Chapter 7

Case Study: Nuclear Powerplant Control Room Operators

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In March 1987, the U.S. Nuclear Regulatory Commission (NRC) was notified that several control room operators at the Peach Bottom atomic power station had been found sleeping while on the job and not performing their duties; 7 days later, the NRC shut down the Peach Bottom powerplant, marking the first time the NRC had ordered a plant shut down for operator deficiencies. The NRC found:

- At times during various shifts, particularly during the 11 p.m. to 7 a.m. shift, one or more of the operations control room staff (including licensed operators, senior licensed operators, and shift supervisors) periodically slept or had been otherwise inattentive to licensed duties while on shift during at least the past 5 months.
- Management at the shift supervisor and shift superintendent levels either knew about and condoned the facts set forth above or as a part of their duties should have known of these facts and taken action to correct the situation.
- Plant management above the shift superintendent position either knew about and condoned the facts set forth above or should have known the facts and taken action to correct this situation (18).

The Peach Bottom nuclear powerplant reopened in April 1989, after a costly, 2-year shutdown. What occurred at Peach Bottom was a situation in which a breakdown in management, combined with disruptions of circadian rhythms and fatigue effects, created conditions in which the safe operation of the plant was jeopardized. In particular, lack of management oversight during the night shift (11 p.m. to 7 a.m.), when performance and alertness decrements are most likely, resulted in the behavior observed by the NRC. Though no accident resulted from operator inattentiveness at Peach Bottom, other accidents and incidents, such as that at Three Mile Island in 1979, have occurred during these hours of operation.

This case study examines the job of nuclear powerplant control room operators, a job characterized by continuous, routine monitoring tasks that must be carried out 24 hours a day, usually on a rotating shift schedule. It is an example of an occupation in which the adverse effects that can result from shift work may have negative implications not only for the worker, but for the public as well.

WHO ARE THE WORKERS?

According to the NRC, there were 111 nuclear power reactors licensed for operation by the Commission in the United States in 1989. Five additional reactors are scheduled to be completed by 1995 (21). The NRC has estimated that there are 5,290 licensed control room operators in the United States, consisting of 1,969 licensed reactor operators and 3,321 senior reactor operators.

Nuclear power operator trainees come from three primary sources: 1) fossil fuel powerplant personnel; 2) U.S. Navy nuclear programs; and 3) interested young people, typically possessing a high school education, starting a career. Training for the novice is carried out by individual utility companies and consists of many months of classroom work on the necessary theories, skills, and knowledge required to operate a facility. This process may be partially waived for persons with equivalent training (e.g., former operators at another facility or persons trained in reactor operations by the Navy). Some experience credit is given to individuals who have worked at fossil fuel plants. Subsequent training consists of actual experience at various nonlicensed operator positions, which familiarizes the trainee with the equipment and control system characteristics. Operators also train on high-fidelity simulators.

The NRC licensing examiners conduct plant-specific oral, written, and simulator examinations of the trainees to ensure that candidates are prepared for, and capable of, performing the tasks of a nuclear reactor operator or of supervising the powerplant control room operations as a senior reactor operator. Continuing training throughout the operator's career is provided by the utility companies through their programs for maintaining and upgrading personnel skills. It takes up to 6 years to complete the training program. Individuals with previous related experience may require 3 years' training. Operators' licenses are renewed every 6 years through NRC testing.

WORKING HOURS AND OVERTIME

NRC Oversight

All nuclear powerplants must be licensed by the NRC. The licenses are legally binding and place numerous conditions on nuclear reactor design, construction, and operations. Part of the licensing process is the implementation of a plant's technical specifications, which describe all aspects of that plant's operations. Besides the licensing process, the NRC has authority to issue policy statements or promulgate regulations related to the operation of nuclear powerplants. NRC policy statements ''urge or strongly recommend" that a nuclear powerplant follow a given course (7). The NRC's policy statements are not enforceable per se, and a plant is not required to incorporate them into its technical specifications and administrative procedures. However, if a plant does incorporate NRC policy statements into its technical specifications or administrative procedures, the plant must follow that policy. The NRC may then issue notices of violations of the technical specifications (7).

Powerplants must comply with NRC regulations. In response to violations of regulations, the NRC may require a plant to change its administrative procedures, perform operations differently, enforce standard operating procedures, or change its design. In cases of repeated violations or failure to comply with NRC directives, the NRC may shut down a facility.

The NRC's resident inspectors are its primary means of monitoring compliance with regulations. These inspectors are assigned to all nuclear powerplants to ensure: 1) that the facility is being operated safely and in conformance with licensing and regulatory requirements, and 2) that the licensee's management is effectively discharging its responsibilities for continued safe operation (24).

Guidelines for the NRC and OSHA

Responsibility for safety and health at nuclear powerplants is divided between the Occupational Safety and Health Administration (OSHA), within the U.S. Department of Labor, and the NRC. OSHA has regulatory jurisdiction for health and safety matters in the workplace, including nuclear powerplants. The NRC, on the other hand, has regulatory oversight of the operations of all utilities licensed to operate by the Commission. In October 1988, in an effort to clarify and coordinate the roles of these two Federal agencies, OSHA and the NRC collaborated on a memorandum of understanding to provide general guidelines regarding worker protection at NRC-licensed facilities (53 FR 43950-43952). The memorandum specifically defines the roles and responsibilities of each agency for achieving worker safety and health at NRC-licensed plants. For example, OSHA investigates worker injuries at nuclear powerplants, as it does for other industries, while the NRC is responsible for regulating hours of work. This memorandum also provides general procedures for the coordination of activities and exchange of information between the two agencies.

The NRC and Shift Schedules

Currently, there are no NRC regulations specifically covering shift scheduling or working hours for nuclear powerplant operators; however, there are NRC policy statements regarding total working hours for operators. Shift schedules at nuclear powerplants are implemented by the plant management and are sometimes the result of management-labor negotiations. Control room operators can work several types of shift schedules. Many work an 8-hour-per-day shift schedule; however, more powerplants are switching to a 12-hour-per-day schedule (2).

The development of policies on work schedules for control room operators is relatively new. The NRC published its first policy on overtime and working hours in a letter in July 1980 (13). In November 1980, the NRC revised this policy to make it more flexible (14), and in 1982, additional revisions provided further clarification and established a formal policy statement, which was transmitted in Generic Letter 82-12 (15) and Generic Letter 82-16 (16) (47 FR 7353). The Generic Letters provide guidance on how to implement the policy statements on shift scheduling and working hours for nuclear powerplant control room operators. They consist of the following guidelines:

- An individual should not be permitted to work more than 16 consecutive hours (excluding shift turnover time).
- An individual should not be permitted to work more than 16 hours in any 24-hour period, more

than 24 hours in any 48-hour period, or more than 72 hours in any 7-day period (all excluding shift turnover time).
- A break of at least 8 hours should be allowed between work periods (including shift turnover time).
- The use of overtime should be considered on an individual basis, not for the entire staff on a shift.

In addition to these guidelines, the NRC urged that licensed operators be periodically relieved and assigned to duties away from the control board, in order to reduce fatigue during a shift (47 FR 7353). The NRC policy statement embodied in the Generic Letters indicates that all nuclear powerplants should establish controls to prevent situations in which fatigue could reduce the ability of control room operators to run the reactor safely. Thus, workers should not be assigned to shift duties while in a fatigued condition, because fatigue could significantly reduce their alertness and decisionmaking capabilities.

The NRC recommends that plants hire enough staff to work shift hours without continuous, burdensome use of overtime and that workers routinely work an 8-hour day and 40-hour week while the plant is in operation. The NRC policy statement also applies to situations in which the operations of the facility require overtime or the plant has been shut down for refueling, major maintenance, or major modifications. To date, approximately 77 of the 111 licensed nuclear powerplants have incorporated these policy statements into their technical specifications.

8-Hour-per-Day Shift Schedules

In 1985 the NRC contracted with a private laboratory to set up an expert panel to study NRC policy related to scheduling (17). The panel's recommendations for a routine 8-hour-per-day shift schedule consist of various suggestions designed to reduce excessive working hours, including:

- limiting the schedule to a maximum of 7 consecutive days of work,
- maintaining a schedule that does not exceed21 days of work (including training) in any 4-week period,
- ensuring that the schedule includes at least 2 consecutive full days off in any period of 9 consecutive days,
- ensuring at least 2 full days of rest following night shifts, and
- rotating the schedule forward, not backward.

To date, these recommendations are still under review by the NRC.

Features of 8-Hour Schedules

Most plants use rotating shifts to apportion the more desirable morning and afternoon shifts and the least favored night shifts equally among all staff members (5). However, there are other reasons for using a rotating shift system. First, locating people willing to work on a permanent night shift is often difficult; second, when seniority governs the choice of which shift is to be worked (as often occurs in permanent shift systems), the older, most experienced people usually opt for day work; and third, the precedent for rotating shifts was set at fossil fuel powerplants.

Control room operators typically rotate through three 8-hour shifts (5):

- a morning shift (usually 8 a.m. to 4 p.m.),
- an afternoon shift (usually 4 p.m. to midnight), and
- a night shift (usually midnight to 8 a.m.).

Continuous three-shift systems usually have four, five, or six crews of workers in order to have workers on duty over weekends and still provide rest periods. Most nuclear powerplants operate with six crews. The Institute of Nuclear Power Operations conducted a survey in 1989 on the number of operating crews commonly used. Of the 75 plants surveyed, 50 reported that they were using six crews. The remaining 25 plants operated with five crews, but two of these indicated that they were preparing to change to a six-crew operations system (4).

As described in chapters 4 and 5, 8-hour shift schedules can vary in their direction and speed of rotation. As in other work settings, many types of schedules are used at nuclear powerplants, although weekly rotating schedules are typical. Figure 7-1 is one example of an 8-hour shift schedule.

12-Hour-per-Day Shift Schedules

Within the last few years, 12-hour work schedules have become more popular in nuclear powerplants. Twenty-three plants now operate under 12-hour schedules (25). If a plant has incorporated its shift schedules into its technical specifications and ad-

Figure 7-l—Example of an 8-Hour-per-Day Work Schedule Used in the Nuclear Power Industry

Day of the week	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S
Crew A	D	D	D	D	D	-	-	-	-	A	A	A	A	A	A	A	-	-	T	D	D	T	T	T	-	N	N	N	N	N	N	N	-	-	-
Crew B	N	N	N	N	-	-	-	D	D	D	D	D	-	-	-	-	A	A	A	A	A	A	A	-	-	T	D	D	T	T	T	-	N	N	N
Crew C	T	T	T	-	N	N	N	N	N	N	N	-	-	-	D	D	D	D	D	-	-	-	-	A	A	A	A	A	A	A	-	-	T	D	D
Crew D	A	A	-	-	T	D	D	T	T	T	-	N	N	N	N	N	N	N	-	-	-	D	D	D	D	D	-	-	-	-	A	A	A	A	A
Crew E	-	-	A	A	A	A	A	A	A	-	-	T	D	D	T	T	T	-	N	N	N	N	N	N	N	-	-	-	D	D	D	D	D	-	-

The world training schedule for five crews (A, B,C,D,E) over a 5-week period is illustrated.
KEY: D= day shift; A= afternoon shift; N= night shift; T= training; — = day off.

SOURCE: U.S. Nuclear Regulatory Commission, *NUREG/CR-4248,* Recommendations *for NRC Policy on Shift Scheduling and Overtime at Nuclear Power Plants* (Richland, WA: Pacific Northwest Laboratory, 1985).

ministrative procedures, it must frost get NRC approval before implementing a 12-hour schedule; if it has not, NRC notification is not required. Currently there is no NRC guidance regarding the implementation of 12-hour schedules. The expert panel on scheduling, described earlier, also developed the following guidelines for 12-hour work schedules (17):

- Adoption of a routine 12-hour-per-day schedule must be authorized by the NRC.
- The schedule should contain a maximum of 4 consecutive 12-hour workdays.
- Four consecutive 12-hour workdays should be followed by no fewer than 4 days off.
- The basic 12-hour-per-day schedule could be one of several types: 2 days on, 2 days off; 3 days on, 3 days off; 4 days on, 4 days off. Another possible schedule would be the every-other-weekend-off schedule, which combines 2 days on, 2 days off with 3 days on, 3 days off.
- The general safety record of the plant should be satisfactory, based on criteria such as those used in NRC's Systematic Assessment of Licensee Performance ratings.
- The plant should have the capability to cover unexpected absences satisfactorily without requiring any individual to work more than 12 hours per day.
- The round trip commute times for the operators should not exceed 2 1/2 hours.

Features of 12-Hour Schedules

A number of 12-hour work schedules are in use at present. An advantage of these schedules is that the worker has more nonworking days during the week, thus allowing more time for rest and leisure. A potential drawback is that the 4 additional hours per shift may produce fatigue and decrements in alertness (2,9-1 1).

Typically there are three types of 12-hour shift schedules (8,12):

1. every other weekend off (EOWEO);
2.3 days on, 3 days off rotating schedule; and
3.4 days on, **4** days off rotating schedule.

Figure 7-2—Example of an Every-other-Weekend-Off 12-Hour Shift Schedule Used in the Nuclear Power Industry

Day of the week	**S**	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Nights	A	B	B	D	D	c	c	c	A	A	B	B	D	D	D	c	c	A	A	B	B	B	D	D	c	c	A	A
Days	D	c	c	A	A	B	B	B	D	D	c	c	A	A	A	B	B	D	D	c	c	c	A	A	B	B	D	D
off	B	A	A	B	B	A	A	A	B	B	A	A	B	B	B	A	A	B	B	A	A	A	B	B	A	A	B	B
off	c	D	D	c	c	D	D	D	c	c	D	D	c	c	c	D	D	c	c	D	D	D	c	c	D	D	c	c

The work schedule for four crews (A, B,C,D) over a 4-week period. For example, during week 1, crew A works Sunday night, has Monday and Tuesday off, works days Wednesday and Thursday, and then Friday and Saturday has off.

SOURCE: H.R. Northrup, J.T. Wilson, and K.M. Rose, "The Twelve-Hour Shift in the Petroleum and Chemical Industries," *Industrial and Labor Relations* Review 32:312-316, 1979.

Figure 7-3—Example of a 4-Days-On, 4-Days-Off Rotating Schedule Used in the Nuclear Power Industry

Day of the week	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Day	D	D	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	A	A	A	A	B	B	B	B	C	C
Night	B	B	C	C	C	C	D	D	D	D	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	A	A

Day of the week		M		W					M		W					M		W					M		W			
Day											B	B	B	B													B	B
Night			B	B	B	B													B	B	B	B						

Day of the week	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Day	B	B	C	C	C	C	D	D	D	D	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	A	A
Night	D	D	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	A	A	A	A	B	B	B	B	C	C

Day of the week	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Day	A	A	B	B	B	B	C	C	C	C	D	D	D	D	A	A	A	A	B	B	B	B	C	C	C	C	D	D
Night	C	C	D	D	D	D	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	A	A	A	A	B	B

The work schedule for four crews (A, B,C,D) over a 16-week period. For example, crew A works the day shift on 4 consecutive days during week 1, has 4 days off, then works the night shift for 4 consecutive days before having another 4 days off.

SOURCE: H.R. Northrup, J.T. Wilson. and K.M. Rose, "The Twelve-Hour Shift in the Petroleum and Chemical Industries," ***Industrial and Labor Relations*** **Review 32:3i2-316, 1979.**

Figure 7-2 is an example of an EOWEO schedule, and figure 7-3 is an example of a 4 days on, 4 days off rotating schedule, both of which are commonly used for control room operators.

Overtime

Nuclear powerplants have used a variety of overtime schedules for operators. The NRC recommends, but does not require, that plants have an overtime policy. In 1988, 76 plants had a specific overtime policy written in their technical specifications; 32 plants did not (6). As described earlier, the 1982 Generic Letters provide guidance regarding the maximum number of hours of work for 24-hour, 48-hour, and 7-day periods. The expert panel on scheduling developed further guidelines for overtime scheduling (7), which include:

- The approval of the plant manager should be required before individuals are allowed to exceed the following limits: 60 hours of work in 7 days, 112 hours of work in 14 days, 192 hours of work in 28 days, and 2,260 hours of work in 1 year.
- NRC approval should be required before individuals are allowed to exceed the following limits: 72 hours of work in 7 days, 132 hours of work in 14 days, 228 hours of work in 28 days, and 2,300 hours of work in 1 year.

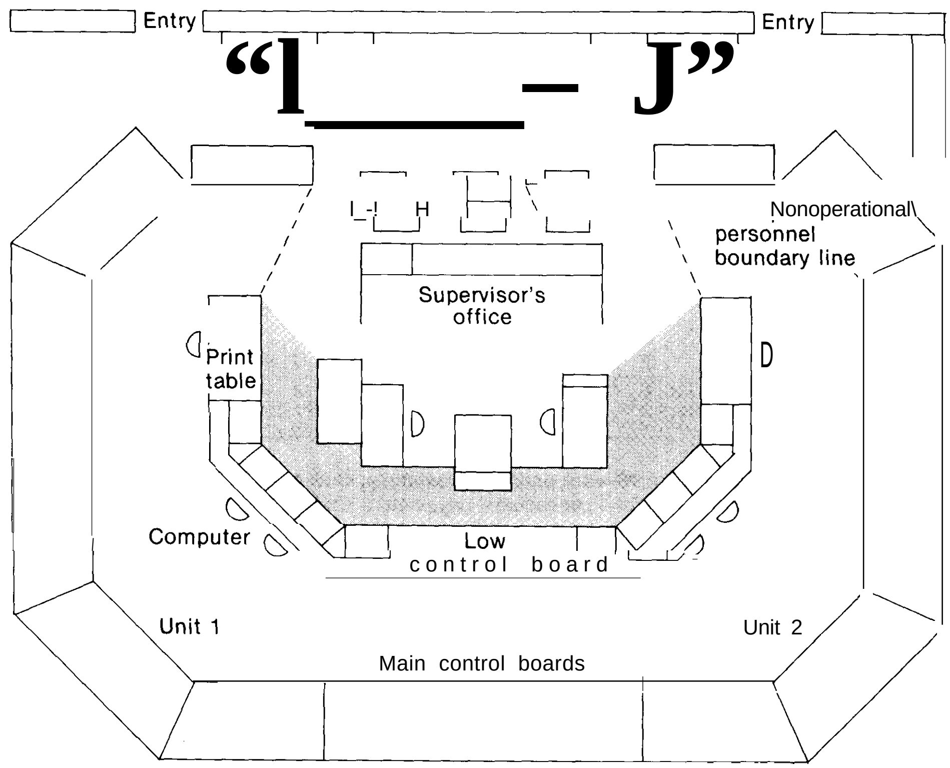
As with the panel's recommendations on 8- and 12-hour schedules, its recommendations on overtime are still under review by the NRC.

Overtime is necessary in outage situations, when every day off-line (not functioning) will result in lost revenues for the utility company. Employees often work 12-hour days in these situations. Overtime also increases when there are staff shortages, typically when someone fails to come to work. In such cases, workers may be required to work double shifts (if they are 8-hour shifts) or split the second shift with another worker. This type of shift activity may have negative effects on the worker, leading to performance decrements and interpersonal problems (l). Currently, there are few effective techniques for minimizing the physiological, psychological, and performance effects of overtime (see ch. 5).

THE JOB OF THE CONTROL ROOM OPERATOR

This section describes the work environment in the control room, the typical tasks for a control room operator, and the effects environmental and physiological factors can have on the performance of these tasks.

Figure 7-4-Example of a Control Room Configuration Used in a Nuclear Power Utility



SOURCE: Electric Power Research Institute, *Human Engineering Guide for Enhancing Nuclear Control Rooms,* Rep. No. NP-2411-project 501-4 (Palo Alto, CA: Electric Power Research Institute, 1982).

Control Room, Operator Tasks, Performance, and Fatigue

The nuclear powerplant control room consists of a panel board that operates each unit (i.e., the reactor containment building and associated systems). In facilities that have two reactors, there will be two control boards, which can be located either in the same or in separate control rooms. Figure 7-4 illustrates a typical control board configuration that is used in a nuclear utility.

The control board is made up of many switches, indicators, computer display systems, and alarm panels, each performing different functions. The two categories of personnel authorized to operate control units, reactor operators and senior reactor operators, are licensed by the NRC. Reactor operators are required to be alert and responsive at all times during the shifts. Their duties typically include monitoring the information displayed on the control board and overseeing the operations of all of the components of the control unit. They are required to execute a variety of monitoring tasks that require low-level, sustained vigilance but no physical activity. Thus, performing such tasks may result in sleepiness or fatigue, or both. Reactor operators' duties also include responding to a variety of alarms indicating that adjustments need to be made. If an emergency arises, they must be able to assess the situation and select appropriate procedures to mitigate it.

Senior reactor operators are responsible for overseeing the activities of the reactor operators in the control room. They are supervisors and have administrative, work control, and other company-related tasks. In addition, they must be ready at all times to back up the reactor operator.

Studies of tasks that require high levels of alertness and attentiveness have repeatedly found that human error increases after about half an hour of continuous vigilance (2). Since working on the same task and not moving around for along period of time can cause fatigue, experts suggest that managers should attempt to vary operators' work tasks every 2 hours (2). Reactor operators are sometimes required to perform additional tasks outside of the control room, such as noting water level temperatures, checking the operations of radiation monitors, and performing general tasks for generator, turbine, and reactor upkeep. The more active nature of these duties can reduce fatigue. Experts have also suggested several other strategies to minimize sleepiness and fatigue (2). These include interventions that can be initiated by the operator:

- taking short walks during periods of low alertness,
- spending time each hour standing up and walking,
- avoiding getting too comfortable, and
- interacting with colleagues on the shift to help stay alert;

and interventions that would have to be implemented by management:

- scheduling tasks that involve physical activity on night shifts;
- allowing operators to take scheduled breaks away from the control panel;
- balancing the workload across shifts and days of the week to eliminate long periods of intense activity and stress;
- redesigning job responsibilities to maximize completeness, variety, and feedback in an effort to make jobs more interesting;
- not allowing individuals to work beyond their scheduled shift or to monitor the control board for over 2 hours without some relief (during the night shifts); and
- scheduling the shift workload so that difficult mental tasks are not required during periods of predictably low alertness.

Effects of Environmental and Physiological Factors on Vigilance

Several other factors can influence the vigilance of nuclear powerplant control room operators. These include lighting in the control room, ambient noise from the control panels and other machinery, ambient temperature, humidity, and ventilation, and the design of the work station. Each of these in some way or another can affect an operator's ability to carry out the job. Improper design of these variables can lead to fatigue, sleepiness, reduced attention span, and changes in mood that can result in errors in performance (2).

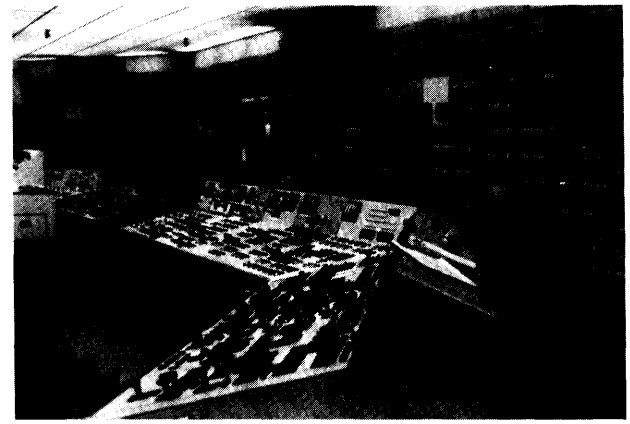


Photo credit: *David Liskowsky*

Control board at a nuclear powerplant.

While there is a substantial body of literature on the effects these factors can have on performance, there is little information available on the interaction of such effects with shift work schedules or the application of that information to the nuclear powerplant environment. Such research could greatly benefit the operators of nuclear powerplants.

MONITORING OPERATORS FOR PERFORMANCE CAPABILITIES

The primary responsibility for monitoring employees on the job rests with the management of the utility that operates the powerplant. The NRC's role is to ensure that the management control system at a plant is carrying out its responsibilities. One task of NRC resident inspectors is to monitor control room activities, including observation of control room personnel (24). In addition, the inspectors are required to spend approximately 10 percent of their time conducting unannounced control room inspections on the night shift. If an inspector observes that individuals are not performing their duties adequately, he or she notifies the appropriate supervisor.

Beyond the supervision provided by the utility management and the observational oversight of the NRC resident inspectors, there are no specific guidelines or regulations set forth by the NRC for monitoring control room operators for possible performance deficiencies related to sleepiness, fatigue, or disruption of biological rhythms. The NRC's Policy on Conduct of Nuclear Powerplant Operators (54 FR 1489-1498) and Regulatory Guide 1.114 (20) both state the Commission's expectation that operators be alert; moreover, since the Three Mile Island and Peach Bottom incidents, there has been a greater awareness among plant operators of the need to monitor control room operators. As a result, some plants have voluntarily carried out more comprehensive monitoring programs.

The purpose of such monitoring programs is to ensure that operators are capable of carrying out their duties on a routine basis. These programs use test batteries that are sensitive to decrements in performance caused by fatigue or disrupted biological rhythms. There is no one test battery capable of adequately measuring decrements in performance specifically for the control room operator. However, many general test batteries that are available assess deficiencies in performance, and these maybe used for control room operators (see ch. 5).

It is not known how frequently voluntary monitoring programs are being carried out at nuclear powerplants. However, when monitoring occurs, it is usually a result of one of two circumstances: either a plant's management has noticed problems in control room operators' work practices and has requested a private testing organization to come to the facility and monitor the operators to help determine the nature of the problem, or a testing organization may approach the management of a nuclear powerplant and ask if it can run a series of tests on the workers to measure performance deficiencies and fatigue using its test battery. The latter affords the testing organization an opportunity to field test and market its test battery.

As previously mentioned, no NRC guidance exists regarding the use of formal testing procedures to monitor control room operators. In response to concerns about decreased performance due to substance abuse, however, the NRC has instituted regulations regarding a fitness-for-duty program for nuclear powerplant operators (54 FR 24468-24508). The fitness-for-duty program is intended to ensure that "all operators and plant personnel are reliable, trustworthy, and not under the influence of any substance (legal or illegal), or mentally or physically impaired from any cause, that would affect their ability to safely and competently perform their duties in any manner" (54 FR 24468-24508) (19, 22,23). Currently, the program is designed only to detect individuals using legal or illegal substances, not to determine decrements in performance caused by sleepiness, fatigue, or circadian desynchronization. However, if deemed necessary or desirable, this program represents an existing mechanism that could be modified to include monitoring for decrements in performance due to the effects of shift work.

SUMMARY AND CONCLUSIONS

NRC guidance related to overtime and shift length for nuclear powerplant control room operators is provided in Generic Letters 82-12 (15) and 82-16 (16); currently the Commission provides no guidance or policy regarding the design of work schedules. Recommendations have been made by a panel convened by a private laboratory under contract to the NRC, but no action has been taken on them to date and they remain under consideration by the NRC. Many nuclear powerplants use an 8-hour-per-day shift schedule; however, the trend is toward a 12-hour-per-day schedule.

Control room operators are responsible for the safe operation of the nuclear utility. Their duties involve engaging in continuous monitoring of all indicators on the control board and responding to numerous alarms. This generally does not require a great deal of physical movement. Furthermore, operators must be ready to respond to any emergency situation that may arise. This requires operators to be alert and attentive at all times while on duty.

Since working on the same tasks and remaining stationary for along period of time can cause fatigue, experts suggest that managers who design work assignments attempt to vary operators' tasks every 2 hours. Experts have also recommended several strategies to reduce fatigue and sleepiness, since remaining awake late at night is often difficult. These may include allowing operators to take scheduled breaks away from the control panel and balancing the workload across shifts to eliminate continuous periods of stress.

Operators are sometimes required to work two consecutive 8-hour shifts, depending on the circumstances, or, especially in an outage situation, they may be required to work additional overtime. Such activities may have negative effects on the workers, leading to decrements in their performance.

In addition to shift work, several factors related to the environment and design of the control room can influence the vigilance of operators. Improper design of these factors can lead to fatigue, sleepiness, and reduced attention span, which could result in errors in performance. Research on the interaction of these factors with shift work effects in the nuclear powerplant control room environment could provide useful information to aid in plant operations.

Although the problems of fatigue and decreased performance capability in connection with shift work cannot be entirely eliminated, several steps can be taken to deal with them. One researcher (3) has suggested several possibilities, including:

> . . . make stricter regulations regarding shift work scheduling; designing schedules to meet the health and safety needs of the plant and its workers; improve the design and lighting of the control room; improving incident reporting systems and incident analysis to ensure that proper remedies are applied regarding the problems associated with 24-hour operations; and continued research and further studies to gain more knowledge and understanding of the impacts from circadian disruption due to shift work on the safety and health of nuclear powerplant control room operators.

One of the duties of the NRC's resident inspectors is to oversee the supervision of operators by the utility. Currently, there is no NRC guidance or policy regarding the monitoring of control room operators for specific performance deficiencies related to fatigue or disruptions of biological rhythms. In some cases, powerplants voluntarily institute a monitoring program using standardized test batteries administered by outside organizations, although it is unclear how frequently this occurs. The NRC's fitness-for-duty program is designed to detect workers who are using legal or illegal substances, not to determine decrements in performance due to decreased attention span and alertness that could be associated with work schedules. The NRC could require that the fitness-for-duty program be restructured to include measures of performance deficiencies resulting from shift work.

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