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Abstract: The nuclear power industry and its associated research and development community depend on the same pool of engineers and technical personnel on which other industries and government agencies in the United States and abroad also rely. Several trends in nuclear engineering cause concern to planners in the nuclear industry and government. For example, there have been decreasing enrollments in nuclear engineering, continuing attrition of engineering faculty, and a declining number of university programs in nuclear engineering. Another factor is nuclear power's public image as a moribund industry that potentially threatens public safety and the environment. As a result students enrolled in nuclear engineering programs feel peer and other pressures to enroll in more socially acceptable programs. The National Research Council organized the Nuclear Manpower Study Committee at the joint request of the U.S. Department of Energy (DOE) and the Institute for Nuclear Power Operations (INPO) to plan and conduct a workshop to identify major issues concerning the supply and demand of engineers and technical personnel in the U.S. nuclear utility industry and its development community. This report presents the issues as identified by the committee and the workshop participants. The report is concerned with the personnel needs of the nuclear development establishment and with the consequences of not meeting those needs. It examines the factors that will influence the demand for various kinds of trained personnel in the next decade, and the adequacy of current manpower projections.

Descriptors: *Personnel management, *Nuclear engineering, Universities, Education, Technology, Specialized training, Skilled workers

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PERSONNEL SUPPLY AND DEMAND ISSUES IN THE NUCLEAR POWER INDUSTRY

Final Report of the
Nuclear Manpower Study Committee
Assembly of Engineering
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1981

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard to appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

The nuclear power industry and its associated research and development community depend on the same pool of engineers and technical personnel on which other industries and government agencies in the United States and abroad also rely. The contraction in the supply of engineers and technicians coupled with increasingly competitive demand for engineers and technicians from other sectors of the domestic economy is a source of alarm for managers and planners in the nuclear utility industry. Several trends in nuclear engineering cause concern to planners in the nuclear industry and government. For example, there have been decreasing enrollments in nuclear engineering, continuing attrition of engineering faculty, and a declining number of university programs in nuclear engineering. Another factor is nuclear power's public image as a moribund industry that potentially threatens public safety and the environment. As a result students enrolled in nuclear engineering programs feel peer and other pressures to enroll in more socially acceptable programs.

As a result of the accident at Three Mile Island Unit 2, and the subsequent studies of that event, these issues and others that bear on the supply of qualified personnel have become very visible to the nuclear power industry. For example, the U.S. Congress in 1980 passed Public Law 96-567. One of the purposes of this law is to "establish a research, development, and demonstration program for developing practical improvements in the generic safety of nuclear power plants during the next five years, beginning in fiscal year 1981."

In implementing this law, the U.S. Department of Energy (DOE) has been examining the supply and demand of personnel for the nuclear utility industry and the the nuclear development community, with the aim of ensuring safe operations by making it possible to obtain and retain highly qualified personnel. To carry out this study, DOE obtained the assistance of the Institute for Nuclear Power Operations (INPO) and the Manpower Education, Research, and Training Division of Oak Ridge Associated Universities (ORAU).

The National Research Council organized the Nuclear Manpower Study Committee at the joint request of DOE and INPO to plan, and conduct a workshop to identify major issues concerning the supply and demand of engineers and technical personnel in the U.S. nuclear utility industry and its development community. This report presents the issues as identified by the committee and the workshop participants. Recommendations for action to treat these issues, and detailed studies of available remedial measures, are beyond the scope of the committee's charge. The report is concerned with the personnel needs of the nuclear development establishment and with the consequences of not meeting those needs. It examines the factors that will influence the demand for various kinds of trained personnel in the next decade, and the adequacy of current manpower projections. It does raise questions about the steps that can be taken to help meet the demand, and about social agencies (government, vendors, universities, utilities, architect-engineer firms, and others) that should be responsible for taking these steps.

Study Methodology

The Nuclear Manpower Study Committee was formed early in August 1981. It held its first meeting on August 26 in Washington, D.C., and scheduled its workshop in Washington, D.C., from September 21-22, 1981. In preparation for the August 26 meeting and the September workshop, materials from relevant programs in DOE and INPO were collected and sent to committee members.

The First Meeting

At the August 26, 1981, meeting in Washington, D.C., the committee received in-depth briefings by DOE and INPO representatives and was also briefed on manpower studies underway at the U.S. Nuclear Regulatory Commission (NRC) and the Edison Electric Institute (EEI). Mr. Paul Havenstein, of the Office of Light Water Reactors, DOE, spoke about the background of the committee's study effort specifically in terms of DOE's response to Congress as stated in Public Law 96-567, the "Nuclear Safety Research, Development, and Demonstration Act of 1980." He was followed by Dr. John Clarke, chairman of DOE's task force on Manpower, Education, and Training, who briefed the committee on the task force's report. Mr. Richard Allen of the NRC spoke briefly of his agency's activities and interests in assessing the nuclear manpower supply and demand problem. Dr. Laurence Blair, of the Oak Ridge National Laboratory, summarized his forthcoming report for DOE entitled "Update of Employment Trends in Nuclear Power Industries." Mr. John Pacillio of INPO briefed the committee on the institute's research in support of DOE's study of the supply and demand problem. Mr. Carl D. Behnke, Director of the Industrial Relations Division of EEI, discussed manpower studies underway there.

The presentations reinforced the committee's impression that, while many people are examining parts of the supply and demand problem, no comprehensive effort has been made to describe the full range of issues and to identify those of greatest importance over the next 10 to 20 years. After the briefings, the committee drew up a list of the issues it deemed most important and ranked them. On the basis of this list, the format of the two-day workshop was developed, and experts were invited to discuss each issue.

The Workshop

At the workshop, September 21-22, the committee discussed the identified major issues with invited experts. (For workshop agenda and list of participants, see the Appendix).

This exchange of information sharpened the committee's insight into the major personnel supply and demand issues confronting nuclear power industry. More important, it helped put these issues in the context of national and international requirements for engineers and technical personnel in many different fields and industries. This report reflects these more acute perceptions.

ACKNOWLEDGMENTS

This report was prepared by the Nuclear Manpower Study Committee under the chairmanship of Robert E. Uhrig. The committee alone is responsible for the report's findings and conclusions, but many others have made valuable contributions.

The committee extends its thanks to those employees of the U.S. Department of Energy and the Institute for Nuclear Power Operations who served as liaison between the committee and those organizations, and who discussed their research with committee members. They provided very helpful briefings at the committee's first meeting, and they gave the committee draft copies of several reports that helped the committee better understand the problems of supply and demand. Special thanks are due the workshop participants for their willingness to prepare and deliver presentations on very short notice.

The final preparation of the report was guided by comments from anonymous reviewers designated by the Assembly of Engineering, under the direction of its Executive Director, David C. Hazen.

Dennis F. Miller served as director of the study. Special recognition is due Helen D. Johnson, administrative assistant to the committee, and to Julia W. Torrence, committee secretary. The committee is indebted to Duncan M. Brown, who served as its editor.

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EXECUTIVE SUMMARY

The anticipated personnel needs of the nuclear power industry have varied widely in recent years, in response to both increasing regulatory requirements and declining orders for new plants. Recent employment patterns in the nuclear energy field, with their fluctuations, resemble those of defense industries more than those traditionally associated with electric utilities.

Reactions to the accident at Three Mile Island Unit 2 by industry and regulators have increased the demand for trained and experienced personnel, causing salaries to rise. Industry, for example, has established several advisory organizations like the Institute for Nuclear Power Operations (INPO). At the same time, the U.S. Nuclear Regulatory Commission (NRC) has imposed many new construction and operating requirements in an effort to take advantage of lessons learned from the Three Mile Island incident and to respond to the perceived public interest in "better" regulation of nuclear power. Thus, at present, utilities, architect-engineer firms, reactor vendors, and organizations in the nuclear development community have heavy workloads.

However, because no new reactor orders have been placed since 1978, and because many existing orders have been cancelled, the nuclear industry appears to offer an unpromising future to those at the point of making career choices. As a result, the number of nuclear engineering departments has declined, along with the number of students seeking undergraduate degrees in the field. The current high demand for engineers, and the correspondingly high industrial salaries, have led many university faculty members to leave their departments; there is little hope of replacing them by equally qualified personnel.

To compensate for the shortage of trained personnel, some utilities and organizations in the nuclear development community have begun to train their own employees. For instance, the Tennessee Valley Authority and Duke Power Company have very comprehensive in-house training programs.

Four issues predominate in considering the supply and demand problem:

- <u>What is the real demand for qualified personnel in nuclear industry and related governmental and research programs?</u>

An understanding of the supply and demand problem requires assessments of the kinds of technical skills needed in the field, the diverse routes by which individuals enter the field, the interrelationship between an individual's job assignments and promotion, and the pressures and demands that are the sources of decisions to leave the field.

- To what extent do nuclear regulatory requirements affect personnel requirements of the industry? Nuclear regulatory requirements have significantly affected the demand for personnel throughout the industry by imposing additional requirements for training, new safety-oriented design criteria and modified operating procedures. Workshop participants questioned whether the NRC had correctly evaluated the impacts of some of its regulatory requirements. Until the significance of these impacts is clearly known, estimates of their consequences for personnel requirements are unreliable.

- Are currently available data adequate to provide a basis for appropriately focused actions? Several recent studies have projected a large demand for new personnel in the nuclear utility industry over the next decade. For example, INPO estimates that 40,000 new personnel will be needed during this period.* About 13,000 would be new positions, and the rest would be replacements for personnel leaving the nuclear power field. These estimates do not reflect the requirements or turnover rates of vendors, architect-engineering firms, fuel cycle suppliers, or government programs, all of which compete with utilities for trained personnel. Such competing demands should be assessed.

- Does the nuclear power industry's negative image affect the supply of nuclear manpower? The image of the nuclear industry as the energy option "of last resort" has probably influenced the number of young people who might choose careers in nuclear power. The effect of President Reagan's recent statement on nuclear energy policy has yet to be observed. Career choices are generally based on individuals' perceptions of opportunities for challenge and growth or for security. Today's stagnant nuclear power industry provides neither.

The failure of the United States Government to develop and articulate a long-term energy policy has had negative effects on the educational system,

*Institute for Nuclear Power Operations. 1981. Manpower Study Series, Report No. 1. Atlanta, Georgia: Institute for Nuclear Power Operations. September.

the financial community, and industry. The utility industry needs time to plan and construct its plants and cannot be expected to adjust its plans or abandon its investments with every change in administration. The supporting industry is hostage to the fate of the utility. Government must enunciate its long-term energy development goals, and they must remain constant for a sufficiently long period of time so that industry, the educational system, and prospective students can plan accordingly.

ENGINEERING PERSONNEL

The primary sources of engineers and engineering technologists for the nuclear power industry are the nation's universities. Foreign universities, primarily in Canada and Western Europe, also supply some graduates to U.S. utilities. Essential to the universities' effectiveness in supplying the full range of technologists and engineers (nuclear, electrical, mechanical, and others) are adequate employment projections, and qualified students and faculty.

Clarifying the general major issue--the adequacy of current and prospective personnel supply--requires research on a number of more specific issues:

- Why do individuals enter and leave nuclear power industry?
- How will U.S. policy toward the development of nuclear power affect future engineering manpower needs?
- Engineering manpower needs in energy areas are broad. How would changes in the level of activity in nonnuclear energy sources affect the nuclear power support requirements?
- To what extent does the loss of nuclear engineering faculty to industry reduce the universities' ability to provide effective educational programs?

Demand for engineers, technologists, and technicians may be at an all-time high. Rapidly growing companies in many industries pay high salaries and recruit graduates who might otherwise seek careers in the nuclear power field. This has caused a dramatic increase in the numbers of undergraduate students in most engineering disciplines. Regarding enrollment in nuclear engineering programs, it is not clear if there is an improvement in the numbers of students electing this field as a major.

It would appear that a rising number of nuclear engineering graduates would alleviate the problem. However, this statement taken alone may be deceptive. There are more nuclear engineering students enrolled in fewer nuclear engineering departments, whose faculties have been depleted by industry. Teaching more students with smaller faculties could well yield graduates of lower quality. In addition, nuclear engineering departments may be unable to respond to the increasing demands for specialized engineers because they lack necessary faculty and specialized up-to-date equipment.

The increasing numbers of faculty leaving all engineering departments for higher paying positions in industry will greatly affect the number, kinds, and quality of programs universities can offer. With a decline in programs, emphasis in many cases shifts from a balanced graduate-undergraduate program to undergraduate education and teaching the basics. This effect and the immediate availability of jobs at excellent salaries for those with bachelors' degrees result in a decreased number and quality of students seeking higher degrees. Without increasing the number of Ph.D.s they award, faculties will be unable to replace themselves, much less increase and diversify their programs.

REACTOR OPERATORS

Reactor systems vary in detail from plant to plant. Each reactor operator must be aware of current conditions in his or her own plant, problems that may develop at similar plants, and regulatory processes that may influence plant operations. The combination of high skills requirements and a not always pleasant job environment makes it difficult to attract and retain qualified personnel.

Evaluating needs for reactor operations personnel poses special problems beyond those encountered in most technical fields. Much of the necessary training is plant-specific, and operators must pass initial licensing examinations followed by regular requalifications.

- What are the appropriate technical qualifications for reactor operating personnel? Requirements for operating personnel have generally been met by specially organized, goal-oriented training programs similar to the armed forces' technician programs for specialized personnel. The Three Mile Island accident and subsequent investigations have called into question both previous standards and this approach to training operators. The NRC, for example, has proposed regulations for upgrading the qualifications of all personnel with operating licenses.* Thus, at a time when more operators are needed, the approximately 3,000 personnel already qualified question the stability of their futures. Clear specifications are needed of the technical skills and character traits required of operators, and of appropriate training programs and evaluations.

- What methods of training are appropriate for reactor operators? With 75 operating plants, about 3,000 licensed

*U.S. Nuclear Regulatory Commission. 1981. "Qualifications of Reactor Operators" (SECY-81-84). Proposed rulemaking. February 2.

personnel at operator and senior operator qualification levels, an attrition rate of 5.5 percent per year (plus promotions, internal transfers, etc.), and some 75 additional plants under construction, the nuclear utilities face enormous training requirements. In fact, the training programs for operating personnel can expect to train some 6,000 to 7,000 people merely to meet staffing needs in 1991. If it is recognized, in addition, that several years are required to qualify an operator and an additional five to produce a senior operator, the magnitude of the training system needed becomes apparent. Training methods differ from utility to utility; an important issue is evaluation of the training's effectiveness. Cost and staffing considerations for training are not negligible, and so cost-effectiveness is a legitimate consideration in meeting training needs.

- What are the special requirements in qualifying senior operating personnel? Senior reactor operators must have more extensive knowledge than that required of reactor operators. They must have the skills required to manage the unexpected. For this reason, the technical examinations to license such personnel involve demonstrations of theoretical knowledge and capacity for analysis beyond that demanded by the reactor operator examination. Most important in responding to emergencies, senior operators must display supervisory and leadership skills as well as the requisite technical background.

- What is NRC's influence on reactor operator availability and quality? One responsibility of the NRC is to evaluate the qualifications of personnel involved in reactor operations. The NRC examination process has been called into question as an adequate test of the actual array of skills required of reactor operators. The focus on qualifications resulting from the NRC's experience in the Three Mile Island accident, and the job-task analysis being performed by INPO, should together provide the basis for examining the NRC licensing process and sharpening the NRC examinations. One option is for the NRC to certify and supervise private training programs.

HEALTH PHYSICS PERSONNEL

The demand for health physics personnel has grown dramatically in the past several years. Part of the growth is occurring in the nuclear industry and part in the NRC and other agencies. Radiation protection programs outside the nuclear power community have experienced similar expansion and compete for health physics staff. At the same time, the number of graduate schools training operational radiation safety personnel is decreasing, as is the size of the typical program. The reasons adduced for decline in the number of schools are (1) that programs have lacked adequate financial support, and (2) that faculty have been hired away by industry. While it is possible to teach technicians on the job at power plant sites, health physicists can be trained only in university programs. There are six major issues in the health physics area:

- The number of professional health physicists is inadequate to meet even current needs.

- The current graduate-level programs in health physics are unable to meet the need. The nature and extent of the problem should be determined.

- To what degree has lack of financial assistance limited the number of students seeking admission to graduate programs?

- Are existing programs vulnerable?

- Can B.S. programs in health physics help meet the need?

- Is the American Board of Health Physics Comprehensive Certification Program for power reactor health physicists adequate and appropriate?

The number of schools with graduate programs in health physics has dropped from about 60 several years ago to about 20 in 1981. Of these schools, only 11 graduated more than two students at the M.S. level in 1980, and no school graduated more than 10; the total number of graduates was less than 100. Part of the reason for the decline may be the almost total lack of government support of graduate education in health physics. This situation is aggravated by the low faculty salaries and the out-of-date equipment with which faculty must work. While enrollments at the B.S. level have increased and will help fill current needs, few of these graduates will be more than high-quality technicians.

Experience with the American Board of Health Physics Comprehensive Certification Program has not been helpful in satisfying the need, since only a small fraction of the working power reactor health physicists have been able to meet the requirements. Some of this difficulty can be attributed to health physicists' heavy workloads and extended overtime requirements, which do not permit them to prepare adequately for the examinations.

COMPETING DEMANDS ON TECHNICAL MANPOWER

An understanding of the supply and demand of engineers and technicians in the nuclear power industry requires understanding of the competing demands on the pool of specialized personnel. The committee identified seven major issues in this area:

- To what extent do the organizations developing new nuclear power technologies compete with utilities for technical personnel?

- Are there services offered by architect-engineer and construction firms to the nuclear power industry that are limited by personnel availability?

- What effects do the armed forces have on supply and demand of nuclear power personnel?

- How do regulatory agencies' personnel needs compete with those of the nuclear power industry?

- Do government contractors and national laboratories offer significant competition for personnel?

- What is the competitive position of the nation's educational institutions in recruiting and retaining technical personnel?

- To what extent might the international nuclear reactor market contribute to the nuclear manpower problem?

Competing demands for personnel exerted by the nuclear development community, by architect-engineer firms, by various government regulatory and research activities, by military programs, and by universities need to be assessed. The number of new graduates entering these organizations, and the number of personnel leaving utilities to enter them, are unknown. The competition for trained personnel has impacts on all of these institutions. In architect-engineer firms, shortages of technical manpower can directly influence construction schedules and plant performance. In the government sector, it is clear that armed services programs train personnel who eventually may enter the private sector, particularly the utility industry, as reactor operators. The demand side is less well understood. Other federal agencies, such as NRC and the U.S. Environmental Protection Agency (EPA), attract personnel from the same manpower pool as do utilities. The growing professionalism in state regulatory agencies is creating yet another source of demand.

Educational institutions clearly play important roles in personnel supply and demand. On the demand side, the need for competent faculty in engineering, health physics, and the varied technical skills and crafts is huge. In the United States, more than 2,000 faculty positions in engineering were unfilled as of late 1981.* Firm long-term goals in engineering education should be established and faculty employment made challenging and financially rewarding.

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*Dean John Kemper. 1980. "Survey of Engineering University Faculty Shortage." Unpublished Paper. Davis, California: University of California-Davis. Frank Atelsek and Irene Gomberg. 1980. Higher Education Panel Report No. 52. Washington, D.C.: American Council on Education. October.

With the decline of U.S. leadership in nuclear energy abroad, employment opportunities have decreased. A change in nuclear policy could reverse this situation by bringing increases in foreign orders, which would be important to our economy. For example, over 60,000 man-years of direct and indirect labor are involved in the typical nuclear power plant for export, from design to lifetime maintenance and operation. With the number of reactors built abroad increasing, foreign demand for the entire range of plant personnel increases as well. For this reason, universities in the United States have many foreign students enrolled in their nuclear engineering and other engineering programs. As competence rises abroad, foreign universities will train more of their own students and numbers sent to the United States will decrease. The effects of such enrollment changes on the U.S educational system are not understood.

PERSONNEL MANAGEMENT ISSUES

Selection and Retention of Personnel

All too often when there is a shortage of personnel, businesses tend to accept nearly anyone who applies. Experience has shown that unqualified personnel in the long run are usually more a liability than an asset. Recruiting programs are needed to identify and attract adequate numbers of qualified applicants for each type of position. Turnover is one critical issue that needs to be addressed; general statistics on trained personnel leaving the nuclear power field are being developed by DOE and INPO, but little is known about those who leave specific types of activity.

- What steps are necessary to ensure the viability of careers in reactor operations? While the demands are high in reactor operations, the challenges and rewards for success are equally high. It is important to give operations staff an understanding of career paths and an indication of their availability to both degreed and non-degreed personnel. More important are the necessity for nationwide commitment to a viable nuclear power industry, and the consequent social acceptance of people involved in nuclear power plant operations. Relegating nuclear power to the fringe of acceptability can only result in employee disillusionment and loss of people with the skills and integrity required to operate nuclear power plants.

Stress and Human Factors

Stress is widely recognized as an important factor in many positions in the nuclear power industry, and it is particularly important as far as reactor operators are concerned. Since different people react differently to the same stimuli, individual differences need to be taken into account. Human factors engineering is necessary in the design of the control rooms and power plants. It can also be used to help design personnel operating positions and define the roles of personnel.

- What aspects of the reactor operations environment have adverse influences on operator performance? Several conditions contribute to the stressfulness of the reactor operator's performance. One is the psychological stress of working on rotating shifts. Operators must also constantly check details of plant operations, and complete regulatory reports and surveys. In addition, there are demands on the operators for on-the-job training, refresher courses, and other career development activities.

EMERGING TECHNOLOGY

One of the newer job design issues is the impact of the computer on the basic nature of the job. The man-machine interface is fast being replaced or supplemented by the man-computer interface. The computer can reduce the routine workload and detailed processing of operational information. Concepts of robotics and artificial intelligence should be introduced, along with the methods of human factors engineering. There are three major issues in this area:

- What will be the total operational effect of advanced computer integration at the man-machine interface?

- To what extent should reactor operations be automated?

- What are the roles of robotics and artificial intelligence in the operation of nuclear facilities?

Technology for computer application to operations is developing rapidly, but it tends to focus on new tasks that can be accomplished only by computers. In established organizations, there is often little pressure to adopt advanced techniques as they emerge. Only when a crisis develops does the attractiveness of change seem clear. There is some question about how much of the operator's responsibility should be delegated to a computer program and the extent to which operator involvement would be improved or impaired as a result. A comparative understanding of human and synthetic intelligence in the context of nuclear power operations should be reached. The appropriate roles for each should be evaluated. Certainly, the integration of robotics and artificial intelligence into plant operations could increase the effectiveness of motivating operations, of carrying out routine calibrations, and of scheduling access to critical work areas, all performed now by plant operators. Certain

CHAPTER 1

INTRODUCTION

The number of trained personnel needed in the future in any field is usually estimated by extrapolating historical trends, while taking into account the expected growth or decline of the field. In the nuclear power field, such estimates have generally been based on the numbers of nuclear plants in operation, under construction, and on order. Because the length of time between placing an order for a plant and putting it into operation usually exceeds a decade, it seems reasonable that, with proper planning, steps could be taken to provide adequately trained personnel in the appropriate specialized fields.

However, the anticipated personnel needs of the nuclear power industry have varied widely in recent years, responding to both changes in federal policies and declining reactor orders. Federal vacillation on such major nuclear policy issues as the desirability of nuclear power, plutonium recycle, reprocessing of nuclear fuel, construction of the Clinch River Breeder Reactor, away-from-reactor spent fuel storage, and nuclear waste disposal (to name a few) have not encouraged people to make careers in nuclear energy. This wavering, coupled with a sharp drop in orders for new plants and deferrals or cancellations of existing orders, has made the employment patterns in the nuclear power field look more like those of the military aircraft and armament industries than like those traditionally associated with utilities. For reactor vendors, too, the extraordinary expansion of orders in the late 1960s and early 1970s, followed by many cancellations of orders in the late 1970s, produced business fluctuations of a severity virtually unknown in the civilian sector.

In the aftermath of the accident at Three Mile Island Unit 2, new institutions (the Institute for Nuclear Power Operations, the Nuclear Safety Analysis Center, reactor owner groups, and others) have been created and old ones expanded, intensifying an already severe shortage of trained and experienced personnel. Salaries of qualified personnel have been driven to all-time highs. (The Tennessee Valley Authority recently sought exemption from government regulations on pay limits to allow reactor operators with overtime to be paid at annual rates greater than its Chairman of the Board is paid.)

In addition, the U.S. Nuclear Regulatory Commission (NRC) issued many new bulletins, requirements, and regulations in an effort to take advantage of the lessons learned from the Three Mile Island accident. As a result, the technical personnel of utilities, architect-engineer firms, reactor vendors, and consultants have been overloaded by work ever since. A recent NRC study suggested that the sheer quantity of these new requirements may be counter-productive so far as plant safety is concerned.*

Supplying the trained manpower, once the requirements are clearly defined, is relatively straightforward, provided that adequate time and money are available. Programs in four-year and graduate academic institutions can be expanded, and two-year institutions and industrial training organizations can provide training for technicians. On-the-job training by industry and utilities can provide the specialized training not provided elsewhere. All of this presupposes that adequate numbers of qualified faculty and teaching personnel are available.

Other considerations that influence supply and demand are the human factors that directly influence the effectiveness of the personnel. The ability to function under the stressful conditions that would accompany an accident is critically important to safety. The working environment at power reactors even under normal operating conditions imposes rather severe psychological stresses on operators, notably those associated with work on rotating shifts. Selection and retention of trained, qualified, and experienced personnel is also extremely important to both industry and utilities. Finally, the role of the computer in assisting personnel, and in some functions refining their tasks, should be addressed.

It is commonly reported that both utilities and architect-engineer firms need two to three times as many people per nuclear unit today as they required only a decade ago. This stems primarily from changes in equipment and in operating rules required by various regulations, bulletins, and orders from the NRC. For instance, it is estimated by one architect-engineer firm that some 13,000 man-years of engineering effort are needed merely to make the changes imposed on the utilities by the "lessons learned" from the accident at Three Mile Island Unit 2. If we assume that these changes must be implemented during a period of two and one-half years, over 5,000 full-time engineers would be required for this one task.

The action that could be most disruptive to the nuclear manpower situation would be a dramatic change in the educational requirements for reactor operating personnel, introduced by changes in government regulations. The suggested requirement that reactor operators have baccalaureate degrees, for example,

*U.S. Nuclear Regulatory Commission. 1981. Report on A Survey by Senior NRC Management to Obtain Viewpoints on the Safety Impact of Regulatory Activities from Representative Utilities, Operating and Constructing Nuclear Power Plants. July.

could very well result in a major disruption of the nuclear manpower situation.* There is serious doubt as to whether the educational institutions for nuclear engineering (which probably have in total no more than 300 faculty members) could meet this requirement in any reasonable period of time, even if an adequate number of candidates were to emerge.

A number of other contingencies could significantly increase nuclear manpower needs. Such contingencies include (1) new construction plans, (2) changes in regulatory requirements, (3) significant licensing reform, (4) favorable treatment of nuclear facilities in rate regulation, and (5) an adequate demonstration of a solution to the waste management situation. In one way or another, almost all of these are directly related to government policy and regulation. What is really needed is a consistent government policy and an official statement of the government's intentions for nuclear power in the context of national energy policy.

The nuclear industry's need for personnel with training below the baccalaureate level (technicians, operators, maintenance personnel, etc.) is even greater than that for degreed personnel. The sources of these personnel vary from specialty to specialty and from utility to utility. The primary suppliers of training for these personnel are two-year programs at community colleges and technical institutes, commercial training organizations, reactor vendors, and the utilities themselves (through in-house programs and on-the-job training).

Some utilities are attempting "full personnel development systems" in which they provide most, if not all, of the nonacademic training for personnel to operate their plants. The primary advantage of such programs is that they free utilities from dependence on training institutions over which they have only indirect influence. One common reason for developing an in-house training program is simply that the utility is not satisfied with the training its employees receive from other sources or with the number of personnel being trained. Also, in an in-house training program individuals can be observed so that problems of morale are anticipated before the individuals are assigned to operating plants. Utilities that have their own in-house training programs often become suppliers of personnel to other parts of the industry, such as vendors, architect-engineers, other utilities, industry groups, and even other in-house programs.

A number of associate degree programs prepare individuals to be paraprofessional technicians, who work along with engineers. A typical associate degree program concentrates on (1) the outlines of the particular technology, (2) problem-solving skills, and (3) abstract reasoning. The primary goal is to develop the individual's ability to handle unexpected reactor trends or transients by analyzing situations as indicated by controls and displays.

*U.S. Nuclear Regulatory Commission. 1981. "Qualifications of Reactor Operators" (SECY-81-84). Proposed rulemaking. February 2.

One of the overriding considerations in any of the nonbaccalaureate degree programs is that there be appropriate career paths for persons entering into these programs. It is not reasonable to expect individuals without baccalaureate degrees to remain in positions where such degrees are prerequisites to promotion.

The nuclear power industry must properly classify jobs and differentiate their requirements. It is all too common to require a baccalaureate degree for a position that could be properly filled by a technician; it is easier to rely on an educational degree as a measure of individual qualifications than to evaluate specific knowledge and skill requirements. However, a mismatch between individuals' training and the requirements of their positions results in dissatisfaction and high turnover rates. It may be possible to use as many as five technicians for every engineer in some situations, provided that adequate attention is given to job definition. The primary ingredient in technician training is the imparting of a specialized body of knowledge focused on the job that needs to be done. This is the traditional approach in cases of personnel shortage: establishing specialized, job-oriented training programs.

MAJOR ISSUES

ISSUE: What is the real demand for qualified personnel in the nuclear industry and related governmental and research programs?

DISCUSSION

An assessment of the demand for qualified personnel must include a comprehensive review of the diverse routes by which individuals enter the field, the relationship between job assignment and promotion and career paths, the effect of technical skills required in the field, and the pressures and demands that are the sources of decisions to leave the field.

TOPICS FOR FURTHER INVESTIGATION

1. What is the capacity, relative to demand, of existing training and educational facilities and programs?

2. What is the turnover rate of personnel in skilled and licensed positions?

3. What is the expected mobility of highly skilled personnel?

ISSUE: To what extent do nuclear regulatory requirements affect the personnel requirements of the industry?

DISCUSSION

It is clear that nuclear regulatory requirements have significantly affected the demand for personnel throughout the industry. Several panelists at the workshop questioned whether NRC had effectively evaluated the impacts of some of its regulatory requirements. It was suggested that personnel were being diverted from activities important to safety to other activities that might have no impacts on safety. A recent NRC report states, "it is the finding, notwithstanding the competence and good intentions of the staff, that the pace and nature of the regulatory actions have created a potential safety problem of unknown dimensions."*

The assertion that gaining control of the regulatory process is an absolute necessity for slowing the increase in personnel requirements became a recurring workshop theme. A corollary is that stabilizing regulatory requirements is essential to any reasonable predictions of future manpower requirements. Electric utility representatives who participated in the discussions all spoke of significant increases, since the Three Mile Island accident, in plant staff time devoted to training, quality assurance, engineering, and licensing activities.

The question of requiring licensed operating personnel to hold baccalaureate degrees (as proposed in a recent NRC letter to all owners of nuclear power reactors*) is of particular concern to the industry. Imposing such degree requirements could adversely affect the recruitment of reactor operators and if not administered carefully could destroy the stability of existing operating organizations.

TOPICS FOR FURTHER INVESTIGATION

1. What is the expectation of cost-benefit criteria in evaluating proposed regulatory functions?

2. What is the impact of imposing a requirement for degrees on all licensed operators in nuclear power plants?

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*U.S. Nuclear Regulatory Commission. 1981. "Qualifications of Reactor Operators" (SECY-81-84). Proposed rulemaking. February 2.

ISSUE: Are currently available data adequate to provide a basis for appropriately focused actions?

DISCUSSION

INPO has estimated that the nuclear utility industry will require some 57,000 new personnel over the next decade.* About 16,600 of these would be new positions, the rest replacements for personnel leaving the nuclear power field. This estimate of new utility positions, however, is uncertain. The estimated replacement requirements, however, represent a much larger fraction of the projected demand over this period and are subject to greater uncertainty.

These estimates are the result of a single survey of nuclear utilities. They may be an accurate representation of the replacement requirements of utility organizations (although a repeat survey would do much to enhance confidence in the representativeness of the data). They do not, however, reflect the requirements or turnover rates of the vendors, architect-engineers, or fuel cycle suppliers, all of which may compete with the utilities for trained personnel. Finally, the estimates need refinement with respect to the various categories of personnel required by the nuclear power industry, so that the demands of this industry can be viewed in the context of the demands for technical personnel in the economy as a whole.

TOPICS FOR FURTHER INVESTIGATION

1. How representative are the INPO survey's data of the vendors, architect-engineers, and fuel cycle suppliers?

2. How do turnover rates vary with personnel categories and how do factors such as shift work, compensation, and career options influence these rates?

3. Is there a significant difference in turnover rates between those organizations having larger nuclear programs and those with single nuclear units?

*Institute for Nuclear Power Operations. 1981. A Survey of Occupational and Training Levels in the Nuclear Power Industry. Atlanta, Georgia: Institute for Nuclear Power Operations.

ISSUE: Does the nuclear industry's negative image affect the supply of nuclear manpower?

DISCUSSION

There would appear to be no question that the image created by the prior Administration's characterization of nuclear energy as an energy option "of last resort" has done much to diminish the number of young people choosing to enter fields related to nuclear power. The effect of the recent Presidential statement on nuclear policy has yet to be determined.*

Career choices are based to a large extent on individuals' perceptions of the opportunities that different choices present. Some seek opportunities for challenge and growth; others desire security and stability. In either case, the nuclear power industry in its present state would hardly exert strong attractions, regardless of its "image."

There have been no new nuclear plant orders in the United States since 1978, and about 80 prior plant orders have been either deferred or else canceled outright. These actions have more concrete bases than Presidentially created images--such bases as diminished load growth rates, increased costs, and regulatory uncertainties. Thus, to the extent that a public image has served to reduce the number of young people choosing professional careers in fields related to nuclear fission energy, it would appear to be an image projected largely by the state of the industry. If this image can be countered by a revitalization of the industry, it should attract growing numbers of professionals seeking challenges; if the industry remains moribund, it must substitute financial considerations for job security, or opportunities for challenge and growth, in attracting the required manpower. It should be recognized, however, that for those who would respond to the latter, a nuclear power career would be viewed as a second choice, and probably a temporary one.

TOPICS FOR FURTHER INVESTIGATION

1. Has there been (and will there be) any significant change in applicants for nuclear or health physics careers as an outgrowth of President Regean's nuclear policy statement?

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*Presidential Statement on Nuclear Power. October 8, 1981.

2, Can an industry public relations campaign substitute for a genuine revitalization of the nuclear power industry?

3. Are high salaries sufficient in themselves to attract the required personnel?

CHAPTER 2

ENGINEERING PERSONNEL

INTRODUCTION TO THE ISSUES

Engineering technologists and engineers to meet the needs of the nuclear power industry will be supplied mainly by academic programs in U.S. colleges and universities. The only other source is foreign universities, primarily in Canada and Western Europe. The universities can produce the necessary numbers of graduates, given adequate time and financial support, sources of qualified students, and means of retaining the necessary faculty.

The nuclear industry needs not only nuclear engineers, but also engineers in a variety of other specialties (mechanical, electrical, civil, chemical, industrial, etc.), with some training or experience in the nuclear field. The primary need is to strengthen engineering programs by all possible methods. Scholarships and fellowships can attract students to any particular field, but in the long run there is also need for research and new ideas. All levels of engineering education must be involved in meeting nuclear manpower needs, with a focus on quality as well as quantity. Many very thorny technical problems still exist in the nuclear power field, and solving them will require the contributions of experts at the doctoral level. As evidence of the need to apply sophisticated technology to nuclear issues, one can point to the use of probabilistic risk analysis in evaluating nuclear safety. The phase lag between demand and supply must also be recognized. Finally, unexpected events, such as the energy crisis of 1974 and the accident at Three Mile Island Unit 2, can perturb the balance of demand and supply significantly.

MAJOR ISSUES

ISSUE: What are the appropriate technical qualifications for reactor operating personnel?

DISCUSSION

The nuclear power industry must compete with other industries and with government and universities for the services of engineers at a time when demand for these services is very high and shows every sign of continuing to be so for at least several years. Students have responded to this demand; the numbers of engineering B.S. graduates and undergraduate students are at record highs. However, engineering schools are in real difficulty; unless corrective action is taken they will probably be unable to meet the technical personnel needs of industry (including the nuclear power industry) and government.

The personnel problems of engineering education are the result of (1) large undergraduate enrollments that have increased the need for faculty, (2) a dearth of qualified candidates for faculty jobs due to recent declines in the numbers of engineering Ph.D. degrees awarded, (3) insufficient numbers of graduate students in engineering due to the attraction of high starting salaries at the B.S. level and the relative unattractiveness of faculty positions, and (4) the loss of faculty to industry because of universities' relatively low salaries, heavy teaching loads, and inadequate and obsolete laboratory equipment.

Nuclear engineering programs are unique in the engineering field in that their undergraduate enrollments have actually declined recently while enrollments in other engineering disciplines have shown dramatic gains. On the other hand, the number of nuclear engineering Ph.D.s awarded, currently about 3-4 percent of all engineering Ph.D.s, has remained relatively constant over the past several years while awards of Ph.D.s in other engineering disciplines declined by 25 percent. It should be recognized that current Ph.D. awards reflect undergraduate enrollments of four to eight years ago.

In meeting faculty shortages, many universities have moved to limit or decrease engineering enrollments. Such limits will increase the competition for B.S. graduates, driving up starting salaries and further decreasing the attractiveness of graduate study.

The immediate approach to reversing this situation lies in correcting the current shortage of faculty and using existing faculty more efficiently. A variety of iniatives underway in both the private sector and the federal government will provide more attractive stipends for engineering graduate students, in the hope of making graduate study a more attractive option for the better students. This very desirable approach will not, however, add to the pool of potential faculty members during the next three to four years. Other approaches, involving both industry and the universities, will be required to provide a short-term solution to the faculty shortage. Some approaches that are beginning to take shape include loans by industry of engineers for short- or long-term teaching assignments, joint appointments between industry and the universities, and a more flexible attitude in the universities regarding experience in lieu of academic qualifications for faculty members. Concerns about the impacts on the quality of faculty are valid throughout these processes.

One appropriate role for the federal government is to support engineering research in the universities and to provide competitive graduate fellowships in selected engineering disciplines; both would tend to increase the pool of engineers with advanced training. With reference to the engineering needs of the nuclear industry, more data are required to determine what distribution should be made of fellowship support among disciplines. The available projections of engineering manpower needs for the industry are in gross terms and do not give the breakdown among disciplines, although the supply picture varies considerably among them.

The problems of overcoming the adverse image of the nuclear industry as a stable career choice is perhaps even more difficult than that of ensuring a viable engineering education system. A clear statement by the federal government that the nuclear power industry will be revived appears essential to attracting young people to study nuclear engineering or, for those with degrees in other engineering disciplines, to choose careers in the nuclear power industry. Such a statement alone, however, probably would not be sufficient to assure the industry of adequate engineering manpower. A concerted public relations campaign by the industry and the universities, coupled with very competitive salaries, would probably also be necessary.

TOPICS FOR FURTHER INVESTIGATION

1. Should the nuclear power industry take actions to help engineering colleges solve the problem of faculty shortages?

2. Should the industry undertake a public relations campaign to attract more students into nuclear engineering?

3. Should the U.S. Department of Energy expand its program of support for graduate students in nuclear engineering and other engineering disciplines, so that graduate study becomes a more attractive option?

4. Should the nuclear power industry initiate a program to supplement faculty salaries to prevent the loss of faculty to industry and to make teaching more attractive to graduate students?

SUBSIDIARY ISSUES

ISSUE: Why do individuals enter and leave the nuclear power industry?

DISCUSSION

Not enough is known about why personnel move into and out of the nuclear power industry. Many of the skills required in the utility industry are represented also in other industries, and competition for the overall supply of engineers could be met by effective recruiting and salary inducements.

TOPICS FOR FURTHER INVESTIGATION

1. What effect does the high level of public scrutiny in the media have on the attractiveness of nuclear careers?

2. What incentives are useful in attracting people to the nuclear field?

3. What steps are needed to instill a sense of purpose and a commitment to excellence in workers in the industry?

ISSUE: How will U.S. policy on the development of the nuclear industry affect future engineering manpower needs?

DISCUSSION

While not expected to have a major impact in terms of numbers of people, the future development of the nuclear industry in such areas as the fast breeder reactor, fusion power, fusion-fission devices, other reactor concepts, and major safety research programs are all likely to affect requirements for personnel with advanced degrees. Here again a clear statement of government policy is essential to estimate future needs for Ph.D. candidates in nuclear and other engineering specialties, as well as personnel with other advanced degrees.

TOPIC FOR FURTHER INVESTIGATION

What are the expected needs for personnel at various levels of education in nuclear related programs?

ISSUE: Engineering manpower needs in energy areas are broad. How will changes in the activities in these energy areas affect nuclear power support requirements?

DISCUSSION

The representative of an architect-engineer firm emphasized at the workshop that engineering personnel needs in energy areas are very broad, corresponding to the range of the energy enterprise. This range encompasses synthetic fuels, petroleum, chemical processing, foreign and domestic nuclear plants, solar developments, and so on. Changes in the activities in these areas affect the utilities' abilility to acquire and retain the technical personnel needed to operate and maintain nuclear power plants. The architect-engineer representative identified shortages in certain specific areas of expertise, such as stress analysis, pipe support design, and reactor startup. An effort should be made to assess these and identify the other areas of shortage and to identify opportunities for training people to move into these areas. In some areas shortages might be partially corrected by better use of personnel (for example, by more use of personnel with two-year degrees.)

TOPICS FOR FURTHER INVESTIGATION

1. What priorities exist for developing energy resources?

2. What criteria will be used in judging between energy supply alternatives?

3. What will be the role of federal funds in meeting the needs for research and development in energy?

ISSUE: To what extent does the loss of nuclear engineering faculty to industry reduce the universities' abilities to provide effective educational programs?

DISCUSSION

While it does not have a major impact in terms of numbers of people, the attraction of university faculty into industry can significantly reduce the universities' abilities to provide effective educational programs. Also, the aggressive recruitment by industry of B.S.-level engineers hinders the universities in attracting good M.S. and Ph.D. candidates. These impacts should be evaluated carefully in all manpower development programs. In particular, the industry may want to develop programs to encourage individuals with high academic abilities to pursue graduate education and to seek faculty positions. Nuclear engineering faculty should be encouraged to become actively involved with the industry in research, summer employment, consulting, and other activities.

TOPICS FOR FURTHER INVESTIGATION

1. What level of educational capability is needed in nuclear engineering?

2. What involvement of university personnel and facilities is appropriate to meet the special research and evaluation needs of the nuclear power field?

CHAPTER 3

REACTOR OPERATORS

INTRODUCTION TO THE ISSUES

The requirements for operating personnel in nuclear power plants are growing. The specific technical skills required of operators are diverse and demanding, and certain aspects of the reactor operations environment are considered to impose stresses that reduce the attractiveness of these demanding jobs. The combination of a high skills requirement and a not always pleasant job environment makes it difficult to attract and retain qualified personnel.

The operation of a power plant is a complex task involving the precisely integrated use of steam, hydraulic, thermal, and electric power; instrumentation, water purity control, environmental monitoring; effluent control; and other systems. The responsibilities of the job include normal operation and maintenance as well as special shut-down activities that range from incorporating design changes to refueling the reactor. Reactor systems vary in detail from plant to plant. Each operator must be aware of current conditions in his own plant, of problems that may develop at similar plants, and of regulatory processes that may influence plant operation.

Since the accident at Three Mile Island (TMI) Unit 2, the requirements on operators have expanded to the point at which most utilities now require six shifts to man a single unit around the clock. That is, 168 hours per week of operation requires the efforts of control room staff whose weekly time coverage would nominally be 240 hours to accommodate vacations, specialized training (including simulator time), supervision of plant modifications during operation, and continuing education regarding Licensee Event Reports, design changes, and regulations. In addition, overtime is the rule, as the only practical way to meet needs for shift overlap, to make engineering changes, to respond to new regulatory requirements, and so on.

Requirements for operating personnel continue to grow, due to the expected doubling in the number of plants over the next ten years and the increase in the personnel now required to operate a single plant. The training and qualification of operators is thus a large and growing task. Training programs are diverse in their approaches to this problem, reflecting the varying extents of utility commitments to nuclear power, overall utility sizes, and so on.

Some candidates for nuclear operator positions have in part come from technician training programs or the Navy's nuclear propulsion program. Some utilities recruit high school graduates, on a very selective basis, to enter in-house training programs. Relatively few reactor operator candidates have baccalaureates in engineering when they enter reactor operations training.

In evaluating the role of reactor operations personnel needs in the complete spectrum of technical skills in the nuclear power field, the major issues to be considered pose special problems beyond those observed in the recruiting, training, and retention of personnel in most technical fields. Much of the training is now plant-specific, and operators must pass initial licensing examinations followed by regular requalification examinations.

MAJOR ISSUES

ISSUE: What are the appropriate technical qualifications for reactor operating personnel?

DISCUSSION

Requirements for operating personnel have generally been met by specially organized, goal-oriented training programs similar to the armed forces' technician programs for specialized personnel. The accident at Three Mile Island and the subsequent evaluations of its specifics, cast serious doubt on the training's completeness and generality, with regard to both the operators' understanding of the overall system and their ability to meet the special challenges of unanticipated events. In response to this, recommendations and proposed regulations like the U.S. Nuclear Regulatory Commission's (NRC) SECY 81-84 have called for, in some cases, an across-the-board upgrading of all personnel with operating licenses so as to require an engineering degree or its equivalent.* Responses from the industry and from individual operators indicated dismay at the withdrawal of trust apparently embodied in such requirements. Thus, at a time when more operators are needed, the some 3,000 already qualified personnel question the stability of their futures.

To review operator qualification requirements and provide recommendations on the education and experience required of candidates for reactor operator

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*U.S. Nuclear Regulatory Commission. 1981. "Qualifications of Reactor Operators" (SECY-81-84). Proposed rulemaking. February 2.

training, the NRC has appointed a peer evaluation group that includes representatives of the NRC, and also of other federal agencies, such as the Federal Aviation Administration (FAA), that also require highly trained, specialized technical personnel. At the same time, INPO has embarked on an elaborate job-task analysis with the object of very precisely identifying the skills required, with regard to both subject area and depth of knowledge, by personnel in reactor operations. The objective of the INPO study is to assess reactor operations in terms of specific job-related responsibilities, rather than by invoking less precise personnel requirements such as possession of an engineering degree. A part of this process is the identification of specific requirements for educational preparation. The NRC and INPO studies together promise to provide an acceptable and workable framework for setting reactor operator qualification and experience requirements. One important legacy of the way the qualification issue has evolved is that the proposed educational requirements, as published in the draft Secretary Letter 81-84, have produced a high level of apprehension among already qualified operators. Steps must be taken to clear the air on this issue if stability is to be regained among these vital personnel.

TOPICS FOR FURTHER INVESTIGATION

1. What are the educational prerequisities for personnel entering reactor operations training?

2. What experience is required by a candidate for licensing?

3. What is the appropriate mechanism for evaluating education and experience needs?

ISSUE: What methods of training are appropriate for reactor operators?

DISCUSSION

The task of training reactor operators is enormous. The approximately 75 operating plants have in residence about 3,000 licensed operating personnel at the operator and senior operator qualifications levels. If the current attrition rate of 5.5 percent per year continues, by the end of the decade two-thirds of the current operational personnel will be gone. Further, the growth in the number of personnel required to operate a given plant is not likely to be curbed entirely. Thus, training programs for operating personnel can expect to train 6,000 to 7,000 people merely to meet licensed staffing needs in the year 1991. If in addition it is recognized that it takes several years to qualify an operator and an additional five years beyond that to produce a senior operator, the magnitude of the training programs that must be maintained becomes apparent.

The methods by which operators are trained vary widely from utility to utility. For the large utilities, which must maintain adequate staffs in existing plants and develop staffs for future plants, the establishment of in-house training programs seems quite popular. In these programs the training of operators is only part of a much more diversified activity, which includes training for instrument technicians, pipefitters, electricians, water system service technicians, and the like. It is true, of course, that the operator training responsibilities are the most demanding of these and in general will require much larger investments of time to meet.

At the other end of the spectrum are the utilities with small commitments to nuclear power, such as the many which have only one operating unit and no plans to expand nuclear capacity. Almost certainly, these utilities must rely heavily on the training programs of equipment vendors, specialized technical training institutes, and others. A particularly noteworthy development is the recently announced acceptance by utilities operating a total of 28 plants, to give on-site training to personnel for plants expected to come on line later. The willingness to accept personnel from other utilities for in-plant training, and indeed the possible future incorporation of such personnel in large utility training programs on a contract basis, could provide welcome relief.

Methods of training are less important than the question of evaluating training effectiveness. The INPO job-task analysis is designed to provide job-specific definitions of skills, and thus specification of needed training for reactor operators. The testing and evaluation of operators should be based on that identified array of skills and should include plant-specific elements as well as basic background. Each utility will be able to rely on the INPO data in developing training programs for its own operators. Economic and staffing considerations for training are not negligible; cost effectiveness is thus a legitimate consideration in meeting training needs.

TOPICS FOR FURTHER INVESTIGATION

1. What is the magnitude of the need for training?

2. What are the necessary variations available to different sized utilities?

3. What should be the basis for evaluating the adequacy of training?

ISSUE: What are the special requirements in qualifying senior operating personnel?

DISCUSSION

The basic body of knowledge required of senior operators is more extensive than that required of operators. The senior operator must have the skills necessary to confront the unexpected with success. Thus the technical examinations required of such personnel involve demonstrations of theoretical knowledge and the capacity for analysis beyond the scope of the reactor operator examination. It is important to recognize that senior operators do not work alone; they have very definite administrative responsibilities, including supervision of certain aspects of the plant's staff, evaluation of the performance of licensed reactor operators and other certified personnel, and often additional responsibilities in on-the-job training and recertification of personnel.

The supervisory and leadership skills required of senior operator personnel are perhaps the most important for responding decisively and effectively to plant upset or accident conditions. It has been suggested that there were plenty of technical skills in the control room when the Three Mile Island accident occurred, and that the missing ingredient was the leadership required to focus those skills on the problem in the first two hours. Certainly the fact that similar precursor events have been noted at other plants, in some cases prior to TMI, and that these events were successfully dealt with suggests that the problem is not purely technical in nature. It would appear that identifying individuals with both the technical and leadership skills necessary to organize the staff under such circumstances should be given greater emphasis. This effort should include special training and guidance for supervisory personnel in the confrontation of crisis situations and the exercise of these skills to the extent possible in appropriate emergency drills. Those with these technical and crisis response skills must be present in each shift.

TOPICS FOR FURTHER INVESTIGATION

1. What are the special demands on senior reactor operations personnel?

2. Should crisis management training be incorporated in their training?

ISSUE: What is NRC's influence on reactor operator availability and quality?

DISCUSSION

Among its many responsibilities, the NRC must evaluate the qualifications of the personnel responsible for reactor operations. Examinations of reactor operators and senior reactor operators are currently required. These examinations are based mainly on technical skills, including detailed knowledge of the plant. In practice, individual utilities may assign additional responsibilities to licensed individuals; senior reactor operator licensees, in particular, may serve also as shift supervisors or training supervisors, or may undertake other special responsibilities. The NRC requirements for reactor operator qualification are quite specific, outlining both formal education and also experience. At present, the NRC's responsibilities are discharged through NRC-administered examinations, which include oral, written, and plant walk-through phases.

The NRC reactor operator examining process has been questioned by some as being out of step with the actual array of qualifications required of reactor operators. The increased scope of qualifications growing out of the TMI "lessons learned" activities and the job-task analysis being performed by INPO should provide the basis for examining the NRC licensing process and sharpening the NRC's examinations. Even more thought-provoking is the suggestion that the NRC should certify training programs and audit their implementation, with the object of eventually moving away from individual operator examination. This alternative deserves serious consideration, since it would place the responsibility for reactor operations on the utility and give the NRC much more of a true regulatory role, instead of its present one as part-time participant.

Certain jobs in reactor operations besides those of reactor operators may require some sort of individual or training certification. This might be particularly appropriate for plant personnel involved in instrument calibration and maintenance, water systems servicing, health physics monitoring, and other activities closely associated with plant safety. Finally, the personnel demands on NRC's licensing staff are expected to grow significantly over the next few years. If the staff continues to issue licenses individually, a careful reexamination of techniques and responsibilities, to ensure that the important aspects of reactor operations receive their due, appears appropriate.

TOPICS FOR FURTHER INVESTIGATION

1. Should the NRC always examine individual operators for qualification?

2. Should the NRC certify training programs, and if so is the graduate of that process to be accepted as meeting license requirements?

3. To what extent is flexibility in entrance, educational, and experience requirements necessary in the NRC criteria?

4. What is the appropriate means of operator requalification and examination?

5. Are there other plant operations positions that should be subject to licensing or certification requirements?

CHAPTER 4

HEALTH PHYSICS PERSONNEL

INTRODUCTION TO THE ISSUES

In the past few years, due in part to "lessons learned" at Three Mile Island (TMI) Unit 2, the need for professional health physicists throughout the nuclear power industry has grown dramatically. As low as reasonably achievable (ALARA) requirements (in both design and operations), emergency planning activities, training assistance, and an awareness that radiation safety is more than simple adherence to technical specifications all contribute to this increase. At the same time, the U. S. Nuclear Regulatory Commission (NRC), and to a lesser degree other regulatory agencies, are for many of the same reasons increasing the sizes of their staffs. Radiation protection programs outside the nuclear power industry have faced similar changes and must compete for health physics staff. Meanwhile, the number of graduate schools training operational radiation safety personnel is decreasing, along with the size of the typical program.

Utilities, hospitals, shipbuilders, research institutes, universities, state health departments, federal agencies, and other institutions and industries contribute to the demand for health physicists. Utilities are only one of the industries that employ significant numbers of health physicists and technicians. The difficulty of producing the required numbers of health physicists and technicians has been exacerbated by the fact that only 24 schools now offer programs in the health physics field, compared to the 64 schools of a few years ago. The primary reason for the demise of these programs in many institutions has been inadequate financial support, and in some cases the fact that faculties were simply hired away by industry. Indeed, utilities are among the worst offenders in this regard, and such hiring amounts to killing the goose that laid the golden egg. While it is possible to teach technicians on the job at power plant sites, health physicists can be trained only in university programs.

It is apparent that the supply of health physics personnel for nuclear power plants is influenced significantly by the image of the nuclear industry. In earlier times this was countered by federal financial support of health physics students. Recently, though, the federal government has determined that it is not its responsibility to assure industry of an adequate supply of health physicists; as a result, the various federal fellowship and traineeship programs have been eliminated. The situation is exacerbated by the fact that there is relatively little support for research or teaching by students at the graduate level, because there is no large body of undergraduate students in the field. Often health physics programs are buried in other academic departments that are not completely sympathetic to their needs. Unrealistic limits on enrollment are often imposed because of the limited financial resources.

Certification requirements for health physicists have been in existence for over 20 years. The basic requirements are a baccalaureate degree in the physical or biological sciences, six years of experience in the health physics area, and the passing of a two-part comprehensive examination. In 1979, a special certification for nuclear power plant health physicists was authorized. Individuals who hold comprehensive certifications can receive this speciality certification by passing an examination or acquiring sufficient experience in the field. Renewals every five years now require a demonstration of competence through an accumulation of continuing education credits. Associate degrees in health physics and registration of technicians are also available. Registration is newer and less well recognized than the certification program.

Alternatives to M.S.-level programs as the source of professional health physicists have met with varying degrees of success. Some of the B.S. programs are oriented toward professional health physics, but many turn out highly qualified technicians instead. Certification programs such as the American Board of Health Physics Comprehensive Certification Program and the American Board of Health Physics Power Reactor Specialty Certification Program, offer a self-taught, in-service-taught, or B.S.-level health physicist an opportunity to demonstrate competence by peer examination. Unfortunately, the use of these certification programs has been minimal in the power reactor industry.

MAJOR ISSUES

ISSUE: The number of professional health physicists is inadequate to meet even current needs.

DISCUSSION

The increasing public concern with radiation and its effects, the regulatory response to that concern, worker concerns, and management awareness have resulted in an ever-increasing demand for professional health physicists.

The nuclear industry has increased its need for professional health physicists as a result of both lessons learned at TMI and the resulting regulatory requirements.

Nearly every sector of society draws upon the same supply of health physicists. Professional health physicists work in state and local health departments, in the many manufacturing industries employing radioactive materials, in educational institutions, in medicine, in pharmaceutical research houses, in architect-engineer and consulting firms, in U.S. Department of Energy contract organizations, in U.S. Department of Defense research establishments, in the U.S. Environmental Protection Agency, and in the NRC.

TOPICS FOR FURTHER INVESTIGATION

1. Is the existing situation a long term problem?

2. How many positions are currently unfilled or filled by marginally qualified people?

3. Are the personnel shortages more or less pronounced in some specific industries?

ISSUE: The current graduate-level programs in health physics are unable to meet personnel needs. What are the extent and nature of the problem?

DISCUSSION

Although more than 50 educational institutions are reported to have active programs in radiation protection, the number of institutions producing M.S. graduates in health physics and radiation protection per se has actually decreased from a high of 64 several years ago to the present level of 24. Even in these schools, over the last year only 11 graduated more than two students at the M.S. level, and no school graduated more than 10; the total number of graduates was less than 100.

TOPICS FOR FURTHER INVESTIGATION

1. Was the job market a significant factor in this decrease?

2. What steps are needed to demonstrate that the educational investments needed will prove wise and productive in a period of declining educational resources?

DISCUSSION

From the mid-1950s through the 1960s, most graduate students in health physics were fully supported, first by the Atomic Energy Commission and later by the U.S. Environmental Protection Agency and the Public Health Service. At present there is no more than token government support for these students. Since there are few undergraduate programs, teaching assistantships are simply not available.

TOPICS FOR FURTHER INVESTIGATION

1. What conditions that resulted in the initial funding no longer obtain?
2. Was the expectation that private and industrial support would fill the gaps left by the withdrawal of federal support realized?

ISSUE: Are the existing programs vulnerable?

DISCUSSION

The small numbers and sizes of the programs make them vulnerable. Since these programs are often presented as options in more general graduate departments, their faculty appointments are relatively insecure or are viewed as providing limited opportunity for individual growth. Such faculty are particularly suspectible to outside offers of employment. This problem is aggravated by the large salary discrepancy between the private sector and universities, particularly at the level of junior faculty members. A similar situation obtains with regard to capital equipment; successful programs in health physics require up-to-date equipment so that students can have practical experience with the equipment they are likely to find on their jobs. Many students who do matriculate in Ph.D. programs find themselves unable to resist the financial pressures of high salaries available to them even if they do not complete their degrees. Although the number of Ph.D degrees granted has been fairly steady over the past ten years, recipients have been drawn to medical physics, with its independence and prestige, and to industry, with its higher salaries. This further increases the vulnerability of small programs.

TOPICS FOR FURTHER INVESTIGATION

1. What steps are required to make salaries competitive between the university community and private industry?
2. What organizational arrangements are used where successful radiation protection programs exist?

3. How and why are the numbers of holders of Ph.D. degrees available for faculty positions threatened?

ISSUE: Can the B.S. programs in health physics help to meet these needs?

DISCUSSION

The number of B.S. degrees in health physics granted has increased dramatically over the past ten years. This is clearly helping to fill part of the need. A few of these programs produce individuals clearly prepared for professional careers, but most tend to produce high-quality technicians. Of course, a major difficulty in filling the short-term demand is that six to eight years are required to produce a health physicist from point of recruitment to eventual placement. M.S. programs can provide such individuals within 2 years or less.

TOPICS FOR FURTHER INVESTIGATION

1. Do the B.S.-level programs have common objectives?

2. Should they have common objectives?

ISSUE: Is the American Board of Health Physics' Comprehensive Certification Program for power reactor health physicists adequate and appropriate?

DISCUSSION

The issue really revolves around the difficulty of recruiting personnel for positions of high responsibility in the nuclear power industry. Certification is only one technique by which those employing health physicists can ensure that individuals have gained the knowledge and skills required for the highest level of operational health physics responsibility. Experience with the American Board of Health Physics (ABHP) Comprehensive Certification Program has not been helpful in satisfying the need; only a small fraction of the working power reactor health physicists have been able to meet the requirements. Some of this difficulty can be attributed to their high workloads and extended overtime requirements, which do not permit them to prepare adequately for the examinations. As a result, in 1979 the ABHP started a specialty program for power reactor health physicists. This program is still in its formative stages, having certified only 19 individuals through the end of 1980.

TOPICS FOR FURTHER INVESTIGATION

1. How many professional health physics positions in the nuclear power industry require certification?

2. Should the nuclear power industry establish programs to prepare their employees for certification?

CHAPTER 5

COMPETING DEMANDS ON TECHNICAL MANPOWER

INTRODUCTION TO THE ISSUES

The special focus of this report is on the personnel required to meet the needs of the nuclear utility industry and its closely allied suppliers, contractors, and service organizations. However, competition from others for personnel can be broken down by source. Each source raises its own policy issues.

MAJOR ISSUES

ISSUE: To what extent do the organizations developing new nuclear power technologies compete with utilities for technical personnel?

DISCUSSION

The companies developing new options for the nuclear power industry (breeder reactor programs, advanced light water reactor systems, or advanced converter reactors), the private sector programs directed toward closing the nuclear fuel cycle (for example, by disposal of high-level nuclear wastes and initiation of chemical reprocessing of spent fuel), and the host of companies involved in risk-venture developments of components and subsystems that may eventually find a market in the power, radioistopes, instrumentation, or other nuclear-related applications all have needs for personnel who might otherwise be employed by nuclear utilities.

TOPICS FOR FURTHER INVESTIGATION

1. What are the anticipated levels of effort in the development of advanced reactor concepts, including the breeder, and in fuel-cycle-related activities over the next few years?

2. Will advanced technology developments in reactor systems and components design be accepted by industry and the regulatory community, and ensure a viable risk-venture sector in nuclear power?

3. Will the waste management issue be resolved by the establishment of an active repository program?

ISSUE: What services offered by architect-engineer and construction firms are limited by personnel availability?

DISCUSSION

These companies require the civil, mechanical, electrical, and nuclear engineering skills that are needed in the design, licensing, construction, and testing of nuclear projects. Shortages of talent in these areas and in the various crafts have direct influences on schedules and performance. Welding, pipefitting, and radiography are some of the areas in which employment shortages are commonly encountered.

TOPICS FOR FURTHER INVESTIGATION

1. What special training programs are required in critical trades?

2. Should special opportunities in continuing education be available to sharpen nuclear skills for those in traditional disciplines?

ISSUE: What role do the armed forces play in the supply and demand of nuclear power personnel?

DISCUSSION

For the most part, the needs of the armed forces are met by normal recruiting and in-service training. The major influence of the armed forces programs is in training personnel who eventually enter the private sector, particularly the utility industry, as reactor operators.

TOPICS FOR FURTHER INVESTIGATION

1. What increased military requirements can be expected for trained nuclear personnel, especially in view of the stated objective of modernizing and enlarging the U.S. Navy?

2. Will the traditional training methods used by the military be altered significantly?

3. Will new initiatives for encouraging reenlistment be effective?

4. Are there new technological developments in nuclear operations in the Navy that may influence methods available in the civilian power industry?

ISSUE: How do regulatory agencies' personnel needs compete with those of the nuclear power industry?

DISCUSSION

The activities of the U.S. Nuclear Regulatory Commission, the U.S. Environmental Protection Agency, the U.S. Department of Transportation the Federal Emergency Management Agency, and various state agencies impose a large demand for professionals in engineering and health physics. Of particular significance in the past few years is the growing demand for professionals in state agencies concerned with commerce in radioistopes and other hazardous materials, low-level radioactive waste disposal, planning for emergency preparedness in the vicinity of nuclear power plants, and environmental surveillance. At the federal level, the establishment of resident inspection staffs at power plants and the increased pace of certification and licensing activities are reflected in requirements for highly skilled and experienced personnel.

TOPICS FOR FURTHER INVESTIGATION

1. Are present levels of regulatory staffs on plant sites sufficient?

2. What staff needs will be required at the state level to implement nuclear waste management activities?

3. Are existing regulatory arrangements sufficient or redundant?

ISSUE: Do government contractors and national laboratories offer significant competition for personnel?

DISCUSSION

Personnel needs at the professional and technician levels depend on the missions of the particular facilities. The reactor safety research program uses the services of highly skilled engineers and technicians. Many of these individuals are deemed to have skills that must be available to serve national defense needs in periods of crisis. To the extent practicable, the assignment of these personnel to study relevant issues in nuclear safety offers both a worthwhile use of their talents and challenges their skill and imagination when they are not occupied with national defense problems.

TOPIC FOR FURTHER INVESTIGATION

What safety issues and development activities are legitimate topics for a national laboratory effort?

ISSUE: What is the competitive position of the nation's educational institutions in recruiting and retaining technical personnel?

DISCUSSION

With a few notable exceptions, the educational institutions involved in nuclear education and training are state-supported institutions with active research efforts supported by the federal establishment. The technical and vocational institutes (both private and public) play an important role in both the supply and the demand aspects of the personnel problem. On the demand side, the need for competent faculty in engineering, health physics, and the varied technical skills and crafts is huge. More than 2,000 faculty positions in engineering are currently unfilled in the United States;* the competition for qualified persons to fill them is fierce, and government laboratories and the private sector have distinct advantages over universities in recruiting. Similar demands exist in health physics. Technicians and skilled craft personnel, too, have opportunities both inside and outside the nuclear

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*Dean John Kemper. 1980. "Survey of Engineering University Faculty Shortage." Unpublished Paper. Davis, California: University of California-Davis. Frank Atelsek and Irene Gomberg. 1980. <u>Higher Education Panel Report No. 52</u>. Washington, D.C.: American Council on Education. October.

industries. The responses of industry and utilities to the current shortages of personnel have included the hiring of additional university and training institute faculty and have thus sowed the seeds of a further shortage of faculty. Protecting the integrity of the educational process is the responsibility of all who use or benefit from the process. In particular, the need to strengthen our education and training institutions in engineering and technology is apparent.

TOPICS FOR FURTHER INVESTIGATION

1. What specific faculty are needed to properly educate nuclear power specialists?

2. What incentives are needed to attract competent individuals to faculty positions?

ISSUE: To what extent might the international nuclear market contribute to the nuclear manpower problem?

DISCUSSION

Until recently, the United States was the major supplier of nuclear power plants to the overseas market. One U.S. vendor is maintaining some supply capacity by completing overseas plant orders, but the perception of the United States in recent years as an "unreliable supplier" has cut to zero the new foreign orders placed with U.S. vendors over the past several years.

Should the United States be successful in regaining a share of the foreign market for nuclear power plants, the demand for specialized personnel could be increased significantly. It has been estimated that a single nuclear plant order would require 30,000 man-years of direct and indirect labor in design, manufacture, and construction, and an additional 30,000 man-years over the plant lifetime for fuel supply, components and services.* Considering that 14 new orders were placed over the past year by foreign utilities (none with U.S. suppliers) while 18 nuclear units were canceled domestically, it is possible that a renewed perception of the United States as a desirable supplier could impose a significant demand on available U.S. manpower resources.

The only nuclear-power-related commodity of which the United States is considered a reliable supplier is training for nuclear manpower from other nations; foreign students constitute a significant fraction of the graduate student population in this country's nuclear science and engineering institutions. Many of these foreign graduates remain in the United States nuclear manpower pool, at least during the early parts of their professional careers.

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*William O. Doub. 1981. Paper presented at the Nuclear Manpower Study Committee Workshop. Washington, D.C.: National Research Council. September.

TOPICS FOR FURTHER INVESTIGATION

1. What is the potential for international sales in the nuclear power field?

2. What services should be included in international trade packages to make them attractive; what are the implied personnel commitments?

3. What movement of trained personnel in either direction can be expected as a result of international trade activities?

CHAPTER 6

PERSONNEL MANAGEMENT ISSUES

SELECTION AND RETENTION OF PERSONNEL

Introduction To The Issue

A vital aspect of the manpower situation in the nuclear power industry is the proper selection of personnel. All too often, when there is a shortage, companies tend to take anyone who applies. Experience has shown that in the long run unqualified personnel are usually more a liability than an asset. A recruiting program is required to identify and attract adequate numbers of qualified applicants for each position.

One issue that needs to be addressed is turnover. The 5.5-percent turnover identified in a recent Institute for Nuclear Power Operations (INPO) survey reflects the number of trained personnel leaving the nuclear power field.* This survey does not provide data by a specific type of activity for which trained replacements must be provided. For instance, if an individual is promoted from a senior reactor operator position to management, it is necessary to provide a trained senior reactor operator replacement. A trained individual who leaves one utility and goes to another utility, a vendor, or an architect-engineer firm hasn't necessarily left the nucler power field, but he or she must be replaced by the the first utility if it is to meet its obligations. Actual experience would indicate that a 20-percent annual turnover in most job categories is more realistic than the 5.5-percent figure.

Because of the limited supply of qualified individuals, particularly reactor operators, some utilities have begun paying 15-percent cash bonuses when individuals are hired. Furthermore, they are now providing professional relocation packages for both operators and health physicists, including technicians. Reactor operators are not as mobile as engineers and health physicists

*Institute for Nuclear Power Operations. 1981. Manpower Study Series, Report No. 1. Atlanta, Georgia: Institute for Nuclear Power Operations. September.

because their licenses are tied to specific plants. Another consideration, more common in recent years, is represented by two-career families; it is sometimes necessary to provide a job for a spouse in order to recruit an individual that the utility wants. More and more often, utilities pay for the educations of individuals, with the understanding (either explicit or implicit) that they will work for the utility for a specified length of time after graduation. Generally this involves hiring local people who have personal reasons for accepting limited mobility.

MAJOR ISSUE

ISSUE: What steps are necessary to ensure the viability of careers in reactor operations?

DISCUSSION

A career in reactor operations requires dedication, stamina, and technical skill. Furthermore, the preparation required to qualify as an operator is such that only the most dedicated will enter and survive the training program. The rewards for success, on the other hand, can be large. Reactor operators as a group are becoming very well paid, and the demand for their services is brisk. For a person without an academic degree, a career in reactor operations represents a path that can lead to a very well paying position, but one that also makes great demands in terms of skill and job performance. For a degreed person, a term of duty in reactor operations may well be regarded as an important stage in career development. The commitment to a long-term stay in operations is not so much necessary for degreed personnel as is the demonstration of the skills and knowledge necessary to perform successfully in the operations environment. For both groups, however, it is important that the perceptions outlined above are credible. At the level of the utility management, an understanding of career paths and an indication of their availability to both nondegreed and degreed personnel is increasingly important. Perhaps more important is the necessity for a nationwide commitment to a viable nuclear power industry, with the implied endorsement of the acceptability of people involved in nuclear power plant operations in our society. Relegating nuclear power to the option "of last resort" can only result in disillusionment and loss of the people with the skills and integrity that are really required to operate nuclear power plants.

TOPICS FOR FURTHER INVESTIGATION

1. What are the attractions of a career in nuclear operations?
2. What reduces the attractiveness of such careers?

3. What steps are needed to give these positions the recognition they deserve?

STRESS AND HUMAN FACTORS

Introduction to the Issue

Stress is widely recognized as an important factor in many positions in the nuclear power industry, and it is particularly important for reactor operators. Since different people do not react in the same way to the same stimulus, the role of individual differences in job performance must be known.

Human factors engineering is recognized today as a necessary contributor to the design of control rooms and nuclear power plants. It also is used to help design the reactor operators' jobs and define their roles. Operators must not only know the plant, but must also know how the plant responds, so that they can handle both normal operation and safe shutdown when necessary. Human engineering is a very important factor in both designing and evaluating procedures to use in the plant.

MAJOR ISSUE

ISSUE: What aspects of the reactor operations environment have adverse influences on operator performance?

DISCUSSION

A number of conditions make the environment confronted by reactor operations personnel highly stressful. Reactor operations is a shift activity. The plant has to be operated 24 hours a day by personnel with at least a minimum level of technical skills. Certain engineering, maintenance, and training activities may be restricted to convenient shifts, but operations must continue around the clock. Thus operators find themselves with schedules that change regularly and that impose special stress on relationships with family, friends, and social contacts. Performance of the most mundane maintenance and plant surveillance activities requires close checks with the status of the plant and with other activities being carried out at the time. Many activities involving ancillary equipment, engineering changes in anticipation of such future tasks as refueling, and the operation of support systems do not require direct participation by reactor operations personnel. On the other hand, reactor operations personnel must be fully aware of and, indeed, approve all such activities.

Finally, the full range of regulatory requirements, including awareness of the status of Licensee Event Reports as they apply to a given plant, the preparation of special reports, and periodic training sessions provide distractions that in many cases are viewed as annoyances by these personnel.

Many of the diverse demands on operators are entailed by the responsibilities of the job. Certainly round-the-clock manning of the plant is necessary, as is the requirement that all activities in the plant be cleared with the plant operators. Finally, reactor operators must expect to be required to grow in their jobs. There are lessons to be learned from LER's and the accumulated experience in a particular plant. Training activities and appropriate refresher courses are necessary, though they are not always simple to plan. Questionnaires, special reports, extra analyses, and potentially interesting studies should be carefully reviewed before they are imposed on the operations staff. It has also been suggested that the use of computerized data bases to keep track of maintenance and other activities at the plant, to indicate the status of various plant components, and to identify those activities which might jeopardize the functioning of safety systems or states of vital plant equipment would be most helpful in reducing the extent to which operators must rely on memory and experience.

TOPICS FOR FURTHER INVESTIGATION

1. What conditions in reactor operations place heavy and distracting demands on operators?

2. Which of these tasks require reactor operator attention?

3. What techniques are available to organize the diverse demands on operators?

CHAPTER 7

EMERGING TECHNOLOGY

INTRODUCTION TO THE ISSUES

One of the newer job design issues is the role of the computer. The man-machine interface is fast being replaced by the man-computer interface; the computer can be programmed to control the plant in an optimal fashion, relieving the operator of much tedious work, reducing routine workload and detailed information processing. At present, many control panels display too much information, much of it poorly. In essence the operator receives the inputs for a calculation and must find the result by hand or in his head. Some of the concepts of robotics and artificial intelligence should be introduced, along with the methods of human factors engineering. One proposal is to use a computer to project on a fast-time basis what will happen if specific steps are taken; when the operator observes the effect of a specific action he can then determine if he wants to take it. Such a computer would also allow the operators to deal with simulated accidents. This kind of simulation might be more appropriately a part of training than of routine reactor operation. Alternatively, the use of the plant computer as a training device during normal reactor operation would help keep reactor operators alert, and might lessen the time required for simulator training away from the reactor. Over the next decade, however, this computer arrangement is not likely to play a significant role in moderating manpower demands.

ISSUE: What will be the effect of advanced computer integration at the man-machine interface?

DISCUSSION

Technology for applying computer capablities proceeds rapidly but tends to focus on selected areas where new mission requirements can only be addressed through the use of computers. In relatively more established endeavors, there is less pressure to adopt advanced techniques as they emerge; only when a crisis takes place does change seem attractive. The major block to applying both hardware and software advances in the nuclear operations field will be the desire to maintain the status quo.

TOPICS FOR FURTHER INVESTIGATION

1. What incentives should be offered to encourage application of advanced technologies to the reactor operations problem?

2. What criteria should be used to judge the acceptability of such advances?

ISSUE: To what extent should reactor operations be automated?

DISCUSSION

The responsibilities of the operator who controls a power plant are fundamental, and the implications of operator error are very well demonstrated. One concern is the degree to which operator tasks should be delegated to a computer. At issue is the extent to which operator performance would be improved or impaired as a result. A comparative understanding of the roles of human intelligence and of synthetic intelligence as it is embodied in computer formalisms should be reached; the expectations from each should be evaluated.

TOPICS FOR FURTHER INVESTIGATION

1. What should be the functions and responsibilities of the operator in an automated power plant?

2. What are the criteria for relying on computer-diagnostic-assisted decisions or computer-generated decisions in emergency situations?

ISSUE: What is the role of robotics and artificial intelligence in the operation of nuclear facilities?

DISCUSSION

Increasing surveillance of all operations including maintenance, systems modification, quality control and verification, routine calibration functions and the scheduling of access to critical work areas place universal demands on plant supervision. The recognition of safety functions of critical systems should also be assured. Other operations may be amenable to automation to reduce human exposure to radiation. These are just examples of the potential for enhancing the level of information about plant status and reducing personnel exposure that may be developed if the climate is favorable to their acceptance.

TOPICS FOR FURTHER INVESTIGATION

1. What advances in plant information systems are attainable using computerized surveillance systems?

2. What routine functions involving high radiation exposures are potential candidates for automated systems or robot utilization?

3. What criteria are needed to judge the acceptability of such innovation?

CHAPTER 8

CONCLUSION

In the final analysis, the number of trained personnel that will be required by the nuclear power industry will be significantly influenced by government regulation and policies. It is equally true that the nuclear utilities quite independently appreciate the importance of an enhanced level of technical skills and judgment in the operation of their facilities.

Such questions as "How safe is safe enough?" may be philosophically unanswerable, but in the real world some sort of answer will be forthcoming from both the regulatory and the utility points of view and that answer will drastically affect the number of trained personnel required. These needs will be met by academic training (at all levels); by specialized technical training by vendors, industrial organizations, and educational institutions (primarily community colleges and specialized private institutions); and by in-house training programs and on-the-job training in the utilities.

There is no record of a national technological effort that has been curtailed as a result of the unavailability of adequately trained personnel. Solutions sometimes require more personnel working on discrete tasks rather than few individuals performing the entire job, but if the committment exists the job is done somehow. Thus, the first issue is to judge the depth of commitment to the task and then to proceed to meet the need as efficiently as possible.

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- "Employment and Labor Requirements in the Design and Engineering of Nuclear Facilities and Manufacture of Reactors and Reactor Components"
- "Employment and Labor Requirements in the Natural Gas Energy Segment: Exploration, Extraction, Transportation, and Power Plants"
- "Employment and Labor Requirements in the Liquefied Natural Gas Energy Segment"
- "Employment and Labor Requirements in the Petroleum Energy Segment: Exploration, Extraction, Transportation, Refining, and Power Plants"
- "Employment and Labor Requirements Projections for Coal Conversion Facilities"
- "Employment and Labor Requirements in the Coal Energy Segment: Mining, Transportation, and Power Plants"
- "Employment and Labor Requirements in the Hydroelectric Energy Segment"
- "Employment and Labor Requirements in the Geothermal Energy Segment"
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MANPOWER ASSESSMENT MODELS AND COMPUTATIONAL CAPABILITIES

I. Energy-Related Models and Computation Capabilities

A. Capabilities at Oak Ridge Associated Universities maintained for the U.S. Department of Energy (DOE)

- Utility Staffing Requirements for Nuclear Power Plant Operation and Maintenance

- Occupation Employment in Nuclear-Related Activities by Industrial Segment

- Scientific, Engineering, and Technician Employment in Magnetic Fusion Energy

- Coal Mining Employment in Deep Mines, in Surface Mines; Nationally, Regionally, or by State

- Direct Employment Related to Biomass Energy System Development

- Direct Employment Related to Ethanol Fuel Production

- Econometric Model for Energy-Related Construction Labor Market Assessment--A Model for Assessing Individual or Geographically-Adjacent Projects

B. The University of Illinois Center for Advanced Computation (CAC) Model. This input-output model has been extended to study energy sectors of the economy and to estimate employment impacts. Its focus does not include the employment of scientists and engineers.

C. The Energy Disaggregated Input-Output Model (EDIO) of the Energy Information Administration (EIA) of DOE, and the Bureau of Labor Statistics (BLS). This system is based on the BLS Economic Growth Model. It embraces both primary and secondary energy sectors, and is designed to provide overall employment estimates related to alternative energy developments. The system is in use, but has not been updated for several years and at present there are no plans to do so.

L. The National Coal Model, maintained by EIA. This model is designed to estimate supply and demand for coal by region; it indirectly estimates demand for coal mine workers--by region, and by type of mining (surface vs. deep).

II. Energy Models which Contain Limited Aggregated Employment Data

A. Models of Energy-Sector Interactions in the General Economy

1. The Hudson-Jorgenson Model

2. The Wharton Econometric Forecasting Associations (WEFA) Annual Energy Model

3. The Energy Technology Assessment (ETA) Macroeconomic Model

4. Other models include those of E. Hnyilicaz, and Data Resources, Inc. (DRI), that of Kennedy and Neimeyer, and PILOT, the Pilot Linear Programming Model for Assessing Physical Impacts on the Economy in a Changing Energy Picture.

B. Energy Sector Models

1. The Energy Model of Decision Focus Incorporated, Stanford Research Institute, and Gulf Corporation (The DFI-SRI-Gulf Energy Model)

2. The Lawrence Berkeley Laboratory Models

3. The Project Independence Evaluation System (PIES) Model

C. Energy Subsector Models

1. <u>Coal Industry Models</u> include that of Argonne National Laboratory; that of Charles River Associates; that of ICF, Inc.; that of J.D. Libbin and M.D. Boehlje, the National Coal Model, and the Bechtel Coal Model (RESPONS).

2. <u>Natural Gas Industry</u> Models include that of J.D. Khazzom, the North American linear programming analysis by Waverman, the MacAvoy-Pindyk model, and the American Gas Association's Total Energy Resource Analysis, TERA.

3. <u>Electricity Demand Models</u> include that of the Rand Corporation; that of Oak Ridge National Laboratory, and the Massachusetts Institute of Technology's Regional Electricity Model (REM).

4. Gasoline and Automobile Models include the WEFA and Sweeny Models, both prepared for the Federal Energy Administration.

5. World Energy Models include LINK, and the Kennedy World Oil Model.

6. Macroeconomic Models include those by Chase Econometrics, DRI, Georgia State University, Kent Economic Development Institute, the University of California at Los Angeles, the University of Michigan, General Electric Corporation, WEFA, and the Federal Reserve Board.

7. Single-Equation Models, in addition to those cross-listed above, include the work of Berndt and Wood.

III. Non-Energy Manpower Models and Computation Capabilities

A. The Scientific and Technical Personnel Studies Section of NSF forecasts national supply and demand trends for scientists and engineers. Data used include demand estimates provided by the U.S. Department of Labor.

B. The Washington, D.C. office of Mathematical Policy Research Inc. is developing for NSF's Scentific and Technical Personnel Studies Section a composite estimating technique and stock-flow labor forecasting model for scientists and engineers.

C. The Bureau of Labor Statistics and U.S. Department of Labor Model projects employment by occupation and industry using an industry-occupation matrix. Some sectors, including utilities and petroleum, are of direct interest to energy studies. Many state, regional, and local models are patterned after this industry-occupation matrix approach.

D. Richard Freeman at Harvard University has developed a distributed-lag cobweb model and a rational expectations model to examine and predict trends in science and engineering enrollment and degrees based on market reactions.

E. Robert Daffenbach of Oklahoma State University, with the assistance of the Engineering Manpower Commission, is developing an industry-occupation model which makes less restrictive assumptions about supply and occupational mobility than do most industry-occupation models.

APPENDIX: THE STRUCTURE AND PARTICIPANTS OF THE SEPTEMBER 21-22, 1981 WORKSHOP

NUCLEAR MANPOWER STUDY COMMITTEE WORKSHOP

AGENDA

MONDAY, SEPTEMBER 21, 1981

Opening Remarks: Dr. Robert E. Uhrig, CHAIRMAN
Overview: Mr. Paul Havenstein, U.S. Department of Energy

9:00 a.m. - 12:00 noon

<u>DEMAND PANEL:</u>	Session Leader:	Dr. Robert L. Long (Member, Nuclear Manpower Committee)
	Panel Chairman:	Dr. Forrest Remick Director, Office of Policy Evaluation Nuclear Regulatory Commission 1717 H Street, N.W., Room 1013 Washington, D.C. 20006
Utility		Mr. Vincent S. Boyer Senior Vice President, Nuclear Power Philadelphia Electric Company 2301 Market Street Philadelphia, Pennsylvania 19101
Vendor		Dr. Peter F. Murray Chief Scientist Westinghouse Advanced Power Systems Divisions Post Office Box 158 Madison, Pennsylvania 15663
Architect-Engineer		Mr. J.H. Battin Vice President of Project Operations Gaithersburg Power Division Bechtel Corporation Gaithersburg, Maryland 21233
Government		Dr. Thomas A. Dillon Executive Director of the Office of the Assistant Secretary for Nuclear Energy U.S. Department of Energy 1000 Independence Avenue, S.W. Washington, D. C. 20585

University	Dr. M. J. Ohanian Associate Dean for Research College of Engineering University of Florida Gainesville, Florida 32611

12:00 - 1:00 p.m. LUNCH

1:00 p.m. - 5:00 p.m.

SUPPLY PANEL:	Session Leader:	Dr. William E. Lear and Dr. D. Wayne Jones (Members of Nuclear Manpower Study Committee)
	Panel Chairman:	Dr. William Kerr Professor of Nuclear Engineering University of Michigan Ann Arbor, Michigan 48109
University		Dr. Richard E. Faw Professor of Nuclear Engineering Nuclear Engineering Department Kansas State University Manhattan, Kansas 66506
Technical Institutes		Dr. D. Wayne Jones Director, Center for Nuclear Studies Memphis State University (Member of Nuclear Manpower Study Committee)
Two Year Programs		Dr. Warren F. Witzig Professor and Department Head of Nuclear Engineering Pennsylvania State University 231 Sackett Building University Park, Pennsylvania 16802
Scholarship and Fellowship Programs		Mr. Richard Stephens Director, Division of University and Industry Programs Office of Energy Research ER-44 Department of Energy Washington, D.C. 20585

Government	Dr. Goetz Oertel Department of Energy NE 320 GTN Washington, D.C. 20545
Industrial	Mr. Dixie Duval President NUS Training Corporation 1350 Piccard Drive Rockville, Maryland 20850

TUESDAY, SEPTEMBER 22, 1981

Session A: (9:00 a.m. - 10:30 a.m.)	Session Leader: Mr. Charles B. Meinhold (Member, Nuclear Manpower Study Committee)
Demand for Health Physics	Dr. James Vacik College of Medicine Cancer Center Clinic, Room 374 University of Southern Alabama Mobile, Alabama 36688
Supply of Health Physics Personnel	Dr. Paul Stansbury Assistant Professor Environmental Science and Engineering University of North Carolina Chapel Hill, North Carolina 28804
Education and Certification Requirements for Health Physics Personnel	Dr. N. A. Greenhouse Health and Safety Engineer Bldg B-75-B, Room 116 Lawrence Berkeley Laboratory University of California Berkeley, California 94720
Session B: (10:30 a.m. - 12:00 noon)	Session Leader: Dr. Robert Seale (Member, Nuclear Manpower Study Committee)
Demand for Reactor Operators	Dr. R. Joe Johnson Chief of Nuclear Training Branch Power Operations Training Center Tennessee Valley Authority Post Office Box 2000 Daisy, Tennessee 37319

Supply of Reactor Operators	Dr. Paul Collins Chief, Operator Licensing Branch Nuclear Regulatory Commission 4550 Montgomery Avenue AR 5221 Bethesda, Maryland 20014
Education and Certification	Mr. W. H. O'Dell Manager of Instructive Services Nuclear Power Generation Division Babcock and Wilcox Post Office Box 1260 3315 Old Forest Road Lynchburg, Virginia 24505

LUNCH 12:00 - 1:00 p.m.

SESSION C: (1:00 p.m. - 3:00 p.m.)	Session Leader: Dr. Morton I. Goldman (Member, Nuclear Manpower Study Committee)
Personnel Management and Development a. Career Paths b. Mobility c. Union interactions d. "Hassle factors"	Mr. Richard Aman Manager, Organization, Planning and Development General Public Utilities Nuclear Corporation 100 Interpace Parkway Parsippany, New Jersey 07054
Industrial Psychology (stress)	Dr. Andres Inn Senior Research Scientist Advanced Research Resources Organization 4330 East West Highway, Suite 900 Washington, D.C. 20014
Task Analysis and Job Design	Dr. Mark Kirkpatrick Essex Corporation 333 North Fairfax Street Alexandria, Virginia 22314
SESSION D: (3:00 p.m. - 5:00 p.m.)	Session Leader: Dr. Edwin T. Layton (Member, Nuclear Manpower Study Committee)
Adequacy of Data	Mr. Michael Crowley Staff Associate, Methods and Analysis Division of Science Resources Studies National Science Foundation 1800 G Street, N. W. Washington, D.C. 20550

Image of the Nuclear Industry	Mr. John Marcum Assistant Director Energy and Natural Resources Office of Science & Technology Policy New Executive Office Building Room 5026 Washington, D.C. 20550
Emerging Technology/1990+	Dr. Edward Teller University of California Lawrence Livermore Laboratory Post Office Box 808 Livermore, California 94550
International Manpower Situation	Mr. William O. Doub Doub and Muntzing 1875 Eye Street, N.W. Washington, D.C. 20006