived on site; it was called the "Vollmer team," after its leader, Richard Vollmer, an operations-oriented member from the HQ Office of Nuclear Reactor Regulation (NRR). Vollmer, prior to his departure, was designated by the NRC management as the person in charge of NRC forces on site.

Another member of the Vollmer team was G. Klingler, also operations oriented, from the HQ Office of Inspection and Enforcement (IE). Klingler was sent by N. Moseley, Director of HQ IRACT of the HQ IRC. His purpose as defined by the HQ IRACT Director was to work with Vollmer as an interface–liaison between the NRR Vollmer management and the RO:I management already in place and on site.[34,35]

Other members with the Vollmer team arriving on site were: G. Mazetis, Plant Procedures/Systems Operation; C. Berlinger, Plant Procedures/Systems Operation; M. Chiramal, Plant Procedures/Systems Operation; F. Ashe, Plant Procedures/Systems Operation; H. Schierling, Plant Procedures/Systems Operation; and E. Adensam, Effluents, Waste, and H/P.

From RO:III, R. Strasma of Public Affairs (PA) was on site.

By mid-Thursday, the NRC structure and management organization on site was formally arranged and was becoming highly organized and well defined. No longer did the NRC onsite team only include NRC inspectors from RO:I; nor did it come under RO:I's control. It was no longer considered an OIT, but now was an NRC team.

In RO:I plans were underway for (and NRC was preparing to institute) an NRC-manned multishift system of surveillance and monitoring of TMI activities.

By shortly after noon, three more operations-oriented inspectors, one being the Project Inspector (P/I) for TMI, arrived on site. Included in this group were: Donald Haverkamp, P/I TMI and Operations Reactor Inspector; D. Beckman, Operations Reactor Inspector; and J. Johnson, Operations Reactor Inspector.

By early evening a third NRC management member from RO:I, E. McCabe, Section Chief, Operations Reactor Projects Section, RONS, was on site.

By the end of Thursday, the NRC presence had grown from 11 RO:I to 28 NRC people, of which Region I IE accounted for 19: 3 management (2 operations and 1 H/P); 2 investigators; and 14 inspectors (5 FFMS, 3 H/P, and 6 operations). A mobile laboratory was in operation.

HQ NRC had eight people on site: one management; one coordinator/liaison, five plant systems and procedures oriented, and one effluents, waste, and H/P oriented. All had operations backgrounds.

One person from RO:III on site was a member of the Public Affairs group.

App. Figures III-7 and III-8 and the following personnel schedule reflect the NRC organization on site, the deployment of NRC personnel throughout the site, and their relationship to the NRC onsite team.

Personnel Deployment

End 3/29/79 On Site

U 1 ECS

D. Neely
C. Gallina, Investigator
F. Costello, FFMS
J. Serabian
B. O'Neill

U 2

J. Higgins, Operations Reactor Inspector
W. Baunack, Operations Reactor Inspector
W. Raymond, Operations Reactor Inspector
D. Haverkamp, Operations Reactor Inspector
D. Beckman, Operations Reactor Inspector
J. Johnson, Operations Reactor Inspector
R. Smith, Investigator
K. Plumlee

Observation Center

R. Vollmer, Management
R. Keimig, Management
E. McCabe, Management
J. Stohr, Management
J. Klingler, Coordinator/Liaison
J. Mazetis, Plant Operations/Systems
C. Berlinger
M. Chiramal
F. Ashe
H. Schierling
E. Adensam
J. Strasma

Off Site

J. Kottan, Mobile Lab
R. Nimitz, H/P
T. Jackson

Harrisburg, PA

K. Abraham

Incident Response Center, IE HQ Bethesda, Maryland

March 29, 1979—From the NRC's perspective, the situation at TMI had improved by late Wednesday. Throughout the night and the next morning, NRC prepared to change its mode of operation, and plans were developed to go from an emergency response mode to an accident clean-up, analysis, and recovery mode.

By Thursday the NRC organization at Headquarters had evolved. The technical staff at the HQ IRC and allied offices was in place, the administrative staffs were functioning, and the management structure was well defined.

A system of shift rotation, personnel deployment, and tours of duty, had been developed as the need arose.

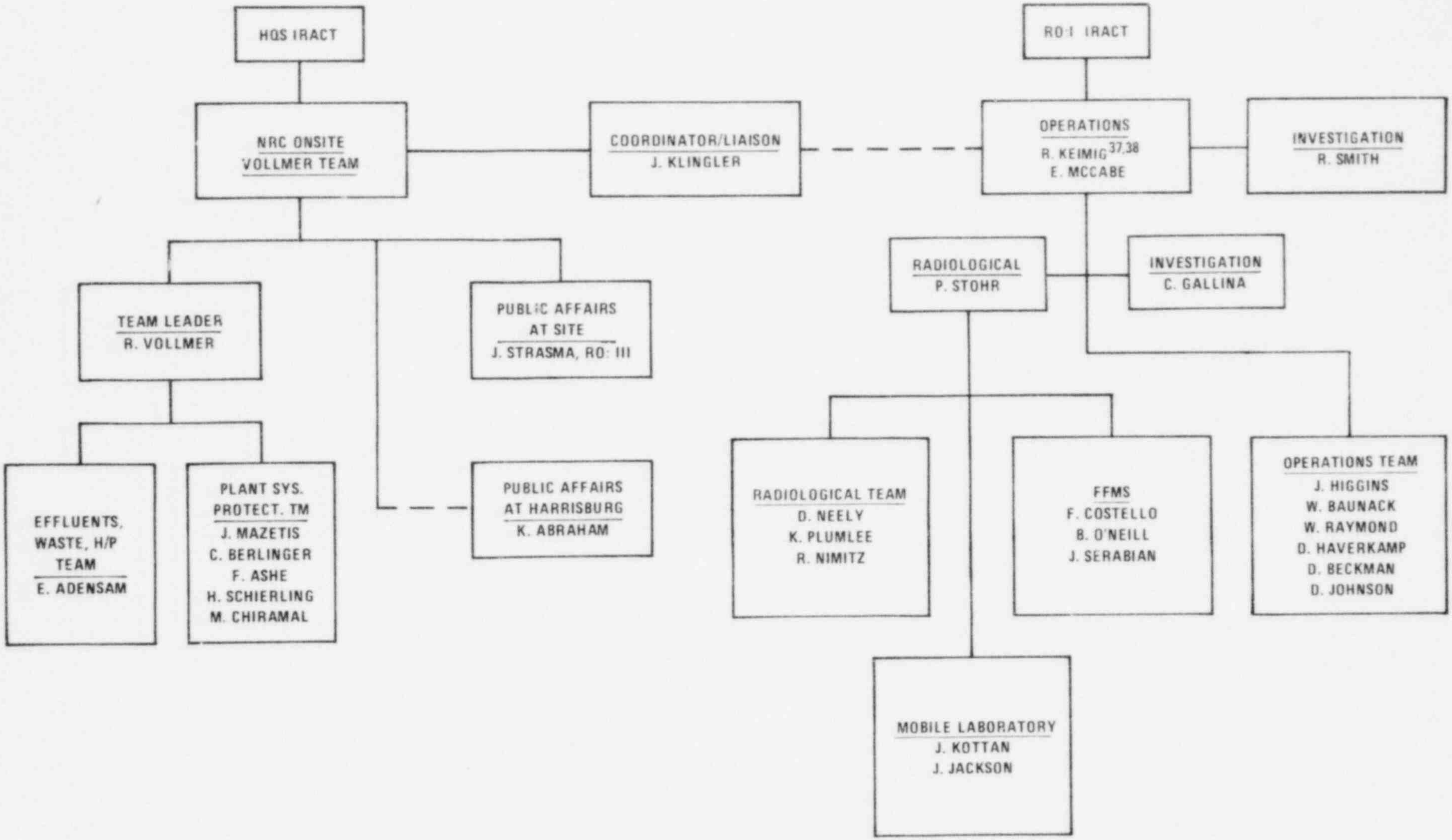
As the need to monitor the situation continued and grew, the personnel rotation system was given more attention and became formally structured.

Personnel involved with the HQ IRC on the previous day were available on Thursday for shift duty. To augment this group, other human resources were needed and were called for.

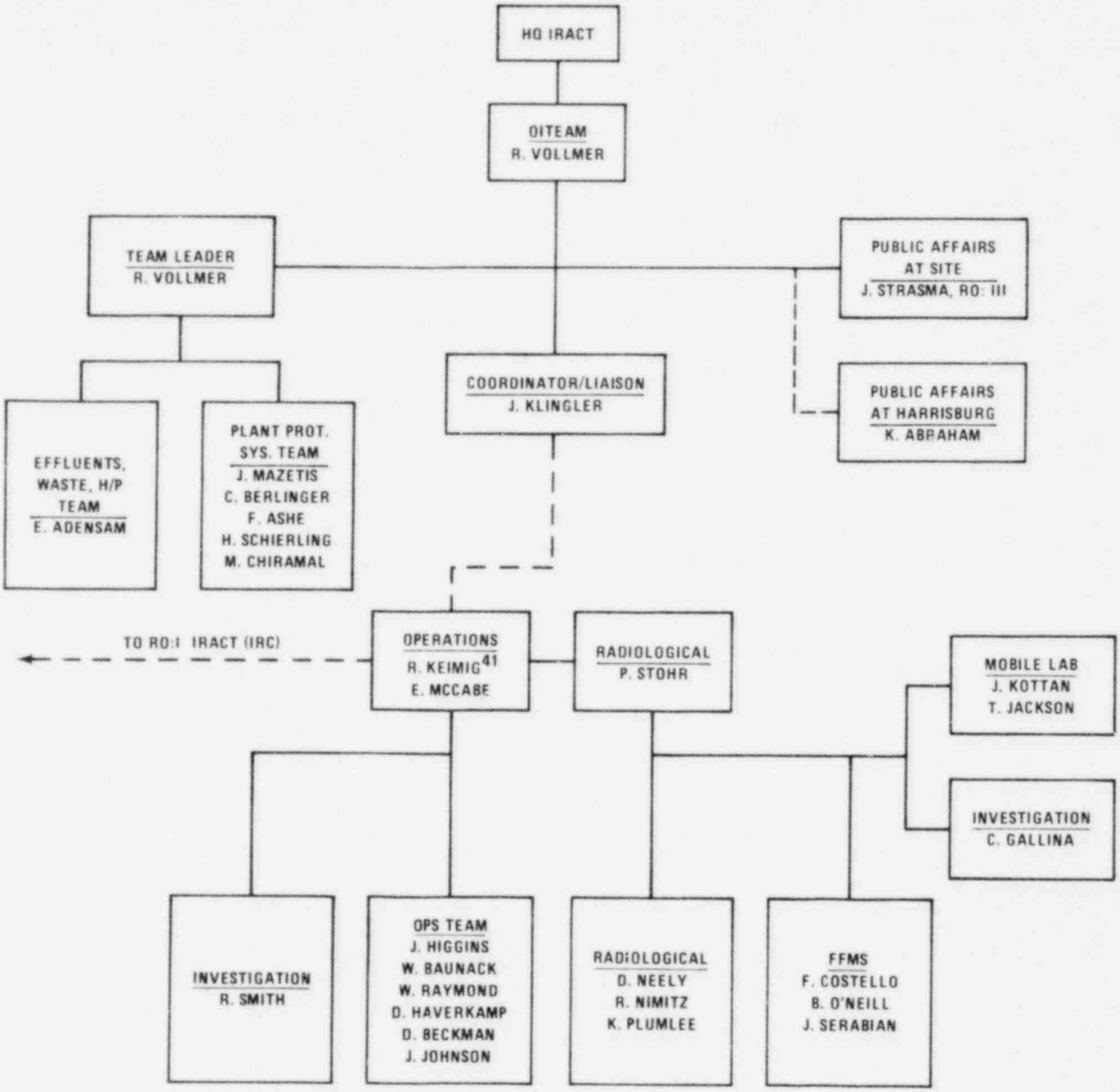
To support the EMT, from the Office of International Programs came Joseph D. Lafleur, Jr., Deputy Director for International Programs and the Assistant Director for International Cooperation, to assist with the liaison team.

From the Office of IE came E. Blackwood, an Inspection Specialist with the Performance Appraisal Team (PAT) to assist as a communicator.

From the Division of Site Safety, Office of Nuclear Reactor Regulation (NRR), came a staff of people to render assistance in the analysis, evaluation, and technical support functions. Included were: W. Minners, Technical Assistant to the Director; R. Tedesco, Assistant Director for Reactor Safety; V. Benaroya, Chief, Auxiliary Systems Branch; L. E.



APP. FIGURE III-7. Onsite Management and Organization Structure, End of Day, March 29, 1979 (as Perceived by Grier and Gallina) (Refs. 35 and 36)



APP. FIGURE III-8. Onsite Management and Organization Structure, End of Day, March 29, 1979 (as Perceived by HQ NRC Top Management) (Refs. 39 and 40)

Philips, Section Leader, Reactor Analysis Section, Analysis Branch; G. N. Lauben, Nuclear Engineer, Reactor Systems Branch; and S. F. Newberry, Reactor Engineer, Reactor Systems Branch.

To assist the IRACT Plant Systems Effects Group, C. DeBevec, Senior Reactor Inspection Specialist with the Office of IE responded.

For radiological and environmental effects came assistance from the Offices of NRR and Research. Representing NRR, from the Division of Site Safety and Environmental Analysis, was F. Congel, Section Leader, Radiological Impact Section, Radiological Assessment Branch, and from the Division of Operating Reactors, Environmental Evaluation Branch, came R. Lo, Nuclear Engineer.

From the Office of Nuclear Regulatory Research, Division of Safeguards, Fuel Cycle and Environmental Research, came P. Reed, Chief of the Environmental Effects Research Branch.

By Thursday, there was no substantial change to the organizational structure; therefore, the structure established on Wednesday remained in effect throughout Thursday (see App. Figure III-5). The schedule of personnel reflecting the NRC people who responded on Thursday, as incorporated with the Wednesday response contingent, follows.

Personnel Deployment

End March 29, 1979 HQ IRC

EMT

Harold Denton
Ed Case
Lee Gossick
John Davis

IRACT

IE Moseley, N. C., DROI
IE Thornburg, H. D., DRCI
IE Howard, E. M., DSI
IE Sniezek, J. H., DFFMSI
NRR Stello, V., DOR
IE Bryan, S. E.
IE Jordan, E. L., DDROI
IE Higginbotham, L., DFFMSI
IE Woodruff, R. W.
IE Thompson, D.

EMT-Indemnity Advisory

Saltzman, J., AIG
Dinitz, I., AIG

EMT-Public Affairs

Fouchard, J. J., PA
Ingram, F., PA
Abraham, K., RO:I
Jaske, R. T., SP
Ryan, R. G., SP
Senseney, R. S., IP

RO:V

Hanchett, J. G.
Fish, R.

EMT-Liaison

Lafleur, J. D., Jr., IP
DeFayette, B., SP
Gaut, H., SP
Davis, D. K., NRR

IRACT: Operations Support Staff

Weiss, B. H.
Paulus, R. C.
Barber, G.
Hegner, J.
Ward, W.
Morales, S.
Brockett, T.
Deliso, C.
Jackson, K.
Eisenhut, D.

IRACT: Communications

Whitt, K. W., Chief, Performance Appraisal, IE
Riesland, J. I., IE
Wilber, H. A., Senior Reactor Inspection Specialist, IE
Stone, J., IE
Klingler, G., IE
Blackwood, E., IE Inspection Specialist Performance Appraisal
Gagliardo, J., IE RO:IV

Analysis-Technical Support

Throm, E., DSS, NRR
Murley, T. E., RSR, RES
Watt, J. J., Senior Reactor Engineer, DSS, NRR
Denise, R. P., DSE, NRR
Jackson, R. E., DSE, NRR
Sobel, P. A., DSE, NRR
Marsh, T., Nuclear Engineer, NRR
Oxfurth, A., Nuclear Engineer, Instructor, IE
Shemanski, P., Senior Engineering Systems Analyst, NRR, DOR
Mendonca, M. M., NRR, DOR
Benaroya, V., DSS, NRR
Minners, W., NRR, DSS
Orr, F., DSS, NRR
Lauben, G., DSS, NRR
Newberry, S., DSS, NRR
Tedesco, R., DSS, NRR
Philips, L., DSS, NRR
Wenzinger, E. C., NRR, DOR

IRACT: Plant Systems Effects Group

Beltracchi, L., DSS, NRR
Silver, H., DPM, NRR
DeBevec, C., SRI, DRO, IE
Kirkpatrick, D., Nuclear Engineer, IE
Showe, S., Nuclear Engineer, IE
Harmon, P., Nuclear Engineer, IE
Bemis, P., Nuclear Engineer, IE
Davis, D., Chief, Systems Evaluation Program Branch, NRR, DOR

IRACT: Radiological and Environmental Effects Group

Martin, J. A., Reactor Safety Engineer, DSE, NRR
Soffer, L., Section Leader, Accident Analysis Branch, DSE, NRR

Congel, F., DSE, RAB, NRR
Barrett, L., DOR, EEB, NRR
Bland, J., DOR, EEB, NRR
Knighton, G., Chief, EEB, DRO, NRR
Lo, R., EEB, DOR, NRR
Block, S., EEB, DOR, NRR
Grimes, B., AD E&P, NRR, DOR
Cunningham, L., Senior H/P, IE
Cohen, L., H/P, IE
Reed, R., EERB, DS, FCER, RES

On Site

March 30, 1979—Early Friday, Region I and HQ independently decided a greater NRC management presence was needed on site.[40]

In RO:I, plans and arrangements were underway to send RO:I top management to the site. By late in the afternoon, a helicopter transported the RO:I Director, Boyce Grier, and the RO:I FFMS Branch Chief and IRACT Director, G. Smith, to the site.

By this time, two more RO:I inspectors had arrived at TMI. They were G. Yuhas and J. White, both with the FFMS Branch, RO:I.

Meanwhile, back at HQ, management was preparing to deploy and establish an onsite ad hoc Executive Management Team (EMT) and NRC–TMI field office. Accordingly, plans were being made, calls were sent out, and preparation was under way to shuttle personnel resources from other NRC Regional Offices to the TMI site.

By afternoon, after Harold Denton was designated as the President's representative on site, a team under the direction of Denton, Director of the Office of Nuclear Reactor Regulation and member of the Executive Management Team (EMT), later called the "onsite team," or OT, flew to the site.

A great many people accompanied Denton to the site. To serve in management capacities: V. Stello, Director, Division of Operating Reactors and originally a member of HQ IRACT; D. Ross, Deputy Director, Division of Project Management; B. Grimes, Assistant Director for Engineering and Projects, Division of Operating Reactors; and D. Mossburg, Secretary to Denton. All of these were from the Office of Nuclear Reactor Regulation, NRC HQ.

To supplement the effluents, waste, and H/P group already established by the Vollmer team on site: John Collins, Chief, Effluent Treatment Systems Branch, Division of Site Safety and Environmental Analysis; W. Kreger, Chief Radiological Assessment Branch, Division of Site Safety and Environmental Analysis; T. Murphy, Division of Site Safety and Environmental Analysis; M. Bell, Division of Waste Management; V. Benaroya, Chief, Auxiliary Systems Branch, Division of Systems Safety; and J. Donohew, Environmental Evaluation Branch, Division of Operating Reactors.

To supplement the plant procedures and systems group on site: J. Holman, Operator Licensing Branch, Division of Project Management; and B. Boger, Operator Licensing Branch, Division of Project Management, both of NRR. For reactor systems: T. Novak, Chief, Reactor Systems Branch, Division of Systems Safety, NRR; and A. C. Thadani, Division of Systems Safety.

Other members of Denton's team accompanying him to the site were J. Fouchard, Public Affairs, and G. N. Lawson, Analysis Branch, Division of Site Safety, NRR.

By early evening personnel from NRC Regions were on their way and arriving on site. From Region II in Atlanta, Ga., came inspectors and section managers. Included were members from the Reactor Operations and Nuclear Support Branch: Reactor Inspectors Richard Wessman, Darrell Hinckley, Ed Verdery, Francis Jape, and John Dyer. From the Fuel Facilities and Materials Safety Branch came Albert Gibson, Radiation Support Section Manager; and Radiation Specialists Herbert Young, Dale Andrew, Gerald Thorpe, George Jenkins, Jr., Roger Zavadoski, Larry Jackson, Daniel Montgomery, and Donald Perrotti.

From Region III in Chicago, Ill., came William Little, Reactor Operations Section Manager; and William Fisher and Thomas Essig, both Section Managers with the Fuel Facility and Materials Safety Branch. With them came Radiation Specialists Robert Greger, Jerry Hiatt, Ronald Paul, Bruce Dicey, Thomas Tongue, William Grant, and William Axelson.

For administrative support from HQ, Division of Facilities and Operations Support came B. A. Love.

By the end of Friday, March 30, 1979, NRC had 74 people onsite: 26 from Headquarters, 23 from Region I, 14 from Region II, and 11 from Region III.

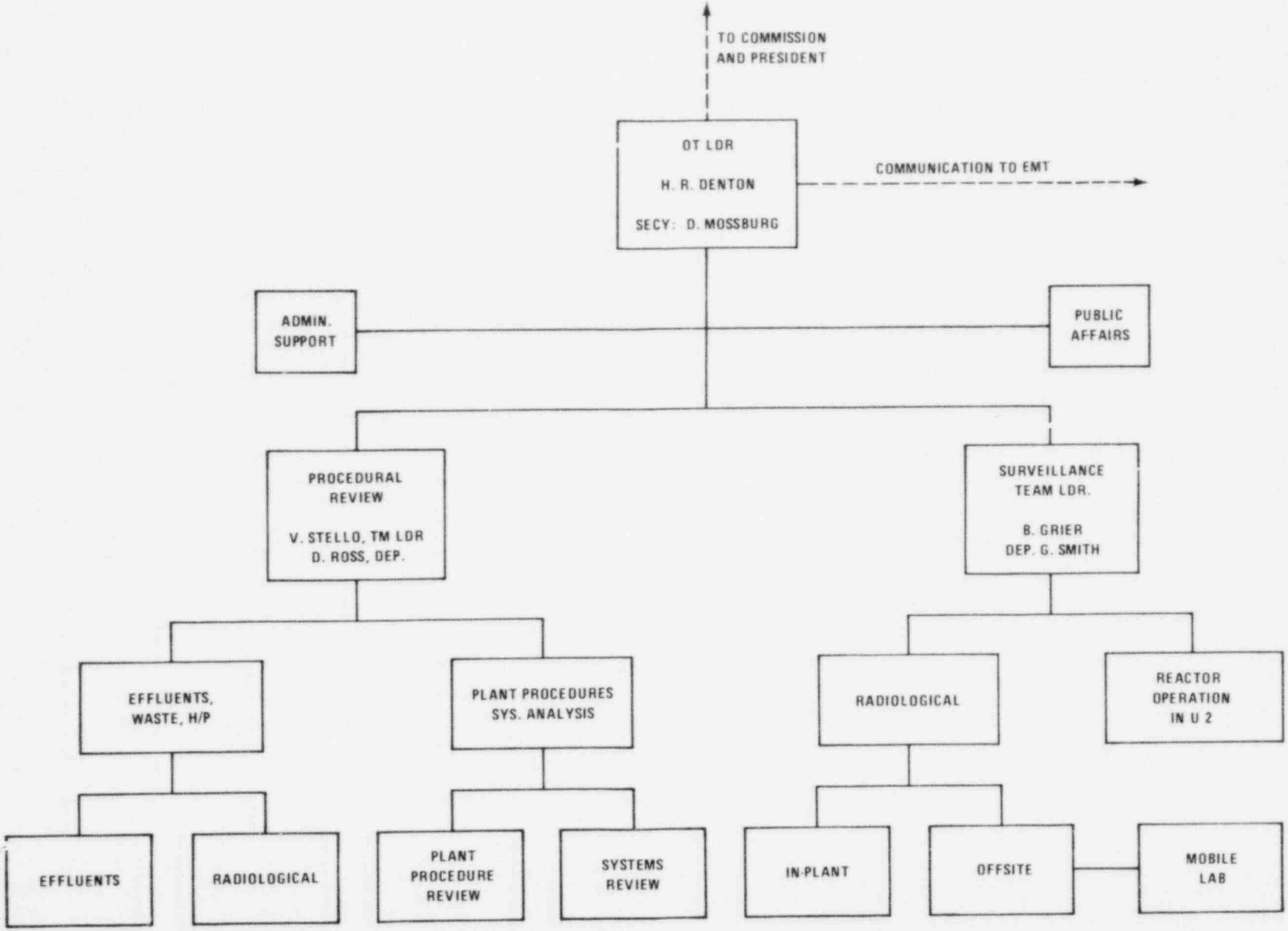
App. Figure III-9 shows the NRC organization on site Friday, March 30, 1979. Following is a schedule of personnel reflecting the NRC members on site in their respective capacities.

Personnel Deployment

End of 3/30/79 On Site

OT Management and Staff

H. Denton, Director
D. Mossburg, Secretary
J. Fouchard, P/A
R. Strasma, P/A, RO:III



APP. FIGURE III-9. NRC Organization Onsite, End of Day, Friday, March 30, 1979

J. Klingler
B. Love
K. Abraham, RO:I P/A, at Harrisburg

Procedural Review Teams

Management

V. Stello, DDOR, NRR
D. Ross, DDir., DPM, NRR
B. Grimes, A/D, E&P, DOR, NRR
R. Vollmer, A/D, DOR, NRR
J. Collins, ETSB, PMgt., NRR
W. Kreger, PMgt., NRR
V. Benaroya, DSS, NRR
T. Novak, DSS, NRR
M. Bell, NMSS
C. Berlinger, DOR, NRR

Staff

J. Holman, DPM, NRR
B. Boyer, DPM, NRR
T. Murphy, DPM, NRR
J. Donohew, DOR, NRR
E. Adensam, DOR, NRR
M. Chiramal, DOR, NRR
H. Schierling, DOR, NRR
A. Thadani, DSS, NRR
G. Lawson, DSS, NRR
J. Mazetis, DSS, NRR
F. Ashe, DSS, NRR

Surveillance Team

Management

B. Grier, RO:I
G. Smith, RO:I
R. Keimig, RO:I
E. McCabe, RO:I
J. Stohr, RO:I
A. Gibson, RO:II
W. Little, RO:III
W. Fisher, RO:III
T. Essig, RO:III

Reactor Operation

J. Higgins, RO:I
W. Baunack, RO:I
W. Raymond, RO:I
D. Haverkamp, RO:I
D. Beckman, RO:I
J. Johnson, RO:I
R. Wessman, RO:II
D. Hinckley, RO:II
E. Verdery, RO:II
F. Jape, RO:II
J. Dyer, RO:II

Radiological

D. Neely, RO:I
R. Nimitz, RO:I
K. Plumlee, RO:I
G. Yuhas, RO:I
J. White, RO:I
F. Costello, RO:I
B. O'Neill, RO:I
J. Serabian, RO:I
J. Kottan, RO:I
T. Jackson, RO:I
H. Young, RO:II
G. Thorpe, RO:II
D. Andrew, RO:II
G. Jenkins, Jr., RO:II
R. Zavadoski, RO:II
L. Jackson, RO:II
D. Montgomery, RO:II
D. Perrotti, RO:II
R. Greger, RO:III
J. Hiatt, RO:III
R. Paul, RO:III
B. Dicey, RO:III
T. Tongue, RO:III
W. Grant, RO:III
W. Axelson, RO:III

Other Staff Members

C. Gallina, RO:I
R. Smith, RO:I

REFERENCES AND NOTES

[1]Neely dep. at 5.

[2]Gallina dep. at 8–10.

[3]G. Smith dep. at 6–7.

[4]Gallina dep. at 7.

[5]Higgins dep. at 8.

[6]G. Smith dep. at 5.

[7]Neely dep. at 6.

[8]Higgins dep. at 15.

[9]Kunder dep. at 94.

[10]Neely dep. at 8.

[11]Gallina dep. at 12.

[12]Higgins dep. at 15.

[13]Gallina dep. at 8.

[14]Region I IRC Tape Transcript 2, at 21.

[15]Baunack dep. at 6–8.

[16]Ray Smith telephone conversation on November 19, 1979.

[17]Region I IRC Tape Transcript 12, pp. 15 and 22.

[18]Sniezek dep. at 13.

[19]Region I IRC Tape Transcript 13, pp. 8–9.

[20]Higgins dep. at 8.

[21]G. Smith dep. at 8.

[22]Gallina dep. at 7.

[23]Stohr dep. at 22–24.

[24]Grier dep. at 8.

[25]Stohr dep. at 22.

[26]Keimig dep. at 13.

[27]Keimig interview (IE), May 7, 1979, at 12.

[28]Stohr dep. at 22.

[29]Bores telephone conversation on November 8, 1979.

[30]Neely dep. at 5, 33.

[31]G. Smith dep. at 6.

[32]Keimig dep. at 6–7.

[33]Moseley dep. at 85–87.

[34]Moseley dep. at 84–85, 88–90.

[35]George Klingler telephone conversation on November 17, 1979.

[36]Grier dep. at 21.

[37]Gallina dep. at 46–47.

[38]Keimig interview (IE), May 7, 1979, at 12.

[39]Keimig dep. at 20.

[40]Smith dep. at 55–56.

APPENDIX III.3

NRC COMMUNICATIONS EARLY IN THE TMI EMERGENCY RESPONSE

Introduction

This independent appendix defines the NRC communications during the initial phases of the response to the accident at TMI-2. It should be noted it is not the purpose of this section to set forth a detailed chronology of NRC communications, but rather to highlight the major events.

Included within this report is a description of the evolution of a data-flow system between the TMI site and the NRC Incident Response Centers. It begins with a general discussion of the substance of information received prior to establishing communications with NRC representatives in the TMI-2 control room.

Appendix III.3 also outlines the principal communications chain, the limitations, and the many modifications made to the initial communications arrangement. It shows the many bottlenecks that information had to pass through between its source and the NRC staff evaluating such information until reliable direct communications were finally established between NRC onsite personnel in the TMI-2 control room and the NRC Headquarters and Regional operations centers 13 hours after the accident began.

1. COMMUNICATIONS: LICENSEE-NRC

At 4:01 a.m. on March 28, 1979, the Station Manager for the Three Mile Island Nuclear Powerplant (TMI) was notified by one of his onsite staff members of the events that precipitated the TMI-2 accident.[1] By 4:35 a.m. the senior TMI-2 supervisors were notified and by 6:35 a.m. the balance of the key station management staff was informed of the accident. By 7:15 a.m., less than 10 minutes prior to the declaration of a General Emergency at the site (which came at 7:24 a.m.), key station management staff had arrived on site and was in the plant.[2]

But it was not until nearly 4 hours after the Station Manager was notified that the NRC learned of the accident at TMI.

The first attempt to contact the NRC came at 7:04 a.m. when an answering service on contract to the NRC's Region I Office received the first call from the site, a call made to notify Region I of the TMI Site Emergency declared 8 minutes earlier at 6:56 a.m.

The answering service tried unsuccessfully a number of times to relay the information to the Region I duty officer at his home, but at the time he was enroute to his office. By 7:38 a.m., 34 minutes later, the answering service successfully paged the duty officer by signalling his beeper; however, because he was so close, he elected to continue to the office.

Before he arrived there however, at 7:40 a.m., another call from the site was received by the Region I answering service. This call was made to notify the NRC that the Site Emergency had been upgraded to a General Emergency 16 minutes earlier. Within 5 minutes, the NRC telephone operator, who also serves as receptionist at Region I, reported for work. She learned of the call from the service and immediately notified Eldon Brunner, the Region I Chief of the Reactor Operations and Nuclear Support Branch (RONS), of this information.[3]

By 7:45 a.m., Brunner had had the call from the site transferred to the office of George Smith, Chief, Fuel Facilities and Materials Safety Branch (FFMS). Smith put the call from the site on the speaker-phone so that Brunner and others now in his office could hear.[4] Based on the information they received, an apparently joint decision was made to activate the Region I Incident Response Center (RO:I IRC).[4,5] Smith departed his office to begin putting the center into operation, but Brunner stayed behind to receive new information and to maintain an open channel of communications with the site.

By 8:00 a.m. the Region I IRC was open, and at 8:10 a.m. the telephone connection between Smith's office and the site was transferred to a speaker-phone in the operations center. The telephone connection with the site was intermittently lost during the next 30 minutes. By 8:39 a.m., however, telephone contact with the TMI-2 Shift Supervisor's office[6] was reestablished and maintained.[6-9]

By about 8:50 a.m., approximately 5 hours after the TMI-2 turbine had "tripped,"[10] the Region I IRC began to "log" data from the site on incident message forms as it was received from the plant over the open telephone line.

The forms included such data as monitor readings, primary pressure and temperature indications, High Pressure Injection (HPI) rate, and notes on efforts to understand what had happened. Region I also began asking questions of the Met Ed personnel concerning meteorological conditions.[11]

By 9:15 a.m. this telephone connection became a continuous open telephone link between the Region I IRC and the TMI-2 control room. On the NRC end of the line at the Region I IRC was Donald Caphton,[12] Chief of the Nuclear Support Section (RONS); on the phone for Met Ed in the TMI-2 control room was Ronald Warren,[13-15] Engineer Senior I, Nuclear.

By 9:26 a.m. Donald Haverkamp, NRC Region I Reactor Inspector and Project Inspector (P/I) for TMI, took over the Region I IRC phone to speak directly to George Kunder, the Met Ed TMI Technical Support Superintendent at TMI-2. They discussed the apparent causes of the accident, the current plant parameters, systems status, pressurizer level, and other conditions related to the Reactor Coolant System (RCS).[16-18]

During this conversation, Gregory Yuhas, Radiation Specialist (RO:I), interjected questions about radiological data.[19]

This system of communications was in effect until 10:17 a.m.[20] At that time all personnel nonessential to the plant's operation were evacuated from TMI-2 because of significant levels of airborne radiation in the TMI-2 control room.[21,22]

Kunder, who was in charge of emergency communications for Met Ed, decided to set up a new telephone station in TMI-1.[23]

Within 10 minutes, at about 10:27 a.m., Walter Marshall,[24,25] Met Ed Nuclear Engineer III, established a communications tie between the Region I IRC and the TMI-1 Shift Supervisor's office. By 10:45 a.m. this open channel of communications was once again being maintained, with Leonard Landry,[26] Met Ed Health Physicist, and later David Smith,[27] TMI-1 Operator, on the phone at TMI-1.

With telephone communications reestablished, Haverkamp directed a series of questions to Smith concerning TMI-2 systems status. Smith turned the telephone over to Gregory Hitz, TMI-1 Shift Supervisor.

Hitz answered Haverkamp's questions dealing with the system's temperature and pressure, but had to leave the phone to get the answers for other questions, and at 10:55 a.m. turned the telephone over to Neely, the NRC onsite inspection team (OIT) leader, who had just arrived in the TMI-1 Shift Supervisor's office.[28,29]

2. COMMUNICATIONS: NRC OIT-NRC OFFICES

By 10:15 a.m., within 2½ hours after the NRC learned of the accident, the initial OIT arrived on site. This initial team of five NRC inspectors (Neely, Gallina, Plumlee, Higgins, and Nimitz) arrived at Three Mile Island about the time all nonessential personnel were being evacuated from TMI-2. Thus, they made their way to the TMI-1 control room.

When they arrived at the plant, at 10:22 a.m.,[30] Charles Gallina called the Region I IRC[31] from an extension telephone at TMI-1 and reported their arrival on site.

After the inspection team's initial orientation and briefing by TMI-1 personnel[32-34] at 10:54 a.m., team leader Donald Neely was summoned to the TMI-1 Shift Supervisor's office by Hitz, who at the time was on the line with Haverkamp at the Region I office. Neely took over the telephone and discussed plant status with the Region I IRC.[35]

Again, the communications system changed when in order to employ NRC personnel on both ends of the line, Caphton of the Region I IRC asked Neely to assign one of the OIT members to monitor the phone line between the Region I IRC and the TMI-1 Shift Supervisor's office.[36]

By about 10:55 a.m.,[37] prior to departing the TMI-1 area, James Higgins of the OIT spoke briefly with William Raymond at Region I and indicated he had not yet been able to obtain the information requested because he had not yet been in the TMI-2 control room.[38,39]

Shortly thereafter, at 11:04 a.m.,[40] Gallina of the OIT was in the TMI-1 Shift Supervisor's office with Neely and functioned as the site communicator with the Region I IRC.

Fifteen minutes later, at about 11:20 a.m., about an hour after arriving on site and some 3½ hours after the NRC learned of the accident, Neely, OIT leader, and Higgins, OIT Operations Reactor Inspector, wearing respirators, finally made their way into the TMI-2 control room,[41,42] while Gallina, remaining at TMI-1, continued to serve as communicator between the TMI-1 control room and the Region I IRC.[43]

Shortly thereafter, at approximately 11:40 a.m.,[44] George Smith of the Region I IRC, spoke with Karl Plumlee of the OIT, who had stayed with Gallina. Smith told Plumlee to take independent air radiation and direct radiation readings.[45]

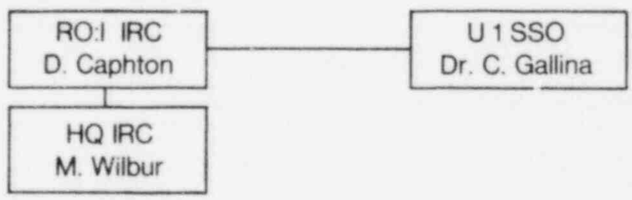
On several occasions during the course of the morning, Caphton of the Region I IRC, on behalf of Region I and NRC Headquarters (HQ), requested data relating to the TMI-2 reactor operations; answers were unavailable until Higgins returned from TMI-2. Walter Baunack of the OIT (who had arrived at about 11:00 a.m. with Ray Smith), was in the TMI-1 control room with Gallina and explained the situation to Caphton.[46]

Because of the high radioactivity in the air at TMI-2, the lack of respirators, and the order to limit personnel in TMI-2 to essential personnel, only Neely and Higgins had gone there to get information. Until they returned, information available at TMI-1 was limited, coming secondhand from James Seelinger, Met Ed U 1 Superintendent. Thus, 7½ hours after the Station Manager was notified of the transient, 3½ hours after the NRC learned of the accident, and an hour after the onsite inspection team arrived, data began to flow from the OIT over the open telephone line to the Region I IRC. By 11:40 a.m. the flow of information over this open telephone line between TMI-1 and Region I was mostly of a radiological and meteorological nature. The initial information consisted of offsite release data gathered by Ronald Nimitz of the OIT from Met Ed offsite survey teams.[47,48] Due to the difficulty of obtaining information from the TMI-2 control room, radiological information was to dominate the available information until about 3:00 p.m.

Shortly after noon, at 12:20 p.m.,[49] the communications systems were once again modified when a three-way tie successfully linked the NRC HQ IRC to the open telephone tie between Region I IRC[50] and the TMI-1 Shift Supervisor's office, where the OIT communicator was located.[51]

On the phone for the HQ IRC, and functioning as communicator, was Mike Wilber, Senior Reactor Inspection Specialist; on the phone at Region I was Donald Caphton; and at the site Charles Gallina continued to serve as communicator.

At a glance, the following diagram graphically depicts this three-way communications system established at 12:20 a.m.



By 1:05 p.m., 1½ hours after members of the OIT went into TMI-2, Baunack reported over the open telephone line from TMI-1 that there was still no contact with Higgins and Neely at TMI-2.[52] Thus, the NRC's information on the TMI-2 reactor status continued to be secondhand reports based on the periodically updated information provided by Met Ed's TMI-1 personnel.

Shortly after 1:00 p.m. the problem was compounded by detection of high levels of radioactivity in the air in the TMI-1 control room, requiring the use of respirators. Again, the number of respirators was limited and OIT members Baunack and Smith, who were not able to obtain respirators, left the plant for the Observation Center across the river.[53,54] Before he left, Baunack informed the Region I IRC he would report in from a telephone at the Observation Center when he arrived. At the same time, Nimitz and Plumlee,[55,56] OIT members, went outside to take radiation readings.

Staying at TMI-1, Gallina began to use a respirator.[57] Because of the nature of a full-face respirator, however, it was difficult for Gallina to communicate and difficult for the IRCs to understand his reports.

In an attempt to improve the communications situation, Gallina put the conference call on a speaker-phone[58] in the TMI-1 Shift Supervisor's office.

At 1:55 p.m. Gallina was still using a respirator.[59] Soon afterward, onsite and offsite data were received[60] at TMI-1 and then communicated by Gallina to the IRCs at Region I and HQ.

By 2:45 p.m.,[61] from a separate telephone line, the Region I IRC successfully contacted the TMI-2 control room.[62] Initially, Met Ed's Sandy Lawyer[63] manned the telephone in TMI-2. Once this second telephone link was established between Region I and TMI-2, Higgins of the OIT, who was in the TMI-2 control room, was able to address the NRC's questions directly. However, contact with TMI-2 using this system was lost several times when Higgins left the phone to go into the plant to get new information, and the unwatched telephone was inadvertently hung up.

With this line between Region I and TMI-2, the overall system of communicating information to the NRC was once again modified. Now, two separate lines from two separate locations at the plant fed data to one location at the Region I IRC over two separate telephone lines.

As operations-related data flowed into Region I from Higgins, Caphton at Region I passed it on to George Klingler, who was at the time an HQ IRC communicator. Caphton also relayed HQ's questions to Gallina of the OIT in the TMI-1 control room. After some uncertainty about the information being requested by the HQ IRC, Wilber, HQ's IRC communicator who relieved Klingler, talked directly to Gallina.

Gallina, in turn, put Hitz, TMI-1 Shift Supervisor, on the phone.[63,64] Speaking directly with HQ, Hitz received their questions[65] and, using the hotline between TMI-1 and TMI-2, spoke with Mike Ross,[66] TMI-2 operator in the TMI-2 control room. As Hitz received status reports, he relayed the information to the NRC over the three-way open line.

At approximately 3:00 p.m., Region I IRC briefly lost contact with Gallina at TMI-1.[67,68] Shortly thereafter, Caphton at Region I IRC reported that the TMI-2 control room personnel were no longer using respirators.[69]

By now, HQ clearly was beginning to dominate the three-way conversation as Wilber, HQ IRC communicator, again conversed directly with Hitz at TMI-1. Hitz was asked: What is the means of cooling down; what is the cool-down rate; what is the pressure, vacuum; what are the parameters, level, pressure, and the feedwater flow; is there any secondary side water activity; and what game plan they intended to use with the power-operated relief release on the pressurizer?

Hitz responded with some answers, but indicated he would have to get on the hotline to the TMI-2 control room to obtain more information.[70]

At about this time, since the TMI-2 personnel were now "off mask," Region I indicated that it would attempt to reestablish a communications tie with the TMI-2 control room. However, since Higgins and Neely in TMI-2 were so busy, Gallina was requested to have another OIT member sent to TMI-2 to act as communicator.[71]

Throughout the next hour, Hitz was back on the phone periodically reporting the TMI-2 status and trying to explain the system's layout by referring HQ to blueprints.[72]

Within the hour Gallina reported that personnel in TMI-1 were no longer using masks.[73]

By 3:56 p.m., Norman Moseley, the HQ IRACT–IRC Director, telephoned Boyce Grier, the Region I Director, and informed him that the HQ IRC was having problems getting operations information from the site. Grier acknowledged his concern and informed Moseley that Region I would set up a new procedure.[74,75]

By 4:05 p.m.[76] a telephone line was once again established between the TMI-2 control room and Region I,[77] but there were still problems because no one was continuously in TMI-2 serving as phone communicator. Region I again asked Gallina to get another NRC person into TMI-2 in order to maintain communications and let it be known also that Region I did not want to lose the line to TMI-1.[78] With this attempt to reestablish and maintain contact with TMI-2, while trying to keep contact with TMI-1, the NRC system of communications was once again modified.

Also by this time, NRC HQ, with Wilber acting as communicator, dominated the conversation over the three-way conference line, querying Hitz about the discrepancies in the hot-leg temperatures,[79] inferring that the data suggested a superheated condition. Wilber questioned the validity of the temperatures reported, and discussed with Hitz the accuracy of the temperature indicators in light of the range of temperatures. Finally, he asked Hitz a new question: "What are the incore temperatures?"

Five minutes later, at about 4:10 p.m., toward the end of the conversation, Victor Stello, the NRR Director, Divison of Operating Reactors, briefly took over the phone conversation with Hitz. They discussed the temperatures, the chances of superheating (which would indicate that the core was uncovered), the possibility of steam bubbles in the core, valve line-ups, and the accuracy of the thermocouples.[80,81]

Again, Hitz indicated he would have to check it out and get more information.

While Hitz was away from the phone trying to obtain answers to HQ's questions, Gallina reported radiological readings. Yuhas, at Region I IRC, questioned the source of the information; Gallina responded by indicating that Met Ed Health Physics Supervisor Tom Mulleavy had just called them in to the State.[82]

Hitz returned to the telephone and, speaking with Wilber at HQ IRC, stated he could not report the incore temperatures because of a problem with the computer or its printer,[83,84] but he did report the hot-leg temperatures and indicated that Met Ed felt there was boiling in both hot legs. However, the TMI-2 people felt that there was no boiling in the core. He then reported the pressure in the pressurizer and the fact that Met Ed was trying to cut the bubble off. Hitz was questioned about why Met Ed felt there was no boiling in the core. He briefly discussed their reasons.[85]

At about this time (4:10 p.m.),[86] Caphton was relieved by R. Keimig as the Region I communicator,[87] and Samuel Bryan relieved Wilber as the communicator at HQ.[88]

Bryan told Keimig that the HQ IRC felt it was apparent that there was boiling in the hot leg.[89]

Hitz came on the line and, when asked by Bryan about the incores, responded that he had not yet checked on them. Bryan then asked him if Met Ed had thought of "simultaneous injection in the hot and cold legs," or if they had considered blowing it down. Bryan informed Hitz he was definitely not telling him to do it, just asking that they consider it. Hitz informed Bryan that he would once again talk to the TMI-2 control room about blowing down.[90]

After the conversation, Gallina reported that personnel in TMI-1 had put their masks back on.[91]

At approximately 4:30 p.m., Bryan informed the Region I IRC and the OIT communicator, who were in the TMI-1 Shift Supervisor's office, that on a separate telephone the HQ IRC had TMI-2 on the line and was about to establish a three-way connection between the Region I IRC, HQ IRC, and the TMI-2 Shift Supervisor's office. Keimig was instructed to hang up so that the three-way connection could be completed.[92]

By 4:34 p.m.[93] the three-way telephone connection was established between the TMI-2 control room, Region I IRC, and HQ IRC.[94]

The establishment of this system resulted in yet another change to the NRC communications system. Finally, after some 6 to 7 hours with a number of only intermittently successful attempts, direct communication were once again established and maintained between the NRC and the TMI-2 control room.

When completed, there was a three-way tie between Higgins in the TMI-2 control room, Keimig at Region I IRC, and Wilbur at the HQ IRC.

The following diagram demonstrates the telephone connection changes that took place and the people manning the phones as communicators and their locations.

Prior to the switch:

After the switch:

Shortly after the switch, Higgins reported the TMI-2 status.[95] He then spoke directly with Moseley, the Director of Reactor Operations Inspection who was serving as HQ IRC IRACT Director, and relayed key operational data and exchanged several ideas as to the current mode of operation in TMI-2 and the actions being taken to control the reactor. Higgins indicated he was returning to the TMI-2 control room to get an update on the plant,[96] and that Baunack and Smith (OIT members) had just arrived and were in the TMI-2 Shift Supervisor's Office.[97,98]

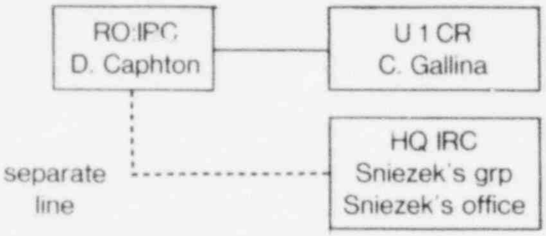
By 5:05 p.m. Ray Smith was manning the telephone in the TMI-2 control room, serving as communicator.[99]

Shortly thereafter, Kermit Whitt became the communicator for the HQ IRC.[100]

By 5:32 p.m., Smith, TMI-2 OIT communicator, suggested that the TMI-1 control room be the source for health physics related questions because Gallina was still there maintaining an open line to Region I and because TMI-1 was the focal point for all incoming radiological and meteorological data.[101]

Following this suggestion, and in order to resolve conflicts between the priority given operations data versus radiological data,[102,103] it was arranged that all operations-related data would flow from TMI-2 and all health physics data would flow from TMI-1.

With this change in the communications system, radiological data flowed to the Region I IRC, was analyzed, and then relayed to the HQ IRC over a separate telephone line as depicted in the chart below:



The operations data remained as shown in the above sketch of "After the Switch" communications. These two channels functioned for the balance of the day until more extensive communications came into existence over the subsequent 3 to 4 days.

In addition, on Thursday night, March 29, 1979, and during the day on Friday, March 30, 1979, a telephone installed Thursday in the NRC Mobile Lab on site was also used for periodic communication of environmental data to the Region I IRC and to HQ IRC.[104,105]

REFERENCES AND NOTES

[1]U.S. Nuclear Regulatory Commission, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," Investigative Report No. 50-320/79-10 (NUREG-0600), August 1979, p. I-3-1.

[2]*Id.* at I-3-15.

[3]*Id.* at I-3-39, 40.

[4]George Smith dep. at 10–11.

[5]U.S. Nuclear Regulatory Commission, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," Investigative Report No. 50-320/79-10 (NUREG-0600), August 1979, p. I-3-39.

[6]Kunder dep. at 92–93.

[7]Keimig Interview (IE), May 7, 1979, at 2.

[8]G. Smith dep. at 11.

[9]Kunder dep. at 94–97.

[10]U.S. Nuclear Regulatory Commission, "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," Investigative Report No. 50-320/79-10, Summary of Operational Aspects (NUREG-0600), August 1979, p. 14.

[11]Region I Incident Message Form C1, C2.

[12]Region I Incident Response Center Transcript 1 at 1.

[13]Region I Incident Message Form C3.

[14]Region I Incident Response Center Transcript 1 at 4.

[15]Warren and Bensel Interview (IE), May 7, 1979, at 1.

[16]Region I Incident Message Form C4-C5.

[17]Region I Incident Response Center Transcript 1 at 5–10, 16–18.

[18]Kunder dep. at 93–96.

[19]Region I Incident Response Center Transcript 1 at 11–15.

[20]Region I Incident Message Form C5.

[21]Region I Incident Response Center Transcript 1 at 18.

[22]Kunder dep. at 94.

[23]Region I Incident Response Center Transcript 2 at 7.

[24]Region I Incident Message Form C5.

[25]Region I Incident Response Center Transcript 2 at 8.

[26]*Id.* at 14–15.

[27]*Id.* at 15–16.

[28]*Id.* at 16–20.

[29]Gallina dep. at 88.

[30]Region I Incident Message Form C5.

[31]Neely dep. at 12.

[32]Gallina dep. at 12.

[33]Neely dep. at 6.

[34]Higgins dep. at 15.

[35]Region I Incident Response Center Transcript 2 at 17–20.

[36]*Id.* at 20.

[37]Region I Incident Message Form C6.

[38]Higgins dep. at 16.

[39]Region I Incident Response Center Transcript 2 at 24–25.

[40]Region I Incident Message Form C6.

[41]Higgins dep. at 15–16.

[42]Neely dep. at 7.

[43]Gallina dep. at 5, 7, and 12.

[44]Region I Incident Message Form C10.

[45]Region I Incident Response Center Transcript 4 at 3–5.

[46]*Id.* at 7–13.

[47]Region I Incident Response Center Transcript 3 at 12-21, 4 at 1–2.

[48]Region I Incident Message Forms C6, C7, and C9.

[49]Region I Incident Message Form C11.

[50]Gallina dep. at 19.

[51]Region I Incident Response Center Transcript 5 at 1.

[52]*Id.* at 1–2.

[53]Region I Incident Message Form C12.

[54]Baunack dep. at 6.

[55]Region I Incident Response Center Transcript 6 at 2.

[56]Region I Incident Message Form C13.

[57]Region I Incident Response Center Transcript 5 at 11.

[58]Region I Incident Response Center Transcript 8 at 8.

[59]Region I Incident Response Center Transcript 7 at 1.

[60]*Id.* at 4.

[61]Region I Incident Message Form C16.

[62]Higgins dep. at 18–19.

[63]Region I Incident Response Center Transcript 8 at 9.

[64]Region I Incident Message Form C18.

[65]Region I Incident Response Center Transcript 8 at 9–15.

[66]*Id.* at 15 and Region I Incident Response Center Transcript 9 at 3.

[67]Region I Incident Message Form C18.

[68]Region I Incident Response Center Transcript 9 at 5–6, 9, and 20.

[69]*Id.* at 6.

[70]*Id.* at 9–25 and Region I Incident Response Center Transcript 10 at 1–7.

[71]Region I Incident Response Center Transcript 9 at 6–7.

[72]Region I Incident Response Center Transcript 10 at 22-25.

[73]*Id.* at 8.

[74]HQ IRC Day 1 Transcript 01-126-CH4/22-HF-1 and 2, and 01-127-CH4/22-[illegible]

[75]Grier dep. at 7–8.

[76]Region I Incident Response Center Transcript 10 at 10.

[77]*Id.* at 12.

[78]*Id.* at 15–19.

[79]Region I Incident Response Center Transcript 11 at 1.

[80]*Id.* at 2–4.

[81]HQ IRC Day 1 Transcript Book 2, 01-033-CH2/20-MEM-6, 7.

[82]Region I Incident Response Center Transcript 11 at 4–5.

[83]Gallina dep. at 19.

[84]Region I Incident Message Form C20.

[85]Region I Incident Response Center Transcript 11 at 6–8.

[86]Region I Incident Message Form C20.

[87]Region I Incident Response Center Transcript 11 at 6.

[88]*Id.* at 10.

[89]*Id.* at 11.

[90]*Id.* at 11–14.

[91]Region I Incident Response Center Transcript 12 at 3.

[92]*Id.* at 3–4.

[93]Region I Incident Message Form C20.

[94]HQ IRC Day 1 Transcript 01-082-CH3/21-Pd 2, 3.

[95]Region I Incident Response Center Transcript 12 at 4.

[96]*Id.* at 14–22.

[97]*Id.* at 22.

[98]Ray Smith telephone conversation on 11/19/79.

[99]Region I Incident Response Center Transcript 12 at 22.

[100]*Id.* at 21.

[101]Region I Incident Response Center Transcript 13 at 8–9.

[102]Sniezek dep. at 13.

[103]Grier dep. at 7.

[104]Stohr dep. at 12, 13, 20–31.

[105]Grier dep. at 18.

APPENDIX III.4

CHRONOLOGY OF TMI-2 HYDROGEN BUBBLE CONCERNS

Mr. Stanley M. Gorinson
Chief Counsel
President's Commission on the
Accident at Three Mile Island
2100 M Street N.W.
Washington, D.C. 20037

Dear Mr. Gorinson:

By letter dated August 30, 1979, you required that a chronology on the hydrogen bubble flammability concern at TMI-2 be provided to the President's Commission by Friday, September 7. It is provided here as Enclosure 1.

An explanation of the development of the chronology should aid in its interpretation. A first draft was compiled on August 20, 1979. On August 21, the first draft was distributed for review by the principal staff involved with the bubble and by the Commissioners of the NRC. Some of the staff participants provided written responses (see Enclosure 2) and some attended a meeting on August 28 to discuss the draft chronology. As a result of the comments received, a number of additions were made. A final draft was prepared and sent to the NRC

Commissioners on August 29 and to a wider segment of the NRC staff on August 30 for review and comment. Substantial additions were again suggested. The memoranda containing these suggested additions are provided here in Enclosure 3. Enclosure 4 is a list of the names and office affiliations of all NRC employees who were afforded an opportunity to comment upon the final draft chronology. Copies of the two draft chronologies and my transmittal memoranda are available in the NRC files for your review, upon request.

Each entry in the chronology is annotated to show the source of the information it contains. The types of sources include transcripts of Commission meetings, transcripts of telephone voice recordings from the NRC Incident Response Center (IRC), contemporaneous notes written by the NRC staff or Commissioners, and memoranda written since the accident. All of these source documents have been made available to the President's Commission. For the sake of brevity, the contents of the transcripts, notes, and memoranda have been summarized in constructing the chronology to highlight the hydrogen flammability concerns.

In addition to such documented entries, the chronology contains a number of "recollections." The only back up sources for the recollections are the minds of the individuals to whom they are attributed. The recollections were given to me in handwritten notes or in conversations to fill in important blanks in the chronology.

I made only a limited personal review of the transcripts of the IRC voice recordings in constructing and editing this chronology. That review was used to corroborate some of the significant milestones.

Where differences in substance were identified between the notes, memoranda or recommendations of two contributors, I called the differences to their attention but did not intervene to require their resolution. It is likely that remaining differences are caused by irreconcilable differences in memory or by the confusion in the IRC from March 29 through April 1 that was generated by poor communications and poor crisis management.

With these caveats, I believe the chronology provided in Enclosure 1 identifies the origins of the concern of the agency with the potential flammable nature of the hydrogen in the reactor coolant system at TMI-2, the sources and nature of the expert advice sought by the agency in dealing with this concern, and the key decisions reached on March 31 and April 1 by the Commission and its principal staff.

Sincerely,

Roger J. Mattson, Director
Lessons Learned Task Force

Enclosures:

1. Chronology of TMI-2 Hydrogen Bubble Concerns
2. Memoranda commenting on first draft of chronology
3. Memoranda commenting on final draft of chronology
4. List of employees given an opportunity to review and comment on final draft.

cc: NRC Public Document Room
All persons listed in Enclosure 4
All persons named in Chronology
Mitchell Rogovin, NRC Special Inquiry
William J. Besaw, DDC

Thursday, March 29, 1979

1800–2200

Lauben (recollection)—Mattson, Novak, Minners, Israel, Lauben at IRC. Information from site indicates unusual "softness" of primary system when attempts were made to depressurize. Discussed possible sources for gas bubble (zirconium–water reaction, radiolysis, steam formation). Estimated radiolysis from TMI FSAR data. Called Matt Taylor on same subject.

About 2030

M. Taylor (memo)—I received a call at home from T. Novak and W. Minners who were at the Bethesda HQ–IRC. Question asked was what would be the radiolytic generation rate of hydrogen if TMI-2 reactor was to be reduced to low pressure levels to permit operation of the low pressure decay heat removal system. Taylor advised that most of his info for making such hydrogen estimates was at Bethesda office, but that he'd try to recall work of approximately 10 years ago and get back to HQ–IRC shortly with an estimate.

About 2200

M. Taylor (memo)— I called Bethesda HQ–IRC (Minners/Novak et al.) with a back-of-envelope estimate for radiolytic hydrogen generation considering near-atmospheric pressure levels and non-boiling bulk coolant temperatures. These estimates made at home relied on past experience and analysis, recall of ORNL experimental work and results, ORSORT notes of 1963, MIT handbook on Reactor Safety (T. Thompson et al.) and extrapolations to and assumptions about TMI-2 conditions. The estimate was roughly 1.4 SCF of hydrogen per hour for these conditions, but HQ–IRC was advised to use a 1–2 SCF of hydrogen per hour range because of considerable uncertainty about actual TMI-2 fuel conditions and fission product releases to coolant, etc. Taylor also advised that if HQ–IRC wanted better estimates and more detail on radiolytic hydrogen behavior, they should make contact with Dr. Bud Zittel of ORNL, or possibly Prof. Reed Johnson, U. Va. (currently technical member on ASLB). Dr. Zittel, in particular, had considerable experimental experience with post-accident radiolysis at our (i.e., AEC) request approximately 10 years ago.

Evening

Novak (memo)— With regard to any information I may have received from B&W regarding the presence of free oxygen in the vessel, I have no recollection of any information transmitted to me on this subject. I do recall having several conversations with B&W personnel during the evening hours of March 29 and for the first few hours of March 30 (before leaving for TMI-2 site) regarding a variety of subjects, but primarily concerned with the state of core coolability and the size of the gas bubble inside the reactor coolant system. My personal recollection is that the members of the staff were evaluating the pros and cons of maintaining the conditions that existed in the reactor coolant system as opposed to depressurizing the system.

Friday, March 30

Morning

Mattson (recollection)— in IRC working on thermocouple data and how to get hydrogen out of reactor coolant system so reactor could be depressurized without interrupting core cooling.

Tedesco (notes)— considering problem of how to get gas out without inhibiting core cooling. Calculated approximately 30 ft^3/day of hydrogen and oxygen at 1000 psi, 275°F from radiolysis (not assuming recombination and therefore conservative). Tedesco estimated effect of releasing 1500 ft^3 of hydrogen from RCS (conservative estimate of volume) was a 2% increase in containment concentration of hydrogen. (Based on COGAP* calculation with G = 0.44 and gamma in core water of 5%).

Milstead (memo)— on Friday, March 30, 1979, Jim Shapaker, Walt Butler and I were requested by Robert Tedesco to try to estimate the contents of a bubble, then reported to be about 1000 ft^3 in volume, in the reactor vessel and its projected growth rate assuming radiolysis of the reactor coolant. We performed analyses of the post-accident generation of hydrogen and oxygen due to radiation induced dissociation of water using the COGAP code. In addition on March 30, 1979, we gathered all the data we could find on the limits of flammability and detonation of hydrogen–oxygen mixtures and the overpressure effect of hydrogen combustion.

* COGAP is a computer code for calculations involving hydrogen–oxygen concentrations within reactor containments. It is used by the Division of Systems Safety in audit calculations performed in review of power reactor license applications. See Appendix A to Standard Review Plan Section 6.2.5.

Hendrie (recollection)—I had a series of discussions with NRC staff at the IRC—notably Denton—on the reactor condition, the releases, etc. During one discussion with Denton on the reactor condition, which included the estimate of a noncondensible volume in the system of about 1000 ft^3 (presumably hydrogen from a large metal-water reaction), I speculated on the radiolytic decomposition rate and on whether free oxygen was being generated and going into the bubble. My initial thought was that the net evolution rate of oxygen was probably small, due to the recombination (or back-reaction). I recalled that a hydrogen-gas overpressure is used in PWR's to inhibit net oxygen evolution in normal operation, and that the effect was probably going on in the present accident condition. However, I wanted an estimate of the net oxygen evolution rate and asked Denton to put some people to work on it. I later repeated this request to other staff members. I also asked for estimates of the flammability limit and the detonation limit (the lowest oxygen concentration, in hydrogen-steam, for upward flame propagation and for an explosive mixture).

Midday

Denton (memo)— My recollection is that Chairman Hendrie was the first to call my attention to the possibility of combustion of the hydrogen within the reactor vessel. Conversation took place by phone on Friday, March 30, sometime after I had arrived at the site. I am fairly certain it occurred after I had been made aware of the pressure spike from hydrogen burning within the containment. I recall that I first heard about the spike while in a car proceeding to the helicopter.

Tedesco (notes)— calculating rate of growth of gas volume by radiolysis using conservative estimate of source terms because of incomplete information of actual TMI-2 situation.

1240

Mattson telecon with Hendrie and other Commissioners (Comm. transcripts)— Mattson summarizes thermocouple data and their implications for staff's earlier conclusion of extensive core damage; reports learning earlier that morning of containment pressure spike on Wednesday afternoon and staff conclusion it was hydrogen explosion; reports methods of measuring volume of bubble in vessel and present size of bubble; concludes that the bubble is mostly hydrogen; indicates that radiolytic decomposition would be very small, therefore bubble must have been caused by considerable amount of metal-water reaction; reports difficulty in finding ways to get rid of bubble without uncovering the core; expressed concern that bubble could grow by radiolysis and eventually uncover the core.

About 1540

Hendrie telecon with Thornburgh (Comm. transcript, pages 126 and 127)—

> *Phone voice*: What are the potentials for an explosion that would rupture the core? Rupture the vessel?
>
> *Chairman Hendrie*: There isn't any oxygen in there to combine with that hydrogen so the answer as far as I know is pretty close to zero.

1600

Lanning (memos)— requested by Ron Scroggins to join himself, Stan Fabic, and Pete Anderson to go to Bethesda concerning accident at TMI-2.

Briefed by R. Budnitz concerning existence of bubble in reactor vessel. Presented data of pressure versus change in pressurizer level and change in incore temperature measurements. Bubble size was approximately 1000 cubic feet @ 1000 psi and 280°F, and increasing. Concerned that core would uncover due to growth. Participated in performing heat-up and boil off calculations for core.

About 1828

Hendrie telecon with McCormick (Comm. transcript, page 192)— Congressman McCormick apparently asked if the hydrogen in the vessel could react. Hendrie replied:

> *Chairman Hendrie*: No, because we're only at a thousand pounds. That will be one of the things that people will be looking at, Mike. I don't know—I don't know—well I ought to be getting an update from the site at any moment now. I'm not sure that—I think the reactor situation will keep it in this state for another day or so probably while we try to think through very carefully the, you know, the route out from here. I don't think, you know, there isn't anything in the core it can react with. You know, ha?; No. There's either none or very little, because the hydrogen got there from a metal-water reaction and you don't get, it isn't a radiolytic bubble.

About 1930

Commission discussion of hydrogen in vessel (Comm. transcript, pages 217 to 225)— Hendrie answers Bradford question on why reactor won't go cold in its present situation:

> Chairman Hendrie: The problem with this thing is that—I'll get to Roger and his troops later tonight. I want a calculation of the radiolytic disassociation rate. At the moment, we've got a hydrogen bubble with some steam—maybe some steam in it in the head of the vessel. It's probably pretty pure hydrogen. The reason is that the evolution is from a metal-water reaction in which you just get hydrogen, you don't get anything else in a gaseous form.
>
> There are two other ways that you get hydrogen in these situations, however, and the one which is of concern is the radiolytic disassociation of water, just ionization; just ionizing the particles of water gives you hydrogen and oxygen.
>
> Now some of the oxygen will trap out as oxide on the structure but some of it will work its way back up. So over some period of time which is probably of the order of many days or a week or weeks, you're going to begin to get enough oxygen up in there to worry about the thing.
>
> And if there's anything I don't particularly think I need at the moment it's flammable—you know, for the bubble to be in a flammable configuration.

This generates a discussion about how long it would take to reach flammable mixture (Hendrie says "a long way out....guessing its some days"), how much oxygen would be required (Hendrie says "you need to get up to 4 percent by volume oxygen to have a mixture which is minimally flammable"), and whether there is oxygen in the bubble (Hendrie says "there's probably no oxygen up there now, but as time goes on, definitely why you'll keep building oxygen...)". Hendrie concludes this part of conversation by saying that he'll make sure a team is started working on radiolytic decomposition calculations.

2000

Lanning (memo)—T. Murley (INEL notes) requested L. Ybarrondo and others at EG&G, Idaho to ascertain the detonation potential of hydrogen gas in reactor vessel (details of request unknown).

After 2000

Lanning (memo)—W. Lanning and T. Murley initiated Semiscale Test to explore venting of bubble through pressurizer relief valve. Obtained system volumes and pipe sizes from Ed Kane at B&W/Lynchburg. Obtained current TMI-2 conditions from Tad Marsh at IRC. Bubble volume in TMI-2 was 1000 ft^3, pressurizer pressure 1100 psi and hot leg temperature 280°F. Noted that pressure surge line had potential for water seal due to geometry layout provided by B&W. Recollect there was a lot of uncertainty concerning size of relief valve opening.

After 2200

Lanning (memo)—Reviewed system description and piping diagrams concerning ways to vent bubble. Reviewed make-up and purification system in attempt to resolve blockage of letdown line.

Evening

Butler (recollection) and John Weeks, BNL (memo)—Walter Butler of NRC asked me to estimate the possible build-up of hydrogen in the containment by radiolysis of water in a high field. I in turn discussed it with Dr. Harold Schwarz of BNL Chemistry Department. His rough guess was that the hydrogen may build-up to several percent which should be approaching the ignition point. The higher the temperature (above 100°C), however, the greater would be the recombination rate and the less the build-up of hydrogen.

After 2240

Hendrie telecon to Eisenhut at IRC (notes and IRC voice transcript)—Hendrie concerned over condition of bubble; Hendrie making calculation that isn't coming out good; Hendrie and Eisenhut estimated volume of helium fill gas in fuel rods; Hendrie says he has asked people to worry about oxygen evolution in the vessel coming from radiolysis; asks Eisenhut to get other people to do a totally independent calculation of evolution rate; Hendrie asks for estimate of detonation pressures; Eisenhut notes his having talked to (Tom) Anderson of Westinghouse to get an independent estimate of radiolysis; Eisenhut says he will also ask Levine and his people to start working on the problem.

About 2300

M. Taylor (memo)— took phone call at site from Chairman J. Hendrie, NRC, who asked that the following item be relayed (note on this call passed to D. Ross): Express concern about oxygen evolution in TMI reactor vessel and possibility of hydrogen/oxygen explosion; he asked for these concerns to be relayed to Bethesda staff so they would get moving on an assessment.

2400

Commission discussion (Comm. transcript, pages 227-229)—After telephone conversation with Stello at site, Hendrie discusses radiolytic decomposition, back reaction in clean and dirty water, change in 4 percent flammability limit as a function of pressure, etc.

Saturday, March 31

0015

Eisenhut (notes)— told Stello at site that IRC concerned with hydrogen explosion—hydrogen and oxygen mixture in dome (of reactor)—notes contain reference to Dr. Zittel of ORNL.

Early a.m.

Hendrie telecon to Eisenhut (notes and IRC voice transcript)— Hendrie asks is gas stripped out in dome (of the reactor) or is it going around in loop? Eisenhut says that Taylor (at site) and B&W are both working the questions on radiolytic evolution of oxygen (and detonation of hydrogen).

0100–0200

M. Taylor (memo)—called Bethesda HQ and relayed to Dr. S. Hanauer the concern about oxygen evolution and the possibility of explosion in the reactor vessel. Taylor asked Dr. Hanauer to assure staff gave prompt attention to this matter.

About 0200

Hendrie telecon to Mattson (recollection)— check oxygen addition rate and potential for RCS explosion; Hendrie calculations of oxygen generation rate indicate there is a problem. Hendrie said he talked to Eisenhut earlier about this problem, but wanted Mattson to confirm that people were working on it.

0200

Minners (notes) telecon to W. Lanning in RES—Research staff getting calculation started on hydrogen explosion. Notes contain reference to Dr. Zittel of ORNL.

0200

Lanning (memo)— Received call from W. Minners who requested a calculation of the explosive force of a stoichiometric mixture of hydrogen and oxygen inside vessel. Assume mixture contents for a 1000 cubic foot bubble at 1000 psi which would produce the largest force.

After 0200

Lanning (memo)— W. Lanning (memory) requested L. Ybarrondo (EG&G) to perform calculation requested by Minners.

Lanning (memo)— monitored progress of Semiscale Test. Transmitted preliminary results of first test to B&W and IRC. B&W requested second test, doubling the size of the bubble and including HPI flow.

0530

Minners (notes) telecon with Jim Taylor of B&W—explosive force of stoichiometric mixture of hydrogen and oxygen (1000 ft^3 @ 1000 psi, 280°F, instantaneous burn) is 14000 psi.

0535

Stello telecon to Eisenhut (notes)— asks for best expected gas evolution rate; can we get burn in reactor vessel or piping?; contingency plan. D. Eisenhut and S. Hanauer tell V. Stello of B&W results for hydrogen burn in RCS (see 0530 above).

About 0700

Lanning (memo)— At request of W. Minners and in coordination with S. Levine, B. Budnitz, T. Murley (and I) supplied information to INEL, Battelle Columbus and Sandia Laboratories to calculate hydrogen burning and explosion potential. S. Levine transmitted results (of the Semiscale test) to IRC. Assisted in evaluating various methods for scavenging hydrogen from primary coolant system.

Early a.m.

Budnitz (recollection)— In conversation with Saul Levine and Tom Murley of RES, either late Friday or early Saturday, the following divisions of responsibility were arrived at. All tasks were to be carried out by contact with contractors and consultants around the country. I was to be in charge of working out at what level of oxygen in pure hydrogen the threshold of combustibility would be reached, and at what higher threshold the explosion possibility would set in. I was then to be concerned with the properties of a fast combustion event and of an explosion, such as the duration of and strength of the pressure pulse inside the TMI vessel from such an event. I was also to be concerned with finding any possible mechanisms that might set off such a combustion or explosion event inside the primary TMI vessel. Finally I was to try to find experts who could suggest and evaluate methods (using chemicals or physical means) to remove or decrease the hydrogen within the primary system.

I recall that Tom Murley undertook the work with Wayne Lanning to study the feasibility of hydrogen removal out the pressurizer relief valve. This last resulted in performance of a quick experiment early Saturday morning at Semiscale at Idaho National Engineering Lab, and another on Monday morning, April 2.

I recall that beginning on Saturday morning Levine and Murley undertook to contact experts on the issue of how much oxygen build-up there would be in the primary system, including the crucial factor of oxygen recombination.

After 0800

Lanning (memo)—W. Lanning (memory) assisted R. Budnitz in evaluating various methods for scavenging hydrogen from primary coolant system. Discussed Minners' request with S. Levine, R. Budnitz and T. Murley.

1030

Hendrie telecon to Mattson (Comm. transcript and IRC voice transcript)—acknowledges that Eisenhut had passed information to Commission from B&W about hydrogen burn in reactor vessel (see 0530 above), and asked about oxygen generation rate and Westinghouse calculation; concerned about rapid approach to flammability. Hendrie asked Mattson to put pressure on getting answer.

About 1035

Commission discussion (Comm. transcript)—Hendrie reports to Commissioners that Denton is working on bubble problem.

1100

Lanning (memo) and Noonan (recollection)—V. Noonan contacted B. Saffel (EG&G) requesting status of finite element reactor coolant system stress model if needed for a hydrogen detonation calculation.

After 1100

Lanning (memo)—Transmitted preliminary results of Semiscale test to B&W (Bob Jones). I recall S. Levine discussing results with someone at IRC.

Discussed results of test with J. Cudlin (B&W) and calculation performed by B&W.

a.m.

Budnitz (memo)—I worked heavily on Saturday and Sunday on the question of understanding the issue of hydrogen combustibility and kinetics in a reactor vessel such as at TMI. On referral from Richard Garwin of IBM, I called Dr. Harry Petschek of AVCO Everett Research Laboratory on the morning of Saturday, March 31, finally reaching him at home in late morning. He responded immediately by indicating that he and some colleagues could assist in understanding the issue of hydrogen combustibility and combustion kinetics in a reactor vessel such as at TMI. Later that day and through Sunday, April 1, I spoke, two or three times, to Dr. Petschek and one or two of his colleagues. I was their sole NRC contact as far as I know. They worked on the question of what concentration of oxygen in pure hydrogen would be the threshold for combustion, particularly at the temperatures and pressures thought to be present at TMI (about 1000 psi at many hundreds of degrees F), and reported back sometime Sunday on those. Dr. Petschek also referred me to Dr. Bernard Lewis in Pittsburgh, who turned out to be a highly-regarded expert in just these same issues. I finally reached Dr. Lewis on Sunday morning, April 1 (see below).

Twice during this period (Saturday, March 31) I talked with Dick Garwin about hydrogen combustion. He gave me insights into how important the back reaction is in a proper calculation of the pressure pulse during a fast burn or detonation of hydrogen in a vessel like the TMI reactor vessel.

Budnitz (memo)—All day Saturday I worked, off and on, on the idea that a snake-like device might be obtained which might be inserted into the primary system to remove the "gas bubble." Dr. Richard A. Garwin of IBM first suggested this idea to me. I telephoned Dr. Heinz Heinemann of Lawrence Berkeley Laboratory on this subject, and on his referral to Mr. Joseph Penick of Mobile Oil. Later that day, Saul Levine contacted Edward Mason of Amoco on the same subject. Although much effort was spent on the part of many people in those companies, and there were many telephone calls back and forth between NRC (me) and various people, neither contact ultimately resulted in anything of use to us.

I contacted Mr. Penick on Saturday morning, March 31. He said that he thought Mobil could assist NRC with advice on the availability of snake-like devices to extract gas from a TMI-like pressure vessel. He called back later during the weekend (I recall his return contact as occurring on Sunday, April 1) and indicated that devices such as we sought were not readily available in the Mobil Corporation, and unlikely to be available elsewhere in the petroleum industry. The problem was that the path into the reactor vessel from the outside to the upper dome was too tortuous for the use of the devices that did exist, and the fabrication of a special device would be quite difficult. I believe that I was Mobil's sole NRC contact on this subject. Our (negative) results were communicated from time to time to the IRC people, mainly to R. Mattson and D. Eisenhut in my recollection.

Budnitz (memo)—As a subsidiary activity on Saturday and part of Sunday, I attempted to find experts around the country who might suggest various chemical means to remove hydrogen from the primary pressure vessel. I first called Dr. Heinz Heinemann of Lawrence Berkeley Laboratory, in the morning of Saturday. Dr. Heinemann is a chemical engineer at my former laboratory in Berkeley and is a colleague and friend there, who spent most of his life working for Mobil Oil Corporation. Dr. Heinemann discussed with me the question of addition of catalytic chemical agents to decrease the hydrogen in water solution. Dr. Heinemann gave me the names of several catalysis chemists who might have expertise in this matter, and also enlisted the advice of two Berkeley colleagues. We talked several times over the weekend of March 31–April 1, but I learned sometime on Sunday, April 1, that this problem was being attacked by engineers at the GPU Service Corporation, and I turned over to Bob Cutler at GPUSC the names of experts I had turned up.

Budnitz (memo)—Dr. Laura Cherubini called me on her own from her home in Billerica, Massachusetts, on Saturday, March 31, with a suggestion of biological/chemical means to reduce or eliminate hydrogen dissolved in the reactor coolant water. I do not know how Dr. Cherubini received a reference to me. The method was to use algae that trap hydrogen from solution by presence of free electron acceptors. Since I was not expert in this matter, I turned it over to others at NRC for follow-up. However, by the time anything more could be done with this suggestion, the perception of the importance of a "hydrogen bubble" had diminished, and I think that no further follow-up occurred.

1050

Mattson (notes) telecon with Tedesco—Discussed results of B&W explosion calculation (see 0530, above). Mattson listed questions for Tedesco to ask of Westinghouse (and KAPL). They were (1) evolution rate, (2) how soon flammable, (3) is oxygen stripping out and going into dome, (4) is oxygen staying dissolved, (5) what does it mean as we go to flammability limit, and (6) how does flammability limit change at high pressure. Westinghouse (Bill Brown) estimated that at 3 days the total gas generation by radiolysis will be 7700 scf.

a.m.

Mattson (notes)—told Tedesco to go to Brodsky to get Naval Reactors help on hydrogen and oxygen problem after 12 noon. Case had suggested to Mattson that Brodsky should be asked to help on this problem.

Levine (memo)—I spoke with Robert Ritzmann of Science Applications concerning hydrogen and oxygen generation rates in TMI-2 vessel in the period March 31–April 1 (starting Saturday a.m.). He informed me that although one could calculate an increase of 1% oxygen per day without considerations of a reformation rate of hydrogen and oxygen due to bubble back pressure, that the 1% rate was probably too high. He also said that he felt the rate was probably no higher than 0.1 percent per day and could be zero, but that he did not have the data to calculate an explicit rate.

I spoke with Dr. Kouts of BNL several times on Saturday and Sunday concerning the possibility of a hydrogen explosion in the reactor vessel. His view was that this would not be likely. He referred me to Harold Schwarz (on Sunday—see 1500 hours) as a source for precise information.

Noonan (memo and recollection)—The Engineering Branch of DOR contributed in the review and evaluation of two main issues regarding the TMI-2 event: 1) Potential overpressure within the reactor coolant system due to a postulated detonation of the hydrogen bubble, and 2) the determination and specification of reactor vessel pressure-temperature limits for various postulated cooldown transients. We did not keep a log of our activities, however, senior members of our staff worked a number of evenings and several weekends as well as regular hours in late March and early April on these issues.

While we were of the opinion (Saturday afternoon) that the hydrogen could not explode due to the sparcity or absence of oxygen (see excerpt of memo by W. Hazelton, below), we were directed (by Darrell Eisenhut) to assume specified hydrogen/oxygen ratios and determine detonation pressures. The actual calculations were performed for us by Dr. Norman Slagg and his staff at USA

ARRADCOM, Dover, N.J., who also had the results confirmed by Lawrence Berkeley Lab., University of California (see Attachment 2). The results of these analyses are in our files. We also had several phone discussions with B&W regarding this matter. EB personnel evaluated the dynamic response of the reactor vessel to the postulated hydrogen detonations.

Noonan does not recall to whom he passed his and Hazelton's concern that Ritzman was in error about the possibility of oxygen being generated. He remembers talking to Research people, with whom he was in close proximity in the Maryland National Bank Building Offices of NRC, and he recalls talking to NRR people by telephone who were located in IE offices just outside the IRC, but he doesn't remember who, specifically, he gave the message to on Saturday afternoon that he believed Ritzman was wrong. Although Noonan felt that there would be no net oxygen generation in the TMI-2 vessel, he knew that others were doing more sophisticated calculations. Therefore, when asked to do the explosion and stress calculations for the reactor coolant system, he and his people proceeded with Dr. Slagg (see below, Saturday evening) to answer what they thought was a conservative question of "what if a flammable or detonable mixture is reached?"

Hazelton (memo)—Because I heard that there was a hydrogen bubble in the reactor vessel, I wanted to evaluate the possibility of hydrogen damage to the reactor vessel material. After coming to the office (about 9:00 a.m.) and checking information in my files, I concluded that there would be no problem in the near term, but this was based on information about 15 years old. Therefore, I decided it would be prudent to check with experts in this field. I called Dr. John Weeks of Brookhaven and Richard T. Begley of Westinghouse, explained the situation and described the conditions. They both called back after several hours and confirmed that my analysis was correct. Mr. Begley reminded me that Dr. Shewman is also particularly knowledgeable in this area, and suggested that I check with him, which I did. Dr. Shewman called back after about three hours and again confirmed my assessment that the specific alloy used in the reactor vessel—(Manganese Moly)—is resistant to hydrogen damage, and that no bad effects would be expected unless the pressure and temperature were significantly increased for long periods of time.

In parallel with this activity, I was helping other members of the Engineering Branch in the assessment of effects of a possible explosion in the reactor vessel. Input to us included the percentage of hydrogen, oxygen, and steam in the bubble. I expressed concern that the oxygen level assumed was far too high, and in fact, I believed that it would be negligible, and no explosion should be postulated. I asked Mr. Noonan to find out why high oxygen levels were being assumed. He found out (from Tom Murley) that a man named Ritzmann was doing the calculations, and obtained his phone number. I called him (about noon), we discussed the approach he was using, and I expressed my concern that no credit was being taken for recombination in the dissociation calculations. He referred to some old work done by Fletcher and Gallagher that I was not familiar with. I then decided to check with the man they had reported to, Paul Cohen (ex-Westinghouse and Bettis, retired), and John Weeks of Brookhaven. They both confirmed that the high hydrogen overpressure would drastically inhibit the dissociation production of oxygen, and in fact, one way to remove the hydrogen might be to add oxygen to the water to "getter" the hydrogen. I relayed this information, including recommendations to check with P. Cohen through Mr. Noonan to the group responsible, but apparently I did not succeed in changing anyone's mind, because for several days I kept hearing on television that the reactor vessel was in imminent danger of blowing up because the oxygen level was increasing to the danger point. I was not pleased.

John Weeks, BNL (memo)—Warren Hazelton asked me what information I had on the thermodynamics and kinetics of the reaction of hydrogen at a high temperature and pressure inside the reactor vessel on the possible decarburization of and methane formation in the vessel material. I discussed this subject with David Gurinsky and J. Chow of BNL, M. Gensamer, Professor Emeritus at Columbia and A. Ciuffreda of Exxon Research. The stainless steel cladding on the inner surface of the vessel would be a partial barrier to hydrogen provided it were intact. There is enough of a chance of a flaw in this cladding, however, that no credit should be taken for it in estimating the performance of the reactor vessel material. The reactor vessel is made of a pressure vessel steel (ASTM A-533-B) which contains 1% Mn, 0.5% Ni and approximately 0.5% Mo. The oil industry is continuously concerned about hydrogen induced decarburization of steels in their refinery equipment. They have prepared a graph stating the safe temperature and pressure for steels (Nelson Diagram) in the American Petroleum Institute report API-941, which was most recently modified in 1977.

A steel of the composition used in the Three Mile Island vessel should be safe from decarburization by 1000 psi of hydrogen at temperatures up to 7000°F for indefinite use. Exceeding this temperature or pressure for short periods would not cause serious damage as there is a definite incubation time, of a matter of several days, before problems begin to develop. Mo appears to be even more effective than Cr in retarding this decarburization although the reasons are not clear. The same steel without the Mo would only be safe up to 500°F at 1000 psi of hydrogen. I think the upper part of the reactor vessel should be carefully checked for any possible damage from decarburization prior to its return to service. A copy of the curve showing this relationship as revised in 1977 is appended to this memorandum.

Hazleton also asked whether radiolysis of the water within the vessel could add oxygen to the hydrogen gas bubble. In my opinion, it should not. Radiolysis of water proceeds by a complex chain reaction and can be prevented even by a small overpressure of hydrogen in an operating PWR. The high hydrogen pressures over the coolant at Three Mile Island should totally prevent oxygen formation. In fact, Harold Schwarz stated it may be feasible to remove the hydrogen by simply adding oxygen slowly to the coolant; this could, admittedly, be risky. I think we should be very careful not to use chemicals such as sulfate or sulfur bearing compounds to react with the hydrogen since these could be reduced by the excess hydrogen to sulfides which are very harmful to a number of the materials in the system, especially the Inconel steam generator tubes. It might complicate the return of the unit to service. I recommended that a nitrate (such as potassium nitrate) be used if one wished to go by this route. However, I think the best means of hydrogen removal would be through venting it from the primary coolant into the containment where it can be recombined with oxygen.

1130

Gilinsky (Comm. transcript)— major hydrogen problem in the pressure vessel.

1145

Gilinsky (Comm. transcript)— people in IRC talking about 10% oxygen.

Commissioners (Comm. transcript)— discussion of vessel rupture by hydrogen explosions in RCS generating missiles or containment rupture.

1145

Hendrie (Comm. transcript)— 1000 cubic feet of hydrogen in vessel, if released to containment, takes you well into the flammability range. Wants an opinion from the flammability crowd—I've got it out working in the vendor shops and elsewhere, Bettis and so on.

Late a.m.

Murley (memo)— On Saturday, March 31, we received a question from the staff at the IRC whether there could be sufficient oxygen gas in the primary system to form an explosive mixture and thereby constitute a threat to the reactor pressure vessel. The answer to this question proved to be elusive.

I discussed this question with staff members from INEL (Sid Cohen, Ron Ayers and Jack Liebenthal). Concurrently, Saul Levine called Bob Ritzmann of Science Applications, Inc., and we understood that Bob Tedesco of NRR was contacting staff at KAPL. The information I received from INEL was based on reported data from the Cooper plant (a BWR) and was scaled down to the power level of 25 MWt. Their conclusions, which they stressed were extremely conservative, were that the hydrogen bubble contained about 2.2% oxygen and that it would take at least 4 to 5 more days to reach 5% oxygen concentration. I was later given some data from the Advanced Test Reactor (ATR) that was purported to support the data from the Cooper plant.

I found it very difficult to piece together all of the information into a consistent story. The Cooper BWR data were not directly applicable to TMI (a PWR) although there was some boiling in the TMI core. Similarly, the ATR is a low pressure (150 psi) reactor and was also not directly applicable to TMI. Late on Saturday evening I received a call from Rob Ritzmann who reported that he was not having much luck in calculating the oxygen concentration, although he believed it was below the flammability limit.

About 1200

Tedesco (notes) called Brodsky— got name and number for Venurs at KAPL.

1200

Denton telecon briefing of Commission and IRC staff (Comm. transcript and IRC voice tape)— general briefing on status at site by Denton. Hendrie tells

Denton that he talked to Mat (Taylor) and Vic Stello last night about a concern that he (Hendrie) had about evolving oxygen from radiolytic decomposition into the bubble. At some of the rates that have been quoted we're either at or getting close to flammability if the 4% limit is correct at 1000 psi. We've got people from Bettis and Westinghouse working on it. Hendrie says this must be considered in the sense of what sort of risk it presents and what does it mean about our judgment on advising the Governor either for some further evacuation—limited evacuation measures or a general recommendation. We didn't cover this scenario with the Governor. Hendrie says either he or Denton should call the Governor and make him aware of it. Denton says he calls the Governor every two hours and will follow up with it the next time he calls.

Two concerns are expressed: 1) are we already close enough to a situation (hydrogen + oxygen explosion in the reactor vessel) where we ought to consider some further evacuation and 2) if we get the bubble out to containment, belief is expressed that we'll be flammable.

1310

Levine telecon to Mattson (notes)— Levine reports that Ritzmann of SAI (formerly at Battelle Columbus Laboratory and a physical chemist used by the Reactor Safety Study for his hydrogen expertise) says 2% oxygen present now, could be 3 depending on g-factor (the rate of production from gammas could be 10 times higher, but Ritzman doesn't believe it). Ritzman also tells Levine that mixture ignition could occur at 8 to 9% oxygen, with detonation higher by factor of 2 or 3. Levine also reports that Sid Cohen (INEL) says 5% oxygen in 4-5 days; 900°F required for spontaneous detonation in wet environment; burns first.

1400

Milstead (memo)—On Saturday, March 31, 1979, we contacted GE personnel at KAPL regarding the TMI-2 program. At about 2:00 p.m. on March 31, we first talked to the GE personnel. We asked them for information regarding the flammability and detonation limits for oxygen/hydrogen mixtures and pressure effects and Navy data on experimental determination of radiolysis rates. We asked that KAPL also use their resources to try to estimate the contents of the bubble and its possible growth rate. The possibility of gamma induced recombination of hydrogen and oxygen was discussed and it was KAPL's initial reaction that recombination in the bubble was not a strong possibility.

1400

Tedesco telecon to Mattson (notes)— Tedesco reported that Westinghouse (Brown) working and Navy (E. Venurs of KAPL) working on hydrogen evolution rate calculation. Depressurization will not get rid of all gas because of high point collection, describes best conditions for depressurizing.

1406

Tedesco (notes)— Westinghouse believes oxygen may stay in solution; at low temperatures, the recombination of hydrogen and oxygen is not likely. KAPL can't preclude free oxygen at this time—oxygen and hydrogen generated by radiolysis not likely to recombine if there is "boil off." Release of all hydrogen in RCS to containment yields 2 volume percent hydrogen increase in containment.

About 1415

Mattson (recollection) briefs Hendrie at IRC– preparing Hendrie for press conference. Described current state of knowledge of IRC staff. Relied on input from Levine (1310 above) and Tedesco (1400 above). I do not recall telling Chairman Hendrie of either a plus or minus uncertainty in the preliminary estimates of Mr. Ritzmann that had earlier been provided to me by Mr. Levine. I do recall telling the Chairman of both the Ritzmann and the INEL estimates relayed to me by Mr. Levine.

1445

Hendrie and Case press conference (transcript)– present situation is not one to hold for a long time; principal problem at the moment is to work out means of working with gas bubble in the vessel; may be prudent to evacuate as precautionary measure when changing status of reactor to deal with bubble; consider evacuation to distances between 10 and 20 miles; considering options for removing gas bubble; concern over potential for explosion of hydrogen in the vessel; working on that problem very intensively; no ignition sources at hand; preliminary indication is that we are some time from any possibility of a flammable condition. Case recalls elaboration on the risks of the various options for continued core cooling—depressurizing or not depressurizing.

1500

Denton telecon to Mattson (notes)— reports that Stello stopped degassing by Met Ed because of concern with hydrogen addition to containment; Denton concerned with hydrogen in vessel; Novak says GPU wrong, bubble size not decreasing.

1527

Full Commission meeting (transcript, p. 28)— in IE directors office with Case and Mattson; concentrated on potential for hydrogen explosion in Reactor Coolant System. Mattson, relying on Ritzman input to Levine, advises that it will require several days to reach flammability limit and he is confident that estimate is not an underestimate of the explosion potential at that time. Uncertainties in the estimates were discussed.

1600

Milstead (memo)—At about 4:00 p.m. on March 31, 1979, we again contacted KAPL. KAPL provided us with the results of experiments run for the Navy to determine the flammability and detonation limits for hydrogen/oxygen mixtures in a range of pressures and temperatures applicable to the TMI problem. Based on their information and our estimates of hydrogen and oxygen concentrations in the bubble, we estimated that we were near the lower flammable limit in the bubble. KAPL informed us that combustion at the lower flammability limit would result in a very small pressure increase (about a factor of 1.2). Based on bubble and oxygen growth rates which we had calculated we estimated that it would take about 10 days to 2 weeks to reach the lower detonable limit in the bubble. KAPL indicated that because of the low temperature in the bubble, they would not predict recombination of hydrogen and oxygen in the bubble. KAPL indicated that gamma induced recombination would be more likely in the reactor coolant liquid and indicated that they were looking into this.

1605

Tedesco (notes) telecon with KAPL— flammability limit curve supplied by KAPL—in 10 days @ 3.5% steam and 10.9% oxygen, can burn—KAPL agrees with Tedesco radiolysis source term of 28-39 cubic feet per day at 1000 psi. Appears now nearing burn threshold but at present 4.7% steam and 4.8% oxygen, the mixture cannot burn. Not close to detonation range for 2 weeks or more—hydrogen and oxygen are not recombining (in the bubble) because of low temperatures—in a nonboiling liquid regime, gamma flux could cause recombination, effective about 1 month after shutdown if oxygen and hydrogen dissolve in liquid. Autoignition is a strong function of amount of water vapor.

1605

Tedesco telecon to Mattson (notes)—answering six questions posed by Mattson at 1050 hours—results of talking to Ernie Vernus of KAPL and Irv Pinkel of NASA—KAPL agrees with conservative estimate of 28-39 cubic feet per day of hydrogen and oxgen at 1000 psi by radiolysis (about 13 cubic feet per day of oxygen). Approaching flammability now (5% mole fraction of oxygen @ 4.7% mole fraction of steam). Detonation limit 10 days to 2 weeks in future. Oxygen probably won't recombine, will stay free, might be some recombination due to gamma flux. 20% overpressure if burned at flammability limit. KAPL had no evidence of spontaneous ignition under present conditions.

About 1625

Hendrie telecon to Thornburgh (Comm. transcript)– discussion of evacuation and NRC press conference earlier that afternoon. Hendrie mentions hydrogen flammability problem and notes that it is not near term; "not something that we have to deal with here immediately."

p.m.

Hazelton (recollection) and John Weeks, BNL (memo)—I estimate that as much as 3200 lbs. of Zr may have reacted with water to produce the hydrogen bubble, assuming it occupied 750 cu. ft. at 500°F and 1000 psi, as stated by Hazelton. This suggests that over 10% of the Zircaloy cladding in the core was converted to oxide by reaction with the water. Whether or not the remaining Zircaloy could act to remove hydrogen from the water by hydride formation is not clear. However, the hydrogen overpressure during normal PWR operation does not cause significant hydriding of the fuel cladding so that hydrogen removal from the bubble by this mechanism seems unlikely. This hydrogen (10-50cc STP/kg H_2O) amounts to a maximum of 3.24 lb. in the primary coolant (329,200 kg) so clearly, the majority of the hydrogen bubble came from some other source such as Zr–H_2O reactions, if the bubble was as large as described by Hazelton on March 31, 1979.

About 1800

Milstead (memo)— We contacted KAPL again on March 31, sometime after 6:00 p.m. KAPL recommended that we not try to bleed the bubble from the RCS to the containment but that we continue to degas while maintaining RCS pressure. They felt there was sufficient likelihood of oxygen recombination in the reactor coolant to continue degassing the coolant through the makeup system rather than release the bubble to the containment.

1800

Tedesco (notes)— update hydrogen/oxygen calculations with new measurement of 880 cubic foot bubble at 875 psi. Result is 5.8% mole fraction oxygen and 4.3% mole fraction steam at this time. (According to flammability limit curve drawn by Tedesco @ 1600 hrs (notes), this is right on the burn threshhold.) KAPL prefers to try gamma induced recombination in the core and vessel rather than bleeding hydrogen into containment where oxygen concentration is high.

Berlinger (recollection)— Lauben and Berlinger (at site) were asked by Stello to provide Stello and Matt Taylor with general information on hydrogen/air flammability and detonation limits. Information was transmitted to Taylor and Stello including 4% flammability limit and 8% detonation limit (most probably 16% at TMI conditions). These figures were off the top of the head best estimates based on our previous experience in combustion processes. Stello was advised to contact Dr. Bernard Lewis (Pittsburgh, Pa.) as a known authority in this area.

1845

Noonan telecon to Mattson (notes)— vessel explosion calculation by consultant Merriman says stoichiometric burn of hydrogen and oxygen (worst case) yields 20,000 psi overpressure. B&W puts in effect of water vapor and calculates 7850 psi total pressure and accounting for enriched hydrogen reduces to 3000-4000 psi. Estimate 11,000 psi to fail bolts, 12,000 psi to fail head (all static pressures, dynamic could be better or worse).

2023

Associated Press editor's advisory (Columbia Journalism Review)—Urgent (with nuclear) the NRC now says the gas bubble atop the nuclear reactor at Three Mile Island shows signs of becoming potentially explosive. A story upcoming. . . (Later press accounts say the mixture is now two to three percent oxygen and could be potentially explosive in about two days when it reaches five percent.) AP apparently relied upon three sources in the 2200 in the NRC staff — Frank Ingram, Ed Case, and an anonymous source. Later on, Denton advised the press at 2130 and again at about 2200 in the Governor's press conference in Harrisburg that the bubble was two percent oxygen, could become flammable at 8 percent, explosive at 16 percent, and there were 12 days before an explosion was possible.

Evening

Denton (memo)— I was subsequently (throughout Saturday) briefed often by Chairman Hendrie and by individuals in the IRC on oxygen evolution estimates and the flammability and detonation limits for hydrogen–oxygen mixtures. The estimates and limits varied with time throughout Saturday. In my meeting with the Governor and in press conferences on Saturday night, I relied upon the most recent estimates obtained by phone from Chairman Hendrie prior to leaving the site for Harrisburg.

My concerns were considerably heightened by the AP story and I returned to the site to determine if our perception of the situation had in fact changed and asked that plans be developed for the possibility that the bubble could not be removed in the next few days.

Early evening

Stello (memo)— Sometime Saturday, I had a call from someone in the White House inquiring about the AP story that had been released. I indicated that I did not know the facts regarding that issue and since there was a reference to statements made by Frank Ingram, I suggested the story was most likely released from Bethesda and referred the caller to the Operations Center in Bethesda. I cannot fix the time, but believe it was probably late afternoon or early evening, Saturday. Shortly after the telephone call referred to above, I recall speaking to Mr. Case in Bethesda, trying to find out the basis for the concern over the hydrogen bubble. This phone conversation provided me with the first insights to the concerns held by personnel in Bethesda. I believe I indicated that I did not share the same concern at that time.

Novak (memo)— With regard to any discussions I had concerning the potential for a hydrogen explosion inside the reactor vessel, the only conversation

I had occurred the evening of March 31. The discussion took place between V. Stello and myself at the NRC trailer complex at TMI. At the time Stello informed me of a concern staff personnel in Bethesda had regarding the potential for a hydrogen explosion inside the reactor vessel. I recall Stello mentioning he did not believe the concern was real but was unable to convince Bethesda staff personnel to change their view.

Evening

Stello (memo)— During the evening of Saturday, March 31, and morning hours of April 1, I asked Mat Taylor to look into the hydrogen problem from the point of view of assuring the need to start the containment atmosphere hydrogen recombiner and the possibility of adding oxygen to the hydrogen bubble believed to be inside the reactor vessel, such that a burn or explosion of a hydrogen-oxygen (mixture) might result.

Mattson (recollection and IRC voice transcripts)— told by Noonan that Dr. Norman Slagg could do authoritative vessel explosion calculations. Asked Noonan to get the work started that night.

About 2000

M. Taylor (memo)—received verbal request from V. Stello to give thought and analysis to following matters and to advise him on these before shift end:

1. Possible "what if" system scenarios and possible consequence outcomes plus best action courses that might be followed,
2. Try to make hydrogen balance calculations to estimate zirconium-water reaction magnitudes and where hydrogen sources might be,
3. Give best judgment on whether or not hydrogen explosion in vessel should be of worrying concern.

Here it should be noted that Taylor recalls discussing with Stello the Taylor estimate of 1.4 SCF of hydrogen per hour (see 2200 hours on March 29). The specific time on March 31 when this information was discussed with Stello is not recalled. It is believed to have been during the latter part of the prior shift, sometime in the am, e.g., 0400–0800.

2200

Anonymous (perhaps Don Davis) notes in IRC of conversation with Jim Taylor on miscellaneous topics— B&W feels that hydrogen recombination is taking place under gamma flux.

Novak (memo)— In reviewing the notes that were available in the IRC, there was indication that B&W had discussed free oxygen after 10:00 p.m. on March 31, 1979. I discussed these notes with Don Davis, formerly of the staff, and he does recall discussions between staff personnel with regard to the amount of oxygen that might be present in the gas bubble. He stated that it was possible he had discussions with B&W (Nitti) regarding this concern. Don Davis also thought that Steve Hanauer was the staff member with whom he had these discussions. I talked to Steve Hanauer on this subject and he noted that he first arrived at the incident center at 2:00 a.m. on March 31 and recalls discussions with Davis regarding hydrogen solubility but none with regard to oxygen. (Ed. note—The conversations described here by Novak were held by him recently, not at the time of the accident.)

Berlinger (recollection)— Lauben and Berlinger (at dinner) discussed the possibility for a hydrogen explosion in the reactor vessel. We concluded, based on available information, that the probability of a hydrogen explosion in the reactor vessel was very remote since oxygen levels in the reactor vessel would have been depleted during cladding oxidation. The effects of radiolysis were unknown at that time.

2230

Levine telecon to Mattson (notes)— INEL says now about 2% oxygen in RCS, oxygen being evolved at about 1% per day. Using Cooper data scaled to TMI-2 decay power level, 12 days required from 10 hours after start of accident until mixture reaches 6% oxygen level, probably no detonation source in the RCS. Ritzman still thinking and working with AVCO experts.

2200–2400

M. Taylor (memo)—in TMI-2 control room participated with V. Benaroya et al., on procedures review and progress toward hook-up of the containment hydrogen recombiners.

Sunday, April 1

About 0100

Murley (memo)— Some time after midnight on Sunday morning, I went to the Incident Response Center where Roger Mattson asked what we were finding. I told him that the picture on oxygen concentration was confused, but that a conservative estimate seemed to be that the oxygen concentration in the hydrogen bubble was increasing at the rate of 1% per day after reactor scram.

About 0130

Eisenhut (notes) telecon Ross (corresponding notes from Ross at site appear to indicate Mattson on phone also)— using makeup adds oxygen, maybe replace air with nitrogen or carbon dioxide. Eisenhut notes say Ross told explosive potential of hydrogen/oxygen bubble was:

2-3% oxygen now in bubble
1% oxygen added per day
6-8% oxygen flammability limit
12% oxygen detonation limit
Have never seen spontaneous detonation.

0200

Tedesco (recollection) telecon with Taylor at site—discussed hydrogen calculations; Tedesco indicated results obtained in Bethesda and given to site were conservative and there was no immediate concern with detonation.

About 0200

M. Taylor (memo)—contacted R. Tedesco (Bethesda) to find out what were latest assessments from Bethesda regarding reactor vessel hydrogen and oxygen concentrations and explosion potentials. Tedesco advised that most recent Bethesda calculations indicated the following concentrations in the reactor vessel (from notes):

∿ 46.5 ft^3, oxygen (radiolysis)
∿103 ft^3, hydrogen (radiolysis)
∿615 ft^3, hydrogen (Zr-water reaction)

∿765 ft^3 (approximates bubble size estimate)

Tedesco also relayed some KAPL info on flammable/detonable concentrations, and he pointed out present estimates indicated that there would be approximately 10 days before explosive concentrations would be reached in the reactor vessel. Taylor recalls Tedesco mentioned some bounding kinds of calculations on the effect of an explosion in the reactor vessel where explosive pressures on the order of 14,000 psi might be experienced. Taylor recalls suggesting again that HQ-IRC make contact with Dr. Zittel of ORNL for added insights on radiolysis behavior.

0300

Anonymous notes in IRC call from Olshinski at site—relays bubble measurement procedure being used by Met Ed.

0430

Eisenhut (notes) telecon with Dr. Marty Haas @ Univ. of Buffalo—KAPL document as source of hydrogen solubility, detonation limits and peak overpressures. Eisenhut "passed info to bubble group of staff."

About 0800

M. Taylor (memo)—advised V. Stello as to the following:

1. Hydrogen balance estimates were very rough, but these suggested a Zr-water reaction magnitude in the range of 25-32% [Note these estimates depended on assumptions about reactor vessel bubble size and on the nature (local vs. free-field) of the hydrogen deflagration observed at roughly 9-10 hours into the accident. Review of pressure recorder spikes suggested local as opposed to a free-field deflagration in containment.]
2. Personal judgment was that he (V. Stello) should not worry about the explosion in the reactor vessel since this was considered to be an exceedingly remote possibility. [Note that due to the press of shift change activities, the reasoning underlying this personal judgment by M. Taylor was not fully explained to V. Stello. Reasoning relied importantly on recall of the ORNL radiolytic work done for AEC approximately 10 years ago. This work covered various post-accident coolant chemistries, temperature conditions and system configurations—flowing and static. Importantly, those experiments where basic ph chemistries were involved led to highest hydrogen yields approaching 7-8 atmospheres (recall) before recombination terminated the net yield of hydrogen and oxygen by radiolysis (i.e., back and forward reactions were equal). This suggested no net evolution of oxygen should be anticipated at the actual TMI-2 reactor vessel conditions of 900 to 1000 psi. Further, the ORNL work with these basic coolant chemistries were assumed to approximate the TMI conditions where NaOH had actually been introduced early in the accident. This ORNL work of approximately 10 years ago also indicated an interesting oxygen scavenging behavior, i.e. oxygen evolution was not stoichiometric with hydrogen. This behavior further suggested that any free oxygen (if it possibly existed in the bubble space inasmuch as this might be attributable to the use of non-degassed water from the borated water storage tank) could be subject to the same scavenging

behavior. These above factors when taken with the realization that the hydrogen reducing environment at TMI probably exceeded, by far, the routine reducing environment usually used in PWRs, plus the need for an ignition source, led to a judgment that a hydrogen explosion in the reactor vessel was of an extremely remote possibility.]

3. Tedesco's estimates were described
4. Some possible "what if" scenarios and thoughts were available for discussion when Stello had further time and need to consider these.

Early a.m.

Stello (memo)—This issue (hydrogen combustion in reactor vessel) was discussed on and off during that period (late March 30 and early April 1) and my best recollection is that it was concluded that no net oxygen would evolve as a result of radiolysis since the back reaction due to the hydrogen overpressure would force all of the oxygen produced to be recombined with the hydrogen to form water.

Neglecting the hydrogen overpressure, results of analysis by Mat Taylor suggested an oxygen evolution rate of about 30 standard cubic feet per day could occur. With this evolution rate, it would take many weeks to reach a flammable mixture. Mat Taylor's advice to me was that I should not have any concerns for the potential of a hydrogen burn or explosion within the reactor vessel.

I believe I also requested others to seek information from representatives of various companies that were located at the site. I believe John Collins returned with some information that suggested GPU (and possibly B&W) also did not consider the hydrogen in the vessel to present a hazard from a burn or explosive nature.

0840

Eisenhut (notes) telecon Vollmer at site—no firm info (at site) on gas in reactor vessel; Taylor thinks not flammable.

About 0840

Eisenhut (notes) conversation with Mattson–
Ritzmann using ORNL and AVCO and Tedesco using KAPL and Westinghouse estimate:

> oxygen production rate 1% per day by radiolysis,
> 5% oxygen in pure hydrogen is flammability,
> 12% oxygen in pure hydrogen is detonation,
> impurities raise these values, but Budnitz says not much.

Budnitz says that microscopically, at almost any temperature, the mixture might possibly ignite on sharp surfaces so unclear whether KAPL and others are right about no spontaneous ignition at flammability limit. Tom Murley quotes Picattiny Arsenal (Slagg) as source on hydrogen flammability.

0900

Berlinger (recollection)—Berlinger at site was asked by Stello/Vollmer to calculate the change in containment hydrogen concentration which would occur if the RCS bubble, assumed to be all hydrogen at 1000 to 1500 ft^3, 875 psia and 300°F, was vented to containment. The analysis results were transmitted to Stello/Vollmer and left in the NRR trailer files. The results indicated a change in containment hydrogen concentration from 1.9% to 3.5%. Since the hydrogen concentration in containment was stabilizing at 2% the possibility of a containment hydrogen explosion appeared remote, unless conditions changed dramatically due to radiolysis.

a.m.

Murley (memo)—On Sunday morning someone suggested that I collect information on what pressures could be generated if there were a hydrogen explosion in the pressure vessel. I found that Vince Noonan of NRR was the focus in NRC for these analyses and I therefore was involved only peripherally.

I received information that Dr. Norman Slagg of Picattiny Arsenal had made calculations showing a sharp peak pressure of 12,600 psi for the case of a detonation of a 1000 cu. ft. bubble containing a mixture of 83% hydrogen, 12% oxygen and 5% steam. This pressure appeared to be consistent with information received by Bob Bud[illegible] om Dr. Bernard Lewis of Pittsburgh that pres[illegible]s could reach 5 times initial pressure for deflagration and 13–14 times initial pressure for detonation (where Po = 1000 psi is the pressure of the bubble and the system initially).

This information was passed on to Vince Noonan and I had little further involvement after Sunday afternoon.

0900

Mattson (notes) telecon Dr. Norman Slagg of Picattiny Arsenal—12% oxygen, 5% steam, 83% hydrogen yields 12,600 psi "striking the wall." IRC voice transcripts indicate Mattson and Noonan agreed to have Slagg begin these calculations the previous evening.

0915

Mattson (notes) conversation with Murley, Levine, Budnitz—preparing for departure to TMI with Hendrie; night shift briefing Mattson who has just returned to the IRC. Group reached decision on hydrogen explosion potential for transmittal by Mattson to Denton and Stello at site. Levine or Murley advised Mattson that Ritzmann had talked to B&W, that the INEL use of Cooper data was uncertain, and that the INEL estimate was to be believed more than theoretical approach of Ritzmann. Group decided upon following:

5% oxygen realistic flammability limit
11% oxygen realistic detonation limit
900°F spontaneous combustion threshold
1% per day oxygen production rate
5% oxygen content @ Sunday a.m.

Levine (recollection)—recalls that the group agreed that these values for the rate of oxygen production and the present oxygen content were upper bound estimates.

Murley (memo)— Later that morning (around 9:00 a.m.) Roger Mattson met with Saul Levine, Bob Budnitz and me at the IRC prior to leaving for the TMI site. Chairman Hendrie, Commissioner Gilinsky and Commissioner Kennedy came and went throughout this short meeting as I recall. Mattson summarized the following information as the distillation of all of the input he had received.

Flammability limit ≥ 5% oxygen in pure hydrogen
Detonation limit ≥ 12% oxygen in pure hydrogen
Combustion limit ≥ 18% oxygen in pure steam
Oxygen production rate ~ 1% oxygen per day in hydrogen/oxygen bubble
Current oxygen concentration ~ 5% oxygen in hydrogen bubble

Budnitz (notes)—Meeting with Mattson, Levine, Murley, and me. Mattson was about to depart for the TMI-2 site by car with Chairman Hendrie, and he asked for an up-to-date, agreed-upon set of numbers about the "bubble." We all agreed on the following set of numbers, which were written down by me and are in my notes.

1. Best estimate for flammability limit, pure oxygen in pure hydrogen at 1000 psi = 5% oxygen.
2. Best estimate for detonation limit, pure oxygen in pure hydrogen at 1000 psi = 12% oxygen.

We also agreed that the best estimate for total *production* of oxygen from radiolysis in the TMI vessel would be about 5% oxygen (as fraction of bubble) as of the present time if there were no recombination. We also discussed the fact that other people among our NRC contractors were actively calculating the true oxygen which would be smaller than the radiolysis production rate because of chemical recombination. We discussed together that the 5% oxygen/hydrogen ratio was a pessimistic estimate, in the sense that the actual value was surely not larger and might be smaller. I remember us discussing how probable it was that the number would ultimately turn out to be much smaller. I remember that we were not yet sure that a smaller number would result from the accurate calculations underway at that time. Some differences of opinion existed as to how "sure" we were of what estimates by which experts, and Mr. Levine was more confident than the others that the oxygen would not be a problem.

I remember that Commissioner Bradford came into our brief meeting just as it was breaking up, and we acquainted him with our discussion.

a.m.

Lanning (memo)— Bob Jones (B&W) requested second test in Semiscale. Suggested doubling size of bubble and include HPI flow based on B&W's contingency plan for depressurization.

Remainder of day spent primarily on coordinating Semiscale test results and second test.

Provided answers to various Labs and individuals who were working on hydrogen explosion, degassing, radiolysis and recombination of hydrogen and oxygen (no notes available).

Tedesco (recollection) telecon to K. Woodward of Pickard and Lowe— called on request of Murley. Discussed results of radiolysis calculations in containment. Recall that Woodward's estimates were high compared to those of NRC staff.

Butler telecon to Tedesco (recollection)— Butler gave results of staff discussion with I. Pinkel about hydrogen in containment.

About 1200

Mattson (recollection) meeting with Hendrie, Stello and Denton at Middletown airport—relayed information agreed to at IRC with Murley, Budnitz and Levine before departure to site. Stello strongly believed IRC was wrong and that oxygen was being recombined because of high hydrogen concentration. Mattson and Stello had not talked earlier because of the press of other assignments and different working schedules and agreed that the two different points of view needed rapid resolution.

President Carter was briefed by Denton and Stello about the hydrogen explosion problem and was told about the uncertainty of staff conclusions at that time.

p.m.

Levine (memo)— I spoke with James Proctor of the Naval Surface Weapons Center about the effects of a hydrogen explosion on vessel integrity. He said the cylindrical portion of the vessel would be subjected to about 6% strain, which should not break it, and that it would also be subjected to a lifting force of about 1.5×10^8 lbs. He could not calculate whether the main loop piping could hold the vessel down when subjected to this force, since he did not have detailed information on plant layout.

Midday

Budnitz (memo)— On Sunday morning, on referral from Harry Petschek of AVCO Everett, I reached Dr. Bernard Lewis of Combustion and Explosives Research, Inc., of Pittsburgh.

He acknowledged that he had much expertise on the combustibility of hydrogen and oxygen; indeed, he is the coauthor of a definitive text book on this subject. He and an assistant, reached at home on Sunday morning, worked through that day and part of Monday, April 2, and gave important advice on the issues that governed the physical behavior of hydrogen and oxygen burning in conditions such as were thought to exist within the primary vessel at TMI. I was Lewis' sole NRC contact during this period. He gave information about the mixture of oxygen in pure hydrogen that would be a combustion threshold, talked at length to me about the physical difference between combustion and explosion, and what would be the impact of gaseous impurities including steam. He reported back his preliminary conclusions sometime after midday on Sunday, April 1, and his final conclusions in midmorning of Monday, April 2. He calculated pressure ratios (pressure within a fast burning situation vs. starting pressure), detonation thesholds, heat release, flame temperatures, and other parameters. His insight was valuable in providing a perspective on which parameters were, and which were not, important in modifying the result of what was easily calculated using approximations. Thus the approximate calcuiations were refined, and the refinements were better understood by me.

Dr. Lewis' best estimate about midday Sunday was that the "pressure pulse" would be about 5500 psi for a fast combustion event (requires above about 5% oxygen) and about 13 000 psi for an explosion (requires above about 12% oxygen). On Monday, Dr. Lewis revised the 5500 estimate downward to about 3200 psi.

Lanning (memo)—Requested and provided information to INEL to perform second test in Semiscale. Obtained plan from B&W on proposed HPI flows versus time. Coordinated information to Labs concerning hydrogen explosion, degassing, radiolysis and recombination of hydrogen and oxygen.

Budnitz (recollection)—By about midday on Sunday, there emerged a reasonably reliable consensus among our outside expert contacts about two questions: how large the short pressure pulse might be if a fast combustion event were to occur inside the TMI primary vessel, and at what pressure the vessel would approach its "yield point" and its "ultimate" point, thereby compromising the integrity of the primary system. I was responsible for coordinating the former concern and Tom Murley brought together the information on the latter.

Our general conclusion at that time was that, for about 1000 cubic feet of pure hydrogen with oxygen just above the threshold value of about 5% at 1000 psi, the "pressure pulse" would be about 5500 psi. This came mainly from Dr. Lewis of Pittsburgh (on Monday, Dr. Lewis revised his best estimate downward to about 3200 psi). The "yield point" of the vessel, according to Tom Murley, seemed to be coming out at about 6000 psi. Both of these numbers had rather large uncertainties, of which I and Murley were acutely aware.

I discussed these rough results with Saul Levine, who suggested that I tell Chairman Hendrie, who was at the TMI site. I spoke by phone with Hendrie and relayed this to him, expressing the uncertainties to him as well as the numerical best estimates. This call occurred just prior to my meeting with the other Commissioners, which began at 1350.

I was requested to give, and did give a briefing on the same subject to the other four NRC Commissioners, all gathered together in the NRC Incident Response Center. This 15-minute briefing was attended also by Len Bickwit (NRC General Counsel), and about 15 other NRC people. This briefing can be found verbatim in the Commission transcripts.

About 1345

Commission Meeting at IRC with Budnitz (Comm. transcript pp. 94-116)— Commissioners Gilinsky, Kennedy, Bradford and Ahearne discuss evacuation scenarios for hydrogen combustion in reactor vessel (pp. 94-99). Thompson relays info from IRC staff that mixture is then 5% oxygen and flammable. Budnitz gives briefing on current assessment by IRC staff of bubble situation (pp. 100–116). He concludes that if a fast hydrogen burn were to be initiated, vessel integrity would be compromised. Didn't know of any initiation mechanisms. Budnitz says that during burn, pressure will increase by a factor of 5.5. Burn will last 10–20 msec. If 1000 psi before burn, pressure during burn will be very close to yield strength of the pressure vessel. A little over 10% oxygen is needed to sustain detonation. In detonation, pressure is increased by a factor of 13.5—the pressure vessel would be lost. Budnitz also points out that if the temperature rises to 680°F, the mixture will go off spontaneously—no ignition source would be needed.

Early p.m.

Milstead (memo)— On Sunday afternoon (April 1, 1979), KAPL reported to the NRC staff in Bethesda the results of analysis performed with Naval Reactor water chemistry code. Using the code and assuming 10% of the core in boiling KAPL predicted a bubble growth rate of 0.4 ft^3/day. If it were assumed the entire core was in boiling the growth rate could be 8 ft^3/day. The reason for this low bubble growth was that total recombination of the oxygen formed by radiolysis in the reactor coolant was predicted due to the large amount of hydrogen in solution. KAPL's analysis indicated the bubble contents to be almost entirely hydrogen (from metal-water reaction) and indicated a net radiolysis of zero in the reactor coolant for most of the transient. On this basis, it was concluded that the bubble had not reached a flammable oxygen content and would not be expected to.

KAPL indicated that effective oxygen recombination in the reactor coolant would be predicted for hydrogen concentrations in the coolant greater than 0.1 scc/kg. They suggested the degassing process be continued and a minimum concentration of 1.0 scc/kg be maintained in the reactor coolant to prevent net radiolysis in the reactor vessel.

On Sunday afternoon (April 1, 1979), we peformed a series of COGAP analyses assuming radiolysis in the containment sump only and no recombination of oxygen. Our analysis indicated 5-day hydrogen production rates from about 600 scf/day (0.03%/day by volume in the containment) to about 3600 scf/day (0.21%/day in containment). The 3600 scf/day rate was calculated using the conservative assumptions of Regulatory Guide 1.7 (i.e., G Value of 0.5 molecules/100 EV and a TID release in containment). Our best estimate calculations resulted in 5-day hydrogen growth rates of 600 to 1000 scf/day (0.03%/day to 0.05%/day in containment). These analyses used estimates of fission products in solution which closer matched the RCS sample obtained on March 30, 1979, and a best estimate G Value of 0.33 molecules/100 EV. Our best estimate calculations compared favorably with estimates of potential hydrogen growth rate calculated by the Office of Research.

p.m.

Levine telecon to Tedesco (recollection)— Discussed calculations of radiolysis in containment using TID source team. Levine advised that estimates appeared high because of use of radiation source term larger than TMI-2 sample analysis. Tedesco directed staff to revise calculation to approximate TMI-2.

Stello (memo)—I recall outlining for the Chairman (at the site) the basis upon which I did not believe the hydrogen bubble in the reactor vessel could reach an explosive potential. Basically, I reiterated the results of the reasoning we (at the site) had gone through that morning and previous night. I requested the Chairman that before any further action be taken on this issue, that I be given some time to contact some other experts to see if I could get additional technical information.

Mattson (recollection)— worked at site command post following briefing of President to resolve differences in IRC and site positions on oxygen generation by radiolysis.

About 1430

Benaroya (recollection)— After working the graveyard shift, woke-up in the motel room thinking about the hydrogen-oxygen problem in the gas bubble. He tried to call the NRC command center in the trailer, but all phones were busy. He finally decided to call the TMI-2 control room and got in touch with Norm Lauben at around 1500. Benaroya explained that normally a hydrogen concentration of 20–40 cc/kg of water is kept in the primary system to eliminate free oxygen. At the pressure and temperature that existed in the primary system, in the radiation field, 20 cc of hydrogen per kilogram of water is enough to push the reaction towards recombination. Since we had a large excess of hydrogen, it was very unlikely that any free oxygen would be present in the gas bubble. Benaroya asked that this information be relayed to the NRC trailer. N. Lauben called back V. Benaroya at the motel saying that he had relayed the information to Mattson, and Mattson told him that this was being calculated in Bethesda.

p.m.

Rosztoczy (memo and recollection)—On April 1 and April 2 of 1979 Brian Sheron, Garry Holahan and myself performed gas bubble size calculations for TMI-2. The work was done on Don Davis' request, who worked in the Bethesda Emergency Center at the time. Frank Almeter (EB) was called in to help. We also had telephone conversations with Ledyard Marsh (DOR) and Paul Cohen (retired from Westinghouse) who is a well-known expert on water chemistry for nuclear plants. Mr. Cohen was very helpful.

We were asked on April 1 p.m. to review the method used by B&W for determining bubble size. Our conclusion was that the method had two errors: a rather major error in the solubility term by omitting the correction factor to account for elevated pressure and temperature and a small error in the multiplier in front of the equation. Both of these are documented in the attached memo prepared by B. Sheron dated April 5, 1979. During the course of our work we also recognized that the anomalous behavior of the letdown line during the bubble measurements introduced large uncertainties in the bubble size. We recommended, therefore, to close the letdown line during measurements.

All of this information was communicated to Davis on the evening of April 1 and early a.m. April 2. My understanding is that the recommendation to close the letdown line during measurements was followed. All measurements taken late on April 1 and early on April 2 had the line closed and showed a significantly smaller bubble size than previous measurements.

1500

Stello (notes)—On April 1, 1979, 3:00 p.m., I requested Bettis Laboratory to evaluate the potential for radiolysis contributing oxygen to the bubble over the reactor core. The following people participated in the evaluation: Don Connors, Lou Bogar, Jim Wright, Ken Vogel, and Bill Walker (KAPL).

The following information was provided and was represented as the Bettis Laboratory position. A report would be prepared if requested. I indicated that I would let them know if there was a need.

(a) The first question I asked them to consider was if we assumed that the bubble over the reactor core is 800 cubic feet, 1000 psi and 300°F is it possible for oxygen to be added to the bubble by a radiolysis process?

Answer: Their best estimate analysis would indicate that no oxygen would be added to the bubble. The analysis is derived from considering Henry's law; they would expect that under the conditions there would be 900 cc per kilogram STP of hydrogen going into the water. Based on experimentally derived information with a concentration of 2 cc's per kilogram at STP in water, radiolysis would be prevented. The experimental information was derived from data collected in the S7G prototype program and a reference is cited to data dating back to 1943.

(b) I requested Bettis to provide me with an estimate of the radiolysis rate assuming there was no hydrogen over-pressure in the bubble.

Answer: Assuming no recombination was permitted, they calculate that approximately 8.4 cu. ft. per day of oxygen radiolysis rate of 29.2 cu. ft. per day at STP. The recombination rate was based on a g-factor that was experimentally determined from S7G and boiling water reactor data.

These data were stated to be conservative relative to PWR conditions. The g-factor used was 0.7 molecules of oxygen per 100 EV of gamma absorbed, at 1.5×10^9 MEV of gammas per square centimeter per second. They assumed that 1/10 of the gammas generated in the core are absorbed in the core and that 1/15 of the gammas absorbed in the core are absorbed by water. They have had informal discussions with people like KAPL who independently determined a radiolysis rate in the same ballpark (estimated to be approximately 65 cu. ft. per day at STP). Dr. Connors is going to ask KAPL for their view to see if their evaluation of the problem is the same.

About 1500

Stello (notes)—On April 1 at about 3:00 p.m., I requested the same information of the General Electric Company (commercial) as I did from Bettis Laboratories. The GE response was that it is theoretically possible that oxygen could be added to a hydrogen bubble over the reactor core. However, they did not consider this would be likely and concluded that they believe that an equilibrium condition may now be present. They calculated a bounding number for the amount of radiolysis that could take place assuming no hydrogen overpressure. They estimated that the bounding number is 10 cubic feet per hour at STP but believe this was too conservative since it was based on BWR data (NEDE-13148 Title KRB Radiolysis Test, Nov. 1970) and that no credit was given for the effects of a back reaction and that the real number is much lower. They speculated that perhaps there is no net oxygen added. The following people participated in the evaluation: Cliff Kent, Jerry Jacobsen, Pat Marriott, Manny Ziegler, and Don Rockwell.

Stello (memo)— (After) I obtained that information (from Bettis and GE) . . . (I presented it) to the Chairman. I believe he was persuaded that we need not have a concern for either a burn or explosion of the hydrogen in the reactor vessel. Following our discussion, he placed some telephone calls to Washington to discuss this information with fellow Commissioner(s).

p.m.

Levine (memo)—I also spoke with Harold Schwarz of BNL, I believe on Sunday afternoon, April 1. He said that he believed that not only would oxygen not be accumulating in the hydrogen bubble, but that whatever hydrogen and oxygen were in the bubble would be depleted at fairly rapid rates. He said that he would calculate the rates and call me later on Sunday. On Sunday evening he told us that he had completed his calculations which confirmed that oxygen could not accumulate in the bubble and that it would in fact be depleted.

About 1500

Budnitz (memo)—On referral from Dr. H. J. Kouts of Brookhaven, Saul Levine and I contacted Dr. Harold A. Schwarz of Brookhaven. I am not sure when he was first reached by Levine, but both Levine and I talked to Dr. Schwarz at various times during the weekend.

Dr. Schwarz worked April 1 (beginning about 3:00 p.m.) on calculating the production and recombination rates of oxygen in the TMI primary coolant water. He did these calculations at home mostly, I think, telephone contacts with him during the weekend were at his home. He reported on the considerations that were involved in his calculations, and ultimately showed definitively that oxygen generation from radiolysis would not result in much oxygen in the gas phase, because of the recombination reaction with the assumed large hydrogen gas overpressure and the associated dissolved hydrogen. We were apprised of the preliminary results of Dr. Schwarz' work on Sunday afternoon, April 1, in my memory, but it was not firmed up until sometime in the evening that day. Dr. Schwarz filed a description of his calculation with NRC on April 24. The April 24 note to me describes well that the calculation is tricky and involves tracking down a number of chemical parameters and calculating several reaction rates. Impurities within the TMI cooling water were important enough that information taken from conditions of normal reactor operations could not be relied upon.

1552

Commission meeting at IRC (Comm. transcript, pp. 131-144)— Commissioners Kennedy, Bradford, and Ahearne discuss evacuation scenarios for hydrogen combustion in reactor vessel. Apparently reaching a consensus to recommmend evacuation that afternoon because of combustion potential. They expressed concern over obvious differences in data coming from the staff. They decided to advise Hendrie at site that they were concerned there may be need to consider evacuation. Kennedy and Ahearne leave at 1617 hours to talk to Hendrie on the telephone.

About 1620

Kennedy telecon with Hendrie (Ahearne recollection and notes)—Kennedy relays to Chairman the advice of the three Commissioners at Bethesda (Kennedy, Bradford, Ahearne) that, based on Budnitz reports, they recommend that, unless people on site have better technical information, NRC recommend Governor Thornburgh advise a precautionary evacuation within two (2) miles of the plant. This would be precautionary, just as the Friday evacuation advisory. Hendrie informs Kennedy that oxygen is not a problem—the hydrogen in the water would capture the oxygen.

About 1700

Mattson (notes) telecon to IRC—B&W tells IRC there is no oxygen in bubble. Salvatore of Westinghouse remembers Bettis data which says that excess hydrogen inhibits oxygen formation by radiolysis. Ritzmann tells IRC that one to two percent per day oxygen generation rate is with no accounting of inhibition, and hydrogen inhibits. Levine says to use 0.1% per day instead of earlier 1%. Levine also advises previous INEL estimate in error by factor of 10 too high.

1800

Mattson (notes) telecon with IRC— Budnitz reports to Mattson that answers from experts range from 0 to 1% oxygen per day. Budnitz reports that Herb Kouts of BNL thinks oxygen generation rate is small; ph is an important parameter; revised INEL calculation says 1% oxygen is now present; current estimate of IRC is less than 1% oxygen; but still working to finalize position.

About 1900

Mattson (recollection)— Mattson and Hendrie met with Industry Advisory Group in Middletown National Guard Armory. Ed Zebrowski of EPRI expresssed strong dismay with NRC for having incorrectly judged the hydrogen explosion potential by not quickly understanding that oxygen could not be evolved by radiolysis in a hydrogen rich environment.

Monday, April 2

a.m.

Thadani (memo)—If my memory is correct, on Monday, April 2, I developed criteria (at the site) for the rate of degassing and the process limits that were to be maintained. Otherwise, degassing was to be discontinued.

About 1000

Lauben (recollection)— Radiophone from control room to Mattson (recollection)—Lauben has been following GPU bubble size measurement and analysis. Expressed confidence that bubble size was decreasing dramatically.

1100

Mattson (notes) for Denton Press Briefing—For the past several days we have been studying the potential hazard of the gas bubble in the reactor. There has been concern that the bubble could reach a flammable condition if oxygen were being added to the hydrogen. Our earlier statement on the effects of bubble flammability on the safety of the plant were primarily based on preliminary theoretical analysis by the technical experts. There is also some experimental data for these conditions. After several days of intensive consideration of the problem by these experts, we now believe that the hazard of hydrogen burning in the reactor is not nearly as severe as earlier indicated. We have much higher confidence today that there is no near term hazard from hydrogen burning.

There is one piece of new information from the plant that contributes to our present state of cautious optimism in this area. Measurements of the size of the bubble over the last 24 hours indicate that it is not as large as originally estimated, and it may be continuing to diminish. We are studying this new information closely to determine the effectiveness of the degasification process that has now been underway for several days and the confidence that can be placed in the bubble measurements.

Bubble Size

Encouraging signs that it is smaller than earlier measurements indicated.

- measurements are better
- degasifying thru recombination letdown seal leakage in pump

Bubble Content

Our present understanding of the gas evolution and decay process says the rate of addition of oxygen is not what we originally estimated. There may be an equilibrium condition in which there is little or no net generation of free oxygen in the reactor or even recombination of any excess oxygen (i.e., either slightly positive, zero or negative).

Combustion Limits

Our earlier estimates were conservative, but there is some uncertainty in the available data, so staying with the 5% and 11% limits.

1115

Denton and Mattson press conference in Middletown (transcript)— Measurements show dramatic decrease in bubble size; don't want to be stampeded into concurring bubble actually this small; certainly reason for optimism; oxygen generation rate described yesterday by Denton was too conservative; oxygen evolution rate is much less than one percent per day; we think it is safer than we did yesterday; hydrogen backpressure inhibited formation of oxygen by radiolysis.

1200

NRC Preliminary Notification PNO-79-67H, Paragraph Two on Plant Status at 12 noon 4/2/79 states—Further analyses and consultations with experts have led to the development of a strong consensus that the net oxygen generation rate inside the noncondensible bubble in the reactor is much less than originally conservatively estimated. Also, measurements at the plant appear to indicate that the volume of gases within the bubble is being significantly reduced. Further developments are being closely followed to confirm these favorable indications.

Midday

Lanning (memo)— Coordinated results of second Semiscale test to B&W and IRC. B&W indicated that they were going to revise HPI flow rates in contingency emergency plan to vent the bubble as the result of tests. Discussed analytical predictions of time period to vent bubble in comparison to Semiscale results.

Relocated from MNBB to East-West Towers. Performed calculations of time period to degas using pressurizer spray. A lot of uncertainty existed concerning flow rates in pressurizer surge and spray lines and makeup and purification system (coordinated with K. Parzewski).

1220

Commission meeting (Comm. transcript)— Hendrie tells other Commissioners of the status of the bubble concern at site as described by Denton and Mattson at 1100 press conference. Concern is very considerably mitigated and on its way to not being of concern much longer. There has not been any substantial evolution of oxygen at anytime in the system.

2052

Nitti of B&W written opinion —on H_2/O_2 bubble (memo Roy to Mattson) includes statement that "A review of the postulated sequence of events on March 28 lead us to conclude that there is no significant amount of oxygen in the bubble that was present in the reactor coolant system of the Three Mile Island Nuclear Plant.... (The) amount of dissolved hydrogen is approximately 50 times the amount required to suppress a net radiolytic generation of oxygen."

APPENDIX III.5

NRC PROCEDURES FOR DECISION TO RECOMMEND EVACUATION APRIL 1, 1979

NRC PROCEDURES FOR DECISION TO RECOMMEND EVACUATION

Who Decides

1. Combination of consequences and times require immediate initiation of evacuation: Senior NRC Official on site recommends to Governor.
2. Unplanned event with substantial risk takes place or is imminent or situation judged excessively risky but there is time for consultation. Senior NRC Official notifies Governor and NRC HQ. Chairman makes recommendation to Governor after consulting with Commissioners if possible.
3. Planned event involving significant additional risk. Chairman and Commissioners make recommendation.

Action Guidelines

a. Notify evacuation authorities two hours in advance (if possible) to standby for a possible evacuation.
b. Projected doses of 1 rem whole body or 5 rems thyroid stay inside.
c. Projected doses of 5 rems whole body or 25 rems thyroid mandatory evacuation of all persons.

Assumes general warning already that some form of evacuation may become necessary.

Weather

The table is based on a realistic prediction of the weather for the next few days, based on the April 1 forecast which would result in high doses at a given distance. At the approach to decision time for evacuation, the appropriate meteorological condition will be factored into the dose estimates to determine the evacuation time, sectors, and distances for the evacuation.

NRC is predicting the dispersion characteristics of the region for the currently measured meteorology as the incident progresses. Rain could lead to higher local radioactivity levels.

Unplanned Events*

Event	Expected Plant Response	Release and Time	Warning Time	Evacuation Scenario
1. Loss of vital function or unplanned leaks	Restore function within 1 hour	No significant change		Possibly precautionary evac 2 mi; stay inside 5 mi
Examples Reactor Coolant Pump Trip; Loss of offsite power;	Switch to Alternate Function involving Primary Coolant in Auxiliary Building	Small leak less than 1 gal/hour		Possibly precautionary evac 2 mi; stay inside 5 mi
		Large leak 50 gal/min	2 hours	Evac 2 mi Stay inside 5 mi
Loss of feedwater; Depressurization to go on RHR; Leak in Auxiliary Building	Serious possibility of failure to restore a vital function See 2			
2. Sequence leading to Core Melt	Maintain Containment Integrity (likely) with Containment Cooling	Design Containment Leak Rate	4 hours	*Precautionary* Evac 2 mi all around and 5 mi, 90° sector, stay inside 10 mi
	Containment expected to Breach	Significant release of core fission products	24 hours (time for containment failure)	Evac 5 mi all around and 10 mile, 90° sector, stay inside 15 mi
3. Hydrogen flame or explosion possible inside reactor vessel	Mixture in flammable range			*Precautionary* 2 mi
	Explosion; major damage Core Melt See 2			
4. Evacuate or Lose Control Room	Loss of Control Treat like major release			Evac 5 mi all around and 10 mi 90° sector, stay inside 15 miles
Planned Manuever	Probability of losing vital function	See releases under loss of vital function	Timing of manuever can be set to provide as much time as necessary	*Precautionary* evacuation 2 mi, stay inside 5 mi PLUS See outcomes under loss of vital function.

*This table includes a number of assumptions about activity and weather, chosen realistically. In an actual release, the release rate and weather should be evaluated as they are at the time, and the decision based on those values.

Heat Generation

The reactor core is now quite cool compared to the conventional design-basis calculations.

1. The reactor is new, so no fuel has more than 3 months equivalent operation, compared to 1–2 years average for other plants.
2. The neutron chain reaction has been shut down for over 4 days.

It should also be noted that the concrete basemat of this plant is unusually thick.

As a result of the above differences, calculations for this plant at this time predict that the core will not melt its way through the containment.

Event 1—Sprays and Coolers Operative

Time=0	Flow stops; core and water start heatup
Time=100 min	Core starts to uncover
Time=150 min	Core begins to melt
Time=200 min	Molten core is in lower head of reactor vessel; pressure is 2500 psia
Time=210 min	Reactor vessel fails; containment pressure goes to 25 psia
Time=210 min	Hydrogen burns; containment pressure goes to 67 psia — Steam explosion possibility is a minor consequence

CONTAINMENT SURVIVES (Failure assumed 130 psia)

Time=10 hours	Molten core has melted about 1 meter into basemat
Time=days	Major problem: handle hydrogen, oxygen; maintain containment integrity
CAUTION:	Keep sprays running Keep water many feet over molten debris WITHOUT RECOMBINERS Hydrogen continues to build up

BASEMAT SURVIVES

Event 1 Conclusion: This event should not produce major releases

Event 2—Sprays and Coolers Failed Before Flow Stops

Time=0 to 210 min	Same as Event 1: containment pressure is 25 psia
Time=810 min	Containment pressure is 70 psia
Time=1 day	Containment fails due to steam (mostly) overpressure, about 135 psia

CONTAINMENT FAILS

Event 2 Conclusion: This event leads to major releases.

APPENDIX III.6

ESSER REPORT

A REPORT SUBMITTED BY GEORGE ESSER, PRESIDENT OF THE NATIONAL ACADEMY OF PUBLIC ADMINISTRATION, TO MITCHELL ROGOVIN (ROGOVIN, STERN, AND HUGE), DIRECTOR OF NRC THREE MILE ISLAND SPECIAL INQUIRY GROUP

Prepared Under NRC-RFPA No. Res-79-210

Introduction

Purpose

1.0 The purpose of this report is to identify and assess major alternatives for governmental policies, organizational structures, and actions in civilian nuclear reactor emergency management in the United States.

1.01 This report was prepared under a contract between the National Academy of Public Administration, Washington, D.C., and the Nuclear Regulatory Commission (NRC-REPA No. Res-79-210, August 20, 1979).

1.02 Under the contract, the National Academy of Public Administration agreed to identify and evaluate alternatives for governmental policies, organizational structures, and actions in civilian nuclear reactor emergency management. It agreed to review present policies and practices in civilian nuclear reactor emergency management, to review selected experiences and practices of governmental agencies other than the Nuclear Regulatory Commission, and industries other than the nuclear power industry, and to identify alternatives to the present nuclear emergency system.

The Academy further agreed to submit a report of findings on November 17, 1979, to Mitchell Rogovin, attorney, Rogovin, Stern, and Huge, who was appointed director of the Nuclear Regulatory

Commission–Three Mile Island Special Inquiry, by the Commission, in May 1979.

This report is the result.

The Panel

1.03 The Academy convened a panel to oversee the project:

Dr. Harold L. Enarson, Chairman
President
Ohio State University
164 West 17th Avenue
Columbus, Ohio 43219

David Cohen, President
Common Cause
2030 M Street, N.W.
Washington, D.C. 20036

Lt. General Julian J. Ewell
6823 Melrose Drive
McLean, Virginia 22101

Thomas W. Fletcher
Senior Urban Management Specialist
Stanford Research Institute
333 Ravenswood
Menlo Park, California 94025

Governor A. Linwood Holton
Vice President–General Counsel
American Council of Life Insurance
1850 K Street, N.W.
Washington, D.C. 20036

Dr. Gary A. Kreps
Associate Professor
Department of Sociology
College of William and Mary
Williamsburg, Virginia 23185

Dr. Chauncey Starr
Vice Chairman
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

Joseph C. Swidler
Leva, Hawes, Symington,
Martin and Oppenheimer
815 Connecticut Avenue, N.W.
Washington, D.C. 20006

Stephen O. Wilson, Manager
Office of Environmental Programs
New York State Energy Research and
Development Authority
Albany, New York 12201

Robert P. Young
Manager of Engineering
Martin Marietta Aluminum
6801 Rockledge Drive
Bethesda, Maryland 20034

Richard Pollock, Director
Critical Mass Energy Project
P.O. Box 1538
Washington, D.C. 20013

Staff

The following individuals served as staff:

Project Director
Dr. James D. Carroll, Director*
The Advanced Study Program
The Brookings Institution
Washington, D.C.

Dr. Harold Orlans
Senior Staff Member
National Academy of Public Administration

Dr. Erasmus Kloman
Senior Staff Member
National Academy of Public Administration
General DeWitt Armstrong, III
Consultant

Mrs. Jean Levin
Research Associate

Mrs. Janet Steigert
Research Associate

Mrs. Margaret Nolan
Editor

Mrs. Karen Webb
Production Supervisor

Editorial Experts, Inc., Alexandria, Virginia, assisted in the production of this report.

1.05 The panel met on September 9 and 10, 1979, and identified issues for the staff to analyze.

The panel met on November 14 and 15, 1979, and expressed judgments on how the issues might be resolved.

*At the time of his appointment, Dr. Carroll was Director, Department of Public Administration, the Maxwell School, Syracuse University.

1.06 Part I of this report summarizes the conclusions of the panel on the issues.

Part II is a staff paper analyzing some of the issues and alternatives, and setting forth staff recommendations.

Part III is a staff paper describing the present civilian nuclear reactor emergency planning and response "system" in the United States. While this part follows I and II, individuals unfamiliar with the system may want to read Part III first.

Part IV describes emergency planning and response experience and practices in other government and industry sections in the United States. This section is the source of some of the recommendations considered in Parts I and II.

Part V reviews the United States Army experience with civil emergencies. This also is a source of some of the recommendations in Parts I and II.

Limitations

1.07 The staff work for this project involved interviews with approximately 100 individuals in federal, state, and local governments, Congress, industry, law firms, public interest groups, and associations. It also involved a review of several hundred documents from NRC and other federal agencies, Congress, industry, public interest groups, and associations.

1.08 This project did not entail a *de novo* review of the events at Three Mile Island, and was specifically limited to emergency planning and action in the United States, although a brief review was made of documents describing practices in a few other countries.

1.09 Furthermore, this project analyzed *only selected* issues. Because of time limitations, several issues were not examined in this project.

1.10 Finally, this review was conducted in approximately six weeks. We believe that a permanent, continuing effort to address the issues considered in this report is needed—and that such an effort does not now exist is a major failure of the research and development effort of NRC and the nuclear power industry. The base of knowledge from which we operated was inadequate, and this report reflects this inadequacy.

If nothing else is done as a result of this report, a greater effort should be made to increase knowledge and understanding of emergency preparedness for nuclear reactor accidents.

PART I

The Conclusions of the Project Panel

1.00 The following is a summary of the panel's conclusions with respect to government policy, organization, and action in civilian nuclear reactor emergency management.

1.01 Three general views were expressed.

Some panel members expressed the view that the nuclear power industry is indispensable to America's future. The safe operation of civilian nuclear power plants must and can be assured.

Some panel members expressed the view that civilian nuclear power is an unproven, hazardous undertaking, the continuation of which cannot be assumed.

Several panel members expressed the view that the available evidence is insufficient to support a judgment on whether civilian nuclear power is or can be made safe.

The Nuclear Power Industry[1]

2.01 In over 20 years of civilian nuclear power plant operation there have been few accidents that have threatened public health and safety.[2] (The supplemental views of Richard Pollock are presented at the end of Part I.)

2.02 The industry has been and should continue to be responsible for the safety of plant operations.

2.03 The events at Three Mile Island have significantly changed both public and industry recognition that a serious nuclear power plant accident is possible.

2.04 The industry is attempting to respond to this new reality.

2.05 Through the Institute for Nuclear Power Operations and other means the industry should:

A. Continue to stress that nuclear power plants require numerous distinctive safety considerations not present in other kinds of electricity generating plants.
B. Upgrade the standards and qualifications for operators and other plant personnel. Increase the frequency and sophistication of testing the ability of plant personnel to respond to operational anomalies and malfunctions and perform other aspects of their job.

C. Make certain that public authorities receive timely warning of any accident with potential off-site consequences, and keep them informed about the condition of the plant.
D. Assure that adequate instrumentation is in place to monitor radiation releases, on-site and off-site.
E. Cooperate with public authorities in the development of emergency plans and responses.
F. Conduct regular on-site and off-site drills of emergency plans, in cooperation with public authorities.
G. Comply with the requirements of public agencies with jurisdiction over civilian nuclear emergency planning and response.

2.06 Discussion—Emergency planning and response is only one limited aspect of an effective safety management strategy. It is at least as important to prevent accidents as to be ready to respond to them. The civilian nuclear power industry has the primary responsibility for the safe construction and operation of nuclear power plants, and should discharge this responsibility with full regard for public health and safety.

There was some difference of opinion within the panel concerning the capability of the industry to put into effect the substantial changes necessary to assure an acceptable level of safety. Increased monitoring and oversight activities by NRC can provide information on which to judge whether the industry initiatives now being undertaken will meet their objectives. When properly administered, a good oversight program can also act as an incentive for industry to do its job well. The fact that utility insurance coverage is to be contingent upon compliance with INPO standards is a positive indicator of the serious intent of industry to make INPO work.

The laxness of the past system for reviewing emergency plans is illustrated by the fact that, as of May, 1979, only four nuclear facilities had been certified as conforming to the NRC's regulatory guide for emergency planning issued in 1975. The fact that this guide is not a binding regulation and has not been applied retroactively is suggestive of past failure on the part of both industry and NRC to take seriously the entire question of emergency planning.

State and Local Governments

3.01 Historically and constitutionally, state and local governments are responsible for public health and safety within their boundaries. They are assisted by the federal government in areas of national priority, such as epidemics, and in matters that cross state lines.

Since local governments are legally creatures of the state, the state bears ultimate responsibility for public health and safety. However, in the event of an accident, local police, fire, health, and other authorities are responsible for immediate action to protect the public.

3.02 The jurisdictional boundaries of state and local governments pose extremely difficult problems of coordinating planning and response. The NRC Emergency Planning Zones suggest a ten mile radius, where practicable, for protection from airborne radiation and a 50 mile radius for radiation ingested through food.

3.03 At most plants, the zones include the jurisdictions of several local governments. An advisory board composed of representatives of these governments as well as key private agencies is indispensable to prepare and coordinate the emergency plans of these governments. The chairman, who should be appointed by the governor, must play an important part in emergency drills and responses.

3.04 Where the zone includes two or more states, the chairman of such a board should be designated by agreement between the two governors or, alternatively, be appointed by each governor on a rotating basis.

3.05 The feasibility of establishing an Emergency Control Center near each site, with the capacity to respond to nuclear and other emergencies, should be considered by each state and by the Federal Emergency Management Agency. One model for such centers would be a mechanism combining private and public sector representatives with the greatest potential to contribute to successful management of crises.

3.06 Discussion—The panel recognizes the need to improve state and local planning and response. However, the panel does not believe that one method or organizational form is appropriate for all states and localities. Every state should develop plans and an emergency response organization appropriate to its circumstances. To the fullest possible extent, planning for and responding to civilian nuclear emergencies should be handled by the same agencies and individuals who are responsible for responding to other emergencies.

The panel's recommendations concerning state and local government roles were developed in the context of the findings of the National Governors Association study entitled Comprehensive Emergency Management. That study underscores the need for a substantial upgrading of the generic emergency management capabilities of state governments as well as special capabilities for nuclear emergencies.

The Federal Government

4.01 The Nuclear Regulatory Commission is responsible for regulating the design, construction, and operation of plants to protect public health and safety. It is not responsible for planning for or responding to the off-site effects of plant radiation releases. It is responsible, with other federal agencies, for helping state and local governments to protect public health and safety in case of such releases.

4.02 The Commission may have the legal right to issue orders to the owners of a plant about how they should operate a plant during emergencies. The Commission should clarify its own emergency plans to determine when and under what circumstances it should do so. The panel believes that such orders should be issued only in the gravest of circumstances that pose a clear and present danger to public health and safety.

4.03 The Chairman of the Nuclear Regulatory Commission should be given plenary power to speak and act for NRC in an emergency. The status of and resources available for emergency planning and response throughout NRC, particularly the Office of State Programs, should be strengthened.

4.04 At present, the responsibilities of various federal agencies for planning for and responding to civilian nuclear emergencies are unclear. Most important, the respective roles of NRC, DOE, FEMA, and EPA need to be clarified by the President and the Congress.

4.05 Legislation should be enacted requiring the President, acting through the Federal Emergency Management Agency, to develop a National Contingency Plan for nuclear emergency planning. This plan should assign duties and responsibilities to federal agencies, designate one authoritative coordinator for all federal activity at a site, and otherwise define and clarify the planning and response process. Regional and national response teams composed of officials from designated state and federal agencies should be formed and given training.

4.06 The Federal Emergency Management Agency should by administrative action assume the "lead agency" powers and responsibilities for civilian nuclear emergency planning and response now nominally assigned to NRC. Its exact responsibilities should be defined in the National Contingency Plan.

4.07 The federal government should establish a grant program to assist state and local governments in planning for and responding to civilian nuclear emergencies. Eligibility should be conditioned upon meeting designated grant requirements.

4.08 The NRC should require higher standards for plant operating personnel and should have an active program for random testing of selected operator personnel to insure that standards are being maintained.

4.09 *Discussion*—Nine months after Three Mile Island there remains a disturbing confusion concerning the responsibilities of federal agencies in responding to a nuclear emergency. A Federal Register notice of December, 1975, stands as the most extensive and comprehensive effort to define these responsibilities, but it is now outdated and provides little effective guidance to help sort out the relative roles of the agencies. A year after the issuance of the Federal Register notice, the General Services Administration issued a document entitled "Federal Response Plan for Peacetime Nuclear Emergencies" (FRPPNE). This document was intended more as a guide for planning than an actual plan, and its current status is uncertain at best.

Relying on legal doctrines of preemption, the federal government has in effect prohibited state and local governments from regulating plant emissions. On the other hand, it has not provided effective assistance or incentives to help state and local governments carry out their responsibilities to respond to accidents. The federal government should take responsibility for this situation, which it has in part created.

The Public

5.01 The primary purpose of civilian nuclear power emergency planning and response is to protect the health and safety of people and the safety of property in the plant vicinity. People need to know the dangers to which they may be exposed, and the actions they can take to avoid or minimize them.

5.02 Plans that require public participation in such actions as staying indoors, taking medicine, or evacuating should be developed to the extent feasible with the participation or representation of the public. It is unrealistic to expect people to implement plans about which they are uninformed.

5.03 The public should be informed about nuclear plant emergency plans and given an opportunity to participate in their preparation and revision by such means as annual hearings.

5.04 *Discussion*—The panel's deliberations on this topic were conducted in the light of the GAO report entitled "Areas Around Nuclear Facilities Should Be Better Prepared for Radiological Emergencies." That report, issued only two days after the accident at Three Mile Island, points up the great ignorance on the part of the public living near nuclear plants about emergency plans.

Emergency Plans

6.01 Because emergency planning often means planning for events that never occur, it can become artificial unless the plans are periodically exercised and revised in the light of experience. Responsibilities for planning should be assigned to agencies and individuals accustomed to preparing for and responding to emergencies. Periodic drills and tests should be conducted to assure that plans can work.

A "living system" as opposed to merely paper planning should include the following features:

- Drilled emergency on-site/off-site plans involving local, state, federal officials and industry representatives who should know each other and be able to work together.
- Pre-arranged stockpiles of specialized equipment, personnel rosters, and transportation.
- Access to scientific/technical expertise.
- Plans for providing accurate and timely information to the press and the public.
- Logistical support for crisis managers and provision for rotation or replacement of personnel.
- Continuous review and evaluation of the effectiveness of response mechanisms and recognition of need for adaptation to meet changing requirements.

6.02 The Governor of each state should exercise responsibility for making certain that "living systems" exist.

6.03 *Discussion*—The panel recognizes that many units of government and industry have done extensive planning for civilian nuclear emergencies. More resources are needed, and continuing efforts should be made to improve these plans and conduct realistic exercises for dealing with both nuclear and non-nuclear crises.

Footnotes for Part I

[1]Panel member David Cohen states that the inclusion of this section on the Nuclear Power Industry at the beginning of the report is inconsistent with the purpose of this project, which was to examine alternatives for *governmental* action.

[2]Panel member Richard P. Pollock states the following supplemental views on the NAPA/NRC Panel on Emergency Planning for Nuclear Incidents:

Reactor crisis management and emergency planning for radiological accidents do not lend themselves to simplistic solutions. It is a highly complicated topic, further clouded by conflicting political jurisdictions and splintered areas of responsibility.

Faced with these complexities, the National Academy of Public Administration demonstrated commendable proficiency, especially given the short time frame NAPA was given to complete their assignment. Their efforts are the product of thoughtful reflection and vigorous investigation.

Given these difficult circumstances, the panel comments are in general a positive step forward, signaling an end to the years of indifference paid to this crucial topic by industry and regulators alike. Given the diversity of the group, it is a fair consensus document.

Nevertheless, there are some particular weaknesses which should be noted.

There is an unfortunate and undeserved degree of deference towards the commercial nuclear industry in this report. The record of "past accomplishments" over the last 30 years is undocumented. The claim that few radiological accidents have threatened the public health and safety is unsubstantiated.

If there is any conclusion to be drawn about the atomic power industry it is quite the opposite. As the Presidential Commission on the Accident at Three Mile Island noted, "To prevent nuclear accidents as serious as Three Mile Island, fundamental changes will be necessary in the organization, procedures, and practices—and above all—in the attitudes of the Nuclear Regulatory Commission, and to the extent that the institutions we investigated are typical, of the nuclear industry."

The statement that few accidents have threatened public health and safety, moreover, is factually in error. In the 17 years since the first commercial reactor was ordered, the Atomic Energy Commission and the Nuclear Regulatory Commission have docketed thousands of accidents involving human error, component failure and design error. Significant accidents, such as the 1966 partial meltdown of the Enrico Fermi I reactor forced local officials to draw up contingency plans for the evacuation of Detroit. Reactor accidents of major significance also have occurred in Illinois, New Jersey, Alabama, Connecticut, Colorado, Florida, Virginia, and Minnesota.

Due to equipment failure or design error close to one-third of all commercial reactors were shut down in 1979. It is not an enviable record of accomplishment. These flat "assertions" of a good record of safety are without corroboration. That they should be published is an indication of a lack of comprehension by the panel of the nature of the risks.

But in any event, past safety is not the issue for this panel. Preparedness for future accidents is the spirit and heart of this panel's concern. Emergency planning will be the last line of defense when all plant safety systems fail. Responsible government officials must develop a capability to protect the public if there is a nuclear emergency in their region. Evaluating federal, state, local and utility emergency plans is the mandate of this panel. That is our mission.

On that note, it must be stated in the strongest terms that the state of emergency planning is poor. This conclusion is inescapable. Only four reactors sites have been certified as conforming to NRC's 1975 regulatory guide for emergency planning. Only thirteen states in the nation have received federal "concurrence" or approval for their state plans. Operator training and testing for the complete spectrum of credible accidents is not required. Neither is the annual testing of offsite emergency plans.

Since Three Mile Island, the industry has begun to adopt some measures to attempt to upgrade their low standards for performance. That too is noted in the report. The industry has established a new institute in Atlanta. A Safety Center will be established in 1980. A flurry of media ads have been purchased to tell the public of these new efforts.

Is the industry responding to this "new reality?" This report suggests that it is. We contend, however, that it is premature to judge. Results, not plans, are what regulators and policymakers must use to measure success or failure. It is therefore inappropriate for this panel to draw any conclusions about the effectiveness about industry efforts—efforts still are in the gestation period. For the event which stirred the atomic power industry out of its self-admitted lethargy was not self-policing officials, but an accident where operators and machines repeatedly failed. How long this new industry "activism" prevails remains to be assessed.

There is also a suggestion that the industry's new standards will be rather rigorous due to the fact that eligibility for entry into the industry institute will be linked to a new insurance program.

This conclusion is unwarranted for the "insurance" being discussed is not liability insurance. This is already secured by reactor owners through the federal Price-Anderson Act. A distinctive feature of the Act is that companies are protected by a Congressionally-imposed ceiling on liability. The limitation is $560 million, less than 1/25th the damages calculated by the NRC's Reactor Safety Study in 1975 for a worse case accident. This insurance pool of $560 million is not conditional upon participation in the new industrial standards program.

The "insurance" being offered is a secondary level of protection to cover the costs for purchasing additional electricity if a nuclear power plant is down for an extended period.

The insurance-standards link is weak. Moreover, it will be even weaker if the industry standards themselves are low. Under those conditions, eligibility for this secondary type of insurance will be almost automatic. It is unfortunate that the panel conclusion report should draw inferences from the link.

In particular, there are a number of quantifiable steps which can be taken to upgrade the state of emergency planning which are not included or clearly stated in the panel's conclusion document. These include:

1. As a part of doing business, utility companies operating nuclear reactors should help local and state governments finance radiological emergency planning and exercises. It is a recommendation urged by the NRC's Office of State Programs.
2. The Federal Emergency Management Agency should preempt NRC on emergency planning. FEMA should evaluate and certify plants and sites. Licensing of reactors should be contingent upon FEMA approval of sites and plans.
3. Where FEMA determines a site to be unevacuable, measures should be adopted to remove the facility from operation.
4. Emergency drills should include voluntary evacuation of the public in different sectors located around plants. Regular notification of what is expected from the public during emergencies should be sent out to all accidents within 50

miles from a reactor. Both the airborne pathway and the ingestion pathway should be explained. Dissemination of this information could be accomplished by inserts in the monthly electric bills, public hearings or public service announcements.

Nuclear power requires a certain degree of risks. But the public, government officials and industry representatives must confront those risks and take prudent steps to cope with them. It is the only responsible approach government can adopt.

APPENDIX III.7

STATE AND FEDERAL EMERGENCY RESPONSE: AN AGENCY-BY-AGENCY ACCOUNT

INTRODUCTION

This Appendix describes the efforts of each State and Federal agency (except the NRC) that played a substantial role in the emergency response efforts. Each section first discusses the agency's statutory and other authorities and responsibilities and then describes how the agency became involved in the response. The sections conclude with details of the agency's response to the emergency at TMI.

General conclusions about the adequacy of any agency's response should not be drawn solely from the information provided in this Appendix. The official response effort comprised work by a large number of agencies, each assigned varying but often overlapping responsibilities. Many agencies made extensive efforts during the accident at TMI; not all can be fully detailed here. Furthermore, some information critical to assessment of a particular agency's performance might not have been obtained by the Special Inquiry Group. For these reasons, we are able to judge only the collective Government performance of a particular emergency response function, such as radiological monitoring, which we do in the main text. Therefore, the following pages should be considered as documentary rather than analytical.

For purposes of this discussion, we have continued to rely on the basic categories of official response functions that are used in the main text: planning, protective actions, radiological monitoring, institutional communications, and technical support for the plant. We refer the reader to the following official documents, explained and examined in the main text, that pertain to the response effort:

1. The Federal Response Plan for Peacetime Nuclear Emergencies (FRPPNE), Interim Guidance, issued in 1977.
2. The Interagency Radiological Assistance Plan (IRAP), as amended in 1975.
3. The Commonwealth of Pennsylvania Disaster Operations Plan, revised in 1977.

4. The Pennsylvania Emergency Management Services Code of 1978.

SPECIFIC RESPONSE OF FEDERAL AGENCIES (OTHER THAN THE NRC) TO TMI

At the time of the Three Mile Island accident, six Federal agencies, the Federal Preparedness Agency (FPA), Federal Disaster Assistance Administration (FDAA), Defense Civil Preparedness Agency (DCPA), Department of Energy (DOE), Environmental Protection Agency (EPA), and Department of Health, Education and Welfare (HEW) bore major responsibilities for responding to a peacetime nuclear accident. This part of Appendix III.7 first deals with these agencies and with the White House involvement. It then examines, in alphabetical order, the response of agencies that played lesser roles. This part of the Appendix also examines three organizations that are not Federal agencies but are of national scope and importance and therefore bear a public imprint either in their charter or management: the American Red Cross, the Civil Air Patrol, and Consolidated Rail Corporation.

Because of space limitations, the Appendix does not treat other Federal agencies and non-government groups such as the Mennonite Relief Service and various short-wave radio groups that played a limited or standby role in the response effort. We here acknowledge the importance of their services.

1. FEDERAL PREPAREDNESS AGENCY

Organization, Responsibilities, and Authorities

At the time of the Three Mile Island accident, the Federal Preparedness Agency (FPA), a part of the General Services Administration, was charged with responsibilities for the governmentwide civil emergency preparedness program. Its mandate included coordination and development of national civil preparedness policies and plans, fostering of State and local participation in preparedness programs, and the performance of functions incident to the emergency mobilization of industrial resources addressed in the Defense Production Act of 1950. (FPA and its functions have been integrated into the newly established Federal Emergency Management Agency (FEMA) as of July 15, 1979.)

In April 1977, in accordance with its assigned responsibilities and functions, FPA issued an interim form of the Federal Response Plan for Peacetime Nuclear Emergencies (FRPPNE). It intended that FRPPNE would provide guidance for the development of response plans for handling serious, but not probable, nuclear-related emergencies, and then integrate these plans with other existing response plans to make a single document.

The stated purposes of FRPPNE were the following:

1. Provide policy and planning guidance for the preparation of Federal and State operational response plans for peacetime nuclear emergencies.
2. Facilitate a complete and coordinated Federal planning effort that would cover all peacetime nuclear emergencies.
3. Provide the basis for compatibility between Federal and State plans related to peacetime nuclear emergencies.
4. Identify responsibility for implementing and coordinating the efforts of Federal agencies responding to peacetime nuclear emergencies.

Under FRPPNE, FPA undertook responsibility for overall coordination of the civil emergency preparedness planning effort designed by the FRPPNE interim guidance. In carrying out this responsibility with respect to peacetime nuclear emergencies, FPA was to do the following:

1. Provide a continuous forum for the coordination of Federal peacetime nuclear emergency planning activities, including making FPA personnel available to facilitate those efforts.
2. Provide additional or revised policy and planning guidance whenever such action would serve a useful purpose.
3. Review the guidance that leading planning agencies provide to support agencies.
4. Provide assistance in resolving Federal interagency or Federal–State problems whenever such action facilitates the fulfillment of responsibilities assigned to Federal agencies by this guidance.
5. Encourage States to produce plans related to this guidance as part of their general State civil emergency preparedness planning.
6. Coordinate visits of Federal agency representatives to States in connection with the development of peacetime nuclear emergency plans under this guidance.
7. Ensure that Federal plans are mutually compatible and consistent, paying particular attention to measures designed to provide for an orderly transition if a situation escalates from a lesser to

a more serious category of peacetime nuclear emergency.

8. Determine the format of the compendium of plans that would comprise the final version of FRPPNE and the manner and timing of FRPPNE's promulgation.

Initiation of Involvement

FPA's regional office in Philadelphia first received notification of the TMI incident from the NRC at approximately 9:45 a.m. on March 28. The information indicated that a relatively serious release had occurred within the facility, but that most of the contamination had been contained within the powerplant. The regional office immediately relayed this information to the FPA national office in Washington.

At 10:00 a.m. the NRC Incident Response Center called the FPA national office with the same information, and with further information that the temperature around the core of the reactor was slowly declining—an indication that the problem was probably under control.

Description of Response

On March 28 and 29, the FPA national office maintained frequent contact with the NRC Incident Response Center in Bethesda, Md., for the latest information on the situation. The NRC also informed FPA about the emergency response role played by DOE and EPA. The FPA regional office in Philadelphia was in frequent contact with the Commonwealth of Pennsylvania's Emergency Management Agency (PEMA) to determine if additional Federal assistance was required.

Following a report received from the NRC on the morning of March 29 that "the reactor [had been] stabilized since 9:00 p.m. on March 28," FPA determined that no additional Federal assistance or coordination of Federal efforts was required during those 2 days. FPA was told that the only additional release of radiological contaminants would be extremely low level, controlled releases made to reduce pressure inside the containment facility.

On Friday, March 30, 1979, two factors resulted in FPA's reassessment of the situation: First, the growing concern with the hydrogen bubble and the potential for explosion led to FPA's conclusion that a serious problem still existed. Second, the reportedly "uncontrolled" release of radioactive gas on the morning of March 30 indicated that a serious level of contamination outside the powerplant was still possible. The FPA Region 3 acting director alerted the regional staff of several Federal agencies to be prepared for a possible call for assistance from the State. He advised further that FPA might at any time call to coordinate their activities.

At midmorning on March 30, FPA was requested to attend a White House meeting to discuss Federal agency involvement at TMI. At the meeting that afternoon, FDAA was designated as the lead Federal agency in responding to the accident.

After that meeting, all FPA action was taken in support of FDAA. During the weekend, FPA continued its coordinating role by organizing a meeting at the request of Adamcik (FDAA) for regional personnel from the Department of Transportation (DOT), Department of Agriculture (USDA), Department of Defense (DoD), Postal Service (USPS), and the Veterans' Administration (VA).

Beginning on Saturday, March 31, the FPA Region 3 acting director was in Harrisburg; the FPA Region 2 director arrived on April 1. At the request of Governor Thornburgh, FPA took part in a Federal evaluation of State evacuation plans. The two FPA regional directors continued to provide support throughout the week, until the possible need to evacuate areas around the powerplant had diminished.

2. FEDERAL DISASTER ASSISTANCE ADMINISTRATION

Organization, Responsibilities, and Authorities

At the time of the TMI incident, FDAA was a part of the Department of Housing and Urban Development (HUD). The FDAA was responsible for direction, management, and coordination of the Federal disaster assistance program activities delegated to the HUD Secretary by the President. About 90% of the disasters to which FDAA had responded before TMI were floods; approximately 99% of its funds were committed to flood relief and recovery. The Administrator of FDAA directed regional and field office disaster assistance activities through 10 regional directors; the regional director for the Pennsylvania area was located in Philadelphia. As a result of a July 1979 reorganization, FDAA is now part of FEMA.

Under Executive Orders 11051, as amended, and 11490, as amended, the Secretary of HUD was to develop a comprehensive, coordinated Federal operational plan for responding to emergencies arising from a serious nuclear incident—one that could reasonably be expected to result in severe property damage or a large number of casualties, or that could cause widespread contamination of people and property.

To the extent that its comprehensive operational response plan relies upon the Disaster Relief Act of

1974 for authority, FDAA is required to coordinate the plan with the appropriate Federal departments and agencies. In addition, the FDAA, in preparing the response plan, is required to provide for liaison and coordination with appropriate Federal departments and agencies providing technical assistance, resources, and support. FDAA is also required to stress the need for coordinating the Federal assistance portion of the plan with State and local agencies engaged in comparable response activities involving peacetime nuclear emergencies.

The Disaster Relief Act of 1974 empowers the President to declare a state of emergency or major disaster, and thereby provides authority for FDAA's emergency function. The formal declaration of a disaster also authorizes expenditure of Federal funds under the Act and provides generally for Federal disaster assistance. After the declaration, the President appoints a Federal Coordinating Officer, who has coordinating authority sufficient to organize the response to the disaster. The Act authorizes FDAA to require any Federal agency to provide whatever services, material, equipment, or facilities are within its capability to provide. FDAA can impose these requirements with or without reimbursing the agencies involved.

Under the Act, FDAA is responsible for administering and coordinating the Federal disaster assistance program whenever a peacetime nuclear emergency results in a Presidential declaration of a major disaster or emergency. Further, the FDAA develops emergency response plans for carrying out its functions whenever any such declaration is made, if the incident constitutes a peacetime nuclear emergency.

TMI presented a unique situation for the FDAA. The Governor did not request Federal assistance under the procedures provided in the Disaster Relief Act of 1974 because, reportedly, he was concerned that calling TMI-2 an "emergency" or "major disaster" would have had an adverse psychological effect on the populace. Thus the President could not declare a disaster under the 1974 Act, and FDAA had no statutory authority either to require assistance from other Federal agencies or to expend funds. But, since it was apparent that both technical and logistical Federal assistance was needed, the White House appointed Robert Adamcik, Director of FDAA's Philadelphia office, and gave him the title, Lead Federal Official, to take the place of the normally appointed Federal Coordinating Officer. The White House also instructed FDAA to operate as though an emergency had been declared. If there should be any reluctance by a Federal agency to provide assistance requested by the NRC or the State, FDAA was instructed to pass the matter to the White House for resolution.

Initiation of Involvement

At 11:00 a.m. on March 28, the NRC notified FDAA of a radioactive discharge at TMI. FDAA took little action until March 30, when Adamcik was designated Lead Federal Official and FDAA was assigned coordinating functions by the White House. Adamcik arrived in Harrisburg at 11:00 p.m. on March 30.

Description of Response

In a March 30, 1979, memorandum from William Wilcox, FDAA Administrator, Adamcik was formally notified that Jack Watson, Assistant to the President, had appointed Adamcik Lead Federal Official, with the task of coordinating all Federal activities related to the TMI accident. Adamcik was given the general charter of performing as if he had been designated Federal Coordinating Officer under a formal declaration of disaster, and had the following specific assignments:

1. Meet with the State Coordinating Officer and advise him of his availability to assist as needed.
2. Meet with the President of Metropolitan Edison Company to obtain a "general perspective of attitudes and situation as viewed by the company."
3. Establish a Federal Congressional Liaison Office.
4. Cooperate with the State in establishing a rumor control center.
5. Establish onsite liaison with Harold Denton of the NRC.
6. Convene a meeting of Federal employees responding to the accident and advise them of his presence.
7. Meet with Federal officials assisting the State.
8. Provide at least daily reports to Jack Watson.
9. Coordinate with John McConnell of the DCPA, who was monitoring local evacuation capabilities.
10. Discuss with State officials the preparation of an unsigned emergency request to the President for immediate use should the situation worsen.

At about the same time, FDAA's National Operations Center in Washington, D.C., became involved in TMI and, throughout the next several days, committed almost all its resources to TMI support.

Upon his arrival in Harrisburg, Adamcik contacted Oran Henderson, Director of PEMA, who by law is the State Coordinating Officer, and who served as Adamcik's primary State contact throughout the incident.

FDAA also served the State by making arrangements to obtain equipment and personnel that the State had determined to be necessary for an evacuation, but which were not available within the State. On April 2, PEMA asked FDAA to locate 440 ambulances, 1 fixed-wing aircraft, 40 incubators for neonatal patients, 183 200 blankets, 183 200 cots, 35 doctors, and 200 nurses. By April 3, FDAA, with assistance from the American Red Cross, had identified sources for most of these needs, although FDAA daily reports to the White House indicated that problems were encountered in obtaining sufficient numbers of blankets and cots.

FDAA provided technical advice and assistance to the State in setting up a Rumor Control Center, which opened April 4.

At the Federal level, Adamcik maintained liaison with the NRC technical support staff on site through Boyce Grier, Director of the NRC's Region I, whom Denton, the lead NRC official on site, had designated as FDAA contact. Adamcik also attended the daily briefing that Denton gave the Governor. Soon after his arrival, Adamcik established liaison with John McConnell of the DCPA, who had been sent to TMI to assist in the development of evacuation plans. FDAA representatives were also stationed at the NRC Operations Center in Bethesda.

Throughout the incident, FDAA served as the principal point of contact for the NRC, the DCPA, and other Federal agencies needing to obtain materials or services in support of Federal operations at TMI. While many of the requests for assistance came through Adamcik's office in Harrisburg, many also were made directly to FDAA's National Operations Center in Washington, D.C. FDAA had no responsibility for and took no part in coordinating the Federal radiological monitoring efforts at TMI.

On Sunday, April 1, Adamcik convened the 25 to 30 Federal agencies and private relief organizations on site at that time for his first Federal agency coordination meeting in Harrisburg. State officials also attended. Daily coordination meetings with all Federal agencies were held right up through the following Friday to discuss general plans and to bring the agencies up to date on recent events and the situation at the reactor. Smaller meetings with representatives from one or a few Federal agencies or with State officials were held as the need arose.

Adamcik did not establish contact with officials of Met Ed because the NRC had already established a relationship with the company. Adamcik did not believe that he should interfere with technical aspects of the accident.

Because of their number, Adamcik chose not to convene a meeting of all Federal employees on site, but rather met with the Federal agency heads and advised them to inform their staffs of his presence and mission.

FDAA submitted to the White House 10 daily reports on Federal activities on site, beginning March 30 and ending April 11. No reports were prepared on Saturday and Sunday, April 7 and 8, or on Tuesday April 10.

FDAA's role at TMI has essentially ended. On April 13, the White House designated various other Federal agencies as lead agencies for specific long term recovery tasks.

3. DEFENSE CIVIL PREPAREDNESS AGENCY

Organization, Responsibilities, and Authorities

At the time of the TMI-2 accident, DCPA was a separate agency under DoD and was headquartered in the Pentagon. Eight DCPA regional centers reported to the Director of the Agency. The regional center responsible for the area around the TMI nuclear plant was the Region Two Center, located near Olney, Md. DCPA and its functions were assimilated by FEMA in accordance with Executive Order 12148, effective July 15, 1979.

DCPA had been responsible primarily for developing and coordinating Federal, State, and local preparedness for a nuclear attack on the United States. In addition to this legislated mission, the civil defense "dual use" doctrine allows military preparedness resources to be used for nonmilitary preparedness functions. Under this doctrine, DCPA has provided extensive support for nonmilitary disaster preparedness planning and operations. Through use of matching funds and other resources provided to States (and indirectly to counties and communities) and through its training programs, DCPA has had a major influence on disaster preparedness planning throughout the United States. At the time of the TMI-2 accident, the Pennsylvania Emergency Management Agency (PEMA) had 47 full-time employees and 6 part-time employees whose salary, travel and administrative expenses were shared equally by the Commonwealth and DCPA. City and county emergency preparedness agencies in Pennsylvania had a total of 92 full-time and 26 part-time employees whose salaries and expenses were also shared equally by DCPA.

Through its regional centers, DCPA maintained routine contacts with State Emergency Operations Centers, and it normally served as the principal Federal communications link with local and State personnel actually conducting disaster operations (as opposed to post-disaster recovery and assistance, for which FDAA and other agencies became involved).

DCPA had signed the Interagency Radiological Assistance Plan (IRAP), which charged DCPA with 1) performing those civil defense and disaster warning functions delegated to the Secretary of Defense, and 2) providing natural disaster preparedness planning assistance to State and local governments.

DCPA also had responsibilities assigned under the provisions of FRPPNE, issued as interim guidance in April 1977. Under those provisions, as applicable to fixed facility nuclear accidents, DCPA was responsible for the following:

1. Issuing guidance on the use of civil defense resources, including warning, communications, training, and radiological defense emergency response systems) at all levels of government;
2. Assisting the NRC in providing State and local governments with training, onsite assistance, and other assistance in preparing and exercising peacetime nuclear emergency operational response plans for fixed nuclear facilities;
3. Warning the population, through State and local governments, if feasible, of the expected impact area in the event of an impending nuclear incident; and
4. Informing the public of protective measures to be taken to mitigate the effects of a major radiological contamination.

Initiation of Involvement

The DCPA Region Two Center near Olney, Md., was notified of the TMI-2 accident by PEMA at 8:45 a.m. on March 28. Although there were no prearranged plans for PEMA to notify DCPA in the event of such an accident, notification was in accordance with the actions PEMA would be expected to take in the event of any sizeable emergency. The Region Two Center notified DCPA headquarters of the accident at 9:00 a.m.

Description of Response

At approximately 10:00 a.m. the DCPA Regional Field Officer for Pennsylvania, who was participating in a preparedness conference at the PEMA Central Area Headquarters in Selinsgrove, Pa., was directed to go to the PEMA Emergency Operations Center in Harrisburg to monitor the emergency and to assist PEMA. A Disaster Operations Center was activated at the DCPA Region Two office. No other action was taken during the first 2 days except for responding to requests for information regarding the accident and maintaining contact with PEMA and the NRC. Based upon the information they obtained, DCPA inferred that the situation at the plant was under control and that no further action would be required.

Following the radiation release on Friday, March 30, DCPA personnel attended the afternoon meeting at the White House to discuss Federal agency response. At the meeting, John McConnell, DCPA Assistant Director for Plans and Operations, was designated Federal advisor to the State for purposes of evacuation planning. McConnell arrived at the PEMA Emergency Operations Center (EOC) in Harrisburg at about 5:00 p.m. Also on Friday, a second Region Two Field Officer was sent to Harrisburg to permit 24-hour coverage of the PEMA emergency center. Eight staff members from Region Two were sent to the principal risk counties to support the county planning efforts, two each to Dauphin, York, Lancaster, and Cumberland Counties. Two U.S. Army Communications Command personnel with high frequency radio sets were dispatched to York and Lancaster Counties, where they established a radio net linking the counties, the PEMA emergency center, and the Olney Regional Center.

Over the weekend of March 31 to April 1, the DCPA personnel assigned to the risk counties functioned as members of the county planning teams, and in some cases served to actually draft the county evacuation plans after county and State authorities had put together the basic concepts of the evacuation. McConnell, operating out of the PEMA EOC, visited the risk counties to provide supervision, and as senior DCPA representative, beginning April 1, he attended the daily Federal agency coordination meetings arranged by Robert Adamcik of the FDAA.

On Monday, April 2, four additional radio operators with equipment were sent to Dauphin, Cumberland, Lebanon, and Perry Counties, allowing for establishment of an independent radio net linking the six counties at risk, the PEMA emergency center, and the Region Two Center. Most of the net was operational by late Tuesday, April 3, in spite of some delays caused by damage to equipment while in transit and a shortage of spare parts.

Although the concept was good, actual performance of the radio net was deficient. Because the sets were designed to operate at the low end of the high frequency band (4 780 KHz), the signal-to-noise ratio was low, and operation of the sets interfered with a computer near the PEMA EOC. The radios were awkward to use since they consisted of more than one unit, and were easily damaged in shipment.

On April 2, DCPA also furnished 6 000 low range personnel dosimeters (CDV-138) in response to PEMA requests. These were issued by PEMA to Federal, State and local personnel operating in potentially hazardous areas. The State already possessed CDV-700 high range dosimeters, but it was difficult to obtain accurate measurements with them in the low radiation fields encountered.

On April 2 two additional DCPA health physicist and radiological defense officers joined the DCPA staff at the PEMA emergency center, and 19 additional DCPA staff personnel were dispatched to the host counties to assist them in planning for evacuees. These personnel had arrived on site by Tuesday, April 3.

A team of three DCPA personnel assisted in radiological monitoring using a portable scintillation counter.

During the period following the accident a total of about 50 DCPA personnel were involved in support of PEMA and the county emergency management agencies. Beginning on April 6 and extending to April 8, the personnel assisting the host counties completed their work and were released. On April 7, Frank Vogel, Deputy Assistant Director for Operations, reported to the State EOC as relief for McConnell. During the period from April 10 to 13, the balance of the DCPA staff returned home.

4. DEPARTMENT OF ENERGY

Organization, Responsibilities, and Authorities

In matters involving nuclear applications of either a military or nonmilitary nature, DOE is the successor of the Atomic Energy Commission and has inherited its technology development and support responsibilities. It is party to written agreements with DoD, the Federal Bureau of Investigation, and the NRC that cover shared responsibilities. With a dozen other Federal agencies, including both the DoD and the NRC, DOE is a signatory of the IRAP. Application of these agreements in an emergency response is not, however, without ambiguity. DOE's agreement with the NRC, for example, provides for DOE support when requested by the NRC in connection with an emergency at a licensed nuclear facility. IRAP, on the other hand, is unclear about how it is to be invoked, but indicates that DOE is the agency "responsible for directing the administration, implementation, and application of the provisions of the IRAP." Appendix Figure III-10 provides a partial organization chart for DOE. The radiological monitoring services supplied through the Operations Offices, which administratively report to the Under Secretary, involved the Radiological Assistance Program (RAP) teams, which report to the Operational and Environmental Safety Division under the Assistant Secretary for Environment.

The organization of the radiological assistance efforts, which were more complex than other DOE support efforts, is indicated in Appendix Figure III-11. Coordination was provided by onsite representatives of DOE's Operational and Environmental Safety Division. RAP teams from DOE's Region 1 office provided direct support to the Commonwealth of Pennsylvania. Three Regional Coordinating Offices and the Nevada Operations Office furnished support for the NRC. Of course, all of the information obtained by DOE was available to all interested persons.

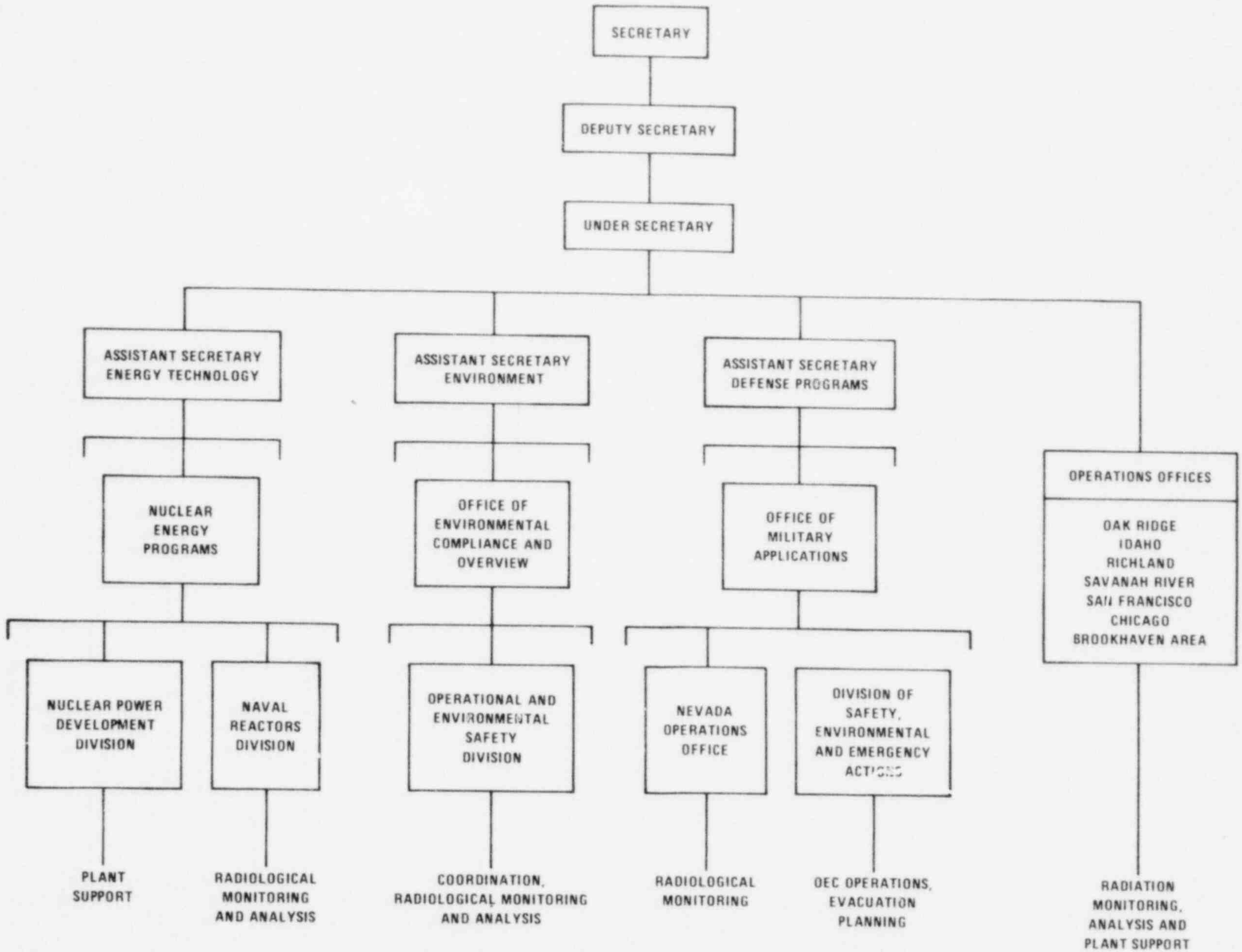
The TMI accident did not involve significant offsite radiological contamination. In an accident at a fixed nuclear facility that did involve such contamination, DOE and its contractors would have participated in the efforts to assess and mitigate the concomitant hazards.

Initiation of Involvement

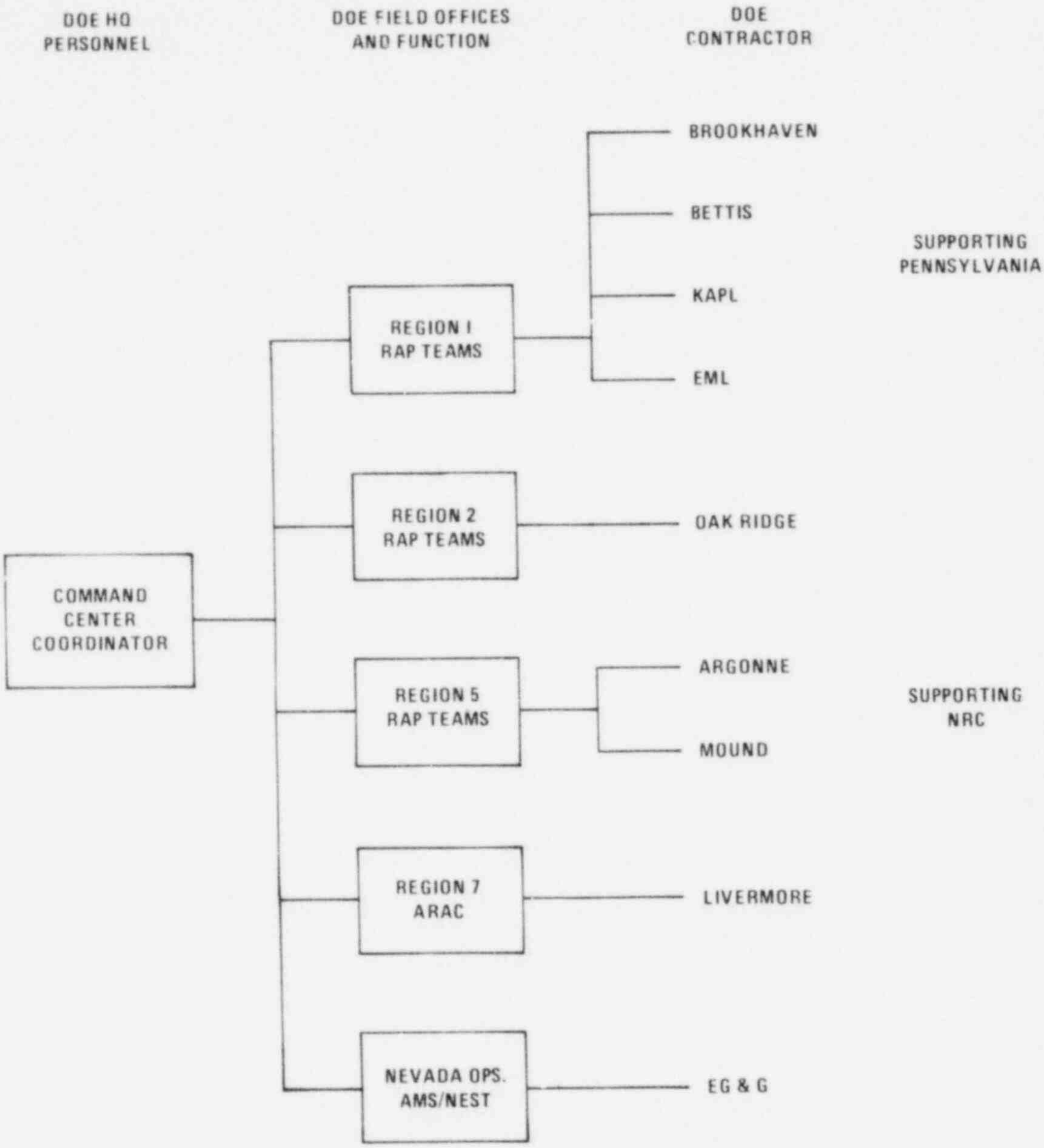
The DOE involvement began at 7:10 a.m. on March 28 when Mr. Bensel, at TMI, contacted Brookhaven National Laboratory (BNL) security to alert the RAP team to the incident. Mr. Greenhouse of BNL contacted TMI to determine the plant status while the RAP team took measures to get a Coast Guard helicopter put on standby. At about 8:45 a.m. the Brookhaven area office manager called the DOE Emergency Operations Center in Germantown, Md., to transmit this information. At 8:50 a.m. the NRC Region I called the Brookhaven area office to determine the RAP team status. Neither the utility nor the NRC requested assistance at that time.

The DOE Emergency Operations Center contacted the NRC Incident Response Center at about 8:55 a.m. to confirm the general emergency condition at TMI. No immediate assistance was requested.

At about 10:00 a.m. the Aerial Measuring System/Nuclear Emergency Search Team (AMS/NEST) stationed at Andrews Air Force Base was placed on standby alert, and at about 11:00 a.m. a request was received from the NRC to have the AMS/NEST moved to the Capital City Airport at New Cumberland, Pa., to await instructions.



APP. FIGURE III-10. DOE Organization Chart (Partial)



APP. FIGURE III-11. DOE Radiological Monitoring/Field Organizations

Meanwhile, the Region I RAP team was contacting the NRC Headquarters Incident Response Center, the NRC Region I Incident Response Center, and the Bureau of Radiation Protection (BRP), of Pennsylvania's Department of Environmental Resources, in a continuing attempt to obtain a request to move. At 11:18 a.m. that request was obtained from BRP.

The AMS/NEST unit arrived at the Capital City Airport at 1:30 p.m. on Wednesday and established an operations center in the airport manager's office. The AMS/NEST equipment arrived [illegible] afternoon, so the team could make aerial measurements of radiation that same day. The RAP team, which had expected to land directly at Harrisburg, had to land instead at the Capital City Airport because of the size of its helicopter, arriving at about 2:30 p.m. The team was driven into Harrisburg by State personnel. They then established their operational center with the BRP, under whose direction they were working. They had begun monitoring at the airport while waiting for transportation to Harrisburg.

Late Wednesday afternoon the Emergency Action Coordinating Team at DOE Headquarters decided that the presence of two independent teams working in support of two different organizations required onsite coordination by someone from DOE Headquarters. Mr. Patterson was designated the senior DOE representative. He arrived at the Capital City Airport at a little after 11:00 p.m.

By midnight on Wednesday, DOE had established the basic structure of its radiological support effort. An airborne measurement capability was in place and operational. Surface measurement teams were in the field taking environmental samples and radiation measurements. An administrative structure had been established for the coordination of DOE efforts, and communication channels had been established with the NRC, the Pennsylvania BRP, and DOE Headquarters.

During the second day of the incident, March 29, 1979, there were only modest changes in DOE involvement. A second AMS/NEST unit arrived from Las Vegas at an early hour. Another RAP team from BNL arrived at about 2:00 a.m. Dickerson, of Lawrence Livermore Laboratory, was requested to come to the DOE Command Post at the Capital City Airport. Since Dickerson was in Chicago at the time, he was able to get to Harrisburg quickly and to begin providing local input to the Atmospheric Release Advisory Capability (ARAC) at Lawrence Livermore Laboratory. The laboratory uses meteorological, topological, and effluent data to predict the temporal and spatial distributions of airborne effluents. Enough telephones were installed in the State hangar at the airport to transfer the Command Post from the manager's office to the hangar, where it remained for the duration of the emergency response period. The BNL RAP teams, which had been on continuous duty since their arrival, were replaced by Pittsburgh Naval Reactors teams. Finally, Joe Deal of DOE's Operational and Environmental Safety Division was sent to the Command Post to relieve Patterson as senior DOE representative.

On the third day, Friday, March 30, the rapid escalation of general concern was directly reflected in the expansion of the DOE efforts in the radiological area. It led also to the initiation of significant DOE efforts in the area of plant support.

The Region I RAP teams, which had been functioning on a short term basis, were placed in a long term operational mode. Brookhaven, Bettis, and Knolls Laboratories personnel were maintained in the area concurrently and used on a shift basis so that the RAP teams could continue to function effectively for an extended period. The Environmental Measurements Laboratory also participated in the terrestrial measurements effort, providing their initial data on April 2, 1979.

On Friday, March 30, at the request of the NRC, DOE dispatched RAP teams from Oak Ridge, Argonne, and Mound Laboratories (in Tennessee, Illinois, and Dayton, Ohio, respectively) to support the NRC's radiological monitoring efforts.

The AMS/NESTs, accustomed to longer term operations, did not require additional personnel. They did, however, require extra equipment and personnel as a result of engine trouble with the H-500 helicopter from which they conducted their monitoring operations. Two AMS/NEST communications pods and support personnel came from Las Vegas to facilitate monitoring communications off site and to improve DOE Command Post communications with the State and the NRC.

The increase in offsite radiation measurement made more effective coordination necessary. At DOE's behest, the NRC and BRP representatives met with the DOE representatives for a coordination meeting. The meeting took place at the Capital City Airport at 5:00 p.m., March 30, 1979. (Pennsylvania's BRP had requested that DOE take the lead in the monitoring efforts.) That meeting, which was also attended by representatives of other agencies, established the pattern for the remainder of the emergency response period. Each afternoon after March 30, all of the organizations involved in offsite monitoring met in the airport hangar to present the data accumulated during the day, to discuss its significance, and to plan the next day's effort. At the request of the BRP, the DOE accepted the responsibility for consolidation and analysis of radiological data from all sources. The information, which was developed at the request of the Commonwealth of Pennsylvania, was made available to all interested parties.

DOE's initial response on March 28, 1979, was made by 18 people in the TMI environs. This level increased almost linearly with time until Sunday, April 1, at which time the number of DOE and DOE-contractor personnel in the area exceeded 100. The involvement remained high through April 6. It then decreased to about 50 for the last week of the emergency response period, through April 15.

Description of Response

Radiological Monitoring and Analysis

The AMS/NEST units used helicopters to locate, radially track, and define both the azimuthal and vertical extent of the effluent plume from the plant. They used the sodium iodide scintillation detector array, which they employ in background survey measurements, as well as hand-held survey instruments, which were used when the sodium iodide detectors became overloaded in the effluent plume. They also obtained air samples in the plume and measured the energy spectrum of the gamma rays to identify the radioisotopes present.

During the first few days, several flights were made each day, but these did not necessarily correspond to intervals of greatest venting from the plant. By March 31, an effort was being made to schedule a flight every 3 hours and to make special flights when releases from the plant were expected.

These flights were facilitiated by information provided to the AMS/NEST units by the Atmospheric Release Advisory Capability (ARAC). ARAC's prediction of plume direction, altitude, and dispersion checked well with flight observations and expedited locating and tracking the plume.

The data obtained with automated survey equipment was recorded on tape for analyses performed in a van at the airport after the flight. The survey instrument readings were written down during the flight and turned in to the coordinator in the Control Center. After the AMS/NEST communications gear became available, direct radio communications with the Command Post were possible, so that some data, particularly unexpected data, was communicated by radio to avoid the normal time delay. When the data became available to the AMS/NEST coordinator in the Command Center, it was telephoned to the NRC and to DOE Headquarters, and a copy was given to the RAP team coordinator in the Command Center.

DOE's Region I RAP team was operating at the request of the Commonwealth of Pennsylvania in support of the Commonwealth's offsite radiation monitoring efforts. The team measured ambient radiation levels, took samples of air, vegetation, soil, and water, and analyzed the samples to determine both the type and quantity of radioactive material they contained.

The BNL team that arrived on March 28 brought and later used an air sampler containing a silver-impregnated gel, a device developed at Brookhaven to serve as a specific absorber for iodine. It was not subject to the interference which led to early erroneous reports of iodine activity, interference caused by xenon absorption, a usual occurrence when using ordinary activated charcoal filters.

The team from Bettis brought a lithium-drifted germanium (GeLi) spectrometer whose resolution facilitated identification of radioisotopes. The Environmental Measurement Laboratory van at the airport was also equipped with high resolution spectrometers. Taken all together, a substantial laboratory analysis capability to analyze the large number of samples collected each day was established at the airport.

All of the data available at the Command Post was communicated to the BRP office, where it was posted on large maps to provide a visual perspective. During the first 2 days of the accident, when the RAP teams were headquartered at the BRP offices, the RAP team data were analyzed and assembled there, and telephones were used to collect data from other sources. After the RAP teams were shifted to the airport to provide additional space at BRP and to achieve better coordination with other DOE radiation measurement efforts, other DOE personnel had to be assigned to BRP offices on a round-the-clock basis to maintain the same level of coordination achieved earlier.

The RAP teams supporting the NRC worked out of a trailer park near the site. The area they covered was closer to the plant and lay principally along the roads paralleling the east and west banks of the Susquehanna River. They appeared to have knowledge of plant operations and were more likely than the BRP-connected teams to be out and looking for activity during a release. These teams, of course, were not requested until March 30, and so were not present during the more confusing early days.

The team from Mound Laboratory was assigned to support HEW's Bureau of Radiological Health in distributing dosimeters out to 20 miles from the plant. Within the Command Center, information obtained by all of the organizations involved in the radiation monitoring effort was continuously collected, correlated, and displayed. A single display technique was commonly used to facilitate comparison of many types of data, including "instantaneous" rate data, cumulative doses at given positions, and population exposure estimates. This display technique was to present the data as an overlay on a map of the area so that the spatial relationships among the data in a given set or among sets of data could be more readily appreciated.

Also, the Director of the Human Health and Assessments Division of DOE spent the first weekend of the emergency in Harrisburg consulting with health officials of the Commonwealth of Pennsylvania and their advisors on the potential biological impact of radiation releases from TMI.

Atmospheric Release Advisory Capability

DOE's ARAC at Livermore Laboratory was definitely an asset during this incident. After data began to be transmitted automatically from the TMI meteorological tower to Livermore, the AMS/NEST unit reported that the ARAC predictions of plume characteristics corresponded very well with their observations and greatly simplified the task of locating and tracking the plume. On the other hand, for the NRC, whose primary concern was with plume behavior close to the plant, the mesh employed in the ARAC analyses was too coarse.

Prospective users of ARAC would prefer that the system be modified from the presently required uniform mesh to a variable mesh, so that better definition close to the source could be obtained without requiring either excessive computation or output.

There were several potential users, and getting the output as rapidly as possible was urgent. The sequential transmission to the various users was slow; simultaneous transmission of output could significantly increase the system's value and acceptance.

Technical Support for the Plant

One of the first technical support efforts undertaken was the analysis of a primary coolant sample from the plant done at Bettis Laboratory, near Pittsburgh, Pa. Additional samples of coolant water as well as samples of containment atmosphere and waste gas storage tank contents were also analyzed at Bettis. Coolant sample analyses were also made at the Savannah River Laboratory, Oak Ridge National Laboratory, and the Idaho National Engineering Laboratory (INEL).

The mobile manipulator "Herman" and a team of operators were sent to TMI from Oak Ridge to obtain primary coolant samples. "Herman" was however never used, because of concerns about its reliability.

When the NRC put out a call for lead bricks to shield a recombiner at the plant, DOE sources as well as other Federal agencies responded. Eight tons of lead bricks were supplied by Bettis; 43 tons by Brookhaven.

The DOE also provided support to the utility through the NRC. This support included public relations personnel from Headquarters and from Oak Ridge; noise analysis, instrumentation capability, and a photographer from Oak Ridge; and technical experts from INEL. They arranged for Mr. Dietz of the Naval Research Laboratory to perform iodine "bleedoff" tests on samples of charcoal from filters at TMI, using a method developed under DOE sponsorship.

Many DOE laboratories at which safety research programs are supported by the NRC took part in investigations and analyses related to TMI plant status. Supplementary supplied air respiratory equipment for use inside the plant was obtained from Savannah River, and two air distribution manifolds were provided through the Richland Operations Office.

5. ENVIRONMENTAL PROTECTION AGENCY

EPA has responsibility for maintenance and improvement of air and water quality, including the establishment of standards for radioactive substances as well as many other contaminants. To meet its responsibilities, the agency:

1. Establishes Protective Action Guides, or PAGs (projected radiation doses that might result from radiation incidents at fixed nuclear facilities or in the transportation of radioactive materials), in coordination with appropriate Federal agencies;
2. Recommends appropriate protective actions that can be taken by government authorities to mitigate the hazards of a radiation incident at a fixed nuclear facility or from an incident involving transportation of radioactive materials;
3. Establishes emergency radiation detection and measurement systems guidelines in cooperation with the NRC;
4. Develops guidelines for the disposal of solid wastes and other debris, whether radioactive or nonradioactive, which might contaminate the environment;

5. Assists the responsible agency at the scene of the incident by providing monitoring teams to measure environmental radiation and to evaluate the extent of the contamination; and
6. Ensures that adequate potable water is available for public use.

In normal operation, radiation monitoring is performed by two offices of the Agency. The Office of Radiological Protection, under the Assistant Administrator for Air and Waste Management, maintains air sampling stations around the country and operates the Eastern Environmental Radiation Facility in Montgomery, Ala. The Montgomery facility, in addition to inhouse analytical capability, has a mobile analysis laboratory which is available for use throughout the Eastern United States. The Office of Monitoring and Technical Support, under the Assistant Administrator for Research and Development, maintains an airborne and terrestrial monitoring team that provides offsite monitoring for the Nevada test site.

EPA had a direct interest in the TMI accident because of its environmental responsibilities. It had authority by legislation and regulation to monitor the environment whenever necessary.

Initiation of Involvement

EPA received notification of the TMI accident from the NRC at 9:05 a.m. on March 28, 1979. The Agency activated its radiation alert office in Washington, D.C., and placed its air sampling stations in Wilmington, Del., Harrisburg, Pa., and Washington, D.C., on a daily collection schedule. The next day, March 29, the sampling station in New York City was also placed on a daily schedule. (Normally, a sample is accumulated for an entire week before being measured.) EPA also volunteered assistance to Pennsylvania and was asked to remain on standby.

On Friday morning, March 30, the decision was made to undertake a comprehensive environmental monitoring program in the TMI area. Douglas Costle, EPA Administrator, requested Stephen Gage, his Assistant Administrator for Research and Development, to establish that program.

The EPA Environmental Monitoring Systems Laboratory in Las Vegas was requested to develop and to implement the necessary monitoring program. Equipment and staff were on the way to Harrisburg by a variety of routes during the afternoon of March 30, arriving in Harrisburg on Saturday afternoon, March 31. By the end of the day, EPA had set up equipment for sample analysis in the facilities of the Pennsylvania Department of Health. An EPA control center was located with the DOE team at the Capital City Airport.

On Friday, March 30, EPA began sampling water from the Susquehanna River and the Chesapeake Bay at its Annapolis Field Station. Aerial photographs of the area within 7 miles of the TMI plant were obtained, and identification of dairy farms and drinking water sources in the area was undertaken by EPA's Warrenton Laboratory in Warrenton, Va. The mobile analysis laboratory from Montgomery, Ala., was alerted, and proceeded to Hagerstown, Md.

The EPA response force from Las Vegas initially consisted of 17 people and was increased to 21 several days later. The peak EPA involvement in the TMI area was a total of 31, including representatives of EPA's Region III Office in Philadelphia.

At the completion of the emergency response phase, EPA's role shifted to coordination of all radiation monitoring during the recovery phase.

Description of Response

The monitoring program that EPA conducted around the TMI plant consisted of air sampling, continuous gamma radiation monitoring, water sampling, dosimetry, milk sampling, and noble gas sampling.

Air Sampling

Sampling stations were established as follows:

1. A ring of 12 stations between 2.5 and 3.5 miles from the reactor with an azimuthal spacing that varied from 15 to 45°.
2. A second ring of 10 stations between 4 and 7 miles from the reactor.
3. Nine stations at populated locations 7 miles or more from the plant.

Each station contained an air sampler with an approximate capacity of 10 cubic feet per minute and having a fiberglass prefilter to collect particulate material and an activated charcoal cartridge to collect iodine. A delay in receiving filters and cartridges postponed the activation of the air samplers. On April 1 six samplers were activated in the inner ring, four in the second ring, and one beyond 7 miles.

On April 2, five more samplers in the inner ring, five in the second ring, and four beyond 7 miles were activated. The final sampler in each of the rings and the remaining four samplers beyond 7 miles were activated on April 3. Filters and cartridges were changed daily and were analyzed by gamma spectroscopy using the EPA's lithium-drifted germanium (GeLi) detector in its analysis laboratory at the Department of Health. Some samples were also sent to Las Vegas for analysis.

Continuous Gamma Radiation Monitoring

A gamma rate recorder consisting of a pressurized proportional counter with a strip chart recorder was installed at each of the sampling stations, except for one station in the inner ring and one beyond 7 miles. Recorders were also located at two residences in Goldsboro and at one in Pleasant Grove. The schedule for activation of the gamma-ray monitors is summarized in the table below.

NUMBER OF GAMMA-RAY MONITORS ACTIVATED BY DATE

Location	3/31/79	4/1/79	4/2/79	4/3/79	4/4/79
Inner Ring	1	6	3		1
Second Ring	5	2	1	2	
Beyond 7 Miles	3	1	1	2	1
Special Homes		3			
Total	9	12	5	4	2

These instruments had been calibrated for ^{137}Cs (662 kiloelectron volt (keV) gamma rays). Because the primary radioactive component of the plant releases was ^{133}Xe, which produces low energy gamma rays (81 keV), recalibration of that equipment was required. Recalibration, which was performed by EG&G Company in Santa Barbara, Calif., and by the National Bureau of Standards, showed that the dose rates were less than the original instrument calibration had indicated.

The strip charts were collected daily, visually examined, and manually integrated when an indication above background levels was noted. A value of 0.1 mR was used as the minimum practical reportable net exposure.

Water Sampling

After the arrival of the EPA team from Las Vegas, the Susquehanna River sampling program initiated by the Annapolis Laboratory was modified to better complement the efforts of the Pennsylvania Department of Environmental Resources (DER). Four sampling stations were established at the Columbia bridge location on the river. River water samples were analyzed in Harrisburg, where the detection limit for ^{131}I was approximately 70 picocuries per liter (pCi/l).

In conjunction with the State DER, EPA developed a program for sampling drinking water. Over 100 sources of drinking water were identified within 20 miles of TMI. Of these, 21 were surface water supplies and thus were identified as priority sampling sites. Samples from these priority sources were gamma-scanned in Harrisburg for gross contamination. Because the detection limit for ^{131}I was too high to detect the maximum concentrations acceptable for continuous consumption under EPA criteria, all samples were sent for analysis to the Eastern Environmental Radiation Facility in Montgomery, Ala., where detection limits for ^{131}I were targeted at 15 pCi/l. Composite samples, accumulated over 24 hours, were collected from major public drinking water supplies and were sent to the Environmental Monitoring Systems Laboratory in Las Vegas for analysis.

Daily sampling of liquid effluents from TMI at their point of discharge was also instituted. Samples were collected by DER and analyzed by EPA in Harrisburg.

Dosimetry

Thermoluminescent dosimeters (TLDs) were also placed at the sampling stations. Three badges, each containing two dysprosium activated calcium fluoride chips were located at each station. In addition, approximately 50 TLDs were issued on a voluntary basis to residents in the vicinity of the sampling stations.

Milk Sampling

Using photointerpretation techniques, 105 dairies within 7 miles of the TMI-2 reactor and 465 dairies within 25 miles of the reactor were identified. After evaluating the milk sampling programs of the Commonwealth of Pennsylvania, the FDA, and Met Ed, EPA initiated a separate milk sampling program on April 5, selecting nine dairy farms for daily sampling. The EPA milk sampling program was undertaken to complement efforts of the other organizations already actively sampling milk. The minimum amount of ^{131}I detectable in these milk samples was 20 pCi/l.

Noble Gas Sampling

Three stations were established for routine radioactive noble gas sampling. Compressed air samples of at least two-thirds of a cubic meter were collected over a 2- to 3-day period. Samples were analyzed in the EPA laboratory at Harrisburg for ^{133}Xe and ^{85}Kr by a cryogenic procedure. Separation of the gases depends upon differences in their volatilization temperatures; quantity is determined by liquid scintillation. The minimum detectable level for ^{133}Xe was approximately 5 picocuries per cubic meter.

Long Term Response

On April 13, EPA was assigned responsibility for coordinating all long term Federal surveillance activities and for preparation of a report to the Presidential Commission investigating the accident at TMI. EPA developed a long term interagency monitoring program that is being carried out by a number of organizations. EPA's report to the Presidential Commission, containing all of the offsite radiological data obtained during the accident until May 1, 1979, is contained in a six-volume compendium from the EPA data file.*

6. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

General Responsibilities

HEW's role in control of radioactive contamination of food and in other emergency actions during the Three Mile Island nuclear accident was delineated in a Federal interagency agreement issued by the FPA (now part of FEMA) and published in the Federal Register on December 24, 1975. This agreement charged HEW with the following:

1. Issuing guidance necessary for evaluating and preventing the radioactive contamination of food and animal feeds.
2. Formulating recommendations on, and facilitating the use of, prophylactic drugs to reduce radiation dose to specific organs (this refers, in particular, to the use of potassium iodide following a contaminating accident).
3. Providing guidance on emergency radiation doses related to health and safety of health personnel and assisting State health departments and other professional organizations in developing plans for the prevention of adverse effects from exposure to radiation.

Within HEW, the above responsibilities are principally carried out by its Food and Drug Administration. FDA's goals are to ensure that food for human consumption and animal feeds are safe, pure, and wholesome; that drugs, medical devices, and biological products are safe and effective; that cosmetics are harmless; and that human exposure to potentially injurious radiation is minimal. FDA also assists State health officials and other health organizations on radiation matters.

In addition to FDA activities, HEW, through its Communicable Disease Center (CDC), and its National Institutes of Health (NIH), acts under a general responsibility for gathering health effects information.

*Three Mile Island Nuclear Reactor Accident of March 1979, Environmental Radiation Data, volumes 1-6, September 7, 1979.

Initiation of Involvement

At 10:30 a.m. on March 28, FDA's Bureau of Radiological Health (BRH) received a report from the NRC that at about 4:00 a.m. an incident possibly creating a radiation problem had occurred at TMI. BRH offered assistance to the Pennsylvania Department of Health and the Pennsylvania BRP. Following a meeting Friday, March 30, between representatives of the White House, EPA, the NRC, and HEW, HEW became extensively involved in responding to TMI.

Description of Response

On March 28, five HEW staff members were on site at TMI. The following week 51 HEW people were onsite and others were in various support roles outside the TMI area. HEW committed extensive resources to the effort and as of July 6, 1979, HEW had expended approximately 20.4 person-years on the Three Mile Island accident. HEW also incurred considerable costs; as of July 6, 1979, HEW had allocated about $775 345 to its TMI response, approximately $400 000 of which was spent to obtain a sufficient supply of potassium iodide for the Three Mile Island area resident population should circumstances have warranted its distribution.

The following is a detailed summary of HEW's TMI-related activities.

FDA Sampling Activities

FDA's milk, food, and water sampling program was initiated March 29. From March 29 through June 30, 1979, 2 037 samples were collected and analyzed by HEW for radionuclide concentration levels (see Appendix Table III-1). Of the samples

Appendix TABLE III-1. Items sampled from March 29 to June 30, 1979

Food	Bread, butter, cake, donuts, cookies, candy, cereal, cheese, cole slaw, eggs, fish, flour, fruit punch, ice cream, market food basket, noodle products, pastry, peanuts, peanut butter, pretzels, soft drinks, sugar, vegetables
Water	Intake, potable, river, treated
Milk	Raw, composite, condensed, skim, low-fat, pasteurized, raw goat's
Other	Hay, grass, silage, animal thyroids, animal feed

collected by the FDA, 1 339 were milk, 525 food, 149 water, 14 animal feed, and 10 miscellaneous. There were 5 718 analytic tests performed on 2 037 samples. Between March 29, 1979, and April 20, 1979, 69 samples—all milk—were reported positive. (One additional milk sample was "spiked," as a check for the quality assurance program; it was reported positive on April 27, 1979.) No positive samples of any kind were reported after this date.

Radiation Dosimeters

As of April 2, 1979, FDA had placed 237 TLDs at 173 sites over a 20-mile radius around the reactor. Most of these dosimeters were situated within a 10-mile radius of the site. Most were placed near public buildings such as schools and hospitals and some were at homes. At 64 sites dosimeter packages were placed both indoors and outdoors to evaluate the shielding effects of the structures.

Photographic Film Dosimetry

FDA initiated a retrospective dosimetry program by collecting samples of readily available, 35-mm Kodacolor 400 film from retail shops in the vicinity of the Three Mile Island facility. This film was recommended by Kodak as being relatively radiation sensitive.

Samples of the film known to have been located in the vicinity of the reactor site during the accident were collected in early May from stores in or near Elizabethtown, Manchester, Steelton, New Cumberland, and Middletown, Pa. Reference samples of film bearing similar expiration and, hence, similar manufacturing dates were collected during the same period in Rockville and Frederick, Md. Eastman Kodak, in cooperation with the FDA, developed the films on May 9 and May 17.

Bioassay

At the request of NIH, the Pennsylvania State Health Department collected urine specimens from 38 individuals residing within 5 miles of the Three Mile Island reactor. The 171 samples were collected from April 4 to April 8, and were delivered daily to NIH for analysis. The radionuclides potentially released to the environment from the Three Mile Island reactor were isotopes of the noble gases krypton and xenon, the iodines, cesium, strontium, barium, lanthanum, and ruthenium.

Health Census

The Center for Disease Control (CDC) and the National Cancer Institute are providing funds for a project to record names, vital statistics, and relevant health data for each of the 50,000 people living within 5 miles of the reactor during the event. Other facts relevant to determining the amounts of radiation that this group may have received are also being collected. This health census, begun on June 20, 1979, is being conducted by the Pennsylvania State Health Department and CDC. It will form the basis for future physical and mental health studies. As of July 5, 1979, 85% of the targeted households had been surveyed.

Thyroid Blocking Agent

Following the Three Mile Island accident, the FDA arranged for the manufacture and stockpiling in Harrisburg, Pa., of potassium iodide solution for use as a thyroid blocking agent to prevent the uptake of radioiodine. FDA's Bureau of Drugs obtained 250,000 ounces of potassium iodide solution, packaged in 1-ounce bottles. Each bottle had a sufficient quantity of iodide solution to accommodate the needs of a household of four throughout the incident. The Bureau of Drugs had 250,000 patient information sheets printed and shipped to Harrisburg so that one could be distributed with each bottle of the solution.

HEW recommendations with respect to thyroid blocking were sent to the White House on April 3, and were then forwarded to the Commonwealth of Pennsylvania. HEW recommended that the Commonwealth do the following:

1. Have workers in the plant and others on the island begin taking blocking doses right away.
2. Have potassium iodide immediately available to all persons whose proximity to the site is such (perhaps up to 10 miles) that they would not have at least 30 minutes advance warning of ^{131}I exposure.
3. Have potassium iodide available at convenient points for distribution to other persons who might be exposed, such that they could have the medication at least 30 to 60 minutes in advance of possible exposure.
4. Accompany all distribution with notification to the effect that: "All persons may take potassium iodide safely for a short time. All persons who: a) have goiter or known thyroid disease; b) are pregnant, or c) are breastfeeding a child, should notify their physician when they start taking iodide and after they have stopped."
5. Prepare for reducing the iodide dose after 2 weeks of administration of the dose specified on the labels. HEW offered to help devise instructions to this effect.
6. Those in immediate touch with the local situation should assess these recommendations in light of

knowledge about current risks and about the likelihood of advance warning of radiation releases.

A list of conditions under which use of the drug should be considered also was available in a publication of the National Council for Radiation Protection and Measurements, NCRP Report No. 55. Upon consideration of HEW's recommendations, the NCRP report, and the advice of consultants the Pennsylvania Department of Health decided to hold the drug in readiness, but not to administer it, since the conditions outlined in the NCRP report were not encountered during the accident.

The potassium iodide sent to TMI has been transferred to the National Center for Toxicological Research, in Jefferson, Ark., for long term storage. Periodic stability testing will be conducted to determine when the potassium iodide no longer meets USP standards, at which time it will be disposed of.

7. THE WHITE HOUSE

White House involvement in the response to the Three Mile Island accident began on Wednesday, March 28. At about 9:00 a.m., Jessica Tuchman Mathews, who was then on the staff of the National Security Council, received a call from Commissioner Victor Gilinsky of the NRC notifying her that there had been an incident at Three Mile Island. The information was sketchy, but Gilinsky was aware that the plant had tripped, that there was radiation inside the containment building, and that a general site emergency had been declared. Mathews drafted a brief memorandum detailing the sketchy facts she had obtained to Zbigniew Brzezinksi, her superior and the President's national security advisor. She hand-carried the memorandum to Brzezinski and, after a brief discussion with Mathews, Brzezinski informed the President of the incident. Throughout Wednesday and Thursday, Mathews stayed in telephone contact with Gilinsky so that she could keep up-to-date on plant status. There was no other White House activity at that time.

On Friday morning at about 9:00 a.m., Mathews was notified by the White House Situation Room that they had received a wire service notification of a 1,200 mR/h release measured in the plume over the plant. Almost simultaneously, she received a telephone call from Gilinsky with the same information, and immediately informed Brzezinski, who in turn informed the President.

The President telephoned Chairman Joseph Hendrie and asked him what the NRC needed to help cope with the situation. Hendrie told the President that there were communications problems; the President promised to provide assistance. Hendrie had already discussed with Denton, Director of Nuclear Reactor Regulation in the NRC, the possibility that Denton would go to the site. When the President, during his conversation with Hendrie, suggested the need for a senior Federal official at TMI, Hendrie told him that Denton was ready to go. They agreed that Denton would go to the site as the personal representative of the President.

At about 11:00 a.m., Mathews and Col. William Odom, military aide to Brzezinski, briefed Jack Watson, Assistant to the President for Intergovernmental Affairs and Secretary of the Cabinet, and his deputy, Eugene Eidenberg. Following this briefing, Mathews briefed Jody Powell on the situation. During her meeting with Powell, she learned that the President had been in touch with Governor Thornburgh, and that the President's directive regarding communications had been expanded to include the Governor's office, so that it would provide a direct link between the White House, the NRC, the site, and the Governor's office.

The White House Communications Agency (WHCA), a military communications unit of the Defense Communications Agency, assigned to support the Executive Office of the President, was the agency responsible for establishing those direct telephone links. Commander Baker of the WHCA proceeded to Harrisburg on Friday afternoon by Marine Corps helicopter. He arrived within minutes of Denton. By using long-haul trunk lines already available through AT&T, Baker tied the White House switchboard directly to two lines at the NRC trailers, one line at the Governor's office, one line to Hendrie at the NRC Headquarters, and one line to the NRC Incident Response Center. Using this dedicated net, any one of these telephones automatically rang the White House switchboard, from which it could be tied either to another telephone on the net or to lines off the net. This dedicated circuit remained in place and in use for nearly a month.

A Federal agency meeting was held in the White House Situation Room on Friday afternoon. It was attended by representatives from the NRC, FDAA, FPA, DCPA, DOD, and DOE. Hendrie briefed the group on plant status. He described the plant as then being in a stable condition, but emitting small discharges of radioactivity which were likely to continue. He mentioned the hydrogen bubble and described the hazard it posed in attempts to bring the reactor to cold shutdown, and the possibility of having to evacuate people from within 20 miles downwind of the plant. He also reported that the Governor had advised a limited evacuation of pregnant women and young children from within 5 miles of the plant.

During the meeting, it was agreed that Watson would take the lead in coordinating the overall Federal response effort. This was a normal role for Watson in his position as Assistant to the President for Intergovernmental Affairs. He had performed a similar function during the strike by the United Mine Workers in early 1978, a strike that had caused shortages of coal for power generation, and during the fuel shortage in the spring of 1979, when he coordinated the efforts of several Federal agencies involved in fuel allocation. During a subsequent meeting in Watson's office, it was decided that DCPA would send John McConnell to Harrisburg to assist in the preparation of evacuation plans; FDAA would assume the lead for the overall Federal nontechnical response and would send Robert Adamcik to Harrisburg to coordinate this effort.

The question of whether there should have been a formal declaration of an emergency or disaster at TMI was an open issue beginning Friday afternoon and extending through the weekend. In general, the Federal agencies, particularly FDAA, initially pressed for such a declaration because they believed it would facilitate their support activities. The Governor's staff did not think it would be advisable, because the declaration would have an adverse psychological impact on TMI area populace. At the same time, however, State officials were prepared to ask for a formal declaration, had such an act been necessary to assure the needed Federal assistance. The White House staff, primarily Watson, obtained assurance from the Federal agencies that full assistance was being provided without the formal declaration, even though the lack of a formal declaration may have caused some administrative problems. Watson assured the Governor that they were providing all possible assistance. At the same time, however, the White House was prepared to issue a formal declaration almost immediately had the Governor requested such action. The final decision whether to request a declaration was left to the Governor.

Following notification of the release of radioactivity on Friday morning, the health agencies of HEW and EPA became convinced that they should be involved in the response. A meeting was held at HEW on Friday afternoon at 3:00 p.m. to discuss the situation. Mathews represented the White House.

On Saturday morning, Secretary Califano of HEW sent a memorandum to Watson reporting on the results of the meeting and recommending that, unless the NRC could provide firm assurance that the reactor was cooling safely, Watson should recommend to the Governor an immediate evacuation out to 20 miles from the plant. Watson discussed the memorandum and the recommendation with Eidenberg, Mathews, and Frank Press, the President's science advisor. He also called Denton. The consensus of all these individuals was that evacuation was not necessary. In Watson's view, Denton held the decisive vote in such a recommendation.

Late Saturday afternoon Watson chaired a second meeting of the involved Federal agencies in the White House Situation Room. Commissioners Gilinsky and Bradford represented the NRC at the meeting. During the meeting, the NRC reported that preliminary calculations indicated that the likelihood of a hydrogen explosion was not an immediate problem, but that it could be a problem in the next few days. Watson asked that press statements not be made by the agencies, but by the White House or the State officials only.

On Saturday evening an AP wire story regarding a possible hydrogen explosion broke at about 9:00 p.m. The AP wire was based upon information from the NRC Washington offices and appeared to conflict with the information that had been given out from the site. After much discussion between the White House and the NRC, the NRC press center in Washington was closed and future press releases from the NRC originated from the site.

Watson called Herman Dieckamp, President of GPU, and suggested that the utility discontinue separate press briefings. Dieckamp agreed to do so. In fact, Walter Crietz of Met Ed had already announced earlier in the day that the company would not hold further press briefings. Later that evening, during their second joint press conference, the Governor and Denton attempted to dispel any anxiety that had been generated by the AP wire story.

On Saturday evening the President decided to visit the site on Sunday. The reasoning behind this decision is not clear; at the time, the NRC was very pessimistic. The hydrogen bubble was believed to be approaching an explosive mixture and it was uncertain whether an evacuation might have to be ordered. Victor Stello of the NRC was contacted at the site by an unidentified person from the White House, who wondered if it was safe for the President to visit. Stello said he thought the visit could be conducted safely. Hendrie was notified of the visit, but was not asked for his opinion regarding safety. Watson notified the Governor of the President's plans later that evening.

The President and Mrs. Carter, accompanied by Watson, arrived at the Harrisburg airport Sunday afternoon at about 1:00 p.m. Denton briefed the President after his arrival. At the time, the NRC was still split on its views of the potential for explosion of the hydrogen bubble. Stello considered an explosion to be impossible, while Roger Mattson of the NRC still felt it was possible.

The President's party proceeded to the plant for a tour and the President subsequently held a brief press conference. Later that day, the NRC concluded that there was no danger of a hydrogen explosion.

The WHCA provided its normal support to the President during his visit to the site. Baker and a communications team took an auxiliary switchboard to Harrisburg, arriving at about 6:00 a.m. Sunday morning. Adequate communication lines were set up prior to the President's arrival.

On Monday, April 2, as a result of questions raised by Jay Waldman and others in the Governor's office, Eidenberg at the White House requested the Public Health Service to prepare recommendations regarding the advisability of prophylactic administration of potassium iodide. In response to this request, on April 3, Califano sent a memorandum to Watson, attaching the Surgeon General's recommendations with respect to thyroid blocking. Recommendations to distribute potassium iodide to the public and to administer it to people on site, which Califano stated had the support of the Director of the National Institutes of Health, the Director of the National Cancer Institute, and the Commissioner of the Food and Drug Administration, were transmitted to the Governor's office by note from Watson. In subsequent discussions with Waldman, Eidenberg was informed that the State had different advice from its own experts and had decided not to follow the Califano recommendations.

On April 13, Watson sent a memorandum to Secretaries Califano (HEW), Schlesinger (DOE), and EPA Administrator Costle, assigning EPA the lead role for long term environmental monitoring of the radiation levels around the plant, with assistance from HEW and DOE.

In summary, the White House played a passive role during the first 2 days following the accident—a period during which it was believed that the situation at the plant was under control. However, beginning on Friday morning, March 30, the White House became actively involved in coordinating the Federal response effort. The White House did not direct agency efforts; however, it did solve some coordination problems and assure that the Federal response would be effective. Some of this coordinating activity was necessary because of the lack of a declared emergency. Beginning on Monday, April 2, the crisis atmosphere began to diminish and the efforts of the White House decreased accordingly, becoming focused on the long term actions that would be required in support of the State and the plant recovery effort.

8. AMERICAN RED CROSS

Organization, Responsibilities, and Authorities

The American Red Cross (ARC) was chartered by Congress in 1905 and charged with two specific tasks: disaster relief, and service to the military. The Red Cross has taken on other responsibilities in addition to these two, but the extent of its additional undertakings varies from chapter to chapter. The two basic services of the Red Cross are provided by all chapters.

There are about 3000 Red Cross chapters throughout the United States. Chapters are generally, but not exclusively, organized on a county basis. Each chapter is semiautonomous, and is headed by a volunteer board of directors. The level immediately superior to the chapter is the division, of which there are 60 within the United States. Above the divisions are four field offices, which are staffed by employees of the national organization and headed by a manager. The National Chapter is headed by a board of governors, of which the President is the Honorary Chairman. The board sets policy for the local chapters, divisions, and field offices. The authority of the National Board of Governors is based on their control of funds and their authority to remove the charter from a local chapter.

During the accident at TMI, the operative organization and the channel of communications within the ARC was from the Harrisburg Chapter to the Philadelphia Division to the Eastern Field Office.

Initiation of Involvement

On March 28, 1979, the Eastern Field Office was advised by Ed Koast, Chapter Manager in Harrisburg, through the Philadelphia Division, that an accident had occurred at TMI, but that there was no real problem. It appeared at that time that any Red Cross involvement would be within the capabilities of the local chapters.

Description of Response

Koast had been in contact with PEMA officials and was aware that about 16 000 persons could be affected by a 5-mile evacuation. There was no real concern within the field office until Friday morning, when the potential problems at TMI seemed capable of outstripping the resources of the chapters and of the division. As a result, Daniel Prewitt, Assistant Director for Disaster Services in ARC's Eastern

Field Office, went to Harrisburg on the evening of Friday, March 30. With his arrival, the National Chapter took control of all Red Cross operations relating to TMI; all subsequent decisions were made by Prewitt or his staff.

Prewitt was first briefed by the Harrisburg Chapter disaster staff. A shelter had already been set up by the chapter in the Hershey Arena in Hershey, Pa., to care for those who had been evacuated under the Governor's advisory relating to pregnant women and preschool children. The shelter operation remained wholly a chapter function. Shortly after his arrival at the Harrisburg chapter office, Prewitt requested National Headquarters to send a team of mass care specialists to assist in the Red Cross efforts. The initial team consisted of an emergency mass care officer from National Headquarters and 16 disaster specialist volunteers from various divisions and chapters. They began arriving in Harrisburg on March 31. The team ultimately grew to include 35 people.

By this time, PEMA had identified 21 host counties that would be prepared to receive and care for potential evacuees from the 20-mile evacuation zone. Specific resources available within each of these counties would need to be identified, so mass care specialists were sent into the field to begin contacting local Red Cross and emergency management agency representatives to ask for assistance in specifically identifying shelter or congregate care facilities. The specialists also requested local Red Cross chapters to identify manpower requirements. The information gathered was then used to determine the adequacy of the congregate care facilities and the degree of outside manpower support that would be needed to staff and maintain these facilities.

Early in the operation it became obvious that the key to quick Red Cross response was a prior written agreement between the ARC and the State of Pennsylvania. The ARC and PEMA jointly determined that civil authorities would have the responsibility for the evacuation, including planning the routes, performing the evacuation, establishing and maintaining receiving centers, and directing evacuees to the designated civil defense shelter areas. It would be the responsibility of the ARC to operate and maintain these facilities. The Red Cross would also assist, within its capabilities, in the staging and reception centers. This agreement was confirmed by letter from ARC's Prewitt to Oran Henderson, the Director of PEMA, on April 4, 1979.

A cursory review of the level of preparedness in the host counties revealed that the majority of the Red Cross and civil defense units had very general and basic plans, and the bulk of these included the identification of large buildings, primarily public schools, as congregate care facilities. The units did not however, have adequate contingency plans for properly staffing these facilities. Many small communities had only identified small units that could house fewer than 100 people. Though most of the units thought they could handle the situation, if necessary, specifics were not available. The communities that had experienced major flooding within the preceding 5 years or so were more prepared for mass care; however, their plans did not provide for receiving evacuees from outside their area and were geared more to natural disasters that damage property, such as a floods or tornados.

Working with local Red Cross and civil defense officials, and with PEMA representatives, the Red Cross mass care specialists began identifying possible congregate care facilities. Each facility that they determined was feasible for use as a congregate care shelter was checked by the Pennsylvania Department of Environmental Resources to determine its suitability. Shelters were basically categorized as either able to hold more than 100 people, or suitable for fewer than 100 people. The larger facilities were assigned a priority based upon the numbers of evacuees each could accommodate; smaller facilities were counted only as contingency planning facilities. The intent was to use the larger facilities first, so that the maximum number of people would be accommodated in the minimum number of shelters. Because the occupants of these facilities were expected to be generally in good health and capable of taking care of themselves, in contrast to evacuees in other disasters where casualties might be expected, minimal staffing was planned for the shelters.

Working in this manner, the Red Cross in conjunction with the State, was prepared to open some 596 evacuation centers that could accommodate about 294 000 people. In addition, the Red Cross was prepared to supply 75 000 blankets, 15 000 cots, 150 nurses, and 300 volunteers to supplement State resources. Actual mass care center operation was limited to the shelter at the Hershey Arena, which cared for an average of 150 people a day. Hershey Arena had a peak occupancy of 173 on April 4.

Since the accident, the Red Cross has urged its local Chapters to better identify and categorize possible mass care facilities within chapter areas.

Several problems overshadowed the Red Cross response. Because there never was a formal declaration of a disaster at TMI, there was some question as to whether the Red Cross could or should treat it as a disaster. This question apparently extended also to other volunteer organizations that normally are quick to respond to disasters. A further problem was that the Red Cross did not know how long it would have to operate the mass care centers. During other disasters the Red Cross can plan that people will leave the shelters in about 10 days, but at TMI they did not know how long the evacuation would last or even if residents would ever be able to return home. Prewitt estimated that if the evacuation had taken place, the Red Cross could have spent about a million dollars a day for mass care—a few days of this operation would have taken a substantial part of the ARC's annual budget, which allocated $29 million for disaster relief.

9. CIVIL AIR PATROL

The Civil Air Patrol (CAP) is a volunteer organization that has no officially recognized duties in the disaster response area. However, the CAP is noted for the assistance it has provided in various emergencies across the Nation. Two elements of the CAP were active in response to the TMI-2 accident.

The Capital City Cadet Squadron, located at the Capital City Airport in Harrisburg, provided auxiliary security services by assisting the airport police from March 31 to April 3 and from April 6 to April 8. With a total membership of about 60, the squadron maintained 10 to 15 members on duty at the airport, sometimes 24 hours a day. Over the weekend of March 31, 20 to 30 members were present.

Group 1100 of the CAP, which is the parent organization for several CAP squadrons in the Reading, Pa., area, acts as an arm of the Berks County Emergency Management Organization. Berks County was designated as a host county in the event an evacuation had been ordered. Group 1100 personnel assisted in manning the county Emergency Operations Center from March 29 to April 2 while the center was open 24 hours a day. Group members also participated in planning for receipt and care of possible evacuees.

10. CONSOLIDATED RAIL CORPORATION (CONRAIL)

The Consolidated Rail Corporation (CONRAIL) has no designated functions to perform in response to a radiological emergency. However, the Superintendent of the Harrisburg Division of CONRAIL, Mr. Lageman, became aware of the TMI-2 accident via media reports and contacted PEMA officials on his own to determine what impact the accident would have on CONRAIL operations and to offer CONRAIL's services, if needed.

Lageman became actively involved in emergency response on Saturday, March 31, when he was asked by representatives of the Pennsylvania Department of Transportation to arrange for rail transportation to assist in the evacuation. He spent most of Saturday, March 31, and Sunday, April 1, in PEMA headquarters, directing his efforts toward supporting Dauphin and Cumberland Counties' in planning for evacuation. By April 2 he had arranged for four 10-car electric trains, each capable of handling 1000 people, to be made available on 6 to 8 hours' notice, for movement to the east. He also had arranged for a diesel train of 10 cars, able to carry 600 people, to be made available on 8 hours' notice for movement to the north or west. Lageman had available two diesel-engine trains of 20 to 25 boxcars, which could have been used for evacuation to the south in support of the Cumberland County evacuation plan.

11. DEPARTMENT OF AGRICULTURE

USDA is one of the 13 Federal agencies signatory to IRAP. The purpose of IRAP is to provide for, among other things, prompt and effective radiological assistance as may be needed for the protection of health, safety, and welfare from radiological hazards resulting from radiological incidents. Thus, USDA has designated individuals in a nationwide network to use USDA's resources in a crisis.

Among USDA's responsibilities is that of assuring the consumer that foods are safe and wholesome. Federal inspection is provided for all meat, poultry, and related products processed by plants shipping in interstate and foreign commerce. The work includes inspection of poultry and other animals at the time of slaughter and of processed products during various stages of production and handling to assure wholesomeness of products and truthfulness in labeling.

During TMI the USDA was not called on as a signatory of IRAP nor was its organized network of emergency personnel called on to participate in the emergency response. The USDA became aware of the TMI incident through media reports and independently initiated its response.

At noon on Friday, March 30, the USDA ordered all Federal packing plants within 5 miles of TMI to cease receiving and shipping meat. This action was taken to prevent possible radioactive contamination of meat and poultry products. The USDA lifted this prohibition on Monday morning, April 2, upon receiving radiological information from the Pennsylvania Bureau of Radiation Protection. The USDA also made available communication equipment to the Environmental Protection Agency and took part in the Federal Regional Council planning for studies of the impact of the incident on TMI area farmers and on food processing and distribution.

12. BUREAU OF LAND MANAGEMENT, DEPARTMENT OF THE INTERIOR

The Department of the Interior became involved in the TMI response through the actions of the Boise Interagency Fire Center, part of the DOI's Bureau of Land Management. The Interagency Fire Center is a group made up of six Federal agencies. Its principal mission is to provide emergency response to fires in the Western United States.

On March 31, at 1:25 p.m., the NRC called the Fire Center and requested a communications officer and technicians, together with communications equipment, to be sent to TMI as soon as possible.

By 3:30 p.m. on March 31, the Fire Center's communications equipment, including about 250 radios, and 6 of its people were enroute to TMI in the Center's aircraft. The communications officer came from Atlanta. They arrived at the Harrisburg Airport late on March 31. The equipment was operational by April 1, and it was used principally for communications between persons doing radiation monitoring in the vicinity of TMI and persons at the base station at the airport.

The last of the Fire Center's personnel returned home with the equipment on April 23. The approximate cost of the Fire Center's response was $27 000.

13. DEPARTMENT OF DEFENSE

Organization, Responsibilities, and Authorities

DoD is responsible for providing the military forces necessary for the security of the United States. Included within DoD are the Department of the Air Force, the Department of the Army, and the Department of the Navy (which includes the U.S. Marine Corps). In addition to its national security role, DoD is also charged with participating in planning for civil and domestic emergencies and with coordinating and monitoring atomic energy matters affecting DoD.

DCPA, a separate agency within DoD, carried out most of the DoD functions concerning civil and domestic emergencies and related emergency planning. However, DoD also has emergency responsibilities in its own right, which it retains, even though DCPA functions have now been transferred to FEMA.

DoD is a signatory to IRAP. IRAP contemplates a DoD role primarily in the context of assistance in the event of an accident involving a nuclear weapon. However, the overall capabilities of DoD are such that support also could be provided in the event of an accident at a fixed nuclear facility.

The radiological assistance capabilities of the DoD are coordinated through the Joint Nuclear Accident Coordinating Center, which is staffed jointly by DoD and DOE. While each of the military services is responsible for the nuclear material under its control, the Army has responsibility for response to any radiation accident of such consequences as to constitute a domestic emergency.

DoD also has been assigned responsibilities under FRPPNE, issued in interim form in April 1977. Under the provisions of FRPPNE, as applicable to fixed facility nuclear accidents, the DoD is responsible for the following:

1. Providing military assistance, both in the form of manpower and other resources, in support of and as requested by civil authorities, subject to the requirements of the military mission and within legal parameters.
2. Coordinating and controlling the use of military forces made available to civil authorities during an accident.

Initiation of Involvement

On Wednesday morning, March 28, at 10:30 a.m., the Department of Energy Emergency Operations Center (DOE EOC) notified the National Military Command Center (NMCC) of the TMI-2 accident. The NMCC, in turn, notified the Assistant to the Secretary of Defense for Atomic Energy, Dr. Wade, who has overall DoD responsibility on nuclear matters.

Description of Response

At 12:25 p.m. on March 28, an Air Force helicopter from the 1st Helicopter Squadron at Andrews Air Force Base in Maryland was dispatched to carry Aerial Measuring System/Nuclear Emergency Search Team (AMS/NEST) personnel stationed at Andrews to the site. This was the only immediate DoD response to the accident. For the rest of March 28 and all day on the 29th, the NMCC maintained contact with the DOE EOC to stay abreast of plant status.

On March 30, DoD was represented at the afternoon meeting of Federal agency officials at the White House. Following that meeting, Colonel James Lampros, an Army officer from Fort Dix, N.J., was sent to Harrisburg by Robert Adamcik of the FDAA to serve as the DoD contact in connection with the coordination of Federal agency response. Requests for military assistance from Adamcik were forwarded by Lampros to the NMCC at the Pentagon for action.

On March 31 an Air Force C-5 cargo plane was used to ship a rawinsonde (a device used to determine the velocity of winds aloft), from McConnell Air Force Base, Kans., for use by National Oceanic and Atmospheric Administration personnel in making upper air measurements in Harrisburg. On the same day, an Army convoy of nine trucks was used to ship lead bricks from the National Bureau of Standards in Gaithersburg, Md., to the site for use in shielding the hydrogen recombiner. On March 31 and April 1, four C-141 flights moved other lead bricks from DOE's Brookhaven National Laboratory and other Federal sources to the site. On March 31, an Air Force C-130 moved potassium iodide from Decatur, Ill., to Harrisburg, and an Army tractor-trailer brought medicine droppers to Harrisburg from Buena, N.J. The same day, three Army tractor-trailers moved DOE communication pods from Philadelphia to Harrisburg. On April 1 a mechanical robot was flown by C-5 to Harrisburg from Eglin Air Force Base, Fla. Water samples from the plant were flown to Pittsburgh, Knoxville, and Idaho Falls, on April 2, 10, and 14, respectively, for analysis. On April 7 and 8, six aircraft were used to ship charcoal filters from Pasco, Wash. to Harrisburg.

On March 31, when it appeared that evacuation of the site might be ordered, the Army made preparations at Carlisle Barracks, Pa., to handle the NRC and DOE support personnel who would have to be evacuated.

The Army had located 315 ambulances and a number of fixed-wing aircraft that could have been made available within hours to expedite evacuation. The Army also had located and was prepared to supply cots and blankets to help equip the mass care facilities that had been identified by PEMA and the Red Cross.

14. FEDERAL BUREAU OF INVESTIGATION

Section 221 of the Atomic Energy Act (42 U.S.C. Sec. 2271) assigns the Federal Bureau of Investigation (FBI), a part of the Department of Justice, responsibility for investigating all incidents of sabotage involving nuclear facilities, weapons, or materials; any theft of nuclear weapons or materials; any extortion using nuclear components, devices, or materials; and any other suspected criminal violations of the Atomic Energy Act.

The local FBI office in Harrisburg, Pa., was notified of the accident at TMI by the NRC on March 28, 1979, as part of NRC's routine notification of other Federal agencies. On April 2 the FBI initiated an investigation to determine whether sabotage was the cause of the accident at TMI. The investigation consisted of three interviews: The first, on April 2, 1979, was with and at the request of officials of the U.S. Labor Party, who alleged that the accident was caused by sabotage. Agents discussed the information obtained in this interview with an attorney in the U.S. Department of Justice, who told the FBI that there was no substance to the allegations and that further investigation of sabotage by the FBI was not warranted. On April 4 the FBI interviewed a private citizen who had made a statement to an acquaintance questioning whether sabotage had been considered as the cause of the accident at TMI. As a followup to this statement, a third interview was held on April 6 with Harold Denton of the NRC, who said the incident at TMI was an accident and not the result of sabotage.

15. FEDERAL REGIONAL COUNCILS

General Responsibilities

Federal Regional Councils (FRCs) were established by Executive Order 11647 on February 10, 1972. A Council was created for each of the 10 standard Federal Regions. Each is composed of the principal regional officials of the Departments of Agriculture; Commerce; Energy; Health, Education, and Welfare; Housing and Urban Development; Interior; Labor; Transportation; the Community Services Administration; and the Environmental Protection Agency. The Councils were mandated to improve coordination of the categorical grant system and to develop closer working relationships among themselves and with State and local governments.

Executive Order 11731, issued July 23, 1973, broadened the FRC mandate to include coordination of direct Federal program assistance to State and local governments. Executive Order 11892 of December 31, 1975, increased the membership of the FRC system, toward the ends of further expanding interagency cooperation and improving coordination of services to State and local governments.

Three broad missions underlie the functions of FRCs: developing close intergovernmental relations, coordinating interagency programs, and delivering services such as emergency aid needed during crises and disasters.

Initiation of Involvement

On April 4, Thomas C. Maloney, Chairman of the FRC for the Pennsylvania area, asked Council members to determine their respective agency's ability to respond to the consequences of TMI. For example, an agency might evaluate the assistance that it could provide if the tourist industry or farming in the TMI area were severely affected by the accident. Following an April 13 meeting with Pennsylvania State representatives at the White House to discuss possible State needs and Federal assistance, Jack Watson designated Maloney to serve as lead Federal official for coordinating Federal response to the ramifications of the TMI incident.

Description of Response

As provided in Watson's memorandum appointing Maloney lead Federal official, Maloney's responsibilities include "assuring effective communication within the Federal Government and with the Governor and State officials, identification of problems requiring Federal assistance, delivery of needed and appropriate Federal assistance, and monitoring the effectiveness and quality of Federal responses." The memorandum also notes that certain Federal agencies continue to have direct responsibilities, which will be performed concurrently with Maloney's duties. For example, the NRC will continue to have full onsite responsibility and the EPA will continue to have the Federal lead for environmental monitoring.

The following is a brief summary of the major Federal responses to postaccident effects of the TMI incident that the FRC will monitor.

Small Business Disaster Loans— The Small Business Administration declared the TMI vicinity an economic disaster area, making small businesses eligible for disaster loans. Disaster loan offices were opened in Harrisburg, Middletown, Lancaster, and York. The volume of loan applications was small. Principally, two kinds of businesses qualified for loans: grocery stores that incurred losses when perishables could not be sold because people had left the area, and retail clothing stores that for similar reasons missed the Easter sales market.

Study on Pregnancy Outcomes—Because of extensive public interest in pregnancy outcomes, HEW Region III funded a study for the State Department of Health to begin immediate data collection. The grant was in the amount of $80 000 and covered the period to September 30, 1979. It has since been renewed.

Population Census—The Center for Disease Control and the National Institutes of Health funded a population census through the Pennsylvania Department of Health of all persons living within 5 miles of TMI on the date of the accident. The census registry will be used for any future health studies of the population.

Mental Health Study—The National Institute of Mental Health designed and funded a mental health survey to study the psychological impacts of the TMI crisis. This will be a long range study concentrating on workers, young children, and people with previously known mental problems.

Emergency Response/Behavioral Survey— The NRC designed and funded a survey to study emergency response and pertinent behavioral issues.

Radiation Monitoring— Several Federal agencies, with EPA as the lead, have engaged in long term radiation surveillance in the TMI vicinity. This monitoring will continue until cleanup of the damaged reactor is completed.

Emergency Preparedness Review— Federal emergency agencies have been reviewing the adequacy of their own preparedness and working with States and local officials to improve the emergency systems.

Socioeconomic Impact Study— Several Federal agencies have awarded approximately $600 000 to the Governor's Office of State Planning and Development to perform a comprehensive study of the socioeconomic effects of TMI. As proposed, the socioeconomic study focuses on the effects of TMI in the following areas: commercial and industrial production and employment, agricultural production and commodity consumption, food processing industries, tourism and travel, new residential and commercial construction, housing, community development, local government budgets, State and local revenues, insurance claims against Met Ed, and coordination of requests for Federal funding. In addition to the State's studies, the FRC has been monitoring the economic impacts of TMI in the Harrisburg area so that it can be prepared to respond if necessary.

16. INTERSTATE COMMERCE COMMISSION

Organization, Responsibilities, and Authorities

The Interstate Commerce Commission (ICC) regulates interstate surface transportation, including trains, trucks, buses, inland waterway and coastal shipping, freight forwarders, and express companies. The ICC is a signatory to IRAP. Under IRAP, the ICC's response to a radiation emergency is to assist in arranging and expediting emergency transportation of people and property moving in interstate commerce to or from the distressed area. The ICC also has responsibilities assigned by FRPPNE. Under FRPPNE, the ICC is responsible for setting priorities and issuing orders to railroads and granting immediate emergency operations authority to motor and water carriers for expediting the surface transportation of people and property to or from areas affected by a peacetime nuclear emergency. Under the coordinating authority of the Secretary of Transportation, ICC is responsible for setting priorities governing surface transportation of people and property by all surface modes.

Initiation of Involvement

The ICC was never called upon for any assistance in response to the TMI accident. Although PEMA alerted the ICC Regional Managing Director in Philadelphia, Ivan Schaeffer, to the accident, PEMA never made a followup contact or request for aid.

17. MINE SAFETY AND HEALTH ADMINISTRATION

Among other things, the Mine Safety and Health Administration (MSHA), in the Department of Labor, investigates accidents at all types of mines—metal and nonmetal mines as well as coal mines. It has the equipment and experienced personnel to do so. The equipment includes breathing equipment with self-contained air supplies.

On April 4, 1979, the NRC requested 24 sets of oxygen breathing apparatus through the FDAA. MSHA's Mine Rescue Unit was alerted to the request at 9:30 a.m. on April 4. The unit packed its equipment and drove 225 miles to the TMI site, arriving by 4:20 p.m. On April 5 it was determined that the NRC wanted MSHA's breathing apparatus as backup for the breathing apparatus they were using regularly. During the following week, 6 MSHA team members trained 30 men to wear the 24 sets of MSHA breathing apparatus and 1 man to keep the apparatus in ready-to-use condition. MSHA personnel then departed TMI, leaving most of their equipment for NRC use. The equipment was later returned to MSHA.

18. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Organization, Responsibilities, and Authorities

The principal statutory functions of the National Aeronautics and Space Administration (NASA) are to conduct research relating to problems of flight within and outside of the earth's atmosphere, and to develop, construct, test, and operate aeronautical and space vehicles. The considerable capabilities developed by NASA to achieve these goals could be very useful in responding to radiation emergencies. The resources that NASA could make available in support of radiation emergencies include: radiological, environmental health, and medical support personnel; radiation measuring instruments; laboratory facilities; firefighting equipment; generators and communications equipment; and various items of heavy equipment. NASA is a signatory to IRAP.

NASA also has been assigned responsibilities under FRPPNE. Under FRPPNE, NASA is responsible for the following:

1. Adapting and using its scientific and technological capabilities as required to meet priority needs of the programs of the Federal Government in a nuclear emergency.
2. Assisting, through its satellite capability, in environmental and weather monitoring, establishing communications networks, and assessing damages as requested by other Government agencies.

Initiation of Involvement

NASA was not formally notified of the TMI accident, and did not become involved until April 1. On the morning of April 1, NASA Administrator Dr. Alan Lovelace received a call from Dale Myers of DOE requesting the services of Wilbur Riehl of the Marshall Space Flight Center as a hydrogen consultant.

Description of Response

In response to the request from DOE, Riehl flew to Harrisburg by NASA aircraft on April 1. He provided advice and assistance relating to the hydrogen-generation problem until April 3. NASA had no other involvement in the TMI response.

19. NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards (NBS) provides the basis for the Nation's measurement standards that lead to accurate and uniform physical measurement and reliable data throughout the Nation's scientific, industrial, and commercial communities. It provides advisory and research services for Federal, State, and local government agencies. NBS is generally recognized as the U.S. authority in the area of calibration of radiation measuring instruments.

On March 31, 1979, the NRC requested NBS to provide lead bricks for the construction of a shielding wall in the TMI-2 auxiliary building. NBS supplied 15 tons of lead bricks, which were picked up by an Army convoy on April 1.

On April 2 the NRC requested information on hydrogen solubility in water at elevated temperatures and pressures. Basic physical data was supplied to the NRC for use in solving the hydrogen bubble problem.

On April 5, 6, and 9, the NRC, EPA, and DOE, respectively, requested NBS to calibrate radiation measuring instruments for xenon. These instruments had been used at TMI. This after-the-fact calibration was obtained in order to determine the validity of instrument readings previously obtained.

20. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Among its principal functions and activities, the National Oceanic and Atmospheric Administration (NOAA), of the Department of Commerce, reports the weather of the United States and its possessions and provides weather forecasts to the general public; issues warnings against such destructive natural events as hurricanes, tornadoes, floods, and tsunamis; and provides special services in support of aviation, marine activities, agriculture, forestry, urban air quality control, and other weather-sensitive activities.

With respect to emergency response to a radiation incident, the functions and capabilities set out for NOAA in IRAP, to which the Department of Commerce is signatory, include the following:

1. Provision of current information, weather forecasts, and warning advisory services to assist in meeting radiation emergencies, especially information about changes in wind, boundary layer mixing, precipitation conditions, and other significant weather parameters.
2. Provision of fallout wind-vector data upon request.
3. Utilization of DCPA equipment at local National Weather Service field offices to provide gamma radiation readings if requested by appropriate agencies.
4. Provision of weather and climate information and advice for use in planning protective action or relief programs. (National Weather Service Regional Offices provide coordination and planning assistance.)

At 9:00 a.m., March 28, PEMA called NOAA at the Harrisburg Airport for the wind forecast, and advised NOAA that there had been an accident at TMI. Beginning on March 28, the NRC requested routine forecasts, and on or about March 30 requested more refined forecasts.

During the first 2 days of the accident, NOAA provided routine forecasts upon request to the NRC, PEMA, and the DER. The request for more refined forecasts was answered using upper-air support teams with special equipment to Pennsylvania. Data provided by the upper-air teams was used by DOE's Lawrence Livermore Laboratory to compute the direction and size of the TMI radiation plume.

On April 2, at NOAA's suggestion, PEMA made a tape for broadcast over the NOAA Weather Radio System advising people to listen to various broadcasting system stations in the event of an emergency. This tape was prepared, but PEMA never requested its use.

21. POSTAL SERVICE

Organization, Responsibilities, and Authorities

The operational group of the U.S. Postal Service (USPS) is organized nationwide into five regions. Each region is composed of a number of districts which, in turn, are composed of a number of sectional centers. The vicinity of Three Mile Island falls within the jurisdiction of the Susquehanna District, which is sudivided into a number of sectional centers. Two of these, the Harrisburg Sectional Center and the Lancaster Sectional Center, are responsible for postal services in the immediate vicinity of the TMI plant. The Middletown and High Spire post offices fall under the jurisdiction of the Harrisburg Sectional Center, while the Etters (Goldsboro) and York Haven post offices are within the jurisdiction of the Lancaster Sectional Center.

USPS is a signatory to IRAP, although the plan makes no mention of the nature of Postal Service capabilities or of its expected response efforts. However, under the provisions of FRPPNE, the Postal Service is responsible for the following:

1. Providing emergency mail service in the affected area.
2. Registering persons and families, in cooperation with HEW, to permit State and local welfare agencies to answer inquiries and reunite families.

Initiation of Response

The Postal Service was not formally notified of the TMI accident. The manager of the Susquehanna District, Robert Brown, first became aware of the accident when he was notified by the postmaster at Middletown.

Description of Response

The Postal Service participated in coordination meetings of the Federal agencies on April 1 and 2, and identified 185 vehicles that could be used in an evacuation effort. Contact was made with the American Red Cross to establish a locator file for displaced persons. Otherwise, as it does in any disaster, the Postal Service assured that the mail was properly handled and protected and that its mail carriers and vehicles were out on the streets, visible to the populace, in an effort to exert a stabilizing psychological effect.

22. SMALL BUSINESS ADMINISTRATION

Among the responsibilities of the Small Business Administration (SBA) is the granting of loans to small businesses; to State and local development companies which, in turn, assist small businesses; and to victims of floods or other catastrophes or of certain types of economic injury. To permit activation of the SBA loan program in response to the TMI accident, it was necessary that a declaration of an economic dislocation area be made.

On April 27, 1979, A. Vernon Weaver, Jr., Administrator of the SBA, approved the request of Governor Thornburgh to declare the five-county area—Cumberland, Dauphin, Lancaster, Lebanon, and York—an economic dislocation area. The declaration was effective immediately, and continued during the subsequent 8 months. SBA operations are carried out through SBA Region III offices located outside of Philadelphia.

Following the declaration of the economic dislocation area, SBA established special offices in Harrisburg, Lancaster, York, and Middletown to handle claims from local businesses. The office in Middletown was kept open for 2 months. The other special offices were closed in October as the result of a low level of activity. The SBA branch office in Harrisburg was made available for any necessary TMI-related business during the remainder of the 8-month declaration period. Through October 15, a total of 59 loan applications, totaling $2 920 000, were received. One application was withdrawn; 30 have been disallowed; 20, totaling $425 000, have been approved; and 8 were still being processed.

23. DEPARTMENT OF TRANSPORTATION

The Department of Transportation (DOT) includes, as major subagencies, the U.S. Coast Guard, the Federal Aviation Administration (FAA), the Federal Highway Administration (FHWA), and the Federal Railroad Administration (FRA). These four subunits of DOT could participate in response to a radiation emergency. In addition, the DOT has designated so-called Regional Emergency Transportation Coordinators (RETCOs) to become actively involved in transportation aspects of the response to any emergency, including a radiation emergency.

IRAP, to which DOT is signatory, provides that in response to a radiation incident DOT functions consist primarily of notification of Federal and local agencies (for transportation incidents), arrangements for special transportation activities, and assistance in contacting consignors and consignees of shipments affected by the incident.

DOT also has responsibilities under FRPPNE, which provides that, in emergencies at fixed nuclear facilities, DOT is responsible for preparing and developing emergency programs in coordination with the Federal transportation operating and support agencies. In addition, DOT is to employ all possible forms of civil transportation in support of efforts to handle and mitigate the effects of peacetime nuclear emergencies. FRPPNE makes DOT responsible for the following:

1. Developing policies, plans, and programs to ensure that all modes of transportation will be used as required and to provide a unified, coordinated

transportation system to meet the requirements of any peacetime nuclear emergency.

2. Coordinating planning activities of State and local authorities in adjoining areas for use of intrastate transportation facilities and services where and when required.
3. Coordinating the development of facilities protection guidance material for transportation systems developed by the modal operating and support agencies. This guidance is to be directed toward protection of personnel and facilities of operating proprietorships, public and private, from the effects of peacetime nuclear emergencies.
4. Providing leadership and executive management as authorized by law and Executive Order to modal operating and support elements in coordinating the development of interagency planning to ensure the effective management and use of transportation resources during peacetime nuclear emergencies.
5. Developing plans and policies for the utilization of the Coast Guard to meet the requirements of peacetime nuclear emergencies.

Initiation of Response

The DOT Headquarters was never formally notified of the TMI accident. It became aware of the accident on March 28, 1979, through media reports.

Description of Response

Soon after the accident, the FAA established a temporary restricted area for aircraft travel over the TMI plant and certified a helipad near the plant to accommodate emergency operations. The Coast Guard was notified in accordance with the TMI emergency plan and provided traffic regulation services on the Susquehanna River upstream and downstream from the plant.

On March 31, John W. Porco, the RETCO, arranged for DOT representatives to attend the Federal agency coordination meetings in Harrisburg that were chaired by Adamcik of FDAA. Representatives of the FHWA and FAA also attended these meetings.

During the evacuation planning period over the weekend of March 31, FPA consulted Porco by telephone regarding the effects of an evacuation on the transportation facilities. He recommended that contact be established with CONRAIL and AMTRAK. During the same period, the FAA activated its Regional Emergency Command Post and advised its field offices in the Middletown-Harrisburg area to begin taking radiological readings and to issue dosimeters to employees. Radiological readings were appended to the hourly weather reports by the flight service sections. A cadre of 24 FAA employees was prepared to evacuate the FAA facilities. The FAA offered the NRC the use of its worldwide communications capability, but little use was made of the equipment.

During early April DOT became involved in truck shipments of waste materials from the TMI site. Three truckloads of waste originally destined for burial in South Carolina ultimately were rerouted to Richland, Wash., after the State of South Carolina rejected the shipments.

Beginning April 11 Porco located the owners of suitable railroad tank cars that could be brought to the site to serve as temporary storage facilities for radioactive wastewater. The cars themselves were located, and preliminary arrangements to have the cars moved to the site were made.

The DOT continues to be involved during the long term recovery efforts, both in shipment of special equipment and material to the site and in shipment of waste materials from the site. Each truckload of waste is inspected by a FHWA representative prior to release.

SPECIFIC RESPONSE OF THE COMMONWEALTH OF PENNSYLVANIA AND OTHER STATES TO TMI

This part of Appendix III.7 details the organization, responsibilities, authorities, and emergency response actions of major State and local agencies. Because of their immediate proximity to the plant and their basic responsibility to provide prompt and adequate protection of their citizenry, the county and local agencies are discussed first. Because of their front line roles in State agency response, BRP (in the DER), PEMA, and the Governor's Office are discussed after that. Other State agencies follow in alphabetical order. This section closes with an examination of the role played by States other than the Commonwealth of Pennsylvania.

1. COUNTY AND LOCAL JURISDICTIONS

Organization, Responsibilities, and Authorities

The accident at TMI directly affected the six counties within 20 miles of the plant—Dauphin, York, Lancaster, Lebanon, Cumberland, and Perry. In addition, over 20 other counties in Pennsylvania had been designated host counties which would provide mass care shelters for evacuees from the six counties at risk. The host counties will not be discussed here. Because the organization, responsibilities, and authorities of each of the six counties at risk are the same, this discussion applies to each of the counties. The response of all counties was basically the same; differences among the responses of specific counties are highlighted. County notifications are described separately.

The concept of operations envisioned in the Commonwealth of Pennsylvania Disaster Operations Plan dated July 12, 1977, is that county and local governments have an inherent moral duty, as well as a legal responsibility, to ensure that their jurisdiction is prepared to cope with any disaster situation. If the county and local governments require assistance, it is provided by the Commonwealth departments and agencies. If two or more counties are affected, PEMA, through its area offices, is responsible for coordination and provision of support to the area of operations.

The Emergency Management Services Code of 1978, as well as the Disaster Operations Plan, clearly require the designation of an emergency coordinator and the development of an emergency plan for each of the 2600 political jurisdictions within the Commonwealth. While there were only two local political subdivisions within the 5-mile radius of TMI that had not appointed an emergency coordinator at the time of the TMI accident, there were no formal, local emergency plans in existence.

The Commonwealth Disaster Operations Plan sets out specific responsibilities for county and local emergency management directors. These responsibilities include the following:

1. Emergency planning, including plans for the movement of support forces to disaster locations, movement of people from danger areas, operation of police lines, casualty care operations, mass care operations, highway traffic control, emergency transportation, public information, emergency supplies, and resource listings.
2. Training county and local officials.
3. Establishing an emergency operations center.
4. Communications.
5. Assuring sufficiency of emergency manpower.
6. Conducting tests and exercises of the county plans.

The primary responsibilities of the county emergency director during a nuclear incident are advising county and local government officials and the public of events having public interest and carrying out, in coordination with local officials, evacuations or other protective measures ordered by the county board of commissioners or the Governor.

The top government organization within each of the six counties at risk is a three-member board of commissioners. Each county has an emergency management agency (variously called the Emergency Management Agency, Office of Emergency Preparedness, or County Civil Defense) with a director who reports to the board of commissioners. In addition to their disaster planning and management responsibilities, the county directors are responsible for central dispatch of the county fire, police, and rescue services.

Because the emergency planning zone around TMI extended 5 miles from the plant (before the accident), only three counties—Dauphin, York, and Lancaster—were required to have emergency plans that specifically accounted for TMI. Each of these counties had prepared plans during 1978 at the direction of PEMA.

Initiation of Involvement

Dauphin County— The Dauphin County Office of Emergency Preparedness was first notified of an onsite incident at Three Mile Island at 7:09 a.m., March 28, by Margaret Reilly, Chief of the Division of Environmental Radiation in the State's BRP. At 7:10 a.m. Dauphin County was notified by the utility, and at 7:13 a.m. the county was notified by the PEMA watch officer.

York County— The York County Emergency Management Agency was notified of the accident at TMI by teletype from the Lancaster County Emergency Management Center at 7:27 a.m., March 28. Lancaster County had been requested by PEMA to notify York County because PEMA was unable to contact York County by telephone.

Lancaster County— The PEMA duty officer notified the Lancaster County Emergency Management Agency of the accident at 7:20 a.m., March 28.

Cumberland County— The Director of the Cumberland County Office of Emergency Preparedness was notified of the accident at TMI by PEMA during a seminar for county coordinators in Selingsgrove, Pa., during the morning of March 28. PEMA had notified the Director's office earlier that morning. Because no part of Cumberland County is within 5 miles of TMI, the county did not become actively involved with the accident until Friday morning, March 30, at 10:00 a.m., when it was advised by PEMA to begin planning for an evacuation of those portions of Cumberland County within 10 miles of TMI.

Lebanon County—The Lebanon County Emergency Management Director was notified by PEMA of the accident at TMI at 9:00 a.m., March 28. Even though no portion of Lebanon County is within 5 miles of TMI, the County Radiation Officer immediately began making radiation measurements within the county. While a very small portion of Lebanon County is within the 10-mile radius of TMI, Lebanon County was not advised by PEMA to begin preparing a 10-mile evacuation plan. At 5:00 a.m., March 31, PEMA advised Lebanon County to begin preparing for a 20-mile evacuation around TMI.

Perry County—Although the Perry County Civil Defense Director was aware of the accident at TMI from news reports during March 28 to March 30, Perry County did not become involved until March 31. At 8:40 a.m. that day, PEMA advised Perry County to begin preparing to evacuate all Perry County residents within a 20-mile radius of TMI. Only a small portion of the county lies within the 20-mile radius.

Description of Response

The major activity of the six counties at risk during the accident was preparing evacuation plans. On March 28, the three counties within 5 miles of TMI had emergency plans for TMI and were prepared to implement them if necessary. On March 30, the planning zone was increased to 10 miles and on March 31 it was increased to 20 miles. These changes significantly increased the planning requirements for the three counties with 5-mile plans and imposed planning requirements on three other counties, which had not expected to be directly affected by an accident at TMI.

Although there is no general agreement among the counties and PEMA as to which counties were advised to begin 10- and 20-mile planning and when the advisory was issued, all of the six counties at risk were actively engaged in 20-mile planning by Saturday morning. The planning approaches taken by the county emergency management directors differed among the counties. The approach taken by Dauphin, York, Lancaster, and Lebanon Counties was to assemble all evacuation support groups, such as fire, police, rescue services, and the Red Cross, and assign them to develop their portions of the plan. The various segments of the plan were then pulled together by the County Directors. In developing their plans, the counties were provided significant help by PEMA, the State Police, the Pennsylvania Department of Transportation, the National Guard, and DCPA representatives assigned to the counties. Local coordinators were then called together and advised of their areas of responsiblility. The basic philosophy of these four counties, however, was that planning for the evacuation would be centralized in each county's emergency management agency and that the localities would be assigned specific local planning and implementation duties.

The philosophy in Cumberland County was different: Cumberland chose to rely largely on local emergency management coordinators for developing the evacuation plans. The County Emergency Management Director provided a basic plan to the local directors; the plan was to be customized to their local needs. The county assumed planning responsibility for all fire and rescue services and evacuation of hospitals and nursing homes so that the localities could concentrate on planning to move their other residents.

The Perry County Civil Defense Director never developed a detailed evacuation plan. The Perry County Director chose to rely largely on his county resource inventory, which he maintains and which can be tapped to fit his needs during any emergency. Planning in Perry County was centralized at the county level; meetings were held on Saturday, March 31, with local directors, Government officials, and emergency personnel to brief them on the plan. The local representatives were then responsible for holding local meetings to brief residents and to prepare them to evacuate. This more informal arrangement likely was adequate, in view of the very small portion of Perry County that was within the 20-mile area.

The county plans were largely completed by Sunday evening, April 1, although the complete documents were not printed and distributed until later that week.

The county emergency management agencies were also a primary source of information and guidance for the public throughout the accident. Every county director commented that a significant portion of his time and the time of his staff was spent answering telephones and responding to public questions and rumors. In fact, Dauphin and York Counties had to install telephone lines specifically to handle rumors.

The counties were dependent on PEMA for information. Though the county directors did not believe PEMA was withholding information from them, PEMA was unable to answer many of the questions the counties were asking. The county directors viewed this breakdown in communications as a major problem and believed it may have resulted in the loss of the counties' credibility from the public's perspective. Many times the county directors did not have time to listen to the media reports, so they did not even have as much information as many of the callers.

Both Lebanon and Lancaster Counties stated that during the accident the county radiological officers made radiation measurements in the portion of their counties closest to TMI. The county officials used civil defense monitoring equipment originally placed in the counties for use in the event of a nuclear attack. Much of this equipment was relatively high level instrumentation that was not suitable for the low levels associated with the TMI accident. The counties did not provide their monitoring results to any agency outside the county, and did not receive the results of State or Federal monitoring programs.

2. BUREAU OF RADIATION PROTECTION

Organization, Responsibilities, and Authorities

At the time of the accident at TMI, planning responsibility within the Commonwealth for incidents at fixed nuclear facilities belonged to BRP, part of the DER. This responsibility had been documented in a 1977 agreement between the Secretary of DER and the Director of PEMA, which had responsibility for planning for other emergencies throughout the Commonwealth.

In September 1977, BRP issued a "Plan for Nuclear Power Generating Station Incidents." Under this plan, BRP is responsible for contacting the facility following notification from PEMA and obtaining a description of the occurrence, the prognosis, and recommendations. From that point, BRP is responsible for the following:

1. Maintaining contact with the facility.
2. Performing supplementary environmental sampling and analysis.
3. Providing appropriate State, county, and local agencies with updated information. PEMA would normally communicate these updating reports to State agencies through the PEMA Emergency Operations Center.
4. Advising State agencies and county and local governments, through PEMA, of the need to take protective actions, the actions to be taken, the geographic area at risk, pertinent facility conditions having influence on the emergency, and withdrawal of protective actions.
5. Notifying and requesting assistance from Federal agencies having interest and expertise in radiation protection.

BRP has 19 professional staff members located in its Harrisburg headquarters and its Pittsburgh and Reading area offices. Most of its personnel are routinely involved in regulatory matters concerning X-rays rather than nuclear powerplant activities, but BRP does have one nuclear engineer with experience in the nuclear power industry. BRP has a laboratory in Harrisburg for analyzing samples generated by the environmental surveillance program.

Initiation of Involvement

At 7:05 a.m. on March 28, the BRP duty officer was notified at home by the PEMA watch officer that a site emergency had been declared at TMI. TMI had requested that BRP call the TMI-2 control room, and the BRP duty officer established contact with the TMI-2 control room at 7:06 a.m. At 7:25 a.m. the Director of BRP, upon arrival at his office, reestablished contact with the TMI-2 control room: this connection remained open for about the next 2 weeks, serving as the principal communications link between the utility and the State.

Description of Response

BRP's radiological monitoring program began at about 10:45 a.m. on March 28, when a BRP monitoring team was sent to the site to verify reports from the utility that small amounts of radiation were being detected off site. Because of concern about the presence of radioactive iodines in the releases from the plant, BRP advised the Department of Agriculture to begin sampling milk from farms in the TMI area, beginning with the evening milkings on March 28. The same concern, coupled with the fact that BRP was not equipped to do radioiodine measurements in the field, prompted BRP to request assistance from the Brookhaven RAP team at 11:18 a.m. on March 28. Throughout the Brookhaven RAP team's stay at TMI, their primary function was to assist BRP in its environmental monitoring program.

As the Federal radiological response increased on Friday, March 30, a need developed to establish a mechanism to coordinate the overall radiation monitoring program. At the request of BRP during a meeting on Friday evening, DOE assumed responsibility for coordinating the monitoring results from all agencies. This request was documented in a letter dated April 6, 1979, from the Director of BRP to the DOE onsite coordinator.

The BRP monitoring program included sampling air, water, milk, and grasses. The laboratory is equipped with a multichannel analyzer, two windowless internal proportional counters, one thin window low background proportional counter, and one liquid scintillation system. BRP's portable radiation detection equipment includes ionization chambers, Geiger-Mueller survey meters, and pocket dosimeters. In addition, each operating nuclear power station has at least one low volume air sampler located near the plant and operated by the Commonwealth. The samples collected by BRP during the accident were analyzed in the BRP laboratory. BRP also was responsible for collecting and analyzing all the radiological data and making recommendations to PEMA and the Governor for protective actions based on that data.

Because of the radiation monitoring results, few protective actions were recommended by BRP. Early Wednesday morning, March 28, based on high radiation readings inside containment and an estimated leak rate, Met Ed estimated a 10-R/h radiation level to the west of the plant. As a result, BRP advised PEMA that it should be prepared to evacuate Goldsboro and Brunner Island. A few minutes later, however, a TMI survey team determined that no radiation above background was detectable in Goldsboro, and BRP withdrew its advisory.

The BRP position throughout the accident was that radiation levels off site were not high enough to warrant taking any protective actions. BRP did not agree that evacuation was necessary Friday morning, despite the NRC's recommendation to PEMA and PEMA's recommendation to the Governor. During a meeting in the Governor's office on Friday morning, the Director of BRP also disagreed that evacuation of pregnant women and small children was necessary, but he believed the State had no choice but to issue the advisory after it had been recommended by the Chairman of the NRC. The Director of BRP has explained that because there were no criteria on which to advise this partial evacuation, there were no clear criteria on which to base a decision to allow evacuees to return.

The only protective action in which BRP did concur was the issuance of an advisory from the Department of Agriculture that farmers shelter their cattle and give them stored feed. Agriculture personnel stated that Margaret Reilly, the Chief of the Division of Environmental Radiation in BRP, concurred in this advisory, although she does not remember doing so. She indicated, however, that she did not disagree with issuing that advisory as a precaution, since forage grasses had not yet begun to grow and stored feeds were readily available.

Of the 19 professional staff in BRP, 18 were involved in the TMI response. Four of these worked in the BRP laboratory. On Friday, March 30, the BRP nuclear engineer was assigned to the TMI site, 12 hours a day, to keep the Governor's Office and BRP advised of any activity that could cause offsite consequences. The remainder of the BRP staff was heavily involved in collecting samples and analyzing the results to determine what recommendations should be made.

3. PENNSYLVANIA EMERGENCY MANAGEMENT AGENCY

Organization, Responsibilities, and Authorities

The Emergency Management Services Code, signed into law by the Governor of Pennsylvania on November 26, 1978, reorganized the Pennsylvania Civil Defense program. This act established the Pennsylvania Emergency Management Council, superseding the State Council of Civil Defense, and gave it responsibility for overall policy and direction of a statewide civil defense and disaster program. The Council comprises the Governor, the Lieutenant Governor, the heads of 10 State agencies, and the majority and minority leaders of the State Senate and the House of Representatives. The Governor has designated the Lieutenant Governor to serve as Chairman of the Council.

The act also provides for a staff, known as the Pennsylvania Emergency Management Agency (PEMA), headed by a Director who serves as the Council Chairman's principal assistant in civil defense and disaster matters and who performs fiscal, planning, administrative, operational, and other duties assigned him by the Council. Since passage of this act, the Council has not assigned specific duties to the Director of PEMA; the Director believes, however, that he has overall responsibility for operation of PEMA and has received no indication to the contrary from the Council.

Historically, responsibility for State planning for incidents at fixed nuclear facilities was vested in BRP as part of the DER under an agreement between DER and PEMA. PEMA did, however, add Annex E to the Commonwealth Disaster Operations Plan of July 1977. Annex E is a plan for responding to nuclear incidents at fixed facilities. Under this plan the Council is responsible for overall coordination of emergency planning and operational response to a nuclear incident. The plan assigns the following specific responsibilities for nuclear incidents to the Council.

1. Issuance of planning guidance.
2. Coordination of State response to nuclear incidents.
3. Maintaining an emergency communications facility.

4. Operating the State Emergency Operations Center.
5. Emergency public information.
6. Notification of Federal authorities.
7. Coordination of State agencies and departments.

A similar, though more detailed, plan for response to incidents at fixed nuclear facilities was developed by BRP in September 1977. This plan establishes PEMA as the State agency to receive notification of an incident from the facility and to transmit this information immediately to BRP. The BRP plan also acknowledges PEMA's responsibility for the following:

1. Notifying the Governor, Lieutenant Governor, State agencies and departments, neighboring States, and Federal agencies of an emergency.
2. Relaying pertinent emergency information and instructions to appropriate counties.
3. Exercising general direction and control over State, county, and local emergency operations.
4. Coordinating assistance provided by Federal agencies and private relief organizations.

Since the accident at TMI, PEMA, with concurrence of the Council, has taken steps to reassume planning responsibility for fixed nuclear facilities. This is in accordance with the Emergency Management Services Code of 1978, and will necessitate a revision (already underway) of Annex E to the Commonwealth Disaster Operations Plan. The plan's most recent draft is dated July 1979.

PEMA has a staff of 67, about equally divided between professional and clerical personnel. The professional staff is not trained in the area of reactor-oriented radiological processes, monitoring, and dose assessment. PEMA is made up of a headquarters staff and three area headquarters in Central, Eastern, and Western Pennsylvania. Each area covers about a third of the State. PEMA also has a stockpile of equipment at Fort Indiantown Gap, Pa., and a maintenance repair shop for radiation monitoring equipment scattered throughout the State. The radiation monitoring equipment is for use during enemy attack.

Initiation of Involvement

At 7:02 a.m. on March 28, the PEMA watch officer received a telephone call at home from a utility employee, who told him that there had been an incident at TMI-2 and that BRP should contact the facility. The PEMA watch officer immediately notified the BRP duty officer at home. During the next half hour, Dauphin and Lancaster Counties and the PEMA area offices were notified by the watch officer. Because the watch officer could not contact York County, he requested the Lancaster County EMA to make that notification. At 7:25 a.m., when he arrived at the office, the Director of PEMA was notified of the event.

Description of Response

Throughout the first 2 days of the accident, PEMA's function was principally one of notifying and updating State agencies and county coordinators on the status of events at TMI. However, because little was known about the reactor status for the first 2 days, and because the radiation releases stayed at a relatively low level during this period, the BRP assessments given to PEMA on almost an hourly basis uniformly reported "no change." Either the Director or his representative attended most TMI-related press conferences and meetings held by the Governor and Lieutenant Governor.

On Friday morning, March 30, as a result of a release of radiation reported by the utility and a recommendation from the NRC for a 10-mile evacuation, PEMA advised the counties within 10 miles of TMI to begin planning for an evacuation. There is some disagreement as to which counties were advised to begin 10-mile planning on Friday. The PEMA log indicates that four counties—Dauphin, Lancaster, York, and Cumberland—were notified at 10:15 a.m. Friday. However, only Dauphin and Cumberland Counties reported that they had been advised at any time on Friday; Lancaster, York, and Lebanon Counties (the latter having only a small area inside the 10-mile radius) reported that they were not notified on Friday of the need for 10-mile plans.

Following a Friday evening briefing by Harold Denton in the Governor's office (at which Denton mentioned that planning for a 20-mile evacuation would be prudent), PEMA advised the counties within 20 miles of TMI to begin evacuation planning. From this time on, PEMA's primary function became coordination of the counties' evacuation planning. Although PEMA supposedly retained its responsibility for communicating with the counties and State agencies, PEMA had been told by the Governor's office that the Governor desired to be the main source of information to the media, and that such information should not be given to the counties in advance of or even simultaneously with the Governor's statements.

At about 11:00 a.m. on Friday morning, PEMA activated its Emergency Operations Center, to which designated State agencies sent representatives to coordinate with PEMA. The center was to provide rapid interagency communications for decisionmaking. Because telephone lines were overloaded and long delays in communications were occurring, PEMA distributed about 85 hand-held portable radios to various State agencies. PEMA also activated its emergency communications van, which is able to link the 40 public safety and statewide radio systems in use throughout Pennsylvania. By Sunday, in an effort to improve communications with the counties, PEMA had "hot line" telephones installed in the six counties within 20 miles of TMI.

To assist the counties in preparing 20-mile plans, PEMA assigned a representative to each of the six affected counties on March 31. PEMA also assigned a headquarters staff member to review and coordinate the county plans and to assure that the State support agencies knew what their responsibilities would be.

One of the major functions performed by PEMA in this regard was coordination of the evacuation routes that would be used by the counties. On March 31, PEMA prepared and distributed a list of suggested evacuation routes.

The counties adapted these suggestions according to their individual needs and desires. In deciding upon their final routes, the counties were assisted by the State Police, the Pennsylvania Department of Transportation, and National Guard representatives assigned to each county. PEMA worked through these representatives to assure that the final evacuation routes chosen by a county did not conflict with other counties' plans. On April 4, PEMA distributed a map showing the final evacuation routes for each county. The major purpose of this map was to indicate to traffic control agencies, such as the State Police, what traffic density to expect along specific routes.

The map was also used by the Pennsylvania Department of Transportation to evaluate traffic movement during an evacuation to estimate evacuation times. Based on this evaluation, the Department of Transportation estimated that a 10-mile evacuation would require 7 hours and a 20-mile evacuation would require 10 hours.

PEMA also served as the primary contact within the Commonwealth for the FDAA and DCPA representatives dispatched to the TMI area by the White House.

4. THE GOVERNOR'S OFFICE

As chief executive officer of the State, the Governor bears the responsibility and the authority to lead in times of domestic crisis. In Pennsylvania, the Governor's responsibility was clearly stated in the Pennsylvania Emergency Management Services Code in effect on March 28, 1979. This statutory code assigned the Governor ultimate responsibility "for meeting the dangers to this Commonwealth and people presented by disasters." The code also established the successor to the State Council on Civil Defense, the Pennsylvania Emergency Management Council, made up of 16 high ranking State officials, including the Governor and Lieutenant Governor. The code assigned policy and direction responsibility to the Council for statewide civil defense and disaster programs and response capabilities. Governor Thornburgh had designated Lt. Governor Scranton as Chairman of the Council prior to the accident at TMI.

Initiation of Involvement

Governor Thornburgh was notified of the accident at TMI by Oran Henderson, the Director of PEMA, at about 7:45 a.m. on March 28, 1979. Governor Thornburgh instructed Henderson to work through Lt. Governor Scranton. Henderson had tried to notify Scranton before he called Thornburgh, but Scranton was enroute from his home to his office. Henderson informed Scranton of the accident upon Scranton's arrival in his office at about 8:20 a.m.

Description of Response

Throughout the first 2 days of the accident, the Governor's office functioned as contemplated by statewide emergency plans. The Lieutenant Governor, in his role as Chairman of the Council, served as senior State official handling TMI and spokesman for the State. In this role on Wednesday the Lieutenant Governor held three press conferences, met with senior Met Ed officials during the afternoon and with NRC and DOE representatives that evening, and continuously kept the Governor abreast of the situation. On Thursday Lt. Governor Scranton visited the site to make a personal assessment of the situation. Governor Thornburgh's first public statement regarding TMI came during a 10:20 p.m. press conference on Thursday evening.

Within the Governor's office a group of senior State officials assembled to consider the course of the accident, to advise Governor Thornburgh, and to evaluate the information being received by the office. On Wednesday and Thursday this group consisted of Jay Waldman, the Governor's Executive Assistant, Paul Critchlow, the Governor's Press Secretary, and Jim Seif, Special Assistant to the Governor, as well as the Lieutenant Governor.

Depending on the issue being discussed, other State officials, including Gordon MacLeod, Secretary of Health, Clifford Jones, Secretary of Environmental Resources, and Penrose Hallowell, Secretary of Agriculture, were also present. Oran Henderson, Director of PEMA, was present at many of the meetings held through Sunday, April I. Governor Thornburgh added Robert Wilburn, Secretary of Budget and Administration, to this group of advisors on Saturday, March 31.

On Thursday evening the Governor's office became involved in authorizing Met Ed to resume dumping industrial wastewater containing small amounts of xenon from TMI into the Susquehanna River. Poor communication between NRC and the State and confusion within the Governor's office over the State's authority to resume the dumping, which had been stopped by NRC officials in Bethesda, Md., delayed the NRC's authorization for Met Ed to resume dumping. After extended discussions among Thornburgh, Paul Critchlow, Thornburgh's Press Secretary, and Karl Abraham, the NRC's Region I Public Information Officer, Thornburgh determined that he probably did not have authority to permit Met Ed to resume dumping.

Negotiation between Critchlow and Abraham on Thursday night over whether the NRC or the Governor should issue a press release announcing that Met Ed could resume dumping resulted in a stalemate not resolved until near midnight on Friday, when Secretary of Environmental Resources Clifford Jones issued a press statement announcing that the NRC and Met Ed had informed the State of the need to dump the water and that DER had "reluctantly agreed" to allow them to proceed.

During Wednesday and Thursday, the mood within the Governor's office was changing. Initially, Lt. Governor Scranton relied heavily on NRC onsite officials and Met Ed officials for information about the plant. However, because of conflicting and overly optimistic reports coming from both the NRC and Met Ed, Thornburgh and Scranton began to lose confidence in the information the State was receiving from these sources. The Governor has stated that on Thursday evening he went to bed "fairly troubled about where we were going to look to determine precisely what was the situation at the reactor."

On Friday morning, March 30, the situation in the Governor's office took a marked change. From that point on the Governor was clearly in charge of the State response to the accident. The Governor chose not to act immediately on the NRC's evacuation recommendation that morning. He chose instead to confirm the basis of the recommendation and the source of the radiation, steps that were not taken by the NRC personnel in the Bethesda Incident Response Center before they made the recommendation. The Governor called Chairman Joseph Hendrie to find out what the situation was and found that the Commission did not support the recommendation, which came from an NRC staff member. It was during this conversation that the Governor expressed the desire to have a central source of information on which he could rely. As a result of this request and subsequent conversations between the President and Chairman Hendrie and the President and the Governor, Harold Denton was sent to the site Friday afternoon as the President's personal representative to serve as the single Federal Government source of information on technical issues. Denton also served as the Governor's principal source of information on the status of the plant.

On Friday Governor Thornburgh also decided that he would be the single spokesman within the State on all TMI-related matters. This decision was communicated to the PEMA Public Information Officer and the Director of BRP by the Governor's Press Secretary that day. From Friday on, the Governor's Office was the focal point for all information coming into or going out of the State.

Throughout the course of the accident the Governor was faced with decisions on protecting the health and safety of the people of Pennsylvania. The Governor has stated that he thought immediately of evacuation on the morning of March 28, when he was notified of the incident, and that it was continuously on his mind for the next 10 days. In evaluating the need for evacuation, he weighed the possible risks from the TMI plant against the proven hazards of moving people under panic conditions. He has stated that he would not have hesitated to order an evacuation if it appeared to be the safest course of events, but could not, in good conscience, have ordered it based on the facts at his disposal.

Based on the situation at the plant and advice from Chairman Hendrie and the Governor's top staff, the Governor did advise certain protective actions: On Friday, March 30, he issued an advisory for those within 10 miles of TMI to stay indoors, an advisory for pregnant women and preschool children to leave the 5-mile area, and an order to close schools in the area around TMI in recognition of the possibility of a general evacuation, as well as to keep school-age children of families with pregnant women or preschool-age children with their families.

Governor Thornburgh's principal source of information on plant status was Harold Denton. Denton briefed Governor Thornburgh each day; each briefing was followed by a joint press conference. All information on PEMA operations came into the Governor's office through Lt. Governor Scranton, information on radiation monitoring was coming through Secretary of Environmental Resources Jones, and information on possible contamination of milk and water came through Secretary of Agriculture Hallowell.

On Friday, March 30, Governor Thornburgh directed radiation and nuclear engineering experts in BRP to go to the site to provide him with a continuing, independent technical assessment of the danger posed by the reactor. For the next month William Dornsife, a BRP nuclear engineer, spent 12 hours a day on site, independently verifying technical information for the Governor's office.

On Friday afternoon at about 2:00 p.m., Lt. Governor Scranton convened a meeting of the Pennsylvania Emergency Management Council. During the 40-minute meeting Scranton briefed those present on his understanding of the accident, each Council member reported on the involvement of his agency, and Henderson, the Director of PEMA, indicated what support he expected from each State agency. At least part of the reason that this meeting was called appears to have been the requirement in section 7312(d) of the Pennsylvania Emergency Management Services Code, that if a disaster is determined actually or likely to exist, the Chairman of the Council shall within 48 hours call the Council into emergency session. Although we are unaware that such a determination was officially made, the escalation of events that morning could have led the Governor or Lieutenant Governor to believe that a disaster situation was likely.

On Saturday, March 31, the Governor directed Robert Wilburn, Secretary of Budget and Administration, to review the emergency plans in existence and those being developed to independently determine how much confidence could be placed in them. This review was carried out throughout the weekend. By Saturday night, Wilburn was able to assure the Governor that a 5-mile evacuation could be carried out and that a 10-mile evacuation could be carried out with a reasonable degree of success and minimal loss from injuries or property damage.

Although review of the 20-mile evacuation plans continued into Sunday, by Sunday afternoon the Governor's office had concluded that there was little use in planning for a 20-mile evacuation since there were no plausible scenarios in which a 20-mile evacuation would be required. This decision was reached on the basis of information from Harold Denton and Dr. Niel Wald, a consultant to the State. It was confirmed Sunday evening by Chairman Hendrie when he met with Governor Thornburgh. Attention within the Governor's office then focused on the 5- and 10-mile plans for evacuation, always recognizing, however, that the consequences of an evacuation order could extend to 20 miles.

A major decision confronting Governor Thornburgh throughout the accident was whether to request the President to declare a disaster under the Disaster Relief Act of 1974, which would commit Federal resources to supplement State operations. According to Thornburgh, Waldman spoke to Watson of the White House on Friday afternoon and was assured that Pennsylvania would receive the same level of Federal assistance, both during and after the incident, without a disaster declaration, as it would if a disaster was declared. In addition, both Thornburgh and Watson were concerned that the declaration of a disaster would unnecessarily escalate the concerns of the populace over the accident. As a result, a disaster declaration was never requested by the Governor. Paperwork was prepared, however, to enable the Governor to request a declaration immediately if there was a change in plant status or if it was required in order to improve Federal response.

The extensive role played by the Governor's office in responding to the accident at TMI is primarily attributable to the extended nature of the accident. Had the accident progressed more rapidly—over hours rather than days—as accidents at reactors had been expected to, there would have been no time for extensive involvement by the Governor's office and the need for protective actions would have been quickly and abundantly clear.

5. PENNSYLVANIA DEPARTMENT OF AGRICULTURE

The head of the Pennsylvania Department of Agriculture is one of the 16 members of the Pennsylvania Emergency Management Council discussed above.

Historically, responsibility for State planning for incidents at fixed nuclear facilities was vested in BRP, part of the DER. BRP developed a plan for managing incidents at fixed nuclear facilities in September 1977. This plan describes the following emergency responsibilities of the Pennsylvania Department of Agriculture.

1. To serve as liaison with the agricultural community.
2. To provide, at the recommendation of BRP, for the protection of the supply of milk and other foodstuffs, livestock, and field crops.

3. To provide for informing the agricultural community of the need to take protective action.
4. To provide for sampling of commodities in the affected areas.

The actions taken by the Department of Agriculture in response to TMI were consistent with those responsibilities.

At TMI-2 a major radiological effort was directed toward investigating, evaluating, and explaining the exposure of people and animals to radioiodine from TMI by way of the grass–cows and goats–milk and milk products–people pathway. The Department of Agriculture worked closely with BRP in this effort.

At 8:15 a.m., March 28, the Department of Agriculture was notified by BRP that there was a problem at TMI. At 11:20 a.m. on March 28, BRP requested the department to obtain milk samples that evening. The department obtained the samples from 10 farms within a 10-mile radius of TMI. Radiological analyses of the samples by BRP showed no radioactivity above the detection level of 10 picocuries per liter. Subsequent milk samples collected by the department showed a maximum of 21 picocuries per liter. Vegetation samples also were collected for BRP.

At no time did the department recommend dumping milk or diverting it to a particular use; however, on Friday, March 30, the department officially issued a recommendation that farmers get their animals indoors, put them on stored feed, and keep them away from streams. The recommendation did not specify to what distance from TMI these actions should be applied, though it was issued when other protective actions were being discussed for the area within 10 miles. After the recommendation had been in effect about a month, it was rescinded through Agriculture's Public Information Office. The recommendation was only a precautionary measure, not a matter of necessity for the protection of public health and safety. It was taken realizing that there was little need for pasturage at that time of year, and that there was plenty of stored feed.

The department responded to a number of alleged cases of sickness or death of animals caused by radiation. Investigation and autopsies by Department of Agriculture veterinaries showed no case in which this was so.

6. BUREAU OF FORESTRY

The Bureau of Forestry is part of the Pennsylvania DER and the secretary of DER is a member of the Pennsylvania Emergency Management Council. However, the Bureau of Forestry has no designated functions in emergency response actions.

The bureau had been aware of the TMI accident through media reports, but it did not become actively involved until Saturday, March 31, when it furnished two trucks and two cars, with radios, for use by EPA personnel in their radiation monitoring efforts. An additional eight vehicles with radios were provided to EPA on April 1. Maps and important telephone numbers were furnished to the EPA personnel, and a radio engineer from the bureau spent about 20% of his time in support of the equipment and EPA operations during the first month following the accident. The vehicles logged up to 3000 miles of travel while they were on loan to EPA and, as of mid-August, EPA was still using some of the Bureau's equipment.

7. PENNSYLVANIA DEPARTMENT OF HEALTH

A primary function of the Pennsylvania Department of Health is to conduct a licensing and regulating program that assures the quality of health within the Commonwealth. It also serves as the surrogate county health department for 61 of the 67 counties in Pennsylvania. The head of the Pennsylvania Department of Health is one of 16 members of the Pennsylvania Emergency Management Council.

BRP's plan for incidents at fixed nuclear facilities, developed by BRP in September 1977, sets the emergency responsibilities for the Department of Health as assisting in the continued delivery of emergency and routine medical care and conducting emergency functions as directed by higher authority. Similar and more detailed responsibilities were set out in the Commonwealth Disaster Operations Plan of July 1977.

At 8:00 a.m., March 28, the Department of Health was notified by PEMA of an incident at TMI. The Pennsylvania Department of Health's incident response activities were principally in five areas: the Governor's advisory that children and pregnant women leave the area, management of potassium iodide, liaison with the medical community, response to concerned citizens, and followup health impact studies.

On Friday morning, March 30, the Governor advised that pregnant women and preschool children within 5 miles of TMI leave the area. This recommendation was consistent with the Department of Health's recommendation to the Governor earlier Friday morning that there should be an evacuation of children under the age of 2 and pregnant women. The Department's recommendation took into account the particular radiation sensitivity of the fetus and the young child and the apparent uncertainty about further developments at TMI.

The Department of Health had a major role in the decision not to distribute and administer potassium iodide to the public. Potassium iodide is a prophylactic drug that is used to block the uptake of radioactive iodine by the thyroid. During the response to TMI, the Federal Department of Health, Education, and Welfare arranged for manufacture and shipment to Pennsylvania of 250 000 bottles of potassium iodide and recommended its use. The Pennsylvania Department of Health assumed responsibility for the drug and prepared for its distribution, but it did not authorize its use. In view of improving conditions at TMI, the department decided not to distribute it to the public.

The department served as a source of information for the Pennsylvania medical community, responded to requests from the public for information on TMI-related health effects, and now has a lead role in an HEW program to determine the health effects of the accident.

8. PENNSYLVANIA INSURANCE DEPARTMENT

The Pennsylvania Insurance Department has no representative on the Pennsylvania Emergency Management Council. However, it still has the responsibility for providing PEMA with such property damage information and data as may be available through insurance industry channels. Of course, this function was not necessary for TMI.

The insurance department was aware of the TMI accident from media reports starting on March 28, 1979. However, the department did not become involved in the response efforts until Sunday, April 1, when department representatives met with representatives of the nuclear insurers. The department representatives helped arrange working facilities for the nuclear insurers' representatives and, during the following days, worked with the insurers' representatives to smooth relations with the public. The department has monitored the claims payments to the evacuees.

9. PENNSYLVANIA DEPARTMENT OF JUSTICE

The Attorney General is a member of the Pennsylvania Emergency Management Council. The Department of Justice provides legal advice to the Governor, to the Lieutenant Governor, to PEMA, and to disaster victims. It is responsible for furnishing PEMA with information regarding disaster damage to and problems faced at criminal institutions and facilities. The Department of Justice is also charged with taking specific actions designed to assure effective consumer protection.

The Department of Justice was notified of the TMI-2 accident on Wednesday, March 28, by PEMA shortly after PEMA was notified by the plant. Later that day, Department of Justice personnel began researching applicable State statutes and drafting executive orders that would have been required by the Governor had he chosen to declare a disaster and direct an evacuation. The Department is now actively involved in various legal actions that were initiated as a result of the TMI accident; it seeks to represent the interests of the citizens of Pennsylvania.

10. PENNSYLVANIA DEPARTMENT OF MILITARY AFFAIRS

The Pennsylvania Department of Military Affairs is directed by the Adjutant General, who is a member of the Pennsylvania Emergency Management Council. The Adjutant General commands the Pennsylvania National Guard (PNG). The designated function of the PNG is to provide assistance, as directed by the Governor or requested by PEMA, and in accordance with the "State Plan for Military Support of Civil Defense," in emergency protection measures, rescue, evacuation, medical and mass care, maintenance of law and order, air and ground transport, debris removal, facility repair, and other basic and essential disaster relief operations.

The Adjutant General was notified of the TMI-2 accident by PEMA early Wednesday morning, March 28. At the request of PEMA, the PNG started to prepare a list of transportation facilities that could be used in support of an evacuation. However, later that morning PEMA advised that conditions at the plant had improved and that planning for PNG involvement could be discontinued.

On Friday, March 30, PNG again became involved after notification of the radiation release at the TMI plant. Selected PNG officers were called to State active duty. An operation plan was prepared and issued on March 31; it provided for use of PNG personnel to assist civilian authorities in evacuation of residents, traffic control, sealing off evacuated areas, and provision of local security. Five PNG battalions and a headquarters unit were placed on alert, but were never called to active duty.

In addition to planning for the mass evacuation, the PNG provided six GP medium tents for use as shelters for emergency workers at the plant site; cots, blankets, and pillows for use at the Hershey Arena mass care center and at the PEMA Emergency Operations Center; helicopter transportation of water samples from the TMI plant to State College.

Pa., for analysis; office space for the NRC in the Air National Guard office building at the Harrisburg International Airport; ground support services for transient aircraft hauling passengers and cargo in support of the emergency efforts at TMI; and a radio communications net linking the PNG headquarters with PNG elements at the county emergency operations centers.

PNG's active duty service was terminated on April 5, 1979. The overall cost for the PNG efforts was nearly $12 000.

11. PENNSYLVANIA STATE POLICE

The Commissioner of the Pennsylvania State Police (PSP) is a member of the Pennsylvania Emergency Management Council. The State Police has a number of designated functions in support of State emergency response actions. These include providing information concerning significant disaster effects and problems, collecting and maintaining records of dead and missing persons, assisting emergency dissemination of essential disaster information and instructions, and assisting in State, county, and local emergency operations.

The State Police were first notified of the TMI-2 accident by a telephone call from the plant at 7:14 a.m. on Wednesday morning, March 28. Several PSP officers were immediately dispatched to the site for traffic control. A PSP helicopter was furnished to fly radiation monitoring teams conducting radiation surveys to the survey locations. The PSP continued to provide traffic control and security in the plant area on March 29. On March 30, following news of the radiation release, the PSP installed a portable radio base station at the TMI observation center to provide a radio link to the PEMA operations center in Harrisburg. A mobile command post was set up near the observation center later that afternoon. Increased patrolling was conducted that evening to prevent looting of evacuated dwellings.

The PSP became actively involved in the evacuation planning on Saturday, March 31. The PSP worked closely with the counties at risk to coordinate evacuation routes, in conjunction with PEMA, the State Department of Transportation, and National Guard personnel. They were concerned also with traffic control and security in the designated host counties. In the event the evacuation had been ordered, the first priority of the PSP would have been traffic control; security would have been a secondary goal. During the days following the accident, a major activity of the PSP was escorting special vehicles that were hauling equipment to the site. A total of 4705 hours were devoted to the TMI-2 response effort from March 28 to April 11, 1979.

12. PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

The Secretary of the Pennsylvania Department of Transportation (PennDOT) is a member of the Pennsylvania Emergency Management Council. PennDOT has a number of specific functions in emergency response actions. These principally involve providing information to PEMA regarding assistance in supply of motor fuel and transport services, technical and administrative assistance in road repair, and disruptions of road, rail, and air transportation.

PennDOT was advised of the TMI-2 accident shortly after PEMA was notified by the plant on Wednesday, March 28. The hot line to the PEMA Emergency Operations Center was immediately activated, but no special actions were taken until Friday, March 30, following notification of the radioactive release at the TMI plant. At that time PennDOT activated its Emergency Response Team and went into 24-hour operation. During the following days, PennDOT personnel arranged for transportation in support of county evacuation plans and worked closely with the counties and the State Police to coordinate county plans for traffic flow and with the National Guard to support the planned evacuation efforts. Coordinated evacuation plan maps were prepared by PennDOT and issued through PEMA.

13. PENNSYLVANIA TURNPIKE COMMISSION

The Pennsylvania Turnpike Commission has been assigned responsibilities in the area of emergency operations. These responsibilities include arranging for toll-free travel of emergency vehicles along the turnpike, assistance in the emergency transport of personnel and materials to points on or in the immediate vicinity of the turnpike, and assistance in emergency communications to points on or in the immediate vicinity of the turnpike.

The role of the turnpike commission in response to the TMI-2 accident was limited to cooperation with PEMA and the State Police in planning for use of the turnpike during a general evacuation. This planning occurred essentially during March 31 through April 2.

14. BORDERING STATES

The accident at TMI-2 caused extensive radiological monitoring efforts by government agencies in States adjacent to Pennsylvania: Ohio, New York, New Jersey, Maryland. These efforts were aimed at determining the extent of TMI-related radiation hazards in the respective States in order to decide what, if any, actions should be taken to protect their citizens. The determinations of the extent of radiation hazards also enabled authoritative responses to citizens about the levels of radiation in their States.

Notification of radiological personnel in four of the neighboring States took place at 9:00 or 10:00 a.m. on Wednesday, March 28. Ohio first learned of the incident from the news media; New York was notified by its regional office of DCPA, which had heard of it on a news broadcast; Maryland was informed by a person regulated for the use of radioactive material by Maryland; New Jersey was informed by the NRC. None of these States were first informed of the incident by Pennsylvania State personnel.

New York, New Jersey, Maryland, and Ohio have ongoing State radiation programs that are conducted by experienced personnel. Upon notification of the TMI incident, those groups took action to evaluate the radiation levels that might result in their respective States and to evaluate the possibility that contaminated water and milk might enter their States.

Milk received particular attention because New York, New Jersey, and Maryland obtain milk from dairies in the TMI area. By 2:00 p.m. on March 28, the Maryland strategy for sampling milk had been established. The strategy called for monitoring milk at farms in Maryland and at selected farms in Pennsylvania that have Maryland-issued permits to ship milk to Maryland. The decision to concentrate on milk sampling at the farm level was based on the reasoning that if any contaminated milk was found, restrictions on its distribution and use could more easily be applied at that level than at other places in the normal distribution channels. Sampling of milk at the retail level was done secondarily.

Maryland obtained samples from the March 29 morning milking. Some samples came from farms as close to TMI as 3 miles. Milk was sampled by Maryland for 2 weeks, although the program was modified during the final 2 days to sample milk from bulk tanks when the milk was delivered to dairies. Maryland obtained and analyzed a total of 123 raw milk samples for possible TMI-related radioactivity.

New Jersey analyzed about 120 milk samples. New Jersey identified approximately six processors that obtained milk from within a 50-mile radius of TMI. Raw milk samples were obtained from milk trucks as they arrived at the processors' plants in New Jersey.

New York collected and analyzed milk samples from both Pennsylvania and New York suppliers. About half a dozen Pennsylvania suppliers of milk to New York were identified. The identification of milk suppliers was somewhat complicated by an ongoing milk strike in New York that disrupted normal sources of supply.

Ohio did no special milk analyses, because Ohio was predominately upwind of TMI, the Ohio-Pennsylvania border is about 200 miles from TMI, and other groups sampling milk from the TMI area had reported no significant contamination. Milk sampling by Maryland, New Jersey, and New York revealed no iodine (the suspected radioisotope) above the minimum detectable limit of 10-20 pCi/l.

On Wednesday, March 28, Maryland began taking grab samples of the Susquehanna River and on Friday began composite sampling to evaluate the extent of TMI-caused radioactivity in the river because a number of Maryland municipalities draw drinking water from that source. Maryland collected and analyzed a total of 85 water samples. The only evidence of radioactivity above normal levels in the Susquehanna water samples taken by Maryland was a low level of dissolved ^{133}Xe found in several samples collected at the Holtwood Dam sampling site, about 35 miles downstream of TMI.

Delaware River water was sampled at the intake to the Trenton filtration plant and analyzed by New Jersey. Because the Delaware River does not flow past TMI, any TMI-generated radioactivity that might have been detected would have been airborne and then deposited in the watershed for the Delaware River. At no time in its radiation monitoring did New Jersey detect any radioactivity attributable to TMI. Both New Jersey and Maryland used helicopters when surveying their respective Pennsylvania borders and detected no radiation attributable to TMI.

New Jersey, Maryland, and New York collected and analyzed air samples. New Jersey found no TMI radioactivity. Maryland found no unusual radioactivity until a sample counted early Sunday night indicated very low levels of ^{133}Xe and ^{131}I; these levels were 1000 and 90 femtocuries per cubic meter respectively. With one exception, New York air sample results showed no TMI-generated radioactivity. That exception was the detection in Albany of very low levels of xenon.

External radiation level measurements were made by New Jersey and Maryland. Maryland also sampled fish from the Susquehanna River and oysters from the Chesapeake Bay. No radiation levels or radioactivity above normal background was found.

Maryland, New Jersey and New York used the results of their radiation measurements in determining that they need not implement any protective actions. The results were also used in responding to numerous questions by concerned citizens.

Maryland was prepared to assist Pennsylvania in handling hospitalized persons if an evacuation of 10 to 20 miles from TMI had been implemented. It developed plans for the use of Maryland ambulances to move critically ill persons from the Pennsylvania hospitals to designated Maryland hospitals.

APPENDIX III.8

DETAILED CHRONOLOGY OF EMERGENCY RESPONSE

3/28/79

4:00 a.m. Accident initiation.

6:55 a.m. Site Emergency declared by shift supervisor based on alarms of process and area radiation monitors.

7:02 a.m. Pennsylvania Emergency Management Agency (PEMA) duty officer notified of Site Emergency by shift supervisor, who requested that PEMA notify the Bureau of Radiation Protection (BRP).

7:04 a.m. Plant attempts notification of NRC Region I. Answering service receives the call.

7:05 a.m. BRP duty officer notified of Site Emergency by PEMA duty officer.

7:08 a.m. Dauphin County Office of Emergency Preparedness notified of Site Emergency by PEMA duty officer.

7:09 a.m. Department of Energy (DOE) Radiological Assistance Program (RAP) office at Brookhaven National Laboratory notified of Site Emergency by plant.

7:09 a.m. Dauphin County notified of Site Emergency by plant.

7:10 a.m. PEMA duty officer attempts to notify York County Emergency Operations Center of Site Emergency.

7:12 a.m. Lancaster County Emergency Management Agency notified of Site Emergency by PEMA duty officer, who requests Lancaster County to notify York County.

7:14 a.m. Pennsylvania State Police (PSP), Troop H, notified of Site Emergency by plant.

7:20 a.m. PSP dispatches several traffic control officers to the site.

7:24 a.m. General Emergency declared by TMI station manager based on reactor building dome radiation monitor reading greater than 8 R/h.

7:25 a.m. BRP calls TMI-2 control room to confirm earlier notification from PEMA. BRP informed of escalation to General Emergency. Telephone line between BRP and control room held open.

7:30 a.m. Dauphin County notified of escalation to General Emergency by plant.

7:35 a.m. DOE RAP office notified of escalation to General Emergency by plant.

7:35 a.m. PEMA notified of escalation to General Emergency by plant.

7:36 a.m. PEMA begins notifying BRP and Dauphin, York, and Lancaster Counties of escalation to General Emergency.

7:37 a.m. Reading, Pa., office of utility attempts to notify NRC Region I. Answering service receives the call.

7:40 a.m. Plant attempts to notify NRC Region I. Answering service receives the call.

7:40 a.m. Plant sends radiation monitoring teams to west shore of Three Mile Island and to Goldsboro.

7:45 a.m. Henderson of PEMA notifies Governor of plant status.

7:45 a.m. NRC Region I switchboard opens.

7:45 a.m. BRP notifies PEMA that there is a calculated offsite release of 10 R/h in the direction of Brunner Island and Goldsboro and that preparations should be made for possible evacuation.

7:50 a.m. NRC Region I calls TMI-2 control room and learns of the accident.

7:52 a.m. PEMA notifies York County of possible need to evacuate Brunner Island and Goldsboro.

7:55–8:15 a.m. PEMA notifies members of Pennsylvania Emergency Management Council of accident at TMI.

8:00 a.m. NRC Region I activates its Incident Response Center and notifies NRC Headquarters of accident.

8:05 a.m. NRC Headquarters activates Incident Response Center (IRC).

8:05–9:00 a.m. NRC Headquarters personnel notified of accident.

8:15 a.m. BRP advises PEMA that based on latest information, evacuation alerts of Brunner Island and Goldsboro should be cancelled.

8:20 a.m. PEMA calls York County to pass on information received from BRP and to advise that alerts could be cancelled.

8:20 a.m. Lieutenant Governor notified of incident by Henderson of PEMA.

8:40 a.m. First team of five inspectors leaves NRC Region I for the site.

8:45 a.m. Defense Civil Preparedness Agency (DCPA) Region Two Center notified of General Emergency by PEMA.

8:45 a.m. Brookhaven Area Office notifies DOE Headquarters Emergency Operations Center (EOC) of the accident.

8:55 a.m. DOE/EOC calls NRC/IRC to verify information regarding accident.

9:00 a.m. DCPA Region Two Center notifies DCPA Headquarters of the accident.

9:00 a.m. NRC Region I contacts Brookhaven RAP office and confirms that two RAP teams are on standby.

9:00 a.m. Second team of inspectors leaves NRC Region I for TMI

9:00 a.m. Commissioner Gilinsky notifies J. Mathews at White House of incident.

9:00–9:30 a.m. NRC/IRC notifies White House Situation Room of accident. Appropriate House and Senate staffs notified of accident by NRC Office of Congressional Affairs.

9:02 a.m. Environmental Protection Agency (EPA) notified of accident by NRC/IRC.

9:02 a.m. Associated Press releases national bulletin advising that a General Emergency has been declared at the plant but that no radiation had been released. Details not yet available.

9:27 a.m. DCPA contacts NRC/IRC to verify information regarding the accident.

9:30 a.m. Plant starts dumping heat through atmospheric dump valves.

10:00 a.m. DOE/EOC places Aerial Measurement System/Nuclear Emergency Search Team (AMS/NEST) at Andrews Air Force Base on standby alert.

10:05 a.m.	Region I response team arrives on site.
10:17 a.m.	Control room personnel don respirators.
10:20 a.m.	Monitoring teams begin detecting increased radiation levels on site.
10:30 a.m.	NRC press release confirms incident; release of primary water to containment; no offsite radioactivity detected.
10:30 a.m.	National Military Command Center (NMCC) and Joint Nuclear Accident Coordinating Center (JNACC) notified of accident by DOE/EOC.
11:00 a.m.	NRC/IRC contacts DOE/EOC and requests movement of AMS/NEST to Capital City Airport.
11:00 a.m.	Second NRC Region I response team arrives on site.
11:00 est.	State requests shutdown of auxiliary building ventilation system.
11:04 a.m.	Auxiliary building ventilation system shut down.
11:10 a.m.	Nonessential personnel evacuated from site.
11:18 a.m.	State BRP contacts Brookhaven RAP office and requests assistance of a RAP team.
1:15 p.m.	Herbein press conference reports no significant levels of radiation; reactor being cooled in accordance with design; no danger of core meltdown.
1:30 p.m.	AMS/NEST unit arrives at Capital City Airport.
2:30 p.m.	Brookhaven RAP team arrives at Capital City Airport.
4:30 p.m.	Lieutenant Governor press conference. Situation more complex than State led to believe; still taking tests; no danger to public health; Met Ed had given misleading information; radiation had been released; levels decreasing during afternoon.
5:00 p.m.	Second NRC press release. Maximum offsite activity 3 mR/h; ECCS functioning; reactor shut down; system pressure being reduced.
10:00 p.m.	Lieutenant Governor press conference. No current radioactive leakage from containment; atmospheric activity result of auxiliary building ventilation; high radiation levels on site; no critical levels off site.

3/29/79

12:15 a.m.	Third NRC press release. Pressure and temperature still dropping; water released to auxiliary building.
2:00 a.m.	Additional RAP team from Brookhaven arrives early. AMS/NEST unit arrives from Las Vegas.
12:45 p.m.	Lt. Governor Scranton visits site.
3:45 p.m.	Lieutenant Governor briefs Governor on visit.
4:00 p.m.	RAP teams from Pittsburgh Naval Reactors (Bettis) replace Brookhaven RAP teams.
5:15 p.m.	Governor holds press conference. No cause for alarm; no danger to public health; no reason to disrupt daily routines; situation appears under control, but important to remain alert and informed.
10:00 p.m.	Higgins informs Critchlow of possibility of extensive fuel damage.

3/30/79

7:10 a.m.	Venting of makeup tanks initiated.
7:44 a.m.	Helicopter dispatched to monitor radiation release.
8:01 a.m.	Helicopter measures dose rate of 1200 mR/h over Unit 2 auxiliary building vent stack.
8:40 a.m.	PEMA notified by plant of 1200 mR/h release.
8:42 a.m.	BRP and Governor's office notified by plant of radiation release.
8:45 a.m.	NRC/IRC notified of 1200 mR/h release.
9:00 a.m.	Mathews of the White House advised of a wire service notification of the 1200 mR/h release. Confirmed almost simultaneously by telephone call to Mathews from Commissioner Gilinsky.
9:15 a.m.	Collins of NRC calls Henderson of PEMA to recommended evacuation out to 10 miles downwind from plant.
9:18 a.m.	Gallina of NRC at TMI calls NRC Region I and NRC/IRC to recommend against evacuation.
9:25 a.m.	BRP calls Collins to state that BRP does not recommend evacuation.
9:30 a.m.	Gallina recommends to Governor's office not to evacuate.

9:50 a.m.	Henderson calls Collins. Informed that NRC/EMT was still recommending evacuation. Henderson reports that BRP recommended to the Governor not to evacuate.
9:55 est.	NRC Commissioners decide evacuation unnecessary.
9:59 a.m.	Governor calls Chairman Hendrie. Governor informed evacuation unnecessary, but advisable to have persons within 5 miles downwind of the plant stay indoors.
10:15 a.m.	PEMA directs Dauphin, York, Lancaster, and Cumberland Counties to start planning for 10-mile evacuation.
10:25 a.m.	Governor makes live broadcast over WHP radio advising people within 10 miles of the plant to stay indoors with doors and windows closed.
10:47 a.m.	President Carter calls Chairman Hendrie; Denton ordered to site.
11:00 a.m.	Mathews and Odom brief Watson and Eidenberg.
11:15 a.m.	President Carter calls Governor Thornburgh. Concurs in "no evacuation" decision, states that Denton coming to site as personal representative.
11:40 a.m.	Chairman Hendrie calls Governor. Denton's arrival discussed; concurs in recommended evacuation of pregnant women and young children.
12:00 noon	PEMA lifts "take-cover" advisory.
12:30 p.m.	Governor holds press conference; announces that while there is no reason for panic, advisable for pregnant women and preschool children to evacuate area within 5 miles of TMI.
12:40 p.m.	Roger Mattson calls Chairman Hendrie. Hydrogen bubble estimated at 1000 cubic feet at 1000 pounds per square inch. Recommends evacuation out to 10 miles.
1:15 p.m.	Mathews advises President Carter of problems with reactor, including extensive fuel damage.
1:30 p.m.	Meeting at White House attended by NRC, DCPA, FDAA, FPA, DOE, and DoD. Decided that McConnell (DCPA) and Adamcik (FDAA) would go to the site.
2:00 p.m.	Meeting of Pennsylvania Emergency Management Council.
2:00 p.m.	Denton and staff arrive on site.
3:30 p.m.	Jack Watson of the White House calls Governor Thornburg. Tells him that McConnell and Adamcik coming to the site.
Midafternoon	Direct telephone lines installed linking White House, Governor's office, NRC, and site.
3:45 p.m.	Chairman Hendrie calls Governor Thornburgh. Reports on core damage and hydrogen bubble problem and suggests that the Governor put his emergency planning people on alert status for 20-mile evacuation. Close to zero chance for a hydrogen explosion in the pressure vessel.
4:00 p.m.	UPI wire quoting Dudley Thompson, NRC, as saying there exists possibility of core meltdown within a few days.
4:05 p.m.	Denton calls Governor with preliminary report.
5:00 p.m.	Powell White House press conference. Meltdown said to be "at the very least speculative."
5:30 p.m.	McConnell of DCPA arrives at PEMA EOC in Harrisburg.
8:30 p.m.	Denton meets with Governor to render status report.
10:00 p.m.	Governor and Denton hold joint press conference. Governor reports no need for general evacuation; earlier advisory regarding pregnant women and children remains in effect. Denton stresses that there could be no explosion in the reactor vessel and that the possibility of a core meltdown is very remote.
11:00 p.m.	FDAA's Adamcik and staff arrive in Harrisburg.
11:30 p.m.	PEMA starts contacting counties to begin planning for 20-mile evacuation.
3/31/79	
morning	Califano of HEW recommends 20-mile evacuation to White House unless NRC provides firm assurance that reactor cooling safely.
11:00 a.m. est.	Utility press conference. Crietz announces no more Met Ed press

	conferences; NRC to act as spokesman in future. Herbein announces that hydrogen bubble is smaller and indicates that the plant is being brought under control.
12:00 noon	Denton press conference. Denton indicates crisis not over; NRC still examining bubble size data; does not believe bubble poses a problem.
2:45 p.m.	Hendrie press conference. Reactor in a stable configuration and fuel cooling down; possibility of precautionary evacuation while hydrogen problem handled; could be some time before there would be any possibility of flammable condition.
5:00 p.m.	Governor's press release. Advisory evacuation of pregnant women and preschool children remains in effect; no necessity of full evacuation; no threat to public health in milk or drinking water.
8:23 p.m.	AP editor's advisory that hydrogen bubble becoming explosive.
8:50 p.m.	AP wire story. Danger in attempting to remove bubble; equally risky to do nothing; critical point within two days.
9:00 p.m.	Denton impromptu press briefing. Hydrogen bubble would not become explosive for 9-12 days; no imminent danger.
11:00 p.m.	Governor and Denton hold joint press conference. Governor notes the erroneous or distorted reports during the day regarding the plant and asks people to listen carefully to Denton. Denton states that there was no possibility of a hydrogen explosion in the reactor vessel in the near term and also that he and Washington were in essential agreement regarding the plant status. President Carter's upcoming visit announced.

4/1/79

10:45 a.m.	Hendrie and Denton brief Governor on bubble status. The problem had essentially gone away.
1:00-2:30 p.m.	President Carter visits the site.
2:00 p.m.	Denton press conference. Core temperatures steady; action still underway to eliminate hydrogen bubble; evacuation still considered unnecessary.
Midafternoon	NRC convinced that there is no chance of a hydrogen explosion in the reactor vessel.
7:00 p.m.	Governor issues press release. Advisory regarding pregnant women and preschool children still in effect; State offices to conduct business as usual on Monday.

4/2/79

11:15 a.m.	Denton press conference. Fuel temperatures still dropping; dramatic decrease in size of hydrogen bubble; earlier reports regarding possible detonation of hydrogen inside the reactor vessel based on data that were too conservative; plant beginning to use hydrogen recombiner to reduce hydrogen concentration in containment.
—	Eidenberg of the White House, in response to questions raised by Waldman of the Governor's Office, asks the HEW Public Health Service to prepare recommendations regarding use of potassium iodide.

4/3/79

1:17 p.m.	Califano of HEW sends memo to Watson of the White House. Attaches recommendations from Surgeon General regarding use of potassium iodide.
2:28 p.m.	Watson telecopies HEW recommendations to Governor.
2:40 p.m.	Denton press conference. Situation at plant stable; hydrogen explosion no longer considered a problem.
9:30 p.m.	Governor's press conference. Hydrogen bubble had dissipated, reactor core is stable; plans being considered to bring plant to safe shutdown.
4/4/79-4/6/79	Denton press conferences. Minor problems noted; basically plant under control; core cooling; radiation releases largely stopped; plans being made for final plant shutdown.

4/9/79 Governor's press conference. Lifts all previous recommendations, advisories, and directives; pregnant women and preschool age children could safely return home; schools to reopen on 4/10/79; State offices to return to business as usual; emergency preparedness forces shifting from full alert to on-call status; no residual threat to public health in milk or drinking water.

4/27/79 Plant placed on natural circulation cooling.

APPENDIX III.9

FEDERAL LEGISLATIVE DEVELOPMENTS SINCE TMI

This Appendix outlines the major executive initiatives undertaken by President Carter since the accident at Three Mile Island and the NRC appropriations bill proposed in Congress for fiscal year 1980.

ESTABLISHMENT OF FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

On March 31, 1979, President Carter activated the Federal Emergency Management Agency (FEMA), which was established under Section 304 of Reorganization Plan No. 3 of 1978. By Executive Order 12127, he transferred to FEMA functions from the Department of Commerce and the Department of Housing and Urban Develo ment and delegated some of his own powe . hese functions concerned fire prevention and control, operation of the Emergency Broadcast System, flood disaster protection, and disaster insurance. On July 20, 1979, the President signed Executive Order 12148, which transferred additional functions to FEMA. These functions had been vested in the President, and were previously delegated to the Federal Disaster Assistance Administration in HUD, the Federal Preparedness Agency in GSA, and the Defense Civil Preparedness Agency in DOD. They also included tasks performed by the White House Office of Science and Technology Policy regarding the reduction of earthquake hazards across the country. On December 7, 1979, the President further charged FEMA with lead responsibility for radiological emergency planning and a number of other related specific tasks in his "Response to the Recommendations of the President's Commission on the Accident at Three Mile Island." Thus, since TMI, there has been a consolidation of Federal functions regarding emergency response to disasters, including response to radiological hazards from nuclear powerplants. In Executive Order 12148, the President specified certain policies that FEMA must follow in executing these functions. The Order provides in pertinent part:

2-2. Implementation.

2-201. In executing the functions under this Order, the Director shall develop policies which provide that all civil defense and civil emergency functions, resources, and systems of executive agencies are:
(a) founded on the use of existing organizations, resources, and systems to the maximum extent practicable;
(b) integrated effectively with organizations, resources, and programs of State and local governments, the private sector and volunteer organizations; and
(c) developed, tested and utilized to prepare for, mitigate, respond to and recover from the effects on the population of all forms of emergencies.

2-202. Assignments of civil emergency functions shall, whenever possible, be based on extensions (under emergency conditions) of the regular mission of the Executive agencies.

2-203. For purposes of this Order "civil emergency" means any accidental, natural, man-caused or wartime emergency or threat thereof, which causes or may cause substantial injury or harm to the population or substantial damage to or loss of property.

2-204. In order that civil defense planning continues to be fully compatible with the Nation's overall strategic policy, and in order to maintain an effective link between strategic nuclear planning and nuclear attack preparedness planning, the development of civil defense policies and programs by the Director of the Federal Emergency Management Agency shall be subject to oversight by the Secretary of Defense and the National Security Council.

2-205. To the extent authorized by law and within available resources, the Secretary of Defense shall provide the Director of the Federal Emergency Management Agency with support for civil defense programs in the areas of program development and administration, technical support, research, communications, transportation, intelligence, and emergency operations.

2-208. All Executive agencies shall cooperate with and assist the Director in the performance of his functions.

The FY 1980 NRC Appropriations Bill (S 562)

The NRC's appropriations bill for fiscal year 1980 was pending before Congress as of October 30, 1979. The Senate bill under consideration (S. 562) contains a number of provisions aimed at improving the NRC and the overall Federal response to emergencies at nuclear powerplants. (Of course, these provisions could be changed significantly before the bill is enacted.) Some of these provisions have particular applicability to coordinated Federal planning:

- Section 202(a) of S. 562 provides that the applicant for a "utilization facility" (a nuclear powerplant) operating license shall furnish the NRC with the emergency plan of the State in which the facility is sited, and that no license shall be issued unless the NRC is satisfied that the plan adequately protects public health and safety.
- Section 202(b) provides that States in which a utilization facility has already been licensed to operate, but which has not obtained NRC concurrence on an emergency plan, must submit such a plan to the NRC and to FEMA. The NRC, in consultation with FEMA, must review the plan for compliance with those NRC guidelines in effect on July 16, 1979. If NRC concurrence is not obtained by June 1, 1980, the NRC shall order such facilities to terminate operations until a satisfactory plan is submitted.
- Section 202(c) requires that the NRC promulgate, within 6 months of enactment of the appropriation bill, minimum requirements for State emergency plans and define a period for expeditious compliance. It provides that the NRC must consult with FEMA in formulating these requirements.
- Section 202(d) provides that the NRC requirements formulated under section 202(c) shall:

> Assure protection of the public health and safety to the maximum extent practicable, and shall at a minimum provide for:
>
> (1) Designation of appropriate planning zones surrounding each facility on the basis of such factors as reactor size, probable release patterns from possible accident sequences, and demographic and land use patterns;
> (2) capability to quickly and safely implement protective measures such as evacuation and sheltering;
> (3) initial and periodic testing of plan feasibility in actual drill of State and local organizations which are assigned responsibility to carry out portions of the plan;
> (4) vesting of responsibility for the development and revision of the plan in a single agency;
> (5) participation of facility licensees, local governments, and appropriate State agencies in that development and revision;
> (6) delineation of respective organizational roles in implementation of the plan; and
> (7) identification of procedures for expeditious and reliable notification and communication.

Section 203 requires the NRC to promulgate by rule, within 6 months of enactment of the appropriations bill, an emergency plan for agency response to an extraordinary nuclear occurrence. The plan must provide, at a minimum, "effective and expeditious procedures" for:

> (1) notification by the licensee of any event or sequence of events at such a facility which may significantly increase the likelihood of such an occurrence;
> (2) determination of the existence of such an event, sequence of events, or occurrence;
> (3) representation at the facility site vested with the authority to act on behalf of the Commission;
> (4) communication among Commission headquarters, the Commission regional office, Commission representatives at the facility site, the Governor of the State of situs and other appropriate State officials, and senior management officers and operator personnel of the licensee;
> (5) comprehensive and definitive monitoring of radiation levels within the boundaries of the facility site;
> (6) function of the Chairman as spokesman for the Commission in accordance with Section 201(a)(1) of the Energy Reorganization Act of 1974, as amended;
> (7) making recommendations on evacuation; and
> (8) acquiring facility design and construction information, equipment, and technical expertise.

It requires further that,

> In the promulgation required hereunder, the Commission shall specifically determine which procedures shall be implemented by majority vote of the Commission, and which shall be implemented through delegation of authority.

Section 204 adds a subsection (q) to Section 170 of the Atomic Energy Act of 1954, as amended:

> q. Within 120 days of the date of enactment of this subsection, the President shall prepare and publish a National Contingency Plan to provide for expeditious, efficient, and coordinated action to protect the public health and safety in case of an extraordinary nuclear occurrence, or an event or sequence of events which significantly increases the likelihood thereof, at a utilization facility licensed under section 103 or 104b. Such Plan shall include, but not be limited to —
>
> (1) designation of an interagency task force, including but not limited to the Federal Emergency Management Agency, which shall be the lead agency, the Commission, the Environmental Protection Agency, the Department of Health, Education, and Welfare, the Department of Defense, and the Department of Energy, and consisting of personnel who are trained, prepared, and available to provide necessary services to carry out the plan;
> (2) assignment of duties and responsibilities among Federal departments and agencies: Provided, however, that the Environmental Protection Agency shall have the responsibility for radiation monitoring outside the boundaries of the facility;
> (3) identification of an official of the lead agency as task force coordinator at the facility site;
> (4) establishment of a national center to provide coordination and direction in Plan implementation; and
> (5) identification, procurement, maintenance and storage of equipment and supplies.
>
> The President shall incorporate in the Plan required hereunder the provisions of the plan of the Nuclear Regulatory Commission promulgated pursuant to section 203 of the Nuclear Regulatory Commission Authorization Act for Fiscal Year 1980. To the maximum extent possible, the Federal response to an extraordinary nuclear occurrence, or to an event or sequence of events which significantly increases the likelihood thereof, at a utilization facility licensed under section 103 or 104b shall conform to the Plan promulgated hereunder. The President may periodically revise such Plan.

IV SAFETY MANAGEMENT FACTORS GERMANE TO THE NUCLEAR REACTOR ACCIDENT AT THREE MILE ISLAND, MARCH 28, 1979 BY C. O. MILLER, SYSTEM SAFETY, INC.

1. INTRODUCTION

a. Basic Nature of the Accident

Little doubt remains about the principal facts surrounding the events at Three Mile Island (TMI) beginning during the early morning hours of March 28, 1979. In retrospect, they appear relatively simple.

A transient to the system during a routine maintenance function led to automatic shutdown of the reactor. A malfunctioning valve interrupted the normal process of residual heat dissipation and created a small loss of coolant accident (LOCA). Inadequate control room design and personnel training coupled with poor procedures precluded timely and proper diagnosis of the problem. Indeed, the accident would not have occurred, except that inappropriate shutdown of the emergency core cooling system had been performed.

The reactor was ultimately brought under control, but not before the accident caused a justifiably perceived threat to thousands of people. Also, the public developed a justifiable disillusionment with agencies responsible for nuclear power reactor safety, including the NRC, which was criticized for its attitude toward nuclear safety.[1] Not only was the handling of the emergency ad hoc, at best, but precursor events—clear warnings that TMI could occur—were readily found during the many investigations of the accident.

Several relatively new aspects concerning accidents, at least as compared on the surface with other kinds of accidents, are notable. For example, this was an accident that was not over quickly. Unlike the crash of a jetliner or even the sometimes protracted devastation of an earthquake, the development, recognition, and control of the TMI hazard took days, not hours. Emergency actions, let alone investigative actions, required the combined talents of countless people in virtually all segments of government and the nuclear industry.

A new accident factor, "severe mental stress," was imposed upon the public, a factor at least highlighted if not identified for the first time as a damage criterion against which an accident would actually be defined.[2] Usually, for investigative purposes, an accident requires some minimum level of physical damage to persons or property; otherwise, the event is referred to as an incident, mishap, or some other relatively mundane term.[3]

A nuclear powerplant represents a unique breed of potential manmade disasters combining the worst effects of facility hazards, "Act of God" environmental disturbances, and disease. Coupled with a general lack of understanding by the public of the nature and limits of errant nuclear energy as found in power reactors, the challenge to those in a position to prevent such potential disasters is profound.

b. Safety Management as an Accident Cause Factor

Commentators in some of the earliest accident prevention texts have expressed the view that all accidents, no matter how minor, are the fault of organization.[4] They were not referring to organization in the literal sense of simple division of work as illustrated by a pyramid shaped chart; rather, they were speaking of the totality of management, the influence and responsibility of those in authority. In this vein, and for purposes of this study, safety management is considered to be the integration of skills and resources specifically organized to achieve a goal of accident prevention along with all other required management objectives. This is analogous to similar logical classifications of management specialization such as fiscal management, schedule management, personnel management, and so forth.

Figure IV-1 further illustrates this precept in modern terms. It reveals management in the dominant role controlling the traditional interacting man, machine, and medium (or environment) safety factors; the organization's mission is the central target or objective.[5,6] This concept could be broadened to include cost and schedule ramifications and reflects management's overall continuing fundamental challenge: To balance the troika of performance (in this case safety performance), cost, and schedule.

Figure IV-1 thus becomes a pattern that safety management can follow in accidents, whether in their prevention or their investigation. That is, when analyzing a safety problem either before or after the fact, the variables shown here, and their relationships, should be examined.

Figure IV-1 also is implicit in the precept of "system safety," which is defined as: "The optimum degree of safety within the constraints of operational effectiveness, time, and cost attained through the specific application of system safety management and engineering principles whereby hazards are identified and risk minimized throughout all phases of the system life cycle."[7]

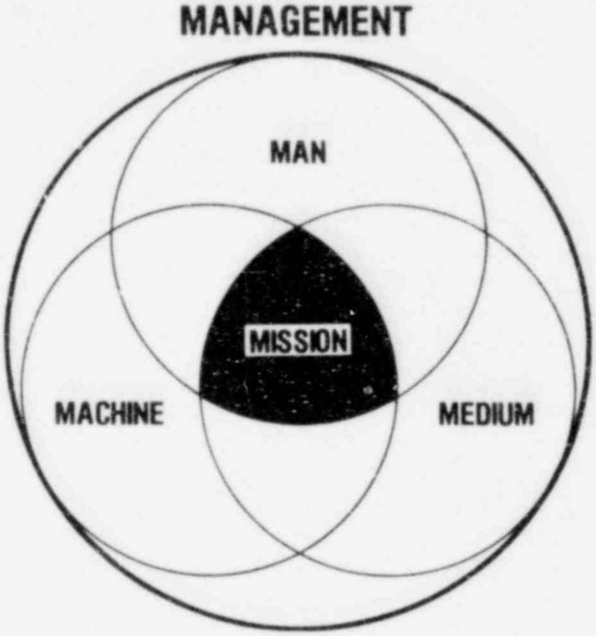


FIGURE IV-1. System Safety Factors

This is a doctrine exercised extensively by the Department of Defense and the National Aeronautics and Space Administration.[7-9] Segments of the Department of Energy, some agencies of the Department of Transportation, and the Consumer Product Safety Commission have also embraced the concept of system safety in recent years. It forms the point of reference for much of the analysis contained in this report although system safety terminology and many of its provisions are foreign to the operation of the Nuclear Regulatory Commission and other segments of the nuclear energy system.

c. Scope of the Report

As indicated in the title, Section IV analyzes safety management factors germane to the TMI accident. It includes a major part of the system safety process noted above and examines, specifically, six areas:

- *Statutory Considerations*—Those background factors associated with the NRC's enabling legislation which influenced NRC's approach to safety management;
- *NRC Safety Policy*—The presence of policies (express, implied or, in fact, absent), which governed NRC's safety mission;
- *Planning*—The scope and effect of various safety plans on NRC's effectiveness;
- *Requirements and Enforcement*—Again, scope and effect from the management viewpoint;
- *Safety Tasks*—The division of work necessary in an effective safety program in addition to the

concept that safety is implicit in the job of everyone associated with nuclear power generation;

- *Organization*—The assembly of tasks and people in a configuration providing efficient and effective accident prevention.

This analysis does not dwell on the details of the TMI accident itself since this is chronicled in numerous other studies.[1,10-17] Nor does this analysis examine safety management performance typified in the NRC by the Office of Nuclear Material Safety and Safeguards, whose activities were not directly applicable to the TMI event. Other agencies such as the Government Accounting Office have provided or are performing such studies.[18] Finally, time constraints have precluded detailed examination of safety management factors as practiced in the industry itself (utilities and vendors), although there is strong evidence that concepts of safety management followed by the NRC have been mirrored by industry.

d. The Positive Side

Like any postaccident analysis, this report highlights shortcomings in an attempt to concentrate on those factors about which something practical can be done to prevent future accidents. As such, the reader is cautioned to remember the overall performance of those charged with the development and operation of commercial nuclear reactors thus far. The record has been perfect in terms of absence of fatal injury or even personal injury in the conventional sense of the term. Also, it can be shown that the NRC safety management deficiencies as described herein are also present in many contemporary industries and have only recently been appreciated and attacked by some of them.

Furthermore, the reader should not underestimate the value of the existing comprehensive nuclear regulatory requirements that safeguard the public's health and safety today. Remember too the exceptional level of professional competence found generally within the NRC, which must function in one of the highest technologies imaginable, and the extremely complex sociolegal environment that brings a lot of pressure to bear on the regulatory process as the price we pay for direct public participation in decisions, pressure that ensures considerable visibility of the regulatory process.

The results of the U.S. nuclear power reactor effort to date have been good. As TMI has shown, however, good is not enough. The public will not tolerate any performance that reveals, under scrutiny, the absence of reasonable application of state-of-the-art techniques to prevent accidents. Such techniques include not only technology peculiar to nuclear power generation but also techniques of a more general nature, such as safety management.

e. Perspective of the Author

This study has been prepared as part of a contract with the NRC[19] in connection with the NRC-TMI Special Inquiry Group, or SIG (otherwise known as the Rogovin Investigation), ordered by the Commission.[20] Complete freedom of expression has been encouraged in the writing of the report, and personnel contacted during the study have been exceedingly candid and cooperative in providing information and documentation. Records, including depositions, interviews, and material cited as references, are available to the public.

Most of the work products of the Special Inquiry Group have been subjected to various forms of peer review. A basic commitment given to the peer review groups has been that differences of view may not always be resolvable and that they will be reflected in the reports insofar as practical. This same approach has been followed in discussions with NRC personnel and in preparing this report, which was exclusively the work of the author.

Prior to this undertaking, the author had no association with the Nuclear Regulatory Commission or the nuclear industry. His education includes an undergraduate degree in aeronautical engineering and a graduate degree in systems management. He is a graduate of the Federal Executive Institute, and will be completing his studies towards a law degree in May 1980.

The author has held senior safety engineering and management positions in the aerospace industry for over a quarter of a century and in the university environment and the Federal service, the latter as Director of the Bureau of Aviation Safety of the National Transportation Safety Board from 1968 to 1974. He is an acknowledged pioneer in the system safety discipline and has been employed as a consultant to DoD in the development of the 1969 System Safety Program Requirements Standard (MIL-STD-882A); to NASA as a safety management consultant after the Apollo fire at Cape Kennedy; to the Urban Mass Transit Authority as a safety management lecturer in their courses at the Transportation Safety Institute; and to the National Safety Council and the American Society of Safety Engineers in their initial incorporation of system safety techniques into training of personnel in the industrial safety field.

Thus the author's perspective in preparing this report has been one of unfettered inquiry involving a relatively foreign technical field. However, based upon past experiences with fields equally foreign at the time, common problems arise when it comes to preventing accidents.

2. STATUTORY CONSIDERATIONS

For all members of the nuclear power community and for the NRC in particular, fundamental authorities and limitations for nuclear safety management are found in the Federal statutes. These involve principally the Atomic Energy Act of 1954[21] and the Energy Reorganization Act of 1974.[22] Interpretations by administrative fiat and court decision may amplify the statutes, but the foundation of nuclear safety rests on the legislation. If that foundation is inadequate to support effective safety management, revisions of the law should be considered.

a. Safety Objectives

The Act of 1954 was passed at a time when attention was focused on the catastrophic nature of accidental detonation of atomic weapons or their use against us by an enemy. As a byproduct of atomic weapons research or simply previous technology related principally to the medical field, radiation hazards to people were also appreciated reasonably well. Accordingly, and without surprise, the Act of 1954 cited safety objectives only in terms of "common defense and security [and] adequate protection to the health and safety of the public."

Significantly, there was little association of safety with the protection of property or other related resources, and what is stated under the Act of 1954 is obscure, seemingly related to facilities used in the conduct of defense and security activities.[23] Clearly, personnel deposed and interviewed during this study did not view safety as related to the protection of nuclear powerplant facilities themselves.

Also, there was no identification of safety whatsoever as a necessary predicate to mission accomplishment, as compared with military policies related to aviation safety beginning in the early 1950s.[24]

The AEC approach to safety was not changed by the Act of 1974. Accordingly, a strict interpretation of the NRC's statutory base suggests little room for considering economic or other factors, which are necessary for a viable nuclear power capability in the U.S., if they come into conflict with the "adequate protection to the health and safety" requirement. However, a recent position paper by the NRC General Counsel states that such a narrow interpretation is not correct and that, "adequate protection" is a term that focuses on radiological risk and that it is not synonymous with "public interest."[25] Thus the Commission may be at liberty in its deliberations to balance safety against competing considerations.

The fact remains, however, that confusion reigns as to what interpretation should be given to the statutory meaning of nuclear safety now, in 1979, as opposed to when the law was initially written a quarter of a century ago. The law appears to adopt the abstract dictionary meaning of absolute freedom from harm as applicable only to human beings. Contrast this with more modern interpretations found in current state-of-the-art safety technology such as:

- Safety (defined)—"Freedom from those conditions that can cause death, injury, occupational illness, *or damage to or loss of equipment or property.*"[7]
- System Safety Program Objective—"to minimize loss of personnel and material resources through mishaps and to *preserve* the combat *capability* of the Air Force . . . ." (Emphasis added.)[26]

That this precept is important within the nuclear power industry is evident by the concern control room operators have to "save the shutdown" wherever they can in the event of a transient. It is estimated that it costs a utility between $200 000 and $300 000 a day every time it has to shut down its nuclear power producing capability.

Acknowledging the effects of accidental losses on resources and the possible effects of accidental loss on mission leads to much greater motivation for safety throughout any organization than does concern with personal injury or death alone.

Finally, the statutes appear to treat safety as a competitor to development of a viable national nuclear power capability, whereas the impact of TMI shows clearly that without a reasonable degree of safety there would be no nuclear power mission to accomplish; indeed, there would be no nuclear powerplants. The statutes avoid the real world meaning of safety that entails management of risk; the trading off of time and cost with hazards defined vectorially in terms of their probability and severity.

b. Regulatory Role of the NRC

The principal purpose of the Act of 1974 was to separate the nuclear regulatory function from the promotional function. A review of the legislative history suggests that much of the thinking during development of the legislation was toward establishing a licensing agency as opposed to a regulatory agency,[27] distinguishable in that licensing is only a process by which permission is granted for a party to perform some desired function, while regulation, on the other hand, has broader meaning. Regulation entails a prescription of rules of order by a superior or competent authority relating to actions of those under its control.[28] It suggests a stronger technological leadership role than would a simple administrative licensing function. It accounts for a perception by the public of the NRC's national safety accountability; the public believes, and rightly so, that the center of nuclear power expertise within the Federal establishment is the NRC.

Unfortunately, the evolution from AEC to NRC had some counterproductive side effects.

1. Some of the staff who were licensing oriented never realized their broader responsibilities. The regulatory process was overwhelmingly geared to approval of licensing applications rather than control through other means as well.
2. Development of nuclear technologies was left initially to the Energy Research and Development Administration, although the NRC was given a research function to support its localized process of developing standards. This resulted in an organizational separation rather than necessary integration of basic and applied research needs. Not until 1977 did Congress expand the NRC research responsibility to include research in advanced concepts, systems, and processes with the potential for improving nuclear safety.[29] Of course, it will take some time before the results of this action become effective.
3. Closely related to the above, at least two safety efforts which could have impacted on TMI became lost in the transition from AEC to NRC. One was the growing awareness of the deficiencies in application of human factors engineering principles to control room design, as typified by Swain's study of the Zion plant near Chicago.[30] Although this work was done in 1974 and 1975, there was an absence of meaningful followup, which can at least be ascribed partially to the organizational change.

   The second was the development of the MORT concept,[31-47] a safety management program begun in 1972 under the AEC, adopted and amplified in 1975 by ERDA, alive and well in DOE today, yet unheard of by all but a few Inspection and Enforcement (IE) personnel within the NRC. This loss of continuity in applying modern concepts was particularly distressing in that MORT was an excellent example of technology transfer from other fields (in this case the aerospace industry) that can often prove very valuable.
4. In an attempt to adhere strictly to the separation of safety regulation from promotion of nuclear energy, the NRC and ERDA seemed to become isolated from one another, each carefully restricting its activity so that each would not be contaminated by the actions of the other. Coordination meetings do occur between the NRC and the components of the DOE formerly grouped under ERDA, but these meetings are primarily for coordination regarding facility use, emergency planning, and similar administrative matters. It can be argued that ERDA had a mandate to educate the public about the realities of nuclear power in the interest of promoting nuclear energy. It chose not to, and the NRC seemed afraid to—at least until TMI. For reasons described earlier regarding the role of safety in mission accomplishment, this entire division of activities was not only illogical but was never really believed by the public. Post-TMI criticism of the NRC's relationship with industry is mute testimony to the truth of that point.

Perhaps the most serious deficiency in the statutory heritage of the NRC is the failure of Congress to realize the true relation between regulatory process and achievable safety. This problem is not unique to nuclear energy; it was pointedly discussed recently at the GAO Conference of Transportation Issues of the 1980s by Gerard Bruggink of the National Transportation Safety Board.[48] In his remarks, he stated:

> The fact of the matter is that any regulatory or standard-setting activity is only part of the safety equation. Regulations and standards—even when they are sound—are no more than abstractions. They can only aim at a certain level of quality in design, manufacturing, maintenance, and operations. The achievement of the safety level intended by rules and standards depends on the recipients' ability and willingness to satisfy regulatory intent. Since the ability and willingness to operate within a regulatory framework are governed by a variety of factors, including the caliber of management, economic pressures, and corporate or individual integrity, we have to allow for corporate and private initiatives in the safety equation. This means that a regulatory agency at best, can only set a potential safety level; the actual safety level is determined by the realities of the market place....
>
> The bottomline in safety is the degree of care exercised by individuals. The responsibility for the ability and willingness to exercise the proper degree of care is shared—in a complex and overlapping way—by the regulatory agency, corporate entities, and individual operators. Whenever the balance between these three areas of responsibility is disturbed, we can expect the safety problems reflected in the present upswing of fatal accident rates, because the imbalance brings erosion of individual accountability. Where is the imbalance and what can be done about it?
>
> As I see it, the imbalance lies in the disproportionate share of the safety role attributed to the regulatory agency. There is a growing tendency to transfer to government even those safety responsibilities that are purely corporate or personal in nature. Perhaps, we should expect that in an age that

> encourages self-indulgence and conditions the citizen to look at "Big Brother" for solutions to self-induced problems....

Simply stated, there are many accident prevention tasks that do not conveniently or conventionally fall under the regulatory process, yet are necessary for an effective safety program. These will be further discussed later.

c. Mandatory Organization at the NRC

Studies both prior to and immediately after TMI have been critical of the decisionmaking process followed by the NRC.[1,18,49] Particular damnations have been aimed at the role of the Commissioners in juxtaposition with the Executive Director for Operations (EDO) and the major offices: Nuclear Reactor Regulation (NRR), Nuclear Regulatory Research (RES), Nuclear Material Safety and Safeguards (NMSS), Inspection and Enforcement (IE), and Standards Development (OSD). Accusations have been leveled regarding lack of leadership, indefinite policies, and policies created by staff and simply endorsed by higher management. "End run" communications were alternately encouraged too much or too little. Authority of the five Commissioners has been described as "20% each," despite a 1975 amendment to the Act of 1974 vesting chief executive authority in the Chairman.[50]

What seems to have been forgotten, however, was the mandating in the Act of 1974 by Congress of specific organizational concepts to be applied within the NRC, namely:

- The equal status of each Commissioner without any specified qualifications for appointment;
- The specific delineation of three of the offices (the NRR, RES, and NMSS), as well as EDO;
- A specific prohibition on any EDO attempts to inhibit Office Directors from communicating directly with the Commissioners except that the EDO can require that the Office Directors keep the EDO informed of such communications, this despite EDO's assigned responsibility of coordinating the activity within Offices.

Further, no clear-cut description was made in the statute of the Commission's role as a group. Were they a collegial body, an advisory body, an adjudicative panel, a committee form of decisionmaking? Were they to function by majority rule, by consensus, by individual influence upon senior staff offices? Were they to convey all of their desires, by whatever method such desires were determined, through the EDO to the various offices? Were they to take charge in times of emergency and, if so, as a group or by other arrangement?

Unfortunately, the Act of 1974 really did not speak to these questions. It seemed to recognize the need to ensure conveyance of information from the highly qualified technical staff to the Commissioners, who may or may not possess understanding of the nuclear power system. However, in doing so, the Act laid the foundation for organizational discipline confusion, especially when considering the doctrine of equality among Commissioners.

3. NRC SAFETY POLICY

Notwithstanding statutory considerations providing the foundation for NRC activities, the NRC—like any Federal agency—is obliged to develop operating policies on its own. Legislation can only provide the necessary authorities and the bounds within which the agency must function. Indeed, if the statutory base is unduly restrictive in terms of either scope of activities or authorities, it is obligatory for the agency to initiate requests for corrective legislation. Thus, blame for operating problems originating in the statutes does not shift entirely to the Congress unless it can be shown that the NRC attempted and was thwarted in the proposing of new laws. No record of this having happened with regard to the above questions has been found.

Safety policy as generated from within the NRC is the integrated result of countless documents. This fact in itself suggests a fundamental problem. Nevertheless, two particular documents are worthy of attention. The first is the collection of rules and regulations published under Title 10, Chapter 1, Code of Federal Regulations—Energy. Part 50 is entitled, "Domestic Licensing of Production and Utilization Facilities," and includes not only administrative processes implicit in licensing, but also definitions, technical specifications, and certain safety engineering and management criteria which effectively define the modus operandi of the NRC. Also included is an "Interim General Statement of Policy" entitled, "Protection Against Accidents in Nuclear Power Reactors," published on August 27, 1974.

Part 100, "Reactor Site Criteria," of the regulations is complementary to Part 50, particularly in providing for a last line of defense in the hardware for accidents which are not prevented through safety engineering of individual systems. Evacuation of the area, sheltering, and medicinal prophylaxis are other defenses to the effects of radiation; however, their social impact is severe and relatively uncontrollable by the NRC alone.

A second major source of safety policy, much less known than 10 C.F.R. 50 or 100, at least outside of the NRC, is a report published in draft form in July, 1973, "The Safety of Nuclear Power Reactors and Related Facilities." WASH 1250.[51] This report was the nearest thing to a single document text combining safety philosophy and basic knowledge about nuclear power reactors found during this study.

What comes through from these documents is a technology that is very highly oriented to engineering and science, as opposed to people or management orientation, in the effort to achieve accident prevention. Licensing rather than regulation prevails, in the broad sense discussed earlier in Subsection 2.b. above. Although no one is promising a risk free system, assessment of risk seems to be so highly emphasized that contr of risk, i.e., safety assurance, becomes obscured.[52] More effort seems to be present in assessing probabilities and meeting some quantitative goal (admittedly hard to define) than in examining alternative, practical solutions. Finally, safety is recognized as being implicit in every activity of the NRC, yet there seems to be no recognition o an overall NRC safety policy that integrates effo ts of all segments of the organization, especiall on a timeline basis.

These an other fundamental policy considerations are a nplified in this and subsequent sections of the report.

a. Safety Objectives

The statutorily defined objectives for "health and safety" have given rise to a three level design approach. First, "nuclear power plants are required to be designed and constructed with a high degree of reliability." Second, provisions must be present, "to forestall or cope with incidents and malfunctions that could occur notwithstanding the assurance offered by careful plant design." Third, "safety systems are required to be installed to control all [design basis] events".[53]

For example, a particular pump in the primary cooling system must be reliable in itself, then there may be dual power sources available for the pump, and finally an independent engineered safety feature (in this case an emergency core cooling system) would be required in the event the pump or pumps failed to perform their intended function.

In addition to these measures, there is the concept of containment. This applies at least for toxic (radioactive) materials and, insofar as practical, applies to the effects of physical destruction of the facility from thermal energy sources implicit in the development of nuclear power.

What is not apparent from the NRC policy documents, however, is a hierarchy of goals toward which their basic approaches should be applied. Such a list can be found in the introduction to the well-known text, "The Technology of Nuclear Safety,"[54] used at the Massachusetts Institute of Technology during their summer nuclear safety courses. The authors propose that reactor safety should be aimed in such a manner that:

1. There must be no "public safety" accidents;
2. The "Economic Accident" should be prevented;
3. The frequency of the "Industrial Personnel Accident" should be reduced to the lowest possible level;
4. The number of "Operational Problems" should be kept at a minimum.

The need for such a hierarchy is threefold. First, it indicates clearly that economic losses are significant, which extends the objectives stated literally in the NRC's enabling legislation.[55] Thus, it would allow the NRC to join other Federal agencies in realistic appreciation for the total scope of safety in the public interest.

Second, and not so obvious, is the need to appreciate that a continuum of events constitutes the spectrum of hazards that must be examined as an effective safety program. "Operational Problems" can and do lead to "Public Safety Accidents" as a function of the control or lack thereof of intervening forces. Thus, a safety program geared only to the major events is depending upon the fickle laws of chance to gain information of ultimate value in protecting the public.

Finally, the protection of the employees of utility companies and their onsite associates is another safety activity needing integration at the objectives phase. Otherwise, segregated and less efficient safety programs downstream will result.

b. Safety Definitions and Principles

Closely aligned with safety objectives is the matter of clear understanding of safety terms. As noted during the introduction to Section V and in the discussion of "Statutory Considerations," (Subsection 2.a.), even the simplest words such as "accident" or "safety" have profound impact on understanding and managing an effective safety program. The Division of Systems Safety within the NRC is not involved with "system safety" as used by other agencies or defined in professional safety literature. The NRR division is highly oriented toward hardware portions of the whole. "Subsystems," if one were to look at "system" defined by other agencies, comprises: "A composite, at any level of complexity of personnel, materials, tools, equipment facilities, and software ... used together in the intended operational or support environment to perform a given task or achieve a specific ... mission requirement."[7]

Other terms can be similarly confusing. Some, like "transient," have relatively peculiar meanings within the power generation community. Others, like "incidents," have widespread meaning independent of the technology. The result is the same. Any attempt made whatsoever to implement safety programs involving terms such as objectives, requirements, tasks, and so on, beyond the confines of one agency, meets with inhibited communication because of semantic difficulties.

This does not necessarily mean requiring standardization. It means a need for clear delineation of competing terminology in documenting policy or requirements.

A close corollary to the simplified definitions described above is the acknowledgement of certain fundamental principles related to accident prevention[6]. These would include:

1. The abstract nature of safety in that safety really cannot be measured in one application except by comparison to another.
2. Accidents when defined in terms of some damage criterion are rare events; hazards, which are simply accident elements that have not occurred, are common.
3. When approached from an accident prevention viewpoint as distinguished from the seeking fault, all accidents involve multiple cause and effect relationships.

Failure to understand these three factors results in a couple of difficulties. The first is the meaningless attempt to treat accidents as a whole statistically. The second, conversely, is the lack of attention to hazards as a part of the whole because of their low order of probability when considered by themselves.

Other fundamental safety principles will be identified later. The point here is that a safety policy should include reference to those principles accepted by the NRC and that such reference should be made clearly and unequivocally wherever possible.

c. Safety Management Philosophy

"Safety management" as a specific term was unknown or, at best, not appreciated among those individuals deposed or interviewed in connection with this part of the SIG study. For example, the Standard Review Plan does not include the concept,[56] which is illustrative of the fact that no safety management requirements are identified as such. This does not mean, however, that firm and well expressed views are not present on the need to manage the NRC in attempts to achieve a high level of nuclear power safety in the public interest. The problem has been that the division of work among NRC personnel did not reflect any approach except that safety tasks are implicit in everybody's job. Effective safety management, however, requires meaningful integration of safety tasks, particularly if they flow across organizational lines. These tasks will be further identified and discussed under Subsection 6, "Safety Tasks."

Review of safety policy documents 10 C.F.R. 50 and 100 and WASH 1250 fail to show safety management attention to anything other than engineering activities, with one notable exception. Appendix B of 10 C.F.R. 50 (and associated Reg Guides and Standard Review Plan Requirements) discusses Quality Assurance programs wherein certain traditional safety oriented quality assurance organization and operational management characteristics are required. Unfortunately however they seem to enter, or at least are reviewed, relatively far downstream in the nuclear powerplant development and use cycle. Similarly, design quality assurance and review seem to be a function more of the integrity of the vendor than of the expertise of the utility or the oversight conducted by the NRC.

Critical by their absence in the NRC's safety management approach are six items usually identified with the system safety process exercised by DoD and others listed earlier.

1. A clear statement of a goal as being "the highest possible degree of safety consistent with various requirements and cost effectiveness."[8]
2. The scope of the system to which the NRC safety management requirements are to be applied. In the past this has been severely limited, usually to the utility alone, which in turn is expected to impose comparable requirements upon its vendors.
3. Life cycle attention paid to the implementation of the NRC's requirements. Not only has adherence to progress been evaluated only at very few discrete points during the plant's life history (at construction and operating license issuance) but also no planned program exists to monitor and evaluate fully and systematically what goes on later throughout the plant's operational life except through routine, relatively narrow inspections.
4. Separate identification of a safety function; that is, clear application of generalized safety technology within the organization applied in those areas that demand high levels of objectivity even though safety is part of everyone's obligation. These

would include, at the very least, accident and incident investigation, safety planning, and safety performance evaluation.

5. Creation of an atmosphere—an attitude—that safety is a positive contributor, not a constraint, to a viable nuclear power capability in the United States.
6. Reliability engineering and quality assurance distinguished from safety engineering and management. The main differences in approach between these two are the technology to be applied and the infusion of the human variable into the imprecise and complicated effectiveness equation.

System safety was once characterized by Elwood Driver, Vice Chairman of the National Transportation Safety Board as the "systematic application of the safety art."[57] The NRC's safety management philosophy has not been systematic nor does it appear to have thus far recognized the existence of artful approaches that might supplement the relatively rigid engineering, scientific, and licensing methods used to date.

d. Safety Responsibility

A recurring issue encountered during this study was the question of who had the responsibility for safety at TMI. Was it the NRC? The utility? The vendor? Congress? Was it the designer? The operator? The supervisors?

In a letter to Congressman Udall in 1978, Chairman Hendrie expressed the view that the Energy Reorganization Act of 1974 placed "full responsibility for nuclear safety within the Nuclear Regulatory Commission."[58] However, WASH 1250 states: "The safe design, construction and operation of each commercial nuclear plant is the direct responsibility of the owner/operator over the life of the plant".[51]

Acceptance of this responsibility for TMI was a routine matter in the Preliminary Safety Analysis Report (PSAR) wherein the utility stated that, "Met Ed will be fully responsible for engineering, design, construction, operation and maintenance of the facility."[59]

Interestingly enough, the Final Safety Analysis Report (FSAR) modified the above to read: "Met Ed is responsible for the design, engineering, construction, testing, startup and safety operation [of TMI-2]."[60]

Note the absence of the word "fully" in the FSAR. Was this simply an editorial change? Was it a phraseology suggested by Met Ed's legal counsel? Investigation failed to review the precise reason but it is probably academic anyway in the face of modern management theory about responsibility.

It is difficult at best to have responsibility for something over which one has no control. For this reason it is much more logical to approach the subject on a division-of-work basis. What management really does is:

1. Assign a task,
2. Provide authority (and presumably resources) to accomplish the task, and
3. Create additional accountability for the success of the task.

This means that if, in the final analysis, the task is not successful, the manager, as delegator, is held as accountable for the failure as the delegatee.

This is just another way of saying that responsibility is never delegated, only tasks and authorities. The confusion arises when questions connoting blame are asked, and more often than not the senior man aboard usually takes the brunt of the criticism.

When the question applies to safety, however, it is much more productive to think in positive terms: Who is in the best position to prevent recurrences of the accident in question?

Then, because of the principle of multiple cause and effect relationships, the responsibility must become shared. That is, if a given accident has numerous causal factors—and they all do—it follows that multiple sources are capable of providing remedial action. Hence, all are responsible, collectively, for the accident.

It should be remembered, however, that there is a timing dimension to all this. For example, at a given moment, such as immediately after an emergency shutdown of a reactor, only the utility is in a position to be responsible or accountable for safety because the matter must be handled right away. But, if one looks at total responsibility for events leading to the shutdown, total events during the shutdown, and total consequences thereafter, accountability (which was once responsibility) depends upon who was assigned what task, what authority was present, and what performance occurred.

This same precept applies whether accountability becomes a question between the NRC and a utility, between offices within the NRC, or between individuals. The highly successful Navy system credited to Admiral Rickover leans heavily on the personal accountability doctrine in true command responsibility format. Quite often this doctrine looks with undisguised distain on sociological and institutional factors present in the civilian free enterprise nuclear power system.[61] Nevertheless, the doctrine's adherents are careful not to look in a single direction when something goes wrong.

e. Organizational Discipline

Any safety management policy and its implementation is only as good as the organizational principles followed in day-to-day operations. An analysis of this in relation to the NRC is made further on (in Subsection g., below). However, one aspect is reviewed here because of its fundamental nature as a matter of NRC policy.

Management of complex endeavors over the past two to three decades has recognized the necessity of the project manager concept. Not that the staff advisory function is not also needed to complement the basic project manager's line or decision task, but someone must be in control. Decision lines of authority must be visible, but they must also be subject to challenge if need be by technical experts whose prime interest does not encompass cost or schedule considerations.

The result has been a matrix system of management whereby project managers are looked upon as the decisionmakers and as heads of a team comprising technical and administrative experts from functional areas on as needed basis. The functional managers, who usually report to the same level as do the project managers, then become the check and balance force.

The other, frankly outmoded, approach is that used by the NRC, a system in which project managers are only coordinators and recordkeepers.[62] It was not always that way. As recently as 1971-1972, project managers ran their own shows. However, as technology came to the NRC in vast quantities of highly skilled engineering and scientific personnel, the "functional groups took over the whip hand," and they have it today.[63]

Since it is beyond the capability of one person to handle ultimately the myriad of projects within the NRC's purview, a key question arises. Should supervisory substructure be established within a functional organization or within a project area, and who has primary decision accountability? Modern project management theory suggests that to delegate the decision task to the functional party opens the door to decisions being made on narrow technical grounds without consideration of the full scope of issues. Conversely, of course, a project manager can fail miserably if he does not communicate with his technical team members.

The events of TMI-2 seem to suggest that an excessively narrow technical view of potential safety issues was taken. Certain project management functions, such as monitoring and effecting corrective action on precursor events went unattended.

Two observations surrounding the time period in which TMI occurred are particularly illustrative of the ill-effects of an excessively strong technical function. First, an examination of the "unresolved safety issues" in NUREG 510 reveals that all of these issues are strongly engineering or science oriented.[64] None of them are aimed at those institutional problems that have been raised by all parties who have investigated TMI, the kinds of problems faced routinely by project managers, not by coordinators. This is not to deny the importance of the technical safety issues, but it should be pointed out that resolution of those technical problems do not create a safe system in the broad context.

Second was the apparent breakdown in handling the genuine safety concerns encountered by field personnel, as shown in the Creswell memo.[65] This breakdown occurred despite an aggressive NRC policy effort to counter tendencies in this regard.[66] Someone (or, more practically, some office) should be in a position to monitor and direct the NRC effort as necessary regarding a given facility from the day it is conceived until the day it is buried. This system life cycle concept applies well beyond safety ramifications and has been implicit in systems management doctrine for years, especially in DoD.

The point has been proffered that DoD can apply system safety or systems management techniques much easier than they can be applied in civilian, free enterprise endeavors. This is probably true in that selection and control of people is probably easier within the military. Also, it is easier to get a mission requirement accepted in a defense environment than in 50 different states with 50 sets of laws and a relatively uniformed public. Finally, the military is a combined buyer, regulator, and operator of the system, and therefore procurement, testing, and evaluation are much simpler.

Still, in either case, it becomes a matter of effectively bringing all resources together to get a job done. The fact that some of these "resources" are private companies or associates as well as government would not seem to present insurmountable systems problems to life cycle management.

f. Recognition of Human Factors

Analysis of accident causes in any field, simple or complex, reveals the impact of human performance.

Even in highly automated systems, human error can become involved, either in the maintenance area or during operations. Certainly the events at TMI-2 proved this once again.

Significant, therefore, by their absence from any NRC policy statements are any references to the specific role control room operators play in avoiding accidents or mitigating their results, other than "just following procedures." Nothing is found in 10 C.F.R. Part 50, for example, that spells out as a matter of policy the attention to be paid to human components in the system. Similarly, the Standard Format and Control of Safety Analysis Reports (Reg Guide 1.70) has minimal refe·ence to anything concerning "human factors," whether the term is used to identify the discipline related to understanding and controlling human behavior or simply as a generic classification of human input to the system.[67]

As discussed in depth in the Essex Corporation report,[68] the TMI-2 control room was not designed to modern, contemporary standards and did not look beyond the nuclear industry for the state of the art. Also, there were no NRC human factors requirements for the control room or for related training and procedural matters; hence, no one at the NRC reviewed TMI-2 in this regard. These facts serve to illustrate the relation between policy and requirements. The former must be present to induce realistic development of the latter.

Approached differently, resources to be integrated as part of a safety management effort are most often thought of in terms of funds, facilities, and organizations or agencies. Another resource to be managed is the innate skill of individuals in the system. A policy should indicate how such skills will be used and what control philosophy should be imposed upon them.

4. SAFETY PLANNING

One of the fundamental elements of management is planning. To be effective it too must be based on a sound policy and defined objectives. It must also identify all the participants, delineate tasks clearly, provide a realistic time base, and include methods of performance assessment. It should be a dynamic document; that is, it should be subject to change at discrete review intervals. Its effectiveness is not only a function of the thought processes which lead to its construction but also the documentation and communication of the results.

Safety management technology has identified f... types of plans. They range from an overall progra... plan with amplified areas to those which are contingent upon the happening of certain events. This spectrum of management effort in the co... of the NRC and nuclear power safety is discussed below.

a. Accident Prevention Program Plan

In theory there should be an overall national nuclear accident prevention plan. This need was expressed indirectly by a member of the ACRS, who said: "The technological community cannot be separated from the political community or the social environment in establishing a suitable regulatory climate. The public will have to determine through legislative or other political processes how the technological issues will be resolved."[69]

The NRC Lessons Learned Task Force was even more direct when they stated: "What seems to be missing is the common denominator of an articulate and widely noticed national nuclear safety policy,"[70] but added, "with which to bind together the narrow and highly technical licensing requirements."

This latter qualification is unfortunate not only because comprehensive long range planning has been nonexistent in the nuclear safety field but also because what has been done has been "narrow and highly technical." Witness, for example, the scope of 10 C.F.R. 50, Safety Analysis Review requirements.

Since the concept of a national plan is new, according to personnel contacted during the study, its creation would require leadership across legislative and executive lines. This raises the question of a mechanism for such an effort. The Commission would logically be the driving force, but the scope of such a program goes well beyond the NRC's charter. This suggests that a White House or Congressionally sponsored effort that could be part of a much needed broader based national safety policy activity would be required.[71,72]

b. Safety Engineering Plan

Specific safety engineering plans have been identified with military aerospace systems for nearly two decades.[73] Modern requirements as indicated in MIL-STD-882A include such elements as:

- ...tem safety engineering management responsibilities,
- ...em safety organization,
- ...em safety program milestones and reviews,
- System safety requirements,
- Hazard analyses,

- Data requirements,
- Safety testing and demonstrations,
- Training,
- Audit programs.

This typifies a somewhat broader military interpretation of "engineering" than might be encountered in academic circles. The military tends to classify everything done prior to the operations phase as "engineering"; hence a system safety engineering plan delves into matters well beyond the application of knowledge of mathematical or physical sciences.

Of course the NRC has a direct equivalent to this form of planning in the requirements for Safety Analysis Reports. The perspective is somewhat different; that is, licensing rather than planning. However, with relatively minor exceptions, the elements of a military system safety engineering program can be found in the process required by the NRC.

What is different substantively, however, is the lack of an organized framework for the NRC to monitor the work from the earliest design phase through construction and testing. Design safety reviews, for example, are not conducted by the NRC with the regularity or independence characterizing DoD or NASA reviews. Similarly, the Quality Assurance program (Appendix B of 10 C.F.R. 50) underscores the potential licensee's promised efforts, not how NRC wants things done and how it will check for compliance.

c. Operational Safety Plan

This type of plan is complementary to the safety engineering plan in that it details how the operating unit will function once the system has moved beyond past the test and evaluation phases. In the military this is a command responsibility which is carried out at various echelons as required.

The elements cited above from MIL-STD-882 for the engineering phase have their counterparts in the operations phase. The words might change slightly but there are still management organization, program review, hazard analysis, data factors, and other factors to be considered in the field.

In civilian nuclear power reactor activity, the planning function falls logically upon the licensee, with appropriate guidance and requirements from the NRC. Once again, most desired requirements typified by 10 C.F.R. 50 and 100 are present in principle. They do not however reflect an easily identifiable operational safety plan. Nor is there any specific program for periodic review of how these plans are being carried out or updated.

d. Accident-Incident Investigation Plan

An accident-incident investigation is the derivation of facts, conditions, and circumstances concerning an event in an effort to analyze their meanings relative to some predetermined objective. In the safety context, that objective is prevention of future accidents rather than enforcement or punitive measures.

It came as quite a surprise, during this study, to find that virtually no planning for this function existed prior to TMI-2. Emergency response plans existed to be sure, but no procedure or other documentation spoke to authorities, assignments of personnel, techniques, etc., which could be applied to investigation as defined above. The nearest thing to standing investigative capabilities was an Incident Investigation Review Committee[74] that had been instituted after the Brown's Ferry Fire in 1975.[75] However, the committee's functions have never been exercised. This was possibly due to the lack of significant events, but was probably also due to the fact that one staff position, that of Chairman, had been vacant for approximately a year.

As late as several months after the TMI accident, no identified and validated photographs existed of the control room configuration. Certainly none were taken or at least made available to the NRC on March 28, 1979, or during the following critical days. The formal investigation did not begin until April 10, 1979, *two weeks after the accident*. Even the NRC interviews with the key participants, the control room operators, were not conducted until April 6, 1979, and then on a basis of noninterference with their other duties.[76] Although Region I dispatched two investigators with the initial response team, both were assigned duties other than investigation.

This entire subject was addressed indirectly in correspondence in 1977-1978 between Dr. Harold Lewis, then chairman of the committee reviewing the Rasmussen Reactor Safety Study, WASH 1400;[77] the Honorable Morris Udall, House of Representatives; Dr. Stephen Lawroski, Chairman of the ACRS; and Dr. Hendrie, Chairman of the NRC.[52,58,78-81] Dr. Lewis had recommended the creation of a nuclear accident review board. The ultimate outcome was a suggestion in December 1978 by Chairman Hendrie to the ACRS "to set up a suitable subgroup to make a trial review of incidents and occurrences."[78] Progress in this area has not been reported.

Implicit in Dr. Lewis' suggestion was the necessity for extensive accident investigation planning, including criteria for choosing events to be investigated, as well as the other specifics noted earlier.

Additional commentary on this subject will be found in Subsection 6.

e. Emergency Response Plan

This function differs from investigation planning in that it aims at mitigating or otherwise controlling the damage resulting from the accident. It parallels or supplements an investigation plan only in its notification of appropriate parties.

Whereas it can be argued that the NRC has the most basic investigation authority and obligation, the emergency response effort involves numerous other parties, most of them actually located at the site of the accident.

The NRC Incident Response Program provides for detailed notification and assembly of NRC personnel in the event of an incident; however, in addition to its failure to account for the investigatory function except in the enforcement sense,[82] its provisions do not appreciate the differing time frames in which accident or incidents occur. Nor are decisionmaking lines of authority or limits clear in the procedures described in the manual. As is discussed in other sections of the SIG report,[83] the emergency response system failed miserably in terms of command and control of the situation. It is perhaps not surprising then that the companion accident investigation function became lost in the confusion.

f. Planning Life Cycle Considerations

The protracted time period required for developing and licensing a nuclear powerplant (which can take a decade, give or take a couple of years), provides numerous frustrations for effective planning and followup, not the least of which are personnel and state-of-the-art changes. This places all the more importance on the clear documentation of requirements, assumptions, bases for changes, elements of compromise, and the like.

Difficult as it may seem, it is acutely essential to have operational personnel participating during planning at early points of the life cycle. No less important is the need to have engineering personnel present as the planning reaches and proceeds through operational stages. This implies possible support activities, to one degree or another, throughout the life cycle by all of the personnel in the system: representatives of the NRC, the licensee, his vendors, the architect and engineer, perhaps State and local representatives, and so on.

"Life cycle," as such, and its phases have not been a clear matter of record within the NRC. From the Project Manager's Handbook,[84] the following discrete milestones can be derived:

1. Initial meeting, between the potential licensee and NRC;
2. Similar preapplication meetings;
3. Construction permit (CP) application and review (ACRS and public hearings);
4. Post CP meetings during construction;
5. Operating license (OL) application and review;
6. Hot functional tests;
7. Online operations begun.

However, these are not programmed in a manner to indicate conventional systems management phasing such as design concept, detail design, construction and production, test and checkout, operations, and shutdown.[85] NRC's approach seems to imply only two phases, construction and operation, an approach that does not lend the regulatory framework to sufficient control during the critical design efforts, including those at the very early stages. Ad hoc "initial," "preapplication," or "post CP" sessions are no substitute for discrete reviews at a time when costs of changes can be minimized.

It can be argued that because of the unique buyer-seller-regulator relationships in the nuclear power industry, extensive safety planning effort cannot be accomplished without overly aggressive regulatory requirements. Alternatively, standards can be presumably developed and adopted by the private sector in management approaches as well as in technical areas. It is enough to say that experience in DoD suggests that the various forms of system safety plans discussed above have had a highly beneficial coordination and safety motivational effect on all parties. How they come about is immaterial.

g. Legal Interface with System Development

There seems to be a growing concern that the hearing process required by law for licensing is having deleterious side effects in the safety review sense. To be sure the hearings provide a valued opportunity for public input and a forum in which issues can be documented and decided. Nevertheless, practical limits exist on the number of hearings that can be held and the manhours that can be spent in preparing for the sessions and analyzing the results.

As indicated above, more definitive safety planning is probably required. But is such planning to produce a more safety efficient, integrated, and timely program, or will it go the way of Safety Evaluation Review (SER) reports? According to discussion within the Advisory Committee for Reactor Safeguards (ACRS), SERs represent "boilerplate information intended mainly for legal purposes."[86] Similarly, in making reference to the public hearings, one ACRS member said, "the quasi legal approach is lousing up the safety review."[87] There were no dissenters.

The solution would seem to be to provide a system which documents for the record the intent of the working parties: the NRC, the licensee, the vendors, etc. Thereafter, at reasonable, discrete intervals—some possibly coming very early—status reports would be made, public input would be obtained, and adjudicatory decisions rendered as necessary. This is perhaps not too different from procedures followed in recent years except that the safety issues are often lost in a plethora of technical, administrative, and legal detail not comprehendible by many NRC people, let alone members of the public. Providing more visibility to safety planning and resultant program reviews would seem to be beneficial.

A vital corollary to the planning and review functions is the effect of safety decisions on the rate base allowed the utilities as the facility progresses down its life cycle, including the operations phases. If the safety planning is more discrete, the socioeconomic legal issues could more readily be adjudicated in the utility's interest as well as that of the public.

5. REQUIREMENTS AND ENFORCEMENT

a. Basic Philosophy of Requirements

Requirements and their appropriate enforcement are a fundamental part of any management program; within a given organization this program is called "direction of the staff." Between separate agencies such as the NRC and its licensees it is called "regulation."

With the structuring of requirements, as in the accomplishment of any safety oriented task, certain precepts must be understood so that both the regulator and the regulated know where they stand. For example, the Act of 1954 proposed *minimum* safety and security regulations, and the General Design Criteria for Nuclear Power, Appendix A of 10 C.F.R. 50 states:

> These General Design Criteria establish *minimum* requirements for the principal design criteria for water-cooled nuclear power plants similar in design for which construction permits have been issued.... (Emphasis added.)

However, the Appendix goes on to say:

> The General Design criteria are also considered to be generally applicable to other types of nuclear power units and are intended to provide guidance in establishing the principal design criteria for other such units.... [The omission of criteria not yet defined] does not relieve any applicant from considering these matters [important to safety] in the design of a specific facility and satisfying the necessary safety requirements.

Question: Are the requirements issued by the NRC *minimum* requirements or are the licensee and their vendors obligated in the public interest to go beyond the NRC's immediate requirements? The answer to both is probably "yes."

Some agencies, the FAA for example, which has a Congressional mandate to provide adequately for national security and safety in air commerce, publicly proclaim that their standards are minimum standards; aircraft manufacturers and operators as a matter of business choice usually exceed these standards. The DoD uses the absolute "thou shalt do this" approach instead of the FAA's minimum standards approach, which can be stated as, "thou shalt do at least this."

Considering the confusion that seems to prevail at the NRC as to what constitutes adequate protection of the public,[25] undoubtedly confusion exists for the licensees and their vendors. Certainly, if they believe they are obligated just to meet the NRC's standards, they will be continually behind the available state of the art because of the delay needed to develop and issue any requirement. Furthermore, if the NRC does not do its job, as was the case with control room human engineering requirements for TMI, criticism will be heaped upon the licensee and vendor as well as the government.

In terms of legal liability positions of the utilities and vendors, it seems clear that adherence to Federal standards is no appreciable defense and no benefit to them in any action that might arise following a nuclear accident. First, the newness if not the nature of nuclear energy would probably result in the courts' applying strict liability under an "abnormally dangerous" theory.[88] Second, as typified by recent developments in product liability law, the courts generally do not look to the statutes defining technical requirements as a test of state of the art since, as has been the case with the NRC, the language is usually ambiguous.[89] Thus the approach to standards imposed upon the industry should have relatively little impact on their tort liability posture. Of course the Federal Government is excused under the discretionary function exception to the

Federal Tort Claims Act.[90] Accordingly, the choice between minimum or absolute standards turns more on socioeconomic factors than on law, especially when the statutes and administrative rules are ambiguous on the subject.

A strong argument can be made for adoption of a minimum standards approach being preferable in a free enterprise versus State-owned utility system. Only in this manner can the motivation for satisfactory performance, including reasonable advances in the state of the art, be expected, because of the forcing function of competition. Most important of all, however, is to be certain all the players know which game is being played.

b. Scope of Requirements

The preceding discussion notwithstanding, NRC requirements in the engineering technical areas are generally comprehensive and well documented in 10 C.F.R. 50, the Reg Guides, and the Standard Review Plans. They are, however, only "performance and reliability" oriented.[91] That is, performance is specified through the use of acceptance criteria "for a set of design basis events... [and] reliability, in its broadest sense, is specified through a set of overall requirements in the General Design Criteria that address quality assurance, seismic and natural phenomena...." There appear to be no design process specifications such as requirements for a human factors engineering program effort or, as will be described more in Subsection 6, no life cycle approach to hazard analysis. These are analogous to some of the Quality Assurance Program requirements, but applied to the design process not to manufacture, construction, or operation.

The virtual lack of the human factors or personnel subsystem requirements during design was the most glaring inadequacy within the scope of the NRC requirements. This is especially true in view of studies, some of which were done by the NRC, identifying the problem as early as 1972.[68] At least part of this problem can be traced to the lack of human factors professionals on the staff. Phrased differently, if new technologies or methods are developed, it would be strange to see them reflected in requirements unless there were staff members qualified in the field on board.

Still another requirements area needing considerable upgrading is program management by the utility, management that must start well before the operations phase as described currently in ANSI N18.7[92] and endorsed by the NRC as part of a required quality assurance program in Reg Guide 1.33.[93] For example, for TMI-1 in 1973, the AEC evaluated the utility "to determine if the applicant is *technically* qualified to safely operate the plant." (Emphasis added) In the SER for TMI-2 in 1976 under the heading of "Principal Review Matters," there were no references made whatsoever to management matters.[94]

The TMI accident has shown clearly that the NRC must go into the management requirements aspects far more than it has in the past. It should not, however, be restricted only to "technical" qualifications of supervisors, which seem to have received the bulk of the criticism thus far.

c. Questionable Requirements Precepts

Three questionable precepts were encountered while examining the NRC's approach to safety engineering. The first two of them, the "design basis accident" and the "safety grade system," were encountered for the first time. The third, the use or attempted use of quantitative approaches to safety has been quite controversial over the years and has a long history of various groups trying very unsuccessfully to use it in dealing with requirements.

Design basis accidents are defined indirectly in 10 C.F.R. 50.2(u) in terms of specific functions, controlling parameters, restraints implicit in the state of the art, and the forecast effects of the postulated event. They have also been defined succinctly by Hanauer as "a sequence of events prescribed as the foundation for the safety evaluation of a plant."[95] They had formerly been equated to "credible" and "incredible" events; however, that terminology has been largely discarded in recent years although it is still found in 10 C.F.R. 100.

The design basis accident concept got mixed reactions concerning the TMI accident. Insofar as it led to development of containment and various systems that performed better and with more flexibility than might have been expected, the concept was successful. When measured against the failure to appreciate control operator actions on the progression of the transient, analysis in terms of design basis accidents leaves much to be desired.

The lesson to be learned seems to be that design basis accidents are a valuable approach as long as other hypothetical accidents are constructed figuratively, if not literally, encompassing those factors that could not be forecast. In other words, any approach to analysis must anticipate lack of knowledge at the time and develop a position amenable to upgrading as operational data become available.

This leads to examination of the "safety grade system" precept because it, too, attempts to narrow the areas of detailed safety analysis and requirements. Granted, practical economic facts of life suggest drawing the line somewhere on redundancy, manufacturing and quality control tolerances, etc., but the designation of "safety grade" must be made not just on intended performance of the system but rather based on the effects of nonperformance of the system and its associates both upstream and downstream in the functional chain being examined. A good example of this was the reaction of control room operators who chose not to believe certain instruments during the TMI transient because the instruments were not "safety related."[68]

The real problem arises when a design basis accident assumes certain performance of a safety grade system only to find that a nonsafety grade component or system is the critical one—like the emergency feedwater system or the pilot operated relief valve during the TMI sequence.

Finally, considerable discussion had preceded TMI and was resurrected afterwards about establishing quantitative safety goals or otherwise using numerical approaches to safety analysis. This has been in fashion among engineers and scientists and, in recent years, among managers as well. How much of this situation rests with the cognitive process within the individuals and how much of it is a psychologically induced prayer for simple solutions to complex problems is open to considerable debate. Nevertheless it is a serious question when it comes to requirements and their enforcement.

Over the years, many attempts have been made to quantify safety. Urged on primarily by practitioners of reliability engineering, exhaustive failure mode and effects analysis (FMEAs) were developed using the most sophisticated computer based statistical analysis techniques. Early as well as current problems in considering safety analysis rest on several factors:

1. The small numbers effects inherent in accidents versus hazards.
2. The lack of good investigative results of failures, incidents, and in some respects even accidents; that is, poor base data.
3. The failure to understand that human performance, even in the face of other systems failures, can be a positive influence, as well as a negative one, on performance.
4. The inability to account for nonfunctional failures, as when the stress level simply was not predictable because the environment factors either were not known or were simply misunderstood.

On the positive side, by disciplined enforcement of thought processes (which mathematical approaches tend to encourage), one hopefully will grasp the *gestalt*—the whole picture. Of course this can only occur if the analyst is mature enough to recognize voids in the data or his logic. Also of no small value in quantitative approaches to safety is giving the public what it wants: a nice simple answer.

The Rasmussen report,[96] was a monumental effort to sort these things out. The Lewis Report[97] was even better in that it brought realism to the value of statistical analysis as applied to nuclear power reactors. It properly discouraged looking at absolute risk and attempts to quantify the unquantifiable. It properly encouraged continued research into areas of vague data so that comparative levels of safety between given designs could be made—a process which for years has been meaningful.

Perhaps the Lewis Report's most important lesson to the TMI postaccident machinations about quantitative approaches to safety is its declaration of the difference between the perceived level of acceptable risk and an objective estimation of risk. That perception in turn hangs heavily on the credibility of the NRC.

Of concern in the final stages of the present study was a statement within a generally excellent discussion in the Lessons Learned Task Force report that stated:

> In circumstances . . . where there are methods and a growing body of data to quantitatively analyze and measure performance parameters, the quantitative goal is a powerful tool *in providing* informed, balanced decisions.[98] (Emphasis added.)

One can only hope that "in providing" was merely an editorial oversight and a better phrase would have been "to aid in." Quantitative approaches to safety either quoted as a goal or as a method of comparative analysis are not substitutes for human judgment. If, in fact the analysis reveals such a disparity in choices that it makes the decision for the man, the analysis probably did not have to be done in the first place.

d. Enforcement Discretionary Function

The Office of Inspection and Enforcement, by logical interpretation of its title, is the "policeman on the block." Viewed by any of the potentially accused licensee personnel, the NRC inspector wears a black hat—the villain in an otherwise peaceful existence.

To be sure, the above implicitly negative description is oversimplified at best. Policeman are vital to the protection of society, as are inspectors in the achievement of nuclear safety. The laws or rules in place are only as good as the informed enforcement given them. Furthermore, as any policeman or inspector will admit, the informal channels of communication used with discretion are at least as effective, if not more so, than raising a billy or writing a citation.

Enforcement, however, does not begin with the field activities cited above; particularly up to the time an operating license is granted, nuclear reactor safety rules are not only written but are enforced by a different organization, the NRR. The appellate function to either IE or NRR actions can extend to the Commission and to the Federal courts where appropriate.

By comparison with IE, NRR wears a white hat, although it can be considered rather gray by a licensee faced with delays in license issuance or backfit requirements. Criteria against which action or inaction is evaluated are less strictly defined in matters before the NRR. In theory, therefore, an adversary relationship should not be present. Nevertheless, the licensee will often be highly defensive, even when the licensee initiates the contact with the NRC.

This elementary recapitulation of the role of IE in relation to the NRR is provided to stress several things not necessarily apparent when viewed from either the vantage point of IE or NRR. The development and enforcement of requirements does not stop at any organizational line of authority. Nor does it occur at one time in the life cycle of a nuclear powerplant. It is a dynamic and sometimes iterative process. It requires the highest level of coordination in establishing the rules, understanding them, and applying them. It requires a recognition that neither the black hat nor the white hat approach by itself can fully and properly influence the licensee's behavior towards nuclear safety. This becomes particularly important when considering safety communications, as will be discussed more in the next section.

What remains here is to recognize that "prosecutorial discretion," as Bickwit called it,[25] is a way of life throughout the NRC. Policies and procedures to provide consistent application thereof are not well understood, albeit attempts were made in the past to be definitive. However, written guidance tended to oversimplify matters by requiring "corrective action for each identified item of noncompliance."[99] One would prefer to think prosecutorial discretion is not so much a question of mandatory wrist slapping as a matter of when and how far authority should be exercised.

A good example of this was raised by the ACRS in a letter to Chairman Hendrie concerning the IE investigation of TMI-2.[100] Commenting upon the actions of the control room operators, ACRS Chairman Carbon stated:

> The question . . . arises whether an operator, using his best judgment, is guilty of a violation if he consciously takes an action that is at variance with procedures which, in themselves, may contain confusing or incorrect guidance. The committee believes that, if so, this is the wrong approach to protecting the health and safety of the public . . . .

Requirements are only as good as their completeness, clarity, and informed enforcement.

6. SAFETY TASKS

Over the past two to three decades, several tasks within management's division of work have become identified as part of safety technology,[5,6] not that they have not been or could not be performed under some other classification of work. It is just that indepth knowledge has developed and been applied in certain areas such that specialization has taken place, and "safety" has become its generic classification. This is not unlike subclassifications developed in engineering over the years, one being "nuclear."

Three of these safety task areas have already been discussed: policy, plans, and requirements with enforcement. In those areas, however, safety technology is usually just a contributor to very large functions which go well beyond accident prevention. In the areas that follow, safety technology plays a predominant role in accomplishing the task; it is not, however, an exclusive role and interfaces with many other technologies.

a. Hazard Analysis

For purposes of this discussion, an immediate distinction must be made between hazard analysis and certain techniques in use by the NRC and the nuclear industry usually referred to as Failure Mode and Effects Analysis (FMEA). First of all, hazard is a much broader term than failure. A hazard is a risk of loss or harm. It is an existing or potential condition that can result in a mishap.[7] More often than not it combines several factors. For example, fuel in an undesired location, where uncontrolled ignition might take place, is a hazard, whereas the fuel itself is not. A failure, on the other hand, is usually defined in terms of something not functioning in the manner for which it was intended. Analyses of failures sometimes reference the environment in which the failure occurred, but fundamentally a hazard and a failure are not necessarily the same thing. Consequence of a failure can produce a hazard or it can be meaningless toward safety.

Hazard analysis includes FMEAs as one of the possible valued inputs to an entire hazard analysis program. In view of the semantic distinction made above, however, it should be obvious that safety demands hazard analysis, not just failure analysis.

Another less obvious distinction becomes apparent only after one examines the techniques used in hazard analyses and failure analyses. Historically, failure analyses were developed to ensure reliability of the system; that is, the system's ability to perform its intended function within certain failure rate limits. They were consequence oriented analyses only in that sense, not with respect to probable damage to persons or equipment. They were oriented to probability. Moreover their process did not identify necessary information for accident prevention such as symptoms of impending failure or intersystem effects. Nor did failure analyses usually include the input of man as an operator. The base error rate data were not available.

Failure analyses start at the part, or component, level, and their logic traces the failure effects toward some system or mission level of performance. Hazard analyses on the other hand are consequence oriented in the sense of analyzing and preventing certain broad categories of accidents. They apply logic from the top down, from the undesired event toward any factors singly or in combination which, if eliminated or controlled, would prevent or at least mitigate damage. They do—or at least should—stress the impact of human performance and be alert for signals generated by failures (mechanical or human) that can be controlled before damage ensues. Hazard analyses attempt quantification and deal in probabilities as do the reliability oriented failure analyses. However, the bitter lessons of the past have demonstrated this is a useless task except under highly controlled conditions, and then only in a comparative sense between relatively easily defined systems.

Above all, hazard analyses, unlike failure analyses, are life cycle oriented. (See Figure IV-2.) Their effectiveness rests in several stages of performance, with each new stage building upon the previous one as new information is available.[101] Only in this manner can one assess the validity of assumptions made earlier which, if proven false by test or operational results, can highlight accident prevention action necessary before proceeding further downstream.

As a minimum, these hazard analysis phases include:

- *Preliminary Hazard Analysis*—A gross assessment of risk and identification of safety critical areas needing detailed study.
- *Subsystem Hazard Analysis*—The identification of hazards associated with component failures and functional relationships with other components or equipment in a given system.
- *System Hazard Analysis*—An examination of the effects identified in subsystem analysis with other subsystems including the software that may accompany either.
- *Operating and Support Hazard Analysis*—The inclusion of those factors in the operating environment (including people performance) which can degrade even the best engineered system.
- *Accident-Incident Analysis*—The necessary feedback process which assesses the validity of assumptions made in the previous analysis and upgrades the results as needed.

To be effective, this process must include human factors considerations throughout the entire analysis life cycle. Examination of hardware characteristics in isolation from potential human inputs is the ultimate in safety technology naivete. Similarly, procedures and training become subsystems of the overall system to be analyzed.

The NRC's approach and, presumably, the nuclear industry's approach to analyses germane to safety is reflected in 10 C.F.R. Parts 50 and 100, Reg Guide 1.70, which is the Safety Analysis Reports requirements document,[67] and comparable sections of the Standard Review Plan (SRP).[102] Recently, the NRC responded to the President's Commission regarding the use of Failure Modes and Effects Analysis. The response included a survey of 10 NRC technical branches as to their use of techniques.[103] From a review of these documents, a search of nuclear industry oriented hazard and failure analysis references in the NRC technical library, and depositions of key NRC personnel[59,95] the following conclusions were reached:

1. Comparatively little, if any, understanding exists at the NRC of the difference between a reliability oriented FMEA and safety oriented hazard analysis. Industry recognition of the difference was reflected in two 1975 papers; however, they were not related to the broad based, life cycle approach to hazard analysis cited above.[104,105]
2. The NRC does not require any particular format for either FMEAs or other forms of analysis.

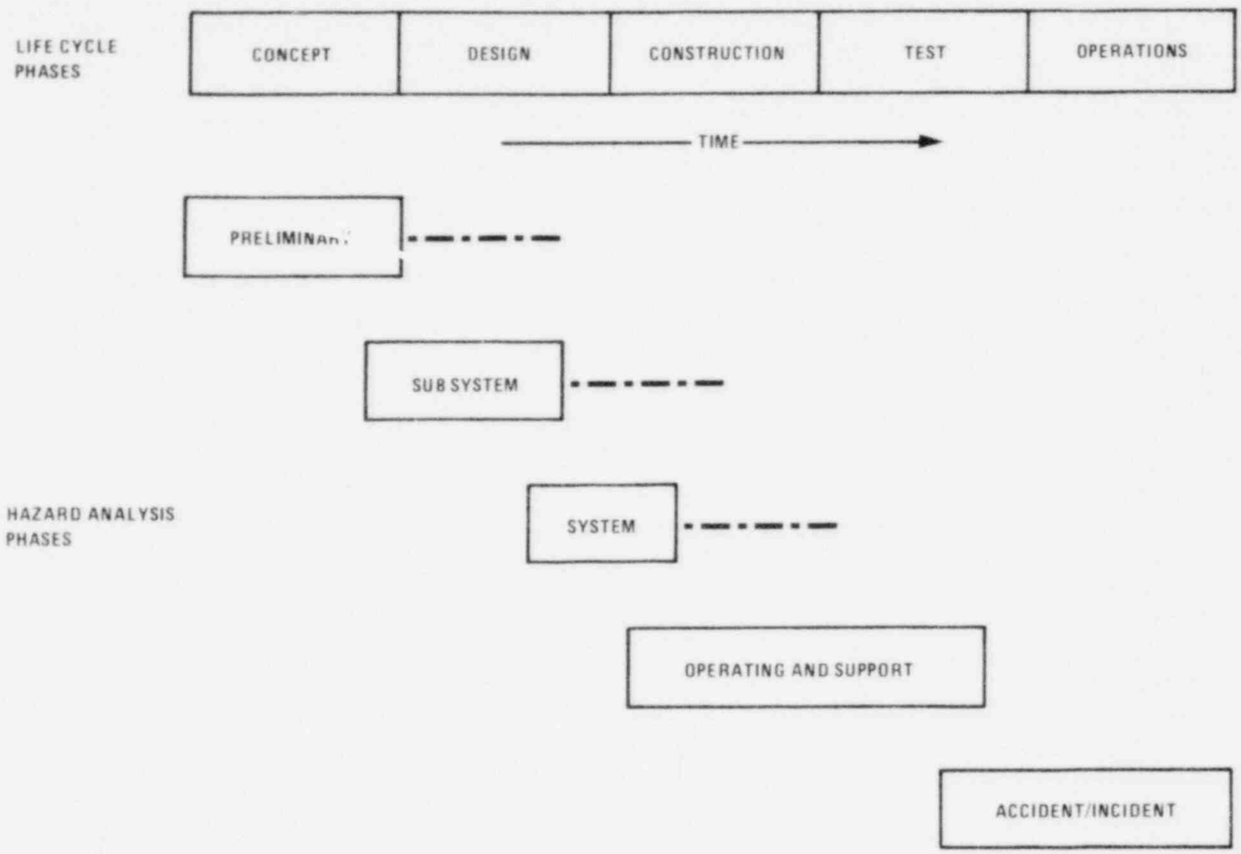


FIGURE IV-2. Hazard Analysis Phases Within a Program Life Cycle (Adapted from Miller, Ref. 101)

3. Even for so-called "safety analyses" in the "Accident Analysis" chapter of the SRP requirements manual, questions asked pertain mainly to output characteristics of given hardware systems failures rather than examining what hazards can really develop. Phrased differently, the results of assessed failures are sought in terms of radiological consequences, rather than first examining what events can produce the undesired results and what can be done to prevent those results.
4. Little if anything is done either by the NRC or the industry beyond the system analysis phase noted above, thereby failing to identify safety degradation possible from operational factors. Further, no structured feedback loop exists where operational experiences upgrade or otherwise test the analyses made earlier.
5. Reporting of results of analyses as shown in SARs is primitive; for example, tables columns are labeled simply "component," "malfunction," and "comment."[106] One only needs to compare this to the extensive guidance and format identified in the Society of Automotive Engineers Aeronautical Recommended Practice concerning design-fault-failure analyses characteristic of aerospace industry processes used for the past 2 decades.[107,108]
6. The NRC encourages application of analyses to design basis accidents and safety systems or both. Once again, this is sometimes counterproductive to examining what factors really can lead to an accident. A false sense of security is developed.
7. The performance of analyses by personnel within the licensee's or vendor's organization seems more appropriate to meeting some licensing requirement than deriving knowledge about hazards within the system; that is, analysis for the sake of analysis or certification, rather than as part of the design process. This, of course, relates back to the form of the NRC requirements.

Somewhat extended discussion of the hazard analysis issue has been provided here compared to other parts of this report. This is because hazard analysis represents one key, if not the key, to safety engineering management deficiency at the NRC. An effective hazard analysis effort over the life cycle of a system is the spine to which all body components of an accident prevention program are attached. Anticipating and controlling hazards at the design stage is just the beginning. Outputs from properly effected hazard analysis efforts are vital to maintenance tasks, training, operational procedures, and knowledge in the mind of the system manager as to the safety of his system. They form the basis for meaningful system safety reviews.

In regard to managing the safety of a system, risk management, as it is more generally known, is not merely a matter of controlling probabilities of accidents as derived from analysis. Not only are there uncertainties in the analysis process which are generally accepted both inside and outside the NRC,[13,97,109] but also management must balance three fundamental elements: performance (including safety performance), cost, and schedule. It entails judgment, but not just technical judgment. It also requires value impact judgment in terms of economy and public interest impact judgment in which the time factor can become significant.

The objective is to take intelligent risks, not to expect to simply accept them or reject them.[110]

b. Safety Communications

If the hazard analysis process just described is the fundamental analytical tool used in producing an acceptably safe system, the area of safety communications becomes vital as both an input and output mechanism related to hazard analysis. Santayana said: "Learn from the mistakes of others, you will never live long enough to make them all yourself." That is a precept that can aid the nuclear power industry as well as any other, but only if means are available and used to derive and exchange safety information effectively.

At the time of the TMI-2 accident, the NRC had several ways to obtain operational data. They ranged from the very broad based Licensee Event Reports[111] through defects and noncompliance reports required under 10 C.F.R. 21, to Abnormal Occurrences (those unscheduled events which the Commission determines are reportable to Congress because of their significance from the standpoint of public health and safety).[112] In response to a Government Accounting Office report examining these systems earlier in 1979,[113] the NRC appointed a task force to consolidate and improve the use of these data. Their report was issued May 15, 1979, and contained numerous recommendations, the principal thrust of which involved more centralized controls and monitoring of the incoming information.[114,115] An organizational change was then made to form an "Office for Analysis and Evaluation of Operational Data."[116] From review of past attempted use of these systems, and notwithstanding the new organization (which really has not yet begun to get underway), the following problems appear to remain:

1. The data base is extremely broad, ranging from the simplest failures through identification of significant hazards (some reportable, others not) to the "abnormal occurrences." A priority system of reporting and analysis is essential, a separating of the wheat from the chaff, while maintaining a capability for analyzing the chaff for residual bits of grain.
2. Human error reporting is vital, yet existing policies and procedures do not provide a path for this to be accomplished anonymously or, within limits, with a guarantee of immunity from punitive action. This form of incident reporting can be a more meaningful way of creating a safety awareness attitude (let alone identifying specific hazards) than any single thing management can do once a system is in operation.[117]
3. No effort thus far has been made to combine the LER program results with other sources of information to form a center for known safety precedents, a single location within the NRC which stores for ready retrieval the bitter lessons of accidents, incidents, or particular related studies of the past. The normal library system or even the extensive information storage program in use at the NRC will not serve the precedent center function unless a specific program is devised to do so.

Closely allied to the above is a need for the NRC to improve and maintain its ties with the safety technology community outside of the nuclear safety field. Therein rests the knowledge of safety engineering and management techniques which can benefit the NRC and the nuclear industry, and conversely can allow nuclear safety experience to benefit others. Therein, too, are sources of accident and incident information whose lessons are applicable to nuclear powerplant design and operation.

In the course of this study, inquiries were made of four professional societies that traditionally have been active in safety work and more specifically in recent years, for some of them, system safety work.

- American Society of Safety Engineers (ASSE)
- Human Factors Society (HFS)

- National Safety Management Society (NSMS)
- System Safety Society (SSS)

These societies were literally unknown to all senior management personnel contacted in this study. Membership by NRC personnel ranged from zero in NSMS, to one in SSS on August 6, 1979, and one in HFS, to a few in ASSE, assumedly in the health physics area.

Similarly, the Electronics Industry Association has sponsored a System Safety professional committee for many years, their G-48 committee. There is no record that any NRC employee has ever been a member.

This is not to deny the importance of the technical liaison between the American Nuclear Safety and the IEEE. However, neither of those organizations has been closely associated with safety engineering and management as known by the other groups cited.

Another safety communications element examined during this study was the use of group dynamics. This comes into focus in safety boards, committees, or councils and in the conduct of safety design reviews, inspections, audits, etc. It was found that except at the utilities, where plant safety committees were mandated by the NRC, the concept of organizational segments whose exclusive charter was the review of safety matters on a routine basis was simply not applied. At the NRC, design reviews tend to be done on paper and, where groups assemble, it is usually on a broader subject than safety. Typical of these would be high level staff meetings and meetings of the Regulatory Requirements Review Committee. IE and NRR tend to meet with licensees separately, thereby negating the benefits of interoffice input.

In the matter of large scale inspections, audits, and the like a spectrum of techniques is available for applying group thinking to possible problem situations. At one extreme is an inspection—another black hat situation—wherein a check is made against existing requirements with censure or punishment looming in the background. Formal reports are made and an adversary process can and usually does develop.

At the other end of the spectrum is the safety survey concept—a white hat approach—sometimes known as a staff assistance visit. Like inspections, these are performed by well qualified people, but not in the formal sense of an inspection. Inquiry may well go beyond the written requirements. It is done on a nonadversary basis with findings reported only to the senior one or two people of the organization being surveyed, from whom a commitment is obtained that no punitive action against personnel will be taken based upon findings of the survey. Such surveys are best done by personnel with no axes to grind for or against the utility or whatever organizational segment is being examined.

This safety survey technique is obviously a derivitive of management surveys which, when done properly, employ group dynamics as well as interviews to elicit and analyze information.

No use of this approach or encouragement to its use was encountered in discussions with NRC personnel, although it was pointed out that, independent of the NRC, some of the utility corporate offices performed station reviews and some vendors accomplished readiness reviews of utilities. To what extent, if any, these reviews were safety surveys as described above is not clear.

c. Safety Attitude Development

As noted earlier, the Presidential Commission investigating TMI was critical of the NRC's attitude toward safety. But accepting this criticism, which most NRC people seem to do, the question remains: How can it be modified? Certainly, attitudes in people, individually or collectively, are the result of sociopsychological behavioral influences too numerous to mention, but with equal certainty such influences include work experience. Accordingly, the statutory considerations, policy matters, and safety management approaches discussed in this report thus far help explain the NRC attitude. Change them, and perhaps the attitude will change.

Another dimension of safety attitude that can be explored deals with specific programs and techniques available to influence NRC personnel or others in modern safety management matters. Four separate approaches are identifiable:

1. *Education*—The process of teaching people to think;
2. *Training*—The development of skills to perform particular tasks;
3. *Indoctrination*—The application of existing experience, education, and training to a new work environment;
4. *Motivation*—The enhancement of a person's commitment toward a particular goal, sometimes called awareness development.

These are not mutually exclusive, but the optimum methods to effect attitude changes through these approaches vary. For example education can best be acquired in an academic environment using case studies rather than teaching machines which, however, have merit in training. Indoctrination may be a standard program for all employees, but motivation may require a more personal appeal because of the difference in individuals.

What was found at the NRC in these regards was minimal safety education, training, indoctrination, and motivation programs—at least among senior personnel. A significant number of predominently NRR and RES personnel have attended the MIT nuclear safety technology courses. A relatively large number of similar personnel have attended statistical reliability or probability analysis courses. A very small number of IE staff began attending MORT programs sponsored by ERDA-DOE about eighteen months ago. Only in this latter area was safety management a specific topic in the curriculum.

Other nuclear safety engineering courses have been given at Catholic University, Georgia Institute of Technology, Northwestern University, and the University of Tennessee, among possibly others; however, these have not been attended significantly by NRC personnel.

Until it came up during the course of this study, the Management Development and Training Office was unaware of a graduate degree program in safety available in Washington, D.C., through the University of Southern California. Similarly, George Washington University has been offering a System Safety Course for nearly a decade. Review of their records showed attendance of three people from the AEC in the early 1970s; none from the NRC.

There is no reason to believe any different results would be found in examining the safety attitude development in the nuclear industry.

In sum, the NRC and the rest of the nuclear power community are blessed with extremely technically qualified and motivated people. Their exposure to safety attitude education, training, etc., has been miniscule in the overall sense of what could be done. Even the MIT courses, which were visionary at the time they were conceived by the late Dr. Thompson in the mid-1960s, are so predominently engineering and science oriented that safety management principles are hard to recognize.

Contrast this to the DoD, NASA, and certain non-nuclear industries that not only provided a full range of safety attitude development programs beginning as early as the mid-1950s, but also made them available to top level managers as well as non-managerial personnel.

d. Accident-Incident Investigation

Competent accident-incident investigation is a vital part of any accident prevention program. Only by such an effort can the realities of operational use of a system be fed back to allow evaluation of the engineering, operational, and management decisions made earlier. It leads not only to upgrading the system in question but also to the improvement of other systems, whether currently operating or being planned.

This purpose for safety oriented accident-incident investigations is different from those investigations whose objective is to determine culpability or adherence to administrative requirements. The techniques used in a safety oriented investigation also differ somewhat from those conducted for enforcement purposes. In the former, a relative level of informality combined with party participation in determining the facts contrasts with the legalistic, adversary process found in the latter. Any "black hat" investigation inhibits determination of some types of facts (for instance, human performance) and often extends the cost of the investigation significantly in both money and time.

Perhaps the most important aspect of a safety oriented versus the enforcement oriented investigation, especially one conducted by a group other than line management, is the outsider's perception of an objective inquiry. For example, the successful image of investigations conducted by the National Transportation Safety Board is directly related to their organizational separation from the Federal Aviation Administration, National Highway Traffic Safety Administration, and others. Also, this aura of objectivity is enhanced significantly by making factual information public as soon as it becomes available and is reasonably verified, and by widespread publishing of the total findings. Because of legal ramifications, enforcement investigations can rarely provide information as promptly and completely as the public usually demands.

As noted in Subsection 4.d., the NRC did not have a structured accident-incident investigation plan in effect prior to TMI. The absence of stated safety objectives of the investigations that were conducted, combined with assignment of the investigative task to IE, resulted in only enforcement oriented investigations of accidents and incidents. Other deficiencies revealed in the NRC process, and typified by the TMI accident, included:

- There is no clear definition of authority, at least as shown by the lack of authority exercised by investigators in taking control of the investigation, securing records, demanding prompt interviews, and other such matters time-critical in any investigation.
- There is a dichotomy of job assignments within IE whereby personnel are designated investigators or inspectors. The investigators are not geared to the technical aspects of plant operation, and

the inspectors are not necessarily competent in investigation.

- There is no organized way to obtain constructive assistance from parties to the investigation (for example, the organization of teams in particular investigative areas to which parties could contribute qualified personnel).
- There is no obligation or motive for IE to gather facts leading to questions about the adequacy of the regulations; the process only determines whether or not the licensee adhered to those in existence.
- Formal training of IE personnel in accident investigation has only recently begun and there is no record of personnel from other offices participating in MORT or equivalent programs.
- There is a lack of familiarity with and use of logic diagrams in reporting the results of accidents.
- No procedures exist to ensure the safety of NRC employees on site at the scene of an ongoing emergency.

IE is currently proposing policies and procedures to correct these problems; however, because of their current organizational charter, they are severely handicapped in any attempts to conduct both safety and enforcement investigations. The very fact that the Special Inquiry Group had to be called in to provide an independent investigation of the Three Mile Island accident is symptomatic of an accident-incident investigation safety management problem at the NRC. Granted, the magnitude of public attention to TMI-2 may have been the triggering force; nonetheless, the scope of the Group's inquiry would be difficult to assign within the existing NRC organization and still have the results accepted as being nonbiased.

e. Resolution of Perceived Hazards

As discussed earlier, the effectiveness of any safety program is not measurable statistically with reference to accidents. Accidents are simply too rare. Incidents provide a better data base but they suffer from inability to control the subjective judgments inherent in the reporting of incidents. Another less well known index of safety program performance is the development of recommended action following accidents or incidents and monitoring actions taken as a result. This can be referred to as the "prevention of action failure" task.

The Incident Investigation Review Committee (IIRC), mentioned briefly earlier, is a group that was to bridge the gap between incident responses described in NRC Manual Chapter 0502 and the development of codes, guides, and standards. Note that incidents in this sense are occurrences of actual or potential hazard to public health and safety. They could conceivably become "abnormal occurrences" upon designation by the Commission. They also could be of no immediate threat or may have relatively insignificant effects. In any event, the IIRC was theoretically in a position to develop and ensure appropriate corrective action following major events.

The problem observed throughout all of these programs thus far, however, is the lack of a consolidated system for logging and tracking corrective action recommendations whether action is taken or whether it is decided no action is necessary. This is not to say a given item cannot be researched and its disposition cannot eventually be learned. What is missing is good visibility of this vital safety management factor.

This tracking requirement is not a new problem; it was addressed at least by 1972 in a report entitled, "Evaluation of Incidents of Primary Coolant Release from Operating Boiling Water Reactors," WASH 1260.[118]

Another shortcoming was the lack of a defined objective and approach to conducting special studies for analyzing data collectively; that is, beyond the meaning of a given report. Many events, taken singly, have little significance. When combined and examined statistically or as a function of changes to the norm of reported events, significant hazards that might otherwise not be seen can become visible.

f. Development of Emergency Procedures

Investigation of the TMI accident revealed little direct input by the NRC into the development and evaluation of emergency procedures used in control rooms. History has shown that this, too, is an area to which safety technology should be applied.

Traditionally, emergency procedures are developed by designers and equipment operators. They know the system extremely well but suffer from two common failings. First, they tend to make value judgments on how others *should* react under given circumstances. Second, their experience usually does not include exposure to a sufficient number of accidents or incidents to appreciate how people *will* react during an emergency. There is a difference between what a person *can do* and what a person *will do* during an emergency.

Additionally, engineers who develop emergency procedures tend to narrow their thinking to those subsystems for which they have design accountability. As TMI disclosed, the problems requiring emergency treatment, especially those involving human action, can and usually do involve more than one subsystem.

These are phenomena that safety specialists encounter continually during investigation, hence one of the safety tasks is to be certain that the real world experience with accidents and incidents is incorporated into operational emergency procedures.

g. The Safety Ombudsman Task

Even the most cursory review of policies and procedures issued at the NRC over the past few years pertaining to "differing professional opinion"[66,119,120] reveals a fundamental safety need within the organization: The ability of anyone to bring a concern about safety to the right people for conscientious attention, review, and disposition. The recent NUREG-0567[120] is by far the most comprehensive statement of policy ever seen in this regard, for which NRC management is to be commended.

It should be appreciated, however, that simply advising people they have a right as well as a duty to bring disagreements forward may not be enough. First, interpersonal relationships that exist between an employee and the supervisor may readily inhibit following the authorized procedures. Second, the party with the information may not be willing to identify himself, either in fear of retribution or because he or she was the one at fault. Thus the desirability of an ombudsman function which, in safety matters, sometimes becomes analogous to the role of Chaplain. Information providing ethical questions as to how it should be handled, especially if the reporting individual is at fault, is received in confidence.

In any event, the availability of a person to hear the safety concerns of others on a very private basis is an integral part of safety management technology.

h. General Observations about Safety Tasks

That specific tasks within the framework described above are significant in the aftermath of TMI is illustrated pointedly in the Lessons Learned Task Force Final Report. Quite independently from the present study, that report detailed numerous suggestions that fit this safety task logic. These are indicated in the following summary, which are direct quotes from the Lessons Learned Report showing the task area into which they fit. The number refers to pages in Reference 16.

- *Safety Tasks* (general)—"...the NRC staff must give increased attention to the detailed methods of obtaining improvements in operational safety" (pp. 2-3).
- *Plans*—"...the NRC [should have] an effective plan to take the lead in articulating a coordinated approach and a generally accepted goal for technical qualifications for both onsite and offsite personnel and for both normal and accident conditions" (pp. 2-5).

  The approach of the licensing reviews should be "integrated...from event initiation through consequence mitigation" (p. A-16).

  Need "Continuity of licensing cognizance and responsibility from initial plant licensing, throughout construction into operation" (p. A-16).
- *Hazard Analysis*—"The staff should initiate a systematic assessment of the reliability of the safety systems in operating units and in the late stages of construction using simplified fault and event tree analysis" (p. A-13).
- *Safety Communications*—"...staff safety reviews may be too prescriptive in nature and do not promote awareness or incentive to pursue on a broader basis new areas of potential safety concern. ...the emphasis should be on system level reviews" (pp. 4-5).

  There should be an "annual workshop ... for exchange of information on operating experiences" (p. A-6).

  "...assure that a mechanism exists through which lessons learned from operating experience...are conveyed to the reactor operators" (p. A-11).
- *Safety Attitude Development*—"As part of the training program for all licensed operators...a course should be conducted [to] include:
  - (a) Safety Analysis
  - (b) Probabalistic assessments
  - (c) Current safety issues and recent significant operating experience
  - (d) NRC and industry responsibilities for safety" (p. A-5). "Assurance of adequate operations experience and training for the NRC technical review staff" (p. A-16).
- *Accident-Incident Investigation*—There is a needed "integration of the new NRC and utility programs for evaluating operating experience" (pp. 2-7).

  There should be "an accident evaluation function within the Office of Nuclear Reactor Regulation" (pp. 4-5).

  "The NRC staff should establish a mechanism whereby ...operational errors are identified in

Licensee Event Reports...should include provisions for protection of the privacy of the individual" (p. A-5).

Per NUREG-0578, "each licensee is now required to have an operations experience evaluation group" (p. A-11).

Establish a "designated Emergency Response Team... multidisciplinary..." (p. A-16).

- *Resolution of Perceived Hazards*—"Use of a formal procedure for followup on questions and requests from ACRS..." (p. A-16).
- *Development of Emergency Procedures*—The emergency procedure review "practice [should] be changed to provide for interdisciplinary review...as part of the operating license review process" (pp. 2-6).

Still another point raised, at least by implication, is the question of who should perform these tasks. This question will be addressed more in the next section, Organization for Safety, but for the present it is enough to say that qualifications and motivation, not organizational position, of the people doing the work are the key ingredients. It follows that safety tasks should not simply be parceled out to exsisting personnel without additional education and training where necessary.

7. ORGANIZATION FOR SAFETY

Organization for safety is analogous to safety management as a whole in that it reflects certain precepts shown by experience to encourage safety effectiveness. Of course organization for safety can be no better than the overall assembly of personnel and resources into discrete organization segments and management's fundamental division of all the work. For example, if an organization has fundamental flaws regarding decisionmaking, the organization for safety is just that much more limited from the beginning, and no amount of band-aid organization changes will produce significant improvements.

In this vein, several perceived NRC organization shortcomings are presented prior to examining organization for safety itself. The first was discussed earlier (see Subsection 2.c.), and involved the conflicting directions implicit in the statutes governing the NRC. The second includes a lack of a systems engineering approach during the licensing process. As typified by the Division of Systems Safety being limited to certain safety systems without a detectable integrating function elsewhere, NRR's technical licensing effort tends to be fragmented. Then, to extend this problem another dimension, a systems management approach is difficult to find which would include relatively nontechnical matters such as choice of site, emergency planning, and economics affecting the public interest. This is another way of saying the NRC's approach to organization and management has been too narrow and too imbalanced in the direction of high technology engineering and scientific activities. The results have been the inevitable voids that develop between subsystems and the lack of attention entirely to certain other subsystems.

Symptomatic of this problem, too, is the physical dispersion of the Washington, D.C., area NRC offices. This is an extremely serious adverse influence toward organizational cohesiveness. It was described succinctly by one deponent as "unconscionable" and leads to the NRC's being "like many agencies in one."[121]

a. The Line (Decisionmaking) Organization

Given resolution of the question about the role of the Commission versus the EDO versus the Office heads, one matter remains when examining the line or decisionmaking function within the NRC organization. It is the current difficulty in identifying the office or person making the decisions on a given project, as typified by any license application. As discussed in Subsection 3.e., this becomes a policy matter to be considered at least at the Commission level; however, without some matrix approach to organization which includes a relatively strong project management function, the probability remains that all factors important to safety will not be heard and decided upon expeditiously.

This does not mean the highly competent technical personnel within the functional offices lose their status in the decision process; rather they may have to take things up the functional chain of command to a higher level if they do not agree with the project manager's decision. This would be the exception rather than the rule among professionals. In a matrix organizaton, an overwhelming percentage of disputed issues are resolved at the project manager-functional manager level.

b. The Staff (Advisory) Organization

The staff function as used here is advisory, where the only authority a staff person has is his or her ability to convince the decisionmaker of the correctness of the position. This is not to be confused with the military chief of staff function in which the chief and his subordinates may be delegated decision authority, along with clout approaching that of the superior, in certain matters.

To be effective, staff functions must report at relatively high levels as a matter of communications efficiency. They characteristically include areas of expertise which may not be needed in project or even functional segments of the organization, at least at that particular time. They often represent skills that extend across and are needed on an interdepartmental basis. For this reason, safety technology is usually seen being applied first as a staff activity and later, if necessary, as a functional area in support of projects, as has been seen in other technical fields. Even when this occurs, however, a safety policy function is usually reserved at the highest levels of management.

Within the NRC the safety staff function is provided in two ways, each with shortcomings of note. The most obvious staff input for safety is the Advisory Committee for Reactor Safeguards (ACRS). Generally successful and having made significant contributions over the years, ACRS suffers from the same narrowness of perspective in safety matters as characterizes the entire NRC organization. This becomes apparent when reviewing the backgrounds of the current members.[122] For example, no record exists suggesting ACRS recognized the human factors engineering problem in licensing; it is not just coincidental that no member of the ACRS has significant experience qualifications in this area. Also, there is no record suggesting recognition by ACRS that safety management problems existed at the NRC before TMI, at least as compared with the magnitude of reports since then. Whereas the same reasoning may apply in explaining this as with the lack of attention to human factors engineering, a much more logical explanation rests with ACRS not choosing to interpret its charter to criticize NRC management.

The second major safety staff advisory source is from the current NRR Office Chiefs and their key subordinates. After all, they are usually experts in one field or another; hence, they could serve in an advisory capacity in their field. The potential conflict occurs when the same people providing technical advice are making all the decisions. The check and balance function of matrix program management is thereby lost. Recognition by upper management personnel at the NRC of this potential conflict was not apparent during this study.

Other offices, besides the program or functional offices, are in a position to supply the necessary staff input for safety, for example, the Office of Policy Evaluation (OPE), IE, or the Office of Research (RES). However, OPE does not seem to have this in its charter nor does it have personnel trained in safety technology. IE has some potentially excellent personnel in this regard, but tends to be overfocused on their inspection and enforcement roles. RES similarly has potential, but the scope of their current research efforts does not seem to include safety technology as described herein.

In any event, it remains a matter for the Commission as a matter of policy and the Chairman as chief executive officer to effect the right balance between line and staff inputs to safety. The line input is needed to get a job done. The staff input is needed to assure the job is done right. The combination of the two produce a balanced and objective result.

c. Considerations Other than Line and Staff

While not usually strictly construed as organizational matters, three other considerations merit attention here. They can influence significantly the conventional internal workings of an organization.

First is the posture of one major office in relation to others in resolution of safety issues. Reverting once again to the benefits of group dynamics (plus the fact that significant safety issues are rarely the province of a given office), some interdepartmental safety organization is needed. Except for the Regulatory Requirements Review Committee (RRRC), no sign of such an approach at the NRC has been evident.

Second is the need for some interagency approach to safety. This includes NRC participation in safety efforts being conducted by other members of the nuclear power community, as typified by professional committee activity. It also includes participation with other government agencies in discussions of safety management matters germane to all segments of the Federal establishment. Nothing like this exists nor has it ever existed, except approximately fifteen years ago when President Johnson mandated "Mission Safety 70," a coordinated effort to reduce accidents involving Federal operations.[123]

Third is the hard to describe informal organization for safety, somewhat theoretical but ever so effective if it can be established. It requires identification of specific personnel in all organization segments who, for one reason or another, have a penchant for promoting accident prevention. They are the volunteers, and the work would not necessarily be part of their job description. They would not be supervisory personnel. They would be an informal two-way communications link to structured safety activities. They are the key to a safety motivated work force; get them on board and other tasks become much easier.

d. Advisability of a Separate Staff Safety Function

If the safety management concept using the growing body of safety technology is recognized, an organization question rises immediately. Should there be a separate safety organizational segment and, if so, how should it be integrated into the total organization structure? This question was considered only once in the past by either the AEC or the NRC. An Operational Safety Branch existed from 1967 to 1972 in the Reactor Licensing Division of the AEC; however, as the title suggests, its assignment was basically limited to operational safety matters. It had an oversight function which did not meet with much favor in the entrenched line organizations. Also it became a matter of "turf conflict," to use a contemporary phrase, between the inspection and regulatory offices. The branch evolved into the Office of Operations Analysis from 1972 to 1975, but was then disbanded. The view taken was that the entire function of the agency was safety oriented, thus a separate safety monitoring organization would be redundant.

When examining history in other fields, noticeably in the aerospace industry, one finds this same question had been faced many times both inside and outside the government. A trend over the years has been toward staff level safety offices, even in applications where safety is "everybody's job." For example, what function is more safety dependent than defying the laws of gravity during flight operations. Safety staff offices are used routinely in aviation agencies both at the engineering and operational ends of the life cycle spectrum.

The general trend towards specialized safety functions notwithstanding, the matter should be approached with caution. The complexity of the total task to be performed, the mores of the organization, and above all the background and motivation of the people available are all determinants at least equal in importance to the applications of safety management theory.

Even given the TMI induced proliferation of required safety tasks as discussed in this report, and the implication that a separate organization segment should be formed to handle them, does not negate the possibility that these tasks can be performed in some format that does not scream "safety office." It becomes a matter of total organization structure and the fundamental right and need of management to divide the work in the most effective way, given its resources.

Principal among these resources are the people. Indeed, most modern organizational theorists will plead: "Build the organization around the people," not simply insert people into some preordained organization chart cubbyhole. Of course, this is sometimes difficult within the Federal Service.

If one is to apply safety technology, however, certain personnel classification factors should be kept in mind. Safety as an occupational specialty is relatively new, probably not more than 20 to 30 years old. An oversimplification exists by calling it a specialty. It requires interdisciplinary skills because the nature of accidents is interdisciplinary. Another way to look at it is that a safety specialist—one who carries out the safety tasks—is a specialist only in one thing, attitude, and that attitude is accident prevention. He or she must be a generalist in knowledge, requiring focus only to the extent needed to communicate with the technical experts in the particular field of application. That field may be nuclear engineering; it might also be human factors, management, law, communications, etc.

Particular care must also be taken not to confuse safety technology with equivalent technologies of reliability engineering or quality assurance. Tracing the history of how these fields developed will reveal distinguishable differences in attitude, techniques, and professional contribution.[124] Overlaps or interfaces occur, thus a generic category of "assurance sciences" can be used to cover the lot. If specialization in safety technology is needed, apply it. Do not just rename something else.

8. CONCLUSIONS AND RECOMMENDATIONS

This assessment of the safety management posture of the NRC has revealed a classic paradox. The mission of the agency and the intent of the persons attempting to carry out that mission focus upon nuclear power reactor safety. Yet some of the most elementary attitudes and approaches to safety as exercised in other agencies are not found in the NRC.

It would be a gross oversimplification to assess accountability for this condition only at the NRC. In particular, the statutory base of the Commission has invited authority and policy problems. Similarly, the role of the nongovernment nuclear energy community—the utilities and their vendors—has been passive, not dynamic and self-desciplined to the degree required in management of a nuclear reactor's highly complex technology.

The NRC, however, seems to have tolerated known deficiencies in its enabling legislation. It has permitted a narrowed span of attention to traditional engineering and scientific areas of endeavor, to the exclusion of modern systems management techniques such as systems engineering and the application of human factors and system safety technology. It has fallen into the trap of allowing risk assessment, which can never produce a meaningful absolute quantified result, to mask the accident prevention benefits available during an effective hazard analysis program. The NRC's project management was allowed to degenerate into what is really project coordination, with management direction emanating from a curious combination of functional, committee, and legal inputs. Finally, the NRC's role has been more oriented to prescriptive licensing of a utility—putting a "Good Housekeeping Seal of Approval" on a proposed product—as distinguished from a role of regulation which must include careful monitoring and control during the entire life cycle of a nuclear facility.

That more TMI's have not occurred is effective testimony to the apparent application of excellent nuclear technology skills thus far. In fact, in retrospect, this is probably why the possibility of TMI-type accident was not really appreciated by personnel at all levels of the NRC. Whereas knowledgeable persons never promised perfect safety—and rightly so—the superb record prior to TMI easily led to a false sense of security in the minds of the vast majority of members of the nuclear power community.

Fortunately, the safety management shortcomings revealed in this study are not insurmountable. Nor in the author's opinion are they of a nature which would demand full correction prior to resumption of an aggressive program of development and operation of nuclear powerplants in the United States. The "hyper" level of management's safety awareness based upon TMI and actions currently underway have combined to produce a much lower probability of an accident than existed before TMI. At least on an interim basis following recognition of critical hazards in a given industry, the level of safety goes up even though the hazards themselves have not diminished. Such is the effect of safety awareness and motivation on the people involved.

To resolve the safety management problems revealed in this study and to effect relatively long term improvement in nuclear power safety, the following recommendations are offered:

1. A National Nuclear Safety Program Plan should be developed and approved by the President, a plan reflecting clearly the nuclear safety philosophy and policy to be followed and the allocation of nuclear safety roles among all segments of the government. A specific proposal for this plan should be developed by the NRC in coordination with other Federal and State agencies, representatives of the industry, and committees of the Congress.
2. Complementary to the above, the President should establish a Federal Safety Policy Board to ensure future cooperation among all Federal agencies in exchanging and applying modern safety technology.
3. The NRC should propose, and the Atomic Energy Act of 1954 and the Energy Act of 1974 should be amended, to:
   a. Establish the objectives of nuclear power safety beyond simple health and safety of the public to include protection against economic loss and maintenance of a viable nuclear power capability in the public interest.
   b. Retain the five-person Commission configuration but provide the Chairman unequivocal decisional authority in matters other than those of an adjudicatory nature brought before the Commission. Further, unfettered freedom of expression of views to the public for each of the Commissioners should be provided. Alternatively, if a single administrator form of organization is chosen, provide that administrator with a truly independent Safety Review Board that ensures adequate incorporation of the safety technology and principles as described in this report.
   c. Require both high order administrative and nuclear technical qualifications for appointment of the senior official of the NRC and for the first two levels of line authority thereunder.
   d. Establish minimum qualifications for the other Commission or Board Members to reflect a cross-section of public perception of the effect of nuclear energy upon the Nation's needs. Where familiarity with nuclear energy technology is not implicit in their background, require a specific nuclear technology indoctrination program prior to assuming an active agency role.

e. Remove the existing constraints on organizational structure of the NRC (the specific Office designations), yet emphasize the need for program direction with effective check and balance between project and functional areas.

f. Rename the Advisory Committee for Reactor Safeguards to Advisory Committee for Reactor Safety and modify its purpose to provide inputs broader than nuclear engineering. Require particular and balanced qualifications among the membership.

4. The NRC should adopt and announce the following as matters of policy:

   a. That "safety" in its application within NRC is a positive, nonconstraining force in the development of a viable U.S. nuclear power capability and includes the protection of the public against significant economic loss as well as protection against injury.

   b. That risk assessment in nuclear safety is a function not only of probability but also severity of the hazard, whereas risk management entails balancing system performance (including safety characteristics) with costs and timeliness as required in the public interest. Risk assessment is therefore only an input to the risk management decision process.

   c. That NRC requirements must be considered minimum standards by the nuclear industry, which has accountability beyond the NRC's to implement reasonably available advancements in safety engineering and management.

   d. That NRC's regulatory role is much broader than licensing, and its scope includes all facets of the nuclear energy production system over the life cycle of that system.

   e. That prosecutorial discretion will be exercised to effect a meaningful balance between enforcement of rules to ensure their accomplishment and yet encourage close cooperation with industry in communications to prevent accidents.

   f. That the fundamental organization precept to be applied throughout the NRC is project management in which the project manager shall have day-to-day decisional accountability, with functional organization management being held accountable concurrently for the technical adequacy of the decision.

   g. That during the course of accident-incident investigations, all factual information will be made available to the public as soon as it has been reasonably verified as long as it does not materially inhibit the ongoing investigative tasks.

5. In accord with the foregoing policy changes, the NRC should accomplish the following in regard to organization matters:

   a. Examine and modify the NRC organization as required to assure application of safety technology in the staff sense as described in Subsection 6 of this report as well as to assure that safety is implicit in the functions of all offices.

   b. Establish a human factors technology base within the functional organizations.

   c. Modify the existing program – project offices and restaff as necessary to strengthen their decisional capability and authority.

   d. Establish a headquarters accident-incident investigation team, reporting to the Commission, with procedures and authorities to investigate particular events for purposes of safety, but not enforcement.

6. Additional actions by the NRC are suggested as follows:

   a. A study should be made leading to incorporation of applicable safety engineering and management features of DoD and NASA standards MIL-STD-882A and NASA Manual NHB 1700.1(V3) into the NRC regulatory process. This includes particularly the planning, system safety review, data item submission, and configuration control functions.

   b. Develop and implement a Regulatory Guide or equivalent requirement to ensure adequate safety management at licensees and their vendors throughout all phases of the utility's life cycle.

   c. A life cycle oriented hazard analysis program should be defined and imposed as a requirement upon all contributors, vendors as well as utilities.

   d. A human error reporting procedure should be adopted, possibly as an adjunct to the LER program, which will permit anonymous reporting and reasonable immunity from censure by either the NRC or the person's employer.

   e. Develop a requirement for and otherwise encourage the use of safety surveys or staff assistance visits at utilities and their vendors.

f. Develop a safety engineering and management attitude development program for all levels of NRC personnel, utilizing optimized education, training, indoctrination, and motivation techniques. Include representatives of industry in each program to facilitate mutual safety policy understanding.

g. Develop a quality assurance program applied to the NRC operations with respect to licensing of utilities.

h. Develop and implement an accident-incident investigation training course for NRC personnel who might become involved in IE or broader based investigations. Consider the current MORT program at least as an interim approach.

i. Encourage NRC personnel participation in safety activities conducted by other industries, to include seminar attendance, participation on professional committees, and membership in professional safety societies.

j. Develop a specific nuclear safety information or known precedent center within the NRC, programmed and coded in such a manner as to be able to respond quickly and effectively to any inquiry concerning lessons learned from previous accidents and incidents.

k. Develop a nuclear safety technology handbook or text which includes not only nuclear engineering matters but also human factors and other considerations germane to a total system safety effort.

l. Establish a single location for all greater Washington area offices.

Establishing a priority for the above recommendations is a difficult task at best. Countless other suggestions have also surfaced as a result of the TMI and, in fact, actions are probably already underway in many areas discussed here and elsewhere. Accordingly one final recommendation is in order. A coordination office should be established to log, examine, track, and publicize the disposition of all recommendations made by responsible parties who have investigated TMI. Once this is done, the Commission will be in a much better position to take whatever action it chooses and to regain at least some of the credibility lost in the eyes of the public.

It is suggested specifically, however, that those recommendations noted above dealing with accident-incident investigation should be implemented on very high priority. Unwanted events have the unfortunate characteristic of not waiting until people are ready for them.

9. EPILOGUE

> Man has been characterized as the only creature with an infinite capacity for making trouble for himself and we seem to be fully exercising that capacity today.... Perhaps it is not too much to hope that the same qualities which have enabled him to triumph over the destructive forces of nature will enable him to master those he himself has created.[125]

REFERENCES AND NOTES

[1]President's Commission on The Accident at Three Mile Island, "The Need for Change: The Legacy of TMI," October 1979, at 7–21.

[2]*Id.* at 13.

[3]As an example, see 49 C.F.R. 830.2 for definitions applicable to aircraft accidents.

[4]Heinrich, H. W., "Industrial Accident Prevention," 4th Edition, McGraw-Hill Book Company, Inc., New York, 1959. (Previous editions in 1931, 1941 and 1954.)

[5]C. O. Miller, "The Role of System Safety in Aerospace Management," Masters Thesis, University of Southern California, January 1967, at 8.

[6]C. O. Miller, "Some Principles of Aviation Accident Prevention," *Hazard Prevention*, January–February 1976, at 17–21.

[7]U.S. Department of Defense, "Military Standard, System Safety Program Requirements," MIL-STD-882A, June 28, 1977.

[8]U.S. Department of Defense, "System Safety Engineering and Management," DoD Instruction No. 5000.36, December 6, 1978.

[9]National Aeronautics and Space Administration, "System Safety," NHB. 1700.1(V3), March 6, 1970.

[10]Warren H. Donnelly, "Nuclear Power: The Three Mile Island Accident and Its Investigation," Congressional Research Service Issue Brief No. IB79035, April 19, 1979.

[11]Electric Power Research Institute, "Analysis of Three Mile Island—Unit 2 Accident," NSAC-1, July 1979.

[12]USNRC, "TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations" (NUREG-0578), July 1979.

[13]USNRC, "Investigation Into the March 28, 1979 Three Mile Island Accident by the Office of Inspection and Enforcement" (NUREG-0600), August 1979.

[14]USNRC, "Report to the Director, Office of Inspection and Enforcement on Lessons Learned from Three Mile Island" (NUREG-0616 DRAFT), October 10, 1979.

[15]President's Commission on the Accident at Three Mile Island, "Report of the Office of Chief Counsel on the Role of the Managing Utility and Its Suppliers," October 31, 1979.

[16]USNRC, "TMI-2 Lessons Learned Task Force Final Report" (NUREG-0585), October 1979, at 3-1.

[17]USNRC, Special Inquiry Group, "Three Mile Island: A Report to the Commissioners and to the Public," January 1980.

[18]Government Accounting Office, "Opportunities to Improve the Effectiveness of the Nuclear Regulatory Commission." In preparation; draft forwarded for comment at NRC October 19, 1979. Restricted to official use.

[19]USNRC, Contract with System Safety, Inc., NRC-17-79-452, dated May 16, 1979.

[20]USNRC, Office of Public Affairs Release No. 79-104, "Attorney Mitchell Rogovin Named to Direct NRC's Special Inquiry Into Three Mile Island Accident," June 14, 1973.

[21]The Atomic Energy Act of 1954 as Amended, Public Law 83-703 (68 Stat. 919).

[22]The Energy Reorganization Act of 1974, Public Law 93-438 (88 Stat. 1233).

[23]Section 161(i)(3) of the Act of 1954 states the Commission is authorized to prescribe such regulations "to govern any activity pursuant to this Act, including standards and restrictions governing the design, location and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life and property." This comes in sequence within Section 161(i) after authorization to "protect Restricted Data" and "guard against the loss or diversion of any special nuclear material."

[24]See 5 above, at 8.

[25]USNRC, Memorandum from Leonard Bickwit, Jr., NRC, to Commissioners, NRC, Subject: Adequate Protection of the Health and Safety of the Public, October 18, 1979.

[26]U.S. Department of the Air Force, "USAF System Safety Programs," AF Regulation 800-16, June 6, 1979.

[27]George T. Mazuzan and Roger A. Trask, "An Outline History of Nuclear Regulation and Licensing, 1949–1979," April 1979.

[28]Black's Law Dictionary, 4th Ed. Rev.

[29]The Energy Reorganization Act of 1974 as amended. Sec. 205(f) Public Law 95-209 (91 Stat. 1482), 1977.

[30]Swain, Alan D., "Preliminary Human Factors Analysis of Zion Nuclear Power Plant" (NUREG 76-6503), October 1975.

[31]MORT, an acronym for Management Oversight Risk Tree: An approach to safety management based upon extensive use of logic diagrams. For a complete understanding of the concept, including its applications, refer to 32–47 below.

[32]U.S. Atomic Energy Commission, "MORT: The Management Oversight and Risk Tree" (SAN 821-2), February 12, 1973.

[33]EG&G Idaho, Inc., "Occupancy-Use Readiness Manual-Safety Considerations" (ERDA-76-45-1), September 1975.

[34]EG&G Idaho, Inc., "Reported Significant Observation (RSO) Studies" (ERDA-76-45-5), March 1976.

[35]Energy Research and Development Administration, "Accident-Incident Investigation Manual" (ERDA-76-20), August 1, 1975.

[36]Energy Research and Development Administration, "A Contractor Guide to Advance Preparation for Accident Investigation" (ERDA-76-45-3), March 1976.

[37]EG&G Idaho, Inc., "MORT User's Manual" (ERDA-76/45-4), November 1976.

[38]EG&G Idaho, Inc., "Standardization Guide for Construction and Use of MORT-Type Analytic Trees" (ERDA 76-45/8), February 1977.

[39]EG&G Idaho, Inc., "Safety Information System Guide" (ERDA 76-45/9), March 1977.

[40]EG&G Idaho, Inc., "MORT: A Safety Management Program Developed for ERDA" (ERDA 77-38), March 1977.

[41]EG&G Idaho, Inc., "Safety Information System Cataloging" (ERDA 76-45/10), May 1977.

[42]EG&G Idaho, Inc., "Risk Management Guide" (ERDA 76-45/11), June 1977.

[43]EG&G Idaho, Inc., "Safety Considerations in Evaluation of Maintenance Programs" (DOE 76-45/12), March 1978.

[44]James E. Davidson, "Practical Applications of MORT Concepts," Sandia Laboratories. Presented at the Professional Conference of the American Society of Safety Engineers, Washington, D.C., June 20, 1978.

[45]EG&G Idaho, Inc., "Events and Causal Factors Charting" (DOE 76-45/14), August 1978.

[46]EG&G Idaho, Inc., "Management Factors in Accident and Incident Prevention (Including Management Self Evaluation Checksheets)" (DOE-76-45/13), August 1978.

[47]EG&G Idaho, Inc., "Applications of MORT to Review of Safety Analysis" (SSDC-17), July 1979.

[48]Gerard Bruggink, "The Safety Role of Regulatory, Corporate and Personal Initiatives in the 80's." Presented at the U.S. Government Accounting Office Conference on Transportation Issues of the 1980's," Washington, D.C., June 19-20, 1979.

[49]General Accounting Office, Letter from P. B. Staats, Comptroller General of the U.S., to Hon. Richard S. Schweiker, Subject: Analysis of NRC's program for licensing nuclear power plant operators, dated May 15, 1979.

[50]The Energy Reorganization Act of 1974 as amended, Sec. 201, Public Law 94-79 (1975).

[51]USNRC, "The Safety of Nuclear Power Reactors (Light Water-Cooled and Related Facilities" (WASH 1250), Final Draft, July 1973.

[52]Letter from H. W. Lewis to Cong. Udall, Subject: Suggestion for an Independent Accident Investigation Activity, dated November 23, 1977.

[53]10 C.F.R. 50, "Domestic Licensing of Production and Utilization Facilities" (Title 10, Chapter 1, C.F.R.—Energy), at 50-50.

[54]T. J. Thompson and J. G. Beckerly, *The Technology of Nuclear Reactor Safety*, the MIT Press, Cambridge, Mass., 1977, at 2.

[55]The NRC's Office of General Counsel believes court interpretations of the NRC's authorities leave room for the Commission to treat economic factors "provided... public health and safety is consistently treated as a paramount consideration." However, AEC and NRC pronouncements to the contrary were also cited. See also reference 25, above.

[56]USNRC, Deposition of Roger Mattson, Director, Division of Systems Safety, NRC, by NRC/SIG, September 24, 1979, at 167.

[57]At a meeting of the Society of Air Safety Investigators, Washington, D.C., June 22, 1979.

[58]Letter from Chairman Hendrie, NRC, to Cong. Udall, Subject: Creation of a nuclear accident review board, August 7, 1978, at 1.

[59]Metropolitan Edison Co., "Preliminary Safety Analysis Report, Three Mile Island Nuclear Station-2," as amended through October 27, 1971, at 1-1a.

[60]Metropolitan Edison Co., "Final Safety Analysis Report, Three Mile Island-Unit 2," Docket No. 50-320 as amended through November 8, 1978, at 1.1-1.

[61]H. G. Rickover, Statement Before the Subcommittee on Energy Research and Development, House Committee on Science and Technology, Washington, D.C., May 24, 1979.

[62]USNRC, Deposition of Albert P. Kenneke, Acting Director, Office of Policy Evaluation, NRC, by NRC/SIG October 22, 1979, at 49.

[63]USNRC, Notes of Interview of Joseph M. Hendrie, Chairman, NRC, by C. O. Miller, NRC/SIG, October 29, 1979.

[64]USNRC, "Identification of Unresolved Safety Issues Relating to Nuclear Power Plants (NUREG-0510), January 1979.

[65]USNRC, Memorandum from J. S. Creswell to J. F. Streeter, Subject: Conveying New Information to Licensing Boards, Davis Besse Units 2 & 3 and Midland Units 1 & 2, dated January 8, 1979. The memo is an account of a precursor event occurring at the Davis Besse plant which, if adequately acted upon, had great potential for preventing the TMI accident.

[66]USNRC, "A survey of Policies and Procedures Applicable to the Expression of Differing Professional Opinions: For Comment" (NUREG-0500), July 1978.

[67]USNRC, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition" (NUREG-75/094), (Reg. Guide 1.70), September 1975.

[68]Essex Corporation, "Human Factors Evaluation of Control Room Design and Operator Performance at Three Mile Island-2," December 1979, at 23.

[69]USNRC, Minutes of the 234th Meeting of the Advisory Committee on Reactor Safeguards, Washington, D.C., October 4-5, 1979, at 202.

[70]See 16 above, at 1-2.

[71]Although a Federal Safety Council existed some years ago, its scope of activity did not encompass work as fundamental as indicated here. Presently, it is merely an Advisory Council to the Secretary of Labor on matters related only to Federal worker occupational safety and health.

[72]U.S. Department of Labor, Federal Advisory Council on Occupational Safety and Health, Articles of Organization, January 1975.

[73]See 5 above, at 25.

[74]USNRC Manual, Chapter 0502, "NRC Incident Reponse Program."

[75]USNRC, "Recommendations Related to the Brown's Ferry Fire" (NUREG 0050), February 1976.

[76]See 68 above, at 23.

[77]USNRC, "Reactor Safety Study: An Assessment of Accident Risks in the U.S. Commercial Nuclear Power Plants" (WASH 1400), October 1975.

[78]Letter from Cong. Udall to Chairman Hendrie, Subject: Suggestion for improved accident analysis and prevention, dated January 2, 1978.

[79]Letter from Stephan Lawroski, ACRS, to Cong. Udall, Subject: Establishment of a quasi-judicial board for accident analysis, dated June 8, 1978.

[80]Letter from H. W. Lewis to Cong. Udall, Subject: Suggestion for an "NTSB" for reactor safety, dated October 4, 1978.

[81]Letter from Chairman Hendrie, NRC, to Cong. Udall, Subject: Nuclear accident review board, dated November 28, 1978.

[82]IE's obligation is to "gather information in order to assist in NRC's independent evaluation of effects of the

incident to assess licensee compliance with plans and procedures." This is not investigation in a safety sense. See 74 above, at 13.

[83]Letter from Chairman Hendrie, NRC, to NRC Commissioners, Subject: Letters pertaining to independent accident investigation activities, dated December 5, 1978.

[84]USNRC, "Licensing Project Manager's Handbook," revised, December 30, 1977.

[85]National Aeronautics and Space Administration, "Facilities Assurance Plan," proposed chapter in the NASA Safety Manual 1700.1, June 21, 1979.

[86]See 69 above, at 227.

[87]*Id.*at 238.

[88]Prosser Torts, 4th Ed., Sec. 78.

[89]U.S. Department of Commerce, "Draft Uniform Product Liability Law," Sec. 106 and 107., F2Federal Register Vol. 44, No. 9, January 12, 1979, at 3006.

[90]Federal Tort Claims Act, 28 U.S.C.A., Sec. 2680(a).

[91]See 16 above, at 3-1.

[92]"American National Standard Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants," ANSI N 18.7-1976.

[93]USNRC, "Quality Assurance Program Requirements (Operation)" (Reg. Guide 1.33), February 1978.

[94]USNRC, "Safety Evaluation Report for TMI-2" (NUREG 0107), September 1976.

[95]USNRC, Deposition of Stephan H. Hanauer, Assistant Director, Plant Systems, by NRC/SIG, September 25, 1979, at 225.

[96]USNRC, "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants" (WASH 1400), (NUREG-75/014), October 1975.

[97]USNRC, "Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission" (NUREG/CR-400), September 1978.

[98]See 16 above at 4-2.

[99]U.S. Atomic Energy Commission, Letter from Donald F. Knuth, Subject: Criteria for Determining Enforcement Action and Categories of Non Compliance with AEC Regulatory Regulations-Modifications," Washington, D.C., December 31, 1974, at 1.

[100]USNRC, Letters from Max W. Carbon, ACRS, to Chairman Hendrie, Subject: NUREG-0600, Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement," dated November 14, 1979.

[101]C. O. Miller, "Hazard Analysis and Identification in System Safety Engineering," *1968 Annals of the Assurance Sciences*. New York: ASME, 1968.

[102]USNRC, "Standard Review Plan for the Review of Safety Analysis Reports" (NUREG-75/087), September 1975.

[103]USNRC, Letter from S. H. Hanauer, NRC, to Dr. William Brand, Subject: Use in the licensing process of failure modes and effects analysis, dated June 19, 1979.

[104]P.Rubel, "Bonsai; Cultivating the Logic Tree for Reactor Safety," *Proceedings 75 Annual Reliability and Maintainability Symposium*.

[105]Joseph R. Penland, "A Formulation of Risk Assessment and Allocation," *Proceedings 1975 Annual Reliability and Maintainability Symposium*.

[106]Westinghouse Nuclear Engineering Systems, "Reference Safety Analysis Report" (RESAR-411), October 1976, and Amendment 11, December 1977, at 6.3-53.

[107]Society of Automotive Engineers, Aerospace Recommended Practice, "Design Analysis Procedure for Failure Mode, Effects and Criticality Analysis (FMECA)," ARP 926, September 15, 1957.

[108]Society of Automotive Engineers, Aerospace Recommended Practice, "Fault/Failure Analysis Procedure," ARP 926A, November 15, 1979.

[109]S. H. Hanauer and P. A. Morris, "Technical Safety Issues for Large Nuclear Power Plants." Presented in Geneva, Switzerland, September 16, 1971.

[110]Willis M. Hawkins, "The Challenge to Take Intelligent Risks," *Aeronautics and Astronautics*, July/August 1979, at 36.

[111]USNRC, "Instructions for Preparation of Data Entry Sheets for Licensee Event Report (LER) File" (NUREG 0161), July 1977.

[112]USNRC, "Abnormal Occurrence Procedure." NRC Manual Chapter 0212.

[113]U.S. Government Accounting Office, "Reporting Unscheduled Events at Commercial Nuclear Facilities: Opportunities to Improve Nuclear Regulatory Commission Oversight," EMD-79-16, January 26, 1979.

[114]USNRC, Donald K. Davis et al., "NRC Task Force Report on Operational Safety Data Analysis and Evaluation," May 15, 1979.

[115]USNRC, "Recommendations on Operational Data Analysis and Evaluation of Nuclear Power Plants (Task Force)," SECY 79-371, May 15, 1979.

[116]USNRC, "Status Report-Office for Analysis and Evaluation of Operational Data," SECY 79-371A, November 21, 1979.

[117]Federal Aviation Administration, "Aviation Safety Reporting Program" (Advisory Circular 00-46B), June 15, 1979. Attention is called to the highly successful Aviation Safety Reporting System underwritten by the Federal Aviation Administration but directed, in the interests of objectivity, by the National Aeronautics and Space Administration. This project has proven highly beneficial in illuminating otherwise hidden flaws in the aviation system and has surmounted numerous attitudinal and legal problems implicit in human error reporting programs.

[118]U.S. Atomic Energy Commission, "Evaluation of Incidents of Primary Coolant Release from Operating Boiling Water Reactors" (WASH 1260), October 30, 1972, at 32-35, 39, 44.

[119]USNRC, "Free Flow of Internal Information and Viewpoints," Announcement No. 209, February 11, 1976.

[120]USNRC, "Proposed Policy and Procedures for Differing Professional Opinions" (NUREG 0567), October 1979.

[121]See 62 above, at 42, 58.

[122]S. Lawroski and D. W. Moeller, "Advisory Committee on Reactor Safeguards: Its Role in Nuclear Safety," *Nuclear Safety*, July-August 1979, at 388.

[123]U.S. Department of Labor, "Report to the President, Mission Safety-70." Washington, D.C., September 1965.

[124]See 5 above, at 54.

[125]Jerome D. Frank, "Galloping Technology: A New Social Disease," *ETC*, Vol XXV, No. 1, March 1968.

V SIG DEPOSITIONS AND INTERVIEWS

WITNESS	POSITION AND ORGANIZATION	DATE
ABRAHAM, Karl	Public Affairs Officer, IE-Region I, NRC	9/24/79
ACKERMANN, Norbert	President, Technology for Energy Corp.	10/25/79
ACRS Members	ACRS	10/6/79
ADAMCIK, Robert	Region III Director, FDAA, HUD	10/25/79
AHEARNE, John	Commissioner, NRC	10/12/79
ALLENSPACH, Fredrick	Technical Reviewer, Quality Assurance Branch, DPM, NRR, NRC	9/12/79
AMYOT, Dennis	Regional Director, Emergency Planning, Canada	12/11-12/79
ANDERSON, Donald	Principal Inspector, Vendor Section Branch, IE-Region IV, NRC	9/7/79
ANDERSON, John	Refueling Coordinator and Acting Quality Control Manager at ANO, Arkansas Power & Light	11/28/79
ANDERSON, Thomas M.	Manager, Nuclear Safety Dept., Nuclear Technology Division, Westinghouse	11/28/79
ANGELO, John	Project Manager, DPM, NRR, NRC	9/17/79
ARNOLD, Robert	Vice President, Generation, GPUSC	9/24/79
BAKER, Robert, Commander	White House Communications Agency	11/19/79
BARRETT, Lake H.	Section Leader, Environmental Evaluation Branch, DOR, NRR, NRC	8/28/79
BAUNACK, Walter	Reactor Inspector, IE-Region I, NRC	10/11/79
BEERS, Marshall	Group Supervisor, Nuclear Training, Met Ed	8/14/79
BILLS, Matthew	Assoc. Deputy Asst. Administrator, EPA	6/27/79
BLOSSER, Thomas	Director, Office of Emergency Preparedness, Cumberland Co., PA	8/14/79

WITNESS	POSITION AND ORGANIZATION	DATE
BORES, Robert	Radiation Specialist, IE-Region I, NRC	8/22/79 & 11/8/79
BOYER, Robert	Director, Emergency Mgmt., Lebanon Co., PA	8/17/79
BRADFORD, Peter	Commissioner, NRC	10/19/79
BRETTHAUER, Erich	Director, Nuclear Radiation Assessment Division, EMSL, EPA, Las Vegas	7/16/79
BRINKMAN, Donald	Technical Reviewer, DOR, NRR, NRC	10/19/79
BROWN, Robert	District Manager, USPS, Harrisburg, PA	9/20/79
BRYAN, Kenneth	Shift Supervisor-Nuclear, TMI, Met Ed	10/11/79
CARRICKER, Wendell	Materials Transportation Bureau, U.S. Department of Transportation	8/9/79
CARROLL, Robert, Brigadier General	Deputy Adjutant General, PA National Guard	8/15/79
CASE, Edson	Deputy Director, NRR, NRC	10/18/79 10/24/79
CAVANAUGH, William	Vice President, Generation & Construction, Arkansas Power & Light	11/27/79
CHASE, Emery	DoD	8/13/79
CHERRY, Bernard	Vice President, Corporate Planning, GPU	10/23/79
CHWASTYK, Joseph	Shift Supervisor-Nuclear, TMI, Met Ed	10/11,30/79
COBEAN, Warren	Vice President, Project Operations Div., Burns & Roe	11/5/79
COLGAN, Paul	Program Coordinator, SBA Regional Disaster Program	8/13/79
COLLINS, Douglas	Health Physics Inspector, IE-Region II, NRC	7/18/79
COLLINS, Harold	Asst. Dir. for Emergency Preparedness, OSP, NRC	9/19/79
COLLINS, John	Chief, Effluent Treatment Systems Branch, DSE, NRR, NRC	9/13/79
CONGEL, Frank	Section Leader, Radiological Assessment Branch, DSE, NRR, NRC	9/25/79
CORCORAN, Robert	Chief, Division of Radiation Control, Dept. of Health & Mental Hygiene, State of Maryland	8/22/79
CREITZ, Walter	President, Met Ed	10/23/79 11/16/79
CRESWELL, James	Reactor Inspector, IE-Region III, NRC	10/12/79 10/15/79
CRITCHLOW, Paul	Governor's Press Secretary, PA	10/12/79
CROWE, Charles	Nuclear Civil Protection Officer, PEMA	9/28/79
DAM, Allan S.	Project Manager, TMI-2, Burns & Roe	11/5/79
DARROW, William	Senior Vice Pres., Research & Medical Director, Wallace Labs., Division of Carter Wallace, Inc.	12/18/79
DAVIES, Sherwood	Director, Bureau of Radiological Health, New York State	9/25/79
DAVIS, Bobby J.	Supervisor, RAP team, DOE-Oak Ridge	8/10/79
DAVIS, Don	Head of Task Force on Need for Systematic Evaluation of Operating Information, NRC	8/22/79 9/23/79
DAVIS, John G.	Deputy Director, NMSS, NRC	9/11/79 & 9/13/79
DAVIS, Sid	Director of News, Washington Bureau, NBC News	9/12/79

WITNESS	POSITION AND ORGANIZATION	DATE
DEAL, L. Joe	Chief, Environmental Protection and Public Safety Branch, DOE	7/31/79
DEDDENS, James	Manager, Project Management (Former Head of Engineering), B&W	10/16/79
DENTON, Harold	Director, NRR, NRC	9/19/79 10/4/79 & 10/23/79
DERIVAN, Michael	Requalification Instructor, Toledo Edison	10/10/79
DIECKAMP, Herman	President, Chief Operating Officer, GPU	10/3/79
DIRCKS, William	Director, NMSS, NRC	10/1/79
DONALDSON, Dale	Radiation Specialist, IE-Region I, NRC	7/13/79 7/18/79 & 8/23/79
DOORE, G. Stanley	Meteorologist, NOAA, Department of Commerce	7/27/79
DORNSIFE, William	Nuclear Engineer, PA Bureau of Radiological Protection	9/19/79
DOYLE, Larry	Northeast Bureau Chief, CBS News	7/25/79
DUBIEL, Richard	Supervisor, Radiation Protection & Chemistry, Met Ed	8/22/79 9/21/79
DUNN, Bert	Unit Manager, ECCS Unit, B&W	10/4/79
DUTRA, Ed	Bureau of Drugs, FDA	11/30/79
DVORCHAK, Bob	Bureau Chief, Harrisburg, PA, Associated Press	8/9/79
EBERSOLE, Jesse	ACRS	8/10/79
EISENHOWER, Elmer	Chief, Office of Radiation Measurement, NBS	7/2/79
EISENHUT, Darrell	Deputy Director, DOR, NRR, NRC	10/11/79
ELLIOTT, Norman	Manager, Training Services, B&W	10/17/79
ENGLE, Leon	Project Manager, DPM, NRR, NRC	8/9/79
ESSIG, Thomas	Section Chief, Fuel Facility & Material Safety Branch, IE-Region III, NRC	7/14/79 7/18/79
EVAN, Maj. George	Disaster Control Officer, PA State Police	8/30/79
FABIAN, Blaine	Manager, Communication Services, Met Ed	8/28/79 10/15/79
FAIST, Fred	Resident Engineer, TMI-1, B&W	10/19/79
FAUST, Craig	Control Room Operator, TMI, Met Ed	9/11/79
FERGUSON, Dale	Health Physics Technical Manager, Nuclear Support Services, Inc.	10/8/79
FISHER, Eugene	Chief, Bureau of Radiation Protection, N.J. State Dept. of Envir. Protection	9/21/79 9/25/79
FLOYD, James	Supervisor of Operations, Unit-2, Met Ed	9/13/79
FOSTER, James	Investigation Specialist, IE-Region III, NRC	8/22/79
FOUCHARD, Joseph	Director, Office of Public Affairs, NRC	9/17/79
FRALEY, Ray	Executive Director, ACRS	8/27/79
FREDERICK, Edward	Control Room Operator, TMI-2, Met Ed	9/11/79
FRIESS, Robert	Technical Assistant to the Area Manager, Brookhaven Area Office, DOE	7/6/79
FRY, David	Civil Defense Director, Perry Co., PA	8/27/79
FURRER, Robert	Management Analyst, PA Dept. of Agriculture	8/24/79
GAHAN, Edward	Senior Supervising Nuclear Engineer, Burns and Roe	9/26/79
GALLINA, Charles	Investigation Specialist, IE-Region I, NRC	9/14/79
GARRETT, Ralph	FEMA	9/18/79

WITNESS	POSITION AND ORGANIZATION	DATE
GERECKE, Kenneth	Asst. Adminstration for Technical Support, Region III, OSHA	9/17/79
GERUSKY, Thomas	Director, Bureau of Radiation Protection, PA. Dept. of Environmental Resources	9/19/79
GIBSON, Albert	Chief, Radiation Support Section, IE-Region II, NRC	9/25/79 9/26/79
GILINSKY, Victor	Commissioner, NRC	10/5/79
GILRAY, John	Technical Reviewer, Quality Assurance Branch, DPM, NRR, NRC	9/17/79
GOSSICK, Lee	Exec. Director for Operations, NRC	9/28/79 10/23/79 & 10/29/79
GOTTILLA, Salvatore	Senior Supervising Engineer in Instrumentation and Control, Burns and Roe	9/17/79
GRABER, William	Manager of Radiological Control, Training & Planning, Electric Boat, Division, Gen. Dynamics Corp.	9/6/79
GRAHAM, John	Treasurer, GPU	9/26/79
GREGER, Robert	Radiation Specialist, IE-Region III, NRC	9/25/79 9/26/79
GREGORY, Bettina	Correspondent, ABC News	8/6/79
GRIER, Boyce	Director, IE-Region I, NRC	9/28/79 10/12/79
GRIMES, Brian	Asst. Director for Engineering and Projects, DOR, NRR, NRC	9/18/79
HAASS, Walter	Chief, Quality Assurance Branch, DPM, NRR, NRC	9/19/79
HALLER, Norman	Director, Office of Management & Program Analysis, NRC	10/11/79
HALLMAN, Donald	Manager, Plant Performance Section, B&W	10/4/79
HALPERIN, Jerome	Deputy Director, Bureau of Drugs, FDA	12/19/79
HANAUER, Stephen	Asst. Director for Plant Systems, DSS, NRR, NRC	9/25/79 9/26/79
HARPSTER, Terry	Reactor Inspector, IE-Region III, NRC	8/30/79
HARTMAN, Harold	Formerly Control Room Operator, TMI, Met Ed	10/29/79
HAVERKAMP, Donald	Reactor Inspector, IE-Region I, NRC	9/12/79 9/18/79
HEISHMAN, Robert	Chief, Reactor Operations and Nuclear Support Branch, IE-Region III, NRC	8/23/79
HELGESON, G. L.	President, Helgeson Nuclear Service, Inc., Pleasanton, CA	7/3/79
HENDERSON, Oran	Director, PEMA	9/20/79
HENDRIE, Joseph	Chairman, NRC	10/9/79
HERBEIN, John	Vice President, Generation, Met Ed	9/19/79 11/7/79
HEUBNER, Arthur	Director, Radiation Control, Dept. of Environmental Protection, CT	11/20/79
HEWARD, Richard	Manager of Projects, GPUSC	9/25/79
HIGGINBOTHAM, Leo	Asst. Director, Division of Fuel Facilities and Materials Safety Inspections, IE, NRC	9/24/79
HIGGINS, James	Reactor Inspector, IE-Region I, NRC	9/13/79

WITNESS	POSITION AND ORGANIZATION	DATE
HILBISH, John	Supervisor of Licensing, Met Ed	9/5/79
HITZ, Gregory	Shift Supervisor, TMI, Met Ed	9/12/79
HOLCOMBE, Edward	Comptroller, GPU & V-P-Compt., GPUSC	9/26/79
HOLMES, Ashley	Chief, Reports Group, ODRR, FEMA	8/29/79
HUNTER, Dorwin	Reactor Inspector, IE-Region III, NRC	12/30/79
HUNTLEY, Donald	District Manager, Coal Mine Safety & Health, Dist. 2, U.S. Dept of Labor, Pittsburgh	9/10/79
HYDE, Richard	Senior Vice President, Hill & Knowlton	8/15/79
INGRAM, Frank	Asst. to the Director, OPA, NRC	9/28/79
ISRAEL, Sanford	Section Leader, Reactor Systems Branch, DSS, NRR, NRC	7/31/79
JACKSON, Leslie	Director, York Co. Emergency Management Office	8/14/79
JACOBS, Ralph	Manager, Instrument Services, Rad Services, Inc.	10/8/79
JAMGOCHIAN, Michael	Site Designation Standards Branch, DSHSS, SD, NRC	9/10/79
JANOUSKI, Michael	Senior Rad. Chem. Tech., Met Ed	9/19/79
JONES, Robert	Supervisory Engineer, ECCS Analysis, B&W	10/3/79
JORDAN, Edward	Asst. Director for Technical Programs, IE, NRC	9/11/79
JUDD, Alfred	Federal Regional Council	11/7/79
KARRASCH, Bruce	Manager, Plant Integration Unit, Plant Design Section, Engr. Dept., B&W	10/3/79
KAUFMAN, Nick	Director, LOFT, EG&G of Idaho, Inc.	9/26/79
KEATON, Robert	Manager of Systems Engineering, GPUSC	10/10/79
KEIMIG, Richard	Section Chief, Reactor Operations & Nuclear Support Branch, IE-Region I, NRC	9/14/79
KELLOGG, Paul	Section Chief, Reactor Operations & Nuclear Support Branch, IE-Region II, NRC	9/28/79
KELLY, Joseph	Principal Engineer, Plant Integration Division, B&W	10/2/79
KENNEDY, Richard	Commissioner, NRC	10/2/79
KENNEKE, Albert	Asst. Director for Technical Review, OPE, NRC	10/22/79
KEPPLER, James	Director, IE-Region III, NRC	8/24/79
KERR, Vernon	Chief, Telecommunications Branch, ADM, NRC	8/15/79
KIRKPATRICK, Donald	Reactor Engineer, Technical Programs, IE, NRC	10/18/79
KLINGAMAN, Richard	Manager of Plant Engineering, Reading, Met Ed	8/30/79
KLINGLER, Gerald	Senior Reactor Inspection Specialist, IE, NRC	11/7/79
KNOP, Richard	Section Chief, Reactor Construction and Engineering Support Branch, IE-Region III, NRC	8/23/79
KOHLER, Joel	Reactor Inspector, IE-Region III, NRC	8/24/79
KOSIBA, Richard	Manager, Customer Service Dept., Nucl. Power Generation Division, B&W	10/16/79
KUEHN, Carl	Warning & Communications Officer, PEMA	9/20/79
KUNDER, George	Unit-2 Superintendent Technical Support, Met Ed	8/13/79 9/18/79

WITNESS	POSITION AND ORGANIZATION	DATE
KUNKEL, James	Manager, Procurement, Met Ed	8/30/79
LAGEMAN, A. G.	Div. Superintendent, Harrisburg Div., CONRAIL	8/17/79
LAMISON, Kenneth	Operations Officer, PEMA	9/20/79
LANDRY, Leonard	Health Physics Engineer, Met Ed	10/9/79
LANE, Rick	Manager, Mechanical Engineering, Arkansas Power & Light	11/27/79
LATHAM, Lee	FBI	11/29/79
LAZARUS, William	Reactor Inspector, IE-Region I, NRC	9/13/79
LEE, Byron	Vice President, Commonwealth Edison Co.	9/5/79
LEE, William	President, Duke Power Co.	10/5/79
LEESE, Paul	Director, Lancaster Co. Emergency Management Agency, PA	8/16/79 9/27/79
LENGEL, Robert	Shift Engineer, Met Ed	10/11/79
LESTER, Martha	WHP Radio-TV Newsroom	10/24/79
LEVENSON, Milton	Director, Nuclear Power Division, EPRI	9/4/79
LEVINE, Saul	Director, RES, NRC	9/6/79
LEVY, Sol	Industry Consultant	9/27/79
LIEB, Melvin	Technical Engineer, Generation Division, Met Ed	10/24/79
LIGHTLE, Robert	Assoc. Project Manager, B&W	10/3/79
LIMROTH, David	Superintendent, Admin. & Tech. Support, Met Ed	8/30/79 10/9/79
LOGAN, Joseph	Superintendent, TMI-2, Met Ed	9/12/79
LONG, Robert	Director of Reliability Engineering, GPU	10/4/79
LOTT, Doris	York County Emergency Management, PA	11/20/79
LOUNSBURY, Roy, Colonel	Director, Div. of Safety, Envir. and Emergency Actions, DOE	7/5/79
LOWE, William	Pickard, Lowe and Garrick	12/4/79
MALSCH, Martin	Office of General Counsel, NRC	10/30/79
MARTIN, James	DSE, NRC	6/22/79
MATTSON, Roger	Director, DSS, NRR, NRC	9/24/79 10/17/79
MAYERCHECK, Donald	Tech. Rep. Nucl. Filter Systems Div., Mine Safety Appliances Co.	8/10/79
MAZETIS, Gerald	Section Leader, Reactor Systems Branch, DSS, NRR, NRC	8/8/79
McADOO, John	Asst. Manager, Nuclear Safety Dept., Nuc. Tech. Div., Westinghouse	11/28/79
McCONNELL, James	Manager, Technology Assessment and Development, GPU	9/14/79
McCONNELL, John	Asst. Associate Director for Population Preparedness, FEMA	8/13/79 & 12/11-12/79
McCORMICK, Frank	Group Supervisor, Technical Training, TMI, Met Ed	10/8/79
McINTIRE, Daniel	GPUSC	9/4/79
McKEE, Kenneth	Communications Services Dept., GPU	10/4/79
McNAMARA, Eugene	Chief, Div. of Forest Protection, Bureau of Forestry, PA	8/16/79
McWILLIAMS, Jim	Asst. Operations Superintendent, ANO Unit-1, Arkansas Power & Light	11/28/79
MEHLER, Brian	Shift Supervisor, TMI, Met Ed	10/11/79 10/30/79

WITNESS	POSITION AND ORGANIZATION	DATE
MICHELSON, Carlyle	Consultant, ACRS	9/6/79
MILLER, Fred	Plant Nuclear Systems Engineer, Power Engineering Division, Toledo Edison Company	10/11/79
MILLER, Gary	Station Manager, TMI, Met Ed	9/20/79 10/29/79
MINOGUE, Robert	Director, SD, NRC	9/26/79
MOLLOY, Kevin	Director, Office of Emergency Preparedness, Dauphin Co., PA	9/21/79
MOSELEY, Norman	Director, Div. of Reactor Operations Insp ction, IE, NRC	9/25/79 9/27/79
MULLEAVY, Thomas	Supervisor, Radiation Protection, TMI, Met Ed	9/20/79
MURRAY, Blaine	Radiation Specialist, IE-Region IV, NRC	9/25/79 9/26/79
MURRAY, Terry	Plant Superintendent, Davis Besse, Toledo Edison	10/22/79
MURRAY, William	Vice President, Communications, GPUSC	8/31/79 10/4/79
MYERS, Melvin	Formerly Office of Asst. Administrator for R&D, EPA	8/1/79
NAGLE, Earl	Vice President, Group Manager, Construction Division, United Engineers	9/25/79
NARROW, Lewis	Reactor inspector, IE-Region I, NRC	9/20/79
NEELY, Donald	Senior Radiological Inspector, IE-Region I, NRC.	9/25/79 9/26/79 & 10/12/79
NEWBERRY, Scott	Technical Reviewer, DSS, NRR, NRC	8/15/79
NIMITZ, Ronald	Radiation Specialist-Reactor Health Physics, IE-Region 1, NRC	11/2/79 11/21/79
NITTI, Donald	Engineer, B&W	10/11/79
NOOP, William	West Virginia News Editor, UPI, PA	8/20/79
NOVAK, Thomas	Chief, Reactor Systems Branch, DSS, NRR, NRC	7/31/79
NRR RADIATION PROTECTION PERSONNEL	NRR, NRC	10/19/79
OBOLD, Charles	Commanding Officer, Group 1100, Civil Air Patrol, Reading, PA	8/27/79
O'TOOLE, Thomas	Reporter, Washington Post	10/18/79
OWEN, Warren	Senior Vice President, Engineering and Construction, Duke Power Company	9/12/79
PATTERSON, David	Chief Occupational Safety BD, DOE	7/31/79
POPE, Norman	Superintendent of Operations, Oconee 1-2-3, Duke Power Co.	10/29/79
PORCO, Richard	Filtration Engineer, Mine Safety Appliances Co.	10/25/79
PORTER, Ivan	Instrumentation & Control Engineer, TMI-2, Met Ed	10/30/79
PORTER, Sydney	President, Porter-Gertz Consultants	10/5/79
POTTER, Tom	Pickard, Lowe & Garrick	6/20/79
PREWITT, Daniel	Asst. Director for Disaster Services, Eastern Field Office, ARC	9/25/79
PRUCHA, R. J.	Food Safety and Quality Service, USDA	8/21/79
RAYMOND, William	Reactor Inspector, IE-Region I, NRC	10/12/79
REID, Robert	Chief, Operating Reactors Branch No. 4, DOR, NRR, NRC	8/27/79

WITNESS	POSITION AND ORGANIZATION	DATE
REILLY, Margaret	Chief, Div. of Environmental Radiation, Bur. of Rad. Protection, State of PA	9/19/79
RIEHL, Wilbur	Deputy Director, Non-Metallic Materials Lab. at Marshall Space Flight Center, NASA	8/8/79 8/10/79
ROGERS, Leland	Site Manager, TMI, B&W	10/11/79
ROSENFELD, Stephan	Press Secretary & Special Asst. to the Attorney General, Dept. of Justice, Commonwealth of PA	8/16/79
ROSS, Denwood	Deputy Director, DPM, NRR, NRC	9/28/79
ROSS, Michael	Supervisor of Operations, TMI-1, Met Ed	9/18/79 10/30/79
ROY, Donald	Engineer, B&W	10/15/79
RUETER, Don	Director, Technical & Environmental Services, Arkansas Power & Light	11/27/79
RUHLMAN, William	Reactor Inspector, IE-Region II, NRC	9/6/79
SAGE, James	DOE, Pittsburgh	8/22/79
SANDMAN, Roger	Deputy Director, Office of Governmental Affairs, USDA	8/9/79
SCHAEDEL, Edwin	Site Operations Engineer, TMI, B&W	10/11/79
SCHAEFFER, Ivan	Regional Managing Director, Philadelphia, ICC	9/24/79
SCHEIMANN, Frederick	Shift Foreman, TMI-2, Met Ed	9/11/79
SCRANTON, William	Lt. Governor, Pennsylvania	11/23/79
SEARS, John	Technical Reviewer, Environmental Evaluation Branch, DOR, NRR, NRC	10/11/79
SEELINGER, James	Unit-2 Superintendent, Technical Support, TMI, Met Ed	8/14/79 9/5/79
SELDOMRIDGE, Howard	Communications Services Dept., Met Ed	10/3/79
SEYFRIT, Karl	Director, IE-Region IV, NRC	9/4/79
SHAPAR, Howard	Director, OELD, NRC	10/1/79
SHEPHARD, Gary	Correspondent, CBS Network News	7/25/79
SILVER, Harley	Project Manager, DPM, NRR, NRC	7/23/79
SIMPSON, Richard	Director, Bur. of Regulation of Rates & Policies, PA. Insurance Dept,	8/16/79
SMITH, George	Chief, Fuel Facility & Material Safety Branch, IE-Region I, NRC	10/11/79
SNIEZEK, James	Director, Div. of Fuel Facility & Materials Safety Inspection, IE, NRC	9/24/79
SPANGLER, William	Manager, Plant Startup Services, Nuclear Power Generation Division, B&W	10/16/79
STAHLE, Carl	Project Manager, DPM, NRR, NRC	8/9/79
STELLO, Victor	Director, IE, NRC 10/10/79, 10/11/79 &	9/12/79 10/30/79
STERN, Fred	Vice President, Products, Services & Development, Combustion Engineering	10/26/79
STERNBERG, Daniel	Section Chief, Reactor Operations Branch, IE-Region V, NRC	8/3/79
STOHR, John	Section Chief, Fuels Facilities and Materials Safety Branch, Region I, NRC	9/7/79
STOLZ, John	Chief, LWR Branch No. 1, DPM, NRR, NRC	8/16/79
STONE, James	Reactor Inspection Specialist, IE, NRC	10/16/79
STOREY, James	Supervisor of Security, Met Ed	11/9/79

WITNESS	POSITION AND ORGANIZATION	DATE
STREETER, John	Section Chief, Reactor Operations and Nuclear Support Branch, IE-Region III, NRC	9/26/79
SUTER, Simeon	Emergency Planning Officer, Bureau of Maintenance, PA. Dept. of Transportation	8/22/79
TAMBLING, Thomas	Reactor Inspector, IE-Region III, NRC	8/22/79 8/23/79
TAYLOR, James	Manager of Licensing, B&W	10/5/79
TENNILL, Major	Public Affairs Officer, PA National Guard	10/1/79
TERPILAK, Michael	Chief, Standards and Regulation Branch, Div. of Compliance, BRH, HEW	7/27/79 8/31/79
THOMPSON, Dudley	Acting Deputy Director, IE, NRC	9/21/79
THORNBURG, Harold	Director, Div. of Reactor Construction Inspection, IE, NRC	9/7/79
THORNBURGH, Richard	Governor, State of Pennsylvania	11/23/79
TOOLE, Ronald	Unit Superintendent, Units 1 & 2, Homer City Power Plant, Homer City, PA, GPUSC	9/26/79
TROFFER, George	Manager, Generation Quality Assurance, Met Ed	8/28/79
TSAGGARIS, Alexis	Supervisor, Station Maintenance, Titus Station, Met Ed	7/18/79 7/24/79
VARGA, Steven	Chief, LWR Branch No. 4, DPM, NRR, NRC	8/8/79 8/15/79 & 8/16/79
VASSALLO, Domenic	Asst. Director for Light Water Reactors, DPM, NRR, NRC	9/5/79
VELEZ, Peter	Radiation Protection Foreman, TMI, Met Ed	9/19/79
VOLLMER, Richard	Director, TMI-2 Support and Acting Asst. Dir. for Systematic Evaluation Program, DOR, NRR, NRC	9/21/79
WALDMAN, Jay	Executive Asst. to the Governor, PA.	10/12/79
WALTERS, Frank	Supervisory Engineer, Plant Performance Services, Operating Reactor Group (Customer Svc.), B&W	10/2/79
WARD, E. Grant	Senior Project Manager, B&W	10/17/79
WASHBURN, Beverly	Reactor Safety Researcher, Univ. of Calif., Los Alamos Scientific Laboratory	9/5/79
WEISS, Bernard	Sr. Technical Operations Specialist, Exec Off. for Operations Support, IE, NRC	9/17/79
WEISS, Seymour	Section Leader, Reactor Safety Branch, DOR, NRR, NRC	9/5/79
W CH, Emmett	Deputy Secy. for Admin., Dept. of Health, Commonwealth of PA	8/29/79 12/4/79
WE SLAWSKI, Frank	Chief, Reactor Radiation Safety Section, IE-Region V, NRC	9/25/79 9/26/79
WILBURN, Robert	Secretary of Budget & Administration, Commonwealth. of PA	9/19/79
WILLIAMS, James	Nuclear Preparedness Officer, Ohio Disaster Services Agency	9/20/79
WILLIAMS, Ronald	Senior Consultant, Generation Div., GPUSC	10/9/79
WILLIAMSON, Craig	Deputy Director, PEMA	9/28/79 10/12/79
WILSON, Jack	Director, Boise Interagency Fire Center, Bur. of Land Management, Dept. of the Interior	9/11/79
WILSON, James	Executive Director, PA. Turnpike Commission	8/17/79

8

WITNESS	POSITION AND ORGANIZATION	DATE
WILSON, Richard	Director, Technical Functions, GPU	8/29/79 10/8/79
WOLZEIN, Tom	Producer, NBC News	7/26/79
WOMACK, Edgar	Manager of Plant Design, B&W	10/15/79
WOOD, James	Assoc. Deputy Director, Office of Governmental Affairs, USDA	8/9/79
WOODARD, Keith	Pickard, Lowe and Garrick	6/20/79
WOODRUFF, Roger	Senior Reactor Inspections Specialist, IE, NRC	8/9/79
YARLETT, Earl	Commanding Officer, Capitol City Cadet Squadron, Group 30, Civil Air Patrol	8/21/79
YBARRANDO, Lawrence	Director, Water Reactor Research, EG&G of Idaho, Inc.	9/26/79
YUHAS, Gregory	Radiation Specialist, IE-Region I, NRC	7/18/79
ZEBROSKI, Edwin	Director, Nuclear Safety Analysis Center, Electric Power Research Institute	9/27/79
ZECHMAN, Richard	Supervisor of Training, Met Ed	9/14/79
ZEWE, William	Shift Supervisor, TMI, Met Ed	9/11/79

VI COMPARISON OF THE SIG RECOMMENDATIONS IN VOLUME I WITH THOSE OF THE PRESIDENT'S COMMISSION AND THE NRR/NRC LESSONS LEARNED TASK FORCE

INTRODUCTION

This appendix provides a comparison of the three subject sets of recommendations to provide a general cross reference as to where recommendations in similar subject areas might be found. No attempt is made to characterize the nature of the recommendations. The purpose of this presentation is to provide a quick overview of the scope of recommendations for each, as well as page references for these recommendations.

The purpose of this is to provide an easy reference to the exact wording and context of a particular recommendation. The Special Inquiry Group makes no representation as to the completeness of these references; this analysis is provided only as an aid to the reader, not as a substitute for reading and fully understanding the source documents.

The source documents used in the preparation of the following table are:

1. Special Inquiry:
   Three Mile Island: A Report to the Commissioners and to the Public, Volume I.
2. President's Commission:
   Report of the President's Commission on the Accident at Three Mile Island.
3. Lessons Learned:
   (ST)TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations, NUREG-0578.
   (LT)Lessons Learned Task Force Final Report, NUREG-0585.

For the Special Inquiry and the President's Commission Reports only the principal, clearly identified recommendations are referenced in the table. No attempt was made to reference other important recommendations that may be found in:

1. The supporting text of the referenced documents;
2. Documents containing differing opinions, such as those of the President's Commission;
3. Other documents, such as various staff reports of the President's Commission.

Furthermore, the Lessons Learned documents contain numerous recommendations of varying importance. Judgment was used to identify the ones presented here. The attempt was to identify those which in our view are of comparable importance to the recommendations presented in Volume I of the Special Inquiry Report and in the President's Commission Report.

IDENTIFICATION OF RECOMMENDATIONS BY SUBJECT AREA

Area of Recommendation	Special Inquiry	President's Commission	Lessons Learned
	Page numbers		
A. General			
1. How Safe is Safe Enough?	91, 116 151	—	LT A15
2. Oversight Over the NRC	92, 93	62	—
3. Public Education	91, 154	77, 79	—
4. Moratorium or Suspension of Licensing Reviews	92, 146	64	—
5. Statutory Base	92	61	—
B. Evaluation of Operating Experience			
1. Basic Responsibility	97	66, 68 73	LT 4-6, A10, A13
2. Office of Analysis and Evaluation of Operating Data (AEOD)	99	66	LT A-1, 3-2
3. Inspection of Plants	100, 101	66, 67	LT A-8
4. Institute of Nuclear Power Operation (INPO)	97, 110	68	LT 2-4
C. Onsite Personnel and Procedures			
1. Training	105	63, 70 71	LT A1, 5, 6, 8; ST 12
2. Technical Expertise	106	69	ST 13; LT A5, 7
3. Station Manning	106	—	LT A8
4. Operating Procedures	146 Vol. II	69	LT A7, 9, 10; LT 2-5; ST 13
D. Industry-Wide Technical Resources			
1. Data and Analysis Centers	107, 108	—	ST 13
2. Industry-Wide Consortium	110	—	—
E. NRC Organization			
1. Single Chief Executive	115-117	61	—
2. Consolidation of Resources Devoted to Operating Reactors	99, 117	—	LT 4-5
3. Independent Nuclear Safety Board	118, 119	62	—
4. Advisory Committee on Reactor Safeguards	119	62	—

Area of Recommendation	Special Inquiry	President's Commission Page	Lessons Learned*
5. Project Management	119	—	—
6. Periodic Manager Reassignments	120	—	—
7. Staff Training	120	—	LT A16
8. Transfer of Non-Health and Safety Responsibilities	121	63	—
9. NRC Office Consolidation	117	61	—
10. Office of Research	—	63	—
F. Human Factors Engineering			
1. Instrumentation	127	72	LT A12, 13
2. Control Room Design	128	63	LT A11, 13
G. More Remote Siting and Improved Emergency Planning			
1. More Remote Siting	130, 131	64	—
2. Emergency Planning	130-133	64, 76, 77	—
3. NRC Emergency Response	134-136	63	LT A16
4. Radiological Monitoring	137	63, 77	—
H. Overhaul of the Licensing Process			
1. Advisory Committee on Reactor Safeguards	140	62	LT A16
2. Ex-Parte Rule	141	—	—
3. One-Step Licensing Process	141	65, 66	—
4. Atomic Safety and Licensing Appeal Board	140-142	65, 66	—
5. Rulemaking	142	65	—
6. Office of Public Counsel	143	66	—
7. Intervenor Funding	143, 144	—	—
8. Standardization	144	63	—
9. Regulatory Requirements Review Committee	146	—	—
10. Bases for Safety Reviews	148, 150, 151	63, 64, 72, 73	LT A14, 15, 16 3-1, 2; ST A45
I. Occupational and Public Health			
1. Occupational Health	155	75	—
2. Public Health	Vol. II	74, 75	—
J. Information Made Available to the News Media			
1. Emergency Response Planning	157	78	—
2. Principal Spokesperson	157	78, 79	—
3. Media Responsibilities	—	79	—
K. Disincentives to Safety			
1. NRC Evaluation of Utility Finances	164	—	—
2. Communication With Other Regulatory Bodies	164	69	—
L. Specific Hardware Modifications	127, 128 Vol. II	72	Many
M. Utility Organization			
1. Management Responsibilities	106, 110 Vol. II	64, 68 69	LT A11; ST 12, A56
N. Post-TMI Efforts			
1. Cleanup and Disposal	—	73	

FINDINGS AND RECOMMENDATIONS IN VOLUME II

The three-part Volume II is an integral part of the Special Inquiry Group Report and contains many detailed findings and recommendations. Some of these findings and recommendations are reflected in Volume I, but others are not. As an aid to the reader, the general subject of the findings or recommendations and the page number(s) where that finding or recommendation can be found are listed below. The reader is advised to refer to the appropriate sections of Volume II so that the meaning and importance of particular findings and recommendations can be judged in context.

Section	Subject	Category*	Pages
PART 1			
I.A.1.c	Licensing and Regulatory System: An overview of its major deficiencies in Assessing Reactor Safety	F & R	23-25
I.A.2	Relevant Staff Actions Taken Outside of the Adjudicatory Process	F	36
I.A.3.a	Regulatory Requirements Review Committee	F	40, 44
I.A.3.b	Quality Assurance	F	49, 50
I.A.3.c	Generic Issues	F	55
I.A.3.d	Technical Qualifications	F	57, 58
I.B.1	Licensing History of TMI-2	F & R	104-105
I.B.2	Operating History of TMI Nuclear Station	F	114
I.B.3	Inspection History at TMI Site	F	126
I.C.	Precursor Events	F & R	130, 135-138
	• Dopchie letter 4/27/71	F	140
	• BEZNAU Incident 8/20/74	F	141, 142
	• Reactor Safety Study 10/75	F	143, 144
	• Michelson Report 9/77	F	148, 149
	• Davis Besse 9/24/77	F	155, 156
	• Kelly-Dunn Memoranda 11/77	F	161
	• Pebble Springs ACRS Questions	F	164
	• Creswell Concerns 12/77	F	171-172
	• Israel-Novak Note 1/10/78	F	173
	• Rancho Seco – 3/78	F	175
	• TMI – 3/78 Sternberg memo	F	176
I.D.	Pressurizer Design and Performance: A Case Study	F & R	198-199
I.E.	Incentives to Begin "Commercial Operation"	F & R	204, 241-247

* F = Findings (or Conclusions)
R = Recommendations

Section	Subject	Category*	Pages
III.B.3.c	NRC Emergency Response	R	986-989
III.C.3	Federal and State Authorities and Responsibilities	F & R	1007-1009
III.C.4	Sheltering and Evacuation Advisories	F & R	1017-1018
III.C.5	Evacuation Planning Before and During the Accident	F & R	1024-1027
III.C.6	Other Protective Actions Considered By Officials	F & R	1033-1034
III.C.7	Radiological Monitoring Efforts	F & R	1038-1039
III.C.8	Institutional Communications During the Accident	F & R	1043-1044
III.C.9	Technical Support for the Plant	F	1045-1046
	Summary of Findings and Recommendations re: Federal and State Emergency Response		1046-1051
	• Root Cause	F & R	1046-1047
	• Siting	F & R	1047
	• Overall Institutional Coordination	F & R	1047-1048
	• Overall Emergency Planning	F & R	1048-1049
	• Evacuation	F & R	1049
	• Other Protective Actions	F & R	1049-1050
	• Radiological Monitoring Efforts	F & R	1050
	• Physical Communications	F & R	1050
	• The Act of Communicating	F & R	1050-1051
	• Comparison with the President's Commission	F	1051
III.D	News Media Interactions	F & R	1073-1075

INDEX

Volume II has many sections where there is substantial overlap of facts, analyses, findings, and recommendations contained in other sections. Such repetition was, to a large extent, unavoidable, because the report was generated by six task groups working substantially independently. However, each had areas of inquiry that of necessity overlapped those of one or more other task groups. Also, areas of intentional overlap exist because a particular event (such as the decision to advise the evacuation of pregnant women and young children) might logically be seen in a somewhat different light by, for example, the Governor of Pennsylvania and the Chairman of the Nuclear Regulatory Commission. We believe that such a perspective is useful to the reader.

The purpose of this index is, for those subjects that are discussed substantively in more than one location, generally to lead the reader to the various locations in Volume II where these discussions can be found. The purpose is *not* to provide a comprehensive, extremely detailed, and highly cross-referenced indexing of all possible subjects. For example, failure of the PORV valve to close is mentioned throughout the report (such as in all of the various chronologies), yet no attempt is made to reference all of these entries. References are only provided to substantive technical evaluations of this valve failure.