

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]

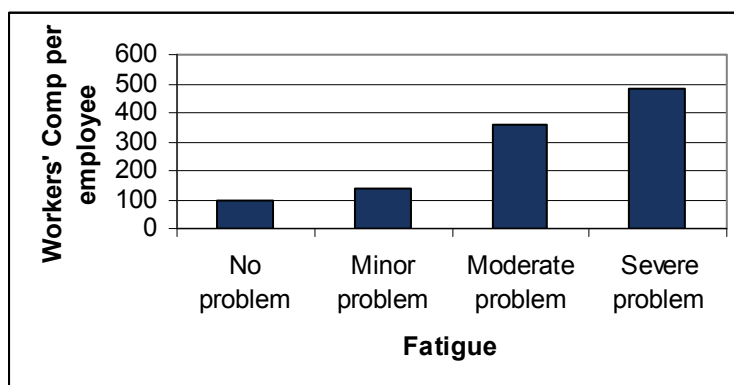
1.1 Overview

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]



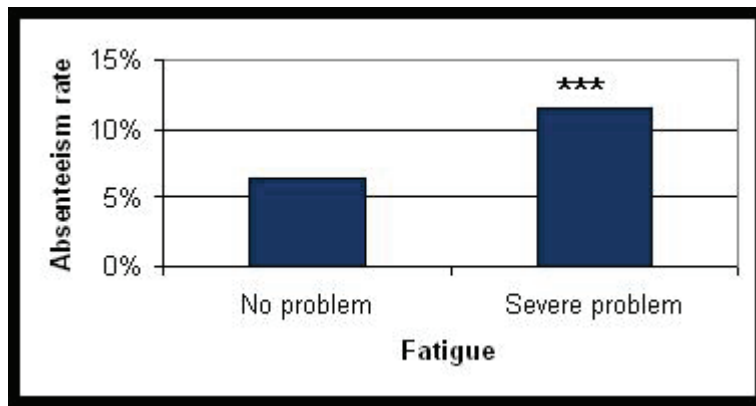
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Figure 1—Employee fatigue levels and Workers' Compensation US\$ costs per employee per year in a survey of 400 shiftwork operations

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.

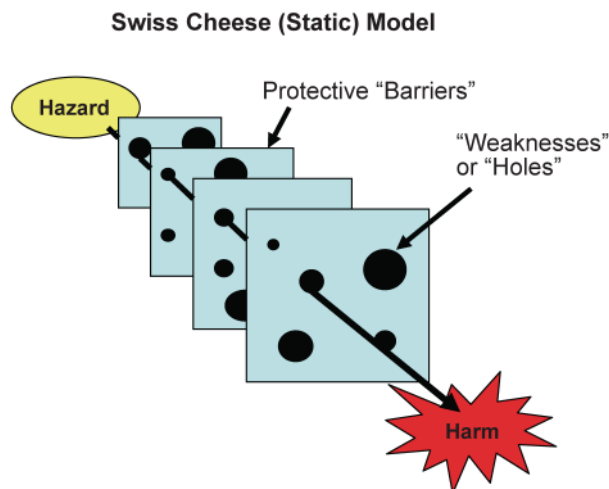


Figure 4—The successive layers of defense in depth in a safety (and fatigue risk) management system and the strategy of addressing risk

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 lose 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, 2nd, 3rd, 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 scientifically-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

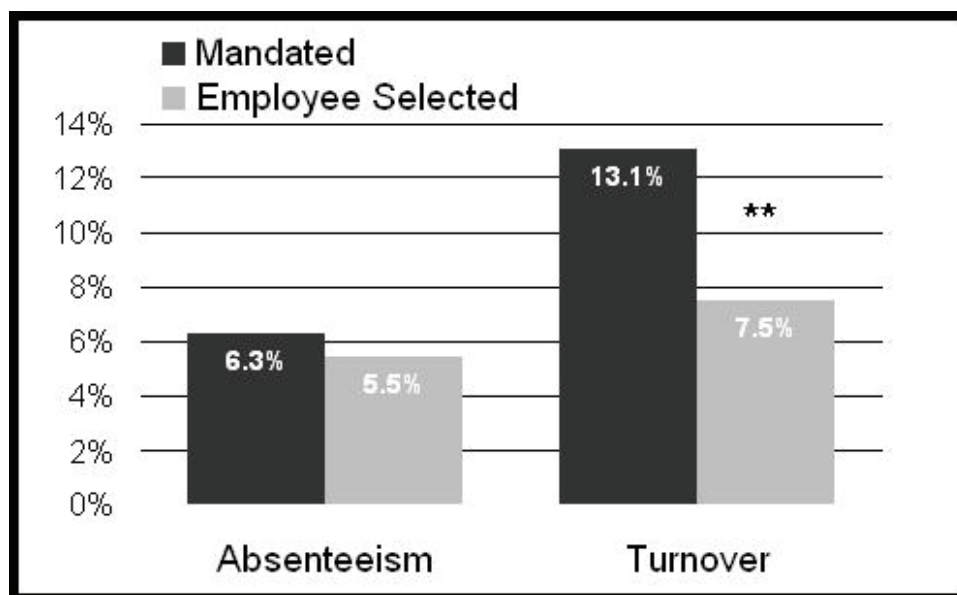
Buy-in by all stakeholders is essential to the success of a FRMS, and buy-in requires education, consultation, and addressing the concerns of all parties who influence the outcome of the FRMS. FRMS requires changes to the operating practices, policies, and procedures, which only management can make, and it requires changes to the behavior and day-to-day 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.

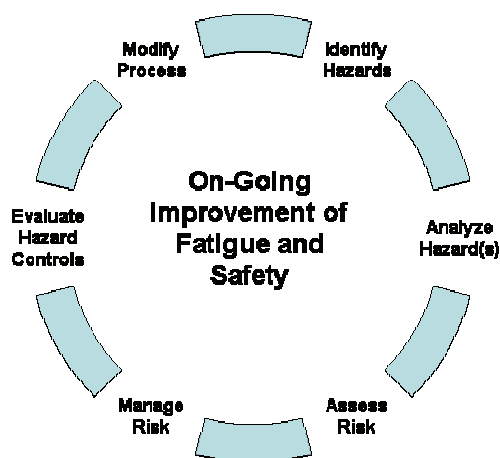


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Figure 5—Absenteeism and turnover rates in facilities that mandate shift schedules vs. those that allow employees to select schedules.
 (**): ANOVA, $F=4.98$, $df=5$, $p<.01$

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

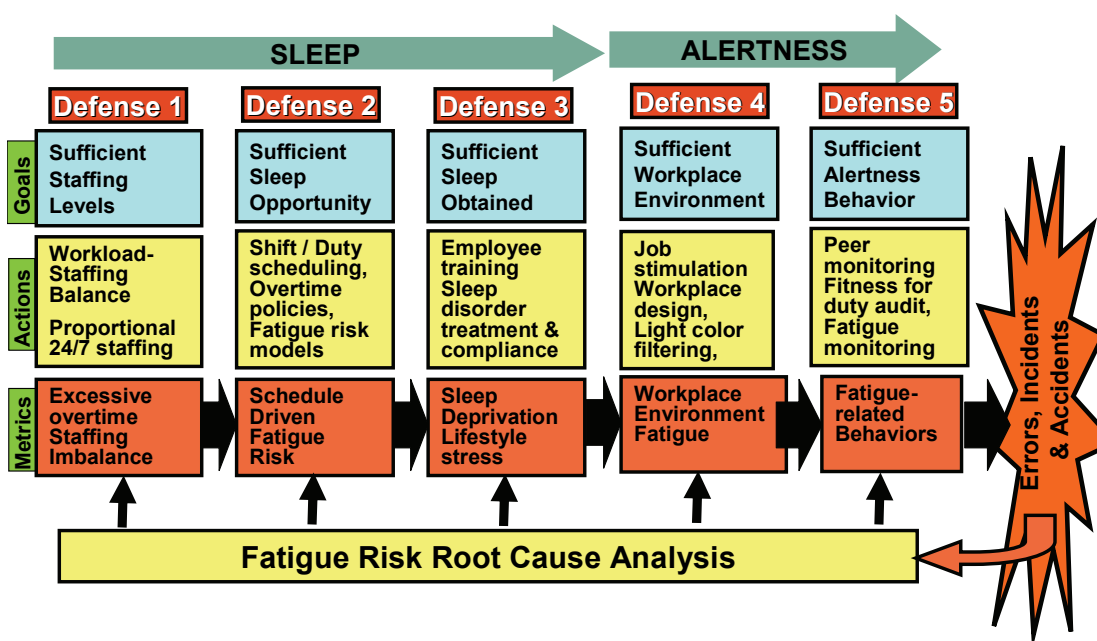
RP 755 provides definitions of the key terms used in the recommendations document. Additional information on some of these terms (e.g. fatigue) can be found in a CIRCADIAN® white paper on the definition of fatigue^[148] and in the other reference sources provided in Appendix 1 of this document.

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.



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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.