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INTERIM REPORT

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NRC Research and Technical Assistance Report

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ORNL

FOREIGN TRIP REPORT

ORNL/FTR-859

DATE: June 16, 1980

SUBJECT: Report of Foreign Travel of R. A. Kisner, Principal Investigator for NRC Research Program entitled "Operational Aids for Reactor Operators"

TO: Herman Postma

FROM: R. A. Kisner

PURPOSE: (1) Attend a demonstration and discussion of the German nuclear power plant diagnostic and analysis system, Storungsanalyserechner (STAR), at the technical research center Gesellschaft fur Reaktorsicherheit (GRS) and at the Grafenrheinfeld nuclear power plant.

(2) Attend the Enlarged Halden Program Group Meeting on Applications of Process Computers in Plant Control.

(3) Discuss research and development activities in man-machine interaction and nuclear power plant control room design with Technischer Uberwachungs-Verein (TUV).

SITES VISITED:

5/28-30/1980	GRS Garching, W. Germany, L. Felkel, W. Buttner, and A. Hold
6/1-6/1980	Halden Conference, Lillehammer, Norway
6/9/1980	BMI Bonn, W. Germany, Dr. Fechner
	BAU Dortmund, W. Germany, H. Kollmeier, MD
6/10/1980	TUV (Rhineland), Koln, W. Germany, Dr. A. Tietze and E. Bohr
6/11/1980	TUV (Essen), Essen, W. Germany, K. D. Paul and Mr. Kietser

ABSTRACT: The central subject throughout this trip was human factors engineering as it relates to nuclear power plants. In particular, the subjects of operational aids for reactor operators and design of nuclear power plant control rooms were emphasized by the traveler. Information outside the scope of these subjects has not been included in this report.

The traveler attended a demonstration and discussion at Gesellschaft fur Reaktorsicherheit (GRS), Garching, West

NRC Research and Technical Assistance Report

Germany, of the computer-based disturbance analysis system, STAR. The purpose of the system is to assist the plant operating crew in determining the prime causes of an alarm and the consequences of propagation of a disturbance. A demonstration system has been installed at the Grafenrheinfeld nuclear power plant (Federal Republic of Germany) and awaits plant startup. A discussion was held on other projects at GRS Garching. A project to develop a digital control system for nuclear reactors and an engineering simulator (GARLIC) is also underway at GRS. The chief objective of this project is to introduce direct digital control (DDC) into German nuclear power plants. Another project, related to operational aids, is to develop computerized procedures. Protection system operation and maintenance procedures will be displayed on a computer driven video display. The system has not been implemented.

To acquire knowledge of current European R&D, the Office of Nuclear Regulatory Research, NRC, requested the traveler to attend the Enlarged Halden Program Group Meeting on Applications of Process Computers in Plant Control. The subjects covered in the conference sessions were control room design; operator's capabilities and role; systems for operator support in reactor surveillance; core power distribution, simulation, and control; and reliable hardware and software design.

The last week of the trip was spent discussing man-machine interaction, control room design, and operational aids with members of the nuclear regulatory body, Federal Ministry for Interior Affairs (BMI); Federal Agency for Occupational Safety and Accident Research (BAU); Technical Supervisory Society (TUV) Rhineland, and TUV Essen. Administrators at these organizations indicate that work in human factors engineering and effects of stress on performance is increasing. A detailed study of plant operating procedures has been completed by TUV, and guidelines are being formulated by BMI. A study on the ergonomic design of the control room is in progress in parallel with a regulatory committee working on ergonomic guidelines. Finally, a study on the communication of information within the plant is starting. The director of the Institute for Accident Research (IFU), a part of TUV, is seeking cooperation with the Oak Ridge National Laboratory to solve human factors problems. An exchange of information is planned.

REPORT

The traveler, principal investigator for the NRC Research Program entitled "Operational aids for Reactor Operators," was requested by the Office of Nuclear Regulatory Research, NRC, to attend the Enlarged Halden Program Group Meeting, June 1-6, 1980, at Lillehammer, Norway. The topic of this conference was directly related to ongoing human factors engineering work at ORNL and NRC. Since, prior to the trip, the traveler had made several contacts in West Germany, the visit was extended to include discussions with these contacts on the subjects of operational aids, control room designs, man-machine interactions, human factors engineering, and other related topics. In addition to attending the conference, discussions were held with the following five German organizations [in English]: Gesellschaft fur Reaktorsicherheit (GRS) [Organization for Reactor Safety], Garching location; Bundeministerium des Inneren (BMI) [Federal Ministry for Interior Affairs], Bonn; Bundesanstalt fur Arbeitsschutz und Unfallforschung (BAU) [Federal Agency for Occupational Safety and Accident Research], Dortmund; Technischer Uberwachungs-Verein Rheinland (TUV-Rheinland) [Technical Supervisory Society-Rheinland Division], Cologne; and TUV-Essen location. In the following paragraphs, discussions held at these organizations will be summarized. The report will conclude with a general summary of the Halden meeting.

GRS, Garching

The traveler was briefed on the technical details of the nuclear reactor diagnostic and analysis system under development in Germany, called Storungsanalyserechner (STAR). The system is based on a technical approach first developed at Halden, Norway. The basic functions of STAR are (1) to filter alarms to reduce them to a manageable quantity, (2) to determine the prime cause of an alarm or burst of alarms, (3) to determine the propagation sequence of a disturbance should the operator choose not to intervene, and (4) to provide appropriate instructions to the operator for plant recovery. As an additional benefit in generating the logic models for STAR, several errors in plant design were discovered.

The present design of STAR is that of a pilot project, and in its present state models only feedwater and component cooling water subsystems of the 1300 MW Grafensheinfeld PWR in the Federal Republic of Germany. This was done primarily to circumvent the regulatory and safety problems that could be encountered if STAR were interfacing the primary coolant loop or reactor core subsystems.

The GRS has at their Garching location a small engineering simulator with a STAR system installed for design and testing purposes. Much of the design was performed at this location. At the Grafenrheinfeld PWR (approx 250 km north of Munich) a second STAR system has been installed. This system is fully functional, but on-line testing is awaiting startup of the power plant sometime in 1981. A third installation, at Biblis-B

a 1300 MWe PWR, is planned to be technically more advanced than that of Grafenrheinfeld. This application will have direct access to plant signals (rather than deriving signals from the plant computer) and will use the European analysis and communication language PEARL.

Discussions were also held on the core supervision project underway at GRS. Under this project, an engineering simulator is being developed. The simulation, performed by the digital computer code GARLIC, is built up from the physics of the physical processes involved. The developers of the simulator are trying to produce a simulator capable of correctly simulating the interactions between plant components, subsystems, and system. They feel that predicting correct system interactions is more important than precision calculation of plant variables for analysis work. Other workers in the group are developing schemes for direct digital control (DDC) of reactor control rods. The control scheme will use the simulator as a development tool.

Other projects are underway at GRS in the areas of hardware and software reliability. One group is developing computerized procedures. Operation and maintenance procedures for the core protection system will be displayed on a computer-driven video display. To prove the reliability of the system, the computerized procedures will be operated in parallel with the normal equipment. This system has not been implemented. Several workers are developing a computer program that analyzes other computer codes for software errors. This tool shows the invocation sequence of subroutines that are called for by each functional software module of the computer code under test. This work was presented at the Enlarged Halden Program Group Meeting.

BMI, Bonn

The traveler met briefly with Dr. Fechner, who is responsible for the Federal guidelines relating to nuclear power plant procedures, control room design, and human engineering. The Federal Ministry of the Interior is similar to the NRC since it establishes the standards and criteria that the States apply. (The actual licensing is done by the State that has jurisdiction over the facility.) Dr. Fechner indicated that the quantity of human factors engineering studies in West Germany is increasing and that he would like to keep informed about man-machine and operator aids developments in the NRC and at ORNL. His budget for human factors studies in 1981 will be around $500,000 for studies and confirming research. He plans by the end of 1980 to identify these areas that require further research and would like to make contact with DiSalvo of the NRC to further discuss current work in the field and future programs. Dr. Fechner seemed very interested in the programs and approaches that are underway at ORNL.

BAU, Dortmund

Research on stress and its effect on humans has been underway at the Federal Agency for Occupational Safety and Accident Research for several years; however, until recently the work was confined to physiological effects of stress. Dr. Heinrich Kollmeier has performed research on the medical aspects of stress: physiology and biochemistry. He is working on the quantification of stress. He indicated that much research has been done in this area in the USSR.

In 1981, researchers at BAU will begin experiments to test the mental reactions of humans to induced stress. Subjects will be given multiple stress stimuli in environmental chambers; their reactions will be tested while performing specified tasks such as numerical calculations. The traveler suggested that the subjects be given a "control panel" that requires simple operation. The subject would be required to read data, make a simple calculation, then make an adjustment based on the outcome of the calculations. Subject errors could easily be recorded. Dr. Kollmeier indicated that he would like advice on how to construct such an apparatus. The traveler indicated that he would contact those workers at ORNL and elsewhere who are experienced with these techniques and, if possible, send back information on design of a test apparatus.

Mr. Kollmeier indicated that he would be willing to attempt to answer any questions on stress analysis and effects of stress. His address is indicated in Appendix B.

TUV, Rhineland

The Technical Supervisory Society (TUV) of Rhineland has been involved in human factors related work for several years. Recently, they performed a study on the procedures and instructional material used at German nuclear power plants. Based on the results of the procedures study, a regulation is being written for the design of power plant procedures manuals.

In progress is a study on the ergonomic design of nuclear reactor control rooms. In parallel with this study, a regulatory committee is preparing guidelines for control rooms. This project will be finished by the end of 1980.

Just starting is a study on communication of information within the power plant. Two subjects to be investigated are the exchange of operations information from one shift to another and the exchange of information between maintenance and operations crew. This study will begin in the next few months.

Researchers at TUV in conjunction with Kraftwerk Union (KWU) are planning experiments on the KWU simulator for operator performance measurements. They want to determine what interaction the operator's model of the plant process has with his job function. They intend

to demonstrate that a well-trained but otherwise normal operating crew will have difficulty stabilizing the power plant under certain specific accident conditions. The inference, then, is that an "average" crew would handle the situation very poorly, Based on the outcome of these simulator experiments, they will develop suggestions on organizing and presenting information that the operator needs. Researchers involved with this work feel that the KWU simulator will not be adequate after the first two years of this project. Possibly a more advanced simulation center will be needed much like that under discussion in the United States by NRC and DOE.

Dr. A. Tietze, head of the Institute for Accident Research - a part of TUV, indicated that his organization would consider a cooperative program with the NRC and ORNL. The subject areas of involvement would be human factors engineering, control room design, operational aids, and man-machine interactions. After discussion, the following time-table was developed as a starting place for cooperation:

1. Exchange of Information: Both parties, TUV (Rhineland) and NRC/ORNL, will prepare a survey of on-going and planned activities in the subject areas that include those activities with which international cooperation would be desirable. If possible, a listing of other institutions and corporations who are interested in these subject areas should be included. These letters should be exchanged by July 10, 1980.

2. Specialists Meeting or Colloquium: After exchange of information, both parties should prepare for an informal meeting to discuss the possible arrangements for shared program tasks or personnel. A specialists' meeting for the further exchange of technical information could be arranged if the initial exchange of program information is felt to be inadequate.

Dr. Tietze will be discussing the details of cooperative work arrangements with Dr. Fechner of BMI and possibly with personnel of the Federal Ministry of Technology (BMFT).

TUV, Essen

Personnel at TUV, Essen, are constructing fault-tree diagrams for the entire nuclear power plant. Mr. K. D. Paul believes he can apply these fault-tree techniques to the operating crew. By including operator actions as a part of the overall fault-tree, better plant reliability estimates can be made. No modeling work of the operations crew has been performed, but Mr. Paul is seeking information that would help him develop the techniques.

Enlarged Halden Program Group Meeting, Lillehammer, Norway

The conference was held to present work performed by Halden research personnel and other researchers working in related subject areas. The subject areas of the process computer applications sessions were alarm and status information systems; operator's capabilities and role; systems for operator support in reactor surveillance, core surveillance, and control; and reliable hardware and software design. The traveler recommends future participation in Halden Program Group meetings on computer application. Much of the information gained at the meeting will serve to stimulate new approaches on projects at ORNL related to operator aids and man-machine interaction.

As an afterthought, the traveler made these observations:

1. Some of the European researchers were unaware of significant work that had either taken place or was taking place in the United States in their subject areas. This may indicate a lack of international information exchange.

2. Organizations work on parts of the overall man-machine control room problem, but no single organization stands out as having a comprehensive research program that encompasses all areas of research applicable to reactor operations problems.

Several techniques for helping the operator through abnormal plant conditions were discussed by lectures through the course of the meeting. A listing of the categories of operator aids follows. Some of these systems are commercially available; some are under development; others are only concepts. Though the list does not exhaust all possible techniques to assist operators, it does serve to illustrate the variety of ongoing projects around the world. (Order does not indicate any priority or importance.)

	Technique	Status
1.	Disturbance Detection and Analysis	Pilot project under development
2.	Success Path Diagramming for Failed Systems	Under development
3.	Surveillance of Critical-Safety Related Functions	One system is commercially available
4.	Alarm Filtering	Under development
5.	Advanced Plant Simulator	Concept

Technique	Status
6. Advanced Video Display	Under development; some are commercially available
7. Incipient Component Failure Detection	Concept
8. Noise Pattern Recognition	Under development; demonstration systems are being tested
9. Signal and Data Verification	Under development
10. Valve and Pump State Indicator	Under development
11. Reactor Core Surveillance	Under development; some devices are commercially available
12. Procedures by Computer Recall	Under development
13. Maintenance Tracking Computer	Concept

At the conclusion of the meeting, session chairmen and participants presented some general conclusions and observations about operator aids and simulators: (1) The electric utilities want simple systems to survey complicated situations and to supply the operator with the necessary information required to bring the power plant under control. (2) The point of view of the operator's role is different with each organization - utility, vendor, research laboratory, etc. Even within organizations, there is disagreement over his role. (3) Equipment designed to provide the operating crew with assistance during normal and abnormal conditions should also help in forming a correctly integrated process image. (4) Some researchers propose that if cause and consequence trees for a disturbance analysis system (DAS) can be constructed, they can be automated, and automation would free the operator to function at a supervisory level above the DAS. (5) Experiments on simulators involving operator performance measurements are valid only under certain limited conditions. A "super simulator facility" should be constructed on which to perform experiments. (6) A simulator placed near the plant control room would give the operator an opportunity to "tune" and update his mental model with the plant. The simulator's physical appearance need not resemble the control room. A facility of this type also could reduce operator boredom.

APPENDIX

A. ITINERARY

DATE	LOCATION	SITE/ ORGANIZATION	SUBJECT	PRINCIPAL CONTACTS
5/28/80	Garching, W. Germany	GRS	STAR demonstration	L. Felkel W. Buttner A. Hold
5/29/80	Grafenrheinfeld, W. Germany	PWR Nuclear Power Plant	STAR demonstration	L. Felkel W. Buttner
5/30/80	Garching, W. Germany	GRS	STAR discussion	L. Felkel
6/1-6/80	Lillehammer, Norway	Halden Project	Conference on process computers	
6/9/80	Bonn, W. Germany	BMI	Regulatory views on control room design	Dr. Fechner
	Dortmond, W. Germany	BAU	Medical research on stress and work performance	H. Kollmeier, MD
6/10/80	Koln, W. Germany	TUV (Rhineland)	Discussion of work on control room design and human factors engineering	Dr. A Tietze E. Bohr
6/11/80	Essen, W. Germany	TUV (Essen)	Discussion of existing regulatory guidelines and application of fault-tree diagrams to operator actions	K. D. Paul

B: LIST OF PERSONS CONTACTED WORKING IN CONTROL ROOM DESIGN OR OPERATIONAL AIDS--BY SUBJECT AREA

1. Government Regulatory

Dr. Fechner
Bundesministerium des Inneren (BMI)
P. O. Box 170290
5300 Bonn 1
Federal Republic of Germany
Telephone: 49-228-681-4549

2. Psychology

Erik Hollnagel, Psychologist
Electronics Department
Riso National Laboratory
DK-4000 Roskilde
Denmark

3. Medicine and Physiology

Dr. Heinrich Kollmeier, MD Director and Professor
Bundesanstalt fur Arbeitsschutz und Unfallforschung
P. O. Box 170202
4600 Dortmund 17
Federal Republic of Germany

Dr. Carl Wilhelm Sem-Jacobsen
E. E. G. Research Institute
P. O. Box 9
Gaustad, Oslo 3
Norway

4. Research and Development Projects

Dr. Alfons Tietze, Director Institute for Safety Research
Technischer Uberwachungs - Verein Rheinland e.V.
Institut fur Unfallforschung
P.O. Box 101750
5000 Koln 1
Federal Republic of Germany
Telephone: 49-221-8393-2934
Telex: 887 3659

Eckhard Bohr, Psychologist
Address as above.

Dr. W. Bastl, Director, Reactor Dynamics Division
Gesellschaft fur Reaktorsicherheit (GRS) mbH
Forschungsgelande
8046 Garching
Federal Republic of Germany

Lothar Felkel, Computer Specialist
Address as above

Wolf Buttner, Analyst
Address as above

A. Zapp
Address as above

5. Control, Instrumentation, and Simulation

Dr. A. Hold
Gesellschaft fur Reaktorsicherheit (GRS) mbH
8046 Garching
Federal Republic of Germany

Dr. O. Lupas
Address as above

Dr. D. Beraha
Address as above

6. Reliability Analysis

Dr. Schuller, Hardware Reliability Specialist
Gesellschaft fur Reaktorsicherheit (GRS) mbH
8046 Garching
Federal Republic of Germany

Dr. Peter Puhr-Westerheide, Software Reliability Specialist
Address as above

Mr. Kietser, Department Head
Rheinisch-Westfalischer TUV e.V.
Dept. IV 3.1
P. O. Box 70 41
4300 Essen 1
Federal Republic of Germany

Klaus-Dietrich Paul, Fault Diagrams Analyst
Address as above

C. BIBLIOGRAPHIC LISTING OF ACQUIRED LITERATURE

Papers were presented at the Enlarged Halden Program Group Meeting on Applications of Process Computers in Plant Control, June 1-6, 1980, Lillehammer, Norway. Papers are listed in the order of their presentation.

1. M. W. Jervis, "Integrated Data and Alarm Systems for Central Control Room."

2. B. B. Thomassen, J. Augustin, "Alarm Generation, A Concept Based on Automatic Logical Filtering."

3. B. Wahlstrom, E. Rintala, J. Helske, "Inhibition of Alarms during Nuclear Power Plant Operation."

4. F. Øwre, J. K. Trengereid, "An Extended Concept for Plant Status Information Handling."

5. E. Edsberg, K. Netland, "The Impact of Non-Technical Factors on Operator's Performance."

6. C. Meijer, "Operational Support Systems to Improve Man-Machine Interaction in a Nuclear Power Plant."

7. O. R. Meyer, "The LOFT Augmented Operator Capability Program."

8. C. W. Sem-Jacobsen, "Brain Computer Communication - To Improve Efficiency and Safety, Reduce Environmental Hazards and Improve the Image of the Industry."

9. R. Stokke, J. Augustin, O. Falmyr, "Simulation Facilities for Operator Performance Experiments."

10. E. Hollnagel, "The Role of Conceptual Structures in Analyzing Operator Behaviour."

11. M. Holmgren, "The Development of "Process Feeling" and Problem Solving Behaviour in Computer Based Control Rooms."

12. J. Ø. Hol, G. Øhra, "Development of Guidelines and Recommendations for Colour Display Based Information Presentation Systems."

13. O. Johanson, "The General Structure of a Disturbance Analysis System."

14. A. Long, "Disturbance Analysis and Surveillance Systems - Critical Appraisal and Future Prospects."

15. W. Buttner, L. Felkel, A. Zapp, "Present Status and Further Development of the STAR Disturbance Analysis System."

16. M. R. Herbert, "A Computer Programme for Assessing the Potential Benefits of Disturbance Analysis Systems in Improving the Availability of Nuclear Power Stations."

17. E. Stokke, R. Espefalt, J. Lorenzen, "Application of Pattern Recognition Principles in Noise Analysis Surveillance Systems."

18. D. Stegemann, P. Gebureck, G. Grondey, "A Multichannel On-Line Noise Analysis Reactor Surveillance System (MONAS) for BWR's Development and Application."

19. J. Christenson, G. Dahll, "Reliability Analysis Methods for Determining Appropriate Operator Response to Different States of the Reactor Safety System."

20. G. R. Burdick, "Operator Support through Modern Optimal Estimation and Control."

21. M. Havranek, J. Elzmann, "A Posterior Evaluation of the Fine Structure of the Power Density in a Light-Water Reactor Lattice during Control-element Withdrawal."

22. K. Haugset, U. Scot-Jørgensen, J. van Nes, Å. Solic, "The Core Surveillance System SCORPIO. Motivation Project Status."

23. J. van Nes, Å. Solie, U. Scot Jørgensen, "The Core Surveillance System SCORPIO: Functions and Structure."

24. A. Hold, O. Lupas, "GARLIC, A Real Time Simulator for PWR Nuclear Power Plants."

25. S. Hval, "A Description of the Core Physics Simulator CYGNUS, for On-Line Applications in Core Surveillance and Control Systems."

26. M. Tsuiki et al., "Power Bias Factor Correction and On-Line Simulator LOGOS02."

27. D. Beraha, J. Karppinen, "Spatial Core Control: On-Line Control and Strategy Prediction by Hierarchical Techniques."

28. I. Leikkonen, "Core Control Optimization by Multistage Mathematical Programming."

29. T. Busi, R. Moen, R. Versluis, "Multivariable Feedback Control. Case Study of CE System 80 Reactor."

30. M. W. Jervis, "Some Practical Aspects of Distributed Digital Control Systems."

31. F. Pettersen, T. Palmgren, "The Development of a Microprocessor-based Distributed Control System."

32. K. Klingstrøm, P. Ofstad, "Portable Software for Microcomputers."

33. W. Ehrenberger, P. Puhr-Westerheide, "The PEARL-Analyser, A Tool for Static Tests of Modules."

34. G. Abbate et al., "An Experience with PSL/PSA Applications in Requirements Specifications of a PWR Protection System."

35. [illegible] Isaksson, J. Lahti, "The Use of a Formal Language for [illegible]ation of Computer Programmes."

36. O. Hatlevold, "Development of a new Test Fuel Data Management System at the Halden Project."

Papers acquired in the Federal Republic of Germany

37. D. Beraha, A. Hold, Z. Jakubowski, "Multilevel Control of the Power Density Distribution in a Nuclear Reactor Core," unpublished paper, Gesellschaft fur Reaktorsicherheit (GRS) mbH, D-8046 Garching, Federal Republic of Germany.

38. W. E. Buttner et al., "Data Base Preparation and Operational Features of the Disturbance Analysis System for the Grafenrheinfeld Nuclear Power Plant," paper presented at the Enlarged Holden Program Group Meeting, Loen, Norway, June 5-9, 1978.

39. W. E. Buttner et al., "Functions and Design Characteristics of the STAR Disturbance Analysis System," unpublished paper, Gesellschaft fur Reaktorsicherheit (GRS) mbH., D-8046, Garching, Federal Republic of Germany.

Other papers acquired in the Federal Republic of Germany, which were sent by mail, did not arrive in time to be included in this listing.

DISTRIBUTION

1-2. Assistant Secretary for International Affai s, DOE, Washington
3. M. P. Norin, Division of Nuclear Power Development, DOE, Washington
4. Director, Division of Safeguards and Security, DOE, Washington
5-6. Director, Division of International Security Affairs, DOE, Washington
7. J. A. Lenhard, DOE/ORO
8. J. S. Denton, DOE/ORO
9-11. Director, Division of Reactor Licensing, NRC, Washington
12-13. Office of Standards Development, NRC, Washington
14-18. Executive Secretary, Advisory Committee on Reactor Safeguards, NRC, Washington
19-20. S. H. Hanauer, Director, Division of Human Factors Safety, NRC, Washington
21. Director, Office of Nuclear Regulatory Research, NRC, Washington
22. R. M. Bernero, Director of Probabilistic Analysis Staff, NRC, Washington
23-25. R. DiSalvo, Probabilistic Analysis Staff, NRC, Washington
26. W. S. Farmer, Research Support Branch, NRC, Washington
27. Director, Office of Nuclear Reactor Regulation, NRC, Washington
28. T. E. Murley, Director of Division of Reactor Safety Research, NRC, Washington
29. C. Michelson, Director, Office for Analysis and Evaluation of Operational Data, NRC, Washington
30-31. Director of International Programs, NRC, Washington
32-33. Division of Technical Information and Document Control, NRC, Washington
34-35. Technical Information Center, P. O. Box 62, Oak Ridge, TN 37830
36. S. Fabic, Chief of Analysis Development Branch, NRC, Washington
37. O. Meyer, Idaho National Engineering Laboratory, Idaho Falls, Idaho
38. D. A. Dahlgren, Sandia Laboratories, P. O. Box 5800, Albuquerque, NM 87115
39. A. B. Long, EPRI, Box 10412, Palo Alto, CA 94303
40. T. O. Sargent, ConServ, 3 Columbia St., Hartford, CN 06106
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43. L. O. Hecht, Lund Consulting, Inc., P. O. Box 315, Mohegan Lake, NY 10547
44. D. J. Cardinale, Sargent and Lundy Engineers, 55 E. Monroe St., Chicago, IL 60603
45. L. S. Hanes, Westinghouse R&D Center, 1310 Beulah Road, Pittsburgh, PA 15235
46. W. R. Corcoran, C. E. Power Systems, Combustion Engineering, 1000 Prospect Hill Rd., Windsor, CT 06095
47. Herman Postma
48-51. R. A. Kisner
52. J. L. Anderson
53. J. B. Bullock

54. W. H. Sides, Jr.
55. H. N. Hill
56. L. C. Oakes
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