

Aamodt, March 10, 1981

United States of America
Nuclear Regulatory Commission
Before the Atomic Safety and Licensing Board

In the Matter of Metropolitan Edison Company, et. al.
(Three Mile Island Nuclear Plant, Unai
Docket No. 50-289)

RELATED CORRESPONDENCE



Intervenor Response to Board
Request for Evidence that Consideration
of Control Room Operator Fatigue is Appropriate

In response to an order of the Board (Tr /2925)
to provide evidence that consideration of the fatigue of control room
operators should be considered within

1. the Commission Orders of August 9, 1979 and March 6, 1980,
- 2.. the TMI-2 accident,
3. Aamodt Contention 2, and
4. in relationship to performance in the Unit 1 Control Room

the following arguments are presented:

1. Containment within Commission Orders

The Commission Order (August 9, 1979) specifically
states (Section II, 1 (e)) that the Licensee shall

Augument the retraining of all Reactor
Operators and Senior Reactor Operators
assigned to the control room including
training in the areas of natural cir-
culation and small break loss of coolant
accidents including revised procedures
and the TMI-2 accident. All operators
will also receive training at the B&W
simulator on the TMI-2 accident and the
licensee will conduct a 100 percent

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reexamination of all operators in these areas. NRC will administer complete examinations to all licensed personnel in accordance with 10 CFR 55.20-23.

(Requirement A)

and the Licensee shall (p. 7, Item 6.)

...demonstrate his managerial capability and resources to operate Unit 1... Issues to be addressed include ... technical capability and training of operations staff...,

(Requirement B)

and in the Commission Order, March 6, 1980, that the Licensee

shall demonstrate whether its

management is sufficiently staffed, has sufficient resources and is appropriately organized to operate Unit 1 safely.

(Requirement C)

(Requirement designations have been added for the sake of discussion.)

Requirement C is clearly dependent on Requirements A and B.

Since

- (a). Requirements A and B have been met by only 12 candidates following completion of the Operators Accelerated Retraining Program and reviews of portions of that program, *(Attach. 1)*
- (b). Letter (Paul F. Collins to H. D. Hukill) assumed on 11/12/81 that 38 candidates would be ready to stand licensing as a function of OARP training,
- (c). Letter (Robert W. Reid to R. C. Arnold) assumed on 11/20/81 that that number (38) of licensed operators would be only marginally sufficient to meet staffing requirements,
- (d). The number of recruits available throughout the industry is scarce (Tr. 12,062),

in order to meet Requirement C, the hours that would be worked by those who have met Requirements A and B (to stand licensing) would

be increased. (The alternative of licensing operators at standards below those considered appropriate in light of the TMI-2 accident, although alluded to (Tr. 12,062 and 12,063), would not be in the interest of health and safety of the public.) How this increase in working hours would alter the competence of the licensed operators on Requirements A and B should be assessed. The Commission Order, August 9, 1979, provides consideration of "sufficiency" of short term requirements on page 12:

- The subjects to be considered at the hearing shall include:
 - (1) Whether the "short term actions" recommended ... are...sufficient to provide reasonable assurance...

This part of the order blankets situations overlooked that threaten reasonable assurance. The increase ^{working} in/hours of control room personnel would cause a serious insufficiency in an area of central concern to the Commission.

The March 6 Order carries this further on page 4:

The Board should apply its own judgment in developing the record and forming its conclusions on these questions.

It is in this area of judgment that decrement of performance/in areas that the Commission has requested augmentation through training, due to fatigue can and should be considered.

In that same Order on page 3, the Commission calls the attention of the Board to identification of errors (Item 9). This should include some attempt to identify those associated with fatigue (and other stressors, as change in shift schedule). Training is clearly related to reducing errors, however the extent to which fatigue overcomes its positive effects should be identified. Scheduling should be arranged to effect a "real" augmentation in Requirements A and B of the August 9 Order as measured in the final test, job performance. .

2. Nexus to the TMI-2 Accident

The Essex Report¹ contains an entire page of fatigue effects (page 23) and their contribution to the accident. It is unfortunate that the Essex Corporation was unacquainted with psychological research and findings although a number of their member held degrees of some sort in psychology. ^{Their insufficiency} ~~This~~ is apparent from the inferences drawn from their observations.

Referring to page 23, Essex discusses several operator errors during the accident as caused by "set" (para. 12). Set is clearly a symptom of fatigue. For instance, NRC documents² refer to studies³ of set:

fatigue results in personnel ignoring some signals because they develop their own subjective standards as to what is important.

Essex overlooks this well-established principle and faults training, ^{totally.}
The operators were using their training -- their on-the-job training -- what had happened in their recent past. (That was considered bad!) The bad part was that they were set on a single, most easily recalled path, ignoring or not looking for other signals -- a sign of fatigue.

Essex goes on (p. 23-24) to infer that set prevented

several decisions, including the determination that the PORV was open

because these decisions were reached by personnel who were fresh to problem. Training not subject to fatigue?

Further Essex refers (p. 24 ¶ 2) to the inadequate reasoning and problem solving at the time of the accident, while indicating that the operators lacked no ability (the shift supervisor on duty during the accident had demonstrated this ability to the highest extent of any and all operators at TMI on recent requalification examinations.) Surely this kind of ability should have overcome

set that was due to training, however, apparently not, ^{that due to} fatigue.

Further, Essex studies^{3a} (Appendix B) the accident in time frames, but fails to find any significance in the time of the accident. The specific time of the TMI-2 accident -- five hours into the backshift -- has been documented as the "lowest" in terms of probability of correct response.^{4,5} 4- 5-p 519 #3, p577 #2

It seems incredulous that Essex Corp., with supposed expertise in the area of human behavior could have introduced their discussion of these (above) observations by dismissing any influence of fatigue -- or that Mr. Blake, counsel for the Licensee, could have referred to this page (Tr./2920) as evidence to the contrary, particularly with the advise of two eminent psychologists as parties in their case. Their inference relative to fatigue was based

on reviewing the transcripts of several interviews conducted with control room operators.

Surely analysis of working hours would have provided a more scientific case.. (Perhaps the oversight of studies of psychological factors of scheduling and the relationship to operator performance is not unusual, in view of the outstanding and prolonged oversight of nuclear engineers of human engineering principles in control room design.)

Following the accident, several NRC documents have dealt with the aspects of fatigue. Perhaps the Inspection and Enforcement branch knows something -- or has "an educated hunch" -- about the work schedule at TMI-2. One document⁶ stated that

excessive work hours can affect the ability of operators to recognize and cope with conditions requiring attention. NRC currently has no limits on the hours a worker can work. There is currently no requirement to assess the capability of the worker to perform the complex function of operating a nuclear power plant. (emphasis added)

Capability is taken here to mean those abilities, training and knowledge available as a result of hours worked. The obvious

omission of study of fatigue is recognized.

An earlier document from I&E ⁷ comes the closest to an analysis. Review of available records of past reactor trip events revealed that seven of ten reviewed incidents occurred within an hour and one half before or after a shift change. This is a significant indication of time effects on operator performance. (The errors made at the beginning of the shift should be studied for evidence of shift rotation effects.) (p. 1-4-33)
#4

It has been observed that operators can operate a nuclear plant from a poorly designed control room. That is essentially what Dr. Christensen testified to (January 15) regarding the TMI-1 control room. The training makes up for the deficiencies. When errors happen in such a situation, since training is in place, something inhibits training -- for instance, fatigue, distraction.⁸ The inhibition due to fatigue would be greater in proportion to the complexity of the task and the adequacy of the training. The arrangement of the TMI-2 control room was surely complex and therefore contributed to the negative effects on training. Additionally the control room itself was fatiguer with barely discernable signals, glare, the need to stand almost constantly, dispersed parameters and noise.⁹ The poorly designed control room contributed to the accident through the effects of fatigue -- it physically fatigued, and its complexity enhanced fatigue effects on training. (C. 177P3)

Corrective actions coming out of TMI-2 accident have included suggestive regulations and regulations relative to working hours. IE Circular No. 80--2 (February 1, 1980) expressed concern for overtime work for members of the plant staff who perform safety-related functions. Shift manning in relation to hours worked is discussed and regulated in other documents emanating out of the accident: Nureg 0694,* 0737. On page 3-6 and 7 of Nureg 0737 it states:

The staff recognizes that there are diverse opinions on the amount of overtime that would be considered permissible and that there is a lack of hard data on the effects of overtime beyond the generally recognized normal 8 hour working day, the effects of shift rotation, and other factors. NRC has initiated studies in this area.

* TMI-Related Requirements for New Operating Licenses, p. 39 of NUREG 0680

Evidence of work weeks of 60 to 90 hours for maintenance workers at TMI-1 were obtained by an intervenor in this hearing. It is reasonable to assume that control room operators worked similar schedules. It appears that the Office of Inspection and Enforcement of NRC should be questioned about their interest in work schedules, post TMI-2 accident, and possible relationship to the accident probed. The control room operators had no 'lunch' break and no planned pauses, which have been clearly demonstrated in numerous studies as needed to offset extremely deleterious effects of fatigue after a few hours.¹⁰ (p 261-292)

Lack of specific reference to fatigue is missing in other studies, perhaps because no psychologists were included on their panels, specifically Kemeney and Rogovin.

3. Relationship to Aamodt Contention 2

In order to design a training program, the performance that is required on the job must be clearly defined. Job performance is clearly the objective and the final test.

For instance, from the procedures that were needed during the first 150 minutes of the accident, the tasks required were defined and analyzed into specific skills and knowledges that are needed.

One skill needed was Perceptual Skill: p. 84

Identifying a display or control
Reading a display
Understanding a display

This skill was then translated into Training Objectives. p. 85, 86

(P. 85,86)

Recognize loss of main feedwater flow to both OTSGs

Determine that an RCP has tripped automatically
 Verify header pressure at 885 Psi
 Recognize a turbine trip

This is what is commonly called monitoring. In designing a program to teach monitoring skills, it is helpful to know that monitoring is particularly susceptible to fatigue.^{11, p. 429 #2#2} Man is rather weak in long-term monitoring activities, such as watch-keeping or radar observation. His performance is not very reliable over long periods of time. Therefore, in training techniques will need to be devised to achieve the required degree of proficiency over the time period covered. (It is interesting to note that the Essex Corp. designates a 100% level of performance in meeting training objectives.) Achieving training goals must certainly take hours on the job and other fatiguing effects into consideration. So must testing if it is to predict job performance.

Regarding the relationship of fatigue to the teaching of knowledge required, Essex¹ admits the effect of training on set (an effect of fatigue), in their discussion (p. 23). Essentially they are saying that overtraining for a wide variety of situations will withstand the effects of fatigue that tends to narrow the field of perception. It has been demonstrated that overlearning overcomes time effects^{12, p. 245} to some extent.

Clearly Aamodt Contention 2 is concerned with job performance as stated:

It is contended that TMI-1 should not open until the performance of licensee technicians and management can be demonstrated to be upgraded as certified by an independent engineering firm. This upgrading should include 100% test performance of job description with provision for retraining and retest, or discharge of those who cannot consistently and confidently master all necessary information for safe conduct of their job description under all anticipated critical situations as well as routine situations.

The Commission's Order and my contention No. 2 share the same concern:

Commission: assuring safe operation of the plant through better job performance by control room operators, and management

Contention 2: assuring health and safety of public through upgraded job performance of control room operators, others and management

Standards of Commission's Concern:

Section II, 1 (e) of the August 9 Order
Item 6, p. 7 of the same order
Item 1 and Item 2 of the March 6 Order

Standards of Contention 2's Concern:

Certified by independent engineering firm
100% test performance of job description
Retraining and retest to 100% or discharge
Trained to all information necessary
Consideration of competence under all critical conditions
Consideration of competence under all routine situations

Commission's concern about capability of management speaks to scheduling, hours worked, overtime, use of human resources, training and testing as it affects job performance.

Commission's concern about training and testing relates to how it is relevant to job performance which would include all the modifiers of that performance including fatigue -- or hours on the job, overtime and shift rotation schedules.

Commission is depending on NRC licensing, Licensee's tests, NRC regulation of scheduling, and Board's recommendations.

Intervenor has found through discovery that not a single concern expressed in her contention has been satisfied through this hearing:

The so-called independent assessment by experts was far from that. Job descriptions have essentially not been written.

Retraining and retest is to a lower standard; discharge does not occur.

Noone knows all the information necessary.

There is no way to test competence under critical conditions..

There is no way to test competence under all routine conditions.

One of the most routine conditions, fatigue, and how it affects performance has not even been considered in this hearing.

Intervenor is being artificially restricted to look simply at a training and testing program and to evaluate that program.

The program and the testing, as well as the results, are an extreme disappoint. In view of what was revealed in cross-questioning there is no assurance that the operators are better prepared.

Intervenor therefore wants to examine how lessening fatigue can optimize what training there has been. Changes in the training program appear far down the road.

While training can offset some of the effects of fatigue, it is not possible to train away all effects. Fatigue is powerful as evidenced by findings from research, attached. There^{we} we asked and The Board Reply, dated May 8, 1980 compelled the Licensee to answer Interrogatories on length of shifts at TMI-2 and TMI-1. Licensee offered intervenor the opportunity to obtain these data from their files in Reading. Intervenor discovered that this was a task that could take days as was the experience of another intervenor seeking work schedules of maintenance workers. At the August prehearing conference, this problem was raised, but no solution was forthcoming. The Board appeared interested in seeing such data, but offered no help in lessening the burden.

The Commission Order of August 9 is specifically interested in job performance as the objective of adequacy of augmented training and testing, page 2:

...in order to provide reasonable assurance that the facility can be operated safely over the long term."

It can also be the final test of adequacy if evaluations of sufficiency do not take into account the identified modifiers of training and testing. Fatigue has been clearly identified. *

Assumptions that performance in the control room is not effected by fatigue is clearly contrary to established findings in other related fields. Since fatigue is controllable (contrary to stress) through appropriate scheduling, to train to overcome it, which appears far-fetched in view of tests given TMI-1 personnel, would seem to be ignoring an important management issue.

The area of fatigue has gone unaddressed in this hearing, and the need for study is recognized. Tr. 14432 1. 18-25.7 & 12426, 12432
*Other well-identified modifiers are stress and attitude. These are also "operational" in occurrence, however the Licensee made no objection during cross-questioning, a n indication of inconsistency that serves Licensee's own purposes rather than the public's.

To divide training from operational considerations as per the NRC departments is artificial. When the Review Committee of Metropolitan Edison assessed the retraining program, there were many discussions of the interconnection of human engineering of the control room and training. There was an entire chapter, written by Dr. Christensen, and included on the the control room. Dr. Christensen, the human factors engineer, was a part of the training program review committee.† The division is not between human engineering and training, or between operations and training; rather the natural division is between man and machine. Each is a machine. We are aware of ways to make the machine's safety systems redundant; that same thinking should be applied to man. That would bring the industry thinking to a 20th century level. Man is a machine with redundant systems: training, knowledge, readiness as evidenced by lack of fatigue, alertness as evidenced by attitudes and lack of fatigue.

All the environmental stressors that affect the man should be considered together as they interplay in making the man an adequate machine to interface with the nuclear machine. Can maintenance of the machine be considered aside from the number of hours a piece of equipment has been in service?

The Board has recognized all the elements of the contention in stating that human factors consideration should have been given this intervenor's attention, "when you take into account that it was almost half of your Contention." Ar 12,431, 1. 7,8 however that division appears incorrect, since the litigation of human factors was solely concerned with changes that should be made to the control room -- on the machine side of the man-machine interface.

4. Relationship of Fatigue to Performance

1. Most experiments on vigilance reveal man as a poor monitor by demonstrating decrement in response proficiency as observation time becomes longer.

"Monitoring of Complex Visual Displays - II. Effects of Visual Load and Response Complexity on Human Vigilance," Human Factors, Vol. 3 (1961) pp. 213-221. Jack A. Adams, Herbert H. Stenson and John M. Humes

2. Fatigue tends to affect high-grade performance long before there are signs of physiological exhaustion. The more complex the performance, the more delicate the discriminations, the greater the number of sources of information which have to be attended to, the more likely the performance is to suffer from fatigue.

Effective human engineering, in facilitating the provision of information about the effects of action through various forms of feedback, can do much to reduce impairment of performance as the result of fatigue.

Fatigue appears most clearly in complex performance where knowledge of results is reduced or minimal.

The above quoted from Occupational Psychology, Vol. 32, No. 4, (Oct., 1958)

3. In certain types of monitoring tasks, performance decrement occurs if rest pauses are not allowed after work periods of 30 minutes. B. O. Bergum and D. J. Lehr, "Vigilance Performance as a Function of Interpolated Rest," Journal of Applied Psychology, Vol. 46 (1962), pp. 425-427.

4.. Shift rotation imposes a physiological hardship on all the workers every time the shifts are changed and may lead to a general decrease in efficiency. Some can adapt to a six-hour change in about a week; others find the adaptation very difficult.

Kleitman, Sleep and Wakefulness, p. 267

5. Companies now using rotating shift should review their scheduling problem to determine whether fixed shifts can be substituted. If rotating shifts prove unavoidable, changes should be made infrequently.

A company with a four-shift cycle could cut the graveyard shift down to five hours by simply adding 20 minutes to each of the other three shifts.

H. P. Northrup, Shift Problems and Practices (Studies in Personnel Policy, No. 118 (New York: National Industrial Conference Board, Inc.)

6. In Sweden, researchers found many instances of failure to adjust to changing shifts. The shift workers were being forced to live in different time sequency from that of their community and of the many people to whom they were intimately related. In a study of errors made in entering figures in the ledgers of a large Swedish gas works under a rotating three-shift system, it was found that a very high number of errors occurred around 3 a. m., five hours into the shift. Errors did not vary either by season or by day of the week. Same variation appeared on the last night of the week as the first, indicating that the weekly rotation system was not allowing workers enough time to change the general pattern of their diurnal rhythm.

A. Pierach, "Biological Rhythm-Effects of Night Work and Shift Changes on the Health of Workers," Acta Medica Scandanavica (Suppl. 307), Vol. CLII.

7. Boredom is psychological fatigue. The greater the change during the rest breaks or lunch hour, the less disruptive will be the effects of boredom. (Another method of counteracting boredom is by teaching the workers the value and meaning of their own job -- attitude)

Duane P. Schultz, Psychology and Industry Today, 1973, MacMillan

Many more references could be cited, however the conclusions are quite consistent.

My research at Brown University was done in the area of fatigue; Resistance to Extinction as a Function of Effortfulness of Task During Acquisition and Extinction, May 1951

References

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- 2
2. A. D. Swain - 1223, Scandia Labs, 8/31/77 Working Paper, Revised 1/20/78, Effects of Hours on Job on Visual Detection and Decision-Making with Implications for Nuclear Power Plant Personnel
3. McFarland, R. A., Understanding Fatigue in Modern Life, Ergonomics, 1971
- 3a. Nureg/CR-1270, Vol. II, Human Factors Evaluation, etc.
4. Kenneth N. Wexley, Gary A. Yukl, Organizational Behavior and Industrial Psychology, 1975, Oxford,
5. Fleishman, Edwin A., Studies in Personnel and Industrial Psychology, 1967, Dorsey, Fatigue, Monotony and Working Conditions
- 6.
7. Nureg O600, Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement, Investigative Report No. 50-320/79-10, August, 1979
8. Hull
9. A Review of the Three Mile Island Unit 1 Control Room From A Human Factors Viewpoint, December 1980, Review Team: GPU, MPR, Dr. J. Christensen, Dr. T. B. Sheridan
10. Gilmer, B. Von Haller, Industrial Psychology, Work and Conditions of Work, Harry W. Karn, Chapter 11
11. Duane P. Schultz, Psychology and Industry Today, 1973 Macmillan, Engineering Psychology, Ch. 11
12. Hilgard, Atkinson, Atkinson, Psychology, 1975 Harcourt, et. al.

Results of PQS Tests Following OARP

Based on Long Data, Tr.

Category		<u>Passed</u>	<u>Failed</u>
(TMI-2 Events Other Locas)		12	14

Based on Kelly Data, Long revisions

All Categories Except		8	4
R0 Exam			
SRO Exam		11	2

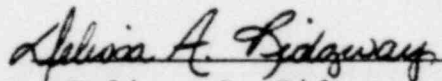
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NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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METROPOLITAN EDISON COMPANY) Docket No. 50-289
) (Restart)
(Three Mile Island Nuclear)
Station, Unit No. 1))

CERTIFICATE OF SERVICE

I hereby certify that copies of the "Intervenor Response to Board Request For Evidence That Consideration of Control Room Operator Fatigue Is Appropriate," which was hand delivered to Licensee's representative by Norman Aamodt on March 10, 1981, were served upon the parties identified on the attached Service List by deposit in the United States mail, first class, postage prepaid, this 10th day of March, 1981.


Delissa A. Ridgway

Dated: March 10, 1981

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NUCLEAR REGULATORY COMMISSION

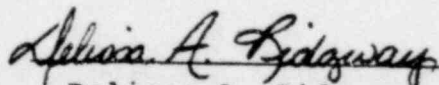
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