Considerations when Implementing Shift Work in Nuclear Operations

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ABSTRACT

Many domestic and international nuclear facilities have processes that require personnel to work on some type of shift. Shift work has many different schedules such as night, morning, swing, and rotating shift. Some common shifts are DuPont, Pitman, and Panama. There are many psychological and physiological impacts to a person working shifts. These impacts can affect work performance, safety, and security within an organization. A well-established nuclear organization relies on a strong security culture that implements a trustworthiness or reliability program. The International Atomic Energy Agency defines this type of program as individuals meeting the highest standards of reliability, trustworthiness, and physical and mental suitability. Psychological and physiological impacts that apply to a trustworthiness program are reliability (an individual's ability to adhere to security and safety rules and regulations) and physical and mental suitability. If shift work is not properly implemented in facility operations, then several issues, or human factors, can arise. An employee that suffers from a poorly designed shift, gets overworked, or does not have the proper rest period implemented, may suffer from shift work disorder, acute fatigue, or cumulative fatigue. Introducing fatigue into facility operations can have severe consequences to security, safety, production, and cost. Another challenge of shiftwork within a facility is laziness and complacency. Creating an atmosphere where an employee is willing to admit fatigue to his or her supervisor is a challenge. It is up to the organization to do the needed research on shift work and to implement the best shift for their facility and personnel.

INTRODUCTION

Nuclear material and facilities demand continuous coverage, which requires employees to operate on a rotational, fixed, or modified shift. This typically entails an established permanent shift for continuous site operations and temporary shifts to support special processes. There are various methods of scheduling these shifts and rotational work, though some schedules support human performance better than others. For schedule planning, several factors should be specifically considered for nuclear operations. These factors include both physiological and psychological effects with emphasis on fatigue, and their consequences on work performance, productivity, safety, and security. Certain factors will never be fully mitigated, but it is crucial to identify the most appropriate shift schedule for the needs of the facility and the workers. Stakeholders, leadership, unions, medical personnel, and workers all need to be involved in selecting the optimum shift schedule for the facility to maintain a reliable program and to prevent unwanted consequences.

The relevance of shift selection spans several roles including security, computer systems, emergency services, and maintenance. Certain processes and locations must be continuously manned at nuclear sites around the world, and site security is a prime example of a continuous coverage necessity. Security readiness is critical for threat, alarm response, patrolling, and access control no matter the time of day. As the risks associated with inattention to planning factors are revealed, their direct impact on overall security should be considered.

Nuclear power plants need continuous operations monitoring requiring employees to work shifts. Computer systems have reduced the workload of monitoring reactors, but people are still required to monitor computers and make adjustments as necessary. Again, the operational effectiveness of power plants will be at risk without close attention to effective shifts.

Emergency services provide another continuous service in support of the nuclear facility. Some sites have a dedicated fire department or ambulance service, but others source outside services for emergency response. It is challenging to determine which type of shift should be selected for this type of organization, but a dialogue between the nuclear facility's management and the outside services is necessary. Careful selection based on relevant factors will allow for the optimal solution.

Finally, there is facility maintenance and construction. Maintenance personnel must be available throughout the day and night for any emergent issue requiring immediate attention. Although regular maintenance typically takes place during normal working hours, certain jobs and projects require scheduled maintenance at night. Nighttime maintenance may also be the best opportunity because of the reduced number of people at the facility. Other circumstances require a temporary shift for augmentation such as road or building construction and fuel transfers. Clearly, the demand for continuous coverage at a nuclear facility is wide in scope.

The variation in continuous coverage roles prevents identification of a single solution that applies uniformly. Shifts are usually structured around an 8-hour workday but sometimes entail a 10- or 12-hour day. Many studies indicate that human performance decreases significantly after a 12-hour shift. For this reason, nuclear facilities rarely employ workdays in excess of 12 hours. Although factors such as overtime and mandatory work can contribute to shifts exceeding 12 hours, this should not be a routine expectation from management.

TYPES OF SHIFTS

There are numerous options when choosing a rotating, fixed, or temporary shift for a facility. Some facilities use teams or lettered groups of workers to man the schedule. They can be broken out as A-shift, B-shift, C-shift, and D-shift for scheduling purposes with a minimum of two shifts to cover the 24-hour day. Limiting shifts to two may work for a temporary schedule, but long-term or indefinite coverage must incorporate time off. To compensate, more teams or groups of people will be necessary. A decision must be made about whether or not the workers will rotate between day and night shifts or stand a fixed or dedicated day or night shift. Figures 1 and 2 depict two common examples of shift types: one rotating (Dupont) and one fixed (Pitman), both with 12-hour workdays. There are pros and cons to each of these shifts, but inclusion here is primarily illustrative.

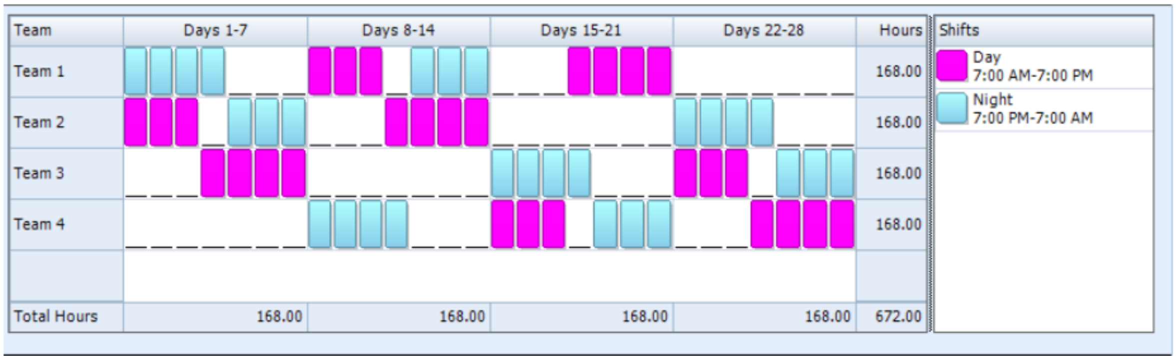

Figure 1. DuPont 12-hour rotating shift example [1]

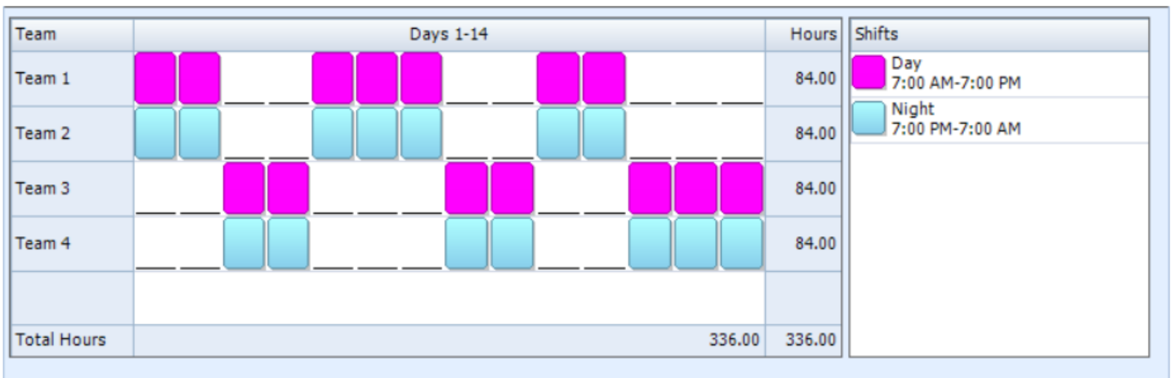

Figure 2. Pitman 12-hour fixed shift example [1]

Nights shifts are an unavoidable requirement for 24/7 operations. They are also a notorious cause of physiological stress. Some choice is available in selecting either rotational shifts or a dedicated night shift, though neither one eliminates risk. The rotational shift allows an individual some adaptation to working night shifts, but a quickly alternating pattern of night shifts and day shifts without a proper adjustment period will induce circadian fatigue. The DuPont rotating shift is one example of this cycle, interchanging day and night 12-hour periods.

The DuPont transition between day and night sometimes entails a full workday, one 24-hour break, and then a full night shift. Many medical professionals argue this provides insufficient time for the body to adjust. The DuPont schedule repeats this cycle between working days and nights over a 4-week period. If prolonged, the employee may develop cumulative fatigue and even circadian rhythm disorder. This fatigue will result in consequences for both work performance and safety. To reduce this risk, consideration can be given to implementing a rotational shift that implements 1 full month of day shifts followed by 1 full month of night shifts. This cycle can be tailored to the unique context, but the intent is for equal distribution of day and night shifts throughout the year. This provides the worker with greater balance, a simpler work schedule, and potentially reduces some of the physical effects.

The alternative option to a rotating shift is a dedicated or fixed shift. A fixed day shift is not concerning, but a fixed night shift invites additional risk. Several studies have been conducted on this type of schedule with little evidence supporting any improvement with fatigue. Inherent risks to the dedicated night schedule include chronic fatigue, sleep disorders, and heightened job dissatisfaction. These drawbacks must be considered by organizational stakeholders and contrasted to those of the routine rotational shift. The Pitman schedule is an example of a fixed shift incorporating 12-hour workdays. This schedule begins the workday at 0700 for a 12-hour shift, in effect implementing a dedicated day and night shift. Adjusting the start time of this shift might help alleviate the effects of the night shift. For instance, if the shifts were 1200–0000 and 0000–1200, the body would experience both day and night in its cycle. Though not providing the body with a normal day, it does have some redeeming features such as sun exposure and vitamin D production. This allows the worker to participate in some normal daytime activities, which may include valuable family time.

Schedules should be selected with attention to several factors and the associated risks. Physiology is a factor that directly affects employee productivity and work performance, making it a critical consideration when determining shift scheduling. Physiological aspects include several biological functions of the body. One function is the circadian rhythm or the body's internal clock. The body reacts to certain cues such as light and darkness. These cues trigger responses such as wakefulness during the day and sleep at nighttime. It is difficult to establish a steady sleep pattern and circadian rhythm when switching back and forth between day and night shift. A fixed night shift can negatively affect circadian rhythm because the body clock is based on a normal day's sunrise and sunset. The body relies on this rhythm for hormone production, cell regeneration, healthy brain function, and beneficial sleep patterns. If circadian rhythm suffers from an adverse shift schedule, the consequences can be severe.

Fatigue should also be considered by organizations when considering shift duration, particularly for labor intensive jobs. Intentional adjustment of work hours or workday limitations may reduce the combined effects of shift work and job intensity. Shift schedules can and should be made to account for fatigue, especially when considered over time. Cumulative fatigue can set in over a period of long workdays in as little as 1 week. This fatigue not only applies to physical activities, but also mental ones, such as monitoring computers or gauges.

Shift work can influence preparedness and worker reaction-time. For example, if a protective force member is fatigued as a result of rotating shiftwork, they may fall asleep on post. This creates a noteworthy vulnerability in the security of the site and employees are likely unwilling to step forward despite suspecting fatigue might degrade their work capacity. Discouraging such a culture takes an intentional effort built on the foundation of a shift or rotation that accounts for fatigue. Though it is the employees' responsibility to manage his or her personal schedule and get the required rest before showing up to work, management should ensure it does its part to foster healthy choices, provide guidance, and engage with employees.

There are several studies that compare the effects of sleep loss to the influence of alcohol. An often cited study concludes that wakefulness beyond 17 hours mimics the effect of a .05% blood alcohol content (BAC) [2]. Motor functions and reaction times are negatively affected by an increase in BAC. Combined with a day-to-night shift transition and probable inadequate rest period, the employee could be operating at an even higher comparable level of BAC in the realm of .1%. The following scenario is typical for a 12-hour workday common to nuclear facilities around the world.

Assume an employee gets up in the morning after 8 hours of uninterrupted sleep at 0430. This employee does his/her required morning routine and departs for work at 0530 for a 30-minute drive, which includes processing through access controls. The employee is notified at 1400 that they have been mandated to stay at work for an additional 4 hours. At 2200, this employee is relieved in place and starts to process out of facility. At 2230 the employee departs from the site for the 30-minute drive home.

At the time of departure, the employee has been awake for 18 hours straight. It can be assumed that this employee is fatigued and lacks quality motor function or reaction times. The organization is accepting risk for an employee operating not unlike an intoxicated driver as they depart the site. This can also be compounded by the employee traveling home at night with less visible cues. There are, of course, some arguments against this comparison, but the intent is to provide awareness of the effects of shift work schedules.

ACCIDENT CASE STUDIES

Certain organizations and industries routinely account for fatigue and human performance, providing a tried and tested model for the nuclear industry. The aviation industry is one such example and embraces the concepts of *crew day* and *crew rest*. Pilots and aircrew are intentionally scheduled with workday maximums and down time minimums to moderate fatigue. Situations necessitating a long workday at nuclear facilities might be unavoidable, but this exists in the aviation community as well. Facility management needs to use its best judgment and avoid extended workdays as a routine practice.

There are numerous examples of fatigue contributing to major catastrophes. The 1989 Exxon Valdez Oil Spill is one example of a major accident attributed partially to long workdays and shift work. The oil tanker struck a reef while en route from Alaska to California and spilled 10.8 million gallons of crude oil into the ocean, resulting in one of the worst environmental mishaps in the oil industry. The National Transportation Safety Board (NTSB) identified several causal factors leading to this major accident in its safety recommendation letter sent on September 18, 1990 [3]. Inadequate sleep is cited as one factor affecting the third mate in charge of helm operation during the mishap. Adding to lack of sleep was the demanding and stressful work done the previous day by the third mate. The NTSB concluded that the third mate could have had as little as 4 hours of sleep before the mishap workday and a possible 6 hours of sleep within the previous 24 hours leading to the mishap. A standard practice for this crew was 6 hours on shift and 6 hours off shift rotation. Fatigue due to lack of sleep and a poor rotational shift schedule contributed significantly to the events responsible for the ship’s mishap.

The aviation industry has had its fair share of mishaps attributable to shift work. One major mishap relating to fatigue was American Airlines Flight 1420, which occurred in June 1999. The aircraft overshot the runway and crashed resulting in 11 deaths and 110 injuries. The NTSB determined that pilot fatigue was a contributing factor to this mishap [4].

Recent military mishaps have also revealed the risk of overworked crews and corresponding inadequate time for rest. In response to two US Navy collisions and other near mishaps, the Readiness Reform Oversight Committee identified a three-tier strategy to deter such tragedies in the future. A common complaint among the US Navy surface (ship) community is the lack of consideration for demanding shift hours distinct from their aviation counterparts. In 2017, the Navy made strides to improve with a "circadian rhythm-based fatigue management policy" and "crew rest management tool," similar to that used for aviators [5]. One collision took place after the policy was released, indicating a lack of compliance which was supported by interviews with crew members. The mishaps were preventable tragedies and an embarrassment to the United States. The Navy has increased efforts for improving fatigue management to avoid future catastrophes [6].

The nuclear industry has not been spared from this phenomenon, as demonstrated by the Three Mile Island Nuclear Power Plant in in March 1979 [7]. The Three Mile Island Nuclear Power Plant experienced a reactor melt down due, in part, to human factors. Shift workers failed to notice the reactor coolant leak during the early morning hours at the end of their shift. Other off-going shift workers were stuck analyzing the problem for several hours in the reactor control room due to the instruments providing insufficient or misleading information. When the new shift arrived, the cause of the problem was finally identified, but by that time it was too late. Performance tends to degrade toward the end of a shift, but this is especially true when combined with long hours and suboptimal shifts. There is a clear connection here between shift work and degraded employee performance.

Four examples have been reviewed correlating shiftwork to mishaps, but there were many other examples to choose from. All nuclear facilities deal with shiftwork in some way and therefore have a vested interest in its implementation. Even if the fraction of fatigued workers is limited, the facility might still be more vulnerable to attack, more disposed to a safety incident, and less productive resulting in substantial inefficiencies. Any veteran of shiftwork can vouch for its negative effects. An open dialog between employees and management is very important to resolve the negative aspects of shiftwork and to build a reliable shift.

HEALTH AND WELLBEING EFFECTS

The preceding examples presented physiological challenges of shiftwork and potential consequences. Psychological impacts should also be considered when picking shiftwork schedules. Consider the night shift worker with a family at home. It is possible for that individual to depart for work before children return from school and return early in the morning before children wake up. The worker would have little to no time to interact with the family except on days off. This would be mentally and emotionally challenging for the employee and their family. Several studies equate higher job satisfaction ratings when working day shifts than when working night shifts. This further emphasizes the need to intentionally rotate workers from night shifts to day shifts and vice versa.

Another psychological effect of shift work can be depression. A recent study determined that "shift workers, particularly women, are at increased risk for poor mental health, particularly depressive symptoms" [8] Employees suffering from depression can have trouble handling daily functions and staying focused. Depression can directly contribute to poor sleep, negative eating behaviors, and some other disorders. The stakeholders should anticipate this and involve medical personnel to help identify and treat depression before it becomes a serious complication or results in a facility mishap. Every organization aims for employee's contentment and work productivity. Good mental health should be a significant part of a nuclear facility's work ethic.

Based on of the physiological, psychological, and fatigue impacts of shift work, doctors and medical professionals must be involved in shift work research and the scheduling process. They can provide sleep studies and monitor employees as they work the necessary shifts. Annual or biannual medical physicals can determine negative health trends of shift work at the facility and present them to the management to allow for a change to be made. This requires additional organizational funding but could prevent a major mishap or security incident, as well as save money in the long run.

CONCLUSION

Many factors should be considered when determining shift work schedules for a nuclear facility, including physiological and psychological factors that must be mitigated when implementing shift work. Several examples have been provided highlighting the risks associated with shift work. Reviewing these factors while learning from shift-work related mishaps informs a foundation for selecting the best schedule for each facility. A fixed schedule of working 1 month of day shifts followed by 1 month of night shifts helps minimize the unavoidable risks of shift work. Alternatively, adjusting the start and end times of a workday to incorporate daylight into both 12-hour shifts can also facilitate a well-balanced schedule and work life. Educating stakeholders, employees, medical personnel, and unions on the risks of poorly planned shift schedules is imperative. This culture must also be endorsed at the highest level. Doing this will allow for better selection of a work schedule and cultivate a safer, more productive, and secure nuclear facility.

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