IC 9378

BUREAU OF MINES
INFORMATION CIRCULAR/1994

PB94-154895

Extended Workdays in Mining and Other Industries: A Review of the Literature

By James C. Duchon and Thomas J. Smith

United States Department of the Interior

Bureau of Mines

U.S. Department of the Interior Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Cover Photograph: Shift worker clocks in before night shift. Because of the association of shift work with increased accidents, lowered production, and health effects, alternative work schedules are being considered in some mining operations.

BIBLIOGRAPHIC INFORMATION

PB94-154895

Report Nos: BUMINES-IC-9378

Title: Extended Workdays in Mining and Other Industries: A Review of the Literature.

Date: 1994

Authors: J. C. Duchon, and T. J. Smith.

Performing Organization: Bureau of Mines, Minneapolis, MN. Twin Cities Research Center.

Type of Report and Period Covered: Information circular/1994.

NTIS Field/Group Codes: 48A, 95D

Price: PC A03/MF A01

Availability: Available from the National Technical Information Service, Springfield, VA. 22161

Number of Pages: 18p

Keywords: *Mine safety, *Productivity, *Coal industry, Work, Work time standards, Human factors engineering, *Compressed workweeks.

Abstract: The use of extended workdays (regular shift lengths of 10 or 12 hours, while still maintaining a 40-hour workweek) in mining operations is attracting growing interest in the United States. While the popularity of extended workdays has been on the increase, there are some serious concens by management, workers, unions and various governmental policy makers that working 10- or 12-hour days may create an added risk of accidents and health problems. The manuscript represents a review of the literature related to the safety and performance issues of extended workdays. The objective of this manuscript is to describe all relevant research that could aid in decisions regarding the use and implementation of extended workdays. The studies examined in this review are divided into three sections: (1) laboratory studies; (2) field studies; and (3) accident analysis studies. In general, results are inconclusive. Studies have shown both positive and negative effects. It is concluded, therefore, that in industries such as mining, where accidents are a serious concern, special measures and evaluation in the use of extended workdays be considered.

PB94-154895

Information Circular 9378

Extended Workdays in Mining and Other Industries: A Review of the Literature

By James C. Duchon and Thomas J. Smith

UNITED STATES DEPARTMENT OF THE INTERIOR
Bruce Babbitt, Secretary

BUREAU OF MINES

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704 0188

1. PB94-154895

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Information Circular (IC) 9378

4. TITLE AND SUBTITLE
Extended Workdays in Mining and Other Industries:
A Review of the Literature

5. FUNDING NUMBERS

6. AUTHOR(S)
James C. Duchon and Thomas J. Smith

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Twin Cities Research Center
5629 Minnehaha Avenue South
Minneapolis, MN 55417

8. PERFORMING ORGANIZATION REPORT NUMBER
IC 9378

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Bureau of Mines
Research
2401 E Street
Washington, D.C. 20240

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The use of extended workdays (regular shift lengths of 10 or 12 hours, while still maintaining a 40-hour workweek) in mining operations is attracting growing interest in the United States. While the popularity of extended workdays has been on the increase, there are some serious concerns by management, workers, unions and various governmental policy makers that working 10- or 12-hour days may create an added risk of accidents and health problems. This manuscript represents a review of the literature related to the safety and performance issues of extended workdays. The objective of this manuscript is to describe all relevant research that could aid in decisions regarding the use and implementation of extended workdays. The studies examined in this review are divided into three sections: (1) laboratory studies; (2) field studies; and (3) accident analysis studies. In general, results are inconclusive. Studies have shown both positive and negative effects. It is concluded, therefore, that in industries such as mining, where accidents are a serious concern, special measures and evaluation in the use of extended workdays be considered.

14. SUBJECT TERMS
Field 5--23-02, Human Factors Engineering & Man Machine Systems

15. NUMBER OF PAGES
11

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

CONTENTS

TABLE

PB94-154895

EXTENDED WORKDAYS IN MINING AND OTHER INDUSTRIES: A REVIEW OF THE LITERATURE

By James C. Duchon[1] and Thomas J. Smith[2]

ABSTRACT

The use of extended workdays (regular shift lengths of 10 or 12 h (hour), while still maintaining a 40-h workweek) in mining operations is attracting growing interest in the United States. There is very little doubt that extended workdays is a very popular alternative among the work force because of the significant increase in days off, including weekends, especially when compared with traditional rotation schedules of working seven straight shifts or having only one weekend off every 4 to 6 weeks.

However, there are some serious concerns by management, workers, unions, and various governmental policymakers that working 10- or 12-h days may create an added risk of accidents and health problems. The U.S. Bureau of Mines reviewed the literature studies related to the safety and performance issues of extended workdays. This report presents a summary of those findings. The studies examined in this review are divided into three sections: (1) laboratory, (2) field, and (3) accident and injury analysis. In general, results are inconclusive. Studies have shown both positive and negative effects. It is concluded, therefore, that in industries such as mining where accidents are a serious concern, special measures and evaluation in the use of extended workdays be considered.

[1]Engineering research psychologist.
[2]Group supervisor, Human Factors.
Twin Cities Research Center, U.S. Bureau of Mines, Minneapolis, MN.

INTRODUCTION

In a survey conducted by the U.S. Bureau of the Census for the U.S. Bureau of Labor Statistics, it was estimated that approximately 1 in 5 Americans (20 million people) is a shift worker. In mining, 21.9 pct (percent) of all employees work some form of shift work. This includes workers who work night shifts, rotate from one shift to another, or work other schedules other than typical day shifts. A recent report by the U.S. Congress, Office of Technology Assessment (*1*),[3] provides various estimates of shift workers in different occupational sectors.

There are several practical reasons why shift work is prevalent in industry, including (1) increased demand for goods and services combined with limited overhead; (2) need to maximize costly equipment for quick capital recovery; (3) need to take advantage of lower utility costs at offpeak-hour utility rates; (4) need for round-the-clock coverage by police, fire, hospital, and transportation; (5) maintenance of services, such as restaurants and grocery stores for the public; (6) need to keep equipment running continuously because of high startup costs; and (7) need to save time and money in time-critical jobs, such as cross-country truck drivers (*2*).

It has been demonstrated in published studies that workers in various industrial groups, such as mining, power, chemical, nursing, factory, and oil refineries, have displayed perturbed performance; more frequent or serious accidents; lower production; higher absenteeism; more health and familial problems; and low morale and job dissatisfaction due to working nights and shift work (*1*, *3-11*). It is easy to understand, therefore, why there is a growing interest among all industries to explore alternative work schedules.

In a review of scheduling practices in the workplace, Thierry and Jansen (*12*) stated that in regards to shift work "interventions are not a luxury." A discussion of alternative work schedules provided several reasons why there is a recent trend in the United States toward new and better schedules (*13*). For instance, an increase in relative affluence creates a climate where many of life's privileges and comforts have become necessities. Also, changes in education levels, cultural changes, employment rates, aging work force, labor force participation, and shift to service work all contribute toward this move to seek alternative schedules.

There is little doubt that working "extended workdays" (regular shifts of 10 or 12 h) while maintaining an approximate 40-h week is a very popular alternative among the work force because of the significant increase in days off, including weekends, especially when compared with traditional rotation schedules of working seven straight shifts or having only one weekend off every 4 to 6 weeks.

While the popularity of extended workdays has been on the increase, there are some serious concerns by management, workers, unions, and various governmental policymakers that working 10- or 12-h days may create an added risk of accidents and health problems (*14*). Unfortunately, there is very little objective information available regarding the nature and degree of safety and health risks associated with the application of extended workday schedules (*1*, *15-16*). As a consequence, when it comes to questions of designing and managing extended workdays, decisionmaking by management must now proceed on limited information.

Health and safety issues are not important considerations for the implementation of 12-h shifts in relatively safe workplaces, such as white-collar settings. However, in labor-intensive and environmentally stressful conditions such as mining, where accidents and health are major concerns, or where safety is a public concern, such as nuclear power, the application of long workdays must be carefully analyzed.

Since all indications are that the introduction of extended workday schedules by U.S. industries will become increasingly widespread over the decade, it is imperative that a careful and comprehensive evaluation of safety and health risks associated with such schedules be initiated. In the U.S. Congress, Office of Technology Assessment, report on worker implications of shift work, requested by the House Committees on Appropriations; Energy and Commerce; Science, Space and Technology; Veterans Affairs and the Senate Subcommittee on Science, Technology and Space, it is stated that there is "... a compelling need for more studies of the interactions between work schedules and safety in the workplace" (*1*, p. 18).

CRITICAL DESIGN DIFFERENCES BETWEEN 8- AND 12-h SHIFTS

The change from an 8- to a 12-h rotating shift implies several critical schedule differences (*17*). The crucial similarities and differences between 8-h rotating shifts and 12-h rotating schedules are listed below. These are the factors that could make a difference in a worker's tolerance to his or her schedule.

1. Length of the workday: An extended workday is typically considered to be a 10- or 12-h workday while still maintaining an approximately 40-h workweek. Length of

[3]Italic numbers in parentheses refer to items in the list of references at the end of this report.

workday could clearly have an impact on performance (*18*).

2. Amount of time off between workdays: Extended workdays typically have less off time between shifts. This would have implications for (1) physical recovery from fatigue and (2) potentially less time for sleep.

3. Length of the workweek: Extended workweeks typically have shorter workweeks at the expense of longer workdays. This could have implications for adaptation of circadian rhythms or less cumulative fatigue across a workweek (*19*).

4. Amount of time off, i.e., length of weekends: Extended workdays usually have more days off. This would have implications for recovery from fatigue or sleep deficit.

5. Speed of rotation, i.e., U.S. shift workers usually rotate slowly (5 to 7 consecutive shifts): Extended workdays usually require faster rotations, 2 to 4 consecutive shifts. This could have implications for adaptation to circadian rhythms.

6. Time of day: Both 8- and 12-h schedules can involve around-the-clock operations. Therefore, working the night shift will still be an issue in extended workdays. There is a 5 pct decrease in work capacity at night (*20*), which is magnified during a 12-h shift (*18*). It could, therefore, be anticipated that the 12-h night shift will be associated with decreased performance.

LITERATURE ON COMPRESSED WORKWEEKS

The objective of this section is to provide a review of previous studies that have added to a data base on the effects of extended workdays. While it is acknowledged that these effects are multidimensional, including biological, performance, health, social, and psychosocial factors, the scope of this review will be limited to performance and physiological aspects. Good reviews of the social, health, and biological effects of working shift work can be found in literature by Scott and LaDou (*21*) and Harrington (*22*). There are relatively few experimental studies that have directly measured the effects of compressed workweeks compared with traditional 8-h work shifts. In 1979, Volle, Brisson, Perusse, Tanaka, and Doyon (*15*) stated that "no study exists to our knowledge on the effects of the prolongation of the workday combined with a reduction of the number of days, the total number of weekly hours remaining equal." A similar sentiment was expressed by Kelly and Schneider (*16*) and by the U.S. Congress, Office of Technology Assessment (*1*).

Other research areas, however, are related to the effects of working extended workdays. For instance, studies not directly focusing on extended workdays that attempt to relate duration of work to fatigue or accidents are relevant, since "work duration" is clearly the critical factor in looking at the performance and physical effects of extended workdays. If a study shows that performance decreases across an 8-h shift, then by extrapolation it *may* have implications for longer than 8-h shifts. Similarly, studies that measure the effects of work episodes over 8 h *may* be relevant to extended work shifts (*23*). However, studies that are not looking directly at extended workdays should not carry as much weight, since there may be critical qualitative differences between regularly working an extended workday compared with working a 10- or 12-h day because of overtime. Whether working 12 h on an overtime day or working 12 h in a regular extended workday shift elicits the same physiological, performance, or psychological changes is an unanswered question that has not been explored to date.

The studies examined in this review are divided into three classes: (1) laboratory, (2) field, and (3) accident and injury analysis. Table 1 provides a summary of extended workday and related studies in each class, on which this review is based. All three types of studies are important. Each type of study has its strengths and weaknesses. The field studies point to results in real-world situations. However, they can be easily influenced by the attitudes of the workers (subjects), especially since extended workdays are usually enthusiastically accepted by the work force. A worker can easily influence his or her behavior on an outcome measure if it is thought that the results of the study could influence the choice of a particular shift design.

Laboratory studies offer more control over this and other extraneous problems, but because of the inherent artificiality of the laboratory setting it may not be realistic to generalize to the real world. Epidemiological studies are very effective indicators of accident and health risk rates, but are not effective in extracting causality.

LABORATORY STUDIES

An area of human performance research referred to as "sustained operations" has been conducted by researchers primarily interested in measuring human endurance to certain performance tasks under conditions of short spurts of continuous work (*24*). These studies typically have been done in the context of simulated military operations where soldiers would need to "work" under extreme "sustained operations." Most of these studies of sustained operations concluded that humans can work 15 to 36 h continuously with little or no sleep before performance manifests significant decrements. For instance, in one such study by Morgan (*25*), subjects performed continuously on tasks such as blinking-lights monitoring, arithmetic computations, and target identification. Overall work efficiency decreased by approximately 15, 20, and 35 pct over the course of 36, 44, and 48 h of continuous operations. The authors in fact concluded that "man should have no trouble working schedules which require 10- or 12-hour workdays" (*25*, p. 18). However, these studies typically were done to simulate possible military interventions, and perhaps more importantly, typically lasted 2 to 5 days. While it is enlightening to know the limits of human behavior under these conditions, generalizing these results to industrial workers is questionable.

Table 1.—Summary of extended workday and related studies

Reference	Nature of study: independent variable	Measure used: dependent variable	Effect of long work-hours[1]
	LABORATORY STUDIES		
Colquhoun, 1968-69 (*26-28*).	Circadian rhythms and fatigue	Discrimination speed	Negative.
Do.[2]	..do.	Discrimination accuracy	Neutral.
Morgan, 1974 (*25*)	Sustained operations in military	Various performance tasks	Do.
Mital, 1984, 1986 (*29-30*)	Temporal factors and maximum acceptable work load.	Heart rate	Negative.
Do.	..do.	Oxygen uptake	Do.
Minors, 1986 (*23*)	Circadian rhythms and unusual work schedules.	Performance tasks	Do.
Do.	..do.	Subjective mood	Do.
Rosa, 1985, 1988-89 (*31-33*)	Extended workdays, 12 h	NIOSH performance battery	Negative, neutral.
Do.	..do.	Subjective measures	Negative.
Mahan, 1991 (*34*)	..do.	Multicue judgement	Do.
Do.	..do.	Analytic task and judgement task	Neutral.
	FIELD STUDIES		
Grandjean, 1971 (*38*)	Air-traffic controllers and time on task.	Performance battery	Negative.
Do.	..do.	Self-report fatigue	Do.
Wynn, 1979 (*46*)	Extended workdays in gas processing, oil refinery, chemical, petrochemical, and fertilizer plants.	Survey	Positive, neutral, negative.
Northrup, 1979 (*47*)	Extended workdays in chemical petroleum, 12 h.	..do.	Positive, negative.
Volle, 1979 (*15*)	Extended workdays in manufacturing, 10 versus 8 h.	Performance battery	Neutral.
Do.	..do.	Heart rate, blood pressure, VO_2max.	Do.
Kelly, 1982 (*16*)	Extended workdays in nuclear power, 12 h.	Error rate	Do.
Do.	..do.	Performance measures	Negative.
Peacock, 1983 (*45*)	Extended workdays	Ergometry	Positive.
Do.	Police	Blood pressure	Do.
Do.	8- (rapid) versus 12-h days	Catecholomines	Neutral.
Do.	..do.	Self-report fatigue	Do.
Lewis, 1986 (*41*)	..do.	Performance tasks	Positive.
Do.	..do.	Management report	Do.
Lindsley, 1944 (*36*); Smith, 1987 (*37*)	Vigilance radar operations	Accuracy of radar detection	Negative.
Daniel, 1989 (*39*)	Extended workdays in chemical factory, 10 h.	Oral temperature (fatigue)	Do.
Do.	8- versus 12-h days	Performance battery	Negative, neutral.
Miller, 1989 (*40*)	Interstate highway truck drivers and time on road.	Subjective fatigue	Negative.
Do.	..do.	Steering adjustments	Do.
Do.	..do.	Heart rate variability	Do.

See footnotes at end of table.

Table 1.—Summary of extended workday and related studies—Continued

Reference	Nature of study: independent variable	Measure used: dependent variable	Effect of long work-hours[1]
	FIELD STUDIES—Continued		
Rosa, 1989 (*32*)	Extended workdays in nuclear power, 12 versus 8 h.	Performance tasks	Negative.
Jorgensen, 1991 (*44*)	Bricklayers, 8-h days	Muscle fatigue (EMG)	Do.
Do.	..do.	Heart rate	Neutral.
Do.	..do.	Self-report fatigue	Do.
Duchon, 1994 (*55*)	Extended workdays in underground mine, 12 versus 8 h.	Self-report	Negative.
Do.	..do.	Performance tasks	Neutral.
Do.	..do.	Physiologic measures	Do.
	ACCIDENT AND INJURY ANALYSIS STUDIES		
Levin, 1985 (*52*)	Last 3 h of shift for paint plant	Frequency of accidents in last 3 h.	Negative.
Leigh, 1986 (*51*)	Overtime in industrial plants	Frequency of overtime accidents.	Do.
Hamelin, 1987 (*48*)	Overtime in U.S. coal mines	Accidents in last 3 h of shift	Do.
Lees, 1989 (*49*)	Extended workdays in manufacturing, 12 h.	Accident frequency	Positive.
Do.	..do.	Health complaints	Do.
Cohen, 1991 (*50*)	Overtime in various industrial plants.	Accident frequency for ladder falls	Negative.
Hunting, 1990 (*54*)	Overtime in U.S. coal mines	Overtime accidents	Do.
Waersted, 1991 (*53*)	8- versus 5-h days for sewing machine operators.	Frequency of musculoskeletal disorders and back pain.	Do.

EMG Electromyographic.
NIOSH National Institute for Occupational Safety and Health.
VO_2max Maximal aerobic capacity.
[1]"Positive" indicates that long work-hours have a positive effect on the dependent measures; "neutral" indicates that long work-hours have a neutral effect on the dependent measures; "negative" indicates that long work-hours have a negative or detrimental effect on the dependent measures.
[2]Ditto.

One of the first experimental studies that considered performance of 12-h shifts, in comparison to 8- or 4-h shifts, was also in the context of military operations (*26-28*). The objective of this series of studies was to compare performance variability with variation of body temperature, a measure of a circadian rhythm. In general, it was found that performance efficiency does follow a circadian change. However, the 12-h day-shift group did not show this effect for response latency on an auditory discrimination task that resembled certain sonar operations. The authors cited fatigue as a variable that masks this circadian temperature effect. Also, it was the speed of response rather than its accuracy that was most sensitive to this effect. The night shift 12-h group was similar to the 8- and 4-h night groups in that performance decrements were observed in each group. These studies were not intended to explore the effects of extended workdays, but used 12-h shifts to explore the possible interaction of fatigue with circadian rhythm in affecting performance variability.

While the studies above used mental or psychomotor tasks as dependent measures, a few studies have looked at physical work load throughout the day. (See reference 18 for a review.) Mital (*29-30*) developed a model to determine maximum acceptable weights of lift for various lift frequencies and shift durations. His primary interest was the development of models to predict physiological fatigue. These models for different types of lift predict heart rate and oxygen uptake at maximum acceptable weight of lifts. For example, the average acceptable lift, according to the model for floor-to-knuckle lifts by males, is 19.64 kg (kilogram) for any given lift. For an 8-h shift of this sort of lifting, the average drops to 16.31 kg and drops further to 15.63 kg for a 12-h shift. Therefore, it is recognized by these researchers that lifting longer than the traditional 8-h work-shift requires special prediction models.

Finally, perhaps the only laboratory studies that looked directly at extended workdays as compared with the traditional 8-h shift were performed by the National Institute for Occupational Safety and Health (NIOSH) (*31-32*). In the first study, a computerized performance battery was developed to measure levels of performance of subjects given a continuous data-entry task, performed across an 8- or 12-h workday. One group of subjects worked 6 straight 8-h days, then worked 4 12-h days after a few days off. A second group reversed the order of shifts, but performed the same tasks. The data-entry task indicated a slight increase in task efficiency in the 8-h week. For the computerized performance battery, the grammatical reasoning task and digit-addition tasks indicated declines in performance across the 12-h day, but not the 8-h day. Subjective reports of fatigue, including the Stanford Sleepiness Scale, Questionnaire for Subjective Symptoms of Fatigue and the Activation-Deactivation Adjective Checklist were also in agreement with the performance tests. Also, the study indicated that for the grammatical reasoning task and the digit-addition task, performance decreased across the 6 days of the 8-h shift, but not for the 12-h shift. A major weakness of the study was its small number of subjects—six. Because of this the authors used a probability level of significance (0.10) that is much more liberal than is acceptable by most researchers. Therefore, the results of this study should be taken with considerable caution. The second study performed by NIOSH (*33*) found similar results, using 11 subjects and traditional significance levels.

However, Mahan (*34*) studied 12-h shifts using a similar technique of a computer performance battery. Although he only studied four subjects on a 12-h shift, he found a significant decrement in performance on a multicue judgement task, but not on the analytic tasks.

Finally, Minors, Nicholson, Spencer, Stone, and Waterhouse (*23*) attempted to quantify changes in circadian rhythms resulting from changes in unusual work schedules with sufficient rest opportunity. Performance measures that deteriorated across schedules over 9 h were digit-symbol substitution, mathematics, and logical reasoning. Subjective mood scores also deteriorated over 9 h. However, there was no evidence of changes across the 9 days of the study.

In summary, these laboratory studies tend to indicate that there appears to be little agreement as to whether performance on extended workdays is differentially impaired, compared with traditional 8-h shifts. Studies of sustained operations seem to reveal a worker's ability to easily cope with a 12-h workday. However, other studies suggest that performance does deteriorate across 9 to 12 h (*23, 26-28, 31*).

FIELD STUDIES

The first comprehensive field study (*35*) of possible links between the length of the workday and behavioral performance was conducted in the early 1940's on military search radar operators (*36-37*). To follow up complaints documented in a health survey of the operators, a systematic perceptual fatigue (vigilance) study of their performance was carried out. The objective was to establish duty-schedule standards for search radar operations. The investigation examined the effects of different duty schedules of 4- and 8-h duration on fatigue accumulation over hours of the day, days of the week, and 3 weeks of operation. Performance criteria used were relative accuracy of radar signal detection and ranging of simulated target blips on experimental radar scopes. On the basis of the results, a 4-h-on, 4-h-off duty schedule for search radar operators was recommended, which subsequently was widely adopted by the military during and after the war.

In general agreement with this original radar operator study, many subsequent field studies have documented decrements in both behavioral and physiological performance across the workday. In a study of 68 air-traffic controllers at the Zurich airport, various measures were used to evaluate job-related fatigue and stress across a 10-h day or night shift (*38*). Every hour beyond the sixth hour indicated an approximate linear decrease in performance on critical flicker fusion (CFF), which is a measure of visual performance, and tapping tasks, as well as on several self-reports of fatigue. It also was found that urine catecholamine's, assumed to measure stress, were found at higher levels when the same workers were performing air-traffic control functions as compared with performing ground-traffic or office-work duties.

In one of the most comprehensive studies of 10-h extended workdays (*15*), a plant manufacturing kitchen equipment in Canada was studied. An impressive array of measures was used, including reaction time, CFF, suspension resistance, heart rate at rest, blood pressure, body temperature, hand strength, maximal aerobic capacity, vital capacity, forced expiratory volume, and a psychological creativity test (omega 37). The authors concluded that in comparison to the 8-h shift, the 10-h shift did not show fatiguing effects across the day, but there was an indication that across the 4 days of the 10-h shift a significant decrement in CFF and hand-grip strength occurred. Differences in all other measures were not significant. This study did not look at 12-h shifts or extended work-shifts at night. Another problem is that each group was statistically analyzed separately because the 8- and 10-h groups worked at different plants, so that a direct comparison was not possible.

Daniel and Potasova (*39*) looked at two groups of operators in a chemical factory. One group worked a rapid rotation 8-h schedule (two morning shifts, two afternoon shifts, and two night shifts). The 12-h operators worked one day shift, one night shift, and 2 days off. Results of this study indicate that performance on psychomotor tasks (reaction time, tapping), but not on purely mental tasks (search task, logical reasoning), follow a circadian pattern of oral temperature. More importantly, it was found that the oral temperature of the 12-h workers dropped 4 h earlier than the 8-h group, which suggests that fatigue linked to the circadian pattern also had an earlier onset in this group.

From the finding of an earlier drop in oral temperature and the finding that the 8-h group performed better on the various tasks, it was concluded that the work demands and/or the demographic characteristics of the 12-h relative to the 8-h group differ (*39*). This point suggests that companies may be allowing 12-h shifts only under conditions where job demands are less. This may be a confounding variable in any field study of "naturally" occurring 8- versus 12-h shifts, which could tend to make extended workdays appear "safer" than they truly are when compared with 8-h shifts. This would argue for the importance of a "within subject" experimental design where the same subjects are tested on both types of shift schedules.

In a performance study of interstate highway truck drivers and bus drivers, fatigue was evaluated throughout the workday and workweek (*40*). In general, fatigue was observed after 7 to 8 h of driving. Indices of fatigue used included subjective fatigue, decrease in fine steering adjustments, increase in coarse steering adjustments, and increase in heart rate variability. Fatigue across days of driving also was indicated by a decrease in frequency of fine steering adjustments and an increase in coarse steering adjustments.

Kelly and Schneider (*16*) reported a serious attempt to make a determination of whether 12-h shifts should be allowed at locations that have a large inventory of hazardous material, such as nuclear-power generating plants and heavy-water production facilities. A company-sponsored task group was formed to evaluate the impact on public safety of 12-h shifts. Kelly and Schneider first looked at company-recorded error rates at a particular site that had 8- and 12-h shifts and determined that there was no difference between the two types of shifts. However, they felt a need for more information because of the coarseness of the data. They reviewed previous research on change in performance over time and extrapolated to 12-h shifts. Variables, such as verbal communication, reading, and observing signals and signs, were important performance descriptions upon which the literature search focused. For example, the search revealed a study that showed reading speed slowed across 4 h. It was extrapolated from these data that 12-h shifts involved 4 extra h of a poor level of reading performance relative to 8-h shifts. Overall, the analysis concluded that human errors were doubled with 12-h shifts, and the company decided not to implement a 12-h schedule at nuclear-generating stations. However, at certain plants powered by fossil fuel where the public is at less risk, extended workdays may be adopted.

Rosa and Colligan (*32*) reported a study of 8- and 12-h control-room operators at a nuclear powerplant using the NIOSH performance battery described earlier. Physical demands for these operators were reported as "light." Grammatical reasoning (reaction time and errors), digit addition (number correct and errors), and dual reaction time (reaction time and misses) all showed decrements on 12-h shifts. None of the tasks showed improvements. Also, cumulative sleep debt was reported to be equal on 8- and 12-h shifts. Even though performance tended to improve across the 12-h workweek but not across the 8-h workweek, the authors concluded that "...the 12-h schedule is inferior."

However, Lewis and Swaim (*41*) reported on the very same data, but did not statistically account for practice effects. They concluded that alertness actually improved on 12-h shifts. They also reported that event fact sheets and technical specification compliance logs showed no difference between the two shift schedules. Also, most operators and all 15 of the on-shift managers judged that workers were more effective on 12-h shifts.

A few studies in the context of the health care industry have been performed. One study (*42*) measured quality of nursing care prior to and after the change to a 12-h shift in a 6-bed surgical intensive care unit involving a staff of 30 registered nurses. Quality of care pertained to the documentation of patient care on the general chart, admission-assessment, progress notes and care plan, as well as observation of care relative to prevention of injury, protection from infection, special treatments, and special procedures. Fatigue was measured after the change to 12-h shifts via three measures: (1) a 30-item fatigue checklist referred to as the subjective sympoms of fatigue test, (2) 3-min (minute) reasoning test, and (3) a paper and pencil search task called the vital signs forms test. Results indicated that while quality of care maintained a high level, there was some indication of fatigue across the 12-h shift. There were subjective reports of increased physical symptoms, such as drowsiness and tiredness. Performance decreased across the 12-h shift, but the authors reported that the decrease that occurred in the last half of the shift was less than that which occurred during the first half of the shift.

A more recent study (*43*) of quality of care comparing 8- and 12-h shifts in two hospitals indicated a decrease in MONITOR scores (measures of quality) on 12-h shifts. Individual measures of performance were not taken in this study.

In contrast to most of the studies cited above that were concerned with occupations that have high levels of cognitive or mental work loads, a recent study by Jorgensen, Jensen, and Kato (*44*) studied muscle fatigue of bricklayers. This study dealt with detection of muscle fatigue throughout the 8-h day in trunk extensors of bricklayers. Electromyographic (EMG) signs of muscle fatigue developed during the workday in the paravertebral muscles; i.e., significant decreases in the mean spectral frequency (MSF) EMG and increases in the amplitude of EMG are present. This indicates that the isometric endurance of the trunk extensor was lowered by the end of the workday. However, heart rate and self-reported fatigue did not change after working approximately 4 h.

A neutral effect of extended workdays was found in a study by Peacock, Glube, Miller, and Clune (*45*), which examined the effects of 12-h shifts on members of the Dartmouth (England) City Police Force. A rapid-rotation 8-h schedule (3 nights, 3 evenings, 3 days, 4 days off) was compared with a rapid-rotation 12-h schedule (2 nights, 1 day off, 2 days, 3 days off). Exercise response using ergometry, blood pressure, urinary catecholamine's, CFF, the Baddeley test of grammatical reasoning, and subjective responses were measured. The ergometry and urinary catecholamine tests were done only once per shift cycle, since it was thought that these tests would be stable across the workweek. The other tests were given at the start and end of each shift across the workweek.

The police officers were able to achieve higher work loads on the ergometry tests with less physiological strain and had a lower average diastolic blood pressure under the new 12-h system (*45*). The 12-h shift also was found to be better with regard to sleep length and quality. No effects of shift length on urinary catecholamine levels, CFF, and subjective alertness were observed. Overall, it was concluded that there were no disadvantages to the 12-h schedule. These fast rotation schedules are seldom used in the United States.

The USBM conducted a study (*55*) designed to examine the safety and health implications of extended workdays at an underground copper, lead, and zinc mining operation.[4] Measures were taken before and after a change from the old 7 days on, 2 days off 8-h continuous schedule to the new 4 days on, 4 days off 12-h continuous schedule, including (1) behavioral performance measures to analyze perceptual-motor changes, (2) continuous heart-rate monitoring and aerobic capacity measures to analyze physical fatigue, (3) pulmonary-respiratory measures to examine air-contaminant exposure, and (4) a variety of self-report questionnaires to measure perceived adaption and satisfaction with the new schedule. A control group consisting of 5 days on, 2 days off shift workers at the same mine was also included.

Survey results indicated an overwhelming support for extended workdays at this mine.[5] However, self-reported mood scales and the Stanford Sleepiness Scale indicated that workers on the 12-h night shift experienced more sleepiness and lowered energy-alertness levels after the eighth hour into their shift. The 12-h shifts did not seem to be associated with a decrease in most measures of performance across the shift. Only on one measure of physical endurance task (tapping lapses) was there a decrease in performance across the shift for the 12-h night shift. Most of the physiological and pulmonary data indicated few differences between the 8- and 12-h shifts.

In this study, the workers on 12-h shifts were expected to lodge at the minesite during their 4-day shift week because of the remote location of the mine.[6] This undoubtedly had a beneficial effect on the sleep and rest between shifts. This was confirmed by the diary data that indicated improved sleep quality and no lessening of sleep length, as compared with the worker's 8-h schedule.

Based upon the overall acceptance of the new schedule by the workers and lack of evidence to suggest serious performance decrements, it was recommended that the mine retain the 12-h schedule, with certain precautionary measures to ensure the safety of the workers.[7] Such measures included maintenance of the on-site lodging for 12-h workers, continuous observation and evaluation of group *and* individual adjustment, and customizing work tasks and work breaks to accommodate longer work-hours.

Field studies are critical in testing particular interventions involving shift schedules before they may be completely accepted. However, lack of control over important factors in these types of studies can lead to divergent conclusions. Measures on behavioral tasks have shown either decrements in performance (*15, 32, 39-40*) or no differences (*45*) with extended workdays relative to 8-h shifts.[8] Physiological measures have shown lowered performance (*44*), and no differences (*15*) or improvements (*45*) with extended workdays. Even the same study can lead to different conclusions (*32, 41*).

Results from field studies of extended workdays based exclusively on subjective responses likewise are not entirely consistent. For example, a survey and interview study was undertaken for 12-h operations in the Alberta, Canada, petrochemical industry, with funding support from the Occupational Hygiene Branch, Occupational Health and Safety Division, Alberta Workers' Health, Safety and Compensation (*46*). A sample of 716 12-h respondents was selected from workers employed in Alberta gas processing plants, oil refineries, and chemical, petrochemical, and fertilizer plants. Adjustment problems with the extended workday schedule were reported by 24 pct of the respondents. Ninety percent of the respondents were satisfied with the schedule. Respondents also indicated that environmental stressors were no more of a problem with the 12-h schedule than they were with the old 8-h schedule. Other factors that either remained the same or improved with the extended workday schedule in the self-reports were job performance, ability to concentrate, interpersonal relationships at work, amount of sleep, and health. However, some workers indicated that on particularly stressful days, the 12-h shift is more difficult and fatiguing. Interviews revealed that, in general, managers

[4]A report on work performance analysis of extended workdays in an underground mine was prepared in 1992 by J. C. Duchon, C. M. Keran, B. Nelson, and T. J. Smith, BuMines, Minneapolis, MN. Also, see reference 55.

[5]See footnote 4.

[6]See footnote 4.

[7]See footnote 4.

[8]See footnote 4.

perceive few adjustment problems with the 12-h schedule (except for some older workers), less absenteeism, less tardiness, and no effect on accidents and health. However, at least one-third of the managers indicated that fatigue with the longer workday is a problem causing decrements in performance and more errors.

A second survey of operations using extended workdays found less uncertainty about perceived benefits of longer shifts, based on subjective impressions of those responsible for managing industrial operations. In an article published in the "Industrial and Labor Relations Review" (*47*), the authors report on their results of interviews with management representatives in 50 plants in the U.S. and Canadian chemical and petroleum industries. They report that in *all* the plants studied, the change in shifts from 8- to 12-h improved morale of the work force without impairing efficiency, job safety, or workers' health. They report, however, that some older workers may have problems adjusting to the 12-h shift and that industries with more arduous work should be cautious about implementing the longer shift. This article also gives an excellent summary of extended workdays from management's perspective. Such topics as wage and staffing factors, and labor relations are discussed. While this report should not be considered a well-controlled scientific study, it nevertheless should not be excluded from consideration.

ACCIDENT AND INJURY ANALYSIS STUDIES

There are a few studies of accidents or injury rates that offer some insight into accident risk associated with extended workdays. An analysis of the time dependence of occupational accidents (*20*) indicates that in most industrial settings, the level of risk for accidents varies according to work demands and environmental circumstances. Further, these factors are closely related to the length of sleep preceding the shift, shift rotation, duration of the shift, and workday organization. Hamelin (*48*) looked at transportation accidents for lorry drivers in France. Risk rates of drivers were measured based upon actual driving time. It was reported that risk rates tend to increase across the length of the driving period. Further analysis indicated that relative risk is higher at night, especially after 11 h of work. This is in agreement with the notion that fatigue is linked to work load, shift duration, and time of day effects. However, for a subset of workers (Transportation Branch), the opposite was true. These workers are far more experienced than other drivers and the author hypothesized that they have a better awareness of their ability or inability to compensate fatigue and to drive under difficult conditions.

Lees and Laundry (*49*) studied accident and morbidity trends in a plant that produces synthetic yarn in Canada. The data were derived from company records from 1965 to 1975 while the work force was on a traditional southern swing (7 days on, 2 days off, rotating between day, afternoon, and night shifts) 8-h shift schedule, and from 1975 to 1985 after the plant changed to a "rotating" 12-h shift schedule. The exact schedule parameters were not described. Accidents, as well as reported stress-related illnesses, such as headaches, gastric ulcers, diarrhea, and general malaise, decreased on the 12-h schedule.

Several studies indicate opposite results. Cohen and Lin (*50*) identified risk factors associated with on-the-job accidents of workers falling from ladders. The researchers interviewed 123 victims of such accidents (not necessarily at the same plants) and 142 control workers with similar characteristics to the victims (at the same plants where the victims worked). Accident risk was analyzed for four factors: (1) personal but not occupation related (i.e., body dimensions, health, drinking, risk-taking behavior); (2) personal and occupation related (i.e., experience, job satisfaction, location); (3) working conditions including shift; and (4) ladder use (i.e., exposure). It was found that working long hours, a subcategory of "working conditions," was one of the most predictive factors for accidents. This was interpreted as an indication of fatigue. However, it may be that risk exposure (which is prolonged with longer hours) rather than fatigue was the cause.

Similarly, Leigh (*51*), Levin, Olier, and Whiteside (*52*), Waersted and Westgaard (*53*), and Hunting (*54*) have looked at accident records and have concluded that long workdays are correlated with accidents or injuries. Leigh (*51*) used 1979 data from a national survey of industrial workers to statistically model the probability of becoming injured on the job and receiving worker's compensation. When job-related variables were entered into the regression equation, most personal variables, such as age, education, and marital status, were found not to contribute significantly to accident risk. When work-related variables were entered, frequent overtime increased the chances of suffering an accident while tenure with the firm decreased the chances. Hunting (*54*) also reported a 1.5- to 2.0-fold increase in accident risk for workers engaged in overtime in the U.S. coal mining industry during a 2-year period, relative to the risk for regular working hours.

Levin, Olier, and Whiteside (*52*) studied two paint plants over 10 years. Accidents reported on day, afternoon, and night shifts, and by time of shift were investigated. There was an indication that there was a significant but slight increase in accidents on the night shift, particularly during the last 3 h of the shift.

In the Waersted and Westgaard (*53*) study, the length of daily working hours as a risk factor for the development of musculoskeletal complaints was studied by comparing the sick leave statistics of 408 sewing machine operators on full-time schedules (8-h days) with 210 operators on part-time schedules (5-h days). Working part time was shown to postpone by 6 months the occurrence of sick leave due to musculoskeletal disorders. Also, part-time workers reported significantly lower levels of low back pain.

Again, these reports of accident and injury investigations are not consistent. Both increases and decreases in accidents were reported. Perhaps the study by Hamelin (*48*) of commercial drivers in France offers a good example of these divergent findings. That is, even within the same analysis, two different conclusions are drawn from two different samples.

CONCLUSIONS

In conclusion, a review of laboratory studies, field studies, and accident and injury analysis studies of extended workdays encompasses research that has positive, negative, and neutral results. Reasons for this lack of consistency in the findings may include the dependent measures used, the type of work done within the 8- or 12-h shift, and especially for the field studies, the motivations or biases of the experimenters and subjects. It also is possible, if not likely, that the specific consequences of introducing extended workdays into a particular operation are highly dependent upon the particular organizational, operational, and work-force characteristics of that operation. For instance, the degree to which management stresses safety, prior labor-management relations, cognitive or physical work load, average age of the work force, and commuting time may affect the outcome of extended workdays.

However, inconsistencies still remain among studies that have used similar outcome measures. For instance, Rosa and Colligan (*32*) and Lewis and Swaim (*41*) drew opposite conclusions from the same data. Even within the same industry, controversy exists. Kelly and Schneider (*16*) rejected the use of 12-h workdays in a nuclear-power company, whereas Lewis and Swaim (*41*) suggested adoption of a new extended workday schedule for the same type of operation.

In an area fraught with inconsistencies, there are several valid comments that can be safely made: (1) Workers tend to embrace the use of extended workdays; (2) in spite of item 1 above, some studies in some industries revealed performance and/or safety decrements associated with extended workdays; and (3) more research on extended workdays is needed, especially for companies and industries considering the use of extended workdays where safety is of major importance. These conclusions underscore the need for caution by companies using or considering the use of extended workdays. Based upon this review, it is recommended that the use of extended workdays be accompanied by special efforts to create safe working conditions. Also, since no *a priori* predictions from prior research can be made with certainty about the probable consequences of introducing 10- or 12-h shifts into a mining company, evaluation of each miner should be made on a periodic basis. For instance, survey methods have been developed by the USBM to evaluate schedules before and after changes are made.[9] Also, long-term monitoring of health, accident, and production effects should be considered.

REFERENCES

1. U.S. Congress, Office of Technology Assessment. Biological Rhythms: Implications for the Worker. U.S. GPO, September 1991, 249 pp.

2. U.S. Subcommittee on Investigations and Oversight. Biological Clocks and Shiftwork Schedules. U.S. GPO, Rep. 29-312 0, 1984, 407 pp.

3. Andlauer, P. Shiftwork. Ch. in Encyclopedia of Occupational Health and Safety, Volume II. Int. Labour Off., Geneva, Switzerland, 1972, pp. 2023-2027.

4. Carpentier, J., and P. Cazamian. Night Work: Its Effects on the Health and Welfare of the Worker. Int. Labour Off., Geneva, Switzerland, 1977, 85 pp.

5. Walker, J. Social Problems of Shiftwork. Ch. in Hours of Work, ed. by S. Folkard and T. Monk. Wiley, 1985, pp. 211-225.

6. Johnson, L. C., D. I. Tepas, W. P. Colquhoun, and M. J. Colligan (eds.). Biological Rhythms, Sleep, and Shift Work. Spectrum Publ. (New York), 1981, 618 pp.

7. Reinberg, A., N. Vieux, and P. Andlauer (eds.). Night and Shift Work: Biological and Social Aspects. Pergamon, 1981, 509 pp.

8. Rutenfranz, J. Occupational Health Measures for Night- and Shiftworkers. Ch. in Journal of Human Ergology 11. Cent. Acad. Publ., Tokyo, Japan, 1982, pp. 67-86.

9. LaDou, J. Health Effects of Shift Work. West. J. Med., v. 137, 1982, pp. 525-530.

10. Moore-Ede, M. C., and G. S. Richardson. Medical Implications of Shift-Work. Annu. Rev. Med., v. 36, 1985, pp. 607-617.

11. Czeisler, C. A., M. C. Moore-Ede, and R. M. Coleman. Rotating Shift Work Schedules That Disrupt Sleep Are Improved by Applying Circadian Principles. Science, v. 217, 1982, pp. 460-464.

12. Thierry, H., and B. Jansen. Work and Working Time. Handbook of Work and Organizational Psychology, ed. by P. J. Drenth, H. Thierry, P. J. Willems, and C. J. de Wolff. Wiley, 1984, pp. 597-642.

13. Cohen, A. R., and H. Gadon. Alternative Work Schedules: Integrating Individual and Organizational Needs. Addison-Wesley Publ. Reading, MA, 1978, 137 pp.

14. Kogi, K. Job Content and Working Time: The Scope for Joint Change. Ergonomics, v. 34, No. 6, 1991, pp. 757-773.

15. Volle, M., G. R. Brisson, M. Perusse, M. Tanaka, and Y. Doyon. Compressed Work-Week: Psychophysiological and Physiological Repercussions. Ergonomics, v. 22, No. 9, 1979, pp. 1001-1010.

16. Kelly, R., and M. Schneider. The Twelve-Hour Shift Revisited: Recent Trends in the Electric Industry. J. Hum. Ergology, v. 11, 1982, pp. 369-384.

[9]See footnote 4.

17. Tepas, D. T. Flexitime, Compressed Workweeks and Other Alternative Work Schedules. Ch. in Hours of Work, ed. by S. Folkard and T. Monk. Wiley, 1985, pp. 147-164.

18. Bonnet, M. H. Dealing With Shift Work: Physical Fitness, Temperature and Napping. Work and Stress, v. 4, No. 3, 1990, pp. 261-274.

19. Wilkinson, R., S. Allison, M. Feeney, and Z. Kaminska. Alertness of Night Nurses: Two Shift Systems Compared. Ergonomics, v. 32, No. 3, 1989, pp. 281-292.

20. Wojiczak-Jaroszowa, J., and D. Jarosz. Time-Related Distribution of Occupational Accidents. J. Saf. Res., v. 18, 1987, pp. 33-41.

21. Scott, A. J., and J. LaDou. Shiftwork: Effects on Sleep and Health With Recommendations for Medical Surveillance and Screening. Ch. in Occupational Medicine: State of the Art Reviews, ed. by A. J. Scott. Hanley and Belfus, Philadelphia, PA, v. 5, No. 2, 1990, pp. 273-299.

22. Harrington, J. M. Shift Work and Health: A Critical Review of the Literature. H. M. Stationery Off., London, 1978, 28 pp.

23. Minors, D. S., A. N. Nicholson, M. B. Spencer, B. M. Stone, and J. M. Waterhouse. Irregularity of Rest and Activity: Studies on Circadian Rhythmicity in Man. J. Physiol., v. 381, 1986, pp. 279-295.

24. Krueger, G. P. Sustained Work, Fatigue, Sleep Loss and Performance: A Review of the Issues. Work and Stress, v. 3, No. 2, 1989, pp. 129-142.

25. Morgan, B. B. Effects of Continuous Work and Sleep Loss in Reduction and Recovery of Work Efficiency. Am. Ind. Hyg. Assoc. J., v. 35, 1974, pp. 13-20.

26. Colquhoun, W. P., M. J. Blake, and R. S. Edwards. Experimental Studies of Shift-Work III: Stabilized 12-Hour Shift Systems. Ergonomics, v. 12, No. 6, 1969, pp. 865-882.

27. _____. Experimental Studies of Shift-Work I: A Comparison of Rotating and Stabilized 4-Hour Shift Systems. Ergonomics, v. 11, No. 6, 1968, pp. 437-453.

28. _____. Experimental Studies of Shiftwork II: Stabilized 8-Hour Shift Systems. Ergonomics, v. 11, No. 6, 1968, pp. 527-546.

29. Mital, A. Comprehensive Maximum Acceptable Weight of Lift Database for Regular 8-Hour Shifts. Ergonomics, v. 27, No. 11, 1984, pp. 1127-1138.

30. _____. Prediction Models for Psychophysical Lifting Capabilities and the Resulting Physiological Responses for Work Shifts of Varied Durations. J. Saf. Res., v. 17, 1986, pp. 155-163.

31. Rosa, R. R., D. D. Wheeler, J. S. Warm, and M. J. Colligan. Extended Workdays: Effects on Performance and Ratings of Fatigue and Alertness. Behav., Res. Methods, Instrum. and Comput., v. 17, No. 1, 1985, pp. 6-15.

32. Rosa, R. R., and M. J. Colligan. Extended Workdays: Effects of 8-Hour and 12-Hour Rotating Shift Schedules on Performance, Subjective Alertness, Sleep Patterns, and Psychosocial Variables. Work and Stress, v. 3, No. 1, 1989, pp. 21-32.

33. _____. Long Workdays Versus Restdays: Assessing Fatigue and Alertness With a Portable Performance Battery. Hum. Factors, v. 30, No. 3, 1988, pp. 305-317.

34. Mahan, R. P. The Effects of Extended Work on Multi-Dimensional Judgments of a Manufacturing Process. Int. J. Hum. Factors in Manuf., v. 1, No. 2, 1991, pp. 155-165.

35. Alluisi, E. A. Comments on Mechanisms of Response. Ch. in Acquisition of Skill, ed. by E. O. Bilodeau. Academic, 1966, pp. 201-213.

36. Lindsley, D. B. (ed.). Radar Operator Fatigue: The Effects of Length and Repetition of Operating Periods on Efficiency of Performance. Off. Sci. Res. Dev., Washington, DC, OSRD-3354, 1944, 40 pp.

37. Smith, K. U. Origins of Human Factors Science. Hum. Factors Soc. Bull., v. 30, No. 4, 1987, pp. 1-3.

38. Grandjean, E. P., G. Wotzka, R. Schaad, and A. Gilgen. Fatigue and Stress in Air Traffic Controllers. Ergonomics, v. 14, No. 1, 1971, pp. 159-165.

39. Daniel, J., and A. Potasova. Oral Temperature and Performance in 8 h and 12 h Shifts. Ergonomics, v. 32, No. 7, 1989, pp. 689-696.

40. Miller, J. C., and R. R. Mackie. Effects of Irregular Schedules and Physical Work on Commercial Driver Fatigue and Performance. Ch. in Human Factors in Transport Research, ed. by D. J. Oberne and J. A. Levis. Academic, 1989, pp. 126-133.

41. Lewis, P. M., and D. J. Swaim. Evaluation of a 12-Hour/Day Shift Schedule. Paper in Proceedings of the Human Factors Society 30th Annual Meeting. Hum. Factors Soc., v. 2, 1986, pp. 885-889.

42. Mills, M. E., B. Arnold, and C. M. Wood. Core-12: A Controlled Study of the Impact of 12-Hour Scheduling. Nurs. Res., v. 32, No. 6, 1983, pp. 356-361.

43. Todd, C., N. Reid, and G. Robinson. The Quality of Nursing Care on Wards Working Eight and Twelve Hour Shifts: A Repeated Measures Study Using the MONITOR Index of Quality of Care. Int. J. Nurs. Stud., v. 26, No. 4, 1989, pp. 359-368.

44. Jorgensen, K., B. R. Jensen, and M. Kato. Fatigue Development in the Lumbar Paravertebral Muscles of Bricklayers During the Working Day. Int. J. Ind. Ergon., v. 8, 1991, pp. 237-245.

45. Peacock, B., R. Glube, M. Miller, and P. Clune. Police Officers' Responses to 8 and 12 Hour Shift Schedules. Ergonomics, v. 26, No. 5, 1983, pp. 479-493.

46. Wynn, S. C. The Impact of the Twelve Hour Shift on Petrochemical Process Operators. Occup. Hyg. Branch, Occup. Health Saf. Div., Alberta Workers' Health, Saf. and Compens., Edmonton, AB, 1979, 133 pp.

47. Northrup, H. R., J. T. Wilson, and K. M. Rose. The Twelve-Hour Shift in the Petroleum and Chemical Industries. Ind. Labor Relat. Rev., v. 32, No. 3, 1979, pp. 312-326.

48. Hamelin, P. Lorry Driver's Time Habits in Work and Their Involvement in Traffic Accidents. Ergonomics, v. 30, No. 9, 1987, pp. 1323-1333.

49. Lees, R. E., and B. R. Laundry. Comparison of Reported Workplace Morbidity in 8-Hour and 12-Hour Shifts in One Plant. J. Occup. Med., v. 39, No. 3, 1989, pp. 81-84.

50. Cohen, H. H., and L. J. Lin. A Retrospective Case-Control Study of Ladder Fall Accidents. J. Saf. Res., v. 22, 1991, pp. 21-30.

51. Leigh, J. P. Individual and Job Characteristics as Predictors of Industrial Accidents. Accid. Anal. Prev., v. 18, No. 3, 1986, pp. 209-216.

52. Levin, L., J. Olier, and J. R. Whiteside. Injury Incidence Rates in a Paint Company on Rotating Production Shifts. Accid. Anal. Prev., v. 17, No. 1, 1985, pp. 67-73.

53. Waersted, M., and R. H. Westgaard. Working Hours as a Risk Factor in the Development of Musculoskeletal Complaints. Ergonomics, v. 34, No. 3, 1991, pp. 265-276.

54. Hunting, K. L. Epidemiology of Transport-Related Coal Mining Injuries. Paper in Proceedings of the 21st Annual Institute on Coal Mining Health, Safety and Research, ed. by E. Hugler, A. Bacho, and M. Karmis. VA Polytech. Inst. and State Univ., 1990, pp. 45-52.

55. Duchon, J. C., C. M. Keran, and T. J. Smith. Extended Workdays in an Underground Mine - A Work Performance Analysis. Hum. Factors, v. 36, 1994, In Press.