Technical Support Document for ANSI/API RP 755, *Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries*

API TECHNICAL REPORT 755-1
APRIL 2010

AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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Prepared for API by CIRCADIAN

AMERICAN PETROLEUM INSTITUTE

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Foreword

Fatigue Risk Management Systems (FRMS) have emerged and been widely recognized as a more effective approach to managing and mitigating employee fatigue risk in the 24/7 workplace. The core feature of the FRMS is that it is a data-driven, risk-informed, safety performance-based system. The FRMS implementation process first identifies all sources of fatigue risk in the business operation, then introduces mitigating policies, technologies, and procedures to reduce the risk, and most importantly then maintains them in a proactively-managed continuous improvement system. The history of FRMS was recently summarized [1].

This method represents a significant step change from the traditional approaches of either relying on maximum limits to hours of work or minimum limits to hours of rest (variously called Hours of Service, Work-Rest Rules, Working Time Directives), or adopting intermittent or piece-meal solutions (e.g. a fatigue training program or a shift schedule redesign), depending on the interests and initiative of local site managers.

One essential feature of FRMS is that it is a system meant to be improved upon on a regular and continuous basis. It is not a set of guidelines designed for one-time compliance, but instead provides a framework that will evolve over time, driven by the collection of data on fatigue risk and fatigue outcomes (e.g. fatigue-related incidents).

This document identifies and explains the scientific and operational issues considered during the preparation of RP 755. By providing the reasoning behind the specific wording in the RP755 document, this document supports each key statement in RP 755 in sequence so that it can be used in parallel with the RP 755 text. To make this document accessible and manageable, key scientific sources and references are provided to help readers gain access to the scientific literature.

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Suggested revisions are invited and should be submitted to the Director of Regulatory and Scientific Affairs, API, 1220 L Street, NW, Washington, DC 20005.

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1 Scope

Provides guidance to all stakeholders (e.g. employees, managers, supervisors, contractors)

The success of an FRMS depends on the willingness of diverse stakeholders to alter their behaviors and practices to help mitigate fatigue risk. It is important to bring employees, supervisors and managers early into the process of designing an FRMS. Doing so helps create a buy-in so that they will support and own the FRMS because of the benefits they see for themselves as well as for the overall safety of the workplace.

This recommended practice was developed for refineries, petrochemical and chemical operations, natural gas liquefaction plants, and other facilities such as those covered by the OSHA Process Safety Management Standard, 29 *CFR* 1910.119

RP 755 was specifically developed for US facilities operating under the OSHA Process Safety Management Standard. Companies voluntarily may also choose to take advantage of RP 755 to design and implement FRMS across their other operations, including upstream and international operations outside the US where fatigue risk can also significantly impact the operational safety. However, doing so is not required under RP 755.

Applies to a workforce that is commuting daily to a job location

RP 755 is specifically designed for employees who live and sleep at their homes during off-duty hours and have normal family-social interactions on a daily basis. These recommendations are not designed for employees who travel to remote locations (e.g. offshore platforms or onshore remote locations) where they live in company-provided accommodations and are isolated from their normal daily family and social interactions.

Research on sleep patterns in offshore platforms and other remote locations shows a greater capacity to adapt to longer sequences of consecutive workdays and maintain adequate sleep when the demands of family and social interactions are not competing with sleep and relaxation time. [2,3]

1.1 Overview

It has been documented that excess workplace fatigue is a risk to safe operations

Fatigue is not just feeling physically tired; it also is a state of impaired alertness, attentiveness, and mental and physical performance. Being fatigued also causes reduced motor coordination and slower reaction times. A working definition of fatigue for the purposes of this document is found under Terms and Definitions in Section 3.3 of RP 755.

Fatigue is a common issue among workers. A survey of US workers found a fatigue prevalence of 37.9% [4], which is consistent with other studies of working-age individuals [5,6]. When an individual is fatigued, the probability of poor, inefficient, and variable performance increases. Performance deficits include increased periods of delayed response or no-response (lapses) during attention-based tasks, slowed information processing, increase in reaction times, reduced accuracy of short-term memory, and accelerated decrements in performance with time on task [7]. Fatigue is also associated with a loss of environmental (“situational”) awareness, impairment of cognitive/logical reasoning skills, poor judgment, and diminished ability to communicate and/or process communications and information.

The inevitable result of the reduced or impaired alertness caused by fatigue includes increased human error, a reduced ability to work safely, and lower productivity. Numerous scientific studies and extensive field experience confirm that shiftworkers with excessive sleepiness as defined by the Epworth sleepiness score [8] are more likely to experience drowsiness on the job, nodding-off, and making mistakes while working, as well as nodding-off or fighting sleep while commuting to and from work. [9] Similarly, a study of shiftworkers found that employees who reported accidents also reported greater fatigue than employees who did not report accidents. [10] The increased accident rate and severity caused by fatigue is reflected in Workers' Compensation claims (Figure 1). The costs per employee per year are almost five times higher in facilities with severe fatigue problems as compared to facilities in which fatigue was not a problem. [11]

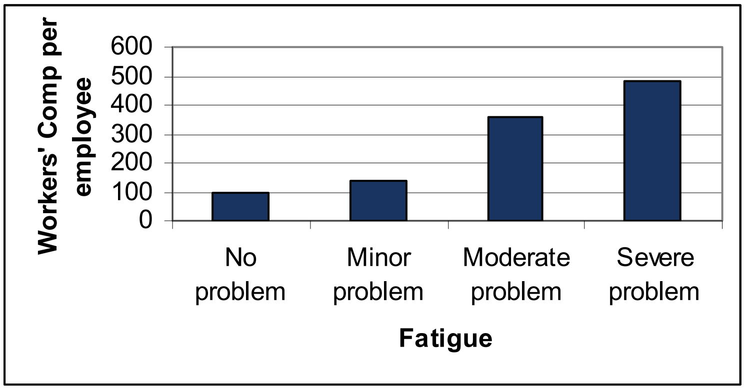

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Figure 1—Employee fatigue levels and Workers' Compensation US$ costs per employee per year in a survey of 400 shiftwork operations

Fatigue has been also been identified by the U.S. Department of Transportation as the number one safety problem in transportation operations. The number of fatigue-related traffic accidents is considerably higher at night than during daytime. [12] In fact, a study found that drivers are 50 times more likely to fall asleep at 2 am than at 10 am. [13] Some studies estimate that the costs of fatigue in US transportation operations exceed $12 billion a year. [14] Most of these costs stem from the sleep deprivation and fatigue that occurs when work intrudes into normal nocturnal sleeping hours, although in some cases fatigue may be exacerbated by underlying sleep disorders.

Fatigue in safety-critical employees impairs their judgment and cognitive reasoning. Divided attention tasks requiring anticipation and proactive planning are typically the first to degrade. As fatigue impairment progresses, the likelihood of automatic behavior (performance of tasks without cognitive awareness) and "microsleep" lapses of attention significantly increases. The risk of such occurrences is proportionate to the degree of vigilance required to safely perform a task.

Fatigue also affects mood. [15] The National Sleep Foundation [16] found that people who do not get enough sleep are more likely get impatient or aggravated and have difficulty getting along with others. Increased irritability and stress negatively influences personal, work, and family relationships, resulting in inadequate/ineffective communications.

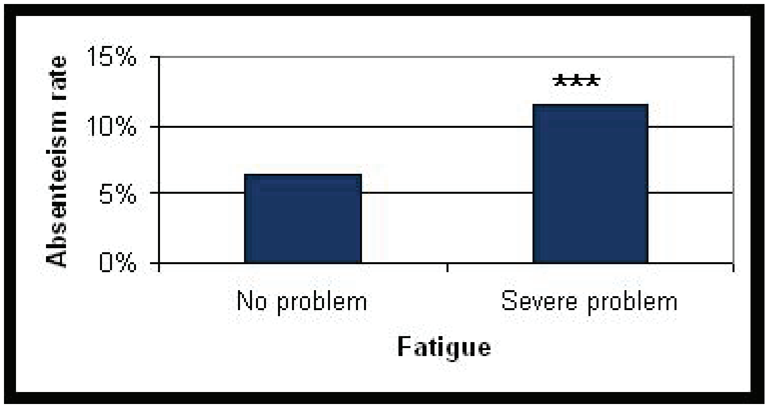

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Figure 2—Fatigue levels and absenteeism in survey of 400 shiftwork operations comparing facilities with no significant problem with those with a severe fatigue problem.
*****: ANOVA,** F=5.99, df=5, p<.001

Fatigue also has been associated with an increase in Lost Productive Time (LPT). [4] Among workers reporting fatigue, 65.7% reported health-related LPT compared to 26.4% of those without fatigue. Workers with fatigue cost employers $136.4 billion annually in health-related LPT, an excess of $101.1 billion compared to workers without fatigue. Fatigue impaired work ability primarily by increasing workers' time to accomplish tasks and impairing their concentration. In addition, fatigued workers reported more physical health and social functioning problems than workers without fatigue.

Fatigue also correlates with increased absenteeism (Figure 2) and turnover as well as reduced morale and poorer labor relations. Industrial surveys reveal that absenteeism rates are nearly double in facilities that have severe fatigue problems among their employees, as compared to facilities in which fatigue is not a problem. [11]

No matter how well-trained, skilled, motivated, or experienced they are, fatigued operators tend to behave more erratically and unpredictably. Unfortunately, many of these incidents are incorrectly blamed on behavioral problems rather than on physiology. Thus understanding human physiology is the key to successfully identifying and managing the inherent problems of shiftwork and fatigue-related human error.

The consequences of fatigue also impact a company's operating efficiency and costs. Fatigue results in reduced productivity and customer service quality, reduced operating reliability and decreased operating profit, increased health and wellness costs, and higher overall costs, risks, and liabilities. There is considerable investigative evidence that fatigue has contributed to serious incidents and accidents in industrial operations, nuclear power plants, and in all modes of transportation. [17]

Prescriptive Hours of Service rules should be supplemented

It seems intuitive that fatigue risk could be controlled simply by limiting the number of hours of work and protecting the daily and weekly minimum hours of rest. This "Hours of Service" approach evolved in the early 1900s as the practice of operating at night with extended hours and 24/7 work schedules spread across multiple industries following the commercialization of electric light. The emerging labor movement in the early 1900s eventually provided the impetus to implement Hours of Service (HoS) regulations. As a result, the issue of workplace fatigue became intertwined with labor pay and rights issues and led to regulatory limits on work/duty duration and minimums of off-duty time duration in all transportation modes by the middle of the 20th century, and eventually some other industries such as nuclear power. In Europe, influential research on both the risk of accidents and the sociological and medical impacts of shiftwork accelerated the momentum. The EU Working Time Directives have now placed limits on work and rest hours in most industries and occupations.

However, advances in the science of sleep, circadian rhythms and workplace fatigue over the past 30 years have shown that relying simply on a prescriptive Hours of Service approach is insufficient. In the late 1970s, two fast-growing areas of scientific research—the electrophysiology of sleep and biological clock research—merged into a dynamic new discipline because they proved to be so interrelated. One of the most influential early studies demonstrated that the brain's circadian clock exerted a strong control over the timing, duration, and stages of sleep. [18] In fact, as was later demonstrated, there were two major interacting determinants of sleep: a homeostatic component related to the time spent awake and accumulated sleep deprivation, and a circadian component related to the time of day of the individual's biological clock. [19]. Because of this circadian regulation of sleep, there was an important difference between a sleep opportunity and the amount of actual sleep it was possible to obtain during that opportunity.

This research showed that the most significant factors influencing employee fatigue are the circadian (24-hour biological clock) times of work and of sleep opportunity, the consecutive number of hours awake (both on duty and off-duty), and the 24-hour clock timing of work and rest patterns over the prior week. However, none of these are addressed by Hours of Service regulations. [20,21] Indeed, an employee can be fully compliant with Hours of Service but highly fatigue impaired, or conversely can be non-compliant with HoS but fully alert and safe. As a result, the measurement of "successful" fatigue management is flawed if it relies on the business' compliance with the input variables (e.g. number of work/rest hour HoS regulatory violations) rather than the evaluation of any output variables (e.g. actual employee fatigue impairment, fatigue-related accidents).

Fatigue mitigation should be addressed through a comprehensive fatigue risk management system (FRMS)

Over the past five years, a broad international consensus has emerged across many 24/7 industries that the optimal way to manage and reduce employee fatigue risk is through a systematic process called a Fatigue Risk Management System (FRMS). Government regulatory agencies, industry associations, and many corporations with 24/7 operations have recently incorporated FRMS into their regulations, industry standards, and corporate policies.

FRMS is a significantly more effective approach to managing fatigue than relying on Hours of Service, or implementing training programs, or isolated policies and procedures to mitigate fatigue risk. The key concepts that define FRMS are listed in Figure 3 and they are essential to the success of FRMS implementations.

- **Science based**—Supported by established peer-reviewed science
- **Data driven**—Decisions based on collection and objective analysis of data
- **Cooperative**—Designed together by all stakeholders
- **Fully Implemented**—System-wide use of tools, systems, policies, procedures
- **Integrated**—Built into the corporate safety & health management systems
- **Continuously improved**—Progressively reduces risk using feedback, evaluation & modification
- **Budgeted**—Justified by an accurate ROI business case
- **Owned**—Responsibility accepted by senior corporate leadership

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Figure 3—Key characteristics of a successful Fatigue Risk Management System

FRMS is not actually a new concept but instead has been in development and operational use for more than 20 years. However, FRMS has only recently reached the "tipping point," gaining the attention of a sufficient critical mass of industry, government, and academic "influencers" to burst through into general international acceptance.

One reason FRMS remained hidden from public awareness is that until recently this system did not have a commonly-accepted name. During the past 20 years, various terms have been used to describe a systematic approach to managing employee fatigue risk in 24/7 operations, including Alertness

Assurance, Alertness Management, Human-Centered Management, and Fatigue Management, and also specifically Fatigue Risk Management. However, during the past five years a consensus emerged, and governments and other organizations worldwide now have adopted the term "Fatigue Risk Management Systems."

The recent general acceptance of FRMS as the standard for managing and mitigating employee fatigue risk represents a significant maturation in the understanding of and response to fatigue risk. It requires moving from a dependence on the old and familiar prescriptive hours of service rules to a process that requires active management but also provides more flexibility. To accomplish this switch, organizations that implement FRMS should ensure that the system is firmly embedded in the health and safety management systems of the company and that it is rigorously maintained, carefully monitored and continuously improved upon. This process should be part of the continuous cycle of managing the risk profile of any organization's management system. Provided it is properly designed, implemented and managed, FRMS offers a major step change in addressing the health and safety risks in 24/7 operations.

Integrated with other safety management systems

In the oil industry (and other safety-critical industries such as aviation), Safety Management Systems (SMS) are an accepted systematic business model for managing safety risks. [22] A key step precipitating the "Tipping Point" of widespread international acceptance of FRMS was Professor Drew Dawson's integration of fatigue risk management with the concept of Safety Management Systems. [23] Since fatigue represents a significant safety risk and interacts with other sources of risk, the FRMS is most effective and efficient in use of resources when it is integrated with SMS, or the company's equivalent risk management systems.

As described in Professor James Reason's 1990 book "Human Error," [24] most major industrial and transportation accidents are the result of multiple latent points of system failure and not just the immediately obvious active error of the human at the controls. Reason introduced the imagery of a series of Swiss cheese slices (Figure 4) to explain that every level of organizational defense against potential hazards has holes in it. It is when the holes line up that a pathway for accidents to occur emerges. These slices of cheese, which Reason calls "defenses in depth," operate at different levels of control.

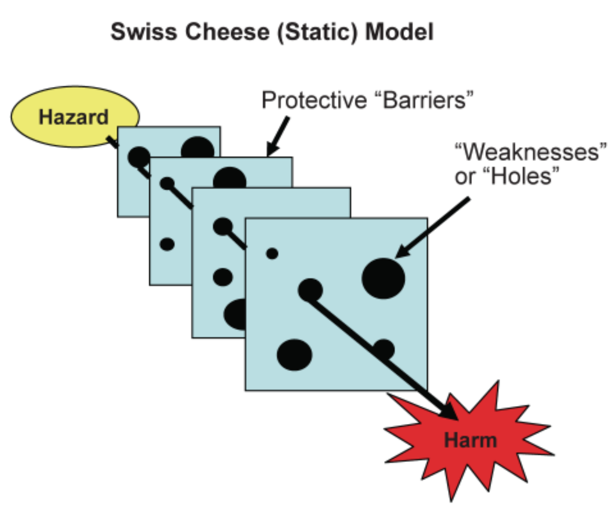

Figure 4—The successive layers of defense in depth in a safety (and fatigue risk) management system and the strategy of addressing risk

One of the key features of FRMS is that the process seeks to identify the holes in the “Swiss cheese slices” from a fatigue perspective and should also identify the mitigation required to either close the holes or at least reduce their size. The outputs from these mitigations, together with the identified fatigue issues, will then feed into the SMS, e.g. in the form of additional policies, revised procedures, or assurance criteria, which will update and strengthen the management systems.

Everyone—the workforce and senior management has a role

FRMS requires a comprehensive review of the policies, practices, and procedures of the company, and in many cases some of these will need to be modified to recognize, prioritize, and implement FRMS as an integral part of how the company conducts its business. Furthermore FRMS requires a long-term commitment to data collection, risk analysis, and continuous improvement. None of this can be accomplished without the strong support and ownership of both the workforce and senior management.

Implementation of an FRMS cannot be left to site managers or to middle management without a champion/owner on the senior management team. Without this commitment, there is a risk that management will move on to address other business problems when the stimulus that led to FRMS implementation has passed, and thus unintentionally allow the FRMS to receive less attention and lose its effectiveness.

Similarly if the workforce perceives the FRMS simply as a management process it will loose its effectiveness, because their personal behavior and sense of personal responsibility in managing fatigue risk is critical to a successful FRMS. Just as it is the responsibility of management to provide its employees with adequate off-duty opportunities for restorative, good quality sleep, it is the equal responsibility of each individual to make optimal use of the available rest periods to obtain adequate sleep, as well as to seek and follow up on medical advice necessary to ensure safe and alert performance of his/her duties.

The FRMS should be based on sound science and recognize operational issues

The FRMS should be based on well-established peer-reviewed scientific research on sleep, alertness, and circadian and fatigue physiology. It also should use a data-driven process to assess fatigue risk, evaluate potential fatigue countermeasures, and to assess overall fatigue management. Doing so not only assures that the FRMS is designed rationally, but it also provides an objective common ground that management, labor, and government agencies can agree upon, and act as a basis for selecting the FRMS solutions to implement. To support this science-based approach, companies should use appropriate, scientifically-valid fatigue risk assessment and countermeasure tools to measure, assess, and mitigate the risks associated with employee fatigue.

At the same time, the FRMS must be operationally realistic. In the critical safety-positions covered by the FRMS, there must always be an operator at the controls. If a relief person is not available, the position cannot be abandoned merely to satisfy an Hours of Service limit. On the other hand, such events should be rare in order to prevent abuses. If they are a frequent occurrence, and there are consistent “open shifts,” then the company has understaffed the position and should correct the situation as soon as possible in order to maintain adequate fatigue risk management.

As is discussed later in this document in the Hours of Service section, companies cannot move immediately from their current operating practices with no HoS limits to the new HoS restricted operating practices without first undergoing a transition period. This period is necessary in order to adequately train staff for these critical safety-sensitive and technologically-complex jobs.

Furthermore, there are significant gaps in the scientific research when it comes to studying shiftwork in operations that already have implemented an FRMS. Instead, most current research focuses on comparing safety on the 1st, 2^{nd,} 3^{rd,} and 4th consecutive shifts in operations in which there is no FRMS. Research is also needed on the extent to which individuals adapt when they work longer blocks of shifts in outage conditions in which they suspend their personal outside commitments to focus on completing the work and getting the plant back on line. Additional research is therefore needed to refine scientific-valid outer boundaries for HoS under FRMS-managed conditions.

The FRMS shall include consultation with key stakeholders in the development and implementation of the local application of the FRMS

Buy-in by all stakeholders is essential to the success of a FRMS, and buy-in requires education, consultation, and addressing the concerns of all parties who influence the outcome of the FRMS. FRMS requires changes to the operating practices, policies, and procedures, which only management can make, and it requires changes to the behavior and day-today activities of the employees, which only they can make. Stakeholders should participate in defining the common goal of minimizing fatigue and in implementing solutions to address that goal. In this way they will own the outcome and the success of FRMS.

One of the most important areas for employee participation in FRMS is the process of designing and implementing new work schedules. Studies comparing schedule implementation methods have shown that employee involvement in schedule redesigns considerably increases their benefits as compared to schedules changed by management mandate alone [25,26,27,28,29,30] including:

- increased worker satisfaction with schedule design,
- decreased unscheduled absences from illness,
- maintained teamwork among employees as well as in-role and extra-role performance on individual levels,
- decreased physical and psychological circadian malaise and overall tiredness associated with shiftwork,
- improved daytime sleep quality,
- improved quality of employees' home and social lives,
- decreased turnover and number of vacant positions,
- increased organizational commitment,
- improved employee understanding of administrative issues involved in management of the facility,
- reduced employee complaints.

Employee involvement in the scheduling selection process is a critical factor in preempting unrest and creating strong employee-level support. Although each employee will bring his or her own preferences into the process, individual preferences can be grouped using cluster analysis to extract the significant preferences from the facility as a whole.

The design of a new schedule should be adapted to the conditions of the particular workplace or operation, and should take into account the local operational needs and specific characteristics of the workforce. This is accomplished by involving both employees and local management in the process. Educating and training of managers and employees about the challenges of shiftwork and how to cope with them, and understanding the basic ergonomic criteria of schedule design will contribute to a better schedule. Facilities in which employees are consulted during the scheduling process experience fewer accidents, improved morale, decreased absenteeism and turnover, and optimized production levels. Employee-driven scheduling processes, in which operational requirements, employee preferences, and physiological factors are optimized, represent the best approach to designing and implementing new shift schedules.

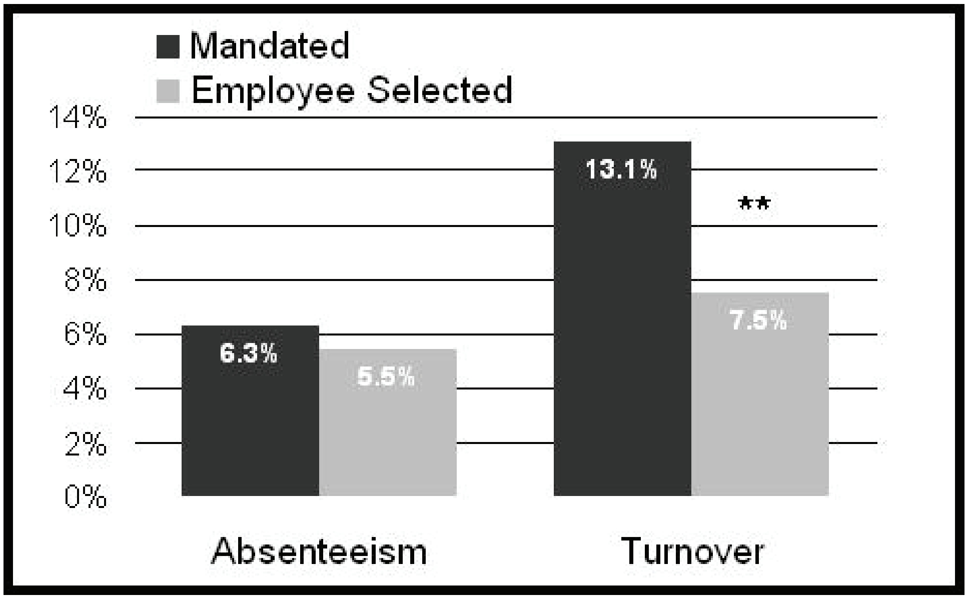

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Figure 5—Absenteeism and turnover rates in facilities that mandate shift schedules vs. those that allow employees to select schedules.
(**): ANOVA, F=4.98, df=5, p<.01

Should include a process to review and enhance the FRMS, as needed, with a goal of continuous improvement

An essential feature of both FRMS and SMS is that they are designed and operated as continuously-improving systems specifically created to collect and analyze data, develop and implement risk-mitigating solutions, and then measure risk in a continuous feedback loop. Therefore, the FRMS should continuously evolve over time to progressively reduce fatigue and improve safety (Figure 6).

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Figure 6—SMS and FRMS continuous improvement loop. Identifying and controlling the hazards and risks of fatigue is a progressive repetitive process.

2 Normative References

The scientific literature that relates to sleep, alertness, fatigue, and circadian rhythms is considerable. More than 8,000 new scientific articles a year are published on these topics, and the included list of normative references is therefore only a starting point to access this literature. Further scientific references are added in this document to provide the sources relevant to specific issues.

3 Terms and Definitions

RP 755 provides definitions of the key terms used in the recommendations document. Additional information on some of these terms (e.g. fatigue) can be found in a CIRCADIAN® white paper on the definition of fatigue [148] and in the other reference sources provided in Appendix 1 of this document.

4 Components of a Comprehensive FRMS

It is important to build and manage the FRMS as a fully integrated system that provides a series of "defenses in depth" against the risk of fatigue. As illustrated in Figure 7, there are five key "defenses in depth" that need to be managed by the FRMS:

- workload-staffing balance,
- shift scheduling,
- employee fatigue training & sleep disorder management,
- workplace environment design,
- fatigue monitoring & alertness for duty.

The first three of these defenses impact sleep management, but the last two provide alertness management, which is a significantly different goal.

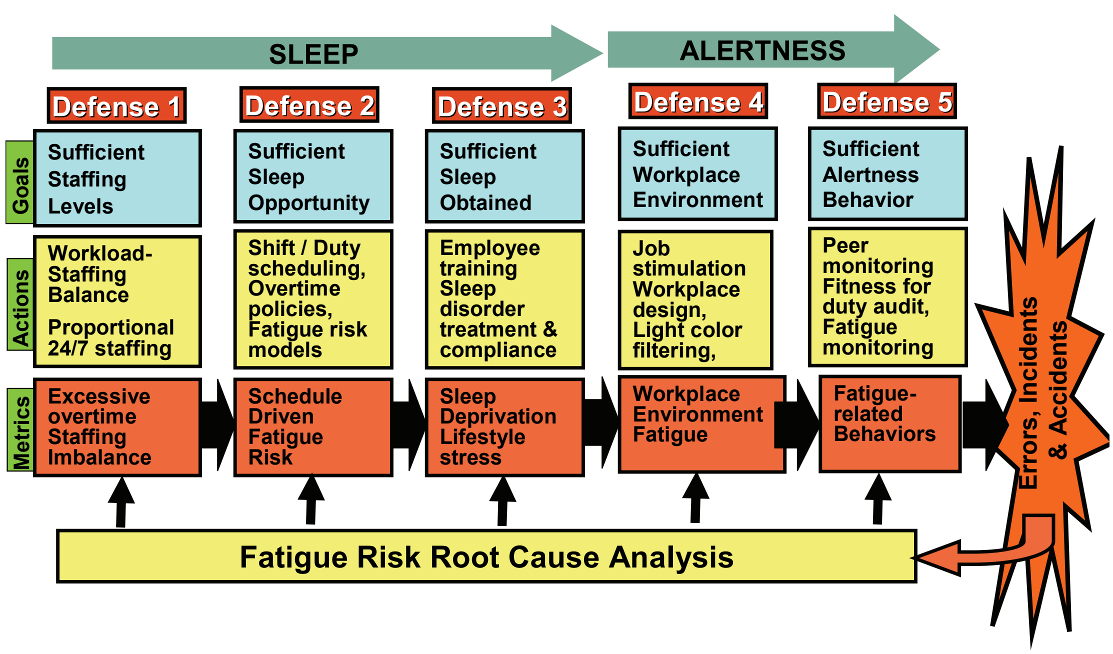

Figure 7—The five key defenses in depth of a Fatigue Risk Management System and the process of continuous improvement using Fatigue Risk Root Cause Analysis

4.1 Roles and Responsibilities

The FRMS should clearly define the roles and responsibilities

Prior to the introduction of FRMS, the management of shiftwork fatigue and health and safety risks largely was left to the managers of each site. As a result, some sites were quite proactive, introducing various individual components of FRMS including fatigue risk assessments, staffing analyses, shift schedule optimization, shiftworker training, and control room design, but usually not as an integrated system. Other sites, even within the same company, did very little to address fatigue risk. Furthermore, because site managers are often moved from site to site during their careers, fatigue risk and shiftwork optimization initiatives lost their effectiveness if the incoming managers did not consider them a priority.

The essential difference of FRMS is that it is a corporate-wide managed system. Therefore, to be successfully implemented and sustained, personnel must clearly define roles and responsibilities:

- **Senior management** must provide strong support and take ownership of the company's FRMS. FRMS cannot be left to site managers or to middle management to implement without a champion/owner on the senior management team. Without this commitment, there is a substantial risk that senior management will move on to address other business problems and unintentionally allow the continuous improvement goals of the FRMS to slip in the corporate priorities.
- **Immediate supervisors** make many day-to-day decisions that can influence fatigue risk for better or worse. By being alert to the issue of fatigue, they intervene in work assignments and rest breaks, which can have substantial benefits. They themselves may also be subject to fatigue risk because of their work hours and the FRMS will address practices that influence their own fatigue risk.
- **Individual employees** make daily choices on how long and where to sleep in their off duty time, the amount of exercise and relaxation they enjoy, how they manage any medical issues, and what they eat and drink. Each of these factors has a major impact on their fatigue risk. Furthermore, teamwork and peer-to-peer monitoring is highly valuable in keeping team members in critical positions alert and safe on the job.
- **Contract companies and their employees** often work at the same workplace as regular employees and may be equally vulnerable to fatigue-related errors which directly impact the safety of company operations and employees. Thus on-site contractors also should be covered by RP 755 FRMS standards.
- **Key support functions (medical, HR, safety, workforce planning, and scheduling)** each have important roles in the FRMS.
    - The medical department should be aware that the health risks and costs are significantly different in shiftworkers than in 9-5 employees [31,32,33,34] and therefore should design health assessment, screening, and disease management programs to address them.
    - HR should be aware of interindividual differences in the capacity of employees to cope with or adjust to shiftwork [35,36] and design policies to address the needs of different employees.
    - Those involved in workforce scheduling and planning should be aware of the substantial impacts of 24/7 work patterns on fatigue, safety and health, [37] and balance these appropriately against operational efficiency goals.

4.2 Positions Covered by FRMS

Involved in process safety sensitive actions & those making process safety sensitive decisions

Employees working in on-site safety-critical positions during their work shifts are the prime focus of the FRMS. However, it also is important to consider managers who may be called to make safety-critical decisions when they are off-site or at home. If an event occurs and a manager is contacted by telephone to make a decision relative to safety-critical processes, he/she should be sufficiently alert to make that decision and not cognitively-impaired by fatigue.

Particularly important when a manager is called at home to make a decision is the issue of sleep inertia, which is the period of grogginess that immediately follows waking from sleep. It is particularly pronounced when an individual is woken from deep (Stage 3, 4) sleep. The performance deficits that have been documented in sleep inertia include hypovigilance, confusion, delayed reaction time, and deteriorations in cognitive and sensory-motor performance. Cognitive tasks requiring a high attentional load are much more affected by sleep inertia than simple motor tasks. [38] Sleep inertia also causes deterioration in short-term memory and speed of cognitive processing. [39] Sleep inertia mostly dissipates within 30 minutes after awakening although there may be some lingering effects for another 30 minutes after that.

4.3 Staff-workload Balance

Initial and periodic assessments of staffing levels and workload balance

The staffing level, and not the shift schedule, is the primary determinant of average employee work hours per week, overtime levels, average duration of off-duty periods, and other key factors strongly associated with employee fatigue risk. Therefore, it is vital first to address taskload/workflow issues and ensure adequate staffing levels, and furthermore to proportionally balance staffing to workload across the 168 weekly hours of the 24/7 schedule.

By its nature, workload may vary over time, and hence the staffing levels should be reassessed by each company worksite on a periodic basis to cope with workload fluctuations. In these evaluations, it is important to deal with actual daily staffing levels (people available to do the work tasks that day) and not just planned or paper staffing levels, which may fail to address vacations, sick leave, long term disability, secondment to other assignments, or other causes of open shifts.

The FRMS should recognize the workload variability

In 24/7 operations, customer or economic demand and equipment and raw material availability often show fluctuations across time. Therefore, production rates and workload levels may vary significantly. Fluctuations can occur by hour of day, day of week, week of month, month of year, or a combination of these, or may be related to other reasons, such as changes in the economy. If a facility maintains the same number of employees working at all times despite fluctuations in workload, there will be times when staff members are underutilized and other times when they must work excessive levels of overtime to meet demand. In such situations, the traditional shift scheduling used in many operations, with its balanced crews and equalized staffing, is no longer appropriate because of its inherent inefficiencies.

In the refining and petrochemical operations covered by the RP 755 standard, significant increases in workload occur during outages when the plant or a section of the plant equipment is shut down for cleaning, repair, and maintenance. A significant part of the additional workload is provided by contractors who move from facility to facility to provide staffing during outages. However, the permanent employees on site also work additional hours during these outages, which is addressed as a special section in the Hours of Service.

In some facilities, outages are infrequent events that might occur every one or two years for an intense 3 to 6 week period of work. During that time, no vacations or other assignments are permitted in order to maximize available staffing levels, and shiftworkers adjust their lives to minimize outside family or social commitments. However, in other facilities, these outages are a regular occurrence where one or more different sections of the plant shut down most of the time. As such, outages become more like normal operations.

To better utilize their human resources, managers should adopt a flexible workforce management system [40] to match employees to workload while still taking into account employee social and physical needs and limitations. This approach should incorporate a process for assessing the performance of a shiftwork schedule, identifying the need for staffing levels, and making adjustments as needed.

Also assess current and anticipated turnover and absenteeism issues

Absenteeism and turnover rates impact effective daily staffing levels (the number of employees actually available to work on any given day), and therefore fatigue risk. Simply put, when an employee is absent or quits the job before an adequately-trained replacement is found, other employees have to work more overtime and with longer work hours per week, as well as have shorter off-duty rest periods and/or fewer days off per week.

It is important to recognize that prolonged periods of understaffing and therefore high overtime levels in turn lead to increased levels of absenteeism as workers become fatigued and may decide to be absent for medical reasons or because of family/social/psychological stress. This creates a vicious cycle in which staffing shortages increase the required overtime levels necessary to compensate for them, which in turn results in increased absenteeism. Not only is this an unhealthy and potentially unsafe practice, but it can be also a very expensive one, as regular pay hours are replaced by overtime pay hours.

As well as accurately diagnosing the causes of current rates of absenteeism and turnover, companies should assess demographic changes that impact future rates of turnover. For example, during the 1980s and 1990s, many refineries and petrochemical plants used the opportunity presented by advantages in process automation to increase productivity and reduce staffing levels, usually by freezing new hires. As a result, these plants now have an uneven distribution of ages in their shiftworker employee population, with a large block of senior employees moving progressively towards retirement age. Recruitment, hiring, and training plans need to take into account the staffing shortages caused by such predictable events.

4.4 Safety Promotion: Training, Education and Communication

Educate all stakeholders on the causes, risks and potential consequences of fatigue

While each individual employee is responsible for using off-duty rest periods to obtain adequate sleep, employers can help them accomplish this by educating them on healthy and safe ways to adjust their lives while working 24/7 schedules, and how to optimally schedule their sleep to maintain alertness.

Some might believe that shiftworkers can work out their sleep strategies for themselves, but in practice, this is untrue. Assessments of fatigue training programs have consistently shown that even experienced employees find the information useful [41,42,43] and that it increases their knowledge of fatigue management. Even senior, experienced shiftworkers often have less than optimal patterns of sleep based on misinformation, and frequently comment they wish they had had the accurate information provided by the training earlier in their lives.

More importantly, between 47% [42] and 96% of 24/7 workforce employees [43] reported that they applied the fatigue management strategies at home. A study [41] found that after attending a Managing a Shiftwork Lifestyle training program, shiftworkers working the night shift increased their average amount of daytime sleep from 4.8 to 5.8 hours, excessive use of caffeine dropped from 32% to 8%, gastrointestinal symptoms index fell from 17.9 to 13.6, and more than 50% made physical changes to their sleeping environment.

Companies that implement shiftworker fatigue and lifestyle training have reduced rates of turnover and workers compensations claims. [44]

Increase family member awareness of how they can help

Educating employees to better understand and manage their personal sleep and fatigue risk is a critical component of an FRMS. However, such education is most successful when the shiftworker's spouse or partner also is supportive and aware of the challenges facing the shiftworker. Factors such as inadequate shiftwork lifestyle coping skills, personal crises (such as a sick child at home), and undiagnosed and untreated sleep disorders may prevent employees from obtaining adequate sleep even when they have work-rest schedules designed to provide adequate sleep opportunity. A supportive partner can make all the difference in the employees' ability to reach that goal.

Spouses and significant others also play a key role in encouraging shiftworkers to seek and follow up on medical advice necessary to ensure safe and alert performance of their duties.

Organizations that invite their shiftworkers to bring their spouses or partners to the fatigue training programs, and make efforts to schedule these programs at times that family members can more easily attend, have found significant value in such outreach efforts. Others may mail newsletters or other educational information to the home address to encourage sharing of tips and solutions among family members.

Specific training programs and supportive education and communications materials appropriately tailored to responsibilities, duties and work environment of stakeholder

There is a difference between broad educational and communication programs designed to promote awareness of fatigue risk and job-specific fatigue training programs that teach practical mitigating strategies. Both are important but they should not be confused.

The process of designing and implementing an FRMS should start with a broad education/communication program throughout all levels of the organization about the special health, alertness, and safety risks associated with 24/7 working hours, as well as about the commitment of the company to be proactive using an FRMS to help all employees address and mitigate these risks. This communication will help build support and ownership of the FRMS process at all levels of the organization.

Training programs should be designed to assist employees in identifying issues involving sleep planning, social/family, and health and sleep disorders that may interfere with their individual ability to perform their duties in an alert manner. These programs should also provide them with the necessary tools and support to proactively manage their own personal health, alertness, and safety. To accomplish these goals, the training should be tailored as closely as possible to the actual job tasks, shift schedules, and work environment affected. Making the training relevant to the shiftworkers' real world is a major factor in gaining their acceptance and increases the chances that they will adopt and use the specific training content.

To provide a firm foundation for the training and to enable shiftworkers to apply the knowledge rationally, the program should provide basic information on the science of human biological clocks, circadian rhythms and sleep, and the direct effects these have on their everyday lives. This program should also teach shiftworkers how to manage the physical and mental stress of shift schedule patterns on the human body as well as provide information on scientifically-valid fatigue countermeasures. Furthermore, it is important to provide tips on how to manage the social and family issues that arise from irregular duty rest patterns, with particular emphasis on improving communication and support within the family.

As part of the fatigue education and training, employees should be given an overview of the FRMS. Such a background will help them better understand the company's commitment to safety, the scope of the FRMS, and the resources that will be provided to them.

Should receive initial and recurring training

Fatigue education or training programs that occur only once in the career of an employee have only limited value. In order to reinforce the message, companies should continue to update the knowledge, encourage its adoption, and maintain ongoing active fatigue management strategies. To support this goal the fatigue training needs to be recurrent, and the general education about fatigue should be ongoing.

Recurring training programs help reinforce the lessons taught in the initial and new-hire training sessions and keep employees informed of new information in this field. They also should provide an opportunity for employees to have practical questions answered, and encourage peer-peer sharing of practical fatigue management strategies that other shiftworkers have found useful.

Both managers and employees should be fully informed about the design of the corporate and their local worksite FRMS, and through recurring communications and training should be kept up to date about the progress being made in the FRMS, the data being collected on fatigue-related incidents and injuries, and the success and challenges in FRMS implementation at other locations in the company. It also helps to reinforce key fatigue management lessons that can be implemented throughout the organization.

Additional initial and recurrent training for those who supervise or manage other employees and contractors

Managers with functional responsibilities that impact employee fatigue need to receive information on how to analyze and implement the staffing, scheduling and employee management practices of the FRMS on an ongoing basis. This education will allow managers to understand the scope and progress of the FRMS, and in turn allow them to more effectively communicate the system and its resources to all employees. As part of this training, managers will also be made aware of the policies and procedures and fatigue risk countermeasures that are available. Furthermore, the management education should cover the best practices for managing the daily fatigue challenges that arise in any 24/7 operation and its workforce.

One of the most important levels to educate and train is first-line supervisors and shift team leaders. Specifically, these employees should be taught how to recognize the signs of fatigue impairment and how to implement effective methods for mitigating them including the following.

- Monitoring signs of fatigue. Since individuals are often poor judges of their own state of impairment, team leaders have the ultimate responsibility for monitoring their team.
- Identifying, assessing, and monitoring fatigue risks in their areas of control.
- Ensuring that employees have access to relevant training, information and assistance.

4.5 Work Environment

However diligently they manage their sleep, employees still may be required to work in the early morning hours at the low point in the circadian cycle or--despite best attempts to get enough sleep during their off hours—will report on occasion to the workplace in a sleep-deprived state. The next critical line of defense, then, is the design of the workplace environment. Key factors, such as the intensity and wavelength of lighting, sound levels, temperature, and humidity, should be designed to protect employees' levels of alertness and prevent employee impairment. [45]

FRMS should take into account the type of work that is being done

Job tasks and work conditions in the industry vary widely. At one extreme, an operator may be sitting alone in a quiet climate controlled control room in the middle of the night with the lights dimmed and little to attract attention on the process consoles. At the other extreme, a field technician may be up high on a catalytic tower in cold windy weather undertaking a physically demanding task. Fatigue can cause significant but different risks in these very different safety-sensitive jobs.

The FRMS should identify the different types of job tasks and the fatigue-related risks associated with each. The specific fatigue countermeasures should be identified for each, and the process for collecting data and assessing the effectiveness of the FRMS needs to be designed to cover every job type.

Adequate opportunity for work breaks based on nature of work

Alertness and performance during long work periods, particularly at night, are significantly aided by short breaks from work. The inclusion of a 15-minute break at the end of each 75 minutes of continuous work has been shown to have considerable beneficial effects, allowing shiftworkers to overcome some of the performance deficits associated with time on task. In a lab study, breaks of 2, 6, or 15 minutes were taken in isolation at the workstation or in a recreational area where individuals were able to interact with colleagues. The results indicated that 15-minute breaks during a period of high workload were sufficient to overcome the performance decrements that have built up in the previous period of work. Two-minute rest periods were considerably less effective, while 6-minute breaks were effective in overcoming performance decrements, apart from on a tracking task in which there was still evidence of some impairment. [46] The results suggest that the benefits of breaks are related to their duration and thus during night shifts, breaks should be provided if the task involves long periods of sustained attention.

Rest breaks are an effective way to maintain performance, but the benefits of rest breaks are related to the nature of the work. [47] For sedentary jobs in control room environments, it is helpful to have opportunities to stretch and walk around. Conversely, a physically-active field operator may benefit from an opportunity to sit down and rest. Because individual needs differ, better fatigue management occurs when the timing of breaks is at the discretion of the individual.

Heavy physical activity may be more fatiguing

The fatigue associated with sleep deprivation is different from the physical fatigue or weariness that is caused by extended physically-demanding work. Both are important to manage in the context of an FRMS because mental and physical fatigue interact and exacerbate each other.

The most concerning types of injuries to ergonomists are also those that lead to the highest costs in workers' compensation claims, absenteeism, and loss of productivity, namely:

- acute injuries from slips, trips, and falls;
- musculoskeletal disorders of the upper extremity;
- low back pain.

Physical fatigue can be perceived as a weakness or soreness in muscles when they attempt to perform a task. The rate of onset of physical fatigue depends on the type of movements involved in the task: speed, force, duration, and repetition. An increase in any of these factors results in a more rapid onset of fatigue. Physiological changes occur to the muscles, bones, ligaments, and tendons during any type of movement and these changes add up across the day or night to result in an increased perception of physical fatigue. These "physiological changes" can be thought of simply as natural low-level damage to the body tissues. Both time of day and consecutive work hours have an impact on physical fatigue.

Physical work may be harder at night than during the day. There are four main areas of focus for the physical risk factors: repetition rate, force, posture, and vibration. These factors have been described by studying daytime operations, but working at night also has an impact on some of them. A human's ability to generate muscle force decreases during the night and it is known that increasing the force of a contraction at night causes a greater risk of musculoskeletal damage. While sleep-deprived subjects can react as fast, and with as much force, as those who have had sleep, [48] the accuracy of those movements, in terms of neuromuscular coordination, has been shown to be reduced. There is an argument that full force, poorly controlled movements (more likely to occur at night than during the day) could be damaging in terms of muscle, ligament, or tendon injury. Therefore, sleep deprivation itself could cause musculoskeletal damage simply by increasing the likelihood of poorly executed movements and overcompensation of control mechanisms.

It should be noted that not only may the damage increase while working nights, but shiftwork may also affect the recovery from physical fatigue. Growth hormone is produced by the body while we sleep and is used to repair the everyday wear and tear of the body tissues. Those with reduced sleep, such as shiftworkers, may suffer limited growth hormone production, and therefore limited or slowed repair to damaged tissues. [49]

It is also important to take into account that physical fatigue also affects vigilance. Several studies have shown that physical fatigue is associated with decreased performance in a vigilance task [50] and with a decrease in beta 2 power in the EEG, which may reflect a decrease in active cognitive processing. [51]

Sedentary work that require constant vigilance may need breaks to help prevent automatic behaviors

Both laboratory and field studies have shown that in order for a worker to maintain a safe performance level, the worker requires an optimal mental workload. As a result, jobs that are either too intellectually demanding or not demanding enough are most likely to produce fatigue. [52]

When people are severely fatigued, they can experience what scientists call “Automatic Behavior Syndrome,” (ABS) which is a low level of alertness that often precedes nodding off. While in this state, a person is able to perform purely routine tasks, but there is a noticeable loss of perception and memory, accompanied with an inability to respond to changing conditions, signals, or communications.

Symptoms of ABS include: blank stare, “auto pilot” behavior, inability to respond to changes, and inability to maintain situational awareness. In this stage of reduced alertness, a person can spend up to 20 or 30 minutes or more still performing routine duties, but without active awareness. For example, if a shiftworker experiences automatic behavior syndrome while working on a control panel, the worker might continue doing a specific task but ignore the fact that other systems have warning indicators. Because of these automatic responses to stimuli without appropriate mental processing, there may be a complete loss of situational awareness. [53]

Work spaces should be brightly lit

Visual acuity depends on good lighting. Light is also the strongest environmental factor determining a person’s ability to stay alert. Our brains are programmed to associate light with alertness and activity and darkness with sleep and inactivity. The ideal lighting situation is one in which all of the visual objects in the field of view have nearly equal brightness. Thus lighter colored walls and bright ceiling lighting systems can provide maximum comfort, elevate mood, and stimulate alertness.

Research studies have shown that working at night under 750 to 1,000 lux of illumination reverses the normal fall in alertness that occurs during the night shift as compared to exposure to only 100 lux. [54] For example, Figure 8 shows that individuals exposed to 1,000 lux during simulated night shifts were less likely to fall asleep on the job and scored better on cognitive performance tests than workers exposed to less light. The minimum level of light, between 100 and 1000 lux, required to sustain adequate alertness has not yet been determined.

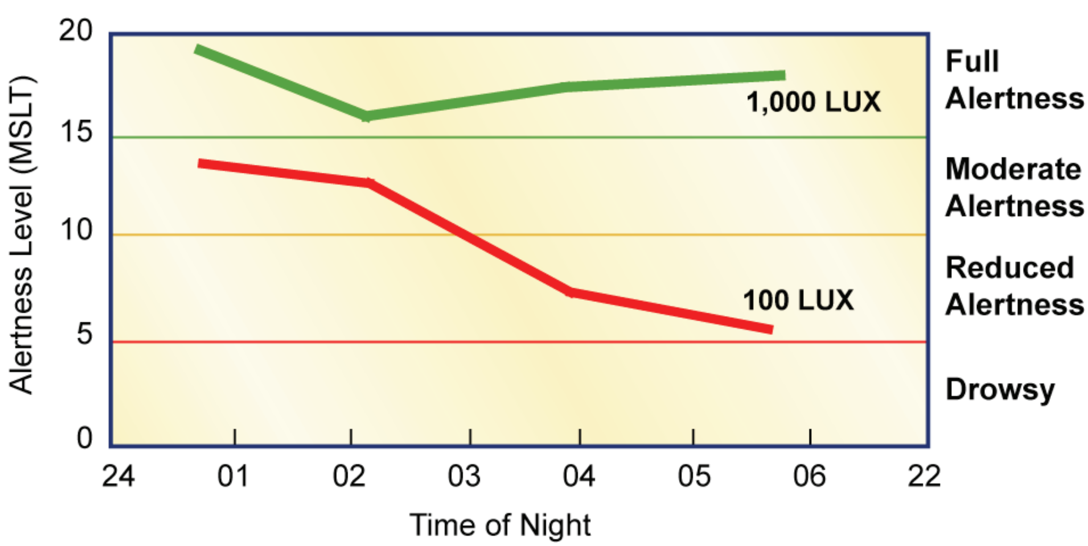

Figure 8—Alertness is sustained throughout a night shift by 1000 lux but not 100 lux of illumination [54]

1,000 lux of illumination may sound very bright, but actually is quite low compared to natural outdoor lighting levels, which range from over 100,000 lux on a bright sunny day in the summer to around 10,000 lux outside on a dark, cloudy day. However, most artificially-illuminated work places only provide around 100-300 lux, which is too low for alertness stimulation, and many industrial night shift workplaces have much lower levels of illumination.

However, exposure to white or broad spectrum light at night has other effects that raise some health concerns. Providing brighter levels of light at night has benefits and drawbacks (see Figure 9).

BENEFITS	CONCERNS
• Increased alertness/reduced sleepiness	• Shift biological clock/disrupt sleep
• Increased vigilance	• Elevation of cortisol—stress hormone
• Improved cognitive performance	• Suppression of melatonin
• Reduced accidents and injuries	• “Probable” carcinogenic risk

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Figure 9—Summary of the benefits and concerns of using bright light at night in 24/7 workplaces

Because of these effects of nocturnal bright light, there has been some reticence over introducing more brightly lit workplaces, particularly since the International Agency for Research on Cancer (IARC) classified [55] shiftwork as “a probable carcinogen,” and suggested this was related to light-induced melatonin suppression. [57]

New research from the University of Toronto [56,58] provides an intriguing and relatively simple solution to obtain the benefits of bright light without the risks. In nocturnal workplace environments that are continuously lit, the melatonin suppression and circadian resetting effects of bright light are limited to a very narrow band of wavelengths in the blue part of the spectrum. As shown in Figure 10, the human visual spectrum extends from blue (380nm) to red (700nm).

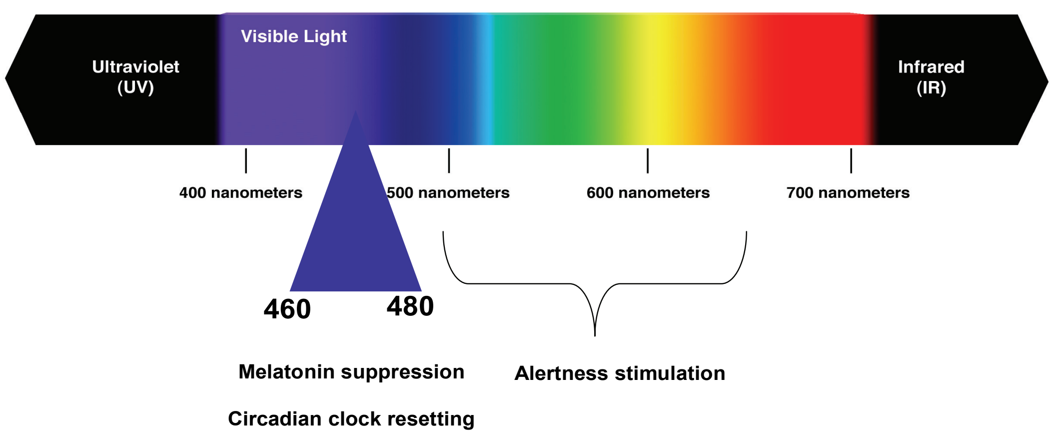

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Figure 10—The narrow spectral band (460-480 nm) responsible for melatonin suppression and circadian clock resetting in continuously illuminated nocturnal workplaces, but not for the alertness stimulation effects of light

In experiments using sharp cut-off filters, [56,58] light wavelengths longer than 480 nm were found to be responsible for the beneficial alertness and performance effects, while the melatonin suppression and biological clock shifting effects were found in a narrow band of blue light between 460 and 480 nm. By wearing light filtering glasses, it is now possible to get the beneficial effects of brighter light at night without the disadvantages. Field trials in industrial shiftwork facilities indicate these results can be obtained under workplace conditions. This new technology represents an example of the ongoing research that may lead to revisions of RP 755 in the next iteration.

Indoor temperature should be controlled at the lower end of the comfortable range

The influence of indoor air temperature on objective performance has been assessed experimentally in numerous studies. The performance tasks included proof-reading, typing, simple arithmetic operation, vigilance tests, time required to interact with clients on the phone, and performing information processing on a computer. The DOE Lawrence Berkeley National Laboratory completed a formal statistical analysis of 24 of these studies to assess the average relationship between temperature and performance at work. The results showed that performance is maximized when the air temperature is approximately 68°F to 73°F. [59]

Taking into account that higher ambient temperatures contribute to sleepiness, especially at night and when individuals are fatigued, it would be wise to maintain temperatures in the lower end of the comfort range. The review study showed that even with temperatures as low as 66°F to 68°F a high level of performance is maintained. [59]

Allowing employees to adjust the temperature to the most comfortable level at night is not conducive to promoting alertness at night because comfort promotes sleepiness in people who are sleep-deprived or fatigued. However, the converse is not true. Simply adjusting the ambient temperature to a cooler level is not by itself a sufficient countermeasure to suppress sleepiness in monotonous situations. [60,61]

Workstations should be designed utilizing ergonomics principles

Ample research exists about the physical ergonomics of the workplace, including physiological, anatomical and biomechanical information about workers as they perform their jobs, but virtually all of this research involves daytime workers. Even federal and state regulations that protect workers and set physical limits on their job tasks are based on daytime research. However, the physiological, psychological, and social factors of working extended hours are much more complex than in day-only operations and may lead to differences in the risks and rates of musculoskeletal disorders.

Even basic ergonomic guidelines must be reassessed when designing workplaces for shiftworkers because issues of environmental light, temperature, and also workstation design are different at night than in the day. Shiftworkers tend to have a higher body mass index than the average US worker, due to a lifestyle that leaves little time for exercise, leads to eating poorly at the wrong times of the day and night, and involves other demands of shiftwork. Purchased seating and workspace equipment should have guarantees covering 24/7 usage and higher than average load limits. In addition, there is a greater amount of sharing of workspace in shiftwork operations than day-only operations, which means that there may be two or three workers sharing one space rather than one day-worker having the space to himself. Any equipment acquired should be adjustable and workers may require training so that they understand how to adjust their workplaces at the start of each shift.

When designing a workspace for night employees, a fine balance exists between minimizing physical and mental fatigue and ensuring that the comfort level does not overly encourage accidental napping. Some of the most high-tech control rooms have dimmed lights in order to prevent screen glare, allow computers or machinery to emit white noise, are kept warm, and have ultra-comfortable reclining seats to support the back. Although these elements were provided with the best of intentions, the resulting atmosphere actually promotes fatigue and allows the employee to fall easily into a microsleep during the early hours of the morning.

Ergonomic improvements in the workplace can reduce injuries and increase productivity, resulting in significant cost savings and an impressive return on investment.

4.6 Individual Risk Assessment and Mitigation

Encourage individuals to be aware of their level of fatigue and take appropriate steps to enhance their alertness while on duty

Keeping constantly aware of the risk of fatigue and the need to manage both sleep and the associated lifestyle of shiftwork is essential to fatigue risk management. It is well recognized that fatigue impairs judgment and that even when individuals acknowledge that fatigue is a problem within the organization, they often think that “other people” are fatigued and fail to recognize that fatigue may also be a problem for them.

People are often poor judges of their level of fatigue and the extent that fatigue may negatively affect their performance. Cognitive performance can deteriorate before individuals consider themselves subjectively sleepy or fatigue-impaired. [62,63] Especially dangerous is the fact that individuals who are fighting sleep cannot reliably anticipate the onset of a microsleep and think they can sustain alertness. [64] Even in the absence of actual micro-sleeps, fatigued individuals miss important information in the visual field. [65]

It is important to educate employees and remind them on a regular, ongoing basis about the potential risks of fatigue as well as how to identify fatigue and mitigate its effects. They need to understand that fatigue compromises the skills necessary for dealing with complex situations [66,67] including:

- progressive degradation in multi-tasking ability with increasing numbers of hours of wakefulness,
- deterioration of higher-order functions such as judgment,
- impaired selective attention,
- significant decrease in the ability to hold in mind and make use of a visual image after a very brief distraction has been introduced.

When they determine they are too fatigued to work safely they shall report this to their supervisor

As mentioned earlier, it is not always easy for individuals to assess their fatigue level, especially when they are already fatigued. When an individual thinks that s/he is too tired to work safely, s/he needs to take it very seriously and take immediate action. The employee should not wait until someone else notices his problem or has an obvious effect on his performance. Each employee should communicate any fatigue risk situation immediately to his supervisor. In industries that traditionally encourage an “iron man” attitude in which employees normally consider fatigue as just an aspect of their work, a significant cultural change may be needed so that employees will feel free to report fatigue. A FRMS should be designed to promote this cultural change.

Individuals should be alert to evidence that others in the work place may be fatigued

Because people tend to be poor judges of their own state of fatigue or unready to admit they are excessively sleepy, their supervisors and peers should be taught to recognize the signs and symptoms of fatigue.

There are three categories of symptoms of fatigue [68] that supervisors and peers should watch for.

1. Physical:
    - yawning,
    - heavy eyelids,
    - eye rubbing,
    - head dropping,
    - microsleeps.
2. Mental:
    - difficulty concentrating on tasks,
    - lapses in attention,
    - difficulty remembering tasks being performed,
    - failing to communicate important information,
    - failing to anticipate events or actions,

- accidentally doing the wrong thing,
- accidentally not doing the right thing.

3. Emotional:
   - more quiet or withdrawn than usual,
   - lacking in energy;
   - lacking in motivation to perform the task well,
   - irritable or grumpy.

A culture of fatigue management should be created in which workers are comfortable in disclosing their personal sleep or fatigue status and seeking assistance is encouraged, consistent with the company protections afforded to reporting other safety concerns

Fatigue issues cannot be adequately addressed unless there is a culture which allows the root causes to be openly discussed. While it is the employee's responsibility to come to work fully rested, a sick child at home might prevent a shiftworker from getting adequate sleep or a daytime meeting called by a supervisor during the middle of the night shiftworker's sleep period, could result in fatigue impairment. Shiftworkers should be able to indicate when they are fatigued because of such special circumstances, and appropriate countermeasures, such as an extra break, being relieved by another team member, and additional peer-to-peer and supervisor monitoring should be put in place in order to mitigate the risk.

Consistent fatigue problems or repeated occurrences experienced by multiple shiftworkers should be recognized as opportunities to use the FRMS procedures to diagnose and correct fatigue root causes. However, if an individual has repeated difficulty maintaining alertness as compared to the majority of his or her colleagues, s/he should be referred to the medical department.

Individuals should use their time off the job to get appropriate sleep

Each employee is responsible for using off-duty time appropriately to obtain adequate rest. The employee also should take this responsibility into account when trading shifts with other employees or volunteering for overtime.

Supervisors shall be alert to signs of excessive fatigue in employees and contractors

An important part of a supervisor's responsibility is ensuring that the employees on duty are alert on duty and not excessively fatigued. Supervisors are responsible for monitoring those with whom they are working for signs of impending fatigue impairment. They also should be encouraged and empowered to reassign positions, change work tasks, provide coverage for rest breaks, and if necessary remove an individual from a safety sensitive position if there is evidence that the person is significantly fatigue impaired.

This responsibility for monitoring and intervention should also include contractor personnel who are assigned to them, and they should take steps to ensure that the procedures for addressing fatigue in contractor employees is clearly defined with the contractors' employer.

Individuals who experience repeated fatigue should be referred to their health professional

When an employee consistently experiences excessive sleepiness on the job, the causes should be investigated. Sometimes fatigue simply may be related to a personal situation (a new child, financial stress, etc). Fatigue also may be related to a disease or a sleep disorder. It should be noted that some of the most common sleep disorders, such as obstructive sleep apnea and insomnia, are more common among shiftworkers than in the general population. Moreover, shiftwork is associated with a specific disorder—"shift work sleep disorder" (SWSD)—defined in the International Classification of Sleep Disorders [69] and characterized by insomnia and excessive sleepiness.

Fatigue also is common in many diseases and illnesses (ranging from flu to cancer) and may occur as a direct result of the metabolic or other systemic pathophysiological disturbances of that disease, as a secondary consequence of sleep disturbances caused by other symptoms such as pain, nausea, etc., or as the primary presenting complaint (e.g. chronic fatigue syndrome). Fatigue also is a commonly-listed side effect of prescription or over-the-counter pharmacological drugs, or may occur as the result of other therapeutic interventions (e.g. surgical procedures). Maintaining good health and taking care to avoid fatigue-inducing side effects of medications and pharmaceuticals are important components of the fatigue risk management program for employees.

Because illness, stress and physical fitness impact fatigue, consideration should be given to implementing programs to prevent/manage medical conditions

Maintaining a healthy lifestyle is crucial for shiftworkers, considering the added stress represented by their non-standard work hours and their increased risk of suffering certain health problems. Health promotion programs help individuals to improve their lifestyle behaviors and thus reduce excessive health risks. The workplace is considered an ideal setting for health promotion programs as it provides easy and regular access to information to a large number of people and it may encourage sustained peer support.

Health promotion programs typically address such issues as weight control and nutrition, stress management, exercise, smoking cessation, alcohol use, and safety education. The types of interventions include: health education with incentives, personalized advice/education, skill development, and environmental modifications. The most efficient interventions seem to be comprehensive programs, including both individual (e.g. education on good nutritional practices) and organizational (e.g. offering healthy food choices in the facility cafeteria) components.

Management of medical conditions, including sleep disorders

Shiftwork has been associated with increased prevalence of health problems, including an increased risk of cardiovascular diseases, [70,71] and an increased prevalence of gastro-intestinal diseases, [72,73] diabetes and metabolic syndrome, [74,75,76] and sleep disorders, including obstructive sleep apnea and shift work sleep disorder.

Shift work sleep disorder, (SWSD), specifically is related to working night and rotating shifts. The ICSD defines SWSD as a primary symptom of either insomnia or excessive sleepiness associated with shiftwork. [69] A study [77] found a SWSD prevalence of 32% in night workers and 26% in rotating workers, with a “true prevalence” (accounting for the percentage of daytime workers who also reported insomnia or excessive sleepiness, which was 18%) of approximately 10% of night and rotating workers.

Obstructive sleep apnea (OSA) is a sleep disorder in which there is a complete or partial obstruction of the airway during sleep, causing breathing to cease. The soft tissues around the airway (the tongue and soft palate) relax onto the posterior pharynx causing an obstruction by closing off the airways. Partial obstruction causes loud snoring and complete obstruction causes “apnea” (cessation of breathing). Sufferers of OSA continue to attempt to draw breath, as evidenced by chest movements, but the blockage prevents air from reaching the lungs, eventually causing a decrease in the oxygen content of the blood. On sensing the decrease in oxygen, the brain arouses the body from sleep and the person frequently awakens gasping for breath. OSA thus results in highly disrupted sleep and chronic exhaustion during waking hours.

OSA is a relatively common disorder. Several studies have described average prevalence of OSA in different populations, ranging from 2% to 33%. [78,79] The sleep specialist community provides a conservative and acceptable measure of the average prevalence of OSA in the working age population in the USA today of 5%. OSA is more common among men than women, and is more common among middle-aged and older individuals. The prevalence of OSA may be higher in shiftworkers than in the general population. For example, an elevated prevalence of OSA (28%) has been previously documented in the trucking industry. [80,81]

Risk factors for OSA include smoking, obesity, having a neck size of 17 in. or greater, the regular use of alcohol or sleeping pills, and moderate sleep deprivation. [82,83] Moderate sleep deprivation, a common consequence of shiftwork, has also been found to aggravate existing OSA. [84]

Sleep apnea has a significant impact on health. Individuals with sleep apnea have an increased risk of cardiovascular disease (hypertension, nocturnal cardiac arrhythmia, congestive heart failure, risk of heart attack) and depression. [85,86,87] The chronic ill health of those with undiagnosed sleep apnea results in increased use of health care and significant medical and operational costs for a business. [87,88,89,90]

- More than twice the number of physician claims.
- 1.9 to 2.7 times more cardiovascular medication.
- 50% more hospital stays.
- 2.63 times the amount of absenteeism.

OSA is associated with excessive daytime sleepiness at work and subjective work performance problems. [91] Those with untreated sleep apnea had more difficulty concentrating, learning new tasks, and performing monotonous tasks as compared to non-snorers. Reduced vigilance and attention due to sleep-disordered breathing causes an increase in the rate of occupational injuries. [92,93] Patients with untreated OSA also have a much higher risk of falling asleep and having an accident while driving. For example, drivers with untreated sleep apnea have a 2 to 3 fold increased risk of having an accident caused by nodding off behind the wheel. [94,95] The increased risk of accidents associated with sleep apnea has been recognized by the U.S. Federal Motor Carrier Safety Administration (FMCSA), which has been considering making apnea screening a requirement for obese drivers.

Those with OSA can treat the disorder simply and effectively through the use of breathing aids while sleeping, such as Continuous Positive Airway Pressure (CPAP) devices. With treatment, patients experience a dramatic improvement in their health and quality of life [96] and reduce their long-term health risks. In one company, preventable crashes for the treated OSA employees were cut 30%, the cost of the crashes that did occur was reduced by 48% from the average, employee retention was 60% higher than normal, and there were savings of $539 per month in health-care costs per employee. The program was so successful that the company expanded the program to test virtually every new truck driver hired since 2006 and provide treatment to all drivers found to suffer sleep apnea.

Disease Management (DM) programs can be useful to prevent/manage chronic conditions. A DM program is an integrated system of interventions and measurements of health care delivery designed to optimize clinical and economic outcomes within a specific population. DM programs provide care to individuals with a specific disease by establishing a group of providers and treatment protocols to ensure that the care required to treat the disease is provided effectively. They include aggressive prevention of complications as well as treatment of chronic conditions. General criteria for selecting a disease as a target of a DM program include: [97]

- high prevalence chronic disease states,
- high-dollar-volume or high-velocity drug use,
- potential for wide variation in treatment approach,
- potential for lifestyle modification to improve outcomes,
- therapies with many treatment options,
- diseases with high risk of negative outcomes.

4.7 Incident/Near Miss Investigation

The investigation of incidents should facilitate determination of the role of fatigue as a root cause

Identification of hazards through the continuous analysis of errors and deviations is essential to the on-going fatigue risk mitigation of an operation. One of the key factors in this analysis is the collection and analysis of data from all sources. Once hazards are identified, a systematic approach that ensures appropriate corrective action is taken will minimize the risk of fatigue in future operations. Regular meetings of the appropriate boards would provide a systematic and consistent review of fatigue-related data and a unified commitment to implementing both individual and system-wide improvements to mitigate the risks of fatigue.

Through hazard identification programs, further analysis may be required to identify the risk of fatigue. It is important to identify the probability that fatigue was a causal factor in the error or deviation through a systematic and repeatable process.

While much of the data required to determine fatigue probability is accessible through existing data collection and hazard identification programs, some cases will require additional information from individuals involved in the error or deviation. Some of this data can be included in the collection methods already available. For example, time of the event, time since last awakening and other demographic information. Following is a full list of data and information that must be collected to provide the most reliable probability that fatigue was or was not a causal part of the error or deviation.

1. The date and time when the last sleep episode ended prior to the incident
2. The date and time when the last duty period started prior to the incident
3. The history of work/wake/sleep for the seven days preceding the incident. Where possible, data on actual sleep times should be collected. Some fatigue risk models can estimate sleep from rest periods when unknown but it is ideal to obtain data on actual sleep patterns.
4. Sleep quality ratings for the last three major sleep episodes.
5. Any observed signs of sleepiness prior to the incident.
6. Information about any known health conditions that may have affected sleep.
7. An estimate for the amount of sleep debt the person usually accumulates during a work week. The estimate is based on the amount of time the person usually sleeps longer on days off compared to days worked.
8. Information about what the person did 24, 48, and 72 hours prior to the incident. Not necessarily specific activities but rather if the person was sleeping, awake, on-duty, etc.
9. Rating of stimulation for the task performed at the time of the incident and the work environment.
10. Rating the amount of regularity for the work and sleep schedule prior to the incident.

4.8 Hours of Service Guidelines

The term “Hours of Service” comes from the transportation industry, which has been subject for more than 100 years to government-imposed regulatory limits and, in some cases, statutes, on the maximum hours of duty per day, per week, and per month, and the minimum hours of rest before the resumption of a duty period. [21] This concept is also known as work-rest regulation, duty time regulations, working time directives, and various other similar terms.

Despite the use of the term “Hours of Service,” RP 755 is not a regulation but instead is an industry recommended ANSI standard. This distinction is important because this standard can and will be continually assessed and revised, at a minimum every five years, to incorporate any significant advances in sleep and fatigue science and the results of analysis of fatigue, safety and operational data collected by API member companies.

The FRMS shall specify hours of service limits which shall not exceed those in this section, taking into account the exception process in 4.8.5

Currently there exist no outer limits as to how many consecutive hours or days an employee may work in the U.S. refining and petrochemical industry, other than those established by each company, site management, or union contract. Establishing industry-wide hours of service limits represents a significant cultural and operational change for the industry.

Historically, there have been concerns about setting hours of service limits in an industry with safety critical tasks and positions that cannot be left unattended. Even when the employee currently working a position becomes fatigued, it is simply not safe to leave the post unattended. And because it takes many hours or even days to shut down safety-sensitive petrochemical operations, an operator cannot simply shut down the process and go home.

At the same time, the absence of any formal limits creates the possibility that companies and their employees might be exposed to excessive fatigue risk from time to time. Managers and employees may sometimes make decisions based on convenience, operational efficiency, and/or economic benefits, without being fully aware of the risks those decisions involved. Sometimes work could be accomplished more quickly, employees could earn more overtime pay, and businesses could avoid the cost of hiring more employees by allowing employees to work more hours per day or more consecutive work shifts if the risks of the resulting fatigue were ignored. Any underlying culture of toughing it out and having the “right stuff” only exacerbates the risk. In the absence of fatigue risk assessments or clearly measured outcomes of fatigue-related human error, risks of fatigue often remain hidden.

The RP 755 Hours of Service limits seek to achieve the right balance between ensuring full coverage of safety-sensitive positions and creating any excessive fatigue-related safety risks. Different recommendations exist for normal operations, outages, and extended shifts, with the understanding that outages and extended shifts are not routine operations and that there are significantly stricter limits during normal operations. At the same time, an exception process ensures that a careful review is undertaken and documented before the Hours of Service limits are exceeded in order to meet a critical operational need for additional coverage.

These limits have been developed in the context of a comprehensive FRMS

There is a fundamental difference between the historical reliance on Hours of Service limits as the sole protection against fatigue-risk in the transportation industry, and establishing Hours of Service limits in RP 755 as part of a comprehensive FRMS. The root causes of fatigue risk are multiple and most of them are not addressed by stand-alone Hours of Service regulations. However, they are addressed by the comprehensive FRMS defined in RP 755 (Figure 11).

Since widespread adoption of FRMS in 24/7 industries is new, most of the data in the scientific literature that has been used to make recommendations on Hours of Service limits in the past has been collected from workplaces operating without the benefit of any FRMS. In addition, previously published best practices on shift scheduling were based mainly on studies of companies running their operations without having implemented any FRMS countermeasures to mitigate the effects of shiftwork. Since a company with a RP 755-compliant FRMS will evaluate and actively mitigate a significant number of other factors that contribute to fatigue (Figure 11) on a continuous basis, it seems reasonable to allow some flexibility regarding the hours of service limits in the context of a fully implemented FRMS.

With improvements in fatigue management tools, data collection methodologies, and scientific research and analysis, more emphasis can now be placed on a proactive rather than a prescriptive regulatory approach to managing fatigue. While the prescriptive Hours of Service rules provide important outer boundaries that limit certain types of fatigue-related risk, they do not provide a framework for a data-driven, continuously-improving system that can identify real-time fatigue risk and take appropriate corrective actions to remove or limit the risk.

Fatigue Root Cause	Addressed by Hours of Service Regulations	Addressed by RP 755 FRMS
Inadequate staffing levels	No	Yes
Staff-workload imbalances	No	Yes
Circadian factor effect on alertness and sleep	No	Yes
Work environment	No	Yes
Sleep environment	No	Yes
Lack of awareness of signs of fatigue	No	Yes
Lack of awareness of fatigue countermeasures	No	Yes
Inadequate shift schedules (e.g. rotating too quickly, irregular hours)	No	Yes
Lack of awareness of importance of obtaining enough sleep	No	Yes
Sleep disorders	No	Yes

Figure 11—Comparison of fatigue risk mitigation when prescriptive Hours of Service are the only countermeasure versus when a comprehensive FRMS is implemented

To address the scientific research gap, API companies should collect and analyze data on operator sleep, health, and safety performance as part of their FRMS and use the information derived to develop and validate a data-driven staffing and scheduling fatigue risk model for petrochemical facilities operating under an FRMS. Doing so will enable the scientific basis to be more firmly established for revisions of the RP 755 recommendations in the context of a comprehensive FRMS.

Consistently working at the limits shown is not sustainable and may lead to chronic sleep deprivation. The overall FRMS shall be designed to prevent employees from frequently working at or near these limits over the long term.

One of the fundamental flaws of a prescriptive set of Hours of Service rules is that the uninformed manager or employee may think that simple compliance with these rules prevents fatigue, which is far from the truth. Working consistently at the maximum number of hours allowed may result in an employee chronically sleeping less than 7 to 8 hours per day and thus accumulating significant sleep debt. Scientific data demonstrated that shortened sleep every day for one or two weeks [99,100] produced significant cognitive decrements.

Limiting sleep to six hours or less over successive nights resulted in a cumulative dose-dependent deficit in performance. Individuals who obtained less than four hours of sleep per night showed increased lapses in performance and reduced speed and accuracy when completing performance tasks, while those who obtained seven or more hours of sleep were able to maintain adequate levels of performance over 14 consecutive days. Other studies have documented the negative impact on health, mood, and safety of chronic sleep deprivation. [101,102,15]

Another problem with simply relying on compliance with Hours of Service is that the rules have to be kept simple to be manageable and understandable. As a result, many important scheduling factors fail to be addressed. For example, despite many revisions and efforts at revision, the U.S. Hours of Service regulations for truck drivers do not recognize the important differences between alertness when driving during the night versus the day or the differences in the duration and quality of daytime versus nighttime sleep. Similarly, the trucking HoS rely on time-on-duty rather than the much more predictive number of consecutive hours awake. On the other hand, incorporating all the various factors contributing to fatigue risk in Hours of Service would result in unduly complex regulations.

The objective of these limits is to establish the triggers at which additional fatigue risk evaluations will be performed in the short term

The guidelines emphasize the need for the FRMS to establish outer Hours of Service limits and to have a plan to minimize the time that employees spend working at or near these limits in order for employees to maintain alertness and safety. There are different recommendations for normal operations, outages, and extended shifts, that make clear that outages and extended shifts are not routine operations and that normal operations have significantly stricter limits.

Operations should address the impact of work-rest schedules on fatigue risk by using fatigue risk models to assess actual (rather than just planned) work-rest patterns. Doing so will allow them to measure and intervene to minimize the risk, as well as to provide a set of outer-boundary limits (e.g. limits on working beyond a certain number of consecutive hours or working more than a certain number of days in a row).

Several teams of researchers have independently developed and validated mathematical fatigue risk models that predict fatigue risk based on the well-established science of the circadian and homeostatic regulation of sleep. These researchers included Torbjörn Åkerstedt at Sweden's Karolinska Institute, who collaborated with Simon Folkard at the University of Swansea, Wales to develop the Three-Process Model, [103] Martin Moore-Ede at Harvard Medical School and CIRCADIAN® who developed the Circadian Alertness Simulator (CAS), [104] Drew Dawson at the University of South Australia who developed FAID, [105] and Steve Hursch at John Hopkins University who developed SAFTE-FAST. [106] To make these fatigue risk models practical for operational use when employees' actual sleep is unknown, sleep prediction algorithms are incorporated so that employers could enter readily available data from timesheets, duty-rest logs, or shift schedules.

In addition to these scientifically-validated fatigue risk models that predict the minute to minute and hour to hour changes in alertness, there are a number of index formulae which seek to assess work schedules without specifically modeling the risk. An example of this is the HSE Fatigue Index. [107]

In selecting a fatigue model to adopt in an FRMS, the user should be aware that the predictive value of any model depends on the data source it is optimized against. Because human performance measures have different characteristics, a model optimized against a laboratory-based performance metric such as the PVT may be of less value than one optimized to predict fatigue rated incidents and accidents in the workplace. Furthermore, the validation of the model should not only be against historic data, but using the model to modify work-rest duty patterns should be shown to progressively reduce workplace incidents.

To give an example, one of the outputs of the CAS fatigue model is a Fatigue Risk Score, which assesses acute and chronic sleep deprivation scaled from 0 (minimal fatigue risk) to 100 (very-high fatigue risk). As Figure 12 shows, the average (i.e. mean) U.S. over-the-road truck driver has a Fatigue Score of 40; as the score rises, accident risk (DOT-recordable accidents) exponentially increases. [108]

Using this CAS model to make decisions as to which drivers are safe to dispatch and which should be given extra rest because they are fatigue-impaired has reduced accident rates in trucking fleets by 50% to 75% and shown continuous improvement for more than 8 years.

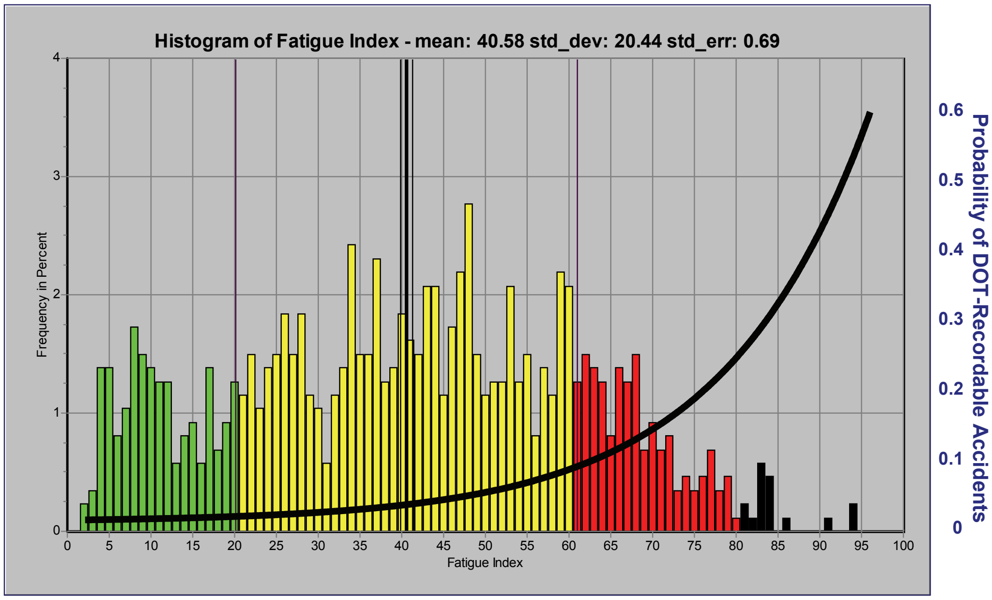

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Figure 12—The distribution of CAS fatigue risk scores (1 = low, 100 = high) in truck drivers, and the probability of a DOT-recordable truck accident per driver in the next year. The percent of truck drivers is shown with each fatigue score. The black line shows that the relatively few drivers with high risk scores (red and black) have a much higher rate of DOT recordable accidents. [108]

A base shift schedule will typically average 40 to 42 hours per week. It is recognized that during normal operations employees may work overtime and the actual hours worked would be greater than the base schedule.

In a 24/7 operation, there are 168 hours per week to cover. With the traditional four crews, the simplest way to run these operations is to have each crew work 42 hours per week and thereby incorporate two hours of overtime into the base schedule.

As discussed in Section 4.3, the balance between the core staffing levels and the rates of absenteeism, turnover, and assignments to other duties or training determines the number of open shifts that must be covered each week and the number of overtime hours worked. Open shifts may be planned (or known in advance), in which case the core schedule will implicitly or explicitly incorporate larger numbers of overtime hours, or unplanned, in which case the overtime is in addition to the core schedule.

Shift schedules have a number of key characteristics that are interrelated and it is important to consider all of them, not just the Hours of Service limits, when evaluating a shift system.

Shift schedule characteristics covered by RP 755 Hours of Service limits include:

- duration of shift,
- time off between shifts,
- number of consecutive working days,
- time off between blocks of consecutive working days,
- direction of rotation (8 hour shifts).

Additional shift schedule characteristics not explicitly defined by RP 755 but equally important in addressing the fatigue risk goals of an FRMS include the following.

- Sequence of shifts:

- fixed versus rotating.

- Speed of rotation:
  - position of working time,
  - starting/ending time of shifts,
  - time of built in (planned) overtime,
  - time of required meetings or training sessions,
  - sleep opportunity time as a result of commuting time,
  - effect of shift swapping between employees,
  - on call schedule and on call duty periods.

All of these characteristics must be balanced when designing a shift schedule that minimizes fatigue risk at the same time that it considers employee preferences (see Section 4.4) and operational needs (Section 4.8 introduction) so that the schedule is practical to operate. Although some general agreement exists about which are the best practices on shift scheduling, there is still discussion in the scientific community about some issues. For example, speed of rotation is still a controversial scheduling issue that so far has no scientific consensus. Shiftwork experts in the U.S. tend to favor slow rotations, while European experts prefer quick rotations (2 to 4 consecutive shifts) rather than weekly rotations).

4.8.1 12-hour Shifts

Over the past decade, 12-hour shifts have become increasingly common. CIRCADIAN's 2007 Shiftwork Practices Survey of 400 North American companies found that 34% of companies had 8-hour shifts, and 37% 12-hour shifts. [11] The preponderance of 12-hour shifts in the petrochemical industry is greater than the average in all 24/7 industries. In the 2007 Shiftwork Practices Survey, 72% of processing operations (including oil refineries and chemical plants) reported using 12-hour shifts. Moreover, 12-hour shifts not only are well-accepted by employees, but often preferred. The 2005 Shiftwork Practices Survey found that when employees selected their work schedule, 74% selected 12-hour shifts. [44]

While a reading of the older scientific literature indicates that there were significant concerns about the health and safety of 12-hour shifts, more recent studies comparing efficiency, productivity, absenteeism and accidents in 12 versus 8-hour shifts have not shown any overall differences (some studies showed improvements, some deterioration, some no changes). Fatigue has been raised by some as a concern because 50% more hours are worked in a day compared to 8-hour shifts. However, some of these fatigue issues relate to the interactions of 12-hour shifts with the other characteristics of shift schedule design (such as rapidity of rotation between day and night shifts) listed in the section above.

The confusion about the relative safety of 12-hour shifts arises because there is some evidence to support an increased risk in the 9th to 12th consecutive hour of work. [109] However, in other studies, the relative frequency of incidents does not increase linearly from the first to the last hour of the shift. Furthermore, often there is an increased risk not only at the end of the shift, but also during the first or second hour [110,111] until the operator gets focused, a risk which occurs three times per 24 hour period with 8-hour shifts versus twice a day with 12-hour shifts.

To counterbalance the concern about the 9th to 12th hour of work, it also should be noted that, when working the same average total hours per week, employees on 12-hour shifts work fewer shifts per week and have twice the number of days off per year as compared to shiftworkers on 8-hour shifts. Increased days off with 12-hour shifts result in more complete recovery from fatigue before starting the next block of shifts. In addition, reduced sequences of consecutive shifts when working 12-hour shifts are associated with reduced risk of fatigue. Thus the shorter number of consecutive shifts with 12-hour shifts compensates for the longer shift length. The shorter number of 12-hour shifts per week also allows employees not only to obtain more rest during their days off, they also provide extra time for family and social activities. The net effect for most operations is that there is no significant difference in risk.

4.8.1.1 Normal Operations

Work sets shall not exceed 7 consecutive day or night shifts

In addition to a daily rest period for sleep and relaxation, every employee needs a recovery period from work at regular intervals to recover from any cumulative sleep deprivation and address personal needs. Given differences in work environment, physical and mental work-related stress, and individual circumstances, these needs may vary.

Although 7 to 14 consecutive 12-hour shifts are common practice in remote locations (off-shore, mining, etc), shiftwork experts recommend limiting the number of consecutive shifts worked by employees who live at home and commute to work every day. This is because commuting time, family duties and social interactions can reduce the amount of time available for sleep during the off-duty periods between shifts.

Epidemiological studies of workplaces without any of the benefits of an FRMS have shown a clear relationship between the amount of work hours per week and health complaints. [112] In such workplaces, people who work more than 60 hours/week have a twofold greater risk of having a heart attack. A recent study on the impact of long work hours in the US demonstrated that working 60 hours per week or more was associated with a 23% increased injury hazard rate, with the injury rate increasing in correspondence to the number of hours worked. [113] This research suggests that in the absence of the extra risk mitigation provided by an FRMS, the upper limit should be 5 consecutive 12-hour shifts.

There is some evidence which suggests that risk is not substantially greater with up to 7 consecutive day shifts. Comparisons of an employee-chosen shift schedule of 12-hour day shifts (7 am to 7 pm) in combination with an extended workweek (7 consecutive 12-hour shifts, i.e. 84 hours a week) showed there were no effects on performance, fatigue and sleepiness as compared to comparable workers on 40 hour a week schedules. [114] The 84-hour per week group did not show any signs of reduced test performance or elevated fatigue and sleepiness compared to the 40-hour group. A similar study evaluated the degree to which seven consecutive 12-hour day shifts (7 am to 7 pm) (84 hours a week) influenced biomarkers for stress, metabolic process and diurnal rhythm. [115] The results showed that the 84-hour schedule was not, in the short term, more harmful for health than working 40-hour a week with a similar type of workload. However, working the 84-hour schedule resulted in signs of a functional shift in hormonal regulation. Another study [116] compared a group of employees living in building-site camps and working extended hours (7 am to 6 pm) and extended workweeks (6 on, 1 off, 5 on, 9 off) with a group of workers working 7 am to 3 pm and returning home after each workday. Although the camp group reported higher fatigue overall, neither group showed signs of increased fatigue ratings in the progress of the two work weeks and no signs of fatigue build-up or accumulation of daytime sleepiness, physical exertion, or sleep disturbances.

A more significant concern relates to the number of consecutive night shifts, since they are usually associated with higher levels of fatigue than day shifts. [117] This is due to the effects of sleep deprivation that are compounded by working during the biologically low alertness periods. Sleep deficits associated with working night shifts are due to daytime sleep (after working night shifts) being shorter and of poorer quality compared to nighttime sleep.

A meta-analysis of several studies of operations without an FRMS indicated that accident and injury risk can increase over consecutive night shifts. [118] However, this meta-analysis did not consider whether or not the first night shift occurred after days off or after a day or evening shift. This omission makes it more difficult to interpret the difficulties of transitioning to night shift. Shiftworkers are likely to suffer from circadian misalignment and increased sleep deprivation over the course of consecutive night shifts. The chronic sleep deprivation can lead to impaired performance, which will be exacerbated by working at night, and this may cause an increased accident risk over several shifts. [119]

While some studies showed an increase in risk over four consecutive night shifts, [109] two studies [120,121] analyzing longer spans of consecutive night shifts reported a decrease in risk from the 4th to the 5th night, which was maintained until the 7th and final night shift in one of the studies.

Based on lab studies, as well as field studies, it has been suggested that for employees with diurnal patterns (active during daytime, sleeping at night), the first night shift after days off is the most difficult. [119,122] The authors also noted that in their study, in which the duration and timing of rest for every day and night shift was carefully controlled, thus likely allowing subjects to obtain greater amounts of sleep and achieve greater circadian adjustment, the first night shift after a series of day shifts was worse than the second and consecutive night shifts.

The key issue in determining the appropriate upper number of consecutive night shifts is whether shiftworker adaptation to night shifts should be taken into account. Those who advocate shorter blocks of 2 to 3 night shifts assume no adaptation occurs, based on data gathered from shiftworkers who did not have the benefits of an FRMS. On the other hand, with the training provided by an FRMS on how to adjust sleep to working nights (by controlling exposure to light and fully darkening bedrooms etc.), and the evidence that this is effective in changing sleep behavior [123] longer blocks of night shifts may be more desirable than too rapid rotations on and off nights.

Laboratory studies simulating shiftwork have shown this adaptation can have significant benefits in reducing fatigue risk at night. For example, a study [124] found that alertness (measured with MSLT) progressively improved over four consecutive 12-hour night shifts, reflecting a decrease in objective sleepiness. Another study, evaluating four consecutive 11-hour shifts, found three different patterns of fatigue on consecutive night shifts, reflecting the loads of the reticular activating system, musculoskeletal, and central nervous system respectively. While the musculoskeletal fatigue increased over consecutive night shifts, the other two patterns showed significant improvement over consecutive night shifts. [125]

These results indicate the importance of the training programs in the FRMS to advise and encourage shiftworkers to carefully design their sleep schedules to mitigate any progressive performance impairment in blocks of consecutive shifts. Working under the umbrella of an FRMS would allow workers to develop and adhere to optimal sleep patterns for their schedule, thus helping to minimize fatigue over the work set.

However, there is no scientific research on safety or fatigue risk with blocks of shifts longer than seven consecutive shifts, when employees are commuting to and from their home on a daily basis. Even after providing FRMS training, cumulative sleep deprivation may occur in individual shiftworkers during the work set because of family or health issues, and so it is prudent to limit the number of consecutive shifts to the 7-day limit supported by research.

Permit 2 consecutive nights of sleep after a work set

The amount and distribution of time off between both consecutive work days and blocks of work days is an important factor of the shift system. As discussed in the previous section, accumulated sleep deprivation (i.e. a “sleep debt”) can occur during blocks of consecutive shifts. This requires that shiftworkers are provided with an opportunity to recover from the work set, and have adequate unrestricted time for sleep to recover from any accumulated sleep debt.

Research studies have shown that two full nights of sleep are usually enough to recover from sleep deprivation. [126] Another study [127] showed that alertness and performance were more impaired on the first three days back at work following a single rest day, as compared to two or three rest days.

It is thus usually recommended that time off between blocks of work days should allow two days with nocturnal sleep. [128,27] This is due to the fact that nighttime sleep occurs at the time when circadian rhythms are conductive to sleep, and thus sleep episodes are longer and more restorative. An off-duty period of 36 hours after daytime shifts and 48 hours after night shifts are required to allow shiftworkers to obtain these two nocturnal sleep episodes.

Minimum 36 hours off after a work set

When considering the minimum off-duty rest period that should be required after a work set, it is important to take into account whether the employee will resume work on the same shift or whether s/he will make a transition from days to night or vice versa. In the case of fixed day shifts, 36 hours off between a series of day shifts allows two overnight sleep episodes. In the case of fixed night shifts, having 36 hours off between a series of night shifts allows two diurnal sleep episodes. This schedule is more beneficial for shiftworkers who are trying to adapt their sleep to a fixed schedule, since it would allow workers to keep a nocturnal orientation and not have to switch back and forth between sleeping during the daytime and nighttime. Doing so minimizes the sleep disruption associated with the resulting changes in circadian patterns.

Based on similar considerations, the FMCSA Hours of Service regulations for truckers [129] provide a 34-hour rest period after a block of work days before allowing a new work week to start, which will permit a majority of drivers to have enough time to obtain two uninterrupted 8-hour recovery sleep opportunities on whatever sleep schedule they are maintaining before returning to work.

It should be noted that if an employee is changing from days to nights, a 36 hour minimum requirement will automatically become an actual minimum of 48 hours before they can start their shift. This off-duty time allows the employee to progressively delay his sleep episodes (going to bed later at night) and then start adapting to night shifts. If an employee is going from nights to days, the 36 hour minimum will automatically become an actual minimum of 48 hours, allowing the employee two overnight sleep episodes, and thus maximizing his recovery.

Minimum 48 hours off after a work set with 4 or more night shifts

How much rest an employee needs between blocks of working days is related to the number, timing, and length of consecutive shifts worked. Allowing more time off after extended blocks of night shifts is important because night shifts are more fatiguing, and sleep debt more prevalent, than with day shifts. Research studies have shown that at least two sleep episodes are needed to recover after a series of shifts and that at least 3 days, including 3 overnight sleep episodes, are necessary to recover from 7 consecutive night shifts. [27]

The additional 12 hours off after night shifts (48 hour versus 36 hour minimum off duty) allows an employee to obtain additional rest, and offers the opportunity for daytime naps to supplement nighttime sleep. The minimum 48 hours off would allow at least two recovery days. Also, as we mentioned earlier, it is important for the employee to maintain the diurnal or nocturnal orientation to minimize the distress associated with circadian changes. If the employee has been working nights but will work a set of days after the break, 48 hours will allow him to switch sleeping during the day to sleeping at night before the employee starts the day shifts, and obtain two nights of restorative nocturnal sleep before returning to work. If the employee has worked a set of night shifts, and is coming back to night shifts, the 48 hour minimum effectively becomes a minimum of 60 hours, allowing two complete days off, and the opportunity of three diurnal sleep episodes, maintaining the nocturnal orientation.

Minimum of 48 hour off after a total of 84 hours worked

A total of 84 hours worked is equivalent to seven consecutive 12-hour shifts. It is necessary to provide a longer off-duty period than the normal 36 hour minimum, since some studies [27] suggest that 3 days are needed to fully recover from 7 consecutive night shifts. If the employee has worked a set of night shifts, and is coming back to night shifts, the 48 hour minimum effectively becomes a minimum of 60 hours, allowing two complete days off, and the opportunity of three diurnal sleep episodes,

Holdover periods should not exceed 2 hours and if possible be scheduled at the end of day shift

While standard scheduled shifts longer than 12 hours are uncommon and generally not recommended on a regular basis, occasionally working 14 hours is acceptable. In continuous-process operations, shift turnover meetings often require some extension of a 12-hour shift for half an hour or so and therefore 12.5 hour workdays may be common. In addition an extension of the shift by up to 2 hours allows for a training session or safety meeting without requiring the employee to come into work on a day-off. Furthermore, if an employee becomes sick or is absent, a replacement operator may not be immediately available for a safety-critical position and leaving the position unattended is not an option. In these circumstances, extending a shift up to 14 hours in order to bring in a replacement would seem reasonable, provided it is not a routine practice.

The safety of 14 consecutive hours on duty in a safety-critical position has been recently endorsed by the FMCSA in the trucking Hours of Service regulations. [129] After much research and consultation, U.S. trucking industry regulations, introduced in 2004, allow drivers to be on duty a maximum of 14 consecutive hours per day.

The ability to maintain alertness with 14-hour on-duty periods relies on employees receiving FRMS training on the importance of obtaining as much sleep as possible during their time off as well as education on how to maximize sleep duration and quality.

Adding the holdover period at the end of the day shift is a good compromise, since the extra hours would occur at a time of the day when alertness is at a higher level due to natural circadian rhythms. Thus any cumulative fatigue that may occur at the end of a day shift will be balanced somewhat by the higher alertness levels. In contrast holdovers at the end of a night shift delay the time of commuting home and of getting sleep, and thereby increase fatigue risk, especially on the drive home.

4.8.1.2 Outages

Outages take place for limited periods of time and generally are not routine operations. Specific operational considerations need to be taken into account during outages and be balanced against the scientific recommendations during these periods. On the other hand employees usually work fixed shifts during outages, and minimize their non-work family and social commitments, and thus have more opportunity to adapt their sleep schedules.

Work sets shall not exceed 14 consecutive day or night shifts

At this time, there is not enough scientific data to define the appropriate outer boundaries for Hour of Service rules for outages under an FRMS. As is discussed above (Section 4.8.1.1 Normal Operations), the published studies of the most common shift schedules mostly look at three or four consecutive shifts and only a few examine up to a maximum of 7 consecutive work days. Virtually all have conducted these evaluations in the absence of a fully-implemented FRMS.

However, the effects of long stretches of consecutive work days have been studied in off-shore platforms under conditions in which other fatigue mitigations are in place. They include:

- absence of family-social demands conflicting with sleep opportunity times;
- fixed shifts or infrequent day/night shift rotations (e.g. every two weeks);
- lack of availability of alcohol or recreational drugs;
- long blocks of off-duty rest between off-shore assignments.

Under these conditions, long blocks of consecutive shifts (15 to 30 days) are well tolerated without significant sleep and fatigue issues. [3] Several field studies of such operations have found decreased fatigue over consecutive night shifts. The U.K. Health and Safety Executive sponsored a comprehensive study analyzing different work patterns and work environments. [130] One of the studies on consecutive night shifts included individuals working offshore. In that group, in which people worked up to 14 consecutive nights, subjective levels of fatigue decreased as the number of consecutive shifts increased. A mining study, analyzing how often operators requested unscheduled breaks, found that the greatest percentage of those requests occurred during the first few night shifts and that, compared to the first two night shifts, there was no significant increase of requested breaks as the number of shifts increases. [2] That fatigue decreases on consecutive nights reflects worker's adaptation to the night shift.

The Australian Joint Coal Board Health and Safety Trust funded a study to evaluate fatigue and performance in open-cut mines. [131] One of the key questions was "What is the limit of successive day or night shifts before chronic fatigue affects operator performance?" Operators worked 14 night shifts, had one day off and worked 14 day shifts (12-hour shifts). It was a fly-in, fly-out operation, with excellent opportunities for restorative sleep. Twenty-four operators participated and were studied for at least two consecutive rosters. A total of 350 hours of real time data were collected, using a fatigue-monitoring device installed in haul trucks. Of the 14 night shifts, nights 13, 14, 7, and 2 were the worst, in this order.

The fact that nights 13 and 14 were the worst suggested cumulative fatigue. However, when discussed with operators, they mentioned that they tended to relax more and not fight tiredness as much because they knew they were close to the end of the night work. The fact that nights 2 and 7 also were among the worst suggest that simply putting limits on consecutive shifts may not be the solution for eliminating fatigue risk. Moreover, the authors noted that the objective data collected proved that operators may get dangerously tired within the first two nights.

As mentioned previously, 7, 14, and even 21 consecutive shifts are common practice in remote locations. In operations in which employees commute to work every day, there are multiple activities competing with sleep that tend to reduce the time dedicated to rest. However, in remote locations, workers are not subject to social and domestic distractions and pressures, and thus are able to devote most of their off-duty time to sleep and thus minimize sleep deprivation. Also, the sleeping quarters tend to be designed to allow for better sleep during daytime (dark, cool, quiet, etc). A study comparing sleep duration after work shifts found that miners working in a remote location obtained more sleep than miners who returned home every day. Workers in the remote location, on average, obtained seven hours of sleep per day, while working both 12-hour day and night shifts. [2]

Under the conditions of an outage in which employees have planned their lives to minimize outside obligations, conditions may become closer to those of a remote facility than a commuting situation. This adaptation can be reinforced by FRMS specific training to help employees understand the importance of organizing their lives and reducing outside commitments so as to obtain enough sleep, as well as provide tips on how to improve sleep quality on fixed schedules. All of these measures would help minimize the potential for accumulating a sleep deficit during long blocks of consecutive shifts during an outage.

It should be acknowledged that the fatigue risk of 14 consecutive 12 or 10-hour shifts in operations with daily commuting shiftworkers has not been studied by peer reviewed science. Applying the conclusions of studies of remote non-commuting shiftwork operations without FRMS to the scheduling of employees in RP 755 FRMS compliant operations with commuting employees needs to be done carefully.

Minimum 36 hours off after a work set

As discussed previously, it is important to minimize the number of transitions from day to night in order to minimize circadian disruption. For this reason, RP 755 recognizes that long blocks of consecutive shifts (especially during outages) are frequently scheduled on fixed non-rotating schedules so that the employee can make an adjustment to the new “time zone” or a compromise adjustment. [132] Forcing individuals back into a nocturnal sleep orientation during brief days off between blocks of shifts is not helpful. Setting the minimum off-duty period at 36 hours facilitates this objective.

Time beyond 36 hours shall be addressed at the company or plant level

Managers and supervisors who make decisions about giving employees additional time off to recover from fatigue should be fully educated and trained as part of the FRMS. When managing work hours and coverage needs under an FRMS, the consequences of management and supervisor decisions should be open to continuous review as part of the data analysis and fatigue risk assessment built into the FRMS.

During outages, individuals tend to work fixed shifts. 36 hours between work sets provides for 2 consecutive sleep opportunities allowing individuals to remain on their established circadian cycle rather than encouraging night shift workers to revert to night sleep on their days off, which would occur likely with longer time between work sets.

It is important to keep the diurnal or nocturnal orientation that employees have established in working blocks of shifts to minimize the distress associated with circadian changes. If employees have been working nights and are returning to nights after a 36-hour break, their training should emphasize the value of maintaining the circadian phase orientation of their sleep-wake schedules during the 36 hours off. Doing so is much more feasible during a 36-hour break than a 60-hour break, which is the next option when on fixed shift schedules.

Holdover periods should not exceed 2 hours and if possible be scheduled at the end of day shift

Note: Already discussed above (normal operations).

Start-ups and planned shut-downs are critical times and due consideration should be provided so safety critical personnel are well rested and fit for duty

The extended blocks of consecutive shifts and the extended work hours permitted during outages address the very real operational demands faced by refineries and petrochemical facilities. However, special efforts need to be made to ensure all the protections of the FRMS are in place and reviewed more frequently than during normal operations.

4.8.1.3 Extended Shifts

Extended shifts (greater than 14 hours) shall occur only to avoid unplanned open safety critical position or accomplish unplanned safety critical task

Extended shifts are not routinely scheduled, but rather are the response to an unplanned circumstance. It is important to recognize the unique characteristics of the industry, with its safety-critical tasks and positions that cannot be left unattended. Even when the employee currently working may be fatigued, it is simply not safe, and not possible, to leave the post unattended if no replacement is available. However, extended shifts should not be the result of known staffing shortages and the consequent open shifts.

The decision to work an extended shift greater than 16 hours shall be managed through an established management process per 4.8.5

Note: See discussion above.

Two options for extended shifts:

Shifts 14 to 16 hours, minimum of 8 hours off before next shift

A minimum of 8 hours off between shifts may allow only 4 to 5 hours of actual sleep, depending on commute times and personal activities (e.g. meals, personal hygiene). A single day with a shortened sleep in a person who otherwise has been obtaining adequate sleep can be tolerated without excessive fatigue risk. However, the number of days when these short sleep episodes occur must be strictly limited because shortened sleep episodes over consecutive days results in chronic sleep deprivation. [100] Four hours of sleep has been suggested as the minimum amount of sleep required to sustain adequate performance levels during a single day, [99] although performance levels are lower than in people able to sleep for eight hours.

The FRMS should train employees not only to maximize their sleep duration and quality during time off, but also employ fatigue countermeasures that could minimize fatigue during the following shift. In addition, the FRMS would provide supervisors with the information necessary to closely monitor employees, both during the extended shift and the following shift, in order to assess fatigue levels and intervene with the appropriate fatigue countermeasures if needed.

Shifts greater than 16 hours, minimum 10 hours before next shift

A minimum of 10 hours off between shifts makes it more probable that 6 to 7 hours of actual sleep can be obtained, especially if the time off occurs during the nighttime. This amount of sleep would be sufficient to maintain alertness during the following shift. As previously noted, individuals who obtained seven hours of sleep or more each night were able to maintain adequate levels of performance over 14 consecutive days. [100]

Extended shifts shall in no case exceed 18 hours

Shifts of 16 hours or longer are unusual, except in emergency situations. For instance, the Nuclear Regulatory Commission [133] sets the limit at 16 hours in a 24-hour period, provided that this is an occasional event. Limited use of 18 hour shifts permit an unplanned open 12-hour shift to be covered by extending the shift of the prior shiftworker, and bringing in the employee working the following shift 6-hours early.

Limited use of 18 hour shifts in such situations has been studied in health care operations. A study evaluated sleep and cognitive performance of flight nurses, comparing 12-hour versus 18-hour shifts during a 72-hour duty schedule: either three consecutive 12-hour night shifts or two 18-hour (7 am to 10 pm) shifts separated by a 24-hour rest period. [134] The data showed that provided that adequate daily sleep (at least 7 hours per day) is obtained, there was no difference or decline in the cognitive function of the nurses working 12-hour or 18-hour shift during a 72-hour schedule.

However, in most industries, 18-hour shifts are worked only in emergency situations. As is true for other extended shifts, the FRMS would train employees not only to maximize their amount of sleep and sleep quality during their time off, but also to employ fatigue countermeasures that could minimize fatigue during the following shift. In addition, the FRMS would provide supervisors with information necessary to closely monitor employees during both the extended shift and the following shift, in order to assess fatigue levels and intervene with the appropriate fatigue countermeasures.

Not more than 1 extended shift longer than 14 hours per work set

Extended shifts are “pushing the limits” and thus should only be a last resource and not something that would be used routinely. Since extended shifts are more fatiguing than shorter shifts, it is reasonable to limit the number of extended shifts to one shift per work set in order to limit the possible sleep deprivation and cumulative fatigue.

4.8.2 10-hour Shifts

4.8.2.1 Normal operations

Work sets shall not exceed 9 consecutive day or night shifts

As noted in the 12-hour shifts section, shiftwork experts usually recommend limiting the number of consecutive working shifts to 5-7 shifts. However, the protections provided by an FRMS can help to safely extend these limits. Employees should be able to minimize their cumulative sleep deficit after obtaining specific training to help them get enough sleep and improve their sleep quality. It should also be taken into account that 10-hour shifts allow 14 hours off duty each day, providing more than enough time to obtain 7 to 8 hours of sleep per day, and still have some time for family and social activities.

Minimum 36 hours off after a work set

Note: Already discussed above (12-hour shifts).

Minimum 48 hours off after a work set with 4 or more night shifts

Note: Already discussed above (12-hour shifts).

Holdover periods should not exceed 2 hours and if possible be scheduled at the end of day shift

Note: Already discussed above (12-hour shifts).

4.8.2.2 Outages

Work sets shall not exceed 14 consecutive day or night shifts

Note: Already discussed above (12-hour shifts).

Minimum 36 hours off after a work set

Note: Already discussed above.

Time beyond 36 hours shall be addressed at the plant level

Note: Already discussed above.

During outages, individuals tend to work fixed shifts. 36 hours between work sets provides for 2 consecutive sleep opportunities allowing individuals to remain on their established circadian cycle rather than encouraging night shift workers to revert to night sleep on their days off, which would occur likely with longer time between work sets.

Note: Already discussed above.

Holdover periods should not exceed 2 hours and if possible be scheduled at the end of day shift

Note: Already discussed above.

4.8.2.3 Extended shifts

Extended shifts (not to exceed 16 hours) shall occur only to avoid unplanned open safety critical position or accomplish unplanned safety critical task

Note: Already discussed above.

Minimum of 8 hours off before next shift

Note: Already discussed above.

The decision to work an extended shift shall be managed through an established management process per 4.8.5

Note: Already discussed above.

Extended shifts shall not exceed 16 hours

This hard upper limit should be reduced from 18 hours under 12-hour shifts to 16 hours under 10-hour shifts for two reasons:

- Longer blocks of consecutive days are allowed in 10-hour shift worksets and hence the risk of cumulative fatigue needs to be carefully managed.
- There is a good operational reason to allow up to 18 hours in 12-hour shift operations to allow coverage of unplanned open shifts, but no such justification exists with 10 hour shifts.

No more than 1 extended shift longer than 14 hours per work set or no more than 2 extended 12-hour shifts in a work set. If 3 or more 12-hour shifts in a work set, follow guidelines for 12-hour shifts (4.8.1)

Extended shifts of greater than 14 hours may increase fatigue during the shift and, if not enough sleep is obtained during the time off after the shift, this increased fatigue and sleep deprivation may also have a negative impact on the following shift. It is thus reasonable to limit the number of extended shifts longer than 14 hours to one per work set. 12-hour shifts are routinely worked in many operations, and this is the reason for allowing two 12-hour shifts during a work set.

4.8.3 8-Hour Shifts

Shifts should rotate in a forward direction

With most 8-hour shift systems, three separate crews are required to provide coverage for each 24-hour period, with a fourth crew off-duty on any given day. Typically the on-duty crews work either a day shift, an afternoon shift, or a night shift. While some operations use fixed 8-hour shifts, petrochemical facilities often require employees to rotate through the three shifts. As a result, they could either rotate from days to afternoons to nights (a forward direction) or they could rotate from days to nights to afternoons (a backward direction).

Work schedules that move forward in time (clockwise) have been found to be less disruptive to sleep patterns and less physiologically stressful for the human body. [135,136] That is because the human biological clock actually does not operate on a 24-hour day, but instead has a period slightly longer than 24 hours. [137,138] Our body keeps functioning on a 24-hour day because the clock is reset everyday by external time cues. In the absence of these cues, people typically go to bed an hour later every night and get up an hour later every day. Backward rotating schedules have been found to require more time for recovery after a period of work days. Forward rotating schedules are associated with better sleep quality and less family-work conflict. [139]

This phenomenon is clearly illustrated when we compare 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). For most people, jet lag symptoms are more severe when traveling east than when traveling west.

4.8.3.1 Normal operations

Work sets shall not exceed 10 consecutive day, evening or night shifts

Based on the data reviewed in section 4.8.1.1, some shiftwork experts recommend limiting the number of consecutive 8-hour work days to no more than 7 shifts. [128,27] This general recommendation includes all shifts (morning, evening, nights). However, since both morning and evening shifts allow sleep during nighttime, and thus are less fatiguing, it is acceptable to occasionally work a greater number of day shifts.

Several studies have studied the effects of consecutive 8-hour shifts on fatigue and alertness. A review of seven studies (mainly of 8-hour shifts) found an increased risk from the first to the fourth night. However, another study found a decrease in risk from the fourth to the fifth night which was maintained until the seventh (last) shift. [121] One study found a continuous deterioration of performance during five consecutive night shifts. [140] The decrement was exacerbated by the sleep loss (1.5 hours to 2 hours per day) that resulted in a cumulative sleep debt. However, lab studies have found that under optimal sleep conditions, the sleep debt that accumulates during consecutive night shifts is relatively small and does not exacerbate decrements in nighttime performance resulting from other factors (time-of-day). When sleep loss in minimized, employees’ performance adapts as their circadian rhythms adapt. [141] These authors found that performance actually improved across the week of simulated 8-hour night shifts. Another lab study (four 8-hour day shifts followed by three 8-hour night shifts) showed similar results, demonstrating that both the increase in attentional lapses and the impairment in subjective alertness were worse during the first night shift than during the subsequent night shifts. [119]

Working under the umbrella of an FRMS enables the limits to be extended without increasing risk because employees receive training to help them mitigate sleep deficits. It is important to note that 8-hour shifts allow 16 hours off duty each day, which provides enough time to obtain 7 to 8 hours of sleep per day and still have time for family and social activities. Also, when it comes to the total number of hours worked during the work set, 10 consecutive 8-hour shifts will result into 80 work hours, which is comparable to the 84 hour work set limit associated with 12-hour shifts (see above). This limit is also close to the maximum of 70 hours of work during 8 consecutive days, or 84 hours per week permitted when using the 34-hour restart allowed by the trucking Hours of Service regulations.

Minimum 36 hours off after a work set

Note: Already discussed above.

Minimum 48 hours off after a work set with 4 or more night shifts

Note: Already discussed above.

Holdover periods should not exceed 2 hours and if possible be scheduled at the end of day shift

Note: Already discussed above.

4.8.3.2 Outages

Work sets shall not exceed 19 consecutive calendar days

Working 19 consecutive 8-hour shifts exceeds by far the standard scientific recommendations. However, it should also be recognized that 14 consecutive 12-shifts are common practice in remote locations (off-shore, mining, etc). As mentioned previously, workers in these situations are not subject to social and domestic distractions and pressures and their sleeping quarters are designed to allow for better sleep during daytime (dark, cool, quiet, etc.). To the extent that employees working on 8-hour shifts during outages adopt these practices, this will help reduce the risk.

Minimum 36 hours off after a work set

Note: Already discussed above.

Minimum 48 hours off after a work set with 4 or more night shifts

Note: Already discussed above.

Any employee shall not be denied up to 48 hours off, if requested.

With the extended block of up to 19 consecutive days of work on 8-hour shifts there needs to be an allowance for employees to request a full 48 hours off.

Time off beyond 48 hours shall be addressed at the plant level.

Note: Already discussed above.

Holdover periods should not exceed 2 hours and if possible be scheduled at the end of day shift

Note: Already discussed above.

4.8.3.3 Extended Shifts

Extended shifts (not to exceed 16 hours) shall occur only to avoid unplanned open safety critical position or accomplish unplanned safety critical task

Note: Already discussed above.

Minimum of 8 hours off before next shift

Note: Already discussed above.

The decision to work an extended shift shall be managed through an established management process per 4.8.5

Note: Already discussed above.

Extended shifts should not exceed 16 hours

In the case of 8-hour shifts, setting the limit at 16 hours permits the occasionally necessary practice of holding an employee after s/he has completed her/his shift for a maximum of another 8-hour shift to cover an unplanned open shift if it is not possible to ask the employee covering the following shift to start work earlier.

No more than 2 non-consecutive extended shifts greater or equal 14 hours per work set or no more than 2 extended 12-hour shifts in a work set. These can be consecutive. For 3 or more 12-hour shifts in a work set, follow guidelines for 12-hour shifts (4.8.1)

As noted above, extended shifts of greater than 14 hours may increase fatigue during the shift and, without sufficient sleep during the time off after the shift, the employee's increased fatigue and the sleep deprivation may also have a negative impact. In the case of 8-hour shifts, the shorter duration of the regular shift allows more time to obtain sleep and recover from the extended shift, which would allow two extended shifts in a work period. Because 14-hour extended shifts may lead to greater fatigue, it is reasonable that those extended shifts would not be consecutive in order to minimize cumulative sleep deprivation and fatigue. Since 12-hour shifts routinely are worked during normal operations in many industries, it seems reasonable to allow two consecutive 12-hour extended shifts during a work set.

4.8.4 Call-outs

Unpredictable pattern of work and rest

By nature, call-outs result in irregular, unpredictable work schedules.

When a person follows a regular sleep-wake schedule—going to bed and waking up at approximately the same hour every day—this helps to synchronize his sleep/wake and other circadian rhythms to a schedule. If they occur at the same time every day, even relatively low levels of light exposure can gradually nudge the biological clock to help synchronize that person to the work-rest schedule. [142] Thus a regular daily pattern of bedtime and awake time, and a regular routine of exposure to light and dark will cause a person's circadian sleep-wake rhythm to become optimally synchronized to the time of day that they are going to bed, even when it is not a typical or traditional time. This synchronization will promote optimal sleep quality and consequently minimize daytime sleepiness. Repeatedly going to bed at the same time also establishes and strengthens associations between factors in the bedtime environment conducive to sleep and the process of falling asleep.

On the other hand, irregular sleep/wake patterns cause disruption in sleep as well as impairment of alertness. The circadian system is not able to adapt instantly to changes imposed by work schedules, [143] which is particularly relevant with very irregular schedules, as is the case for call-outs. The negative impact on alertness and safety of irregular work patterns has been noted by the NTSB which in a 1995 study concluded that "irregular duty and sleep patterns are a significant risk factor." [144]

Adequate rest prior returning to work

Not knowing when they will be called in to work makes it difficult for operators to plan their off duty time in such a way as to properly time their sleep so that they will be rested and alert.

Call-outs during nocturnal hours would likely result in sleep disruption

Since most on-call operators would tend to sleep at night, being called during the night will most likely wake up individuals. Call-outs during the night will result in shortened/curtailed sleep, forcing an operator to wake up and go to work after only a few hours of sleep. Furthermore, studies have shown that sleep quality itself is impaired when individuals on-call attempt to sleep. [145,146,147]

Multiple call-outs during a day provide little opportunity for restorative sleep

As noted above, research studies have shown that sleep quality is impaired when individuals attempt to sleep while they are on call. In addition, if an individual receives multiple calls during the day, it would be difficult to obtain enough sleep during daytime. In addition, it takes usually longer to fall asleep during the day and daytime sleep is usually of poorer quality. All these factors would make quite difficult to obtain restorative sleep during daytime.

Call outs that end shortly before next scheduled shift or shortly after a shift result in extended shifts, conform to guidelines

If there is not sufficient time to commute to and from home, take care of personal needs, and obtain any significant amount of sleep (i.e. only a brief nap), then in effect the employee should be considered as someone who has been continuously on duty. In this case the extended shift rules provide reasonable outer limits for work hours.

Call-outs occurring on day prior /after work set may contribute to cumulative sleep debt

As noted above, call-outs would likely result in short sleep episodes and, moreover, sleep quality is likely to be poor. In the case of call-outs occurring just before a work set, it is likely that the employee will start the work set already fatigued due to the possible sleep deprivation during the call out. In the case of call outs after the work set, it is possible that the employee would be fatigued after completing the work set, especially if the employee has not been able to obtain enough sleep during that time. In this case, the employee would already be fatigued before the call-out, and this fatigue will be increased by the likely sleep deprivation occurring during the call out.

Exception Process

If any of the criteria or limits specified in the HoS guidelines is expected to be exceeded or an extended shift is contemplated, and established management exception process shall be initiated. The exception process shall involve the employee's immediate supervisor and 1 other management representative. The process shall include a documented risk assessment and mitigation plan. In cases where the maximum daily hours may be exceeded, the supervisor should evaluate the personal travel situation for individual following completion of work and need for alternate arrangements.

To be qualified to make this judgment on relative risk, and to implement mitigation strategies, it is important that the person giving supervisory approval has received training in fatigue risk management including the role of supervisors in reducing risk in shift crews. Issues to be considered include the relative consequences of not filling the position, allowing that person to continue working, and the risk mitigation strategies that are available. Risk mitigation strategies should be available, and employees should have been educated on how to recognize the signs of fatigue and the appropriate use of fatigue countermeasures, including caffeine, exercise, and if possible, napping. Providing adequate breaks during the shift and between shifts also is essential.

4.9 Periodic review of FRMS to achieve continuous improvement

Once the FRMS is implemented, its effectiveness as a continuously improving management and mitigation system relies on the reliability and accuracy of the collected fatigue-related data and confidentiality-protected databases. Rigorous analysis of the data will identify conditions, scheduling practices, policies, employee characteristics, and other variables that may identify existing and potential fatigue risk.

Periodic FRMS reviews should include an assessment of the following.

- The quality of the FRMS process.
- Probable and confirmed correlations between fatigue, fatigue risk causal factors and errors, deviations, incidents and injuries.
- Progress of FRMS on the implementation time line.
- The need for change in the administrative processes of the FRMS.
- The interaction between FRMS and SMS.
- Lessons learned.

Appendix 1

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