A REVIEW OF THE "REPORT OF THE PRESIDENT'S COMMISSION ON THE ACCIDENT AT THREE MILE ISLAND"

by the Engineers Committee On Three Mile Island

March, 1980

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*The names of two members of the Engineers Committee do not appear in this Report.

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PREFACE

The Engineers Committee on Three Mile Island is composed of members from sixteen nationally-recognized professional engineering societies. The viewpoints expressed in this report represent those of the Committee and not the societies. The National Society of Professional Engineers (NSPE) acted in a coordinating role to form this Committee in August, 1979. The purpose of the Committee is to contribute to and form independent engineering reviews of the reports of the official investigations of the Three Mile Island accident. These investigations include the Nuclear Regulatory Commission's Special Inquiry Group, the investigation of the Senate Subcommittee on Nuclear Regulation, and the President's Commission on the Accident at Three Mile Island, which is the subject of this review. Through these activities, the Committee is working to make technical contributions to the investigation process and to help achieve a more effective understanding, interpretation and use of these reports on the part of government, industry, and the general public. Details relating to the qualifications of the members of the Engineers Committee are provided in the Appendix.

I. SUMMARY

The findings of the Engineers Committee on Three Mile Island are offered in this report as a corollary to, and are based upon the content of, the "Report of the President's Commission on the Accident at Three Mile Island". We have taken some exception to the Report and have provided additional recommendations in a number of specialized engineering areas. We have addressed issues in the following areas:

1. system design, construction, operation and maintenance;
2. system safety management;
3. emergency management; and
4. regulation and legislation.

The Commission's Report is one with which most groups can generally concur. As stated in the Report, fundamental changes need to be made to assure the ongoing, safe operation of commercial nuclear power. The accident--while having insignificant consequences on public health and welfare--nevertheless indicated that improvements could and should be made.

From an engineering standpoint, the "defense in depth" approach of the system design proved itself in actual operation. The accident demonstrated that the system of equipment performed well. The Commission reported, however, that operation, maintenance, training, management and regulation of the Three Mile Island system needed improvement. The accident also demonstrated that equipment modifications can contribute to further improvements in the safety of existing and future reactors in this country.

The nuclear industry and the Nuclear Regulatory Commission (NRC) have responded in a positive manner. Since the accident, they are developing and initiating new procedures to correct potential problems.

II. ISSUES RELATING TO SYSTEM DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE

The Engineers Committee supports the Commission's conclusion that the Three Mile Island accident did not indicate that nuclear power is inherently too dangerous to expand as a form of power generation. The design, construction, operation and maintenance of nuclear power plants require a demanding and complex technology. However, the engineering profession has the necessary skill, competence and enterprise to enable nuclear power to fulfill its promise of safely and effectively providing the electric power upon which modern society depends.

The Commission's Report identified certain inadequacies in the combined performance of the reactor manufacturer, architect-engineers, utility company and the Nuclear Regulatory Commission. Because of these inadequacies, what should have been a minor accident became a major national event. The result may be the reduction of public confidence in nuclear technology at a time when a growing energy crisis is threatening the health and survival of our economic system and our nation. In the areas of system design, construction, operation and maintenance, we submit the following recommendations, based upon the conclusions of the Commission's Report:

a. Better attention should be paid to system and component failures and particularly those incidents which impair plant safety. These incidents should be better analyzed and more effectively communicated throughout the industry. A central agency should be charged with ensuring that effective preventive and corrective actions are taken to avoid future accidents. A "systems approach" which gives more attention to single and multiple "lower-consequence but higher-probability occurrences" that threaten the safety of nuclear systems should be applied throughout the phases of design, construction, operation and maintenance. This approach should utilize the techniques of systems engineering, reliability, systems safety, human factors and quality assurance.

b. The issues relating to human factors, operator errors, and man-machine interrelationships in such areas as instrumentation and control room design should receive full technical visibility to aid in the prevention of future accidents through the formal programmatic application of established human engineering techniques. These human factors engineering principles include:

-hardware design of man-machine systems;
-personnel selection criteria and procedures; and
-personnel training programs.

The application of these techniques has shown that human errors and operator errors can be significantly reduced and their effects minimized. An example of the improvements that can be achieved by applying human factors

engineering is the "advance control room design" developed within the nuclear industry prior to the accident. These advance control rooms are noteworthy for more reliable acquisition, clearer presentation of information, more effective information management and factor information retrieval. These and other design features also greatly increase the operator's ability to manage the reactor's safety control system during incidents and abnormal conditions.

The central methodology applicable to all three principles is the performance of job and skills analysis, and the utilization of the combined disciplines of psychology, physiology, and industrial engineering. The use of this methodology can prevent the occurrence of situations where the operator's information processing capacity is overloaded, eliminate the confusing presentation of information, and establish an appropriate hierarchy of alarm indications. Job-skills analyses are also essential to the proper design of training simulators and the retraining of personnel.

c. <u>The Commission's Report did not address the desirability of a detailed, postmortem engineering analysis being performed on the core and core materials. The Committee believes these analyses are essential to establish a basis for possible design improvements for future facilities and to further evaluate the effects of the accident</u>

The Commission's Report finds that "The nature and extent of damage to the core is not likely to be known with assurance until the core materials are recovered and carefully examined." Preliminary estimates of the extent of zirconium cladding oxidation and cladding failure and comments on fuel temperatures and melting, possible fuel-zirconium oxide reactions, control rod melting, mechanical blockage of coolant paths by slumping or falling fuel rod material, and lack of physical contact between core materials and the reactor vessel are included in the findings. The core support materials, core design, fuel form, fuel cladding, and reactor vessel are integral parts of the "defense-in-depth" design approach used to assure nuclear reactor safety. It now appears that the TMI-2 core damage was less, and concomitantly the radioactivity released from the core to the containment was less than had been assumed in the Rasmussen safety study, WASH-1400. From an engineering viewpoint, it is important to understand that core performance and reaction during the TMI accident. This requires a detailed post-accident study of the core, the core materials, support materials, reactor internals and pressure vessel.

These components and materials represent a vast store of valuable information. Any removal and handling of parts should be accomplished to preserve the integrity of the information. This is a rare opportunity to study first-hand the structural and material effects of a severe reactor transient. These studies could permit the assessment of code predictions and the subsequent improvement in the accuracy of the predictions. In addition, evaluation of engineering margins can be performed, and better estimates can be made of the safety risks associated with cladding failure and the partial core melting. Improved thermalhydraulic analyses of core cooling by water-steam phases should also result from these studies. Material reactions such as zirconium oxidation, fuel-clad reactions, rates of boron and hydrogen permeation and their effects are some of the potential study areas likely to yield results very useful to improve our understanding of the consequences of reactor transients. It is recommended that careful attention be paid to the study of the damaged core. The current joint EPRI/DOE/NRC task group planning the TMI-2 core studies should be fully supported and the recommendations carefully weighed.

d. The "long-term neglect" of maintenance that was reported at TMI-1 deserves more attention than it was originally given. The safety and performance of nuclear systems are dependent upon the adequacy of the maintenance programs utilized for the prevention and the correction of systems failures. The NRC, industry and manufacturers should give more attention to the engineering development, review and control of maintenance plans, procedures, training, equipment and management to assure the reliability and safety of nuclear systems. This not only requires close integration of the maintenance engineering and maintenance management functions, but also requires a systems engineering approach which utilizes reliability and systems safety engineering, data and analytical techniques. During the regulatory process, the system design process, and throughout the operating life of the system, constant consideration should be given to the planning, control and implementation of maintenance functions.

III. ISSUES RELATING TO SYSTEM SAFETY MANAGEMENT

System safety considerations are inseparable from all of the issues raised by the accident at Three Mile Island. The safety of nuclear systems is dependent upon the degree of excellence achieved in system design, procurement, construction, installation, operation, maintenance and regulation. The variables affecting each step of these processes must be controlled if system safety is to be achieved. This control can be achieved by the use of the methodologies included in systems safety and the assurance sciences (e.g., reliability engineering, quality assurance, human factors and systems engineering).

Because the Commission's Report does not concern itself with the subject of systems safety engineering, the following important supplementary recommendations are given:

a. There is a need to establish a cooperative government/industry safety engineering effort to continually evaluate, monitor and report on nuclear safety. This activity should include a data bank staffed by enough qualified engineers to facilitate the collection, processing, analysis and distribution of data from operating plants and new system designs which are significant to the control of nuclear systems safety. The data would include failure event reports, proposed design changes or proposed changes in operational and maintenance procedures and concepts, instrumentation and controls, reports of accidents and accident-aversions, and other technical information pertinent to the assurance of system safety. The center could be a focal point for coordination with, and assistance to, the NRC and industry for the resolution of safety issues.

b. The accident demonstrated the need for improving the NRC analysis and classification system used to identify safety-related items. The approach to system analysis in the past was "piecemeal", not a unified "systems" approach. Therefore, it is recommended that a joint industry/NRC working group be established to develop the criteria and methodology for the classification, analysis and control of safety-related elements of nuclear systems. The scope of this effort should include all system elements -- i.e., hardware, software, and the operational and maintenance concepts and policies.

c. This Committee endorses the Commission's recommendation that generic safety issues should be resolved by rulemaking rather than relitigation in adjudicative hearings for each new power plant.

d. To provide a basis for the technical visibility and management control needed for system safety throughout the life cycle of nuclear facilities, it is recommended that a full-time technical staff, readily accessible to the facility and

independent of the organizational elements being monitored, be established to perform the continuing assessment of the performance of the facility, system, components and of the individuals involved in operation and maintenance. The safety assurance functions of this staff should include continual monitoring of the performance of the equipment and personnel for the prompt detection and correction of potential sources of hazards. These activities should be directed not only to the evaluation of normal operations, but also to the maintenance, quality control, and emergency response functions.

e. The Committee recommends that the unresolved safety issues be settled as expeditiously as possible. It is recommended that a strong analytical program and schedule be established to accomplish this task, using all of the available systems safety engineering techniques and supported by other essential engineering disciplines such as reliability, quality assurance and human factors.

IV. ISSUES RELATING TO EMERGENCY MANAGEMENT

The Committee supports all of the recommendations of the President's Commission in this area. We also wish to present the following statements:

a. The planning and implementation of plant emergency procedures are mandatory management responsibilities requiring strong participation and support from engineering personnel.

b. The federal, state and local agencies which provide services in planning and implementing emergency management should make full use of the engineering community in this area.

c. Periodic drills of plans and procedures to be used for emergency management should be required for purposes of validation, training and improvement.

d. Scenarios for rehearsals should be developed in the light of plant operating practices, the probability of anticipated events, and new developments in technology. Key personnel who would be involved in evacuation planning and implementation should participate, but the general population should not be required to participate in a test evacuation.

V. ISSUES RELATING TO REGULATION AND LEGISLATION

The Committee recognizes that all issues involved in the accident at Three Mile Island may be related to legislative or regulatory actions, particularly those concerning system safety. It is particularly concerned with the manner in which the Commission's Report deals with the safety area. The Commission's Report advocates that a presumption in favor of additional safety should guide any nuclear regulation. However, the Commission fails to provide guidance as to the degree of additional safety desired because it has "not undertaken to examine how safe is 'safe enough'." Nonetheless, the Commission concludes that "fundamental changes are necessary if...risks are to be kept within tolerable limits." There is a need for the establishment of appropriate safety goals and/or limits.

This Committee agrees with Commissioner Pigford on the need to recognize that "over a long enough time period, even low-probability accidents may occur," and that there are ever-present "trade-offs between the risks and the benefits" which apply to all decisions relating to safety management. Therefore, the Committee recommends that the legislative or regulatory action taken in response to the Report be thoroughly coordinated with the engineering community to establish their technical implications before adoption.

The Commission recommended a combined construction permit and operating license hearing when practicable. This Committee endorses the idea of examining this possibility. However, it recommends that a broader study of the total licensing process be performed to improve the rulemaking procedures and to increase public confidence. The Engineers Committee supports the position taken by President Carter to strengthen the role of the Advisory Committee on Reactor Safeguards (ACRS) and continuing its independence.

The confusion that exists regarding licensing and regulation must be overcome quickly to avoid crippling effects on nuclear energy. It seems imperative that incentives be provided, and any disincentives of present regulatory practices be alleviated, so that the best of proven engineering design and practice can be fully incorporated into commercial nuclear reactors.

APPENDIX

BACKGROUND INFORMATION

ON THE MEMBERS

OF THE

ENGINEERS COMMITTEE ON THREE MILE ISLAND

APPENDIX

Seymour Baron, Ph.D.

--Ph.D., Chemical Engineering, Columbia University;
--M.S., Chemical Engineering, Johns Hopkins University;
--B.S., Chemical Engineering, Johns Hopkins University;
--Nuclear Engineering Training-Institute of Nuclear Science and Engineering, Argonne National Laboratory;
--Published over forty technical papers on all energy matters with approximately thirty to forty percent of these papers in the field of nuclear engineering;
--Served as both Chief, Nuclear Engineering, and Vice President of Engineering, Burns and Roe;
--Director, Power Technology Division, responsible for work in the development of new technologies;
--Currently employed, Senior Corporate Vice President, Burns and Roe directly responsible for work on the fast breeder reactor and participating on a number of corporate reviews of the TMI-2 accident.

Dwight Bellinger, P.E.

--M.B.A., Management Operations Research, Seton Hall Graduate School of Business;
--A.B., Statistics, Columbia University;
--Certificate Statistical Quality Control, Rutgers University;
--Certificate Reliability Engineering, Pasadena State University;
--ASQC Certified Quality Engineer, Certificate No. 152;
--ASQC Certified Reliability Engineer, Certificate No. 547;
--Consultant, Lawrence Berkley Laboratories;
--Twenty-eight years of experience in the management and technical direction of the reliability, maintainability, quality assurance activities in major programs in aerospace, transportation and utility systems. This experience also includes research studies in the reliability of ground electronics equipment, satellite electronics equipment, and automobile braking systems;
--Currently employed, TRW Energy Systems, Manager, Performance Assurance, responsible for providing technical support to the Fossil Energy Office of the Department of Energy for the development and implementation of reliability, maintainability, availability, systems safety and quality assurance programs in support of the National Energy Plan.

S. Neal Broome, P.E.

--B.S., Civil Engineering, North Carolina State University;
--Twenty years experience in engineering, management, and supervision for construction, industrial, and land development operations;

--Currently employed, McNeary Insurance Consulting Services, Inc., activities include consulting and design in fire protection, detection, and signal systems, with continuing applications of local, state, and national codes and standards.

Spencer Bush, P.E., Ph.D.

--Ph.D., Metallurgy, University of Michigan;
--M.S., Metallurgical Engineering, University of Michigan;
--B.S., Metallurgical Engineering, University of Michigan;
--B.S., Chemical Engineering, University of Michigan;
--Senior Scientist, Hanford Atomic Products Operation, General Electric Company;
--Supervisor, Physical Metallurgy;
--Supervisor, Fuels Fabrication Development;
--Metallurgical Specialist;
--Consultant to the Director, Battelle-Northwest;
--U.S. Nuclear Regulatory Commission, Senior Review Committee on Seismic Safety Margins;
--U.S. Nuclear Regulatory Commission, Special Task Group on Stress Corrosion Cracking.
--Currently employed, Senior Staff Consultant, Battelle-Northwest.

Robert Cunitz, Ph.D.

--Ph.D., Experimental and Engineering Psychology, University of Maryland;
--NASA and USPHS Predoctoral Fellowships;
--M.S., Psychology, Lehigh University;
--B.A., Psychology, Lehigh University;
--Deputy Program Manager, Technical Analysis Division, National Bureau of Standards;
--Chief, Human Factor Section, Center for Consumer Product Technology, National Bureau of Standards;
--Chairman, Noise Control Advisory Board, Montgomery County, Maryland;
--Author of nineteen papers in the field of experimental and engineering psychology;
--Engineering Psychologist, Morris and Ward;
--Currently employed, President, Consumer Usage Laboratories, Inc.

Brian Dunfield

--B.S., Engineering Management, Business Administration, Northeastern University;
--A.S., Mechanical Engineering, Northeastern University;
--Management Development Program, Northeastern University, College of Business Administration;
--Manager, Cost and Scheduling Department, Stone and Webster Engineering Corporation, responsible for the administration and management of resources in the implementation and maintenance of all estimating, cost engineering, cost control, planning and scheduling activities as related to power and industrial project control;
--Manager, Projects Cost Division;

--Assistant Manager, Estimating and Cost Division;
--Chief Estimator, in the Cost and Scheduling Department;
--Currently employed, Assistant Manager, Cost and Scheduling Department, Stone and Webster Engineering Corporation.

Angelo Giambusso

--Graduate courses in Civil and Nuclear Engineering, Massachusetts Institute of Technology;
--B.S., Mechanical Engineering, Massachusetts Institute of Technology;
--Power Plant Engineer with an electric utility;
--Project Manager for the First Army Package Power Reactor Plant(SM-1);
--Chief, Water Reactors Branch and Assistant Director for Reactor Projects, Atomic Energy Commission;
--Deputy Director, Division of Compliance, Atomic Energy Commission;
--Deputy Director, Division of Radiological and Environmental Protection, Atomic Energy Commission;
--Deputy Director for Reactor Projects, Office of Regulation, Atomic Energy Commission;
--Director, Division of Reactor Licensing, Nuclear Regulatory Commission;
--Deputy Assistant Administrator for International Affairs, Energy Research and Development Administration;
--U.S. Coordinator for the International Fuel Cycle Evaluation (INFCE), Department of Energy;
--Currently Employed, Vice President and Manager of the Washington Operations, Stone and Webster Engineering Corporation.

J. Read Holland, Ph.D.

--Ph.D., Engineering, Physical Metallurgy, University of Kentucky;
--M.S., Metallurgy, Physical Metallurgy, University of Sheffield, England;
--B.S., Metallurgical Engineering, University of Kentucky;
--Materials Laboratory, Wright-Patterson Air Force Base, serving as Chief of the Advanced Metallurgical Studies Branch, associated with research and development of refractory metal alloys and with new metallurgical concepts, such as fiber reinforced composites;
--Active in research on shockwave phenomena in crystalling solids, the application of materials in nuclear ordnance, high-strain rate effects phase transformations, and lattice defects, Sandia Laboratories;
--Currently employed, Manager, Reactor Materials, Westinghouse Research Laboratories, directs research on irradiation effects on reactor fuels and structural materials, nuclear fuel development, development of advanced fuel cladding materials for LMFBR applications.

Philip Hufnell, P.E.

--B.M.E., University of Delaware;
--Draftsman, E.I. DuPont de Nemours & Co., Engineering Department, Design Division;
--Control Engineer;
--Specialist Engineer, power, heating and ventilating;
--Senior Specialist Engineer, power, heating and ventilating;

--Currently employed, Project Engineer, E. I. DuPont de Nemours & Co., Engineering Department, Design Division, Atomic Engineering Section.

Frank Jenkins, P.E.

--B.S., North Carolina State University;
--Further advanced work, General Electric Company's Engineering Training Program;
--Transmission Engineering Department, Duke Power Company;
--Transmission Line Engineer;
--Manager, Transmission Engineering;
--Assistant Vice President, Transmission Engineering;
--Vice President, Transmission and Electrical Installations;
--Currently employed, Vice President, Transmission, Duke Power Company.

William Koster, Ph.D.

--Professional Degrees, Mechanical and Metallurgical Engineering;
--Background in Failure Analyses of Metallurgical Structures;
--During the past ten years has been directly responsible for a series of research efforts at Metcut Research Associates, Inc., in the surface integrity area sponsored by the Air Force Materials Laboratory, the scope of this work included an assessment of the effects of various metal removal methods and ranges of operating perimeters within each method on the performance of manufactured components in service;
--Currently employed, President, Metcut Research Associates, Inc.

Harry Lawroski, P.E., Ph.D.

--Ph.D., Chemical Engineering, Pennsylvania State University;
--M.S., Chemical Engineering, Pennsylvania State University;
--B.S., Chemical Engineering, Pennsylvania State University;
--Twenty-nine years of research, development, and technical consulting in energy technologies and their applications;
--Instructor, Petroleum Refining, Pennsylvania State University;
--Instructor, Chemical Engineering, Idaho National Engineering Laboratory for the University of Idaho Graduate Program;
--Experiences include design, construction, and operation of nuclear power plants as well as operation and technical development of nuclear fuel processing and nuclear waste solidification plants;
--Currently employed, private consultant.

John O. Mingle, P.E., Ph.D.

--J.D. Washburn University, Degree expected in 1980;
--Ph.D., Northwestern University;
--M.S., Kansas State University;
--B.S., Kansas State University;
--Consultant, Argonne National Laboratory;
--Consultant, Southern California Edison;
--Consultant, Wilson & Company Engineers;
--Director, Institute for Computational Research and Engineering, Kansas State University;
--Resident Research Associate, Argonne National Laboratory;
--Currently employed, Professor of Nuclear Engineering, Kansas State University.

Peter Morris, Ph.D.

--Ph.D., Physics, University of Virginia;
--B.S., Mathematics, Swarthmore College;
--E.I. Du Pont de Nemours and Company, Savannah River Plant production reactors, involved in developing improvements in reactor design and operation and procedures for safe operation of the Savannah River reactors;
-- Reactor Inspector and Chief of the Reactor Inspection Branch in the Division of Compliance, Atomic Energy Commission;
--Scientific Representative in Tokyo, Atomic Energy Commission;
--Director, Division of Reactor Licensing, Atomic Energy Commission;
--Director, Division of Operations Evaluations, Atomic Energy Commission;
--Currently employed, Executive Vice President, Scandpower.

William Ramsay, P.E.

--B.S., Mechanical Engineering, University of Maine;
--Thirty years of professional engineering and management activities related to the planning, design, and construction of mechanical systems for industrial and commercial buildings and special purpose facilities, predominately in association with Westinghouse Electric Corporation;
--Responsibilities include the planning, design, and construction of mechanical systems including plumbing, piping, heating, ventilation, air conditioning, fire protection, and special purpose mechanical systems;
--Design of HVAC and Support Systems, Floating Nuclear Plants, Offshore Power Systems;
--Currently employed, Manager, Technical Support Commercial-Industrial Air-Conditioning Division, Westinghouse Electric Corporation.

John Reiter

--M.B.A., American University;
--M.S., Nuclear Engineering, Columbia University;
--B.S., U.S. Coast Guard Academy;
--Nuclear Engineer, Columbia University;
--Certification, U.S. Army Nuclear Plant Engineer;
--Design Review of Offshore Power Systems, Floating Nuclear Plants and U.S. Maritime Administration Nuclear-Powered Merchant Ship Program;
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A. R. Robinson, P.E.

--M.S., Irrigation Engineering, Colorado State University;
--B.S., Civil Engineering, University of Iowa;
--Additional studies, Hydraulics and Sedimentation, Colorado State University and University of Minnesota;
--Civil and Irrigation Engineer, USDA and Colorado Experiment Station, conducted laboratory and field studies on seepage, drainage, groundwater, hydraulic and measuring structures;
--Director and Research Agriculture Engineer, USDA Snake River Conservation Research Center, responsible for construction of Center and staffing-

for research programs that included soils, plants, water use, water management, and distribution, irrigation methods and structures;
--Director and Research Hydraulic Engineer, USDA Sedimentation Laboratory;
--Director of National Laboratory which had field and laboratory research programs on hydrology, erosion, nonpoint pollution control, tillage, and cropping systems;
--Staff Scientist, USDA, SEA Agriculture Research, provided technical guidence in water and wind erosion and sedimentation research;
--Currently employed, consulting engineer.

Gavriel Salvendy, Ph.D.

--Diplomas in Industrial Engineering, Cost Accounting, Business Administration and Ergonomics;
--Ph.D., Engineering Production, University of Birmingham, England;
--M.Sc., Engineering Production, University of Birmingham, England;
--Author of over seventy archival publications including Editor-in-Chief of the Industrial Engineering Handbook;
--Consultant to a variety of organizations on productivity and quality of working life improvement;
--Recipient of the 1979-80 Fulbright-Hays "Distinguished Professor Award";
--Currently employed, Professor of Industrial Engineering, and Chairman, of the Human Factors Interdisciplinary Program, Purdue University.

Otto Tennant, P.E.

--M.A., Drake University;
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--Worked for General Electric two years before going into World War II as a meteorologist and navigator;
--Application and Sales Engineer, Westinghouse Electric Corporation;
--During tenure with Westinghouse Electric Corporation, successfully completed two short courses on the engineering and application of PWR's;
--Currently employed, Manager of Marketing and Technical Services Operation, Iowa Power and Light.

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--Test Engineer, General Electric Company;
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--Chemical Engineer, General Electric Company;
--Technical Policy Analyst, Division of Operations Analysis, Atomic Energy Commission;
--Senior Officer, Division of Nuclear Power and Reactors, International Atomic Energy Agency;
--Chief, Engineering Branch, Division of Operations Analysis, Atomic Energy Commission;
--Materials and Processing Control Engineer, Division of Operational Safety, Atomic Energy Commission;
--Chemical Engineer, Program Manager, Research & Development Branch, Division of Waste Management and Transportation, Atomic Energy Commission;
--Program Engineer, Research & Development Branch, Division of Waste Management, Production and Reprocessing, Energy Research and Development Administration;
--Acting Chief, Technology Branch, Division of Waste Products, Department of Energy;
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Monroe Wechsler, Ph.D.

--Ph.D., Physics, Columbia University;
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--Engineer, U.S. Naval Air Magnetics Laboratory;
--Solid State Division, Oak Ridge National Laboratory;
--Professor, Department of Chemical and Metallurgical Engineering, University of Tennessee;
--Head, Radiation Metallurgy Section, Solid State Division, Oak Ridge National Laboratory;
--Chairman, Department of Metallurgy and Chief, Metallurgy Division, Ames Laboratory, Energy Research and Development Administration;
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Herbert Woodson, P.E., Ph.D.

--Ph.D, Electrical Engineering, Massachusetts Institute of Technology;
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