CIRCADIAN® Report

# ALTERNATIVE WORK SCHEDULES

## Determining the Best or Optimal Shift Patterns for your Operation

CIRCADIAN®

24/7 WORKFORCE SOLUTIONS

# Introduction

There are literally thousands of mathematically possible alternative work schedules available for use in 24 hour operations. However, there is no single best schedule. Every schedule brings with it some measure of physical stress and social conflict. Human biology is simply not designed to operate around the clock, and our individual family and social needs do not always align with our shift schedules. Nevertheless, we have become a 24-hour society and continuous operations have become critical in supporting our modern economy.

However, there is a best schedule for each group of shiftworkers, which can be readily determined through an educational process and some creative mathematical designs based on science and experience. Thus, the optimal solution for any particular facility is not only determined by the business goals and operational needs of that site or facility, but also on the family and social preferences and lifestyle needs of the employees who work there and on the biological factors that impact employee health, safety, and performance.

In 24/7 operations, shift schedules are typically changed or redesigned when the current shift schedule no longer properly supports the production requirements, or when it no longer satisfies the needs of the majority of the workforce. Employee needs change over time as we age, as our family situations change, and as the workforce composition changes due to attrition and the hiring of younger people and/or imported labor, or to a higher percentage of female personnel. Whatever the reasons, it's often healthy for both the employees and the business to evaluate other scheduling options together, particularly when there are persistent requests from the workforce to do so. Unfortunately, simply looking at the limited batch of commonly known shift schedules will seldom yield the best result, and often no solution at all, because of the difficulty in achieving a consensus among the workers themselves. Even in the rare event that a consensus is achieved, nagging doubts persist as people experience the stress unique to that new schedule. It is therefore necessary to first satisfy both management and the workforce that every mathematical possibility has been evaluated, and that the resulting short list of 6 or 7 alternatives are the best of the best and that there is nothing else out there that's any better for this plant or for this group of workers. That can only be achieved through an objective and systematic educational process that involves the entire shiftwork force in the solution.

## Components of Best Practices in Shift Scheduling

There is no one single, optimal shift system that can be used at all work places. One size does not fit all. The shift schedule structure must take into account business goals, the operational constraints, the employee preferences, and the human factors (physiological and sociological) criteria. It is also important to ergonomically consider the work environment and the type of tasks involved.

Although there is still some discussion in the scientific community regarding certain schedule features, there is general agreement about which are the best practices for designing safe, healthy, and productive schedules...and these key components have been validated by extensive field experience. Thus, the most important factors for evaluating the effectiveness of a shift include:

**Duration and distribution of working time:**

- Number of consecutive shifts
- Length of shift
- Time off between shifts
- Overtime levels

**Sleep/wake transitions:**

- Daytime vs. nighttime sleep
- Number of transitions from daytime to nighttime sleep

**Periodic long breaks (3 days or more):**

- Full rest and recovery plus quality time
- Return from long breaks onto day shifts

**Sequence of shifts:**

- Fixed versus rotating
- Speed of rotation
- Direction of rotation

**Scheduled working time:**

- Starting time of shifts
- Ending time of shifts

**Schedule pattern of work days and off days:**

- Regular or repeating patterns
- Irregular or variable patterns

## Duration and Distribution of Working Time

Every individual worker needs a recovery period from work at regular intervals. Given the differences in work environment, physical and mental work-related stress, and individual family circumstances, it is challenging to specify specific limits. In general, however, experts recommend limiting the number of consecutive working days to five, six or seven days (Knauth 1993). However, it is important to take into account the length of the workday when deciding the number of consecutive shifts. Experts recommend limiting 8-hour shifts to a maximum of seven in a row, and 12-hour shifts to a maximum of four or five in a row, to avoid excessive sleep deprivation and fatigue...particularly with night shifts and day shifts that start before 7am.

It is equally important to consider the number of hours worked per week. It has been noted that long work weeks increase stress levels, both by increasing the demands for maintaining high performance levels while facing increased fatigue levels, and by increasing the time a worker is exposed to other sources of workplace stress and safety hazards. There is growing evidence that when the work week is extended by excessive overtime, the increased number of extended or consecutive shifts directly correlate with health and safety issues as a result of the increased stress levels and chronic sleep deprivation. High levels of stress are considered to be contributors to the development of cardiovascular disease, musculoskeletal type injuries, gastrointestinal disorders, and certain mental problems (Spurgeon et al. 1997). Moreover, a study analyzing the lifestyle of hundreds of people who have experienced a heart attack found that 65% of them regularly worked more than 60 hours/week, with some working over 50 hours of overtime per month, as well as half of their vacation days and holidays (Uehata 1992).

When considering the amount of hours worked, it is thus important to take into account not only the regularly scheduled hours, but also the overtime, whether mandatory or voluntary. While the typical shiftworker logs only 250-350 hours of overtime per year, there are those in every workforce who annually exceed 500, 600, even 1000 or more overtime hours. Moreover, the annual overtime hours for shiftworkers has been steadily increasing over the past decade as businesses strive to "do more with less". It is not unusual today for overtime levels to exceed 20%, in terms of extra hours worked over and above regularly scheduled hours. It should also be noted that overtime is rarely evenly distributed among employees. As a result, it is typical to find people working 40% to 50% overtime levels within an organization that is only averaging 12%-15% overtime overall. Fatigue-related human error due to excessive overtime was cited as a major causal factor in the Texas City Refinery explosion that killed 15 people and injured hundreds more (U.S. Chemical Safety Board, 2007). In addition to safety incidents, excessive overtime equates to higher absenteeism and worker compensation costs.

In 24/7 operations, what drives overtime is the staffing level…not the workload. If the workforce is understaffed, overtime will increase and the integrity of the work schedule will be compromised. The resulting irregularity of the shift pattern, in turn, creates further disruption in one's sleep/wake patterns, thus decreasing quality of life, increasing health issues, and increasing fatigue and the probability of human error that causes safety incidents and loss of productivity. To avoid this scenario requires not only sufficient staff to fill the required positions, but also additional personnel to provide relief coverage for the scheduled benefit days off (e.g. vacations, and floating holidays, etc.) for sick or personal days, and for any training days and special assignments that must be completed on an ongoing basis. Otherwise, the required coverage will have to be achieved through overtime. Apart from the staffing level, the next best way to offset the negative effects of overtime is to ensure that the extra shifts required are distributed across the entire workforce on both a monthly and annual basis to the best possible degree.

## Time Off Between Shifts

The rest period between shifts should provide enough time shiftworkers to obtain adequate sleep. Kurumatani et al. (1994) found a very high correlation with the length of the time off between consecutive shifts and sleep duration, and concluded that individuals who had 16 hours of time off between shifts had a better chance to achieve a sleep duration of seven or eight hours than those with less time off. A series of other studies have shown that rest periods of 10 hours or less between consecutive shifts result in shorter sleep episodes, sometimes four to five hours of sleep. Thus, the time off between the end of one shift and the beginning of the next one should be at least 11-12 hours (Knauth 1997), all factors considered.

## Time Off Between Blocks of Work Days or Shift Turns

There is clear agreement that a single day off between blocks of workdays is inadequate for achieving full rest and recovery especially after night shifts (Knauth 1997). Research data has also shown that mood, irritability and social satisfaction tend to be worse on the first rest day compared with subsequent rest days. The amount of rest needed between blocks of working time is related to the number and length of consecutive shifts. Most studies have confirmed what every shiftworker knows…that feelings of ill-being are worse on days off after night shifts compared to days off after day shifts, especially on the first and second days off. Further research and field experience has confirmed that a minimum of 2 days off (i.e. 48 hours) should be provided to ensure full rest and recovery between shift turns, with a periodic long break of at least 3 or 4 days off built into each schedule cycle.

The adaptation to night work never fully occurs, even after an extended series of consecutive night shifts. This results in cumulative sleep deprivation and fatigue. Some studies have shown that workers need at least three days off to recover from seven consecutive 8-hour night shifts. Shiftworkers on a schedule with only three consecutive night shifts only need two days off to fully recover (Kecklund and Akerstedt 1995). The length of the shift is also an important factor. Thus, schedules with 12-hour shifts often have short sequences of workdays (two to four) followed by several days off, as compared to 8-hour shifts that require more consecutive shifts and fewer (e.g. 1-2) days off.

## Long Breaks

Nevertheless, long stretches of days off before night shifts could also be challenging. Many studies have shown that certain performance measures decrease during night shifts following five or more consecutive days off than after three or four days off. This means that workers have become are more adapted to a daytime biological cycle after a long break, and this makes it more difficult for them to adjust back to night work. In addition, the mental adjustment required to catch up with the changes that have occurred while they were off-duty is compounded by the physical adjustment that has to be made in terms of now having

to stay awake all night and having to sleep in the daylight for the first time in a week or more. Thus, it is advisable to set up the shift pattern so that you can return from the long break onto a day shift to ease the transition, and many companies require that workers coming back from a long break report to a briefing room 20-30 minutes prior to their shift start to help bring them up to date on the process status before starting their shifts.

## Duration of Shifts

The traditional workday has long been 8-hour shifts in many manufacturing industries, with a Monday through Friday work schedule dating back to the early 1900's. However, with the rapid growth of automation and extended hours of operation in the 1980s and 1990s, coupled with an influx of younger people, workers started demanding 12-hour shifts to obtain more days off and weekends off than mathematically possible with 8-hour schedules. And with the increase in automation came an increase in continuous operating environments requiring full use of productive capacity 24/7. As a result, the most commonly utilized schedule structures today has become those based on 12-hour shifts operating 24/7 with 4 "balanced" crews (i.e. same number of people and skills in each crew, and same productive capacity with each shift). These types of schedules are being driven by the employees, although 8-hour shifts are still quite acceptable to management.

When 8s are used, three of four crews are needed to cover each 24-hour period (thereby requiring employees to work 3 out of every 4 days of the year). However, when 12s are utilized, only two of four crews are needed to cover each 24-hour period (thereby requiring employees to work only half of the days of the year). Compared to 8-hour shifts, 12-hour shifts are often popular among workers because they provide not only double the number of days off, but also twice as many weekend days off per year as is mathematically possible with 8-hour shift schedules. In facilities where new schedules have been implemented, and where when employees were involved in identifying their own work schedule through an educational, employee involvement process, they have tended to select 12-hour shifts. The key, however, is to provide the workforce with the factual information needed for them to make good value judgments and informed decisions for themselves and their families, and thus take "ownership" in the newly selected schedule. Regardless of the length of shift or type of shift pattern, all schedules work best when the ownership vests with the employees who have to work them.

## Fixed Versus Rotating Shifts

One of the most challenging questions in shiftwork schedule design is whether to rotate crews or keep them fixed. With rotating shifts, employees' scheduled work hours change periodically. Under a fixed schedule, employees' work hours are the same on every workday.

From the employees' point of view, fixed schedules provide stable work hours, making it easier for them to plan their lives. Fixed shifts may also be related to less sleep disruption and fatigue, at least for the day shift personnel. However, workers on fixed night shifts may end up even more fatigued and unhealthy than workers on rotating shifts because they invariably switch back to a daytime schedule on their days off to accommodate family needs and personal activities. This essentially creates a fast, defacto rotation that can be stressful for many people. Fixed evening shifts may also have a substantial negative impact on family life due to the social isolation inherent in those work hours (i.e. typically 3pm-11pm). All of these factors can also create difficulties in balancing the mix of skills, qualifications, and experience across each of the crews and thus can cause imbalances in productivity. They also pose significant communication and training challenges for both management and the employees.

There is still a lack of conclusive data on the effects of fixed versus rotating shifts on safety and performance. Studies comparing workers on fixed and rotating shifts often find that the groups are not similar in age, marital status, freedom to choose the shift, the type of task performed and/or on sleep management. Some studies have found that permanent night workers sleep much less and have a higher prevalence of fatigue, poorer performance and more safety issues than rotating shiftworkers (Tepas and Carvalhais 1990, Alfredsson et al. 1991). However, some researchers have described a lower accident rate, a higher rate of performance, and a lower rating of effort in permanent night workers as compared to rotating shiftworkers (Gold et al. 1992, Totterdell et al. 1994). Certainly, the type of shift pattern can also create mixed results with these studies. Experts conclude that the best solution is to provide employees with education on the research findings and on the personal pros and cons of fixed vs. rotating shifts, and then let them collectively identify and take ownership in the preferred approach. In the final analysis, this will yield the best result in terms of personal adaptation and performance.

When evaluating rotating schedules, two unique factors need to be considered: speed and direction of rotation. Speed of rotation refers to the number of consecutive shifts worked (i.e., morning, evening, night) before changing to a different shift, and to the amount of time off in between those shift changes. Despite this being a key factor, it is still a controversial scheduling issue. Shiftwork experts in the U.S. tend to favor slow rotations (e.g. staying on the same shift for 1 or 2 weeks, while European experts prefer quick (e.g. daily) shift rotations. The arguments in favor of quick rotations are as follows (Knauth 1993):

- Quick rotations are thought to keep the circadian rhythms in a daytime orientation; that is, the circadian rhythms are theoretically not in a constant state of disruption from switching between day and night work
- Too many consecutive night shifts may cause chronic sleep deprivation, which could lead to long-term health problems
- Shiftworkers have some free days, evenings and nights every week, allowing them more regular contact with family and friends

The benefits of the slow rotations preferred by North American experts include:

- More consistent or regular work patterns reduce the number of sleep-wake transitions between day, evening and night work, minimizing stress and maximizing sleep quantity and quality
- The body adjusts better to regularity in schedule patterns due to less biological (i.e. circadian) disruption.
- Slower rotations make it easier for workers to plan and manage their family and social lives
- Quick rotations are foreign to the North American mentality of Industrial scheduling

This is further illustrated in the Shiftwork Practices Survey of North American plants. Among the facilities reporting 8-hour rotating shifts, the majority (63%) rotated on a weekly basis, 9% rotated on a monthly basis, 11% on a bi-monthly basis, and only 17% rotated on every turn (i.e. set number of work days). For best results, however, the speed of rotation should be tailored to the specific shift pattern. For example, a 2-2-3 x 12 hour shift rotation is less stressful with a 2 week rotation (i.e. 2 weeks on the day pattern and 2 weeks on the night pattern), than with its customary rotation with every turn (i.e. shifting every 2-3 days). However, with the 3-3 and 4-4 x 12-hour schedules, it is more effective to rotate with every turn to minimize the number of sleep/wake transitions, rather than on longer intervals which literally can double the number of transitions between sleeping at night and sleeping in the daytime.

Direction of rotation refers to the sequence of shifts in the schedule, but this is only a factor for 8-hour schedules having three shifts per day. With an 8-hour schedule, for example, a forward rotation would have employees changing from morning shifts to evenings and then to nights, while a backwards or counterclockwise rotation would have employees transition from working nights, then evenings and then days. With 12-hour shifts, this issue is moot. By eliminating the evening, or "swing" shift, all 12-hour schedules inherently rotate clockwise…regardless of whether transitioning from days to nights, or nights to days.

Work schedules that move forward in time are easier and less physiologically stressful because they are consistent with the body's natural tendency towards longer days. This is readily illustrated by comparing the direction of the rotation of a shift schedule with the direction of jet travel across multiple time zones. Forward rotations are comparable to westbound flights (with a "prolongation" of the day) and backward rotations to eastbound flights (with a "shortening" of the day). Jet lag symptoms are much more severe when traveling east than when traveling west (Barton and Folkard 1993, Knauth 1995). Moreover, switching to "daylight savings time" further illustrates the "forward" or "clockwise" flow of our circadian or biological rhythms. We enjoy a good nights sleep and wake-up refreshed when we lengthen the day (and gain an hour of sleep) in the Fall, but feel sluggish and tired when we shorten the day (and lose an hour of sleep) in the Spring. Not coincidentally, automobile accidents increase 8-10% following the day that we "Spring Ahead"! This is primarily due to the fact that we humans are fundamentally "hard-wired" biologically to drift in a clockwise or forward rotation, rather than a counter-clockwise or backwards rotation.

## Scheduled Working Time: Start and End of Shifts

Regarding the shift start and end times, the main issue revolves around balancing the best time for starting the morning shift with the best time for ending the night shift, so that workers can get enough sleep before the morning shift and after the night shift. Evening shifts usually do not create a problem regarding sleep, plus they only apply to 8-hour shift patterns.

During the human 24-hour (i.e. circadian) cycle, there are two periods when alertness is low and sleeping is easy, and two periods when alertness is highest and sleeping is more difficult. The largest alertness drop normally occurs between 3:00 and 6:00 a.m., and a smaller drop occurs during the early afternoon between 1:00 and 3:00pm for most people. It is easiest to fall asleep during these times than at any other time during our daily cycle. On the other hand, alertness is highest during the morning and early evening, making it difficult to fall asleep at these times.

### Start of the Morning Shift

Most people require seven to eight hours of sleep to feel well rested and at their best. However, with a shift start time before 6:00 or 6:30a.m., achieving seven to eight hours of sleep is very difficult biologically (Folkard and Barton 1993). There is thus a general agreement that too early a start time reduces sleep before the morning shift because most workers go to bed at the usual physiological and social time. Moreover, there is a tendency for the body to reject sleep earlier in the evening. This creates cumulative sleep deprivation and fatigue for the day shift personnel, and consequently the risk of errors and accidents during their commute and in the early hours of their day shift.

### End of Night Shift

Numerous studies have shown that daytime sleep is shorter and less efficient and restorative nighttime sleep. This is due not only to environmental factors (there is more light and noise during the day) that may disturb sleep, but also to physiological factors (our circadian clock releases hormones (e.g. melatonin) that promote sleep during the night, and others (e.g. adrenalin) that promote alertness during the day). Moreover, a number of researchers have demonstrated that the later the daytime sleep starts after a night shift ends, the shorter and less quality it will be (Foret and Lantin 1972). Thus, night shifts that finish late in the morning will not allow a person to obtain enough daytime sleep, and that will lead to sleep deprivation and fatigue.

Besides the physiological factors, another issue to consider when deciding shift start and end times is the worker's commute. Late starts (and end times) for the night shift may be difficult for employees biologically and socially. Conversely, late morning shifts starts may conflict with traffic patterns in urban areas. It should also be considered that biological alertness is at its lowest for most people in the pre-dawn hours between 3:00 to 6:00 a.m. As a result, more single-vehicle accidents occur around 5:00 to 6:00 a.m. than at any other time of day. Moreover, to (proportionally) ensure the safety of employees during their commutes to and from work, it is advisable that shift start and end times do not occur during this time of day when alertness is at its lowest level. In the final analysis, all factors being considered, the best balance of shift starting times for both the day and night shifts is from 7:00 a.m. to 8:00 a.m.…traffic conditions permitting. Earlier starting times negatively impact the alertness and performance levels of the day shift, while later starts adversely affect the ability of night shift personnel to obtain adequate sleep.

# Solutions

### Optimization of the Work Schedule

The challenges faced by extended hours operations are diverse, encompassing a wide range of industries and employees. Developing and implementing an effective plan to optimize workplace health, safety and performance thus requires both a detailed knowledge of the site-specific issues and an expert grasp of continuous operations and scheduling design factors. While it is tempting to look for a one-size-fits-all solution to scheduling challenges, it simply does not exist. The "ideal" solution depends on many factors including the makeup of the workforce - male/female, younger/older, married/single, with children/no children, the nature of the work, the local customs and culture, commuting issues, type of industry, corporate policies, and State and Federal laws, Collective Bargaining or Employee Agreements, etc…not to mention the mathematical expertise required to design operationally sound and user friendly shift schedules.

### Employee Involvement on Schedule Planning and Implementation

Finding the ideal schedule for a particular facility that will minimize the costs, risks, and liabilities of the 24/7 operation requires careful attention to the process of shift schedule design. Who determines or chooses the shift schedule, and how it is determined, is vital to its success. Management-mandated or negotiated schedules usually do not properly account for the needs of the employees and can result in increased fatigue, decreased morale, and higher absenteeism and safety rates. This can obviously have negative effect on facility performance. Thus, it's critical for management, union representatives, and the employees themselves to work together in determining the best solution. Absent employee involvement, management, and union officials will invariably upset as many people as they can hope to please.

Thus, the conflicting interests of the parties involved, and the potential labor-management relations issues, often prevent the successful determination and implementation of a new shift schedule, let alone determine the best shift schedule for a given facility. At the company or corporate level, there may be concerns regarding financial aspects and production demands. From the union perspective, there may be contractual issues, and the employees will likely resist change due to uncertainties about dealing with new conditions, as well as fear of loss of income or jobs. Conversely, there may be a desire to change expressed by some segment of the workforce, usually for personal, family, social and quality of life reasons that may be inconsistent with other segments of the workforce and/or with the company's needs and union agenda.

To reach the best solution between operational needs, employees' preferences, and employee health and safety, which are key to the success of any new schedule, the involvement of both labor and management in the process of developing and implementing the new schedule is essential. Moreover, the technical support from a neutral, third party, subject matter expert has proved extremely beneficial in providing the necessary technical support, and the objectivity required to help facilitate the process, as well as to help factually resolve what are often philosophical debates and "roadblocks" based on insufficient data, mis-information, and/or misunderstanding.

### Achieving the Best Results, or "Optimal" Shift Schedule

Now comes the matter of which schedule...from literally thousands of mathematical possibilities... which is the best one for your specific operation and your unique workforce demographic and local culture? To answer this question, one must consider that, short of perhaps early retirement... there is no perfect schedule. Straight day shifts, worked Monday through Friday, is not too bad, because we humans are designed for daytime performance and nighttime sleep. However, that only accommodates one shift, and it compounds the adjustment problems for the night shift. Moreover, as a society, we enjoy weekend time off. However, we now live in a world that operates 24/7. While certainly this is convenient for shopping, entertainment, and businesses that have to compete globally, it has also created work schedules that require regularly scheduled weekend work, along with increased physical stress (born of our biology) and social conflict (due to our sociology).

So how do we determine the "best" schedule from such conflicting situations? By what criteria can we make a rational decision, and would that decision apply to all shiftworkers in all industries, or is there one best schedule for each industry? As it turns out, the best schedule is a site specific phenomenon, driven by the site specific operational needs, by the biological impact of different shift patterns on different people, and by the family/social needs and lifestyle preferences of the unique, demographic composition of the workforce. To paraphrase the comedian, Billy Crystal..."there are 9 million stories in the naked city, and every one of them is a shiftworker with a different schedule preference"! That's why mandated, negotiated, benchmarked, transplanted, or otherwise arbitrarily selected schedules often have negative outcomes. That's why the shiftworkers themselves not only need to be involved in every step of the scheduling change process, but they first need to be educated as to all of the possibilities and all of their pros and cons in order to be able to make informed decisions, rather than emotional and irrational ones based on misgivings and misunderstanding. Thus, in the final analysis, the best schedule will be the one that best satisfies the operational requirements, that is the most physiologically healthy and safe, and that aligns to the best degree possible with the family/social needs and personal preferences for the majority of the workforce. The best way that scheduling experts have found to accomplish this is through a systematic Shift Schedule Optimization Process utilizing a neutral, third party expert to provide the required technical support, and to help facilitate the process with an internal employee task team or shift committee.

# References

A Spurgeon, JM Harrington, CL Cooper. Health and safety problems associated with long working hours: a review of the current position. Occup. Environ. Med. 54, 367-375. 1997.

Akerstedt T, Torsvall L, Kecklund G, Knutsson A. The shift cycle and clinical indices of insomnia. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 421-426. 1990.

Akerstedt T. Psychological and psychophysiological effects of shiftwork. Scand. J. Work Environ. Health. 16, 67-73. 1990.

Akerstedt T. Work hours, sleepiness and the underlying mechanisms. J. Sleep Res. 4 Suppl. 2, 15-22. 1995.

Alfredson L, Akerstedt T, Mattson M, Wilborg B. Self-reported health and well-being amongst night security guards: a comparison with the working population. Ergonomics 34, 525-530. 1991.

Barton J, Folkard, S. Advancing versus delaying shift systems. Ergonomics 35, 125-133. 1993.

Bonjer FH. Temporal factors and physiological load. In: Measurements of man at work, Singleton WT, Fox JG and Whithfield T. (Eds.)Taylor and Francis, London. 1971.

Circadian Technologies, Inc. Shiftwork Practices Survey. www.circadian.com.

Czeisler CA, Dijk DJ. Use of bright light to treat maladaptation to night work and circadian rhythm sleep disorders. J. Sleep Res. 4, Suppl. 2, 70-73. 1995.

Dembe AE, Erickson JB, Delbos RG, Banks SM. The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States. Occup. Environ Med. 62(9), 585. 2005.

Folkard S, Totterdell P. Circadian variations in performance. Implications for abnormal work hours. International Symposium "Shiftwork and Job Demands". Paris 10-14. 1994.

Foret J, Lantin G. The sleep of train drivers: an example of the effects of irregular work schedules on sleep. In: WP Colquhoun (ed.) Aspects of Human Efficiency. The English Universities Press, London. 273-282. 1972.

Gold DR, et al. Rotating shiftwork, sleep and accidents related to sleepiness in hospital nurses. Am. J. Publ. Health. 82, 1011-1014. 1992.

Harma M et al. A controlled intervention study on the effects of a very rapidly forward rotating shift system on sleep-wakefulness and well-being among young and elderly shift workers. Int. J. Psychophysiol 59(1), 70-79. 2006.

Harma M. Individual differences in tolerance to shiftwork: a review. Ergonomics 36 (1-3), 101-110. 1993.

Harrington JM. Shift work and health. A critical review of the literature on working hours. Ann. Acad. Med. Singapore 23, 699-705. 1994.

Hedden I, Grzech-Sukalo H, Nachreine4r F. Classification of shift rotas on ther basis of periodiv components. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 197-202. 1990.

Ingre M, et al. Variation in sleepiness during early morning shifts: a mixed model approach to an experimental field study of train drivers. Chronobiol. Int. 21(6), 973-90. 2004.

Jee Ng-A-Tham, Hk Thierry. An experimental change of the speed of rotation of the morning and evening shift. Ergonomics 36 (1-3), 51-57. 1993.

JM Harrington. Shift work and health. A critical review of the literature on working hours. Ann. Acad. Med. Singapore 23, 699-705. 1994.

Kecklund G, Akerstedt T. Effects of shifts on sleepiness and sleep duration. J. Sleep Res. 4 Suppl. 2, 47-50. 1995.

Knauth P, Kieswetter E, Ottmann W, Karvonen MJ, Rutenfranz J. Time-budget studies of policemen in weekly or swiftly rotating shift systems. Appl. Ergon. 12, 247-252. 1983.

Knauth P, Schonfelder E. Effects of a new shift system on the social life of shiftworkers. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 537-545. 1990.

Knauth P. Changing schedules: shiftwork. Chronobiol. Int. 14(2), 159-171. 1997.

Knauth P. Design of shiftwork systems. In: Shiftwork: problems and solutions, Colquhoun WP, Costa G, Folkard S, Knauth P (Eds.) Peter Lang, Frankfurt am Main. 1996.

Knauth P. Speed and direction of rotation. J. Sleep Res. 4 Suppl. 2, 41-46. 1995.

Knauth P. The design of shift systems. Ergonomics 36 (1-3), 15-28. 1993.

Kurumatani N, Koda S, Nakagiri S, et al. The effects of frequently rotating shiftwork on sleep and the family life of hospital nurses. Ergonomics 37, 995-1007. 1994.

Rosa RR et al. Intervention factors for promoting adjustment to nightwork and shiftwork. In: Shiftwork. AJ Scott (Ed.) Occupational Medicine 5(2), 391-416. 1990.

RR Rosa. Extended workshifts and excessive fatigue. J. Sleep Res. 4 Suppl. 2, 51-56. 1995.

Saito Y, Kogi K. Psychological conditions of working night and subsequent day shifts with short sleep hours between them. Ergonomics 21, 871. 1987.

Samel A, Vejvoda M, Maass H. Sleep deficit and stress hormones in helicopter pilots on 7 day duty for emergency medical services. Aviat. Space Environ Med. 75(11), 935-40. 2004.

Spurgeon A, Harrington JM, Cooper CL. Health and safety problems associated with long working hours: a review of the current position. Occup. Environ. Med. 54, 367-375. 1997.

Tepas DI, Carvalhais AB. Sleep patterns of shiftworkers. Occup. Med. 5, 199-208. 1990.

Totterdell P, Spelten E, Smith L, Barton J, Folkard S. Recovery from work shifts: how long does it take? J. Applied Psychol. 80 (1), 43-57. 1995.

Tsaneva N, Nicolova R, Topalova M, Danev S. Changes in the organism of shift workers operating a day and night 12-hour schedule in carbon disulfide production. In: Costa, G, Cesana G, Kogi K, Wedderburn A (eds.) Shiftwork: Health, sleep and performance. Peter Lang, Frankfurt. 324-329. 1990.

Uehata T. Long working hours and occupational stress-related cardiovascular attacks among middle-aged workers in Japan. J. Hum. Ergol. (Tokyo) 20, 147-153. 1992.

# About Circadian®

CIRCADIAN® is the global leader in providing 24/7 workforce performance and safety solutions for businesses that operate around the clock. Through a unique combination of consulting expertise, research, software tools, training and informative publications, CIRCADIAN helps organizations in the 24-hour economy optimize employee performance and reduce the inherent risks and costs of their extended hours operations.

Working from offices in North America, South America, Europe, Asia, and Australia, CIRCADIAN experts ensure that over half the Fortune 500, and other leading international companies, improve their competitiveness in the global 24/7 economy. CIRCADIAN's core expertise is the staffing, scheduling, training and fatigue risk management of their most vital asset – the 24/7 workforce. For more information about CIRCADIAN, please visit our website at www.circadian.com.

CIRCADIAN® HQ
2 Main Street, Suite 310
Stoneham, MA 02180
USA +1-781-439-6300
Fax: 781-439-6399
Info@circadian.com

CIRCADIAN® Canada
100 King Street West,
Suite 5700, Toronto
Ontario, M5X 1C7
Canada, +1-416-594-0600
info@circadian.ca

CIRCADIAN® UK
1 Heddon Street
Mayfair, London,
W1B 4BD, UK
+44 (0)207 470 7148
Contact@circadian.uk.com

CIRCADIAN® Australia
12 Birubi Street
Coorparoo, QLD 4151
Aus, +61 (07) 3394 3922
Fax: (07) 3394 3900
info@circadianaustralia.com.au

CIRCADIAN® Netherlands
Erich Salomonstraat 500
1087 JA Amsterdam
The Netherlands
+31 (0)6 3633 6050
NLinfo@circadian.com

CIRCADIAN® Chile
Av. 11 de Septiembre 1881,
Oficina 1620, Providencia
Santiago, Chile
+56-2 440 5128
Fax: +56-2 440 5101
infoChile@circadian.com

CIRCADIAN® Japan
1-10-1 Shigigaoka
Sango-cho, Ikoma-gun,
Nara 636-0813
Japan, +81 745 47 0104
JPinfo@circadian.com

PUBLISHER'S NOTES: Publisher: Circadian Information LP



Circadian Information provides information and publications on scheduling, training, and other services for 24-hour operations.

CIRCADIAN® 2 Main Street, Suite 310, Stoneham, MA 02180 USA, Tel 781-439-6300, Fax 781-439-6399, Email: info@circadian