

White Paper: Shift Plans with Seven Consecutive Shifts

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Introduction

This white paper addresses three shiftwork plans that use work compression with seven consecutive days or nights of work and varying numbers of consecutive days off: the 7-days-on and 7-days-off plan used in oil fields and offshore operations (7-on/7-off); the Continental *rota*; and the low-weekend-work-demand plan, which combines 8- and 12-hour shift lengths. The duPont plan, which uses work compression to allow seven consecutive days off, is discussed, also.

There are nine principles of shiftwork scheduling that describe the essential qualities of shiftwork plans (Miller, 2006):

- Principle 1, Circadian Stability: minimizing shift-lag fatigue and malaise by maintaining circadian entrainment to the local, 24-h daylight-darkness cycle; includes guidelines on sleep hygiene
- Principles of Chronohygiene
 - Principle 2, short shift length
 - Principle 3, minimum consecutive night shifts
 - Principle 4, recovery after each night shift
 - Principle 5, maximum number of free days on weekends
 - Principle 6, at least 104 days off per year
- Shiftworker Satisfaction
 - Principle 7, equity among shiftworkers for types of work days and free days
 - Principle 8, predictability of specific work and free days
 - Principle 9, good quality of time off

Principle 9, Good Quality of Time Off, may be the primary concern of shiftworkers (Coleman, 1995). Shiftworkers and weekday-only workers tend to prefer schedules with long, continuous periods of time off. Such work schedules are perceived as being “good” schedules. For example for weekday-only workers in the United States, there are two popular types of work compression. One is the “10-hour day” schedule in which the 40-hour work week is completed in 4 days, allowing 3-day weekends. The other is the “every-other-Friday-off” schedule in which there are eight 9-hour work days and one 8-h workday across a 2-week period. This allows every other weekend to be a 3-day weekend. Note that an additional contributor to the perception of “good” schedules is having days off on weekends.

It is possible that regular periods of four consecutive days off may be optimal for shiftworkers. The desire for 3-day weekends in weekday-only workers suggests that these non-shift-workers desire three consecutive days off. By extension, shiftworkers may need more than three consecutive days off because of the fatiguing effects of night work. However, given too many days off, workers are more likely to partake in excessive leisure or additional-work activities and return fatigued to their primary job. Shiftworkers may also seek work compression so that they may work at second jobs. Obviously, the risk for compounding fatigue is substantially increased by the demands of the second job.

Work Compression

The weekday schedules, above, illustrate the important point that, because of the zero-sum nature of 24/7 operations, work compression is desired to allow the expansion of continuous time off. Within this zero-sum

system, any gain must be offset by an equal loss. For example, one may work six 8-hour shifts for a total of 48 hours in the 8-day cycle of the Metropolitan *rota* and have only 2 days off: DSSNNOO (where D is a day shift, S is a swing shift, N is a night shift, and O is a day off). Or one may work four 12-hour shifts in the same eight days and have 4 days off: DDNNOOOO. Note the difference in the number of consecutive days off: four vs. two. Why does this happen? Because a faster rate of work in the second schedule allows work compression:

- With 8-h shifts, you work 48 hours in 6 work days, a rate of 8 hours per day
- With 12-h shifts, you work 48 h in 4 work days, a rate of 12 hours per day
- The ratio of 12 hours per day to 8 hours per day gives a 1.5 times faster work rate
- When you move from 8-h to 12-h shifts, as in this example, the work that would have taken 6 days (144 hours) will now be accomplished in $(144 \text{ hours} \div 1.5 =) 96 \text{ hours}$ (4 days), leaving the remaining 96 hours (4 days) in the 8-day cycle for continuous time off.

With respect to the concept of work compression, the highest numbers of consecutive days off within a plan are reached when all occurrences of the same shift are consecutive or when all work days are consecutive.

Shift Plans with Seven Consecutive Shifts

Eight-Hour Shifts. The Continental *rota*, or 2-2-3 plan, is a 4-crew, 8-hour shift plan in the $3nW:1nF$ shift system¹ ($n = 7$, thus 21W:7F) with a cycle length of 28 days. It includes three sequences each of two, two, and three consecutive night shifts (N), swing shifts (S), day shifts (D), and days off (O). The 3-day sequences are underlined here:

DDSSNNNOO DDSSSNNOO DDDSSNNOO

A weakness of this plan is the repeated occurrence of seven consecutive work shifts. The Metropolitan *rota*, or 2-2-2 plan, may be used to reduce this weakness by one shift. The Metropolitan *rota* is another 4-crew, 8-hour shift plan in the $3nW:1nF$ system ($n = 2$, thus 6W:2F), with six consecutive work shifts in an 8-day cycle: DDSSNNOO.

Eight- and Twelve-Hour Shifts. Another method of work compression is supported by a complex, low-weekend-work-demand plan (Miller, 2006). This 4-crew, 8-plus-12-hour shift combination plan supports situations in which work is slower on the weekends than during the week. The plan has a 28-day cycle length. On the 20 week days/nights in those 28 days, 8-hour shifts are worked on in a $3nW:1nF$ system ($n = 5$, thus 15W:5F). One of the four crews is always off during the 20 week days/nights. On the four weekends, 12-hour shifts are worked in a $2nW:2nF$ system ($n = 2$, thus 4W:4F). Two of the crews are off on weekends instead of just one crew being off. A plan for one crew is:

SSSS[OO]NNNOO[OO]DDDD[DD]OOONN[NN]

where the brackets indicate weekends; [DD] is two 12-hour day shifts and [NN] is two 12-hour night shifts. The main weakness of the plan is the seven consecutive work shifts, which are underlined. Another weakness is sequence of four night shifts at the end of the cycle, but note how the night shifts are split across two weeks as opposed to working seven consecutive night shifts.

Twelve-Hour Shifts. As noted above, the highest numbers of consecutive days off within a plan are reached

¹ For an explanation of shift system notation, see Miller (2006). W is a work day, i.e., a day on which a shift begins. F is a free day, or day off, a day on which no shift begins.

when all occurrences of the same shift are consecutive. The 7-on/7-off, 12-hour plan uses this method to deal with remote operations, i.e., folks working at sites in the desert or off shore. In this 28-day cycle, the workers spend seven days at the site working 12-hour day shifts, then are off for seven days, then spend a week at the site working seven 12-hour night shifts, then have seven days off. This 4-crew, 12-hour, 7-on/7-off plan falls within the 2nW:2nF system (n = 7, thus 14W:14F). One justification for using the 7-on/7-off schedule might be a transportation issue, i.e., the difficulty of getting to and from the site. Another justification might be the allowance of five days of time off (seven days minus two travel days), assuring the opportunity for good recovery from the week of night shifts.

The duPont plan that is used in pipeline control rooms seems to be a spin-off of the 7-on/7-off plan that uses less work compression (i.e., there is no period of seven consecutive work shifts), but retains one period of seven consecutive days off per 28-day cycle. The duPont plan is a rapid-rotation, work-compression plan that also uses four crews and 12-hour shifts in the 2nW:2nF system with n = 7 (14W:14F), also with a 28-day cycle:

NNNNOOO DDDONNN OOODDDD OOOOOOO

If this plan starts on a Monday, then there are two weekends off in each 28-day month. The main weakness of the duPont plan is the string of four continuous night shifts. Because of Principle 9, above, it is highly unlikely that pipeline controls rooms will ever be able to use less work compression; controllers will rebel strongly if they are threatened with the loss of their string of seven consecutive days off.

Fatigue Issues

The main problem with working seven consecutive shifts is the potential for the build-up of cumulative fatigue. Cumulative fatigue builds up across major waking and work periods when there is inadequate recovery (due to inadequate sleep) between the duty periods. Recovery from cumulative fatigue cannot be accomplished in just one good-quality, nocturnal sleep period.

Given good-quality, nocturnal sleep, little cumulative fatigue will occur as a result of working seven consecutive day shifts. A caveat here is that, if the worker sleeps fewer hours than his or her sleep need between day shifts, then fatigue will accumulate and increase the risk of an incident or accident at work. Working seven consecutive night shifts certainly presents a problem. With the exception of perhaps 1% of the population, humans function quite poorly when we are required to work at night and sleep during the day. Our basic biology is wired to support the opposite, i.e., working during the day and sleeping at night.

Several myths are invoked when people choose to work too many consecutive night shifts.

- Myth: "I only need a few hours of sleep." Reality: The average sleep need has been quantified at 8 hours \pm 1 hour. Thus, half of the population needs more than eight hours.
- Myth: "I can sleep when I die." Reality: This is a completely inappropriate and irresponsible attitude for controllers because they hold safety-sensitive jobs, i.e., jobs that involve public safety and health.
- Myth: "I can adapt to nighttime work." Reality: Without the careful use of specialized devices and methods (discussed below), only about 1% of the population can "adapt" to night work.
- Myth: "Sleep is a passive, vegetative state." Reality: This is a myth with deep roots in Greek mythology and Shakespeare. Actually, several circuits in the brain generate the state of sleep. These circuits can be disrupted easily by anxiety, poor sleep hygiene, stimulants, depressants, time zone changes, and rotating shift work.
- Myth: "24/7 shiftwork scheduling is an art, and not quantitative." Reality: Schedules may be

quantified in terms of W:F ratios and judged in terms of measures of effectiveness such as the numbers of hours worked per unit time, the numbers of weekend days off per year, etc.

- Myth: “Other-industry shiftwork guidelines do not apply to my industry.” Reality: This is true only if your employees are not human.
- Myth: “Fatigue can’t be measured.” Reality: Sleep has been quantifiable for more than 50 years, and mental fatigue for more than 15 years.

When we quantify the predicted effects on cognitive performance or safety risk of working seven consecutive nights, the two leading modeling tools that are used for shiftwork planning, FAST® and FAID®, tell us pretty much the same story. FAST® predicts that 49% of work time across the seven nights will be spent below a performance effectiveness of 77.5%, the approximate equivalent of 0.05 BAC (Figure 1). Conversely, FAID® predicts that 59% of work time will be spent below the risk tolerance level of 80 (Figure 2). Based upon these predictions, we should expect that extraordinary fatigue countermeasures will be used during 40 to 50% of the hours of work across the seven nights.

Risk Management

We note that in the report of the meta-analysis of seven industrial studies it was observed that the relative risk of accidents and incidents increases sharply across the first four successive night shifts (Figure 3; Folkard & Tucker, 2003). Folkard and Tucker noted that it would “be of great interest to determine whether risk ... [would be] reduced over longer spans of successive night shifts. However, while it has to be admitted that this might occur, there is as yet no good evidence to indicate that this is the case” (page 97).

Based upon the meta-analysis by Folkard and Tucker and upon model predictions, we conclude that the periods of greatest concern are the 6th and 7th successive day shifts, the 4th through 7th successive night shifts, the last 4 hours of any 12-hour shift (doubly so if they fall in the midnight-to-dawn period), and when driving home from a work site. Operators have been sued successfully when fatigued employees have had serious traffic accidents after night work.²

The countermeasures to be used in the control room may be described in a comprehensive fatigue risk management plan (FRMS) and should be included in relevant education and training modules. Among other countermeasures listed elsewhere by PHMSA and other agencies, they might include:

- Bright ambient lighting in the control room that is designed to suppress melatonin secretion at night
- Sit-stand workstations that are easy to use and are used appropriately
- Spectacles that block blue-green light, to be used on the way home after the night shift to allow melatonin secretion to begin
- Strict adherence to tactical caffeine use as opposed to widespread caffeine abuse
- Access to occupational health physicians who would prescribe and monitor sleep aids for voluntary, occasional use for daytime sleep, and modafinil for voluntary use during night work
- Good-quality facilities and good management practices for on-the-job napping

The operator must still consider individual differences among their controllers and any unique risks that may exist in their control room and/or in their procedures, and what specific countermeasures should be applied to deal with these risks.

² For example, Francisca Escoto, et al vs. The Estate of Robert Ambriz, et al., Cause No. 00-81, Raymondville, Willacy County, 197th Judicial District, Texas.

References

Coleman, R. M. (1995). *The 24-Hour Business*. New York: AMACOM.

Folkard, S., & Tucker, P. (2003). Shift work, safety and productivity. *Occupational Medicine (Oxford, England)*, 53(2), 95–101.

Miller, J. C. (2006). *Fundamentals of Shiftwork Scheduling*. Brooks AFB, TX: Air Force Research Laboratory. Defense Technical Information Center reference no, ADA446688.

Figure 1. FAST® prediction of the effects on cognitive performance effectiveness of seven consecutive, 12-hour night shifts: 49% of work time across the seven nights will be spent below a performance effectiveness of 77.5% (about 0.05 BAC).

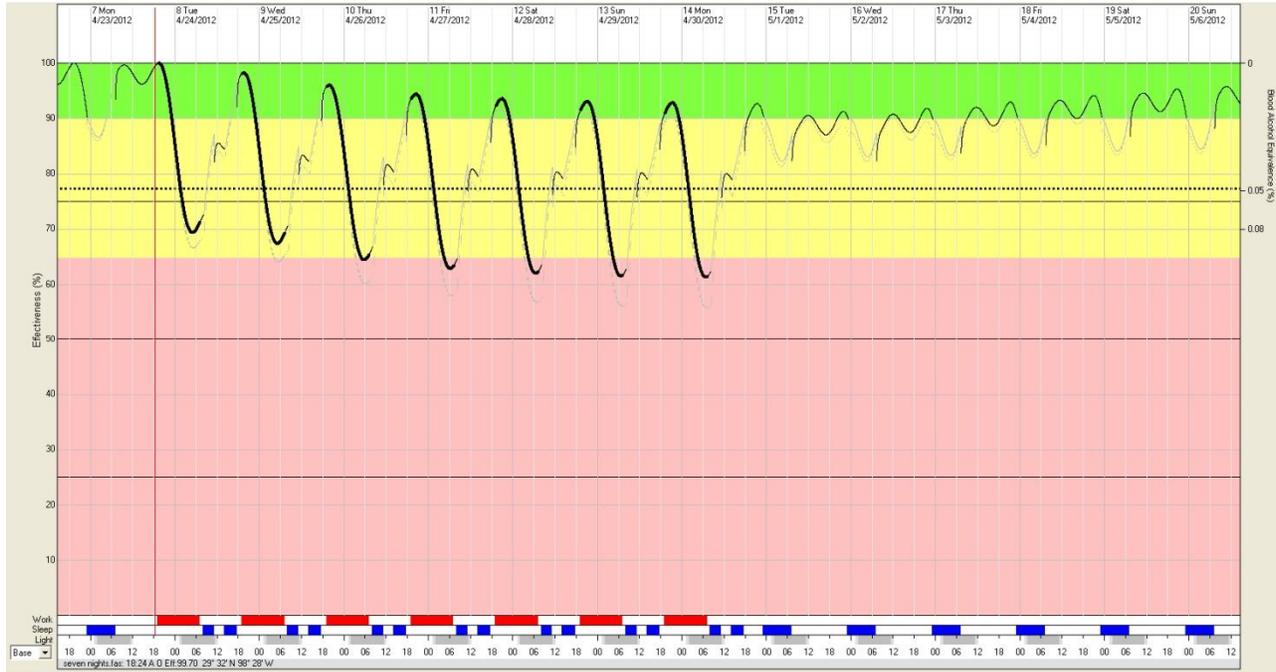


Figure 2. FAID® prediction of the effects on cognitive performance effectiveness of seven consecutive, 12-hour night shifts: 59% of work time will be spent below the tolerance level of 80.

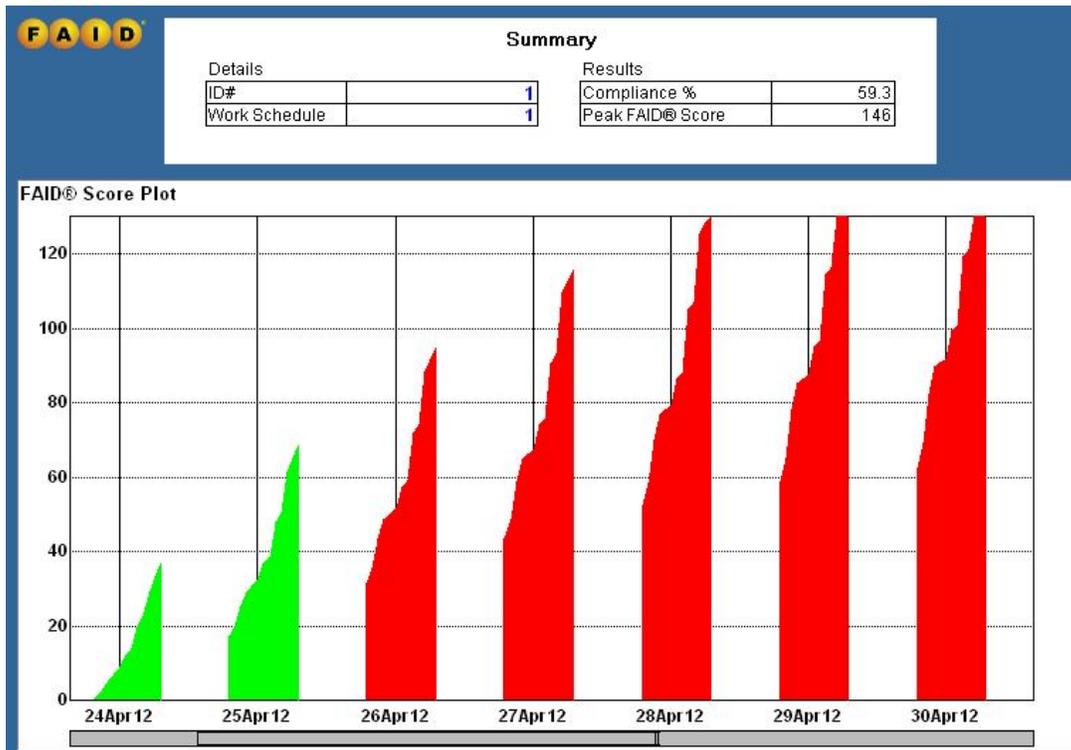


Figure 3. "...risk was ~6% higher on the second night, 17% higher on the third night and 36% higher on the fourth night." (Folkard & Tucker, 2003, page 97; seven studies).

