September 24, 1982



UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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| In the Matter of | ) | |
| | ) | |
| THE CLEVELAND ELECTRIC ILLUMINATING COMPANY | ) | Docket Nos. 50-440, 50-441 |
| | ) | |
| (Perry Nuclear Power Plant, Units 1 and 2) | ) | |

APPLICANTS' ANSWER TO "SUNFLOWER ALLIANCE ET AL. MOTION TO SUBMIT AN ADDITIONAL CONTENTION"

In a motion dated September 10, 1982, intervenor Sunflower Alliance, Inc. et al. ("Sunflower") submits yet another late-filed contention. This contention asserts:

> Applicants should design shift rotation schedules in conformance with circadian principles.

According to Sunflower,

> PNPP workers, particularly control room operators, may be forced to work unnatural shift rotations. This may lead to human error in the operation and maintenance of the plant. Human error is known to be a problem which can degrade the safety of nuclear power plants.

As in the case of its other late-filed contentions, Sunflower has failed to show good cause for its tardiness. It has also failed to demonstrate a basis for the contention as well as a nexus between this latest late contention and the Perry facility. The contention must therefore be denied.



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I. TIMELINESS

The factors to be considered in determining whether to admit late contentions have been reviewed in many previous filings and need not be revisited again here. Applying these factors to the facts, however, shows that Sunflower has not met its burden.

The good cause advanced by Sunflower is a short article which appeared in the July 31, 1982 issue of Science News.[1/] The article discusses a study which evaluated shift rotation and circadian rhythms. The study found that a rotation system where workers rotated to succeeding shifts (forward in time) improved job satisfaction, health, personnel turnover, and productivity. If the Science News article had been the first widely available publication to reflect this idea, Sunflower's good cause argument might have had merit. Unfortunately for Sunflower's position, the idea has been discussed in the popular press for more than four years.

Wholly apart from the general topics of circadian rhythms (which was recognized as long ago as 1729[2/]) and internal biological clocks (first noted in the 1930's[3/]), the idea of adverse

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1/ Science News articles have been the basis for a number of late-filed contentions. See Ohio Citizens for Responsible Energy Motion for Leave to File its Contention 14, dated July 6, 1981; Ohio Citizens for Responsible Energy Motion for Leave to File its Contentions 17, 18 and 19 (April 22, 1982).

2/ Raloff, "Biological Clocks -- How They Affect Your Health", 78 Science Digest, 62, 64 (Nov. 1975).

3/ Takahashi and Zatz, "Regulation of Circadian Rhythmicity", 217 Science 1104 (September 17, 1982).

effects from shift rotation due to its disturbance of circadian rhythms has been studied and discussed for more than four years. A 1978 study by National Institute for Occupational Safety and Health examined this question.[4/] While it might not be fair to hold Sunflower accountable for a study by a relatively obscure government agency,[5/] this study and the arguments on shift rotation have received significant coverage in the popular press for several years. A quick survey located the following:

1. Bennets, "Studying the Woes of Working Nights", New York Times, April 5, 1978, at C1, 18.

2. "Study Finds Health Perils in Rotating Work Shifts", New York Times, December 27, 1978, at A13.

3. "Rx for Shift Workers", Human Behavior, March 1979, at 36.

4. Slade, "Shifting the Dangers of Shift Rhythms", Psychology Today, April 1979, at 107.

There are, of course, many other articles in scholarly journals on the same topic.

With this readily available literature, Sunflower cannot claim that the July 3, 1982 Science News article was its first available opportunity to learn about this issue. Clearly, had it

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4/ Tasto and Colligan, "Health Consequences of Shift Work", DHEW/NIOSH Report No. 78-154 (March 1978). See also Johnson, et al. "The Twenty-Four Hour Workday", DHHS/NIOSH Report No. 81-127 (1981) at 261-268.

5/ Cf. Memorandum and Order (Concerning Motions to Admit Late Contentions), July 12, 1932, slip op. at 5 ("We therefore agree with OCRE that it would be unfair to charge it with current knowledge of all NRC publications....")

chose to do so, Sunflower could, with reasonable diligence, have uncovered this issue prior to filing its original petition for leave to intervene. While the July 31, 1982 article calls attention to another study in this area, it merely adds to the existing body of literature on the topic. The recent appearance of such cumulative information is not good cause for Sunflower's late filing.

Nor was the issue so esoteric as to escape notice by intervenors in other proceedings. For example, during the February 1981 evidentiary hearings on the Three Mile Island Unit 1 Restart (Docket No. 50-289 SP), one of the intervenors discussed the shift rotation issue in her direct testimony and sought to elicit information on the issue during her cross-examination of other witnesses. Testimony of Intervenor Marjorie Aamodt at 7, foll. Tr. 12,931; Tr. 11,651-2, 12,244-5, 12,434-9, 12,952-3; 13,159-61. Sunflower's failure to raise the iss earlier stems from its failure to think of it, not from the lack of readily available literature on the subject. Lack of diligence cannot be equated with good cause.

Sunflower's showings on the other timeliness factors do not help its cause. While no other party has raised the issue, Sunflower has not shown why the NRC Staff's actions (discussed below) will not protect its interest. The motion does not even allege that Sunflower's participation will assist in developing a sound record; instead Sunflower claims that consideration of the issue will aid in developing a sound record. The appropriate issue is Sunflower's abilities,[6] a subject on which the motion is silent. Finally, Sunflower alleges that any delay will have "minimal impact". Sunflower bases this claim on the absence of a hearing date. Since the predicate for the claim has now disappeared,[7] Sunflower's argument likewise disappears.

In sum, Sunflower has not met its burden of demonstrating that its late filing is justified.

## II. BASIS AND SPECIFICITY

Sunflower seeks to relate the shift rotation issue to this proceeding by its assertion that "unnatural shift rotations ... may lead to human error in the operation and maintenance of the plant." A reading of the Science News article and the report on which it is based fails to disclose the connection. And the only area of possible concern, operator fatigue, has already been addressed by NRC.

The Science News article starts off with a reference to the TMI accident, which began at 4 a.m. on a day, according to the article, that the employees had rotated shifts. The article's first paragraph concludes by stating that "increasingly, researchers have been looking to unnatural shift rotation as a possible cause of occupational mishap." The implication is that

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[6] See Memorandum and Order (Concerning Sunflower's Late-Filed Radiation-Dose Contention), September 15, 1982, slip op. at 3.

[7] Memorandum and Order (Concerning Scheduling), September 16, 1982.

the new study reported by Science News deals with shift rotation and occupational mishaps. It does not.

Even the description of the underlying study set forth in the Science News article makes clear that accidents and occupational mishaps were not studied. According to the article, the study looked at comparisons of "job satisfaction, health, personnel turnover and productivity." Nothing there deals with accidents, occupational mishaps or safety.

Had Sunflower examined the study itself, rather than merely a news report of it, the scope of the study would have been clear. Since the Science News article provided the reference (Science, July 30, 1982), Sunflower's lack of research is hard to understand.

The underlying Science article,[8/] a copy of which is attached hereto, is clearly aimed at issues unrelated to occupational mishaps caused by shift rotation.

> We report that rotating shift workers are often dissatisfied with the features of their schedules that violate circadian principles, and that when schedules are introduced which taken into account the properties of the human circadian system, subjective estimates of work schedule satisfaction and health improve, personnel turnover decreases, and worker productivity increases.

217 Science at 460. None of these factors would seem to have a direct bearing on safety issues.

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8/ Czeisler, Moore-Ede and Coleman, "Rotating Shift Work Schedules That Disrupt Sleep Are Improved By Applying Circadian Principles", 217 Science 460 (July 30, 1982).

The only bit of information in the study which might affect safety at Perry is the possibility of workers falling asleep on the job. According to the Science report, workers on rotating shifts fell asleep at work more often than workers who did not rotate. Id. at Fig. 1 and 461. Fatigue is an appropriate concern for nuclear plant workers. However, it is a concern which has already been addressed.

For example, in February 1980, the NRC Staff recommended guidance on nuclear power plant staff working hours, based on recognition that fatigue can adversely affect worker performance. IE Circular No. 80-02 (February 1, 1980).[9/] In NUREG-0737, "Clarification of TMI Action Plan Requirements" (November 1980), the Staff stated that the administrative procedures shall include as an interim measure the guidance set forth in IE Circular No. 80-02 until additional information is developed on "the effects of overtime beyond the generally recognized normal 8-hour working day, the effects of shift rotation, and other factors". NUREG-0737 at I.A.1.3-1. On February 18, 1982, the NRC published a policy statement concerning fatigue of operating personnel at nuclear reactors. 47 Fed. Reg. 7352 (1982). A revised version of the policy statement was published on June 1, 1982. 47 Fed. Reg. 23836 (1982). Applicants have also committed to include in their admini-

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[9/] Interestingly, when this Circular was sent to Applicants, a copy was also mailed to Sunflower's counsel. Letter from James G. Keppler, Director, Region III to Cleveland Electric Illuminating Company, dated February 1, 1980.

strative procedures limitations on maximum working hours. Safety Evaluation Report, NUREG-0887, §13.5.1.4 (May, 1982). Sunflower has failed to recognize these actions (even though it had actual notice of them) or indicate why they are inadequate.

Sunflower has also failed to recognize that The Cleveland Electric Illuminating Company, which will operate the Perry facility, has used the same shift rotation system since before World War II, and has never received a complaint. In addition, many of the Perry operating personnel come from the Navy nuclear program. See, e.g. FSAR Table 13.1-3; ACRS Subcommittee Tr. 94, 139-141, 144-145 (June 28, 1982); ACRS Tr. 101-102 (July 8, 1982). Navy personnel have generally worked on rotating shifts. Of course, if individuals cannot adapt to rotating shift work, they would not choose to work on a job which requires it.

One final point on fatigue is the lack of any evidence that the TMI accident was caused by fatigue. Despite the speculation of a link which appeared at the end of the Science News article (but which did not appear in the Science report), the only study to deal with this issue found

> there is no evidence that, at the time of the accident, the actions and inactions of the operators were significantly influenced by fatigue, disorientation, or distractions.

NUREG/CR-1270, "Human Factors Evaluation of Control Room Design and Operator Performance of Three Mile Island", vol. 1 at 23 (January 1980). The human factors study concluded:

> The primary conclusion reached on the basis of this investigation was that the human errors experienced during the TMI incident were not due to operator deficiencies but rather to inadequacies in equipment design, information presentation, emergency procedures and training.

Id. at v. Thus, Sunflower has failed to provide any substantive basis to support the primary factual underpinning of its late contention -- that fatigue somehow was related to the TMI accident.

For all of the above reasons, Sunflower's late-filed contention on shift rotation should be denied.

Respectfully submitted,

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iological systems. Osmotic swelling of cytoplasmic vesicles could, in principle, occur through a number of mechanisms, including mobilization of osmotically inactive constituents in the vesicle, alteration of vesicle membrane permeability to ions, or stimulation of ion pumping into the vesicles. In the experiment represented in Fig. 1B, osmotic swelling of the vesicle was accomplished by substituting a permeant solute (glucose) for a nonpermeant one (stachyose). This is formally equivalent to a biological vesicle osmotically swelling because of an increase in the permeability of its membrane to cytosolic constituents, such as ions.

Numerous examples already exist of vesicle swelling being associated with exocytosis (although it is not yet clear that the swelling precedes fusion). Among these are mucocyst discharge in *Tetrahymena* (*13*), serotonin release by mast cell granules (*14*), and granular discharge by *Limulus* amoebocytes (*15*). It has also been shown that antidiuretic hormone–stimulated fusion of cytoplasmic tubular vesicles with the luminal plasma membrane of toad urinary bladder can be regulated by osmotic forces in a manner consistent with that of vesicle–planar membrane fusion (*16*). Although in our system $Ca^{2+}$ stimulates fusion by promoting the close association of vesicle and planar membranes, this need not be its role (or its only role) in biological exocytosis. The possibility that increased levels of $Ca^{2+}$ trigger fusion by stimulating osmotic swelling of vesicles (by any of the mechanisms mentioned above) merits serious consideration.

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22. This work was supported by NIH grants GM29210-05, 5T32GM7288, and GM 27367-02.

29 April 1982; revised 4 June 1982

# Rotating Shift Work Schedules That Disrupt Sleep Are Improved by Applying Circadian Principles

Abstract. *Workers on rotating shifts dislike those aspects of their work schedules that violate circadian sleep-wake cycle physiology. Work schedule satisfaction, subjective health estimates, personnel turnover, and worker productivity improve when schedules are introduced that are designed to incorporate circadian principles.*

The human sleep-wake cycle has evolved on a rotating planet with a regular 24-hour alternation between day and night. Yet within the past 50 years, the need for round-the-clock operations in many industrial plants and emergency services has led to major changes in the day-night schedules to which 26.8 percent of the U.S. work force is exposed, many of whom work shifts which rotate between night, evening, and daytime duties (*1*).

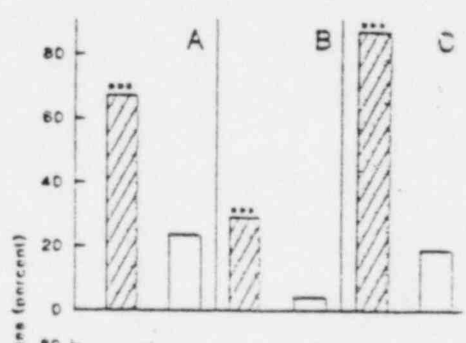


Fig. 1. (A to C) Comparison of sleep-wake cycle questionnaire responses from workers on weekly phase advance rotating shifts and nonrotating day and swing shift workers. The rotating shift workers reported greater problems with (A), poor quality sleep, $\chi^2(1) = 26.4$, $P < .001$; (B), falling asleep at work, $\chi^2(1) = 15.6$, $P < .001$; and (C), the schedule changing too often, $\chi^2(1) = 55.0$, $P < .001$. (D) The number of days taken for the sleep time of the weekly phase advance rotating shift workers to adjust after each shift rotation. ***$P < .001$.

Numerous medical and psychosocial problems associated with rotating shift work schedules have been reported (*2*), and several different approaches to the problems have been suggested (*3*, *4*). Because research findings (*5–7*) indicated to us that most rotating work schedules are outside the range of entrainment of the pacemaker timing the human circadian sleep-wake cycle, we postulated that a practical and effective intervention would be to resolve this aspect of the shift work problem. We report that rotating shift workers are often dissatisfied with the features of their schedules that violate circadian principles, and that when schedules are introduced which take into account the properties of the human circadian system, subjective estimates of work schedule satisfaction and health improve, personnel turnover decreases, and worker productivity increases.

We compared 85 male rotating shift workers, aged 19 to 68 (mean ± standard deviation, 31.4 ± 10.0), with a control group of 68 male nonrotating day and swing shift workers with comparable jobs, aged 19 to 56 (mean, 27.3 ± 8.2), at the Great Salt Lake Minerals and Chemicals Corporation in Ogden, Utah (*8*). For 10 years at this plant, weekly shifts were rotated with each crew working a given 8-hour shift for 7 days before rotating to the preceding 8-hour shift. Hence the scheduled work time rotated in a phase advancing direction from night (midnight to 8 a.m.) to swing (4 p.m. to midnight) to day (8 a.m. to 4 p.m.) shift (*9*).

Each worker was given the job descriptive and health indices of Smith, Kendall, and Hulin (*10*), and sleep-wake and schedule preference questionnaires. The response rate was 84 percent (*11*). The rotators reported significantly more [$\chi^2(1) = 26.4$, $P < .001$] problems with insomnia than did nonrotators (Fig. 1A) and 29 percent of the rotators reported that they had fallen asleep at work at least once during the previous 3 months (Fig. 1B). A major complaint was that the schedule changed too often (Fig. 1C), and 81 percent reported that it took 2 to 4 days or more for their sleep schedule to adjust after each phase advance; this included 26 percent who said they were never able to adjust before being rotated again (Fig. 1D).

To design a rotating work schedule that would take into account the properties of the circadian timing system, we focused on two key issues: the direction of rotation and the interval between phase shifts. In normal human subjects the endogenous free-running period of the sleep-wake cycle averages 25 hours, but that cycle can usually be entrained by periodic environmental time cues which are within 1 to 2 hours of the endogenous period (*6*). Thus the typical range of entrainment in man easily accommodates normal synchronization to the 24-hour period of the earth's rotation. This range allows in any one cycle only a small phase advance with respect to environmental time but a 2- to 3-hour phase delay (*12*). This explains why adaptation is more rapid after westbound travel (requiring a phase delay) than after eastbound travel (requiring a phase advance) (*13*). These considerations led us to conclude that work schedules that rotate should do so by successive phase delays and that the interval between phase shifts should be as great as is practical.

To test this hypothesis, we divided shift workers on phase advancing work schedules into two groups and placed them on phase delay schedules: 33 workers continued to change shifts each week and 52 others rotated shifts by phase delay once every 21 days (*14*). Before implementation of the schedule, all workers and managers attended an audiovisual presentation on the basic properties of the circadian sleep-wake cycle that had suggestions for adjusting their sleep time to their schedule, and each received an educational booklet designed for the workers at this facility.

The workers' preferences were evaluated from questionnaires distributed 3 months after the introduction of the new schedules (Fig. 2, A to D), and personnel

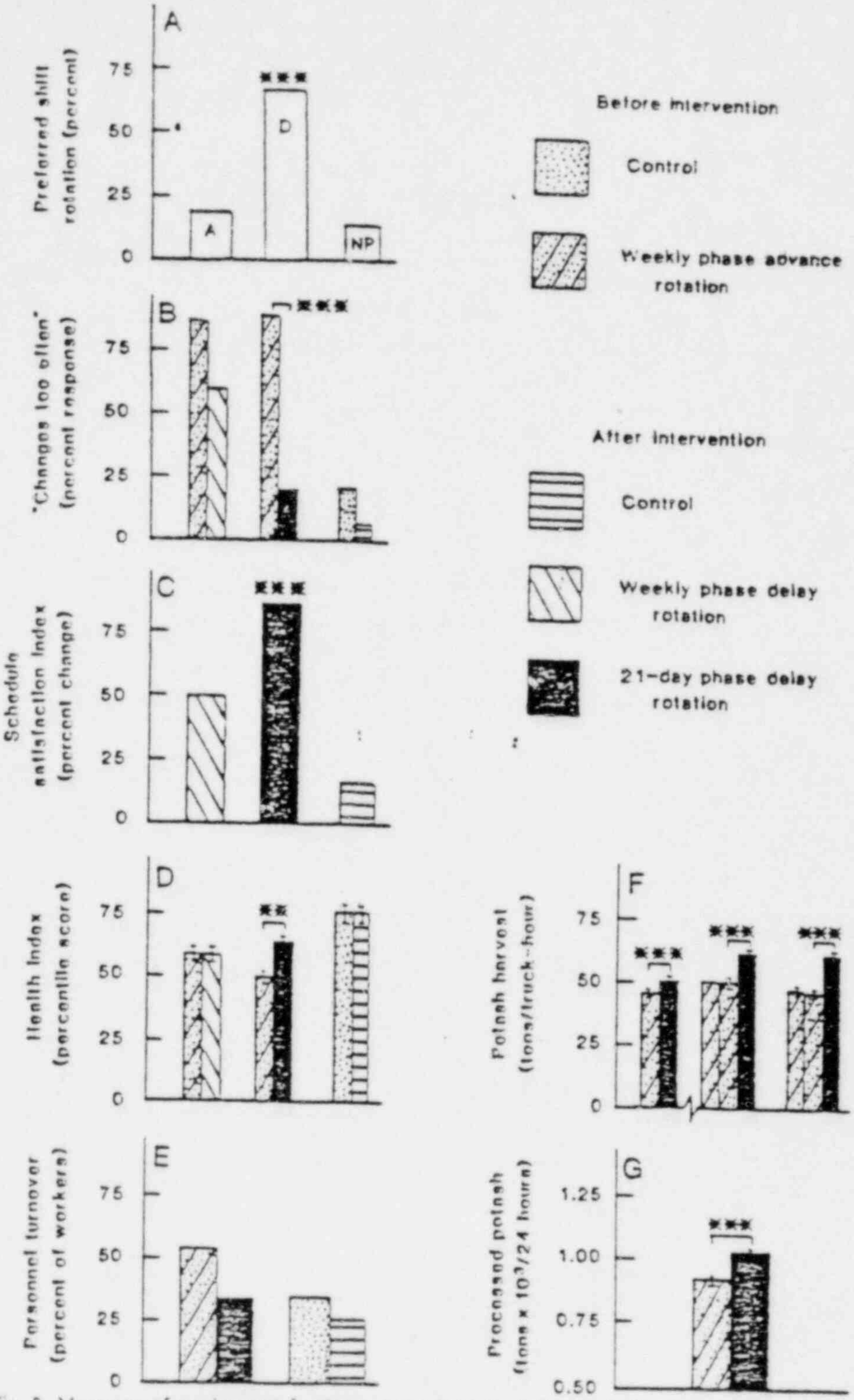


Fig. 2. Measures of worker satisfaction and productivity before and after introduction of new shift work schedules. (A) After experience with both schedules, workers preferred delay (*D*) rotating schedules over the advance (*A*) rotating schedule [$\chi^2(2) = 43.6$, $P < .001$]; *NP*, no preference. (B) There was a significant reduction [$\chi^2(1) = 47.8$, $P < .001$] in the complaint that the schedule "changes too often" by rotators on the 21-day phase delay schedule but not by rotators on the weekly phase delay schedule or by controls. (C and D) Rotators on the 21-day phase delay schedule had significantly increased scores on both the schedule satisfaction index and on the health index [$t(51) = 4.86$, $P < .001$, and $t(51) = 3.23$, $P < .01$, respectively]. (E) Personnel turnover rate during the 9-month study period among rotating shift workers (left) was reduced (after the 21-day phase delay schedule was introduced) to the same range as a comparable control group of nonrotating shift workers (right). (F) Potash harvesting productivity increased significantly (Student's *t*-test) during the quarter season immediately following the introduction of the 21-day phase delay rotating schedule [$t(103) = 3.49$, $P < .001$] (left cluster); compared to the previous 2 years there were also increases in the first [$t(96) = 7.58$, $P < .001$] and second [$t(99) = 10.89$, $P < .001$] quarters after the summer break (middle and right clusters) (*11*, *12*). (G) The production of processed potash increased significantly [$t(398) = 6.99$, $P < .001$] after introduction of the 21-day phase delay rotation schedule in comparison with the same period the previous year when the workers were on the weekly phase advance schedule. $^{**}P < .01$; $^{***}P < .001$

turnover and plant productivity were analyzed 9 months after the introduction of the new schedules (Fig. 2, E to G) (*15*). The workers clearly preferred the phase delay direction of rotation (Fig. 2A): complaints that the schedule changed too often dropped from 90 to 20 percent among the workers on the 21-day phase delay rotation schedule (Fig. 2B). This was associated with a substantial increase on the schedule satisfaction index (Fig. 2C), improvements in the health index (Fig. 2D), and a reduction in personnel turnover (Fig. 2E) (*16*). At the same time, the rate of potash harvesting (Fig. 2F) by men operating front-end loaders in the evaporation ponds and the rate of processed potash production in the plant (Fig. 2G) also increased after the introduction of the new schedule, and the increases in productivity were maintained in the harvest season which followed the completion of our study period (*17, 18*).

Previously three major strategies have been used to address the problems of adaptation to shift work. The first, and perhaps most obvious, is to schedule workers on straight shifts without rotation. However, it is often difficult to staff the night shift, and straight shift scheduling still results in conflicting environmental synchronizers for the night worker who adopts daytime activities for social reasons on days off. The second strategy, favored in Europe, is to rotate from one shift to the next rapidly in order to escape the consequences of partial temporal adaptation (*3*). However, the circadian system may be affected, even on rapid rotation regimens, since a change from the phase advance to the phase delay direction of a rapid rotation system resulted in some improvements in both psychological and physiological measures (*19*). A third strategy would be to take advantage of differences between individuals in measurable properties of the circadian timing system, such as rhythm amplitude (*4*), to select individuals with the greatest tolerance for working or sleeping on abnormal schedules.

In contrast, our strategy was to take advantage of those properties of the circadian system that individuals share in common: the longer than 24-hour endogenous period and the limited range of entrainment. The results of this field study indicate that work schedules that rotate by phase delay with an extended interval between each rotation are most compatible with the properties of the human circadian timing system. However, the design of any specific work schedule must, of course, take into consideration both the nature of the work and the specific needs of the workers.

The improvements recorded on the 21-day phase delay schedule are consistent with the results of temporal isolation and clinical studies (*5, 6, 12, 20*). Mills *et al.* (*20*) showed that the circadian rhythms of volunteers usually show a phase delay of 16 hours in response to an 8-hour phase advance shift of schedule because such an abrupt phase advance is beyond the usual human range of entrainment (*6*). Most workers on phase advancing schedules may therefore be in a state of continual forced internal desynchronization (*13, 21*) between the pacemakers (*7, 22*) of their circadian system.

The consequences of such disruption in temporal organization are just beginning to be understood. It was only recently recognized, for example, that the normal timing and organization of sleep depend on an appropriate phase relation between circadian pacemakers (*5, 23*). The forced disruption of phase relations inherent in shift work schedules accounts for the previously unexplained sleep disturbances reported in earlier field studies (*24*). Failures in homeostatic regulatory mechanisms are also associated with internal desynchronization of the circadian system (*25*), and chronic external desynchronization induced by light-dark phase shifts results in decreases of 5 to 20 percent in longevity in insects (*26*) and in mammals (*27*). In humans, the long-term effects of such phase shifts are not known, but field studies indicate that there are more sleep and digestive disorders among workers on rotating shifts (*2*), with some unable to tolerate the schedules (*28*). Concern about the possible long-term health consequences of rotating shifts is growing (*29*). It may be that the application of circadian principles to the design of schedules can maintain the temporal integrity of the circadian system and minimize for the shift worker any detrimental consequences of circadian disruption.

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6. R. A. Wever, *The Circadian System of Man* (Springer-Verlag, New York, 1979).
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8. This was a nonhomogeneous work force from both urban and rural settings; many had moved to the area from surrounding states such as California, Idaho, and Nevada because of economic opportunity.
9. In keeping with circadian terminology, we use phase advances ($+\Delta\phi$) to mean shifts to an earlier hour on the reference time scale (in this case, local clock time) and phase delays ($-\Delta\phi$) to mean shifts to a later hour.
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11. For assessments of the effects of our intervention, only rotators who completed both initial and follow-up assessments were included (93 percent of initial subjects).
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14. The 21-day phase delay schedule was originally designed so that work hours were shifted gradually by 1 to 2 hours per day for 5 days until the new shift time was attained. This procedure was eliminated after a month when it proved inconvenient for the workers' family life and car pooling arrangements; thereafter an 8-hour phase delay was undertaken on every 21st day.
15. Rotating shift schedules for these workers generally operated during the potash harvest season from September through May. During the summer, most workers work straight day shifts.
16. That these effects are due to increased tolerance of the circadian system to the work schedule is supported by the fact that there was little improvement in other factors, such as indices of interference with family or social life.
17. It is unlikely that these increases in productivity reflected the presence of the study team since (i) productivity statistics were derived by retrospective analysis of company data that was routinely gathered; (ii) hourly pay scales were not linked to individual or group productivity; and (iii) the increases in productivity persisted throughout a 6-month follow-up after departure of the study team [H. M. Parsons, *Science* 183, 922 (1974)].
18. A time and motion analysis by a company operations engineer revealed that the modification and replacement of one of the harvesting machines during the summer of 1981 may have contributed up to 4 percent of the increase in productivity in the first and second quarters after the summer break (Fig. [illegible], middle and right clusters), but this could not explain the increase in the quarter before the summer break

(Fig. 2F, left cluster), nor for more than a fraction of the increases in the subsequent quarters.

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## eficiency of Functional Messenger RNA for a Developmentally egulated β-Crystallin Polypeptide in a Hereditary Cataract

Abstract. *The messenger RNA for a β-crystallin polypeptide with a molecular size f 27 kilodaltons, first detected 5 to 10 days after birth in the normal mouse lens and e Nakano mouse cataract, was not detected in the Philly mouse cataract with anslation in vitro. The heterozygous Philly lens had intermediate levels of the 27-ilodalton β-crystallin polypeptide and exhibited delayed onset of the cataract. The eficiency of functional 27-kilodalton β-crystallin messenger RNA is the earliest sion reported yet for the Philly lens and points to a transcriptional or posttranscrip-onal developmental defect in this hereditary cataract.*

Development of the ocular lens is haracterized by differential synthesis of e crystallins (structural proteins) and is onsequently a favorable system for the udy of differential gene expression in ukaryotic cells (*1*). Normally the lens is ansparent. In certain strains of mice, owever, the lens becomes opaque—ataractous—after birth. The Philly ouse, a derivative of the Swiss-Web-er strain, develops an osmotic cataract ring the fourth postnatal week (*2*). The illy cataract progresses from an initial nt subcapsular opacity to a dense nu-ear cataract in about 1 month (*3*). Crys-llin synthesis is severely depressed in e fiber cells of the Philly cataract (*4*). is appears to be caused, at least in rt, by ionic changes within the lens at interfere with the translation of crys-llin messenger RNA's (mRNA's) (*5*). ior to the general reduction in crystal- synthesis, a β-crystallin polypeptide h a molecular size near 27 kilodaltons K) is selectively missing from the lly cataract (*6*). We now report that β-crystallin polypeptide is a devel-entally regulated protein whose NA cannot be detected by translation until the second week after birth for the normal Swiss-Webster mouse and cannot be detected at all by translation in vitro for the Philly mouse.

The polypeptide compositions of normal Swiss-Webster and Philly mouse lenses were examined by sodium dodecyl sulfate–polyacrylamide gel electrophoresis (Fig. 1). The arrows in Fig. 1 point to the 27 K β-crystallin polypeptide band. This band of protein was not present in the normal Swiss-Webster lens at day 1 or day 5 but was easily visible by day 10 and accumulated thereafter. In contrast, the 27 K β-crystallin polypeptide appeared to be missing from the Philly lens at all stages examined. Experiments were not performed on older mice because β-crystallins degrade during the process of opacification (*4*, *6*).

A trace of the 27 K β-crystallin polypeptide was observed as early as days 1 and 5 after birth, and considerable amounts were evident by the tenth postnatal day in the BALB/c and Nakano lenses (Fig. 1). Nakano mice were derived originally from BALB/c mice. The Nakano mouse develops a hereditary osmotic cataract associated with ionic imbalances (*7*) caused by the production of an inhibitor of the cellular Na,K–adenosine triphosphatase (*8*). Thus the time of appearance for the 27 K β-crystallin polypeptide may vary slightly with the strain of mouse. Moreover, the deficiency in the 27 K β-crystallin polypeptide is not due to general osmotic imbalances.

Total RNA's extracted from the lenses of Philly and control mice were tested by translation in a reticulocyte lysate to determine whether the Philly lens lacks a functional mRNA for the 27 K β-crystallin polypeptide. Autoradiograms of sodi-

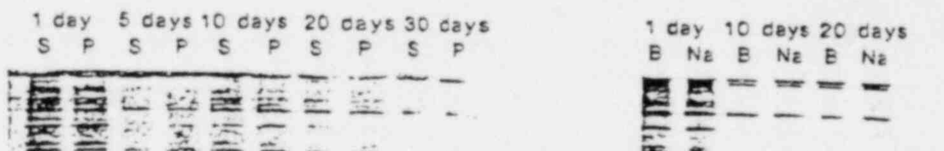


Fig. 1. Sodium dodecyl sulfate–polyacrylamide gels of lens proteins from Swiss-Webster control (*S*), Philly (*P*), BALB/c (*B*), and Nakano (*Na*) lenses. The lenses were removed from the eyes and homogenized in 10 m*M* 2-mercaptoethanol, 1 m*M* EDTA, and 1 percent sodium dodecyl sulfate. Samples of total lens protein (25 μg) were subjected to electrophoresis in a 15 percent polyacrylamide slab gel (*15*). Gels were stained with Coomassie brilliant blue R (Bio-Rad). The arrows point to the 27 K β-crystallin polypeptide; other small differences between the control and Philly lens proteins were not reproducible.

September 24, 1982

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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| In the Matter of | ) | |
| | ) | |
| THE CLEVELAND ELECTRIC ILLUMINATING COMPANY | ) | Docket Nos. 50-440 50-441 |
| | ) | |
| (Perry Nuclear Power Plant, Units 1 and 2) | ) | |

## CERTIFICATE OF SERVICE

This is to certify that copies of the foregoing "Applicants' Answer to 'Sunflower Alliance, Inc. et al. Motion to Submit an Additional Contention'", were served by deposit in the United States Mail, First Class, postage prepaid, this 24th day of September, 1982, to all those on the attached Service List.

JAY E. SILBERG

Dated: September 24, 1982

NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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