HARVARD UNIVERSITY

Prof. Richard Wilson
Department of Physics
Harvard University
17 Oxford Street,
Jefferson Physical Laboratory Room 257
Cambridge, MA 02138

Office Tel: (617) 495-3387
Office Fax: (617) 495-0416
website: http://physics.harvard.edu/~wilson

email: wilson5@fas.harvard.edu
DATE: May 18th 2012

Mailing Address
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
1-800-368-5642, 301-415-7000
TTD: 301-415-5575
11555 Rockville Pike
Rockville, MD 20852

Subject:
Pilgrim Nuclear Power Plant license and relicense

Dear Irs,

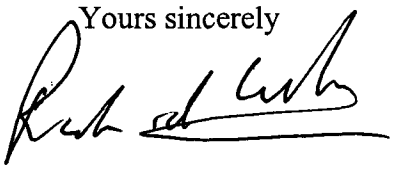
I know that you have been considering the relicense of this power plant since the application in 2006. That is a period of time longer than even the first license hearing!

I had the honor of being asked to be chairman of a special advisory board reporting to Governor King of the Commonwealth of Massachussets , in January 1990. I attach a copy of the report . The report implicitly accepted the federal preemption in matters of safety. I believe that every one of the rccommendations is still applicable today, have urged everyone concerned to consider them and while asking NRC to address appropriate questions and issues, to do so in a timely ashion and to recognize the reasons for federal preemption.

I am at your service to discuss this 1970 report, the safety of the neighboring nuclear power plants and the adequacy of the responses of the NRC commissioners and staff to the challenges produced by faced by the Tsunami in Japan

If there is a way of following the progress of this slow process, please let me know

Yours sincerely



Richard Wilson
Mallinckrodt Professor of Physics, (emeritus)

Encl. 1980 report

January 1980

Advisory Panel to the Governor and Cabinet Task Force On Nuclear Safety Following the Accident at the Three Mile Island Nuclear Power Station

Commonwealth of Massachusetts

Richard Wilson (Chairman)

Harvard University

George Rathjens

Massachusetts Institute of Technology

Susan Wiltshire

League of Women Voters

Contents

1. Introduction.....3

2. Summary of Recommendations.....6

3. Kemeny Report.....12

4. Operator Training.....14

5. Accident Prevention.....16

6. Radiation Monitoring in Massachusetts.....17

7. Radiation at Pilgrim I.....21

8. Accident Management.....22

9. Emergency Plans of Massachusetts.....24

10. Communications in the Event of an Accident.....26

11. Transportation of Radioactive Materials.....29

12. Waste Disposal.....32

13. Suitability of Plymouth as a Site for Pilgrim II.33

Appendix I. Events at Three Mile Island.....36

Appendix II. Review of Reports and List of Reports.....47

Appendix III. List of People at Meetings.....52

Appendix IV. Glossary.....57

Appendix V. Letters received.....63

1. Introduction

All of the United States was shaken by the reactor accident at Three Mile Island, near Harrisburg, Pennsylvania on the morning of Wednesday, 28 March 1979. The reactions of the power company, the neighborhood, the state and federal governments, the regulatory authorities, and the media (newspapers, radio, and TV) in the following days showed major deficiencies in preparedness for a major nuclear accident.

It is essential to learn what we can from the accident at Three Mile Island to help prevent a future accident with more grave consequences. Several studies and investigations have already been initiated. A committee appointed by President Carter and chaired by John G. Kemeny, President of Dartmouth College, has reported to the President; the Nuclear Regulatory Commission (NRC) is conducting on-going detailed reviews; and the Electric Power Research Institute (EPRI), the research arm of the electrical utility industry, has set up a Nuclear Safety Analysis Center which makes and publishes reports and analyses.

Each state which has or contemplates a nuclear power plant also has a responsibility to address the problems of public safety raised by Three Mile Island. In this context, Governor Edward King of the Commonwealth of Massachusetts established a Special Nuclear Cabinet Task Force to review the situation. The Cabinet Task Force is composed of the heads of the state agencies which have responsibility in the area: the Executive Office of Human Services, the Executive Office of Public Safety, the Executive Office of Environmental Affairs and the Massachusetts Office of Energy Resources.

Governor King also appointed this three person panel stating in a press release:

> "The reason for creating this panel...is to assess those reactor safety issues that will have an impact on the future of nuclear energy in Massachusetts...
>
> "No region of the country is more dependent on nuclear energy, and no greater potential exists for stabilizing our costs than the nuclear option. In fact, nuclear energy provides us with one third of our electricity needs and has saved New England consumers $500 million and 80 million barrels of high-priced residual fuel oil since its inception. The benefits are worth pursuing as long as the general public is confident that this technology does not pose unacceptable risks to our public health and welfare...
>
> "However...in light of the Three Mile Island incident, any further actions with regard to this state's involvement in licensing new reactors should not occur until we are certain

that every measure involving public safety and health, which could have precluded the incident in Pennsylvania, is in place in Massachusetts...

"As a result, I have appointed this distinguished panel and asked them to review the NRC's investigation of the Three Mile Island incident and report their findings to the Legislature and the Cabinet-level task force that I have appointed as soon as possible."

Discussions with the Governor, and with the Energy Committee of the Legislature, made it clear that the panel was to be independent of the legislative and executive bodies; and, that, within the broad responsibilities outlined in the Governor's press statement, the committee was to determine its own frame of reference. The panel regarded its responsibility as a task of prime importance.

As in the Kemeny study (report page 4) we did not attempt to reach a conclusion as to whether, as a matter of public policy, the development of commerical nuclear power should be continued or should not be continued. That would require a much broader investigation involving economic, environmental, and political considerations. This panel did not review the general status of nuclear power in Massachusetts. We felt that that larger question also involved too many issues for us to consider properly.

Because 33% of electric power in New England is now generated by nuclear plants we did make an initial assumption that nuclear power is likely to continue as a source of electricity in this state. In addition we proceeded on a premise that the generation of electricity by nuclear power involves a potentially dangerous technology which requires continuous and risorous care in its use. If in the course of our deliberations we had felt it was clear that the necessary care would be impossible, that the nuclear hardware would be so liable to failure that it should not continue to be used, or that human beings are so fallible that they could not operate this technology, we would have said so. Without going this far, we do say that people can be careless, that equipment may fail and that bad judgements are sometimes made. Our task was to point out approaches which might minimize the number of failures by people or machines and prevent the results of any failure from causing harm to the citizens of the Commonwealth.

Since the panel had limited personnal time and no funding or staff, it was not realistic for us to undertake the thorough independent review necessary to certify the adequacy of various state and utility actions and programs. Rather it was decided that the most useful contribution we could make within our resources would be to provide advice to the Cabinet Task Force about their

work and additional actions which could be considered.

To carry out this task the panel met with the Cabinet Task Force on May 15, 1979 and July 14, 1979, had three open public meetings on October 12, 1979, November 19, 1979 and December 14, 1979 as well as several other working meetings. We have reviewed a number of documents and solicited aid and clarification from state agencies, power companies, and the general public. A review and list of these documents and a list of letters are in the appendices.

Although many officials in the responsible state agencies have been working diligently to upgrade the preparedness of the Commonwealth for nuclear emergencies, the decision making level of the Cabinet Task Force is still in the early stage of its work. Therefore, in most cases our recommendations form a work program for the Cabinet Task Force.

We believe that the Commonwealth in its accident prevention management plans and evacuation plans must act in a prudently cautious manner and assume that accidents such as Three Mile Island can lead to meltdown and under some circumstances meltdown can lead to release of an appreciable fraction of the radioactivity in the core.

Finally, we wish to stress that nuclear safety demands continuous vigilance. It should not take a Three Mile Island in Massachusetts to ensure that the problem is treated with the needed urgency.

2. Summary of Principal Recommendations

The Panel has reviewed the report of the President's Commission on the accident at Three Mile Island (Kemeny Commission) and agrees with its recommendations almost in their entirety.

In most cases, our recommendations are based on the Kemeny recommendations pointing out those actions appropriate to the Commonwealth. After each recommendation, we note the section in which the subject of the recommendation is discussed in the detailed report which follows. The order in which our recommendations are listed follows the order of the Kemeny report.

1. The Cabinet Task Force should find out what actions the Nuclear Regulatory Commission (NRC) is taking in respect to Kemeny Commission recommendations A4a (P. 63) and C2 (P. 70) that the NRC operator and supervisor licensing functions be upgraded. The Cabinet Task Force should decide in the light of this information whether or not to support the proposal of the Department of Public Safety to widen the scope and increase the frequency of state licensing examinations. Our reading of the Kemeny recommendations and the present NRC role is that the NRC examinations will cover the nuclear aspects of the power system. If that is the case, the state examination emphasizing ordinary steam power operations is not a duplication and might therefore usefully be retained and strengthened. Possible use might be made of the large reservoir of talent in the Boston area to help in these examinations. (Section 4 of this report.)

2. The Cabinet Task Force should satisfy itself that the Energy Facilities Siting Council of the Commonwealth has the competence to address the siting issues discussed in Kemeny recommendations A6 (P. 64). The Kemeny report recommends that to the extent feasible, reactors be located remotely from concentrations of population. The existing reactors in Massachusetts were "grandfathered" (previous approval not re-examined) when the Siting Council was established. The Pilgrim II site was also grandfathered as an adjunct to Pilgrim I. However, Pilgrim II was not grandfathered under NRC rules and although testimony has been closed in the N.R.C. hearing, the Cabinet Task Force should consider whether the Siting Council or other agencies of the Commonwealth should take a position before the N.R.C. hearing board if this issue is reopened. (Section 13 of this report.)

3. The Cabinet Task Force should take a hard look at the

Kemeny recommendation A10a (P. 65), that duplicate consideration of issues be avoided whenever possible, and see to what extent the issues of importance to the Commonwealth can and should be considered at the same time, possibly in a simultaneous hearing with the considerations of those issues by the NRC.

4. The Cabinet Task Force should satisfy itself that Kemeny recommendations A11 a and b (P. 66) that there be systematic safety evaluation and assessment of experience in existing reactors, are being properly implemented. On paper these programs were already taking place before Three Mile Island, but the experience of Toledo Edison Co. in September 1977 which might have prevented mistakes by the Three Mile Island operators was not adequately used. If the Task Force is not satisfied, it should take further action--such as including these matters on the agenda of an independent safety committee established by the Commonwealth (see recommendation 6 below).

5. The Panel notes that the two nuclear power plants in the Commonwealth, Yankee Rowe and Pilgrim I, as well as Vermont Yankee, have separate safety groups reporting to high level management as recommended by Kemeny B2 (P. 68). We recommend that the committees include members with different training and background than normally found in utilities--such as a physicist and a chemical engineer and include members who obtain no more than 20% of their salary from the nuclear industry so that there can be no reasonable doubt about their independence. (Section 5 of this report.)

6. The Cabinet Task Force should review the safety committees noted above, and if they consider them inadequate should set up a Commonwealth safety committee. This committee should be a professional committee with adequate compensation. If Kemeny recommendation A3b (P. 62) is implemented, that the Advisory Committee on Reactor Safeguards (ACRS) of NRC not review individual reactors, this review could be a charge to a Commonwealth Safety Committee. (Sections 3 and 5 of this report.)

7. If a safety committee is set up by the Commonwealth it should include in its review the issues of recommendation B5 d of Kemeny (P. 69) that the utilities and suppliers systematically resolve safety questions in plant operations.

8. We particularly endorse the Kemeny recommendations B 3 (P. 69) that there be clearly defined roles and responsibility both during ordinary operation and during an emergency, and that the responsibility for operations during an emergency rests with the utility company. The Cabinet Task force should satisfy itself that these recommendations are implemented and that the rules and responsibilities be not merely defined but also written down, agreed to and understood by each and every person who is likely to be involved in an incident or its aftermath, including not only utility company employees but also the employees of every agency of state government concerned. (Sections 8, 9 and 10 of this report.)

9. The Cabinet Task Force should satisfy itself that the rate setting board of the Department of Public Utilities is allowing reasonable safety related charges to be reflected in the rate base.

10. The representatives of the utility companies informed us that they are improving operator training in accordance with Kemeny recommendation C 3d (P. 71) by increasing the frequency of simulator training from once a year to twice a year and by having accident scenarios incorporated in the simulator. We urge continued attention to this aspect of operator training. (Section 4 of this report.)

11. The Commonwealth, through its Department of Public Health and the Advisory Council on Radiation Protection should maintain its capability to monitor the exposure to radiation of various population groups in addition to the research proposal recommended by Kemeny (E1c, P. 74) to be coordinated by the National Institutes of Health (Section 7 of this report).

12. The Cabinet Task Force should determine whether there is adequate training for health professionals and emergency response personnel in radiation problems in the Commonwealth as recommended by Kemeny E3 (P. 74) and whether the personnel in the Nuclear Incident Advisory Teams (NIAT) are adequately trained and their level of training is known to those who would be in command in a nuclear incident. (Sections 6 and 9 of this report.)

We recommend that this program of education also be extended to those employed in the industry. In particular, employees should be altered to the ways they can reduce their own exposure, for example, by avoiding high radiation areas, and this awareness should be

reinforced regularly. (Section 7 of this report.)

13. The Commonwealth should verify that the monitoring of radiation is adequate in all circumstances as recommended by Kemeny E4 (P. 75). We are particularly concerned that the present stack gas monitors will overload during accident conditions (E4a). (Section 6 of this report.)

14. We recommend the Commonwealth obtain a supply of potassium iodide (or other thyroid blocking agent) and decide where it should be located (Kemeny recommendation E5, P. 75). Note should be taken of the fact that although potassium iodide has been approved as a drug by FDA, it should not be taken unless necessary because possible side effects are unknown. (Section 6 of this report.)

15. The emergency plans of the Commonwealth have recently been revised in accordance with Kemeny recommendation F1 (P. 76). The panel urge particular attention to clear and consistent delineation of the actions public officials and utility company officials should take. This delineation should also be well advertised so that the coordination recommended in F1c can be achieved. We also recommend that the Department of Public Health, clearly identify the criteria sussested in Kemeny F2a and that the Cabinet Task Force review that effort. (Sections 8, 9 and 10 of this report.)

16. We have some reservations about the practicality of Kemeny recommendation G1a (P. 78) that the utility company be responsible for the dissemination of information during an emergency. The utility company has the responsibility to determine the status of the power plant, whether, for example, a meltdown is possible or likely. However, even if information should be disseminated clearly by the highest possible technical official of the company, we are concerned about whether or not the information will be accepted as reliable due to the present lack of public confidence in utility companies. We anticipae that, as at Three Mile Island, an NRC official may have more public credibility, but in any case we do not feel there is a major role for the Commonwealth in dissemination of information about the status of the plant itself. (Section 10 of this report.)

17. In respect to recommendation G1b, we believe that everyone concerned in the Commonwealth should be clear in advance who should provide the information about radiological releases and evacuation plans. Several times in this

report we suggest circumstances where one or another agency of the Commonwealth--usually the Department of Public Health, should be officially designated the lead agency.

18. We concur in the recommendation of Kemeny F4 (P. 77) that the public must be informed about nuclear power. At present public information is often unreliable and incomplete. The principal role we see for the Commonwealth in this is education about emergency and public health planning and we applaud the actions already being taken by the Civil Defense director and the Department of Public Health in addressing public meetings, responding to questions and providing information. (Section 10 of this report.)

    We feel it is a general responsibility of technically informed people to share their information with others and encourage them to do so.

19. We concur with the recommendation G3 (P. 79) of Kemeny, that the newsmedia should improve their ability to cover a nuclear emergency in accordance with their responsibilities. In addition to the detailed list in Kemeny, we suggest that the media should be asked to print verbatim the official press releases of NRC and state officials as well as any interpretations the media may wish. The official releases are likely to be more complete and easily understood by the technical public than the press interpretations. The general public will turn for information analysis to those technical individuals in whom they have confidence, and the supplying of reliable and detailed information to the technical community is an important part of dissemination of information. (Section 10 of this report.)

20. We recommend, in the event that Pilgrim II is licensed, that the Cabinet Task Force consider whether the Department of Public Safety should be asked to inspect the work in progress as the D.P.S. suggests. (Section 13 of this report.)

21. The Cabinet Task Force should examine the relationship of the Commonwealth with the adjacent states (in particular, Vermont) in which a nuclear power plant exists. We have no good way of judging the existing situation with respect to emergency responses, operator training, and reactor safety, but what we have heard suggests that the interests of the Commonwealth may be served by a cooperative effort

to improve safety. (Sections 4 through 12 of this report.)

22. In view of the hearing of the U.S. Department of Transportation scheduled for February 1980, we are disappointed that the relevant agencies in the Commonwealth, the Department of Public Health, the Department of Transportation and the Massachussets Turnpike Authority do not appear to have made an effort to resolve differences they have with respect to a nuclear transportation policy. We are encouraged however, by the statements of December 14, 1979 that they will now meet and try to arrive at a common approach. We suggest guidelines for this in Section 11 of this report.

23. Under current practice spent fuel is being stored at the reactor site and will remain there until there is a plan to reprocess the fuel or store the fuel elsewhere. This is a situation not envisaged in the original plans. We recommend, therefore, that the Cabinet Task Force reexamine the situation to see whether the consequences of any possible accidents at these pools should be included in emergency planning. (Section 12 of this report.)

24. Although not directly related to reactor safety, the panel notes that the Commonwealth is at the mercy of decisions made by others when it sends wastes to repositories in other states. We accordingly recommend that the Cabinet Task Force consider whether it is appropriate to develop a repository within the state or region for low and/or medium level wastes--mostly hospital and laundry wastes with half lives less than 100 years. The analysis might be carried out in conjunction with the consideration of toxic waste disposal now in progress by the Executive office of Environmental Affairs. (Section 12 of this report.)

25. The Cabinet Task Force should review the problems of theft and sabotage at the nuclear reactor sites and the recommendations about this of the Rathjens committee. (Section 13 of this report.)

26. The Cabinet Task Force should consider whether a stack gas monitor be installed to read directly into a state building to give an immediate indication of problems. (Section 6 of this report.)

3. The Kemeny Report

The Kemeny Report, on which we have based most of our recommendations should be carefully read by all those in the industry and state government who have the responsibility for nuclear safety.

We note that the report emphasizes the human element at Three Mile Island. The statements by Herbert Diekamp, President of General Public Utilities, that the operators and staff at Three Mile Island were trained as well as any in the industry seem to be true as far as paper qualifications are concerned. However, the repeated statements of these same operators to the Kemeny Commission that they did not understand what was going on in the first 3 hours of the accident are a damning indictment of the training. We discuss this further in section 4 on operator training.

Among the many comments on regulation in the Kemeny report, it was noted that both in industry and in the NRC there is a preoccupation with meeting regulations, rather than addressing the safety issues directly.

The panel saw this clearly in its open meetings, as both industry and NRC representatives kept discussing whether or not the regulations had been met before and even instead of addressing the safety issues themselves. This is a dangerous trend but to a very considerable extent it is inevitable. One consequence of this method is the insistence on incorporating any safety idea into a regulation, before acting upon it. Writing a regulation and establishing its legality and workability, and abolishing or modifying regulations when appropriate are necessary and appropriate activities. However in this process both regulated and regulators may tend to forget the original objective of the regulation. We see a very useful role for the Commonwealth here, both in the licensing hearings and in continuous review subsequently. That is: to be certain the objective of public safety is not lost in the maze of procedure but is constantly used as the standard for measuring any action or regulation.

It appears to this panel that an independent review of crucial issues by a committee appointed by and responsible to the Commonwealth suggested in recommendation 6 above may be useful even when changes in regulations are not an issue. We envisage activities similar to those of the Advisory Committee on Reactor Safeguards (ACRS) of the Nuclear Regulatory Commission. In contrast to the ACRS, a state committee would be expected to act on matters specific to one particular nuclear facility rather than on generic issues, and primarily to address those areas over which the state has some jurisdiction. The committee members should not be full time state employees, but drawn from the larger pool of talent available in Massachussets and they should be recompensed for their

services in the same way as federal government advisors.

4. Operator Training

The Kemeny Commission emphasizes the human errors involved in the Three Mile Island accident. We note here that Dr. Herbert Diekamp, President of General Public Utilities, in a press statement commenting on the Kemeny report noted that the operators were trained as well as any in the industry. This statement is based on examination performance in the Nuclear Regulatory Commission examination.

It is, of course, conceivable that the operators and staff in the utility companies in Massachusetts are better trained and better qualified than those at Three Mile Island. It appears to us to be a role of the Commonwealth to ensure that this is true. Already, Massachusetts has a separate examination for power plant operators. The Department of Public Safety, which is in charge of this licensing, emphasized to us that accident prevention depends upon good training in steam systems and not specifically on nuclear matters. This is not extensively covered in the federal licensing process. While this distinction is to a large extent true, there is no analogue in a coal fired power plant to the necessity of keeping the core covered at all times. Before the accident at Three Mile Island, the Massachusetts operators were trained in unusual operating conditions but not in accident conditions. This is done on a computer simulator at Morris, Illinois for Pilgrim I and Vermont Yankee and at Keyesport, Pennsylvania for Yankee Rowe; Seabrook will have its own. The staff for Pilgrim are trained with their own computer code to reflect the particular plant they have.

Only since the accident at Three Mile Island have accident scenarios been placed on the simulators. Kemeny noted that failure of a pressure relief valve to reseat was only put on the Babcock and Wilcox simulator in April 1979, after the Three Mile Island Accident. The panel was informed that some of the accident sequences in the Rasmussen report (see Appendix II) are now on the General Electric simulator. We recommend that they all be on the simulator as soon as practical.

We note and applaud the fact that the American Nuclear Society is upgrading its recommendation on administrative control procedures, operator selection, and simulator training.

The nature of operator training in the neighboring states of Vermont and New Hampshire is unclear. we recommend that the Commonwealth make common cause with Vermont and New Hampshire, possibly with common testing procedures.

If, as we believe is the case, operator licensing in Massachusetts should continue, then the examiners themselves should be trained on the simulators, and the Commonwealth should appropriate funds for that purpose.

The Executive Office of Public Safety has drafted a bill to improve the state licensing procedure and we recommend that the Cabinet Task Force consider it seriously.

We recommend that the Executive Office of Public Safety consider making use of the large reservoir of independent talent in Massachusetts to help structure a rigorous testing procedure. Although our detailed recommendations are open for discussion, we suggest that this could include:

1. review of the 80 odd event tree sequences for serious accidents, such as those outlined in the Rasmussen report and review of the operator actions necessary in these cases.

2. simulator training on these and other accidents.

3. oral examination in which the operator explains safety to an independent expert.

5. Accident Prevention

The Kemeny Commission recommended that each utility company have a safety review group reporting directly to top management. The panel in its open meeting on November 19th, 1979 ascertained that both Boston Edison and the Yankee Atomic group have such review groups and details of their composition were given to us.

We recommend that these groups should each include one or two members with a wider range of expertise than normally found in the utility companies--such as a chemical engineer or physicist.

It is also important that the safety groups include among their membership some persons who derive less than 20% of their salary from the nuclear industry to assure there can be no reasonable doubt about their independence.

We are concerned that there be such safety groups for reactors close to Massachusetts borders: Vernon, Vt. and Seabrook, NH. Although these are now part of the Yankee Atomic group, the situation is in a state of flux, and we are concerned that if they become totally independent they may have too little internal expertise to draw on. The adequacy of these in house safety groups should be reviewed by the Cabinet Task Force as suggested in recommendation 6.

We suggest that the Commonwealth consider establishing a safety review committee of competent professionals able and willing to work hard. The prototype for this committee would be the Advisory Committee for Reactor Safeguards (ACRS) to the Nuclear Regulatory Commission. This committee has a high reputation. (recommendation 6)

We make a suggestion to the Cabinet Task Force not covered by the Kemeny Commission that they consider establishing an anonymous letter office associated with this review committee for safety questions.

We are fully aware of, and share, the deep and natural repugnance of Americans for anonymous letters which question the honesty and competence of individuals, private citizens, public officials or politicians. But in the matters of public safety we feel there might be some modification of this absolute stand. It should be made clear that any letter will be transcribed before being passed on; that no attempts will be made to locate the sender, but that the contents may be acknowledged in the public press. Of course, anyone violating the anonymity should be subject to appropriate civil penalties.

6. Radiation Monitoring

The Nuclear Regulatory Commission reports, especially NUREG 0558, indicate that the amount of radioactivity released to the public at Three Mile Island was not large, and it was released through filters out of a tall stack, and dispersed throughout the surrounding area.

As a result, the effects on public health are predicted to be miniscule. While this is very reassuring, we asked the following questions of the power plant operators in Massachusetts and of the agencies of the Commonwealth:

1. Is monitoring adequate to ensure understanding of the small releases of radiation in ordinary operation?

2. Is the monitoring adequate to make an ex post facto measurement of radiation dose in the event of an accident in which the releases are the size of those at Three Mile Island?

3. Is the monitoring adequate to measure radiation releases in real time, so that indications can be given of whether and how to evacuate?

On October 12, 1979 at an open meeting, the panel discussed these questions with representatives from the power companies, the NRC, the Department of Public Health, the Department of Environmental Quality Engineering, the Department of Public Safety and the Advisory Committee on Radiation Protection.

It seemed clear that most of the monitoring is geared to releases in ordinary operation and that a good job can be done under ordinary conditions.

In accident conditions the situation is likely to be less satisfactory. At Three Mile Island the stack gas monitor saturated, and as the incident progressed no one was able to tell how much radioactivity was being released. This could only be deduced from meteorological calculations and doses measured in the field. Although doses in the field are in the final analysis what we need to know, this leaves out an important piece of information which would be particularly useful for immediate prediction of hazard in the event of an accident to aid a decision about whether or not to order an evacuation.

We were told that it would take over a year to install equipment at Boston Edison Co. Pilgrim Reactor that would not saturate under accident conditions, i.e., instruments capable of indicating the levels of radiation that might be expected in the event of a serious accident. While we believe that this may be

true for a bureaucratically acceptable monitor--one which has been approved in advance (on paper), is fireproof, and so on--it seems to us that a temporary one that could measure the unusually large amounts of radioactivity in an accident could and should be available in a week. We urge that such a monitor be obtained promptly and that the Department of Public Health assure itself that this did take place.

Although the 2 nuclear plants in the Commonwealth are no better equipped to measure stack gas effluents during an accident than were those in the State of Pennsylvania, they have been better equipped to measure releases at distances remote from the plant in the event of an accident and the provisions have been recently improved. Detailed plans exist to use the results from ground base monitoring to quickly estimate the magnitude of the radioactivity release. Twice as many radioluminescent dosimeters are now in place around Pilgrim I as were around Three Mile Island. The company, the NRC and the state separately maintain dosimeters which are checked against each other.

When it comes to on-line monitoring the situation is less clear. No stations exist with continuous recording monitors. Monitoring depends upon radiation monitoring teams which can be sent out at the first sign of trouble.

This ensures that calibrated monitors are used, but it depends entirely on word of mouth for immediate feedback. In retrospect this worked at Three Mile Island, but we have some misgivings about whether the feedback is adequately prompt and whether radiation survey teams will be sent out early enough.

At Three Mile Island the operators realized there was trouble by 6 a.m., the radiation level in the containment went up to 25 mr/hr, more than fifty times normal, at 6:35 a.m., but not until 6:54 a.m. was a site emergency called and radiation monitoring teams dispatched. By this time the radiation level in the containment had risen to 400 mr/hr (it rose to 100,000 mr/hr [= 100 R/hr] by 7:20).

Although the nuclear engineers at Three Mile Island (incorrectly) measured a high dose of 40 R/hr in the containment at 6:55 a.m. and calculated a dose in Goldsborough of 40 R/hr due to the presence of noble gases, it was not until 7:48 a.m. that accurate measurements were made confirming a low dose. Part of the delay was in checking equipment--which could have been checked anytime in the previous 3 hours if the monitoring teams had been alerted.

Although we questioned the power company representatives, it is not clear to us that if an emergency occurs in Massachusetts there will be any more rapid response. We were not told of the existence of procedures which identify specific events that would

lead to:

1. Summoning a radiation survey team to the site

2. Checking instruments and ensuring that a vehicle is available

3. Sending out radiation survey teams

We recommend that this aspect of emergency readiness be clarified and improved. A suggestion was made to us that a stack gas monitor be installed to read directly into a state building, so that there is immediate indication of problems. Such a readout may be useless unless it has well defined points which trigger a response. The power companies argue that the information supplied could be misused by an overly exuberant public relations official. Yet it would be a safeguard against failure to obtain adequate information from the reactor operators. This might occur, for example, if sabotage and terrorism were the cause of the accident. We urge that this question be re-examined by the Cabinet Task Force.

At the present time, the Department of Public Health is responsible for emergency monitoring while the Department of Environmental Quality Engineering reads some of the thermoluminescent dosimeters for the Department of Public Health. This we believe to be a sensible and proper arrangement. The Department of Public Health has monitored radiation devices for many years and has expertise and staff who routinely monitor radiation sources such as medical x-ray equipment, and thus their skills and equipment are kept up-to-date. All of their staff is available in any emergency.

The reasons for the assignment of this responsibility to the Department of Public Health may not be obvious to the executive and legislature in the future and we recommend that the Department of Public Health be formally designated the lead agency to avoid possible confusion.

We note that there are a number of personnel throughout the state who have training in radiation monitoring who can be called upon, some of whom form the NIAT teams discussed earlier. However they may not be present during the critical early stages of an accident.

We note that in a major nuclear accident, the total quantity of the noble gases and also a large fraction of the iodine, tellerium or cesium present as fission products in the fuel might be released. It is these last three elements that account for estimates of large possible hazards to public health, since they are absorbed by the human body and iodine concentrates in the

thyroid. Although it is reassuring that at Three Mile Island only 15 curies out of 30 million curies of iodine present were released, (because of chemical plate-out and because of filters) it is possible that in a major accident such filtering processes would be rapidly saturated.

The iodine which has a half life of 8 days can be an important contributor to the short term hazard and the possibility of its release would dominate any evacuation plans. This is made very clear in a report for the Council on Environmental Quality by Dr Jan Beyea of Princeton, and in a 1978 NRC report (NUREG CR-1131) by Aldrich et al of Sandia laboratories.

Tellerium and cesium are particulates and to be released require evaporation of core products. Their release is less likely than the iodine releases but they are also important and are a longer term hazard.

For purposes of judging evacuation plans, therefore, a rapid measurement of iodine and particulate releases seems to be very important. This is not made clear in the N.R.C. guides on emergency planning. There are presently no adequate monitors which distinguish these releases, although we were told that they are forthcoming, and the important distinction between releases with and without particulates is not included in any of the emergency plans presented to us. We recommend that all personnel involved with measurement of radiation, and with possible evacuation, learn and understand the distinction between the effects of noble gas release, iodine release and particulate release.

Two mitigating features are worth noting. First, if people are exposed to iodine, some of the effects can be reduced by taking medication--such as potassium iodide--that blocks the uptake of iodine in the thyroid. The Commonwealth should ensure that in the case of accident it has access to an adequate supply of such medicine within 24 hours.

Second, the cesium and tellurium release is a long term hazard for which prompt evacuation is not essential. Evacuation and/or decontamination subsequent to the accident can prudently be postponed until radioactivity levels are actually measured.

7. Pilgrim I Operating Staff Radiation Exposures

There has been some discussion about unusual levels of exposure of workers to radiation at Pilgrim I.

Cobalt steel in a reactor vessel becomes radioactive as a result of neutron bombardment. Some of it leaches into the reactor coolant system and is conveyed to all parts of the reactor. This radioactivity should be removed by filters, but it appears that these filters were clossed in the first year of operation of Pilgrim I and radioactive cobalt, half life of 10 years, was deposited on many parts of the reactor coolant system. This produced unnecessary radiation exposure to the reactor staff. This was clearly a major error on the part of the Boston Edison Company.

A graduate student at Harvard, Mr. Huffman, has measured radiation at several places near the reactor and confirms that indeed it is dominated by cobalt 60. We are informed that over the past two years a massive effort has been in progress to identify, replace, or shield radioactive piping.

The occupational radiation dose, added up over all employees, was 2800 person rems in 1977, and this fell to 800 person rems in 1979. The original high radiation doses were a sign of sloppy management. However the doses have remained within the standards recommended by the International Committee on Radiological Protection and have now been reduced. We urge continued efforts in this direction. In addition to cleaning and replacing pipes, we urge that the operating staff continue to pay attention to the level of their own exposure to radiation. Staff members can reduce their own exposure levels, by careful avoidance of places with high radiation levels but Boston Edison must provide the framework in which this can take place.

8. Accident Management

At Three Mile Island an incident was allowed to escalate into an accident. Everyone seems to agree that operator training is the primary cure and improved plant control design a secondary cure; we address at this time a third issue of responsibility during the accident.

Mr. Olson, of the Department of Public Safety, told us that the law is clear. General Law 146 of the Commonwealth states that the shift engineer has complete responsibility and in his absence the shift supervisor, and then the most senior operator takes over. If they think it is appropriate, they can ask for anyone present to leave the control room.

If an accident develops, additional personnel are sent to a technical support center, separate from the control room. When radiation is released, an emergency control center is established and it is to this center that radiation monitoring teams report and where a Department of Public Health official goes.

We are concerned that not everyone is clear on the chain of authority. In view of what happened at Three Mile Island we believe this can be a very serious problem. We understand the authority and responsibility to be as follows.

To operate the reactor the chief engineer or his delegate as above. To measure radiation: whoever is in charge at the emergency control center; to assess radiation and whether to recommend an evacuation: the Department of Public Health through its representaive at the emergency control center. To carry out an evacuation: Civil Defense from an emergency control center in town.

A reactor operator at Three Mile Island decided to release radioactive gas out of a storage tank at 9 a.m. on Friday, March 30th to prevent a more serious situation from developing; it was his authority to do so, but he did not inform those monitoring radiation to expect a sudden increase, causing unnecessary alarm. If a reactor operator in Massachusetts decides to initiate such a release he should discuss it with the representative of the Department of Public Health and to give as much warning as possible to avoid confusion, although he is not required to do so.

We recommend that procedure relative to chain of command during an accident be clarified and that it be made known to all who might be involved. In our meeting of November 19th we were not convinced that everyone agreed to who has authority for what. In our view this is inexcuseable and we call it to the attention of the Cabinet Task Force.

It appears that at Three Mile Island the operators were

reluctant to call in help. In our meeting of November 19th it became clear that most operators would be so reluctant--indeed it is a natural human characteristic which can be found in other situations. It was represented to us that after a transient the operators must first bring the reactor to a stable condition before reporting the situation, that the solution to the operator errors at Three Mile Island is better operator training and that after such training, operator judgement will be as good as that of a supervisor. We are reluctant to accept this.

That 5 operators, in a time of stress should all make the same incorrect diagnosis for 2 1/4 hours does not surprize us since they were working together in the same situation. It is possible, although far from certain, that another person coming in fresh to the situation and possibly with a different training could find their error.

We find it strange that an operator can turn off an emergency system (the HPCI) without immediately calling his supervisor, or maybe his supervisor being called automatically. This type of practice needs reexamination and we recommend a procedure whereby supervisors would be immediately called without judgement on the part of the operator under certain circumstances.

9. Emergency Plans

The panel met with the Civil Defense Director and his staff, together with representatives of Boston Edison Company, the Department of Public Health and the Department of Public Safety, at the Civil Defense headquarters in Framingham, Mass. on 16th of July and with representatives of the power companies, the Civil Defense Director, the local communities, NRC and the state agencies (Department of Public Health, Department of Environmental Quality Engineering and Civil Defense) on Friday, October 12.

On brief examination it appears that Massachusetts has a good general emergency plan which has been well tested. There have been four recent incidents in the Commonwealth involving evacuation. These are:

1. Blizzard in the Boston area February 6 and 7 1978
2. Hurricane Belle in Cape Cod and the Islands, Aug. 9 and 10, 1976
3. Chlorine tank car overturned in Western Massachusetts, March 9,1966
4. Propane tank accident at Tewksbury, Feb 9,1972

During Hurricane Belle, 17,000 people were evacuated within 4 hours from the initial decision. Prompt evacuation after hurricane warnings has saved many lives in the U.S. in the past.

Although the situations are similar, there are important differences. In the case of hurricanes there is advanced warning of the storm and the decision to evacuate will not normally catch people unaware. Of course, this need not happen in a nuclear incident. It is reasonable to expect at least 2 hours notice of a major radiation release, and limited windspeeds can provide more time. At Plymouth the local authorities feel they can alert everyone within 10 miles within one hour, with a street by street, home by home, notification. The vast majority of people would be notified within a shorter time.

This suggests that evacuation can be complete before high radiation doses occur, provided that the initial warnings based either on radiological measurements or reactor operation from the reactor staff are prompt and provided that people are adequately informed in advance about what action to take.

There is a problem with evacuation in nuclear incidents which we feel has not been adequately addressed; psychological concern for nuclear events is far greater than that for other events of similar calculated risk. We have only to compare the casual media coverage of the Canadian evacuation of 250,000 from a region of a

spilled chlorine tank car to the coverage of the Three Mile Island incident to know that there will be more trauma in the nuclear incident. This may hinder evacuation.

The panel asked for detailed reports on each of these incidents with a discussion of the successes and failures of the plans. We were disappointed that we only got press summaries of some of them, although one was more thoroughly reviewed.

The Cabinet Task Force could ask that the Civil Defense authorities carry out postmortems on each evacuation incident and on the practice drills and we recommend that the power companies be asked to include these post mortem reports im personnel training. Although they can then be accused of merely being ready to fight the last war, that is better than not being ready to fight a war at all.

In general we found the written emergency plans to be incomplete and lacking in detail. Our confidence that they will be adequate stems more from oral discussion than from the written submissions. Since personnel may change and can only be expected to read the written words and not the minds of their predecessors, written plans are important.

We have been informed that evacuation plans are now being rewritten to integrate all aspects of emergency planning in one document, listing clearly the assigned responsiblities. We hope that this plan will answer these concerns. The Cabinet Task Force should satisfy itself that this document is complete.

10. Review of the Communications in the Event of an Accident.

One of the major problems in the Three Mile Island accident was informing the public. There were failures by the power company, the Nuclear Regulatory Commission and of the press and media generally.

Power company press releases were not sufficiently detailed. Press statements were made which appeared to be contradicted by NRC officials on the spot and in the Bethesda headquarters, and there was a lack of understanding by the press, radio, and TV.

In retrospect the official press releases of the Nuclear Regulatory Commission were good. They were brief, precise, and accurate. But they were hard to obtain. The public would have been well served if the press had printed them verbatim. One of the recommendations, then, of this panel is that the press be requested, in an emergency, to print official press releases verbatim (and make whatever additional comments they choose to make separately).

Also, it is important that the power company have a procedure for giving adequate press releases and not merely leave this to the Nuclear Regulatory Commission since the power company is responsible for the plant, not the Nuclear Regulatory Commission.

The Kemeny Commission recommended that in the event of an accident, the utility company should continue to have responsibility for operation and for dissemination of information to the public. In principle we agree, but have some qualms about the ability of the utility company to properly inform the public. Accordingly we recommend that the responsibilties of public communications be handled by persons more technically qualified than the usual public relations staff. This person or persons should be technically competent, have access to all information, know the special skills of each member of the Nuclear Safety Advisory Center set up by the Electric Power Reseach Institute, and develop an ongoing rapport with the press.

In the days subsequent to the Three Mile Island accident, the issue that caused the most confusion and panic was that of the gas bubble (or bubbles) in the reactor vessel.

At about 5 p.m. on Wednesday, March 28, the reactor was repressurized and shortly thereafter the reactor coolant pumps were restarted. The reactor pressure did not rise instantaneously as water was added showing the presence of a gas bubble. The gas was slowly bled from the relief valve at the top of the pressurizer, but even when all available gas had been bled, measurements of the change of pressure with amount of liquid showed a residual bubble.

On Thursday, March 29, the chairman of the Nuclear Regulatory

Commission, Dr. Joseph Hendrie, asked a series of reasonable and proper questions. What is the gas? Could it be hydrogen? Could it be an explosive mixture of hydrogen and oxygen, disassociated from water by radioactive bombardment? We now know that it could not have been hydrogen and oxygen, but do not know whether the gas was hydrogen or steam or in what proportions.

The NRC staff, under Dr. Roger Mattson, made calculations, and said that the bubble could be composed of hydrogen and oxygen. This led to consideration of the possibility of an explosion in the reactor vessel, large enough to crack the containment vessel. There was a flurry of activity at NRC which got their contractors to calculate ab initio the probability of each of these.

Not until Sunday, April 1, was it clear to the NRC staff that they had made a mistake in the calculation; that a mixture of hydrogen and oxygen could not have been present; that if it had ignition was in any case unlikely, and that an explosion consuming all the gas would not have cracked the containment. In subsequent congressional hearings, the NRC staff and in particular Dr. Roger Mattson apologized for the error. Meanwhile on Friday, March 30, the Governor of Pennsylvania and his staff were in confusion, not knowing what to do or whether to order an evacuation. Some citizens were close to panic.

In retrospect also, an examination of the calculations in the NRC report of Aldrich et al already referred to, which was already available in 1978, suggest that even if a complete core meltown, with containment violation, had occurred on Friday March 30th, no immediate evacuation beyond 2 miles would have been called for. The short lived radioactive elements had decayed, and since Three Mile Island II had only operated at full power for three months, the long lived ones had not built up.

What should we hope for in these circumstances? We want to encourage those we charge with protecting us to ask reasonable and proper questions. The answers will not always be accurate. But there were men at Babcock and Wilcox, at the Electric Power Research Institute and Metropolitan Edison Co. who had thought through the problems before and knew the right answers. Some others steadfastly maintained (correctly) that there was no problem. Moreover some of the NRC contractors knew the answers.

This panel does not know whether, how soon, and in what way the right answer was given to NRC by Babcock and Wilcox and the Electric Power Research Institute. The answer may have been too brief and without the backup necessary to be believed or it may have reached an overly tired or pugnacious NRC staffer. It seems to us, however, that in these days of telephones, TV and jet aircraft, that 3 days is too long a time for this and that there was a communications foul-up of major proportions. The primary responsibility must lie with the utility company, the president of

Metropolitan Edison Co., who was in charge of the reactor and did not ensure that technical questions got adequate technical answers including sufficient detail to ensure acceptance.

11. Transportation of Radioactive Materials

There are several "levels" of radioactive waste which must be shipped:

1. High level waste--mostly spent fuel from reactors which is to a large extent a future problem.

2. Low level waste--e.g. workers' clothing with small amounts of radioactivity.

3. Transuranic wastes where the level is low but the half-lives are long.

Radioactive sources for medical and industrial use are also shipped in the Commonwealth and have characteristics similar to 2 and 3 above. The rules for transportation of these sources are, and probably should continue to be, the same as those for transportation of waste.

The high level wastes are the ones which represent a potential major hazard. These wastes contain the fission products and the transuranic elements from fission.

High level shipments that can be foreseen in and through the Commonwealth of Massachusetts are of complete spent fuel rods. These will contain all the waste inside the zircalloy tubes under normal circumstances. The spent fuel will not move from the reactor site for many months--or even years--after removal from the reactor, and much of the short lived radioactivity (particularly the gaseous iodine 131 and xenon) will have decayed. However the regulations should anticipate that if there is a reactor accident where the fuel rods are cracked open as at Three Mile Island, earlier transportation may be desireable. In the event of a transportation accident, most of the material may be expected to stay in place, with a possible exception of cesium isotopes. Transfer of radioactivity to the biosphere might take place as a result of dissolving in water, or airborne dispersion by means of an (externally caused) explosion and fire.

To guard against such events, unlikely though they may be, the high level wastes, including fuel rods, must be transported in specially designed containers which are not likely to break in the event of collisions, droppings, immersion in water or fire. The specific criteria are spelled out in rules of the U.S. Department of Transportation.

The U.S. Department of Transportation rules also specify that the shipment shall travel by a route that avoids population centers as much as possible. This is an obvious rule to avoid problems in the event of an accident. The problems could be of two types: a

real spillage--an event considered to be very unlikely; or an accident where the truck is destroyed, but the shipping cask remains intact. It is important to realize that even in the latter case, there will be considerable disturbance before it is ascertained that no radioactivity is spilled. Thus in either case it is desirable to take a route which minimizes the accident probability. More than one designated route is necessary to allow for closed roads and so forth.

At the present time, the Department of Public Health is informed of every shipment involving nuclear fuel and medium or high level wastes (but not including the numerous shipments of low level medical wastes.) In the event of an accident it is then prepared to send the appropriate personnel and monitoring equipment to check for spillage of radioactivity.

A public hearing of the U.S. Department of Transportation has been scheduled in early 1980 to discuss this matter further. It seems likely that the preference for direct routings will be confirmed. Some shipments (from the University of Lowell and MIT reactors) will probably be made within a year thereafter.

A question about direct routings arises because the Massachusetts Turnpike is privately owned. The Turnpike Authority feels an obligation to bondholders not to allow any cargo to travel along the Turnpike for which there is not adequate liability insurance.

About 5 years ago, subsequent to the licensing hearings on Maine Yankee Atomic Power Plant, the Maine Turnpike agreed to allow shipments of waste on a regular basis along the Maine Turnpike from Brunswick to Kittery. This was at the request of the state, made through its Attorney General and with an understanding that the state would provide all necessary police escort and reimburse the turnpike authority for any clean up expenses and any lost revenue in case of an accident. This was based on a business judgement; not only is the frequency of road accidents on the Turnpike less than on city roads, the clean up costs in the countryside are less than in a city.

About five years ago also, the New Hampshire Turnpike made a similar arrangement, and Dr. Alan Altshuller, then Secretary of Transportation in the Commonwealth of Massachusetts made representations to the Massachusetts Turnpike Authority. We have no record of the result, but in 1975, MIT had to ship spent fuel from its reactor along route 20 instead of the preferred route, the Massachusetts Turnpike. In 1975, the committee set up by Governor Sargent, and reporting to Governor Dukakis (the Rathjens committee) also recommended that the Turnpike be used when it is the most direct route.

Mr. Driscoll of the Massachussets Turnpike Authority raised the question of liability to bondholders both in writing and orally at our December 14th meeting and commented that his insurance costs would increase were radioactive shipments to be permitted. We have sympathy with the problems of the Turnpike Authority, but are concerned that it has no positive suggestions about how these concerns might be resolved. The Massachussets Turnpike Authority has some obligation to the residents of the Commonwealth in return for the undertaking of the legislature not to permit a competing east west freeway.

While the Price-Anderson Act specifies that there shall be $560 million in insurance to cover accidents to life, limb and loss of property. Whether lost revenues would be recovered will be determined in the courts as various claims resulting from the accident at Three Mile Island are litigated. A question has been raised by the Massachussets Turnpike Authority and the Massachusetts Department of Transportation, whether $560 million is enough to cover costs of a severe transportatoion accident.. The accident with the most severe consequences would probably be one resulting from sabotage, with an explosive fragmentation of the load. It seems probable that this would be less severe than the most serious reactor accident since only a few percent of the total fuel inventory would be carried at any one time, and then usually only many years after removal from the reactor. Issues such as this, should be raised in the forthcoming hearing of the U.S. Department of Transportation.

Most of the above discussion is specifically relevant to the transportation of high level wastes. In our view the same criterion, avoiding populated centers when possible, could well apply to all radioactive material, including radioactive sources for use in medicine and industry.

It is important that at the forthcoming hearing of the U.S.Department of Transportation, that the agencies of Massachussets should speak with a united voice if possible and if not that each has a thorough understanding of the concerns of all other state agencies involved. At our December 14 meeting, Dr. Parker for the Department of Public Health,Ms Murray for the Department of Transportation, and Mr Driscoll for the Massachussets Turnpike Authority agreed to try to develop a common approach.

We recommend that a listing of these recommended routes be kept in the appropriate state offices to avoid the cofusion now created by the circulation of inaccurate private lists.

12. Waste Disposal in the Commonwealth

A large amount of radioactive waste is generated in the Commonwealth; although the focus is primarily on the waste generated by the power plants, there is a significant amount generated by hospitals and research laboratories.

The classification of waste by radioactivity--high, medium, and low-- corresponds approximately to a classification by half life. The medium and low level wastes are usually fission products of half lives less than 20 years, whereas the high level wastes contain also some transuranic elements with half-lives of thousands of years.

At the moment, the high level waste is retained, in fuel rods on the site of each power reactor (the fuel of the research reactors at MIT and Lowell University are transported out of state). Although some of the low level waste is kept on reactor site for a while, most is transported to a federal repository, and all the medical and research waste is so transported.

Originally industry planned to remove the fuel to a central reprocessing plant to extract residual uranium and useful plutonium, and to leave separated wastes for ultimate burial. The desire to limit the free availability of plutonium, and financial constraints have led the U.S. Government to forego this procedure until adequate safeguards against theft of plutonium and international guarantees against proliferation of nuclear weapons are available. Until there is reprocessing or provision for permanent disposal, the fuel rods will probably not be removed from the reactor spent fuel pits and this method of storage will continue to be permitted for as long as the reactor site remains operational.

Since this was not the scenario planned for when the plants were built we recommend the Cabinet Task Force satisfy itself that adequate attention has been given to the safety implications of the change in plans.

The relationships between Massachussets and other states would be much improved if Massachussets had its own storage site located within the state or region for low level waste, which are mostly of half lives less than 100 years. Accordingly we concur in a recommendation of the Advisory Council on Radiation Protection, that the Commonwealth explore, probably in concert with neighbouring states, the setting up such a repository. This could be done in conjunction with toxic waste disposal which is now being considered by the Department of Environmental Affairs.

13. Suitability of Plymouth as a Site for Pilgrim II

One obvious question which is raised as a result of the accident at Three Mile Island is whether Plymouth is a suitable site for a second reactor. The proposal to build this plant was made several years ago, and although a construction permit has not yet been issued by the Nuclear Regulatory Commission, the licensing hearing has already been the longest licensing hearing in history.

Many issues are brought out clearly by the "Proposed findings of fact and conclusions of law" submitted by the Attorney General's office of the Commonwealth of Massachussets on November 5th 1979.

These issues are:

I. Financial qualifications of Boston Edison Co. to construct a power plant.

II. The adequacy of the quality assurance of the Bechtel Corporaton and of Boston Edison Co.

III. The need for power.

IV. Alternative energy sources.

V. Alternative sites.

VI. Risks of theft or sabotage.

Issues on which no testimony has been submitted:

VII. Emergency planning.

VIII. Cost benefit analyses.

IX. Safety issues subsequent to Three Mile Island. (The numbering I-VI is that of the Attorney General, and VII-IX is ours.)

The panel feels a duty to comment on those aspects which have a bearing on safety.

On issue I, the Attorney General noted that the Boston Edison Company does not have cash in hand to complete Pilgrim II, and depends with some optimism on cash becoming available. The safety concern is that a company which is short of cash might be tempted to cut corners and to rush to commence operations before it is proper.

We recommend that the Commonwealth exercise due vigilence, probably through the Department of Public Safety, to ensure that no corners are cut if Pilgrim II is licensed. The Cabinet Task Force should review the suggestion of the Department of Public Safety

that they intensify their inspection efforts in this eventuality.

The issue II on quality assurance is much more serious. The past performance of Bechtel Corporation and of Boston Edison Company which between them constructed Pilgrim I, must be considered in speculation about their possible future performance for Pilgrim II.

There is no doubt that both Bechtel and Boston Edison Company made mistakes.

One of these we noted in section 10 on Radiation at Pilgrim I. There have been several violations of regulations, for one of which the Nuclear Regulatory Commission fined Boston Edison Company $12,000.

We hope that both Bechtel and Boston Edison have learned from their mistakes. If Pilgrim II is licensed this should be watched carefully by the Department of Public Safety.

Issue III the need for power, and issue IV alternative energy sources, have in our view little direct impact on the current safety of nuclear power and we chose not to discuss them. To satisfactorily discuss these questions we would have to consider the growth of electricity consumption both in the Boston Edison region and in the whole New England power pool (NEPOOL). We would have to consider the desireability of replacing imported oil, the possiblity of importing hydroelectric power from Quebec and whether and how soon renewable energy sources such as solar power and wood can be used. We would also have to take into account the safety and health effects of each of alternatives.

Issue V on alternitave sites and issue VII on emergency planning are very much the direct concerns of this panel. We have in section 9 of this report discussed the emergency planning for Pilgrim I. Pilgrim II is planned to have twice the power of Pilgrim I.

Whether another site would be preferable for Pilgrim II is a more complex question. There are many aspects of site selection and the possibilty of a severe accident is only one of them, although it is the one we consider here. Would the choice of another site be significantly better in the event of an accident?

It was already clear from a close study of appendix VI of Rasmussen's report, and is underlined by the more recent work of Beyea and of Aldrich referred to earlier, that in the event of the most severe accident, there would be fewer fatalities around some sites than others. The reactors at Indian Point N.Y. and Zion, Illinois are close enough to the population centers of New York and Chicago respectively that an accident during a northerly wind could cause many more than the number of latent cancers calculated by

Rasmussen for an average of the 50 reactor sites used in 1974. On the other hand, the nearest population center to Maine Yankee is Bath, and even with a northeast wind the latent cancer rate would be 10 times less than average.

The Plymouth site lies inbetween these extremes, and the results of Rasmussen apply almost directly to it. The principal concern is the large population that lies to the northwest. A great deal of attention has been focused recently on the question of siting as a safety issue. We urge the Cabinet Task Force to follow the discussin closely.

Issue VIII has no direct safety conequence, and issue IX is discussed extensively throughout the rest of this report.

The question of sabotage and theft of nuclear materials which is the substance of issue VI, remains very important. The RathJens Committee of a few years ago made recommendations on these subjects, which we call to the attention of the Cabinet Task Force and the Utility companies. Professor RathJens testified on this subject at the Pilgrim II licensing hearing. We were pleased to be told that the Department of Public Health has studied these questions, and has been briefed, in secrecy, by the Nuclear Regulatory Commission. We suggest that this also be reviewed by some members of the Cabinet Task Force.

Appendix I. The Three Mile Island Accident

To determine which state actions are now appropriate it is useful to follow in some detail the course of events between 4 a.m. on Wednesday, March 28, 1979 and the following Sunday, April 1, 1979. There are several voluminous reports on this, and we condense from these a simplified account. This summary is intended not to replace these more comprehensive and, therefore, more accurate accounts, but to place in clear language the problems as they arose so that the reader of this report can see the perspective of the recommendations.

Three Mile Island is 20 miles south of Harrisburg in the middle of the Susquehanna River. Two nuclear power plants are located there, Three Mile Island 1 and Three Mile Island 2. The nuclear steam generating systems were in each case desisned by Babcock and Wilcox Co. The reactors are pressurized water reactors and the relevant parts are shown in a simplified diagram in fisure 1.

The nuclear reactor core consists of about 30,000 fuel rods about 1/2 inch in diameter and 16 feet long; each rod is a tube of zirconium alloy (zircalloy) filled with many ceramic pellets of uranium oxide, 1/2 inch in length. During operation nuclear fission takes place within the fuel rods, releasing energy within them. The zircalloy tubes are filled with helium under pressure and sealed to contain the radioactivity. The whole is surrounded by water. Neutrons from the nuclear fission escape from their tubes, are slowed down by collision with the water, and the slow neutrons reenter the tubes where most start a new fission in new uranium nuclei.

The fuel rods heat up as a result of the nuclear reactions producing a total power of 2772 megawatts maximum and water flowing around the rods is heated by them to 600 F; the water is pressurized to 2155 pounds per square inch (psi) (150 atmospheres) to prevent boiling. The water is pumped to a heat exchanger, called a once through steam generator (OTSG) where much of the heat in the water is removed. The water then passes back to the bottom of the reactor vessel. There are two such reactor cooling loops, each with 2 pumps. All of this is inside a concrete containment vessel desisned to contain any radioactivity that would be released if the barriers of the zircalloy fuel rod and the reactor coolins system were to break.

Steam is produced in the steam generators, where the water is at a lower pressure of 900 psi, and passed to the turbine, where it is used to generate electricity. The steam is condensed back to water in the condenser, and flows through the condensate pumps and the feedwater pumps back to the steam generator. These two "secondary" loops pass through a penetration in the containment vessel to the turbine room.

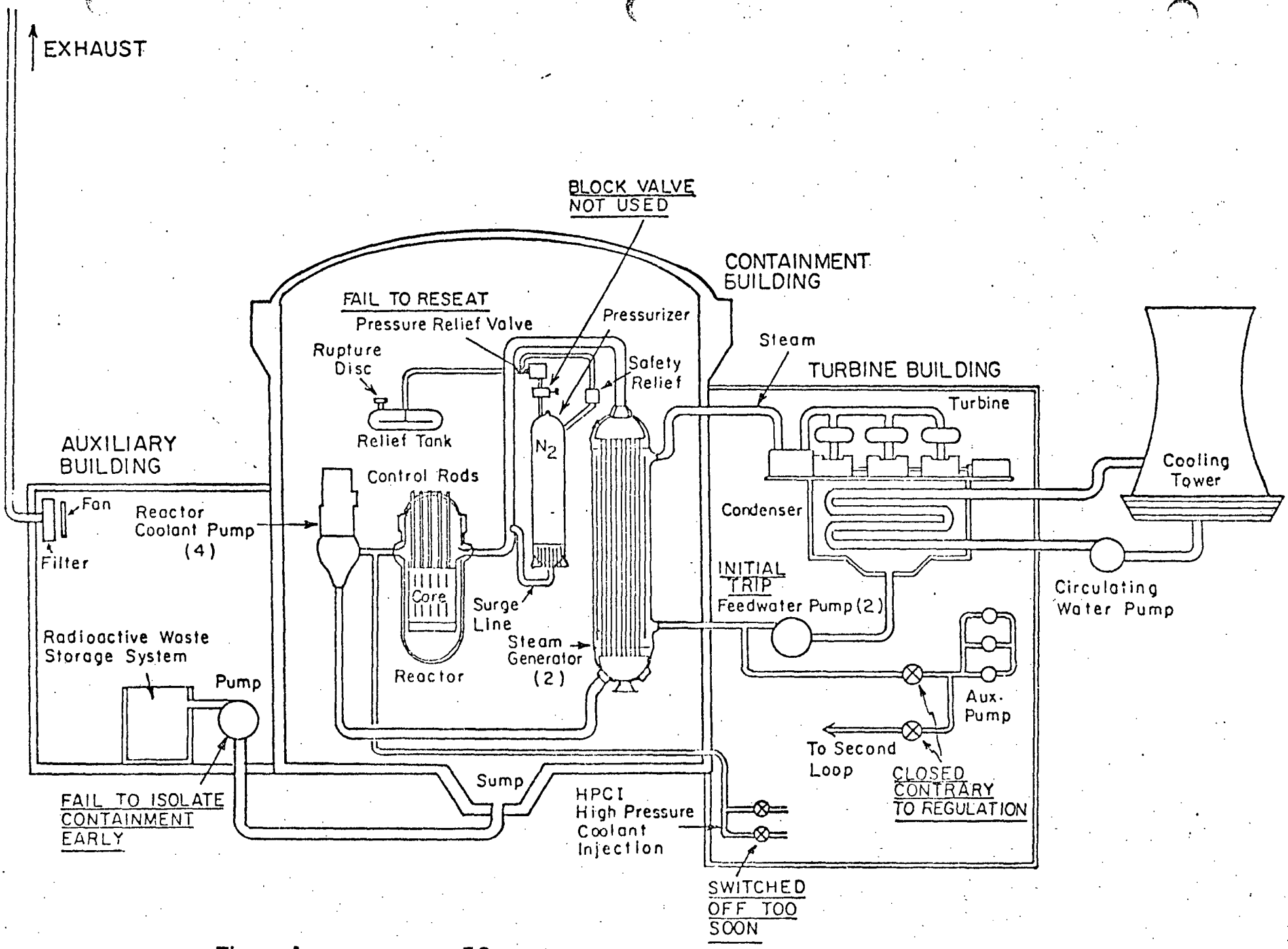


Figure 1 page 36

Various safety systems exist to insure that the radioactivity always stays within the fuel rods; this is done by ensuring that the generated heat is always removed and the fuel does not crack or melt. To shutdown the nuclear reaction (SCRAM the reactor) boron shutdown rods can be rapidly inserted into the reactor core; this can happen either manually or automatically.

Although the nuclear reaction can be (and was at Three Mile Island) shut down in less than a second, the radioactive fission products continue to provide some heat (decay heat). Immediately after shutdown this is almost 8% of full power or 200 megawatts at Three Mile Island.

If the main feedwater pumps fail, there are 3 auxiliary pumps to provide water to the steam generators. Two are electrically controlled, and one is operated by the steam turbine. If the reactor pressure gets too high, there are pressure relief valves; one can be controlled from outside the containment (electromagnetically operated relief valve EMOV) and two others which cannot be operated from outside the containment vessel are set at a slightly higher pressure in case the first fails to operate.

If the water in the reactor evaporates so that cooling slows down, a number of emergency core cooling devices exist to put water back in the core. This water is borated to ensure that the nuclear reaction ceases.

On March 28, 1979, just before 4:00 a.m., Unit No. 2 at Three Mile Island was operating at 97% of full power, under automatic control and had been for three weeks. Three of the operating crew of 4, the shift foreman and two operators, were engaged in transferring resin from a condensate polisher tank to a regeneration tank, and produced a block in the transfer line.

Probably as a result of action to clear the resin blockage, the plant suffered a total loss of feedwater, which automatically triggered a turbine trip, (i.e. a switch off of the turbine) at 04:00 and 37 seconds. All emergency feedwater pumps started, as they were supposed to do and this starting was noticed by the operator. The reactor continued to operate at full power, and since the heat was no longer being taken away as rapidly as normal, the reactor operating temperature and pressure rose. So far, the response to the transient was as anticipated.

The subsequent behavior can be seen most readily by examination of several figures and tables. In Figure 2 are the outputs of several strip chart recorders during the first 10 minutes after the transient. In figure 3 these and other recorders are shown over a period of 16 hours, and both figures show times of crucial events.

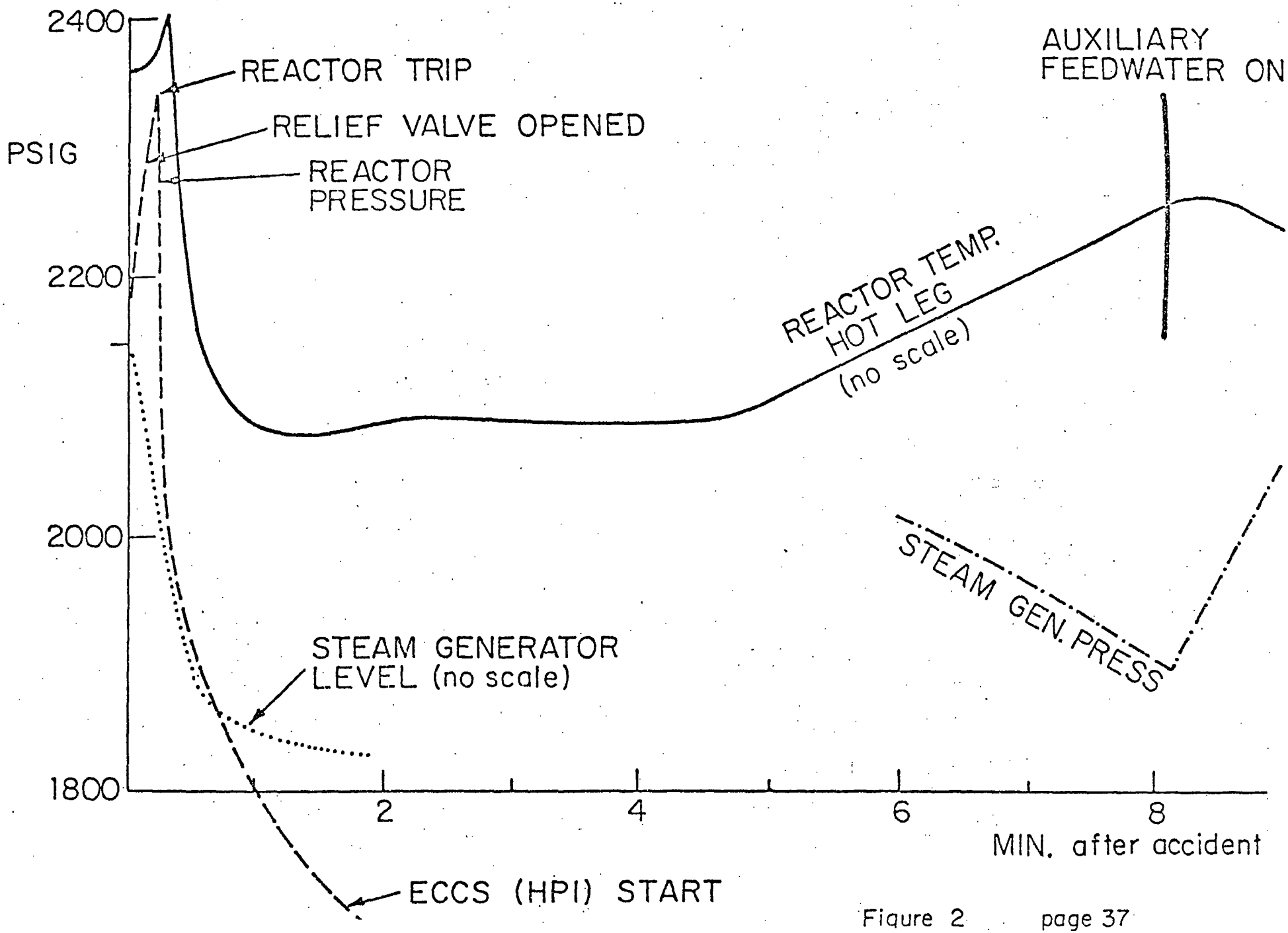

2400
2200
2000
1800
PSIG
REACTOR TRIP
RELIEF VALVE OPENED
REACTOR PRESSURE
AUXILIARY FEEDWATER ON
REACTOR TEMP. HOT LEG (no scale)
STEAM GEN. PRESS.
STEAM GENERATOR LEVEL (no scale)
ECCS (HPI) START
2
4
6
8
MIN. after accident

Figure 2

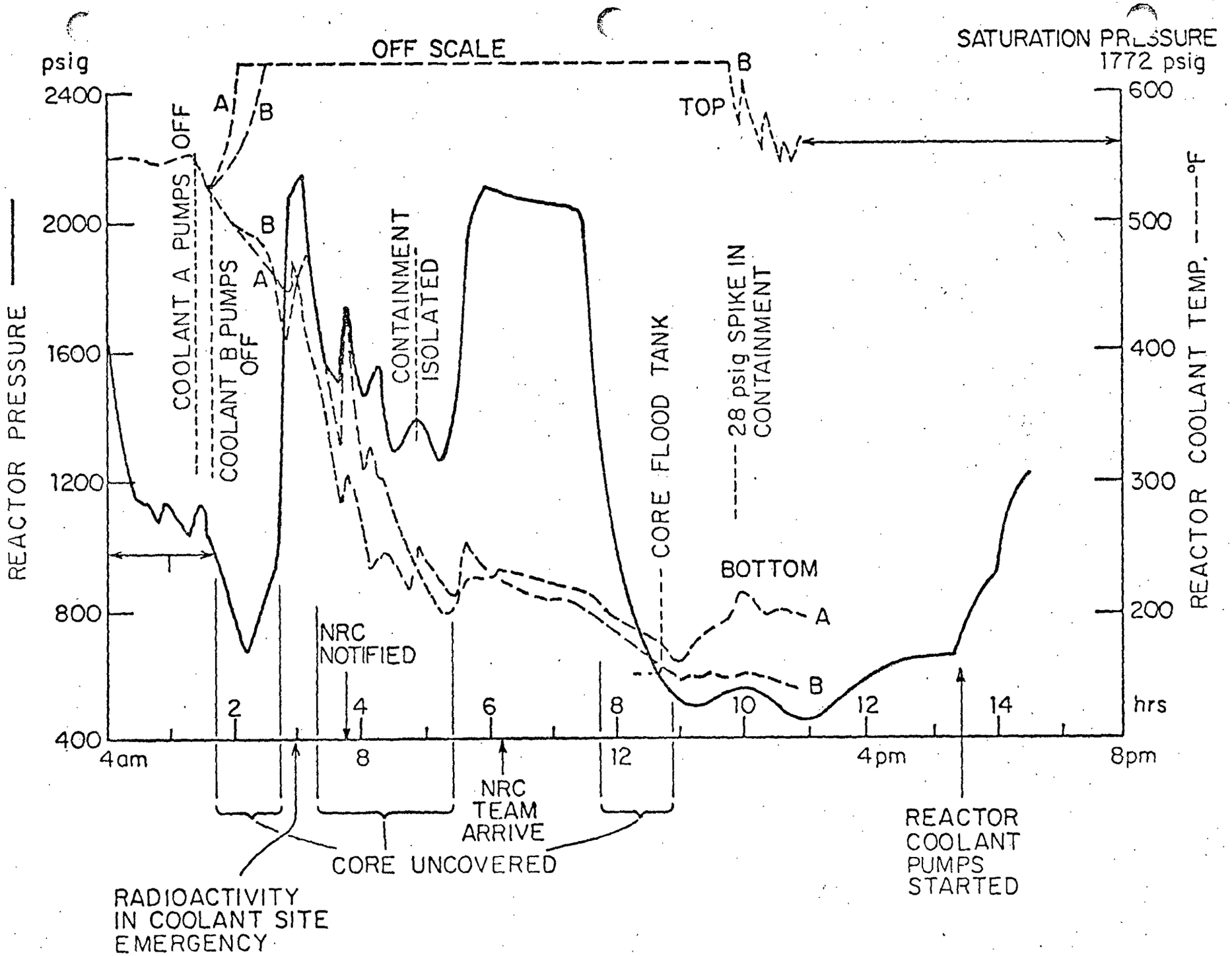


Figure 3 page 37

Approximately 8 seconds after the accident, the electromagnetically operated pressure relief valve (EMOV) opened, at a set point of 2255 psi to relieve the pressure. The reactor system pressure continued to rise, until the set point of 2300 psi was reached when the reactor tripped according to design and the control rods were injected, stopping the nuclear reaction.

We pause and note some problems that had developed. For safety, it would have been desireable (and possible) to have the reactor trip in the event of feedwater interruption. Were this the case, in many incidents the relief valve would not need to operate (although in this particular incident it would have).

After the reactor tripped, reactor system temperature fell; the pressure fell as steam was vented through the relief valve. The relief valve was supposed to close again as the pressure fell to 2100 psi (13 seconds after the accident) but it failed to do so. This failure was unnoticed by the operating crew, because falling temperature also leads to a drop in pressure (although a slower drop).

The reactor pressure continued to fall and when it reached 1600 psi (after 2 minutes) emergency pumps (hish pressure core injection or HPCI) started to inject more water into the reactor. If this had been allowed to continue the reactor would be intact--and probably operating--today.

Unfortunately the operators were watching another indicator--the pressurizer level. The pressurizer is a small tank, normally half filled with reactor water, and covered by pressurized nitrogen gas. This gas enables the system to cope with small volume changes without large pressure changes. The operators are trained not to allow the pressurizer to be completely filled with water for this normally indicates that no gas is present. Control of the reactor is difficult in that case. (This is referred to as a "solid" plant.) The pressurizer began to indicate a high level of water, because of a combination of release of gas from it through the relief valve and formation of steam voids elsewhere in the reactor system. These steam voids formed because the pressure became low enough for the water to boil. The operators mistakenly thought that the reactor system had too much water and made the terrible mistake of turning off the emergency pumps which add water to the system; these pumps were turned on and off throughout the day, actions which showed a complete lack of understanding of the status of the reactor. It appears that this lack of understanding has been widespread throughout the nuclear industry. Naval reactor operators also are taught to follow the pressurizer level.

At 8 minutes into the accident, an operator noticed that the steam generators were dry of water on the secondary side, although the auxiliary feedwater pumps had been seen to start. The operator found that these pumps had been isolated from the system by closed

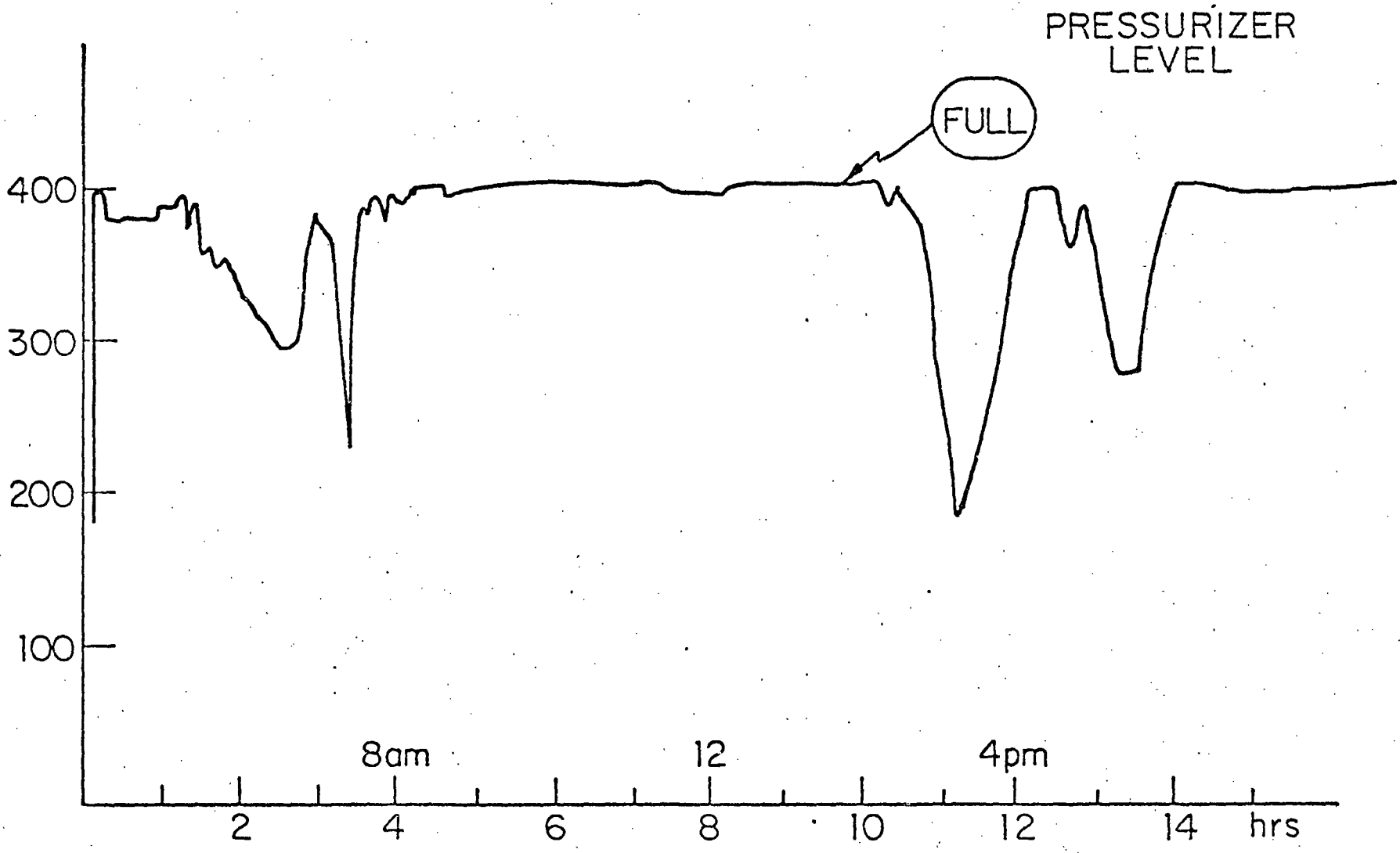


Figure 4 page 38

block valves, and the operator opened these valves. It still appears to be unclear why these valves were closed, and how long they had been closed. Although it was initially thought that this was a major contributor to the accident, it contributed nothing directly except added confusion. It misled the operators into false actions in the first minutes of the accident.

The reactor system temperature and pressure appeared to stabilize between 4:20 A.M. and 5:14 A.M.; this is because the water was boiling and the steam was going out of the relief valve. The reactor system was by this time rapidly filling with steam and emptying of water, and the circulating pumps were pumping a steam/water mixture.

This steam/water mixture was still adequate to maintain adequate cooling of the fuel rods, but the coolant pumps are not designed to pump steam and began to be noisy (cavitation). The operators turned off the pumps, one set at 5:14 a.m. and the other at 5:41 a.m. expecting that natural circulation would occur. Natural circulation would indeed have occurred if the reactor system had been filled with (subcooled) water. But since it was filled with a boiling water/steam mixture the decision led to a disaster. The water settled to the bottom and the steam rose to the top, making circulation impossible. Only the bottom 2 feet of the core was covered with water and the top part of the core was cooled only by steam.

Immediately after the pumps were turned off, the thermocouples measuring temperature in the coolant loops showed that the core was uncovered but the operators did not interpret them correctly. The temperature of the hot leg (top) went off scale, the temperature rising to a point that at that pressure could only indicate that the thermocouple was in pure steam, and the cold leg cooled down showing that circulation had stopped.

The operators had created serious problems, although they still did not know what the problems were or how they had created them. For about 1 hour--5:40 to 6:40 a.m.--the top of the core was uncovered and undercooled. Subsequent detailed calculations show that the temperature in the top of the core rose to 2000°F. At this temperature two phenomena occurred; the steam interacted chemically with the zirconium fuel rod cladding, oxidizing the cladding and releasing hydrogen:

$$Zr + H_2O \rightarrow ZrO + H_2$$

The fuel rods, by then brittle, cracked open and released the gaseous fission products (xenon, krypton, and iodine) to the reactor coolant water whence some left via the relief valve to the containment vessel and some to the outside environment through leaks in the primary coolant system. Rising radiation levels were observed as early as 5:20 a.m., a site emergency declared at 6:35 a.m. and a general emergency at 7:24 a.m.

Fortunately, at 6:18 a.m. an operator noticed that the tail pipe temperature on the electromagnetically operated relief valve was 35 F higher than on the adjacent safety valves, indicating steam flow. Why this was not noticed earlier, at 5:20 a.m., when the computer printed out this information on operator request, (the temperature difference was then 65 F) is not clear. However, the block valve was closed at 6:18 A.M., isolating the electromagnetically operated relief valve and ending the uncontrolled loss of coolant. The reactor began to repressurize and continued partial use of the emergency water injection system recovered the core by about 6:45 P.M.

Attempts soon after to restart the circulation pumps failed because the pumps were filled with steam. The reactor for the next 11 hours was cooled by the boiling of water to steam which left by the electromagnetically operated pressure relief valve.

There was still not complete understanding of the situation. The emergency coolant water was again turned off at 7:30 A.M.. and the reactor was partially depressurized twice more in attempts to get a stable situation, until at 2:28 P.M. the temperature in the hot leg of coolant loop A came on scale again. The reactor pumps (A) were finally operated again at 7:50 P.M. and the reactor core temperature and pressures stabilized.

The incident was over, although that was not clear for many more days.

The Hydrogen Bubble

As the reactor was being repressurized about 5 to 6 P.M. on Wednesday, March 28, 1979, it was noticed that although water was being rapidly fed into the reactor, the pressure rose only slowly. This was evidence that there was a gas bubble in the reactor coolant system. Moreover the bubble wasn't steam or it would have condensed.

The questions then arose:

1. Where was the bubble?

2. What was the composition of the bubble? Hydrogen (From zirconium and water reactions)?

3. Or was the hydrogen/oxygen mixture from a photodissociation of water present?

The location of the bubble was quickly determined; it could only be gas trapped in the head of the reactor vessel, where it could not be vented by remote control.

The composition of the bubble was originally assumed to be

condensible steam, then hydrogen, but on Friday morning, March 29, Dr. Joseph Hendrie, Chairman of NRC, asked his staff the third question. He got the (incorrect) answer that it could be a hydrogen/oxygen mixture. This, if true, could be alarming because hydrogen and oxygen can be ignited producing an explosion. No one was quite sure whether that would a) destroy a pump or b) open the reactor coolant system boundaries or even c) crack the containment vessel. It was feared that a) or b) could lead--even at this late stage of the accident--to a complete meltdown of the core. Not until Sunday afternoon, April 1 were definitive answers available. By then it was understood that:

a) The photodissociation of water to hydrogen and oxygen does not take place under these conditions. On the contrary, they recombine to form water (in ordinary operation hydrogen is added as a scavenger for oxygen to prevent corrosion). It was not however obvious that it is also true when fission product gases are in the waters as they were by 8 a.m. on Wednesday morning, but it transpires that it was the case.

b) Subsequent calculations made for NRC suggest that an explosion would not have broken the coolant system boundary anyway.

The question with the incorrect answer and the failure of industry to get the correct one rapidly to the right place, caused great confusion and even panic from Friday to Sunday, March 30th to April 1.

The release of the fission product gases to the primary reactor coolant systems also allowed the release of some fission product gases to the containment vessel--via the open pressure relief valve. Various small leaks in the piping allowed radioactivity releases to the other buildings, whence some were released through a filter to a stack and the atmosphere. Short lived radioactive isotopes had mostly decayed before release, or before passing over population centers. The dominant radioactive element released was xenon 133 with a half life of 5.27 days which emits a beta ray with maximum energy of 0.35 mev, average 0.17 mev, and a gamma ray of 80 kilovolt energy in the case of almost every disintegration. This is not a very high energy compared with some other radioactive decays. Most of this xenon was released within the first few days, before much had decayed. Xenon is a noble gas which for all practical purposes is chemically inert. The radiation from the xenon 133 is easily absorbed. This isotope was the dominant contributor to the radiation hazard. Most of the radioactive iodine either plated out on metal surfaces or was trapped in filters. In all it was estimated that of 2,000,000 curies of radioactive iodine (I 131) in the main building and 40,000 curies in the auxiliary building only 15 curies were released to the environment, but that 10,000,000 curies of noble gas, mostly xenon 133, were released in the period March 28-April 30, 1979, 2/3 of it in the first 36 hours.

The following agencies cooperated in radioactive monitoring:

The Department of Health, Education and Welfare (Center for Disease Control and the Food and Drug Administration)

The Department of Energy (Brookhaven National Laboratory)

The Environmental Protection Agency

The Metropolitan Edison Company

The State of Pennsylvania (Bureau of Environmental Health)

Their preliminary findings are given in a preliminary report, (with authors from several of these agencies who appear to be in agreement), and a final report is in preparation.

The preliminary report states that no one person in the general public received a dose (exposure) of more than 100 millirems. If the dose is added up over all persons within a 50 mile radius, the preliminary report showed an integrated dose of 3500 +1500 man x rems. Later correction is made for the facts that:

1. Xenon 133 is a favorable isotope and that response of people to xenon 133 is less than thermoluminescent dosimeters suggest

2. People were shielded by clothes and buildings

3. Many people moved away

This brought down the estimate of total population dose to about 2000 manrems or less.

The significance of these doses can be seen by comparison. Eighty millirems is an average yearly background radiation dose at sea level. Assuming a proportional relation between dose and response and based on observation, 5000 man rems leads to one cancer according to the BEIR (I) report.

Accordingly, the Three Mile Island accident will add less than 1/2 to the expected number of cancers among the population within 50 miles of the site of the power plant. This is an increase from the normal number of cancers expected in the area of approximately .5--from 350,000.0 to 350,000.5. The meaning of the fraction 0.5 is statistical; it is clear that it it will never be possible to determine whether the accident at Three Mile Island produced an additional cancer.

It is virtually certain that the Three Mile Island accident did not and will not cause many cancer cases, although we believe

it is irrelevant to this panel's work, since the main issue is whether the Commonwealth is prepared in the event of an accident with more serious results.

How Close Was the Three Mile Island Accident to a Disaster or Serious Accident?

The concern over Three Mile Island is for us not the accident itself but the perspective on accidents that it provides. Does it mean that serious accidents are more probable than previously supposed?

A class IX accident is defined in the Federal Resister (10 CFR 100) as one in which the radiation exceeds 100 mr/hr at the site boundary which dose was not achieved at Three Mile Island. However the Nuclear Regulatory Commission has stated that as far as core damage is concerned, the accident was large enough to be considered a class IX accident.

The "waiver of defenses" clause in the provisions of the Price-Anderson Act takes effect at about this level.

In answering the question, are serious actions more probable, we will first discuss intermediate questions. How close did the reactor come to a meltdown of the fuel? How close did the reactor come to a breach of the containment vessel and liberation of radioactivity?

The answers to these questions will be discussed in voluminous reports and hotly debated over the next several years. However some features seem definite.

1. The reactor came closer to a meltdown than any previous commercial reactor accident in a light water reactor.

2. It is not easy to say how close, for two reasons. On the one hand human failure was present in a way that had not been previously taken into account--the operators, by reasoning incorrectly, intensified the accident by a series of incorrect actions. The statistical question becomes: if we imagine 1000 independent accidents proceeding as happened at Three Mile Island up to 6:10 a.m. in how many of them would the operators have noticed the leaking relief valve--and if they had, would they therefore taken correct action? These questions are hard to answer. Secondly, there is disagreement over what would have happened to the reactor core if they had not acted correctly. It seems that the cooling of the top of the reactor from 5:30 a.m.--when it first became uncovered--to 7:00 a.m. when it was covered again, was greater than had been feared. This has led some to claim that a small loss of coolant accident could never lead to a meltdown since convective steam cooling may be adequate.

3. The probability of violating containment may still be small after a meltdown occurs. In reactor safety studies

a probability of 1/10 has been estimated.

4. All the radioactivity will not be released even if the containment is violated. Particularly critical are the chemical elements iodine, tellurium and cesium; if released they interact chemically in the body whereas xenon does not. Filters and plate out mechanisms kept the iodine release low at Three Mile Island, but in a serious accident these filters might be overloaded; they were in fact not as effective as they should have been at Three Mile Island because they had become saturated in previous use.

Acceptability of Accidents and Their Consequences

The panel made no attempt to decide whether one particular accident is publicly acceptable or unacceptable. The Kemeny Commission made a point that the present level of safety--which includes the accident at Three Mile Island, must be improved.

> "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 are typical of the nuclear industry."

It also note (P. 32 paragraph 16) that implicit among the calculations in the Rasmussen Report is an estimate of frequency of accidents similar in size to Three Mile Island. This frequency is one in several hundred reactor operating years. We have now had nearly 500 reactor operating years and one accident of this magnitude. Although the accident at Three Mile Island was not predicted by Rasmussen it was not in itself contrary to the probability estimates therein. Since Rasmussen and colleagues, and many of those who have read and understood the report, believe the results, if correct, were acceptable, it seems to us that this assumption of the Kemeny report represents a significant departure from those past beliefs and needs examination. This is particularly true when we realize that the main public criticisms of nuclear reactor safety and Rasmussen's report in particular, have been based on a disbelief in the numbers--not declared statements that even if the low accident probability estimates are correct, reactors are still unacceptable. Discussion by individual critics and the public seem not to have considered adequately whether the results in Rasmussen's report would be acceptable if true. However the nuclear industry and the Nuclear Regulatory Commission proceeded as if it were.

Kemeny doesn't address this discrepancy.

Appendix II. Review of Available Reports

Members of the Panel reviewed a number of reports. The most relevant are discussed below.

a) The adverse effects of exposure to low levels of radiation and to levels of radiation likely as the result of an accident.

There have been many reports on this topic. Of these, we note in particular the reports of the Committee on Biological Effects of Ionizing Radiation of the National Academy of Sciences, particularly the first of these in 1972 (BEIR I) and the most recent (1979) of which only a draft is available (BEIR III).

We note that the members of the BEIR III committee are presently disagreeing on whether the incidence of cancer in a population is proportional to exposure, or whether this is an overestimate of the number at low doses and therefore an overestimate of the risk. However we also note that there are a few scientists (e.g. Karl Morgan of Oak Ridge National Laboratory) who believe the linear hypothesis understates the risk by a factor of about 5.

Until this is settled we believe it is reasonable to assume that radiation exposure causes cancers in a population in proportion to the exposure.

Accepting this and the estimates given in the BEIR I report, the expected number of cancers expected in the event of an accident is

$$L = \frac{\sum^{N} D_i}{5000}$$

where the summation is over the whole population exposed (N people) and D is the exposure of the individual in rems.

b) The Rasmussen Report had flaws, some of which we list:

1. It is not very readable

2. The executive summary does not summarize the report

3. The discussion of common mode failures where several safety systems fail simultaneously from the same cause is not always correct. The best known example is the incorrect calculation of the probability of core melt arising from an anticipated transient without scram (ATWS) for a boiling water reactor.

4. The uncertainties in the numbers are larger than Rasmussen

states.

This study was overly praised by NRC and industry and overly damned by critics. Subsequently, the NRC expressed reservations about it. It was misused, including in Congressional testimony by its authors, but insofar as we know neither it nor the methodology used in it has been used to improve safety.

We agree for the most part with the conclusions (which include some of the above) of a committee set up by NRC at the request of Representative Udall and chaired by Dr. H. Lewis. We agree that the basic methodology of event tree analysis is useful. We agree with Dr. Lewis also in his testimony subsequent to Three Mile Island that this methodology can and should be used in licensing reactors, and training and licensing of operators.

In particular the Lewis review report said:

1. The [Rasmussen report] was an essential step beyond earlier attempts to estimate the risks of nuclear power.

2. The report attained a far reaching objectivecation of safety assessment, introduced a workable accident classification, and presented a methodology for the quantitative determination of risks.

3. The event tree/failure tree procedure, together with an adequate data base, has proved to be the best available tool for the quantification of the occurrence of low probability accidents.

4. The importance of late fatalities and property damage was recognized besides that of early fatalities although this is not apparent from the summary report and was not reflected in many of the statements purporting to have been based on the report, including those by the authors, about the risks of nuclear power.

The occurrence of an accident at Three Mile Island does not "invalidate" the general conclusions of the Rasmussen report or any of these reports. Rasmussen's general point that an accident falling just short of a meltdown is likely once every few hundred reactor years, but that other defenses will in the vast majority of cases prevent anything more serious, is not altered although not necessarily correct. Indeed the accident itself suggests the desirability of using the methodology for plant design and training purposes. The specific conclusions of this report applied only to two specific reactors--the Surry plant in Virginia (for which Westinghouse Electric Corp. provided the nuclear steam supply system) and Peach Bottom in Pennsylvania (a General Electric

plant). Rasmussen did not analyze a Babcock and Wilcox reactor, and if he had one so, it is possible that he would have realized that the accident sequence that took place at Three Mile Island was more probable than acceptable.

A more recent reactor safety study in Germany, chaired by Dr. Birkhofer of Munich is now available and the panel had a copy of the summary. While overcoming some of the defects in presentation of the Rasmussen report, it comes to similar conclusions.

c) The reports of NRC on the details of Three Mile Island accident and the radiation measurements thereat are thorough, seem very factual and show no bias that we could discern.

d) The best known general reports on comparative risks of nuclear and other power sources include the Ford-Mitre study; a report of a subcommittee on CONAES (Committee on Nuclear and Alternative Energy Sources of the National Academy of Sciences), the risks associated with nuclear power; and a report from Canada by Inhaber. The last of these, by Inhaber, is so full of errors that it is useless for policy purposes.

These reports put a large uncertainty on the comparison of nuclear power with the most obviously comparable alternative--coal (coal because its price is comparable, it is best burnt in large power plants, and there is plenty of it). But they all agree that unless the uncertainties all conspire to favor coal, and so against nuclear, nuclear power is probably safer. It is important to note that this argument depends upon a belief that the question of disposal of nuclear wastes can be safely dealt with. The responsibility for the resolution of this question lies with the federal government rather than an individual state.

Staff Report on the Generic Assessment of Feedwater Transients in BWR's and PWR's, NUREG-0560, May 1979.

Investigation into the March 28, 1979, Three Mile Island Accidnet, Office of Inspection and Enforcement, Nuclear Regulatory Commission, NUREG-0600, August 1979.

TMI-2 Lessons Learned Task Force, Status Report and Short Term Recommendations, NUREG-0578, July 1979.

Analysis of Three Mile Island Unit 2 Accident, Nuclear Safety Analysis Center, NSAC-1, July 1979, P.O. Box 10414, Palo Alto, California 94303.

Indexed Bibliography of TMI-2, NSAC Bib, August 1979.

Population Dose and Health Impact of the Accident at Three Mile Island Nuclear Station, NUREG-0558, May 1979.

The Effect On Populations of Exposure to Low Levels of Ionizing Radiation, Report of the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR I), NAS/NRC, Nov. 1972.

The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (BEIR III) Draft Report, NRC/NAS May 1979.

E.J. Sternglass--extensive list of references in BEIR report.

Mancuso, Kneale and Stewart, Radiation Exposures of Hanford Workers Dying From Cancer and Other Causes, Health Physics, 33:5, p. 36 (1977).

Mortality From Leukemia and Cancer in Shipyard Nuclear Workeers, T. Najarian and T. Colton, Lancet 1:8072, 1018 (1978).

Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, "The Rasmussen Report", WASH 1400, NUREG 75/014, October 1975.

Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission, H.W. Lewis, et al., NUREG/CR-0400.

Population Dose and Health Impact of the Accident at Three Mile Island Nuclear Station, NUREG 0558, May 1979.

The German Risk Study--Summary, Gesellschaft fur Reaktosicherheit (GRS) mbH, Glockengasse 2, 5000 Koln 1, Germany, August 15, 1979.

Jan Beyea, Some Long Term Consequences of Hypothetical Major Releases of Radioactivity to the Atmosphere from Three Mile Island, Princeton, N.J., Draft, Sept. 7, 1979.

D.C. Aldrich, P. McGrath, N.C. Rasmussen, Examination of Offsite Radiological Emergency Protective Measures for Nuclear Reactor Accidents for Questioning Core Melt; NUREG /CR-1131 or SAND 78-0454

J.G. Kemeny, B. Babbitt, P.E. Haggerty, C. Lewis, P.A. Marks C. Marret, L. McBride, H.C. McPhersoan, R.W. Peterson, T.H. Pisford, T.B. Taylor, A.D. Trunk; Report of the Presidents Commission of the Accident at Three Mile Island. November 1979

Demographic Statistics pertaining to Nuclear Power Reactor Sites, NUREG 0348 October 1979.

Massachusetts Commission on Nuclear Safety (Rathjens report) Department of Public Health, Commonwealth of Massachusetts September 1975

Title list, Publicly available documents Three Mile Island Unit 2, Docket 50-320 Cumulative to May 21 1979 NUREG 0568

NIAT (Nuclear Incident Advisory Team) Handbook (draft) Department of Public Health, Commonwealth of Massachusetts June 1979

New England Interstate Radiation Plan; New England Radiological Health Committee, March 1979

Commonwealth of Massachusetts Comprehensive Emergency Plan, Civil Defense Agency and Office of Emergency Preparedness January 1979

Areas around nuclear facilities should be better prepared for Radiological Emergencies. Report to the Comptroller General of the United States Congress. EMD -78-110 March 30,1979

Planning basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants NRC, EPA NUREG -0396 (EPA 520/1-78-016)

Protection of the Thyroid Gland in the Event of Releases of Radioiodine; National Council on Radiation Protection and Measurements NCRP report 55

Regulatory guide 1.111 Methods for Estimating atmospheric transport and dispersion of gaseous effluents in routine releases from light water cooled reactors NRC Rev 1 July 1977

Risks of Energy Production; H. Inhaber; AECB 1119/Rev 2 Nov 1978

Appendix III. Meetings

The following persons were present at meetings of the panel; the meetings of October 12, November 19 and December 14 were open. Formal presentations were made by Mr. Lydon of Boston Edison and Paul Cahill of the Civil Defense Agency on June 25. Informal discussions and response to the questions of the panel were the format of the last 3 meetings. Any person present was able to present his views and on December 14 a written submission from the South Shore Chamber of Commerce was made.

Many written and oral responses to our questions were supplied by the utility companies and state agencies.

We are grateful to all of these participants for sharing with us their views and thereby helping us to form our recommendations.

The list of attendees at the meetings follows.

June 25, 1979, Civil Defense Facility, Framingham

Richard Wilson, Harvard University

Susan Wiltshire

C.D.W. Thornton, Executive Office of Environmental Affairs

Al Comproni, Massachusetts Department of Public Health

John K. Olsen, Dept. of Public Safety

George Surteli, Massachusetts Department of Public Health

Edward Howard, Boston Edison Company

James Lydon, Boston Edison Company

William J. Bell, Mass. Dept. of Public Health (Radiation Control Program)

John Clement, Mass. Dept. of Public Health (Div. of Hazardous Materials)

Bernard Holan, Mass. Civil Defense Agency

George H. Tully, Asst. Sec., Executive Office of Public Safety

Lillian Morgenstern, Mass. Office for Energy Resources

Paul Cahill, Mass. Civil Defense Agency

October 12, 1979, Saltonstall Building, Boston

Frank Congel, Nuclear Regulatory Commission

Ed Wojnas, Mass. Civil Defense Agency

Bernard V. Holan, Mass. Civil Defense Agency

Robert H. Cunningham, Director, Mass. Civil Defense Agency

Robert Boulay, Mass. Civil Defense Agency

John Louerins, Mass. Civil Defense Agency

Gerald Hayes, Plymouth Civil Defense

Tom Sowdon, Boston Edison Company

Harrison Balfour, Boston Edison Company

Fred J. Mogolesko, Boston Edison Company

Christine E. Bowman, Boston Edison Company

Robin R. Shult, Boston Edison Company

Edward Karaian, Mass. Institute of Technology

James F. Wright, Dept. of Public Safety, Div. of Inspection

Joel Brown, Consultant to Boston Edison Company

R. Merlino, Consultant to Boston Edison Company

Frank Archibald, Mass. Dept. of Labor and Industries

Lewis Draffer, Dept. of Environmental Quality Engineering

Al Comproni, Mass. Dept. of Public Health

William J. Bell, Mass. Dept. of Public Health

Patrick Cassio, Mass. Institute of Technology

James A. MacDonald, Yankee Atomic

David E. McCurdy, Yankee Atomic

Thomas C. Elsasser, State Liaison Officer, U.S. Nuclear Regulatory Commission

Ronnie Lipshutz, Union of Concerned Scientists

V. Carlisle Smith, Dept. of Public Safety, Rep. on Governor's Council on Radiological Protection

John H. Clement, Mass. Dept. of Environmental Quality Engineering

George Swible, Mass. Dept. of Public Health

C.J. Maletskos, Advisory Council on Radiation Protection

L. Morsenstern, Mass. Office of Energy Resources

J.S. Fitzpatrick, Director, Mass. Office of Energy Resources

Judy Shore, Mass. League of Women Voters

Mary Gorham, Senator Sharon Pollard

Andrew C. Kadak, Yankee Atomic

Efford H. Pierce, Rowe Civil Defense Dept.

Joseph Mowe, Monroe, MA 01350

Richard Wilson, Harvard University

Susan Wiltshire

George Rathjens, Mass. Institute of Technology

November 19, 1979, McCormack Office Building, Boston

Lillian Morsenstern, Mass. Office of Energy Resources

John Olsen, Dept. of Public Safety

George Swible, Mass. Dept. of Public Health

C.J. Maletskos, Advisory Council on Radiation Protection

J.S. Fitzpatrick, Director, Mass. Office of Energy Resources

G. Parker, Dept. of Public Health

F.S.W. Wright, Attorney General's Office

Several representatives from Boston Edison

Several representatives from Yankee Atomic

Helen Woodman, State House News Service

George Rathjens, Mass. Institute of Technology

Susan Wiltshire

Richard Wilson, Harvard University.

plus many others.

December 14, 1979, State House, Boston

Gerald Parker, Mass. Dept. of Public Health

C.J. Maletskos, Advisory Council on Radiation Protection

George Swible, Mass. Dept. of Public Health

Bob Cunningham, Civil Defense

Jerry Ackerman, Boston Globe

Andrew C. Kadak, Yankee Atomic

Lincoln Clark, Jr., Mass. Institute of Technology (Reactor Laboratory)

Edmund C. Tarnuzzer, Yankee Atomic

Larry Carpman, Mass. Office of Energy Resources

Frank Archibald, Dept. of Labor and Industries

Helen Woodman, State House News Service

James W. Gosnell, Boston Edison

W.R. Griffin, HMM Associates, Consultant to Boston Edison

James F. Wright, Dept. of Public Safety

William H. Dormer, Jr., Dept. of Public Safety

John K. Olsen, Dept. of Public Safety

Harrison R. Balfour, Boston Edison Co.

John Murphy, Boston Edison Co.

Pat Granahan, 36 Croydon Rd., Hingham, MA

Joy Ausenstern-Stuart, 883 Nantasket Ave., Hull, MA

Joe Baerlein, New England Council

Elizabeth Murray, Executive Office of Transportation Construction

Lillian Morsenstern, Mass. Office of Energy Resources

Richard Wilson, Harvard University.

Susan Wiltshire

George Rathjens, Mass. Institute of Technology

Appendix IV. Glossary of Terms

Auxiliary building. A structure housing a variety of equipment and large tanks necessary for the operation of the reactor. These include make-up pumps, the make-up and waste gas decay tanks, and the reactor coolant hold-up tanks.

Babcock and Wilcox (BW). The company that designed and supplied the TMI-2 reactor and nuclear steam supply system.

Background radiation. Radiation arising from natural radioactive materials always present in the environment, including solar and cosmic radiation and radioactive elements in the upper atmosphere, the ground, building materials and the human body.

Beta particles. High-energy electrons; a form of ionizing radiation that normally is stopped by the skin, or a very thin sheet of metal.

Boston Edison Company. A local utility responsible for the operation of Pilgrim and other nuclear power reactors in the New England region.

Caesium or Cesium. A chemical element produced in fission. Cesium of isotope 137 has a half life of 10 years and has a gamma of 600 kev.

Chain reaction. A self-sustaining reaction; occurs in nuclear fission when the number of neutrons released equals or exceeds the number of neutrons absorbed plus the neutrons which escape from the reactor.

Cladding. In a nuclear reactor, the metal shell of the fuel rod in which uranium oxide pellets are stacked.

Collective dose. The sum of the individual doses received by each member of a certain group or population. It is calculated by multiplying the average dose per person by the number of persons within a specific geographic area. Consequently, the collective dose is expressed in person-rems. For example, a thousand people each exposed to one rem would have a collective dose of 1,000 person-rems.

Condensate booster pumps. Three pumps located between the condensate polisher and the main feedwater pumps.

Condensate polisher. A device that removes dissolved minerals from the water of the feedwater system.

Condensate pumps. Three pumps in the feedwater system that pump water from the condensers to the condensate polishers.

Condensers. Devices that cool steam to water after the steam has passed through the turbine.

Containment building. The structure housing the nuclear reactor; intended to contain radioactive solids, gases, and water that might be released from the reactor vessel in an accident.

Control rod. A rod containing material that absorbs neutrons; used to control or halt nuclear fission in a reactor.

Core. The central part of a nuclear reactor that contains the fuel and produces the heat.

Critical. Term used to describe a nuclear reactor that is sustaining a chain reaction.

Curie. A unit of the intensity of radioactivity in a material. A curie is equal to 37 billion disintegrations each second.

Decay heat. Heat produced by the decay of radioactive particles; in a nuclear reactor this heat, resulting from materials left from the fission process, must be removed after reactor shutdown to prevent the core from overheating. See radioactive decay.

Emergency core cooling system (ECCS). A backup system designed to supply cooling water to the reactor core in a loss-of-coolant accident.

Emergency feedwater pumps. Backup pumps intended to supply feedwater to the steam generators should the feedwater system fail to supply water. Also called auxiliary feedwater pumps.

Feedwater pumps. Two large pumps capable of supply TMI-2's two steam generators with up to 15,500 gallons of water a minute.

Feedwater system. Water supply to the steam generators in a pressurized water reactor that is converted to steam to drive turbines; part of the secondary loop.

Fission. The splitting apart of a heavy atomic nuclus, into two or more parts when a neutron strikes the nucleus. The splitting releases a large amount of energy.

Fission products. Radioactive nuclei and elements formed by the fission of heavy elements.

Fuel damage. The failure of fuel rods and the release of the radioactive fission products trapped inside them. Fuel damage can occur without a melting of the reactor's uranium.

Fuel melt. The melting of some of the uranium oxide fuel inside a reactor.

Fuel rod. A tube containing fuel for a nuclear reactor.

Gamma rays. High-energy electromatic radiation; a form of ionizing radiation, of higher energy than x-rays, that penetrates very deep into body tissues.

General emergency. Declared by the utility when an incident at a nuclear power plant poses a potentially serious threat of radiation releases that could affect the general public.

General Public Utilities Corporation (GPU). A utility holding company; parent corporation of the three companies that own TMI.

Genetic defects. Health defects inherited by a child from the mother and/or father.

Half-life. The time required for half of a given radioactive substance to decay.

Health physics. The practice of protecting humans and their environment from the possible hazards of radiation.

High pressure injection (HPI). A pump system, capable of pumping up to about 1,000 gallons a minute into the reactor coolant system; part of the emergency core cooling system.

Iodine-131. A radioactive form of iodine, with a half-life of 8.1 days, that can be absorbed by the human thyroid if inhaled or ingested and cause non-cancerous or cancerous growths.

Ionizing radiation. Radiation capable of displacing electrons from atoms; the process produces electrically charged atoms or ions. Forms include gamma rays, x-rays, and beta particles.

Isolation. Condition intended to contain radioactive materials released in a nuclear accident inside the containment building.

Isotope. Two nuclei of the same chemical element but different mass.

Krypton-85. A radioactive noble gas, with a half-life of 10.7 years, that is not absorbed by body tissues and is soon eliminated by the body if inhaled or ingested.

Let-down system. A means of removing water from the reactor coolant system.

Loss of coolant accident (LOCA). An accident involving a broken pipe, stuck-open valve, or other leak in the reactor coolant system that results in a loss of the water cooling the reactor core.

Make-up system. A storage tank in the auxiliary building which

provides water for the make-up pump.

Meltdown. The melting of fuel in a nuclear reactor after the loss of coolant water. If a significant portion of the fuel should melt, the molten fuel could melt through the reactor vessel and release large quantities of radioactive materials into the containment buildings.

Metropolitan Edison Company (Met Ed). Operator and part owner of the Three Mile Island nuclear power plant.

Millirem. 1 one-thousandth of a rem; see rem.

Natural cooling. The circulation of water without pumping by heating water in the core and cooling it in the steam generator.

Neutron. An uncharged particle found in the nucleus of every atom heavier than ordinary hydrogen; neutrons sustain the fission chain reaction in nuclear reactors.

Noble gases. Inert gases that do not react chemically and are not absorbed by body tissues, although they may enter the blood if inhaled into the lungs. These gases include helium, neon, krypton, xenon, and radon.

Nuclear Regulatory Commission (NRC). U.S. agency responsible for the licensing and regulation of commerical, test, and research nuclear reactors.

Nucleus. The central core of an atom.

Person-rems. See collective dose.

"Poisons". Materials that strongly absorb neutrons; used to control or stop the fission reaction in a nuclear reactor.

Pilot-operated relief valve (PORV). A valve on the TMI-2 pressurizer, designed to open when steam pressure reaches 2,255 pounds per square inch.

Potassium iodide. A chemical that readily enters the thyroid gland when ingested. If taken in a sufficient quantity prior to exposure to radioactive iodine, it can prevent the thyroid from absorbing any of the potentially harmful radioactive iodine-131.

Pressure vessel. See reactor vessel.

Pressurizer. A tank that maintains the proper reactor coolant pressure in a pressurized water reactor.

Pressurized water reactor. A nuclear reactor system in which reactor coolant water is kept under high pressure to keep it from

boiling into steam.

Primary system. See reactor coolant system.

Radioactive decay. The spontaneous process by which an unstable radioactive nucleus releases energy or particles to become stable.

Radioactivity. The spontaneous decay of an unstable atom. During the decay process, ionizing radiation is usually given off.

Radiolysis. The breaking apart of a molecule by radiation, such as the splitting of water into hydrogen and oxygen.

Reactor (nuclear). A device in which a fission chain reaction can be initiated, maintained, and controlled.

Reactor coolant pump. One of four large pumps used to circulate the water cooling the core of the TMI-2 reactor.

Reactor coolant system. Water that cools the reactor core and carries away heat. Also called the primary loop.

Reactor vessel. The steel tank containing the reactor core; also called the pressure vessel.

Rem. (Roentgen equivalent man) A standard unit of radiation dose. Frequently radiation dose is measured in millirems for low-level radiation; 1,000 millirems equal one rem.

Respirator. A breathing mask that filters the air to protect against the inhalation of radioactive materials.

Safety-related. The NRC employs several broad definitions for this concept. By one, safety-related items are "structures, systems and components that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public." However, the NRC has no specific list of safety-related items. The licensee designates what in its plant is considered safety-related. If the NRC disagrees, the question is negotiated. Safety-related items receive closer quality control and assurance, maintenance, and NRC inspection.

Saturation temperature. The temperature at which water at a given pressure will boil; the saturation point of water at sea-level is 212 F.

Scram. The rapid shutdown of a nuclear reactor, by dropping control rods into the core to halt fission.

Secondary systems. See feedwater system.

Site emergency. Declared by the utility when an incident at a

nuclear power plant threatens the uncontrolled release of radioactivity into the immediate area of the plant.

Solid system. A condition in which the entire reactor coolant system, including the pressurizer, is filled with water.

Steam generator. A heat exchanger in which reactor coolant water flowing through tubes heats the feedwater to produce steam.

Steam table. A chart used to determine the temperature at which water will boil at a given pressure.

Tellurium. A chemical element produced in fission. Solid under ordinary conditions.

Thermoluminescent dosimeter (TLD). A device to measure nuclear radiation.

TMI. Three Mile Island; site of two nuclear power reactors operated by Metropolitan Edison Company.

Transient. An abnormal condition or event in a nuclear power system.

Trip. A sudden shutdown of a piece of machinery.

Turbine building. A structure housing the steam turbine, generator, and much of the feedwater system.

Uranium oxide (UO_2). A chemical compound containing uranium and oxygen that is used as a fuel in nuclear reactors.

Waste gas decay tank. One of two auxiliary building tanks in which radioactive gases removed from the reactor coolant are stored.

Xenon-133. A radioactive noble gas, with a half-life of 5.3 days, that is not absorbed by body tissues and is soon eliminated by the body if inhaled or ingested.

Yankee Atomic Group. A company formed by several New England utilities to build the nuclear power plant at Rowe, Mass. Now also an engineering service organization for the New England utilities.

Zircaloy-4. A zirconium alloy from which fuel rod claddings is made.

Appendix V. List of Letters

7/10/79 and 8/2/79--J.T. Driscoll, Mass. Turnpike Authority, Use of Turnpike with enclosures.

7/19/79--L.E. Beshian, University of Lowell, Shipment from the University of Lowell Reactor.

7/23/79--L. Clark, Mass. Institute of Technology, Shipment from the MIT reactor.

8/13/79--G.E. Parker, Department of Public Health, Fundins for DPH work with enclosures.

8/6/79--R.H. Cunninsham, Civil Defense Asency, Emergency plans

12/14/79--R.F. Frazier, South Shore Chamber of Commerce, Need for Pilgrim II.

8/31/79--M.B. Meyer, Attorney General's Office, Pilgrim II hearins.

9/4/79--J.M. Lydon, Boston Edison, Response to questions

10/3/79--J.M. Lydon, Boston Edison, (A) Management of unusual events (B) radiation exposure (C) communication flow paths.

8/30/79--N.M. Haller, NRC, response to questions with enclosure NUREG-0578.

9/10/79--D.E. Vandenbursh, Yankee Atomic Electric, response to questions with enclosure.

10/11/79--C.J. Maletskos, Advisory Council on Radiation Protection, report on emergency plans with enclosure.

10/12/79--J.M. Lydon, Boston Edison, Oyster Creek incident.

11/1/79--J.C. Brooks, Boston Edison, response to questions.

12/14/79--G.E. Parker, Department of Public Health (handed to Richard Wilson), list of TLD's.

12/17/79--J. Driscoll, Mass. Turnpike Authority, use of turnpike.

Several letters from Mr. Harold Rafton, 9 Aldan Road, Andover, MA concerning work by the Union of Concerned Scientists and nuclear power in general.

Mr. Dave Miner (undated), a letter concerned with sabotage of nuclear reactors.