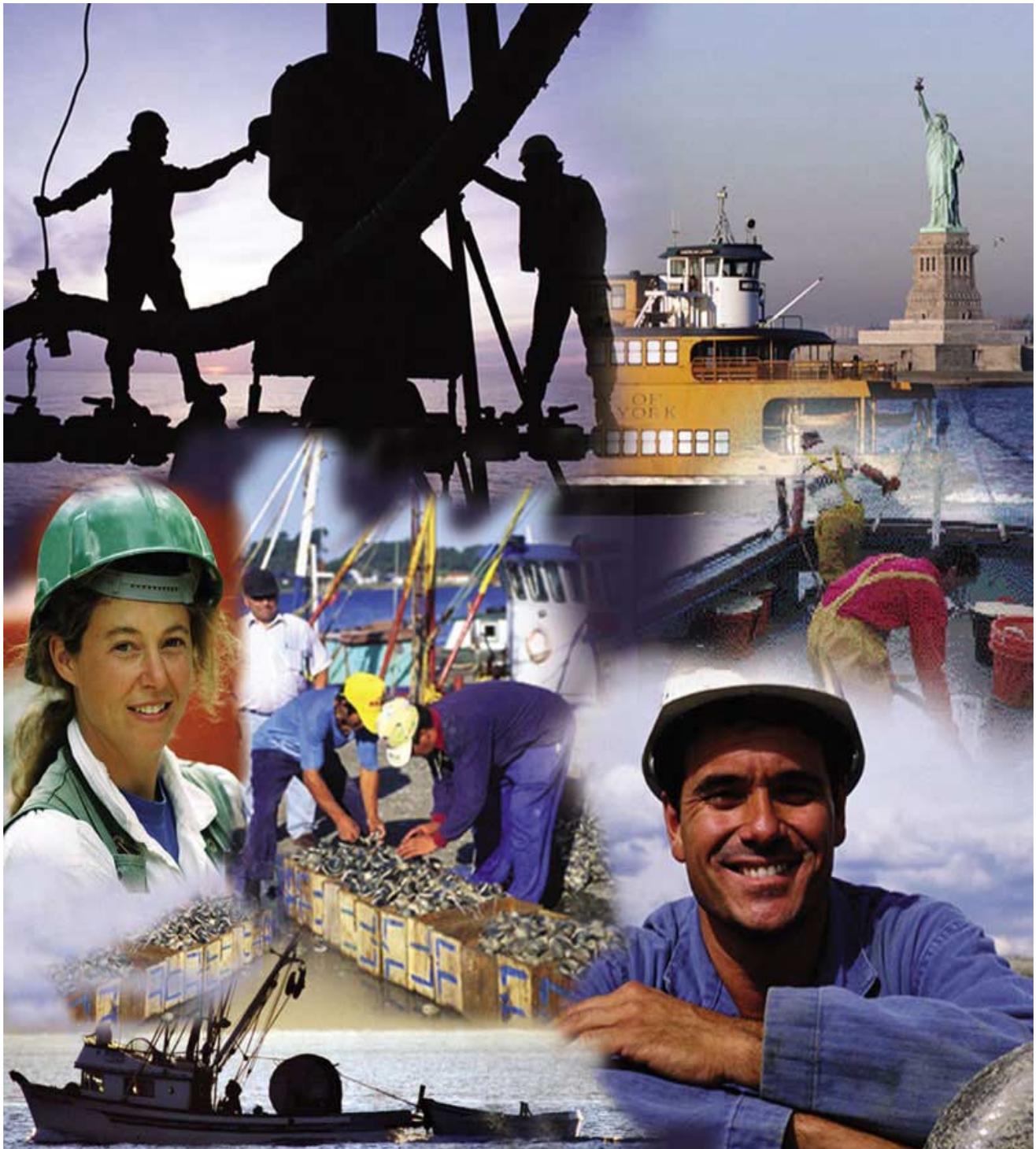


# MANAGEMENT OF ENDURANCE RISK FACTORS

## A Guide for Deep Draft Vessels

---



---

**United States Coast Guard**

# U.S. Coast Guard Research and Development Center

1082 Shennecossett Road, Groton, CT 06340-6096

---

Report No. CG-D-07-01

## MANAGEMENT OF ENDURANCE RISK FACTORS A GUIDE FOR DEEP DRAFT VESSELS



Final Report  
February 2001



This document is available to the U.S. public through the  
National Technical Information Service, Springfield, VA 22161

Prepared for:

U.S. Department of Transportation  
United States Coast Guard  
Marine Safety and Environmental Protection (G-M)  
Washington, DC 20593-0001

# NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

This report does not constitute a standard, specification, or regulation.



Marc B. Mandler, Ph.D.  
Technical Director  
United States Coast Guard  
Research & Development Center  
1082 Shennecossett Road  
Groton, CT 06340-6096

Technical Report Documentation Page

<b>1. Report No.</b> CG-D-07-01		<b>2. Government Accession Number</b>		<b>3. Recipient's Catalog No.</b>	
<b>4. Title and Subtitle</b> MANAGEMENT OF ENDURANCE RISK FACTORS: A GUIDE FOR DEEP DRAFT VESSELS				<b>5. Report Date</b> February 2001	
				<b>6. Performing Organization Code</b> Project No 3302.4.1	
<b>7. Author(s):</b> Carlos A. Comperatore, Ph.D., Leonard Kingsley, Albert W. Kirby, Ph.D., and Pik Kwan Rivera				<b>8. Performing Organization Report No.</b> R&DC 205	
<b>9. Performing Organization Name and Address</b> U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096			<b>10. Work Unit No. (TRAIS)</b>		
			<b>11. Contract or Grant No.</b>		
<b>12. Sponsoring Organization Name and Address</b> U.S. Department of Transportation United States Coast Guard Marine Safety and Environmental Protection (G-M) Washington, DC 20593-0001				<b>13. Type of Report &amp; Period Covered</b> Final Report	
				<b>14. Sponsoring Agency Code</b> Commandant (G-MSE) U.S. Coast Guard Headquarters Washington, DC 20593-0001	
<b>15. Supplementary Notes</b> The U.S. Coast Guard Headquarters point of contact is CDR Timothy Close (G-MSE-1), 202-267-0177. The U.S. Coast Guard Research & Development Center's point of contact is Dr. Carlos Comperatore, 860-441-2751.					
<b>16. Abstract (MAXIMUM 200 WORDS)</b>  Crew members aboard deep draft vessels traditionally endure harsh working conditions, extreme temperatures, long work hours, frequent separation from loved ones, and fatigue. While a ship's endurance is determined by how long it can support operations at sea without replenishing supplies or requiring in-port maintenance, its crew members' endurance is determined by their ability to cope with job related physiological, psychological, and environmental challenges. Uncontrolled stress factors reduce mental and physical endurance and demand more concentration on the immediate task at hand. Crew members forfeit advanced planning and the ability to anticipate safety risks. Safety deteriorates as a crew becomes more reactive. Controlling these decrements in performance is critical to productivity and safety. This Guide is designed as a resource for captains, department heads, and officers, as well as company safety and operations managers in the shipping industry to control crew endurance risk factors such as stress, fatigue, sleep deprivation, and problems resulting from working and living on deep draft vessels. Section I introduces the concept of crew endurance management. Section II provides specific guidance on how to recognize endurance risk factors and the detrimental effects of psychological, physiological, and environmental stress factors. Specific recommendations are provided as to how to effectively address crew endurance risk factors. Section III provides specific guidelines on how to assess crew endurance and implement improvements in crew management practices. The principles provided in this Guide have been tested in a variety of maritime environments, including marine shipping companies, towing vessel companies, U.S. Coast Guard cutters, small boat stations, and aviation units.					
<b>17. Key Words</b> endurance, crew endurance, fatigue, stress, extreme environments, environmental stress factors, deep draft, shipping, commercial maritime, risk factors			<b>18. Distribution Statement</b> This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.		
<b>19. Security Class (This Report)</b> UNCLASSIFIED		<b>20. Security Class (This Page)</b> UNCLASSIFIED		<b>21. No of Pages</b> 98	<b>22. Price</b>

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized.

## FOREWORD

In many commercial maritime environments, mariners traditionally endure challenging working conditions, extreme temperatures, long work-hours, frequent separation from loved ones, and fatigue. Crewmembers working under the influence of these stress factors cannot perform at their best. As a result, these factors have a direct impact on productivity and safety.

Company chief executive officers, operation managers, safety and human resource managers, ship captains, department heads, and mates need to have a clear understanding of performance decrements resulting from exceeding human endurance limitations.

This Guide provides critical information to help you recognize when crew performance can be expected to decline, and most importantly, how to manage shipboard crew endurance. More specifically, the Guide provides information you need to manage factors that increase the risk of developing severe crew endurance decrements.

Your diligent application of this information will proactively control endurance risk factors, improve crewmember performance and productivity, and most importantly, improve safety.

---

CAPT Jeffery G. Lantz, Chief  
Chief, Office of Design and Engineering Standards

## EXECUTIVE SUMMARY

In all occupations, mental and physical stressors impact workers' ability to concentrate on job related tasks. In the maritime environment, planning ahead for the next task allows crew members to anticipate risks that may compromise shipboard and operational safety. If stressors are not controlled proactively, crew members' mental and physical endurance degrade as task completion requires more effort and attention. Inevitably, crew members experience frequent lapses of attention that ultimately set the stage for the occurrence of errors in job performance. In brief, work related stressors are endurance risk factors that must be controlled to prevent compromising shipboard safety.

The Crew Endurance Management (CEM) practices proposed in this Guide compile field-tested methods used to manage risk factors that affect crew members' health and performance. The CEM principles refer to the concept of endurance management, rather than sleep or fatigue management, because in maritime environments a variety of stressors, not solely sleep loss, have a direct impact on crew performance. In this context, the term **endurance** refers to the ability to maintain performance within safety limits and to control the adverse effects of environmental, physiological, and psychological stressors.

This document emphasizes that the control of endurance risk factors is critical to both productivity and safety. With this in mind, the contents of this Guide are intended to aid the professional mariner in the constant struggle to control crew endurance risk factors aboard deep draft vessels. Section I takes the reader directly into the practice of CEM. Section II provides practical recommendations for the control of specific endurance risk factors such as extreme environmental temperatures, work related stress, unpredictable work schedules, sleep loss, fatigue, etc. Section III guides the reader on how to design, implement, and test CEM plans aboard deep draft vessels.

# TABLE OF CONTENTS

	Page
<b>FOREWORD</b> .....	iv
<b>EXECUTIVE SUMMARY</b> .....	v
<b>ACKNOWLEDGEMENTS</b> .....	x
PURPOSE OF THIS GUIDE .....	xi
CREW ENDURANCE MANAGEMENT .....	xii
GUIDE ORGANIZATION .....	xii
HOW TO USE THIS GUIDE .....	xiii
<b>SECTION I: CREW ENDURANCE MANAGEMENT</b> .....	I-1
Crew Endurance .....	I-3
Crew Endurance Risk Factors .....	I-4
The Cornerstone of Crew Endurance Management: Developing a Crew Endurance Working Group (CEWG) .....	I-6
CEWG Characteristics and Activities .....	I-7
Endurance Risk Assessment Form .....	I-11
<b>SECTION II: UNDERSTANDING AND MANAGING ENDURANCE RISK</b>	
<b>FACTORS</b> .....	II-1
Endurance and Energy .....	II-3
What Energy is and How it is Produced .....	II-3
How the Body Turns Food Into Energy .....	II-4
When Energy Demands Outweigh Normal Energy Production .....	II-5
Common Risk Factors .....	II-6
Cold-Related Illness .....	II-7
Risk Factor .....	II-7
Consequences .....	II-8
Endurance Tips .....	II-9
Heat Illness .....	II-11
Risk Factor .....	II-11
Consequences .....	II-11
Endurance Tips .....	II-13
Motion Sickness .....	II-15
Risk Factor .....	II-15
Consequences .....	II-15
Endurance Tips .....	II-16
Stress .....	II-17
Risk Factor .....	II-17
Consequences .....	II-18
Endurance Tips .....	II-19
Ways to Reduce Stress .....	II-20
Sleep and Shiftwork .....	II-21
Risk Factor .....	II-21
Biological Clock .....	II-22

Consequences .....	II-23
Work Schedules.....	II-23
Shiftwork Maladaptation.....	II-26
Endurance Tips.....	II-27
Total Adaptation to Night Work .....	II-27
Partial Adaptation to Night Watch or Work Schedules .....	II-28
Caffeine .....	II-29
Risk Factor.....	II-29
Consequences .....	II-29
Endurance Tips.....	II-29

**SECTION III: CREW ENDURANCE MANAGEMENT PRACTICAL**

<b>RECOMMENDATIONS .....</b>	<b>III-1</b>
Controlling Endurance Risk Factors .....	III-3
Phase I: Initial Evaluation .....	III-4
Phase II: Implementation .....	III-5
Phase III: Follow-up Evaluation .....	III-6
Summary of Crew Endurance Management Process.....	III-10

**APPENDICES:**

<b>A: Sleep Management and Circadian Rhythms .....</b>	<b>A-3</b>
A-I: Sleep Management.....	A-3
A-II: Napping .....	A-7
A-III: Circadian Rhythms .....	A-9
A-IV: Shiftwork, Sleep, and Biological Clock Management .....	A-13
A-V: Night Watch, Daylight, Sleep, and Work Management.....	A-17
<b>B: Phase III-Follow-up Evaluation – Endurance Plans Effectiveness Tests - Crew Sleep Duration .....</b>	<b>B-3</b>
<b>C: List of Supporting Documents .....</b>	<b>C-3</b>

## LIST OF ILLUSTRATIONS

1.	Network for development of functional CEWG.....	I-6
2.	Example of the system of elements that may impact endurance in shipping operations .....	I-9
3.	Food is broken down into energy substrates .....	II-4
4.	Daily energy cycle as a function of time of day .....	II-22
A-1.	Sleep cycle .....	A-3
A-2.	Transition to night schedules when work ends after sunrise.....	A-20
A-3.	Transition to night schedules when work ends prior to sunrise.....	A-20
A-4.	Transition from nighttime to daytime schedules.....	A-21
B-1.	Daily sleep duration plotted in hours over 27 days during the months of May and June 2000 .....	B-3
B-2.	Daily sleep duration plotted in hours over 48 days during the months of May and July 2000 .....	B-4
B-3.	Daily sleep duration plotted in hours over 29 days during the months of May and June 2000 .....	B-5
B-4.	Daily sleep duration plotted in hours over 25 days during the months of May and June 2000 .....	B-6
B-5.	Daily sleep duration plotted in hours over 10 days during the months of April and May 2000 .....	B-7
B-6.	Daily sleep duration plotted in hours over 6 days during the months of April and May 2000 .....	B-8

## LIST OF TABLES

1. 4-Step Process of Crew Endurance Working Group to determine crew endurance management system .....I-8, III-3
2. List of medications commonly used to fight the symptoms of motion sickness .....II-16

## **ACKNOWLEDGEMENTS**

The authors wish to express their sincere appreciation to the organizations and colleagues listed below. These individuals, and their organizations, assisted in coordinating and performing activities that contributed to both the successful completion of the study and the production of this guide. Without their support and assistance, neither could have been accomplished.

### **Keystone Shipping Company**

Mr. Charles Kurz II  
Captain Bruce Fernie  
Captain G. Hodgdon  
Captain T. Malanchuk  
Crew of the KEYSTONE-TEXAS

### **Seabulk International, Incorporated**

Mr. Richard Scricca  
Crew of the HMI DYNACHEM  
Crew of the HMI NANTUCKET SHOALS

### **USCG Headquarters Office of Human Element and Ship Design (G-MSE-1)**

CDR Timothy Close  
LT Scott Calhoun  
Ms. Mayte Medina-Darr

### **USCG Headquarters Office of the Maritime Personnel Qualifications Division (G-MSO-1)**

CDR Steven Boyle

### **USCG Headquarters Office of Safety and Environmental Health (G-WKS-3)**

Dr. Antonio Carvalhais

### **USCG Research & Development Center**

Mr. David Beene	Mr. Jan McNutt
Ms. Joy Simmons	Dr. Anita Rothblum
Ms. Dinah Mulligan	Mr. Dave Pianka
Ms. Susan Stevens	LTJG Chris Bloch
YN2 Gerald Joncas	

### **Potomac Management Group, Inc.**

Ms. Jennifer Blain

### **Battelle Seattle**

#### **Human Factors Transportation Center**

Mr. Chuck Ferry  
Mr. Fedner Tovar  
Mr. Roger Jones

## PURPOSE OF THIS GUIDE

This Guide provides managers and leaders with proven “how to” methods to implement ways of addressing fatigue and stress related risk factors that threaten the safety of operations in the commercial maritime industry.

Fatigue is an undeniable factor of injuries and accidents in the commercial maritime industry. This fact has long been known and accepted by mariners, who view fatigue as an unavoidable aspect of the industry. But there are proven methods for managing fatigue. Successful implementation has been difficult, though, because too often ships’ senior personnel and company managers have been tasked with interpreting and integrating technical scientific information. To implement practical fatigue prevention and educational programs for crew members, the magnitude of thoroughly understanding such methods cannot be underestimated. The success of these efforts depends on a number of factors, including:

- underway and in-port operational tempo
- crew member availability
- coordination with unions
- company support
- flexibility of company policies
- equipment availability

This Guide is designed as a resource for the shipping industry to control stress, fatigue, sleep deprivation, and problems resulting from working and living on deep draft vessels. It also provides ways to address risk factors associated with these stress factors when they cannot be completely eliminated. Key users of the Guide include:

- Schedule planners who design ways to optimize crew member performance and safety
- Trainers who must teach captains, department heads, and officers about 1) the harmful effects of these stresses on crew member performance, and 2) the endurance management process to prevent and handle risk factors that the stress factors cause
- Safety managers who must design and maintain safety programs

## CREW ENDURANCE MANAGEMENT

**Crew endurance refers to the ability to maintain performance within safety limits while enduring job related physiological and psychological challenges.**

The Crew Endurance Management (CEM) practices proposed in this Guide compile field-tested methods used to deal with fatigue and stress related risk factors to safety. The CEM principles use the concept of endurance rather than simply fatigue because crew members' performance and abilities are not threatened only by loss of sleep, but also by environmental and psychological stress factors. The term **endurance** refers to the ability to maintain performance within safety limits and handle the adverse effects of environmental, physiological, and psychological stress factors (defined in Section I).

Mental and physical stress factors impact the human ability to focus on the task at hand and can cause errors in performance. Unless the impact of stress factors on performance is controlled, crew members aboard deep draft vessels must dedicate a larger part of their mental resources to the immediate task at hand and focus less on advance planning. Planning ahead during a task allows crew members to anticipate specific risks and maintain operational safety. However, when stress factors are not controlled proactively, crew members must simply dedicate all their attention and effort to the task at hand and forfeit planning their next task. These are the conditions that result in momentary lapses in safety. For the planner and maintainer, it means fewer resources available for dealing with the important details of their critical tasks. Effectively addressing these weaknesses in performance is critical to productivity and safety. The contents of this Guide are dedicated to aid in the control of stress factors commonly affecting crew members aboard deep draft vessels.

### GUIDE ORGANIZATION

Section I introduces the concept of crew endurance management and a Crew Endurance Working Group. Section II provides guidance recognizing the detrimental effects of endurance risk factors such as stress, fatigue, and unpredictable work schedules on crew member's performance. This section also provides specific recommendations on how to effectively

address crew endurance risk factors. Finally, Section III provides practical recommendations on implementing crew endurance management principles.

## **HOW TO USE THIS GUIDE**

This Guide is a living document. It will be updated periodically as research and testing by the U.S. Coast Guard (USCG) Research and Development Center (R&DC) reveals new information and new methods for using crew endurance to protect crew members. Already under development by the USCG R&DC is a decision support system (not included in this edition) that will assist managers, captains, department heads, and officers applying the principles offered in this Guide to develop crew endurance plans for specific departments aboard deep draft vessels.

The authors of this Guide have highlighted the most important concepts by outlining them in boxes. This was done to help the readers refer back to important information and assist them in developing a better understanding of the main ideas of crew endurance management. These boxed concepts are supported with information that provides details and the mechanics of the highlighted issue. Readers can refer to the Appendices for even more detailed and supporting information. Of particular interest in the boxes are Management Nuggets, which are concepts that leaders and managers can use to make immediate improvements in crew endurance. It is recommended that the readers first review the Guide by scanning through and reading all the information in the boxes. Doing so will help the readers understand how the Guide is structured and hopefully increase interest in these concepts.

It is also the authors' hope that information on the importance of crew endurance will be used in training leaders and planners at every management level. When leaders recognize the risk factors of fatigue, stress, sleep deprivation, and shiftwork maladaptation on the safety and performance of their crew members, controls will be developed and risks will be managed to preserve the safety of shipboard operations.

This Guide is not intended to replace guidelines currently in Oil Pollution Act of 1990 (OPA 90) or Standards of Training, Certification and Watchkeeping for Seafarers (STCW) regarding hours of work and rest. The fundamental reason for this Guide is to provide managers, captains, department heads, and officers tools to manage crew endurance related risk factors. Leaders should use this information along with the guidelines

provided in OPA 90 and STCW to minimize risks associated with crew endurance, to ensure crew endurance issues are considered when risk factors are assessed, and to institute controls to promote productivity and safe operations.

The crew endurance management practices provided in this Guide have been tested in a variety of maritime environments, including marine shipping companies, towing vessel companies, U.S. Coast Guard cutters, small boat stations, and aviation units.

# **SECTION I**

## **CREW ENDURANCE MANAGEMENT**

[This page left intentionally blank.]

## CREW ENDURANCE

Mariners traditionally endure harsh working conditions, extreme temperatures, long work-hours, frequent separation from loved ones, and fatigue. These unfavorable conditions quickly accumulate and impact a mariner's ability to perform work safely and efficiently. Maintaining a safe performance level while facing such job related challenges is the concept of endurance.



**FACT:** Crew endurance refers to the ability of a crew to maintain performance within safety limits while coping with job related environmental, physiological, and psychological challenges.

While a ship's endurance is determined by how long it can support operations at sea without replenishing supplies or requiring in-port maintenance, its crew members' endurance is determined by a combination of environmental, physiological and psychological factors. These factors — which will be discussed in greater detail throughout this Guide — include the internal state of crew members (e.g., emotional state, stress level), physical conditioning, motion discomfort level, quality and duration of sleep periods, diet, and stability level of the body's internal timing system, or biological clock. Each of these factors affects a person's endurance level by exerting a direct influence on a person's energy levels, alertness, and performance. Therefore, a person's safety level depends on his or her endurance.



**FACT:** *Environmental factor* — Effects of motion, and temperature on the body. *Physiological factor* — Effects of sleep loss and shiftwork on the body and performance. *Psychological factor* — effects of stress and working conditions on performance.

## **CREW ENDURANCE RISK FACTORS**

Risk factors to a crew's endurance deteriorate crew members' ability to perform their duties. The following list depicts some job related mental and physical challenges that threaten crew members' ability to maintain performance within safety limits.

- **Insufficient daily sleep duration (less than 7-8 hours of uninterrupted sleep)**
- **Poor sleep quality (awakenings during the night due to work related disruptions or noisy environment)**
- **Sleep fragmentation (daily rest periods are numerous but never allow 7-8 hours of uninterrupted sleep)**
- **Sleep at wrong physiological times (human body naturally designed to sleep at night)**
- **Changing work/rest schedules (rotations from day to night work-hours one or more times per week)**
- **Long work-hours (exceeding 8-12 hours per day)**
- **Sustained work-hours with no breaks (optimal to break 15 minutes per hour)**
- **No sleep recovery opportunities (napping during the day is not possible)**
- **Poor diet (frequent fried foods, high fat and sugar content, frequent caffeine consumption)**
- **High workload (high physical and/or mental effort requirements)**
- **High stress (caused by extreme temperatures, high sustained physical or mental workload, rotating work-schedules, and/or authoritarian leadership style)**
- **Lack of control over work environment or decisions (workers are isolated and not allowed to contribute in problem solving)**
- **Harsh operating environment (noise, vibration)**
- **Excessive exposure to extreme environmental temperatures (cold and heat stress)**

These endurance risk factors are often observed in shipping operations (and other maritime operations), but their impact on crew performance remains unnoticed until crew members experience severe deterioration of alertness and energy. This Guide provides a means to

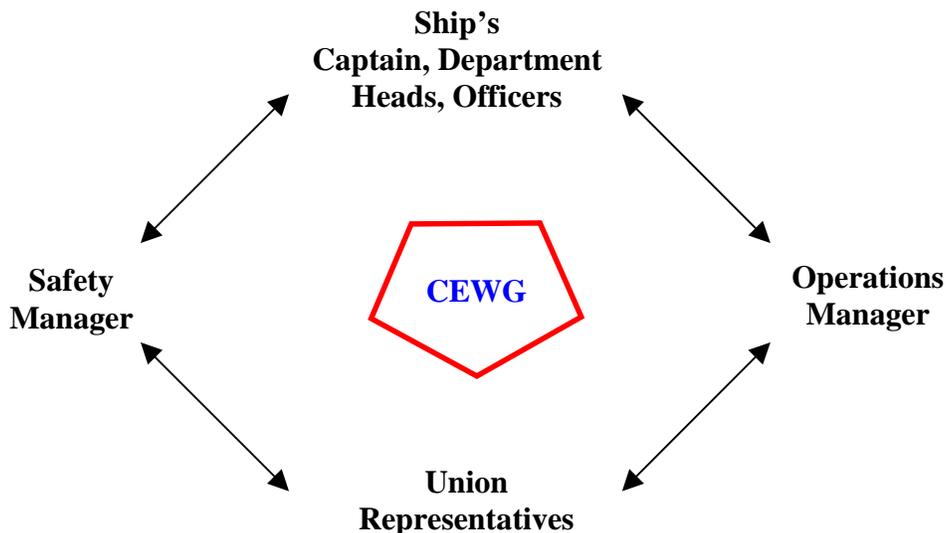
prevent the deterioration of both the crew members' performances and the ship's safety.

## THE CORNERSTONE OF CREW ENDURANCE MANAGEMENT: DEVELOPING A CREW ENDURANCE WORKING GROUP (CEWG)



**FACT:** Controlling risk factors to crew endurance requires the development of a supporting organizational infrastructure. Without management support, individual crew members cannot effectively implement endurance management practices.

Managers of company safety, operations, and human resources, as well as ship's captains, department heads, and officers, are critical members of the infrastructure that can support the implementation of crew endurance management practices. They must, above all, understand how to control crew endurance risks and create a collaborative network to facilitate the implementation of crew endurance management practices aboard ships and throughout the company. Ultimately, management staff must support, encourage, and lead crew members to the consistent practice of endurance strategies. Thus, the first critical step of endurance management is the formation of the CREW ENDURANCE WORKING GROUP (CEWG) (see Figure 1 below).



*Figure 1. Network for development of functional CEWG. This illustration depicts the necessary network for the development of a functional CEWG. Members must be able to maintain two-way communication — they must be able to listen as well as advance creative ideas through discussions.*

## CEWG CHARACTERISTICS AND ACTIVITIES

The goal of the CEWG is the development of a crew endurance management system that is directly applicable to that group (whether it is just the specific vessel or the entire company). The system consists of four basic levels, and all activities that affect endurance can be included in one of them. However, it is the responsibility of each CEWG to determine the specific factors within each level that affect their particular group. The four levels are as follows:

**Mission objectives** — set purposes of the group's operation that cannot be changed (traveling routes, safety levels, etc).

**Individual actions** — actions that crew members can take to maintain their own endurance (eating healthy, sleeping 7-8 hours each night, etc.).

**Management support** — actions by management that supports crew members' efforts to maintain good endurance levels (improvements of sleep rooms, coordination of ship's routine to prevent disruption of rest periods, etc).

**Environmental factors** — outside elements that may impact crew endurance during operations (noise exposure levels, environmental temperatures, etc).

To determine the type of crew endurance management system that is best for the particular group, the CEWG should follow the four steps listed below (see also Table 1 on the following page).

**1<sup>st</sup> Step:** The CEWG first meets to review endurance management information. Prior to this meeting, all members should review this Guide with a specific focus on the "Endurance Risk Assessment Form" (at the end of Section I). The objective for this first meeting is for all members of the CEWG to reach the same level of expertise in understanding crew endurance risk factors and ways to address them.

**2<sup>nd</sup> Step:** The next step involves identifying crew endurance risk factors that have been or are experienced during actual operations. CEWG members should again use the "Endurance Risk Assessment Form" to

determine whether any of the endurance risk factors are a concern during shipping operations, recognizing that any of these factors can significantly degrade performance and compromise operational safety. The detection of several factors during shipboard operations is of great concern because two or more endurance risk factors will interact and impact performance more adversely than any one single factor.

**3<sup>rd</sup> Step:** The third action item of the CEWG is identifying all the elements that may affect crew endurance during shipping operations. This is accomplished through the identification of activities, environmental conditions, policies, and operational situations that may adversely impact crew members' ability to maintain endurance.

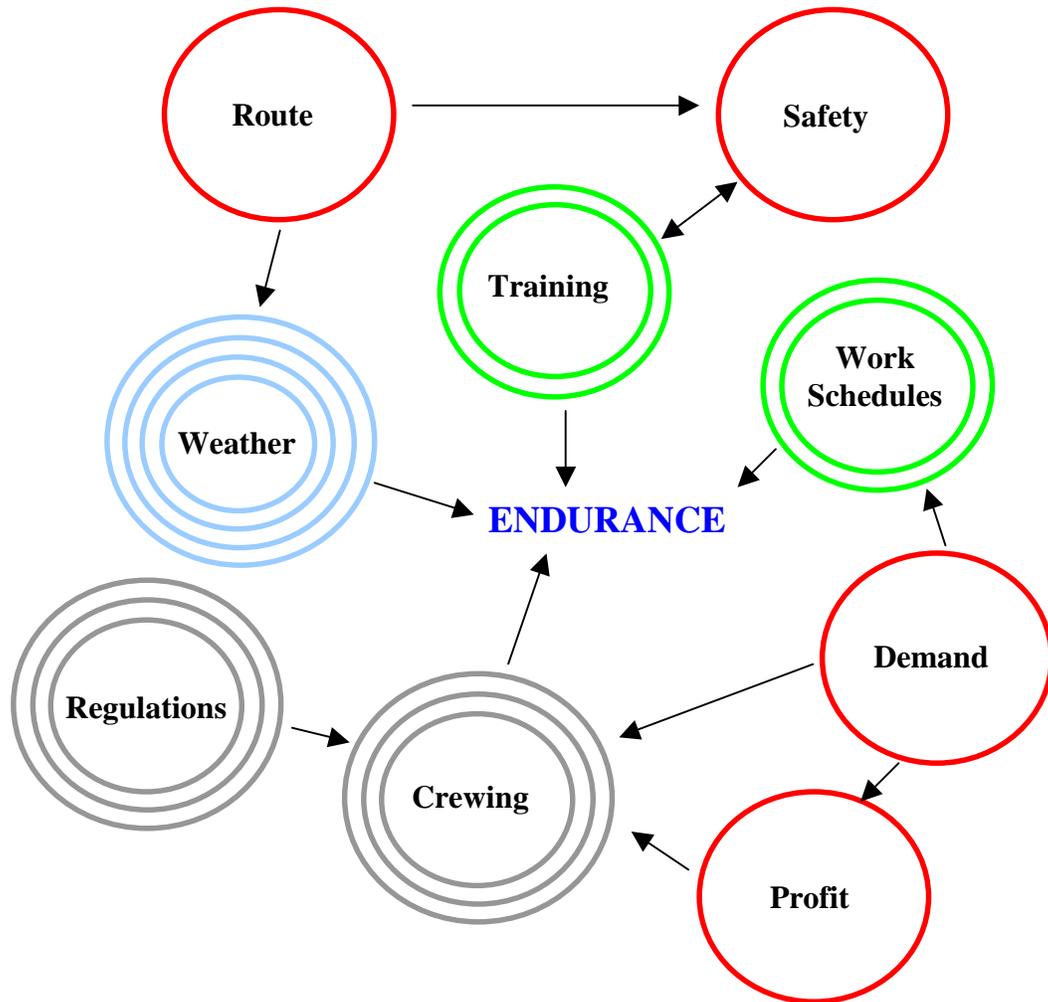
**4<sup>th</sup> Step:** The CEWG then analyzes the relationships between these elements and determines modifications of the system that may improve endurance. The value of understanding the system elements that may affect crew endurance lies in the identification of a) those elements that can be changed easily, b) those that can change with more effort, and c) those that cannot change. In this manner the CEWG can identify potential areas of improvement and establish a plan of action. This step is the focus of Section III, which provides practical recommendations to help determine and implement modifications.

*Table 1: 4-Step Process of Crew Endurance Working Group to determine crew endurance management system.*

Step 1	Review crew endurance management information.
Step 2	Identify endurance risk factors.
Step 3	Identify elements affecting endurance during shipping operations.
Step 4	Analyze relationships between elements; determine modifications.

Figure 2 on the following page shows an example of results produced by a CEWG during their analysis of a commercial maritime environment. This particular example does not include all elements that may be relevant to maritime environments, but it does include some basic common basic ones. Figure 2 can be used as a template for CEWG members beginning the analysis of their particular system.

*Example of CEWG Results*



**Figure 2.** Example of the system of elements that may impact endurance in shipping operations. A single circle indicates mission objectives, unchangeable elements. A double circle indicates individual actions, elements that an individual or group can modify. A triple circle indicates management support, elements that may be changed through negotiations. A quadruple circle indicates environmental factors. Arrows indicate reciprocal or unidirectional relationships — bi-directional arrows indicate that the elements involved have reciprocal effects.

Once risk factors are identified, it is recommended that the CEWG use the specific information in Section II to identify specific organizational actions that will help to alleviate the impact of a specific endurance risk factor on crew member performance and safety.



**MANAGEMENT NUGGET:** The working group should employ the “Endurance Risk Assessment Form” to determine the actual incidence of endurance risk factors in the operational community and to discuss how elements of the system (e.g., watch or work schedules) impact endurance.

## **ENDURANCE RISK ASSESSMENT FORM**

The CREW ENDURANCE WORKING GROUP can determine the specific crew endurance risks by checking the boxes associated with risk factors that pertain to a department, ship, or company. Use this list to focus the search for solutions. Section II of this Guide provides specific suggestions on what to do in order to minimize the impact of these risk factors on crew endurance.

- ❑ 1. Insufficient daily sleep duration (less than 7-8 hours of *uninterrupted* sleep; see **Section II-3, II-21, and Appendix A**)
- ❑ 2. Poor sleep quality (awakening during the night due to work-related disruptions, ship motion, or noisy environment; see **Sections II-15, II-21, II-23, II-28, and Appendix A**)
- ❑ 3. Sleep fragmentation (daily rest periods are numerous but never 7-8 hours of uninterrupted sleep; see **Section II-23, and Appendix A**)
- ❑ 4. Sleep at wrong physiological times (human body naturally designed to sleep at night; see **Section II-24, and Appendix A**)
- ❑ 5. Changing work/rest schedules (rotations from day to night work-hours one or more times per week, see **Appendix A**)
- ❑ 6. Long work-hours (greater than 8-12 hours per 24 hours; see **Section II-27**)
- ❑ 7. No sleep recovery opportunities (napping during the day is not possible, see **Section II-21, and Appendix A**)
- ❑ 8. Poor diet (menu includes frequent fried foods, high fat and sugar content, frequent caffeine consumption; see **Section II-4, and II-29**)
- ❑ 9. High workload (high physical and/or mental effort requirements, see **Section II-17**)
- ❑ 10. High stress (induced by environment, workload, work-schedules, authoritarian leadership style; see **Section II-17**)
- ❑ 11. Lack of control over work environment or decisions (workers are isolated and not allowed to contribute in problem solving, see **Section II-17**)
- ❑ 12. Excessive exposure to extreme environmental conditions (cold, heat, high seas; see **Section II-7, II-11, and II-15**)
- ❑ 13. No opportunity for exercise (not enough time or no equipment/facilities; see **Section II-20**)
- ❑ 14. Isolation from family (need to know how family is doing; see **Section II-17**)

[This page left intentionally blank.]

## **SECTION II**

# **UNDERSTANDING AND MANAGING ENDURANCE RISK FACTORS**

[This page left intentionally blank.]

# Endurance and Energy



**FACT:** Energy comes from the Greek work *energia*, or “in-work,” and it refers to the capacity to do work.

Endurance is directly based on the amount of energy within the body. Therefore, it is important to understand how energy is produced, how it affects endurance, and how it can be increased or decreased in certain situations.

## WHAT ENERGY IS AND HOW IT IS PRODUCED

Energy is a molecule, called adenosine tri-phosphate (ATP), found in all cells of the body. Cellular energy-producing machines called mitochondria make ATP. The level of energy produced is dependent on good nutrition, adequate hydration (water intake), oxygen, and sufficient sleep.



**Insufficient Sleep = Insufficient ATP**



Studies of brain function have shown that seven to eight hours of continuous sleep are necessary to restore energy supplies and for the human brain and the body to function well. If the human body does not produce enough ATP, the brain and the nervous system cannot function efficiently. Research shows that people’s physical and mental abilities are significantly reduced when this happens. Under these conditions, people:

- Think less clearly
- Become irritable
- Have problems communicating with others
- Experience fatigue throughout work and leisure hours
- Become withdrawn and less willing to resolve issues and problems
- Have less ability to fight disease

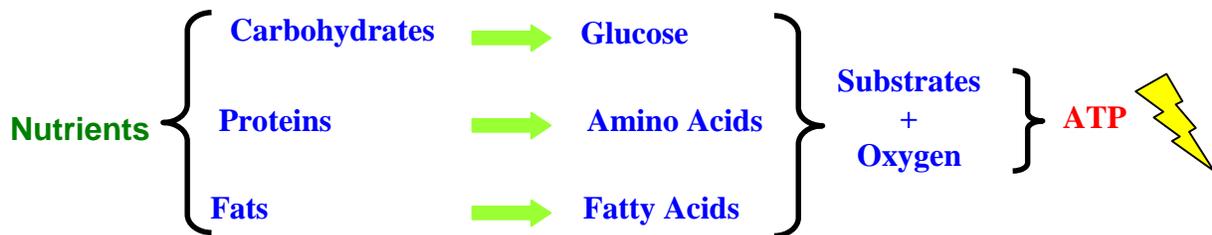
Unfortunately, ATP cannot be consumed as a dietary supplement. It must be produced within cells in the body. Regardless of how hard people might try to compensate for lack of energy, their ability to carry out both physical and mental tasks is simply reduced. This compromises their safety as well as the safety of those around them.



**WARNING! Be cautious of products that claim to boost energy resources. They provide dietary input to the energy producing machinery, but they do not produce energy. The only way to produce energy efficiently is through sufficient sleep, a balanced diet, and regular exercise.**

## HOW THE BODY TURNS FOOD INTO ENERGY

The digestive system breaks down food into carbohydrates, proteins, and fats. Digestive enzymes convert these compounds into glucose (or sugar), amino acids, and fatty acids. Cells throughout the body then process these compounds to make energy or ATP.



*Figure 3. Food is broken down into energy substrates.*

## WHEN ENERGY DEMANDS OUTWEIGH NORMAL ENERGY PRODUCTION

Chronic, or constant, stress and sleep disruption deplete energy resources and induce fatigue. This can be extremely damaging not only to crew members' health, but also to operational safety. To keep up with job demands, crew members might seek artificial ways to increase alertness. One very damaging threat in this situation is the recurring use of stimulant substances such as caffeine (found in sodas, coffee, and chocolate) and medications that increase alertness artificially (e.g., pseudoephedrine).



**WARNING! All medications containing pseudoephedrine warn against chronic use. In fact, most recommend discontinuation after three days of continuous use and always recommend physician supervision. Be sure to read the label to see if your medication contains pseudoephedrine.**

Caffeine is a stimulant drug. High doses of it can result in increased anxiety, lack of concentration, and digestive disorders. Frequent consumption of caffeine will also result in addiction and in the further draining of energy resources.

Other drugs used in the management and treatment of allergies or diet pills (e.g., those containing pseudoephedrine or ephedrine) can maintain alertness, but at a high cost if chronic use develops. These drugs are also addictive and marred with severe side effects.

There are positive ways to control energy at the individual level, though, without relying on caffeine or drug stimulants. A few basic ways are listed in the box on the following page.

### **Controlling Energy at the Individual Level**

- Exercise daily (e.g., any simple form of regular exercise helps: a 20-minute walk, running, weight lifting, 10-minute aerobic workouts, etc.)
- Consume a balanced diet (e.g., low sugar, low fat, low starch, high in green and yellow vegetables, high in chicken, turkey, and fish)
- Obtain sufficient sleep (7-8 hours of uninterrupted sleep daily)
- Manage stress (using relaxation methods to reduce stress at the individual level)

### **COMMON RISK FACTORS**

The remainder of Section II highlights common risk factors experienced in the maritime industry. These factors are responsible for decreasing a person's endurance level. It is therefore vitally important to recognize the hazards and understand how to control them. Each of these risk factors highlighted here includes a description of the factor itself, its consequences, and related endurance tips. More specific information on managing endurance at the individual and organizational levels is also provided in Appendix A.

- Cold-related illness
- Heat illness
- Motion sickness
- Stress
- Sleep and shiftwork
- Caffeine

# COLD-RELATED ILLNESS



**WARNING!** Winter months threaten crew members' health and endurance — working in unprotected deck areas exposed to the cold can result in extreme reduction of body temperature (hypothermia) and severe frostbite of hands and feet.



## RISK FACTOR

Everyone is at risk for a cold-related illness (the risk increases with age). Cool high winds, dampness, and cold water (all encountered on the weather decks) can cause cold-related illness. In these environments, crew members must be aware of a number of risk factors that will combine to threaten their health and endurance:

- Wet clothing
- Insufficient insulation of body, head, hands, and feet from wind, ocean spray, and cold temperature
- Use of medication that disrupts the body's ability to regulate core body temperature
- Physical exhaustion
- Prolonged work-related exposure to cold, windy, and wet environments allowing numbness of fingers and toes to set in



## CONSEQUENCES

- **Frostbite** (skin tissue freezes at 30° F). Fingers, cheeks, nose, and ears are most at risk. Symptoms include sensation of coldness, tingling, stinging, aching, and numbness. If left untreated, this condition can result in amputation or loss of function of the affected area. First aid requires treating tissue with warm water (102-110° F) as long as there is no chance for re-freezing tissue. Bed rest and medical attention must follow first aid.
- **Trench foot** (long exposure to wet and cold). This results in damage of the circulatory system. Symptoms include tingling, itching, swelling, and pain. If left untreated, this condition can result in death of skin tissue and ulceration. First aid requires moving crew members to a warm area, and treating the foot with warm water (102-110° F) or warm packs. Bed rest and medical attention must follow first aid.
- **Hypothermia**. Environmental air temperatures of 50° F and below, or water temperatures of 72° F and below, will cause persistent loss of body heat. Symptoms involve shivering uncontrollably, confusion, carelessness, and disorientation. Untreated this condition can result in death. First aid requires moving crewmember to warm and dry environment, removing wet clothing, offering warm nonalcoholic drinks, and using warm blankets to insulate body from further cold exposure. Bed rest and medical attention must follow first aid.



## ENDURANCE TIPS

### **Train crew members to:**

- Wear 3-layered warm clothing.
  - The outside layer should be a weatherproof, breathable barrier that breaks the effects of wind chill — Gortex and nylon materials are best.
  - The middle layer absorbs sweat, retains vital body heat, and insulates the body from the external cold — wool and synthetic-pile are recommended for this use.
  - The innermost layer must provide ventilation and the escape of perspiration, keeping the skin dry and wicking away moisture — synthetic fibers are best inner layer materials.
- Bring sufficient change of clothing to prevent working with wet garments.
- Keep the head covered at all times. Most body heat is lost when the head is unprotected from cold.
- Keep hands, feet, and face covered and warm. Fingers and hands can't function properly below 59° F.
- Keep feet well insulated from cold and dampness. Layered socks and insulated boots are a must.
- Keep garments clean. Soiled clothing loses its insulating properties.

### **Provide Crew members with:**

- A heated shelter
- Protected work areas
- Radiant heaters
- Thermal insulating materials placed over handles at environmental temperatures below 30° F
- Extra breaks for crew members exposed to cold environments (deck personnel)
- Reduced work pace
- Training session on how to endure cold-related risk factors

[This page left intentionally blank.]

# Heat Illness



## RISK FACTOR

Exposure to hot environmental temperatures is common on deck during the summer months. However, this exposure is always present in the engineering spaces. Dehydration and loss of minerals needed to maintain body functions become constant risks to crew endurance. Depending on the degree of severity, heat illness is classified as either heat exhaustion or heatstroke. Insufficient water intake, salt intake, and production of sweat cause heat exhaustion. Heatstroke will follow if the heat exhaustion is not quickly and properly treated. A person in heatstroke will stop sweating, have an extremely high body temperature, and potentially collapse from prolonged exposure to the environment's high temperature.



**WARNING!** Heat illness is caused by prolonged exposure to heat and insufficient water intake.



## CONSEQUENCES

The most noticeable outward signs of someone overexposed to heat are:

- Pale and clammy skin
- Fast and shallow breathing
- Rapid, but difficult to detect pulse

The physiological symptoms of heatstroke consist of the experience of several or all of the following:

- Intense thirst
- Hot and dry skin
- Dizziness
- Headache
- Fatigue
- No sweating
- High body temperature (above 98.6° F)
- Confusion
- Loss of consciousness



**WARNING!** Crew members suffering from any illness that result in fever, vomiting, or dehydration will be more vulnerable to heat illness.

Prolonged exposure to heat depletes the body of water and salt. Heat exhaustion is inevitable if crew members do not maintain an appropriate amount of water and salt intake during their exposure to extremely hot environmental temperatures. Continued exposure to hot environments will result in the breakdown of the body's ability to regulate core body temperature. Under these conditions, heat stroke will be induced when the body approaches temperatures of about 107° F.



**FACT:** Acclimatization, the process of adaptation to heat exposure, can be achieved by a minimum of sixty to ninety minutes of exercise or strenuous work in the heat each day for one to two weeks. Adaptation begins to occur within a few days.



## ENDURANCE TIPS

### How to Prevent Heat Illness

Train crew members to:

- Drink water often, and not wait until they are thirsty
- Drink extra water if they are sweating heavily (can't make sweat without water). Begin each work period by drinking approximately one pint of water. Water is best consumed in volumes of no more than ½ pint at a time
- Drink extra water if urination becomes less frequent than normal or if urine's color becomes darker
- Replace electrolytes with commercial sports drinks that contain 6% glucose and 10-25 mEq/L of sodium. Most commercial sports drinks contain these proportions. In most cases it is not necessary to replace electrolytes because enough salt can be obtained from regular meals and snacks
- Wear loose fitting clothes of light colors
- Seek well ventilated places
- Avoid the use of alcohol or drugs that may impair temperature regulation
- Adapt to heat exposure by working for sixty to ninety minutes per day in the heat environment



**WARNING!** Should a crew member exhibit heat illness symptoms, use a cold water bath or cold wet sheets to cool her/his body temperature. Seek medical advice immediately.

[This page left intentionally blank.]

# MOTION SICKNESS



## RISK FACTOR

Motion sickness is caused by an internal conflict in the brain created by external visual and movement stimulation. Standing on the ground, the brain senses the body's position (e.g., upright, upside down, or horizontal) relative to the ground. This sensory pattern becomes coded in memory (as a template) and it is updated constantly.



## CONSEQUENCES

Standing on a moving platform creates confusion, since the information stimulating the sensory systems does not match with the existing memory template. This mismatch creates a series of changes in physiology as the brain tries to create a new memory template. These changes are often experienced in terms of "cold sweats," fatigue, dizziness, headaches, yawning, nausea, and vomiting.

A new template eventually forms through constant exposure to the movement effects of sea states. Some people adapt quicker than others, getting "sea legs," sometimes after several days of misery suffering from motion sickness symptoms. However, some never do adapt sufficiently to feel well enough to work.



**WARNING!** Motion sickness induces fatigue and deteriorates performance. Crew members experiencing symptoms should sleep as much as possible, and walk around when able in order to help the brain speed up adaptation. Safety is at risk when crew members encounter motion sickness because fatigue and drowsiness are experienced until the brain adapts to the moving environment.



## ENDURANCE TIPS

Medications used to ease the symptoms of motion sickness or to prevent its onset usually have side effects that cause either severe drowsiness and/or fatigue. A list of medications and their side effects are provided below (see Table 2). It is recommended that crew members receiving medications to relieve the effects of motion sickness be warned that performance will definitely degrade. The captain, department head, or officer needs to keep in mind that crew members receiving medications should not be involved in tasks that may endanger their safety or that of other crew members. If at all possible, crew members receiving motion sickness medication or experiencing severe symptoms should avoid shipboard work environments. It is strongly recommended that the ship's medical officer closely supervise crew members using these medications. Self-administration is strongly discouraged.

*Table 2. List of medications commonly used to fight the symptoms of motion sickness. Note that Scopolamine is the only medication that may help speed the process of adaptation.*

MEDICATION	SIDE EFFECT	USE
Scopolamine Patch	Drowsiness Degrades vision	Speeds adaptation within 72 hours
Dramamine	Drowsiness	Reduces symptoms
Antivert	Drowsiness	Reduces symptoms
Phenergan	Drowsiness	Reduces symptoms
Amphetamines	High blood pressure Disrupts heart rate Addictive	Reduces drowsiness
Ephedrine	High blood pressure Disrupts heart rate Addictive	Reduces drowsiness

# STRESS



## RISK FACTOR

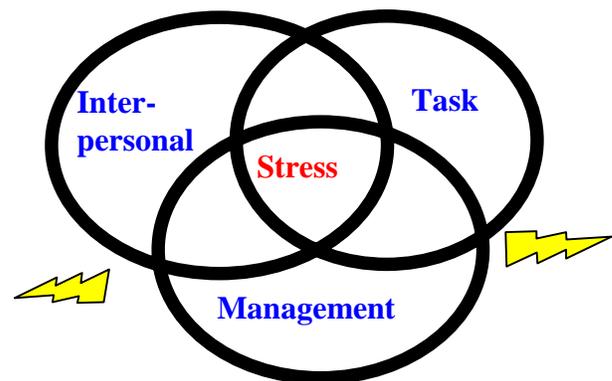
Chronic stress, the type of stress induced in work environments by the three factors outlined below (interpersonal relationships, task design, and management style), creates a constant drain on people's energy levels. Similar to a house that leaks heat during winter, stress turns crew members' bodies into energy-leaking homes, requiring more energy than what can be normally produced.

### Interpersonal relationships:

- Lack of support from coworkers and supervisors

### Task design:

- Heavy workload
- Infrequent rest breaks
- Long work-hours
- Shiftwork
- Hectic routine tasks
- Little sense of control



### Management style:

- Lack of participation by workers in decision making
- Poor communication between management and employees
- Lack of family friendly policies

These factors increase stress levels and cause physiological responses, such as increased heart and breathing rate, elevated blood pressure, etc., which uses up energy even during rest periods.



## CONSEQUENCES

Epinephrine (commonly referred to as adrenaline) is a hormone released during life threatening situations that provides the necessary energy to manage the threat. This hormone can be released during stressful situations, both in social and work environments. The presence of adrenaline in the body's various tissues temporarily increases the amount of energy available to the individual. This is a short-lived event — once energy is released it cannot be restored unless stress levels are reduced.



**FACT:** The body's response to any stress, life threatening or not, involves energy expenditure and disruption of energy-producing activities during rest periods. Even during sleep, stress simply robs us of needed energy by disrupting the quality and duration of sleep.

In a stressful work environment, crew members can be expected to have difficulty in enduring physical and mental challenges. They may experience frequent periods of reduced mental concentration and situational awareness — both undesirable states of mind in safety-sensitive jobs. The chronic use of over-the-counter pharmacological stimulants (e.g., caffeine and pseudoephedrine) can result in decreased attention, irritability, and adverse health effects.

Therefore, the implementation of stress management is a must-do for effective endurance management. This is particularly relevant in shipping vessels where crew members work for three months at a time with little or no opportunity to break away from work related duties. Under these conditions, work related factors such as interpersonal relationships, task design, and management style (previously outlined) can easily induce chronic stress if not adequately managed.



## **ENDURANCE TIPS**

Stress reduction and morale boosters can add up to a big pay-off for a relatively small investment. For instance, one towing company implementing an endurance management plan found that installing satellite television and making cell phone time (e.g., 30 minutes weekly) available to all crew members were consistent morale boosters. Although cell phones on oil tankers may not be used freely in port due to safety procedures, there are practical and worthwhile alternatives. Coordinating the use of a phone landline, a cell phone when possible, or providing Internet access may easily boost morale as crew members realize the company's genuine interest in their mental and emotional well being. It can also help crew members communicate more with their families, and reduce crew members' time waiting in line for a port's public phone.

Captains, department heads, and officers can contribute to the control of stress related risk factors by implementing a consistent stress management program. The following recommendations provide a well-rounded list of ways to reduce stress.

## WAYS TO REDUCE STRESS

- Train employees new to their job situation, particularly those recently promoted, to implement:
  - Time management strategies
  - A regular exercise program
  - Relaxation exercises (needed to reduce anxiety, increase concentration, and optimize quality of rest periods)
- Promote crew participation in problem solving. Always use a team approach to solve problems. The process of participation reduces the feeling of alienation and promotes feelings of self-worth. It allows individual crew members to become part of a network.
- Identify and reduce stressful factors, particularly those involving interpersonal relationships.
- Maintain good communication with crew members realizing that alienation, withdrawal, and lack of participation are signs of stress.
- Provide access to stress-reducing activities:
  - Have a variety of exercise equipment (e.g., free weights, a stationary bicycle, a rowing machine)
  - Allow good quality exercise equipment on board
  - Implement a nap policy during long work days
  - Provide satellite television for sports viewing
  - Provide consistent mental and physical health counseling
- Modify the daily menu so that meals are balanced and offer plenty of fresh vegetables, fruits, whole wheat bread, and low fat meats such as turkey, fish, and chicken. It is best to consume proteins, carbohydrates, and unsaturated fat and let the body break down food into glucose, amino acids, and fatty acids (*see energy explanation in beginning of Section II*).
- Provide a variety of nonalcoholic drinks and avoid the use of extremely sweetened soft drinks. Fresh water and fresh fruit juices are the best drinks for people.

# SLEEP & SHIFTWORK



## RISK FACTOR

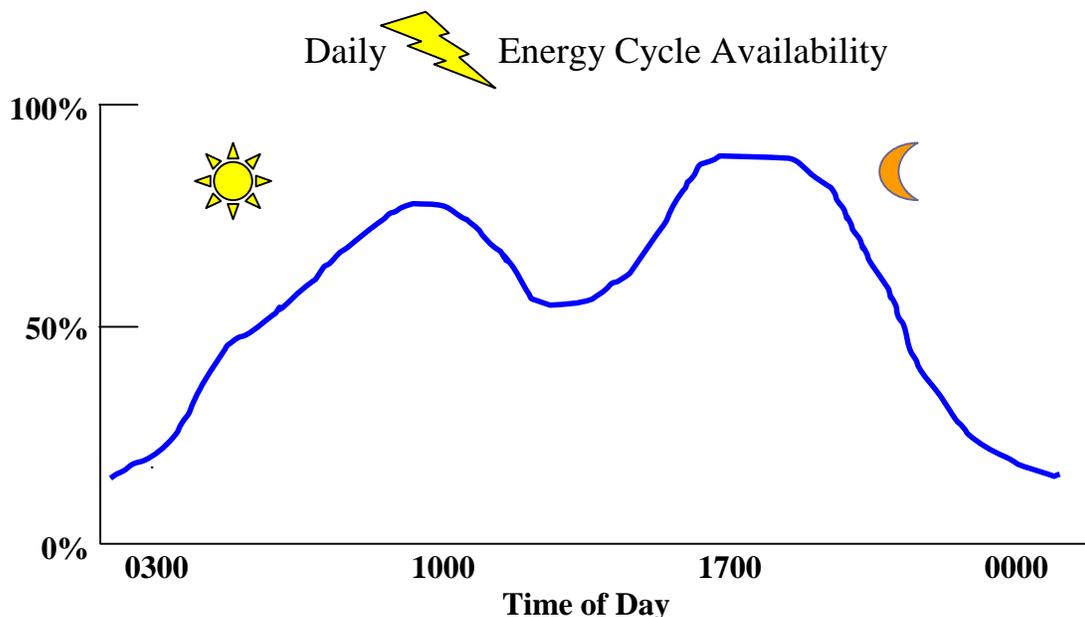
The human brain requires approximately **seven to eight hours** of uninterrupted sleep daily to replenish mental and physiological resources (see Appendix A for details). During sleep, the brain fluctuates among periods of light, deep, and dream sleep. These fluctuations are periodic, organized, and require approximately 90-120 minutes to complete each cycle. These cycles are repeated throughout the night. Any interruption of this process due to noise, bright lights, or movement, interrupts this sequence, causing the brain to spend more time in light sleep. Sleep disruption reduces the effectiveness of energy restorative processes and it results, inevitably, in degraded mental and physical capability upon awakening.



**WARNING!** Energy is stored optimally during uninterrupted sleep periods of seven to eight hours in duration on comfortable mattresses, in dark and quiet rooms, at environmental temperatures between 65-70° F, and humidity levels between 60-70%.

## Biological Clock

Optimally, sleep must take place during a period of time established by the human internal biological clock. The clock is a physiological mechanism composed of neural networks and hormonal outputs that regulates the timing of sleep onset and wake-up, as well as the availability of energy resources (see Appendix A for details). The body's clock system maintains a sleep/wake schedule in synchronization with local sunrise and sunset, along with the duration of daylight hours. Because the human body is naturally inclined to sleep during the night and spend energy during daylight hours, the biological clock reflects this cycle. The biological clock regulates energy cycles so that alertness increases after wake-up time, peaks in the mid-morning hours, dips in the afternoon hours, peaks again in the early evening hours, and begins to decrease in the early night, reaching all time lows in the middle of the night (Figure 4 below). The exact times of these peaks and valleys depend on specific inputs to the biological clock system, namely wake-up times, bedtimes, and daily time of daylight (and/or artificial bright light) exposure.



**Figure 4.** Daily energy cycle as a function of time of day. Energy cycles and alertness increases after wake-up time, peaks in the mid-morning hours, dips in the afternoon hours, peaks again in the early evening hours, and begins to decrease in the early night, reaching all time lows in the middle of the night.



**FACT:** Personnel exposed to regular work schedules, allowing consistency from day-to-day, enjoy the benefits of a well-adapted biological clock. This allows daily energy restorative cycles to take place on a regular basis.



## CONSEQUENCES

### Work Schedules

Work schedules that impose frequent changes from daytime to nighttime duty hours, and long duration shifts that are greater than 12 hours in a 24-hour period, disrupt energy restorative processes and induce fatigue. Disruption in the daily adjustment of the biological clock can also add to the degradation of alertness and performance. For instance, if a person wakes up at 0600 five consecutive days for work, the body will adjust itself to wake up at that time. Sleeping in much later on the weekend will send conflicting signals to the biological clock, because the body is now sleeping past the “internally set” wake up time. The clock then begins to adjust to the later wake up time, thereby causing difficulty waking up at 0600 when the workweek begins again. These changes in the body’s timing mechanism affect the normal regulation of physiological functions such as core body temperature, cellular metabolism, and production and release of hormones and neurotransmitters.

In general, the biological clock system requires approximately two to three days to fully adjust to a new input, such as a two-hour advance in daylight exposure time due to earlier wake-up times. This readjustment will take place more easily if the new sleep/wake schedule is consistent from day to day. However, if the inputs are inconsistent, the clock’s timing can become disorganized in such a way that previously mentioned physiological functions under its control will no longer occur in a predictable pattern.



**FACT:** Inconsistent inputs to the body clock can result in:

- Sleepiness during work hours
- Paradoxical feelings of fatigue, “feeling too tired to rest”
- Lack of mental clarity
- Degraded physical ability

Inconsistent inputs to the biological clock are common when personnel work nighttime shifts. For instance, a watch schedule prescribing a six-hour watch during the night (e.g., beginning at 2400) then two hours of time off (from 0600-0800), followed by a two-hour watch beginning at approximately 0800, can result in jet lag like symptoms. In this particular work schedule, if personnel work under normal lighting (e.g., engineering) or in dim light environments (e.g., bridge), exposure to daylight after sunrise will set the biological clock in a daytime orientation. Rather than falling asleep after the nighttime shift, this exposure will signal the body that it is daytime and therefore time to be awake.



**WARNING!** Inconsistent inputs to the biological clock are common when personnel work during nighttime or early morning duty hours. When night vision is required during the night watch, schedules that expose crew members to daylight after sunrise will result in inevitable degradation of sleep during the day and of performance during the night.

Personnel accustomed to waking up and seeing daylight at approximately the same time of the day (e.g., 0700) will be more likely to work during daylight duty hours and sleep during nighttime hours. Their biological clock will be day-oriented, thus synchronized to provide energy and cognitive resources during daylight and evening hours. As pictured in Figure 4 earlier, two peaks of alertness and energy availability will take place throughout the day — one in the morning and one in the early evening — with dips in energy and alertness immediately upon awakening, sometime in the mid-afternoon, and prior to sleep between sunset and bedtime. This pattern of energy availability will be maintained consistently if

personnel obtain good quality sleep during rest periods (uninterrupted sleep in quiet and dark environments) daily for seven to eight hours.

Interrupted sleep and reductions in duration for less than seven to eight hours per day will result in the accumulation of daily sleep debt. The consequences of this debt will be first experienced in the degradation of alertness, decision-making ability, and performance of mental functions requiring logical ability. Persistent sleep debt throughout a week will result in increased daytime sleepiness and degradation in performance.

## **Shiftwork Maladaptation**

Adaptation to nighttime or daytime work requires the synchronization of physiological and cognitive resources with the biological clock. Maladaptation results from the inability to adjust the clock to the watch schedule. To adapt the clock, crew members must see daylight (or bright artificial light, 2,000 lux or more) on awakening and throughout their active periods (e.g., during work-hours). Light management is a critical need in the process of adaptation to watch schedules.



**MANAGEMENT NUGGET:** The only way to fully adapt to night watch schedules is to reset the biological clock so that energy peaks during nighttime. Work must take place under artificial bright lights (approximately 2000 lux or greater) mimicking the effects of daylight. Sleep must take place in a dark and noise-free environment for approximately seven to eight hours. Lacking control of daylight and/or light exposure is a significant contributor to the induction of fatigue and shiftwork maladaptation.

Maladaptation to shiftwork schedules and lack of energy-restorative sleep can result in persistent fatigue symptoms (e.g., sleepiness, low energy, lack of motivation, depression), performance degradation during duty hours, and reduced safety. Other health effects such as increased incidence of cardiovascular disease, gastrointestinal disorders, and sleep disorders have been historically documented in populations exposed to shiftwork maladaptation. The combined effects of disrupted sleep (less than seven to eight hours) and biological clock disorganization can lead to fatigue, jet lag like symptoms, irritability, depression, and sometimes psychosis.



## ENDURANCE TIPS

Optimizing crew rest, and the prevention of inadequate adjustment to shiftwork schedules (or shift lag), can contribute significantly to the crew members' adaptation to work and life aboard ship. Listed below are some critical recommendations that, if implemented, will prevent watch schedules from inducing short and disrupted sleep periods and shift lag.



**MANAGEMENT NUGGET:** Avoid allowing personnel to work more than 12 hours in a given 24-hour day. Count the 24 hours beginning from crew members' wake-up time from their normal daily and longest sleep period (not naps).

### Total Adaptation to Night Work

- Provide bright light exposure (e.g., cold fluorescent bulbs of at least 2000 lux) during the work period (see Section A-11). This can be accomplished in environments where night vision is not required to perform duties (e.g., engineering). However, bridge personnel, for instance, can only achieve partial night work adaptation (see Section II-28).
- Provide nighttime personnel with small size meals that promote energy and alertness (e.g., high protein, low fat, low sugar, low starch, no dairy products, no turkey).
- Adjust meal times so that Midnight watch personnel can eat a brunch on awakening (approximately 1300), including brewed coffee and breakfast foods if desired.
- Adapt the mess services to serve crew members' needs. This effort supports both safety and crew morale.

## Partial Adaptation to Night Watch or Work Schedules

When bright lights can not be used in the work environment, follow the following recommendations:

- Reduce the duration of the watch (e.g., three-four hours) to minimize the impact of fatigue on safety. Promote exercise in the evening hours.
- Allow crew members in the mid-0400 watch (or any other night watch that ends in the morning hours) to retire prior to sunrise and sleep a solid block of time that allows them to achieve at least six to eight hours of sleep, free of noise and with absolutely no interruptions. It is critical not to allow interruptions to the long block of sleep. Overtime should be scheduled to occur after wake-up time (e.g., from 1400-1800). Leisure time then takes place during the evening hours.
- A second approach to reduce fatigue in the Midnight watch is to allow one watch section to work most of the night by extending the watch duration to five or six hours (e.g., Mid-0600). For this to work, the night watchstanders must be allowed to retire prior to sunset and sleep six to eight uninterrupted hours in a dark and quiet environment with absolutely no interruptions. Allowing for one watch section to cover the entire night watch avoids the need to physiologically adapt other crew members to night work.
- These crew members must see daylight or sufficiently bright artificial light (e.g., at least 2000 lux) after they awake from their uninterrupted sleep period and throughout their work period. Exposure to daylight provides a critical input that facilitates the body clock's adjustment to the sleep/work schedule.



**FACT:** Daylight or sufficiently bright artificial light is the necessary input to set the body's biological clock.

# CAFFEINE



## RISK FACTOR

Caffeine is a stimulant drug. For caffeine to serve as an alertness boost, it must be consumed at low levels and only when needed.



## CONSEQUENCES

High doses of caffeine can result in increased anxiety, lack of concentration, and digestive disorders. Some people develop a greater sensitivity to caffeine and experience these symptoms even at low doses. Unfortunately, frequent consumption of caffeine will result in addiction and in the further draining of energy resources.



## ENDURANCE TIPS

Caffeine should be used sparingly and avoided within four hours of bedtime. It can be used as a stimulant, only when necessary, to boost alertness. This means withdrawing from daily use. The withdrawal process may last two weeks, and can include headaches, attention deficit, fatigue, and lack of motivation. Sleep patterns should begin to improve within this period, but energetic alertness after awakening may not be restored until the withdrawal process is complete. If withdrawal is not desirable, reducing the consumption of caffeine to one beverage (or substance such as chocolate) per day will also help. If caffeine is needed to maintain alertness during daytime hours, a physician should be consulted.

[This page left intentionally blank.]

## **SECTION III**

# **CREW ENDURANCE MANAGEMENT PRACTICAL RECOMMENDATIONS**

[This page left intentionally blank.]

## CONTROLLING ENDURANCE RISK FACTORS

As mentioned in Section I, the 4<sup>th</sup> and final step of the Crew Endurance Working Group is analyzing the relationships between crew endurance risk factor elements and determining modifications that may improve endurance (see Table 1 repeated below). These elements can be divided into three groups: a) those that can be changed easily, b) those that can change with more effort, and c) those that cannot change. Effective working groups look for small or inexpensive changes that yield the greatest benefits. Slow progressive modifications can be effective and less difficult to implement. Radical system changes are usually the most difficult to implement.

*Table 1: 4-Step Process of Crew Endurance Working Group to determine crew endurance management system.*

Step 1	Review crew endurance management information.
Step 2	Identify endurance risk factors.
Step 3	Identify elements affecting endurance during shipping operations.
Step 4	Analyze relationships between elements; determine modifications.

It is important to note that CEWG members must use the crew endurance information gathered in steps 1-3 to identify areas of improvement and avoid using the crew endurance process to advance their own agendas. Thus, it is necessary to choose a group leader respected by all stakeholders and capable of guiding the group dynamics away from individual agendas.



**MANAGEMENT NUGGETS:** Effective Crew Endurance Management requires the development of work and rest management plans that optimize alertness and performance during duty hours. This goal is accomplished by:

- Forming a ship's working group to coordinate training, documenting crew rest during the implementation of new work schedules, and supporting the overall implementation of crew endurance practices
- Providing information to ship's department heads on how to design and implement work schedules that both meet the operational objectives of the vessel and do not result in inadequate adjustment to changing schedules
- Providing information to crew members on how to maximize the benefits of rest opportunities (refer to both Section II and Appendix A)
- Implementing crew rest test protocols that document: 1) the timing and number of rest opportunities and environmental conditions made available for crew members, and 2) crew members efficiency in taking advantage of rest opportunities (refer to Phases I-III below).

Determining which modifications are best to implement requires an evaluation. During this evaluation (divided into three phases), the CEWG can review current work policies on rest and see how the planned modifications will impact them.

### **Phase I: Initial Evaluation**

The process of controlling endurance risk factors requires an initial evaluation of the impact of the ship or company's current work policies on crew rest. This evaluation must be conducted during at least a 15-30 day period to properly document duty hours, workload, and crew rest associated with periods of low and high workload. Depending on the

geographical location, workload may be directly affected by seasonal changes; thus, some evaluations must be conducted during both winter and summer seasons. This evaluation provides an opportunity to obtain information on the impact of work schedules, work-hours, and operational requirements on crew rest and stress levels. The CEWG uses the results of this evaluation to identify elements of the system that may need adjustment.



**WARNING!** Successful working groups avoid personal or organizational agendas and seek improvement of policies and crew management practices that will help crew members maintain endurance.

Upon completion of the Phase I evaluation analysis, the working group must decide a course of action. The process requires dedication, cooperation, and self-discipline. Unfortunately, working group members that hold on to their individual agendas add to existing problems and obstruct progress. If agendas cannot be left for labor negotiations, then the process of crew endurance management cannot succeed. In cases where agendas obstruct progress, it is recommended that the working group focus on identifying changes that all stakeholders can support, no matter how small. Actions that elicit unsolvable arguments must be considered “long-term projects.” Long-term projects may need to be transferred to labor negotiators. For such cases, negotiators will be able to discuss issues in light of the data produced during the Phase I evaluation.

## **Phase II: Implementation**

In addition to the formation of a CEWG, successful implementation of a crew endurance management plan requires an aggressive education program to instruct various personnel on its coordination and execution. Sleep and body clock management, as well as stress management, are some of the critical blocks of instruction necessary to make certain the CEWG members, management, and personnel at large share the same critical information. Coordination of a crew endurance plan requires all levels of an organization to share the responsibility for success. Once the education program is in place, the system modifications or crew endurance plan is implemented for at least two consecutive months.



**MANAGEMENT NUGGET:** The successful implementation of new operational policies to improve endurance requires the activation of an aggressive education program. It must be designed to instruct company managers, ship captains, department heads, officers and crew personnel on their contribution to the coordination and execution of the various elements of the new endurance management plan.

### **Phase III: Follow-up Evaluation**

The third phase requires an additional crew endurance evaluation during the implementation of the crew endurance plan. As was the case with Phase I, the Phase III evaluation must be conducted over a long period of time (approximately 30 days). As many as sixty days may be required in some environments depending on how frequent high workloads are experienced. It is critical to obtain information during high operational tempo to accurately determine the effectiveness of the crew endurance plan. Ultimately, the Phase I evaluation determines whether a crew endurance plan is needed or not, while the Phase III evaluation tests how well a newly developed crew endurance plan is working under real-world conditions.

In both Phase I and Phase III evaluations, it is necessary to objectively document the impact of watch, work, and training schedules on crew rest and stress levels. Wrist activity monitors, used since the early 1980s to document sleep in field conditions, are highly recommended for this purpose. These devices are the size of a large wristwatch, and provide accurate information on the quality and duration of the wearer's sleep. The U.S. Coast Guard Research and Development Center can provide access to these devices and data analysis reports to the CEWG. However, due to limitation on the number of devices available for field use, an electronic logbook or E-logbook is also highly recommended. The E-logbook can be used to document crew members' daily activities. The USCG R&DC is in the process of developing the E-logbook, which when fully operational, and tested, can be used in field research projects both in commercial maritime and Coast Guard work environments.

The data collected with these devices can be used to determine whether crew members' rest periods occur consistently and under environmental conditions that promote the restoration of alertness and physical energy from day to day. In addition, these data reveal how well personnel take advantage of rest periods provided by the ship's crew endurance plan. Methods to test the effectiveness of crew endurance plans are provided in several reports published by the R&DC; a list of these reports is provided in Appendix C.

Phase III data results will provide the CEWG with objective information on crew rest and stress levels during the two-month implementation period. These observations can help determine the need for further modifications to the crew endurance system. Samples of Phase III efficacy tests conducted on board two oil tankers are provided in Appendix B. Figures B-1 and B-2 illustrate daily sleep duration recorded from deck and engineering crew members standing a six-hour night watch period. Management staff implemented the "alternate" watch schedule that prescribes two watch periods, one of six hours in duration and the other of two hours in duration. Data are also shown for crew members standing daytime "alternate watch" schedules (Figures B-3 and B-4). All crew members were wearing wrist activity monitors provided by the USCG R&D Center throughout a period of approximately 30 days of testing. Note that sleep duration values fell within acceptable levels most of the time (6-8 hours).

These data provided objective evidence that the "alternate" watch schedule, adopted by both ships, provided sufficient time off for crew members to establish a regular sleep schedule, even if they were standing watch during the night. One common element to both ships, namely the shipping route, made it possible for the "alternate" watch schedule to succeed. Routes that are consistent from one voyage to another and consist of at least four to five days underway with brief port-calls make it possible for sleep and overtime (OT) work hours to occur consistently from day to day.

In contrast, implementation of the "alternate" watch schedule aboard a third vessel was not possible due to long in-port duration periods, requiring frequent movements to different gates and unpredictable voyage duration from one port to another. When underway and in-port periods are inconsistent from day to day, crew members can't optimize sleep periods

under the “alternate” watch schedule. In these cases, overtime work hours occur at unpredictable times of the day and disrupt rest periods. Crew members consistently interrupted sleep periods to take advantage of OT work (Figures B-5 and B-6).

In these cases, the use of a “standard” watch schedule prescribing four hours on watch, eight hours off watch, and four more hours on watch resulted in shorter and more frequent opportunities to work throughout the day. It should be noted that crew members remained on the same watch schedule for at least two weeks or more. Crew members could choose to work OT during the 4 hours off between watch periods or at the end of the second watch. These choices left one period of eight hours off undisturbed. Crew members took advantage of this eight-hour period to obtain at least six hours of uninterrupted sleep. Aboard the third oil tanker, crew members, working under the “standard” watch schedule, tended to obtain six hours of sleep as long as they participated in the crew endurance plan. When frequent product loading and off-loading occurred during long duration in-port periods, the shorter period of time off (provided in the standard watch schedule) was less likely to be interrupted. The sleep period became more consistent under the standard schedule because time off duration was shorter than in the “alternate” watch schedule. Less time-off demanded better personal organization and more discipline, and also guaranteed a four-hour OT period during the workday.

In general, crew members aboard vessel three were less likely to thrive under the “alternate” schedule due to the long in-port periods and heavy workloads and to crew members’ preference of shorter duration off-periods. The use of the standard schedule was well received and resulted in longer sleep periods.

This type of information is of great value to CEWG members because it helps to identify endurance risk factors, both of organizational and operational origin. The analysis of risk factors is necessary to develop crew endurance plans for specific real-world operational conditions (one size does not fit all). As critical risk factors are identified, the CEWG can develop plans to control their impact on safety. For instance, some of the controls applicable to Deep Draft vessel operations read as follows:

- Encourage department chiefs to manage OT work ensuring that all crew members will have the opportunity to work OT without disrupting their rest periods
- Implement the “alternate” watch schedule during the underway period
- Revert to the “standard” watch schedule during frequent and long duration in-port periods
- Train crew members to take advantage of rest opportunities under both the “alternate” and the “standard” watch schedules
- Identify operations that prevent crew members from obtaining at least six hours of sleep per day and develop plans to reduce the total number of days of exposure to those conditions

As a matter of good crew endurance management practice, it is recommended that the CEWG maintain an active education program for crew members and ensure that crew endurance evaluations occur on, at least, a semi annual basis.

## **SUMMARY OF CREW ENDURANCE MANAGEMENT PROCESS**

The consistent use of the CEM process allows company and ship management staff as well as crew members to use objective methods to constantly improve the work plan, safety, and personnel endurance. This system does not prescribe specific schedules, but it provides a process to maintain endurance, prevent fatigue and burnout, and contribute to enhanced safety of overall operations. CEWG members can become champions of the endurance plan aboard deep draft vessels and contribute to the maintenance of crew endurance industry-wide. The implementation of CEM practices can help companies' and ships' crews enhance their current efforts towards maintaining high levels of crew endurance and safety. Further information on equipment, development, and implementation of crew endurance plans can be obtained by contacting Crew Endurance Team members at U.S. Coast Guard Headquarters' Human Element and Ship Design Division (202-267-2997), or the U.S. Coast Guard Research and Development Center in Groton, CT (860-441-2600).

## ***APPENDIX A***

---

### **Sleep Management and Circadian Rhythms**

[This page left intentionally blank.]

## A-1

# SLEEP MANAGEMENT

### Sleep cycles

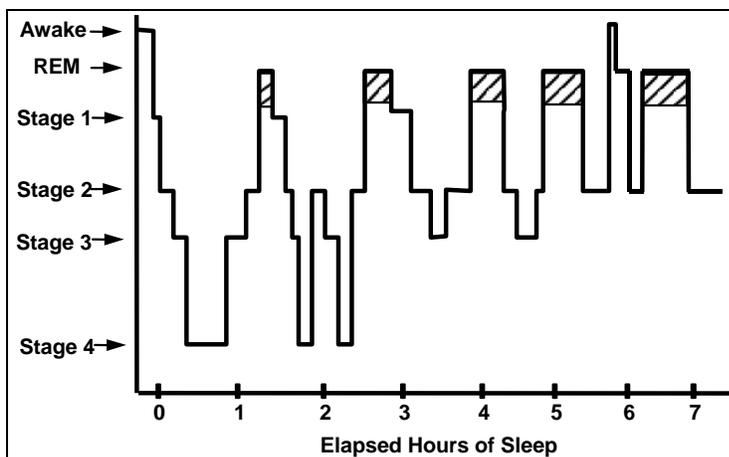
Sleep is an active process, with a defined cycle of activity that progresses predictably throughout the sleep period (see figure A-1 below). The brain activity that occurs during sleep is measured in five stages:

**Stage 1** is the transition from wake to sleep. This stage is characterized by a slowing of brain activity (compared to wakefulness). When aroused from this stage, many people believe they were never asleep. After about five to ten minutes of stage 1 sleep, the person progresses to a deeper sleep, stage 2.

**Stage 2** is characterized by even slower brain activity than stage 1 and is considered by many to be the true beginning of sleep. Within ten to 15 minutes, brain activity slows down even further and progresses into the deepest sleep, stages 3 and 4.

**Stages 3 and 4** are termed slow-wave sleep (SWS). It may be very difficult to arouse a person from SWS, and once awake, the person may feel sluggish for several minutes. After 20 to 30 minutes of slow-wave sleep, brain activity reverts briefly back to stage 2 sleep, and is then followed by rapid eye movement (REM) sleep, or dream sleep.

**Stage 5**, REM or dream sleep, is characterized by quick eye movements, little to no muscle tone, and very active brain patterns. The first REM period of the night is relatively short, lasting five to ten minutes.



*Figure A-1: Sleep Cycle*

After REM sleep, the sleep cycle repeats itself, returning to stages 2, 3, 4, and back to REM. Each cycle lasts approximately 90 minutes, with approximately five to six cycles occurring per night. Most SWS occurs during the first half of the sleep period, while most REM sleep occurs during the second half of the period. Overall, stage 2 sleep occupies the majority of the sleep period, followed by REM sleep, and then SWS. This cycle of sleep activity is important for personnel to

acquire restful sleep. The cycle can be disrupted by schedule changes, frequent awakenings, medications, and so forth. When a significant disruption in this pattern occurs, personnel may not obtain restful sleep and will be fatigued the next day.

## **Everyday Sleep Management**

Many times the ability to achieve good quality sleep depends on good sleep habits. It is unwise to become dependent on sleep medications for a variety of reasons, and when one adheres to some common sense behavioral strategies for sleep, sleep aids may not be necessary except in extreme situations. Leaders and personnel should be aware of the following factors that can affect ability to sleep and the quality of sleep achieved.

### **Planning for sleep**

- The amount of sleep each person needs varies; one cannot determine individual sleep needs from what other people require.
- If a sleep aid was taken previously, the first and possibly the second night of sleep without medication may be disrupted. Falling asleep may be delayed, and the person may awaken several times during the night. However, this will subside within one to two nights.
- Try to sleep at the same time every day, including weekends. If possible, go to bed at the same time and get up at the same time each day.
- Alcohol should never be used to aid sleep. Although sleep onset may come more quickly after ingestion of alcohol, it is more disrupted and less restful after the first one to two hours of sleep.
- Avoid eating or drinking substances that contain caffeine (coffee, tea, and chocolate) four to five hours before bedtime.
- Do physical training no closer than one hour before bedtime since exercise has a temporary alerting effect.

### **Good sleep habits**

- When trying to sleep outside the usual sleep period (e.g., during the day), prepare as if it is the normal sleep period — wear normal sleep clothes, darken the room as much as possible, keep noise to a minimum, and use a white-noise generator, such as a fan, if possible.
- Use bed only as a place to sleep; do not read, work, or do other similar activities in bed. Associating bed with sleep will eventually allow sleep to come more easily.
- After 24 to 48 hours of sleep deprivation, do not sleep overly long during the recovery period (more than ten hours). Sleeping too long may interfere with the normal sleep/wake schedule and will cause significant sleep inertia and lethargy during the day. The normal sleep period for an individual is usually sufficient to recover from 24 hours of sleep deprivation.

## **Problems with sleep**

- If you cannot fall asleep after about 30 minutes in bed, do not remain in bed awake; get up to avoid associations of waking and anxiety with bed. Stay up several minutes and then try again. Continue to get up if you cannot go to sleep within 30 minutes, no matter how many times this may occur during the sleep period. Eventually, fatigue will take over.

A person who has difficulty sleeping during the normal sleep period should not nap during the day; this may delay sleep onset.

[This page left intentionally blank.]

## A-II

### NAPPING

If the pace of operations or the available staffing level permits, naps can be used to sustain performance during the continuous work period. During this time, leaders should encourage napping; allow time and provide a quiet, comfortable place for short naps as the mission permits; educate personnel about the benefits of napping; and inform them that rest is no substitute for sleep. Napping during continuous operations will reduce performance impairment but will not totally alleviate effects of sleep deprivation. Individual differences in sleep needs must be considered in determining nap length. Several factors are important to consider when scheduling naps:

#### **Pre-existing amount of sleep loss**

- The best time to nap is before significant sleep loss has occurred — such preventive naps will help stop subsequent performance impairment during continuous work schedules. Personnel who nap for one to four hours prior to a night work period will show improved subsequent early morning performance and alertness above those who do not nap. Preventive napping may be better than a nap during the sleep-deprivation period.
- Naps do not totally eliminate the normal circadian dip experienced in the early morning around 0500, but the degradation in both cognitive performance and alertness is reduced.

#### **Nap length**

- A single two-hour nap during a 24-hour continuous work period can rest the individual and cause performance to be close to pre-sleep-loss levels.
- If longer naps are not possible, several naps of as little as ten minutes each taken over a 24-hour period can help personnel endure continuous operations.

#### **Timing of the nap**

- It will be easier for personnel to nap when core body temperature is at its lowest (around 0300 and 1300) and more difficult when at its highest (around 1500).
- Post-nap sleepiness is higher and performance lower for several hours when a person is awakened from a nap during the circadian dip as compared to awakening from a nap taken during the circadian peak.
- Early morning naps (0200 to 0600) are beneficial in restoring alertness and performance, but time should be allowed for personnel to fully recover from the nap.

### **Length of time between end of nap and work period**

- Performance is generally lowest during the first five minutes after awakening (sleep inertia), but usually recovers after 15 to 30 minutes.
- Extensive sleep inertia is especially likely when one is awakened from slow-wave sleep, which occurs most often within the first two hours of sleep.
- Awakening from sleep that follows a long period of sleep deprivation leads to high levels of sleep inertia; the longer the sleep-deprivation period, the higher the sleep inertia.

During continuous operations when a person must return to work immediately upon awakening, naps in the circadian dip should be avoided because sleep inertia will be high.

## A-III

### CIRCADIAN RHYTHMS

#### Physiology

A day-oriented body clock controls specific patterns of hormones, alertness and core body temperature. The word circadian (Latin: circa = about; dies = day) is used to describe biological and behavioral rhythms regulated by the body clock.

As a person transitions from daytime to nighttime work, the body clock provides mental and physical energy during the day, but not during the night. This energy cycle will be stable and predictable only if the body clock receives daylight exposure at consistent times from day to day. Scientific research has demonstrated that mental alertness follows a 24-hour cycle which mirrors core body temperature and is inversely related with melatonin levels. Melatonin is a hormone produced during the night that regulates sleep and the timing of the body clock.

#### Consequences of Desynchronization

Desynchronization refers to the disruption of synchronized physiological functions due to changing sleep and work routines or due to travel across time zones. Studies of the performance of night-shift workers and long-distance travelers show a consistent reduction in work effectiveness, and in some cases, safety. The following list summarizes a few specific work-related consequences due to jet lag (travel across time zones) or shift lag (shiftwork):

- Truck drivers have been shown to have twice as many accidents between 2400 and 0200 compared to during the day.
- Locomotive operators have an increased probability of missing warning signals when working the night shift.
- Night-shift workers perform worse on tasks of vigilance and reaction times when compared to day workers.
- Aviators flying in flight simulators at night have reduced hand-eye coordination, poorer vigilance and calculation proficiency, and impaired flight performance compared to day fliers.

#### Desynchronization Controls

The following list of recommendations should be helpful in the prevention of circadian desynchronization. Once shift lag or jet lag actually develops, returning to normal can take several weeks of a consistent sleep/wake schedule. Desynchronization symptoms are unlikely to disappear in just a few days of normal sleep. Individual crew members and staff personnel planning work and briefing schedules can use these general recommendations.

## **General recommendations**

- Maintain consistent schedules in the timing of sleep, wake-up, daylight exposure, and naps after arrival in the new time zone and/or shiftwork transitions.
- Avoid changing sleep/wake schedules during days off.
- Always sleep in completely darkened rooms. If sleep must occur under daylight, wear a black cloth sleep mask.
- Strive to sleep at least six continuous hours per day.
- Become aware of how many hours of sleep you need to feel refreshed and alert upon awakening. Short sleepers may need as little as five hours, long sleepers as many as eight hours.
- If after sleeping, you feel very sleepy during the afternoon hours, you need more sleep.
- Prevent noise from disrupting the sleep period. Use masking noise (e.g., the noise of a fan, a power generator, or commercially available sound-masking devices), or wear foam earplugs.
- Avoid meals of high-fat content for a least three days after the transition to the new location or work schedule. Gastrointestinal disorders can surface while readjusting to a new time zone and/or work schedule.

## **Napping and circadian desynchronization**

In the context of body-clock adjustment, naps are recommended for certain situations. Some of these are highlighted below.

- You rotate from day to night shift, cannot sleep more than four to five hours during the sleep period, and the next night is going to be another work period.
- Naps longer than one-two hours are not recommended if your next sleep period will take place during the following night. In this case, naps taken during the day may interfere with the onset and duration of that night's sleep.
- When rapid shift rotations are used, personnel should be encouraged to use naps during time off to compensate for sleep loss incurred during the transition to nighttime duty hours.
- When shifting from daytime to nighttime duty hours, opportunities for naps may occur:
  1. During the afternoon (e.g., 1500 to 1700 hours).
  2. In the evening prior to reporting (e.g., 1600 to 1900 hours) for the duty period (e.g., work period from 2100 to 0500 hours).

Research on the effects of the restorative value of naps indicates that:

- A two-hour nap taken in mid-afternoon (e.g., 1500 hours) results in greater restoration of alertness than a two-hour nap taken in the evening (e.g., 1900 hours).
- Naps taken during the mid-afternoon (1500 hours) contain more total dreaming time (REM sleep) than naps taken at 0300 hours.

- When transitioning from daytime to nighttime duty hours later that day, a nap at 1500 hours may well compensate for sleep loss incurred during the assigned sleep period.
- Naps taken in the afternoon may be more restorative than naps taken in the evening, before reporting for duty. Naps taken during the work period after midnight, however, may not only be less restorative than earlier naps, but may also induce sleepiness upon awakening and performance degradation for up to one hour. This consideration limits the value of a nap after midnight.

### **Pre-adaptation prior to travel across time zones**

Prior to travel, personnel can attempt to pre-adapt to the new work shift or destination time zone. While potentially useful, pre-adaptation requires much coordination and cooperation from all levels of the organization. In a pre-adaptation scenario, personnel typically begin shifting their sleep/wake cycle from their current time toward the new sleep/wake cycle several days before transition.

- The number of days devoted to pre-adaptation and the number of hours shifted daily will depend on many factors, including the number of time zones to be crossed and amount of advance notice received.
- The magnitude of the phase shift should not exceed six hours per day and preferably should range for two to four hours per day.
- Sufficient support must be provided to allow pre-adapting personnel access to finance and personnel services, properly timed meals, and so forth, or personnel will be unable to follow the adaptation schedule.
- Family members must be educated regarding the pre-adaptation plan so that they support the person's changing sleep/wake cycle.
- Under some circumstances, pre-adaptation is particularly difficult

### **Timed light exposure**

The timing of daylight exposure is critical for the resynchronization of the body's biological clock. By carefully scheduling exposure to daylight or proper artificial light, it is possible to speed adaptation to a new work schedule and/or time zone. Specific suggestions are included in the scenarios provided later in this appendix. However, the following general guidelines apply:

- Light levels of over 1000 lux (dawn brightness) are necessary to affect the body's timing mechanism. Exposures lasting at least one hour are effective in resynchronizing the sleep/wake cycle and other physiological rhythms.
- For individuals who are accustomed to sleeping during the night, working during the day and retiring during the night (e.g., 2200), daylight or sufficiently bright light exposure between 0300 and sunrise time will consistently advance sleep onset approximately one to three hours earlier per day. The time period between 0300 and sunrise time is referred to as the **advance body time zone** because light exposure in this period results in earlier wake-up times and

bedtimes. Predicting the exact amount of the advance requires information on physiological rhythms (e.g., core body temperature or melatonin production) that will be impractical to obtain in most applied field situations.

- In eastward travel, seeking daylight exposure during the advance body time zone (clock times calculated from the time zone that the traveler lived in prior to the trip) for the first three days will speed the resynchronization process. Daylight should be avoided between sunrise and 1100 local time (these clock times are calculated using the destination's time zone) for the first three consecutive days in the destination location. The advance zone will shift to earlier times from day to day, and it is difficult to accurately predict the time range after two days of advances without data on physiological rhythms. Therefore after the third day, daylight exposure should be coordinated to occur as soon after awakening as it was in the origination time zone.
- In westward travel, seeking daylight or bright light exposure between sunset time and 0300 (**delay body time zone**) will help delay sleep onset. The duration of the delay depends on the duration of light exposure. In most cases, exposure durations of one to three hours will result in significant delays of 1 hour or more, depending on individual differences.
- Artificial bright lights can be used to influence these changes in sleep prior to or during shift changes or travel, provided that the appropriate equipment is available. Bright light banks are available from commercial suppliers and appear to be effective. Providing a brightly-lit work area for night-shift workers may be of benefit.
- Wearing dark sunglasses may minimize unwanted exposure to daylight (see eastward travel). Very dark sunglasses may be ordered from commercial sources. If these are not available, conventional sunglasses should measurably reduce light exposure.

## **SHIFTWORK, SLEEP, AND BIOLOGICAL CLOCK MANAGEMENT**

### **Shiftwork maladaptation**

Optimizing crew rest and preventing physiological maladaptation to shiftwork can contribute significantly to one's ability to endure long-term exposure to harsh working conditions without compromising work performance and safety. Shiftwork maladaptation results from the inability to adapt human physiology to rapidly rotating cycles of sleep and work. Adaptation to nighttime or daytime work requires the adaptation of physiological and cognitive resources under the regulation of the human biological clock. The biological clock is a physiological mechanism composed of neural networks and hormonal outputs that regulate sleep and wakefulness cycles and the daily availability of energy and cognitive resources.

Maladaptation to shiftwork schedules and the lack of energy-restorative sleep result in a multitude of persistent symptoms such as:

- Low energy
- Lack of motivation
- Introversion
- Reduced and unclear communication with coworkers
- Apathy
- Reduced attention to detail
- Depression
- Performance degradation during duty hours
- Degraded endurance
- Reduced safety

Other health effects such as increased incidence of cardiovascular disease, gastrointestinal disorders, and sleep disorders have been historically documented in populations exposed to shiftwork maladaptation (Congressional report, 1991).

### **Physiological Consequences of Frequent Changes in Work Schedules**

#### **Inconsistent sleep and daylight exposure reduce safety**

Personnel accustomed to waking up and seeing daylight in the morning hours (e.g., approximately 0700) are adapted to work during daylight duty hours and sleep during nighttime hours. Their biological clock is day-oriented, thus adjusted to provide energy and cognitive resources during daylight and evening hours. Two peaks of alertness and energy availability will take place throughout the day, one in the morning and one in the early evening. Day-oriented personnel will normally experience reductions in energy and alertness immediately upon awakening, sometime in the mid-

afternoon and prior to sleep in late evening. This pattern of energy availability will be maintained consistently if personnel obtain good quality sleep (uninterrupted sleep in quiet and dark environments) daily for seven to eight hours.

However, should the sleep period become reduced to less than six hours per day and/or frequently interrupted by bright lights, noise, or movement, a daily sleep debt will begin to accumulate. The consequences of this debt will be first experienced in the degradation of:

- alertness,
- decision-making ability, and
- performance of mental function requiring logical ability.

Persistent sleep debt throughout a week will result in increased daytime sleepiness and degradation of performance in cognitive and psychomotor tasks. As performance fares so does safety.

In addition to sleep duration, the stability of the body's biological clock directly affects both alertness and performance. Frequent disruption in the daily adjustment of the biological clock adds to the deterioration of alertness and performance. For instance, working on the bridge under a watch schedule that requires waking-up at 0700 on Mondays, Wednesdays, and Fridays, but requires a 0330 wake-up time on Tuesdays, Thursdays, and Saturdays, will send conflicting signals to the biological clock, particularly during the summer. On the days that wake-up times are required at 0330, the clock will receive daylight exposure earlier than usual (approximately at 0500) resulting in an advance of wake up times and bedtimes. Conversely, on the days that the clock does not receive the early morning daylight dose, bedtimes and wake-up times will be allowed to slip to a later time. This advance of body time can be approximately one-half to one hour per day. These changes in the body's timing mechanism affect the alignment of daily peaks and troughs of other physiological rhythms such as core body temperature (usually high during daylight hours and low during nighttime), and production and release of hormones and neurotransmitters.

In general, the biological clock system requires approximately three days to re-adjust to a new input, such as a two-hour advance in daylight exposure time due to earlier wake-up times. This readjustment will take place if the new sleep/wake schedule is consistent from day to day. However, if the inputs are inconsistent, the clock's timing can become disorganized in such a way that the physiological rhythms under its control will no longer be expressed in a predictable pattern. The individual impact results in:

- sleepiness
- insomnia
- deterioration of performance in mental and motor tasks

Inconsistent inputs to the biological clock are common when personnel work nighttime shifts and do not control daylight exposure after the end of the shift. For

instance, a watch schedule prescribing a six-hour watch during the night (e.g., beginning at 2400) then six hours of time off (from 0600-1200), followed by a six-hour watch beginning at approximately 1200, can result in jet lag-like symptoms. In this particular work schedule, if personnel work under normal lighting (e.g., engineering) or in dim light environments (e.g., the bridge at night), exposure to daylight after sunrise will set the biological clock in a daytime orientation. In a daytime orientation, the biological clock predisposes the brain and energy cycles for sleep, and not work, during nighttime. Fatigue induced deterioration of performance will occur during nighttime hours.

### **Shiftwork maladaptation prevention**

Optimally, sleep must take place during a time of day scheduled by the internal biological clock. This clock system (details in next section) regulates the timing of sleep onset and wake-up times. Due to evolutionary pressures and physiological characteristics, the human body is predisposed to work during daylight hours and sleep during nighttime hours. The body's clock system maintains a sleep/wake schedule in synchronization with local sunrise and sunset and the duration of daylight hours. Energy cycles regulate the experience of high and low levels of alertness throughout the day. Alertness peaks in the mid-morning hours, dips in the afternoon hours, peaks again in the early evening hours, and begins to decrease in the early night reaching all time lows in the middle of the night. The exact times of these peaks and valleys depend on specific inputs to the biological clock system, namely wake-up times, bedtimes, meal times, and more importantly the time of daily daylight exposure (and/or artificial bright light).

Personnel exposed to regular work schedules that allow for consistency from day to day will enjoy the benefits of a well-synchronized biological clock. This allows daily energy restorative cycles to take place regularly and for the experience of predictable alertness peaks and troughs. In contrast, work schedules that impose frequent transitions from daytime to nighttime duty hours disrupt energy restorative processes and induce fatigue.

The adjustment of the biological clock requires the implementation of a specific schedule of daylight, and/or bright artificial light exposure, as well as the maintenance of a consistent sleep schedule. One way to minimize fatigue during nighttime work is to reverse the biological clock's synchronization from daytime to nighttime orientation. For the clock's timing to reset energy resources to peak during nighttime, work must take place under bright lights (approximately 1000 lux or more) mimicking the effects of daylight. Sleep must take place in a dark and noise free environment. Lacking control of daylight and/or bright light exposure times is a significant contributor to the induction of fatigue.

If the use of bright, artificial light is incompatible with the work environment (e.g., on the bridge of a cutter or the cockpit of a helicopter at night), a specific light and sleep management schedule can be designed to shift the biological clock towards a night

orientation. Professionals working in the fields of circadian rhythms and sleep management should develop these light and sleep management schedules. Experimentation with light exposure schedules can result in the induction of chronic fatigue and jet lag-like symptoms. It is recommended that organizations use consultants with proven experience in the implementation of sleep and light management plans in various work environments.

The synergistic effects of disrupted sleep (less than seven to eight hours) and biological clock disorganization can lead to fatigue, jet lag-like symptoms, and the exacerbation of psychological maladjustment symptoms such as irritability, depression, and sometimes psychosis. Other physiological symptoms associated with this condition include cardiovascular disease and gastrointestinal disorders.

## A-V

### NIGHT WATCH, DAYLIGHT, SLEEP, AND WORK MANAGEMENT

The purpose of this appendix is to recommend how to transition from a day to night and night to day work hours. It is assumed that prior to either day or to night duty, the crewmember has been working the same work hours for at least two weeks and is well adapted to that schedule. It is further assumed that bright lights cannot be used in the work environment while on night duty. (If bright lights *are* in use at night, then refer to Section II-27, *Total Adaptation to Night Work*)

The figures below suggest work-sleep-nap schedules to assist personnel during a transition to and from night watch schedules. Figure A-2 is for changing from a day schedule to a night schedule when the night schedule will cause your work period to end *after sunrise*. Figure A-3 is for changing from a day schedule to a night schedule when night work ends *before sunrise*. Figure A-4 shows how to transition from night duty back to daytime work.

Daylight exposure (or bright artificial light exposure of at least 1,000 lux) is a necessary input to set the body clock and keep it stable. These schedules show you when to seek daylight exposure and when to avoid it. The figures assume that sunrise is at 0500 and sunset is at 2000. Of course, the real times for sunrise and sunset depend on geographical location and time of year, so modify these figures accordingly. The daylight symbol (*d/*) indicates the time range during which you should attempt to obtain daylight. Conversely, daylight-blocking symbols (*db*, daylight-blocking; *wb*, work with daylight-blocking; and *sb*, sleep with daylight-blocking) all denote times of day when daylight is present, but you want to avoid it by staying inside and keeping blinds/curtains closed. If you have to be outside (or on the ship's bridge) during these times, wear dark sunglasses (*sg*) to limit your exposure to bright sunlight. Pay close attention to the daylight and daylight-blocking symbols, as they change during duty hour transitions.

When you are on the night watch (for example, Days 4-6 on Figure A-2), you want your body clock to be in a nighttime orientation. That means you must avoid any early-morning exposure to sunlight, because you want your body clock to think it's nighttime so you will be able to get to sleep. Avoidance of early-morning sunlight is particularly important to night workers--seeing daylight at the end of the night watch will reset the body clock back to a daytime orientation, making it hard to sleep during the day and making you more fatigued during your night watch. So wear dark sunglasses if sunrise occurs before you get off the night watch. Sleep periods (shown as *sb*, for "sleep with daylight blocking") start when you get off watch and go to early afternoon. When you arise in the afternoon, you want to seek daylight exposure in order to set that time as the beginning of your "day". To promote daylight exposure (during afternoons and evenings for those on night duty), you may want to schedule outdoor activities such as exercise or a walk outdoors. When naps are indicated, you should try to take a nap

that is at least one to two hours long to compensate for the anticipated sleep debt. Try to follow the sleep and daylight management schedules as closely as possible.

In all three figures, your current work-rest schedule (the one you are on before you make the transition) should approximate the schedule shown as “Day 1”. During the first two days of transition to any nighttime duty schedule, reduce workload between 0400 and 0700 to prevent increased risk due to fatigue and sleepiness. During the transition back to day schedule, reduce workload near the end of the work period (after 1500).

Daylight exposure periods must begin at the earliest time indicated in the time range and end at the latest time. Daylight exposure should last as long as possible. Normal activities such as lunch and exercise should be scheduled to occur within the time range. Daylight exposure is not required to occur continuously; however, two-hour exposures are recommended.

Let’s walk through the schedule shown on Figure A-2 as an example. Day 1 shows a normal daytime duty schedule. This crewmember has been working in the daytime from 0700-1500 and has been sleeping at night from 2200 to about 0600 (0600-0700 would probably be showering, dressing, and eating breakfast). To begin the adaptation to upcoming night work, this person on Day 2 begins daylight blocking until about 1000, effectively delaying “sunrise” for the body clock. If the crewmember is working indoors, the blinds would be drawn to block daylight; otherwise dark sunglasses would be worn until 1000. The sleep period would begin at 2200. Day 3 begins the nighttime duty. Daylight blocking would be used until 1000, at which time daylight exposure is desirable. A nap of at least one-hour is taken in early evening to help prevent excessive sleepiness during the night watch. The night watch and collateral duties are shown from 2000 until about 0700. Note that work duties are occurring *after sunrise*; this requires either daylight blocking (if working indoors) or the use of dark sunglasses to prevent exposure to daylight. Sleep, with daylight blocking, occurs from 0700-1400. Upon arising in the afternoon, daylight exposure (dl) is sought in order to set the body clock to the nighttime orientation. Again, an early-evening nap is recommended to help prevent sleepiness while on the night watch.

The second figure shows a similar approach to the adaptation to nighttime duty hours, with few, but notable, differences. The main difference is that in this figure, the work period ends *before sunrise*, so that daylight blocking during the work period is not necessary. The same major concepts apply: blocking daylight during the sleep period and getting daylight exposure upon awaking in the afternoon.

Figure A-4 shows a crewmember who has been on the night watch schedule and is transitioning back to a daytime watch. The important things to note are that on Day 2 there is an extended evening nap prior to the Day 3 midnight watch. To help adjust oneself to the upcoming daytime work schedule, daylight exposure is desirable at sunrise and during the morning hours. At 2200 nighttime sleep is taken. Daylight exposure is obtained as soon as possible after waking on Day 4, and the day watch is

worked, with a *short* nap if needed (a long nap may prevent getting to sleep at night). Daylight exposure in late afternoon and early evening help to reinforce the new day watch schedule for the body clock.

Figure A-2. Transition to night schedules when work ends after sunrise

	<i>sunrise</i>														<i>sunset</i>									
	24	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1	s	s	s	s	s	s	s	w	w	w	w	w	w	w	w								s	s
Day 2	s	s	s	s	s	sb	db	wb	wb	wb	w	w	w	w	w	w							s	s
Day 3	s	s	s	s	s	sb	db	db	db	db	dl	dl	dl	dl	dl	dl	dl	dl	n	dl	w	w	w	w
Day 4	w	w	w	w	w	sg	sg	sb	dl	dl	dl	dl	n	dl	w	w	w	w						
Day 5	w	w	w	w	w	sg	sg	sb	dl	dl	dl	dl	n	dl	w	w	w	w						
Day 6	w	w	w	w	w	sg	sg	sb	dl	dl	dl	dl	n	dl	w	w	w	w						

A-20

Figure A-3. Transition to night schedules when work ends prior to sunrise

	<i>sunrise</i>														<i>sunset</i>									
	24	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1	s	s	s	s	s	s	s	s	w	w	w	w	w	w	w								s	s
Day 2	s	s	s	s	s	sb	db	wb	wb	wb	w	w	w	w	w	w				n	n	n		
Day 3	w	w	w	w	w	sb	dl	dl	dl	dl	dl	dl	w	w	w	w								
Day 4	w	w	w	w	w	sb	dl	dl	dl	dl	dl	dl	w	w	w	w								
Day 5	w	w	w	w	w	sb	dl	dl	dl	dl	dl	dl	w	w	w	w								
Day 6	w	w	w	w	w	sb	dl	dl	dl	dl	dl	dl	w	w	w	w								
Day 7	w	w	w	w	w	sb	dl	dl	dl	dl	dl	dl	w	w	w	w								

Sleep (s)	Sleep with daylight blocking (sb)	Nap (n)	If possible, wear sunglasses (sg)
Work with possible daylight exposure during daytime (w)	Work with daylight blocking (wb)	Daylight Blocking (db)	Daylight exposure or artificial light exposure (dl)

Figure A-4. Transition from nighttime to daytime schedules

	<i>sunrise</i>													<i>sunset</i>										
	24	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1	w	w	w	w	w	w	sb	dl	dl	dl	dl	dl	dl	n	n	w	w							
Day 2	w	w	w	w	w	wb	sb	dl	dl	dl	dl	n	dl	n	n	n	n							
Day 3	w	w	w	w	w	dl	dl	n	dl	dl	dl	dl	dl	dl	dl	dl	dl	dl	dl	dl			s	s
Day 4	s	s	s	s	s	s	dl	w	w	w	w	w	n	w	w	w	dl	dl	dl	dl			s	s
Day 5	s	s	s	s	s	s	dl	w	w	w	w	w	n	w	w	w	dl	dl	dl	dl			s	s
Day 6	s	s	s	s	s	s	dl	w	w	w	w	w	n	w	w	w	dl	dl	dl	dl				

Sleep (s)	Sleep with daylight blocking (sb)	Nap (n)	If possible, wear sunglasses (sg)
Work with possible daylight exposure during daytime (w)	Work with daylight blocking (wb)	Daylight Blocking (db)	Daylight or artificial light exposure (dl)

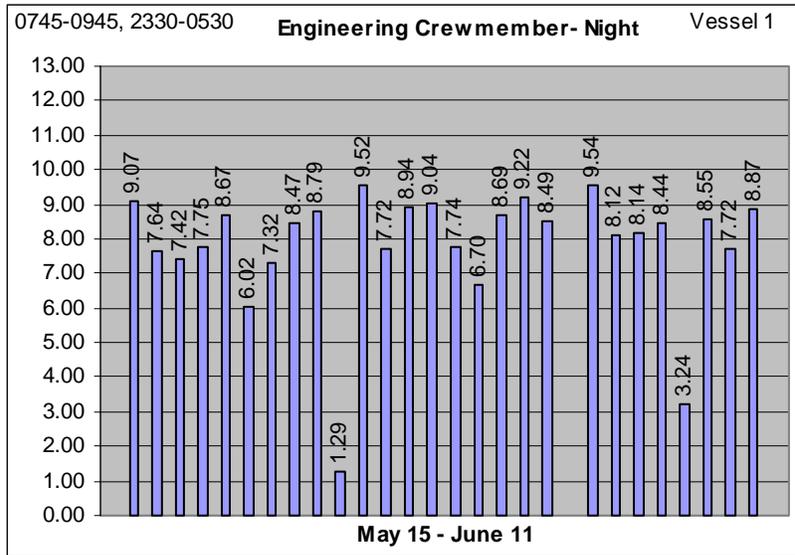
[This page left intentionally blank.]

**APPENDIX B**

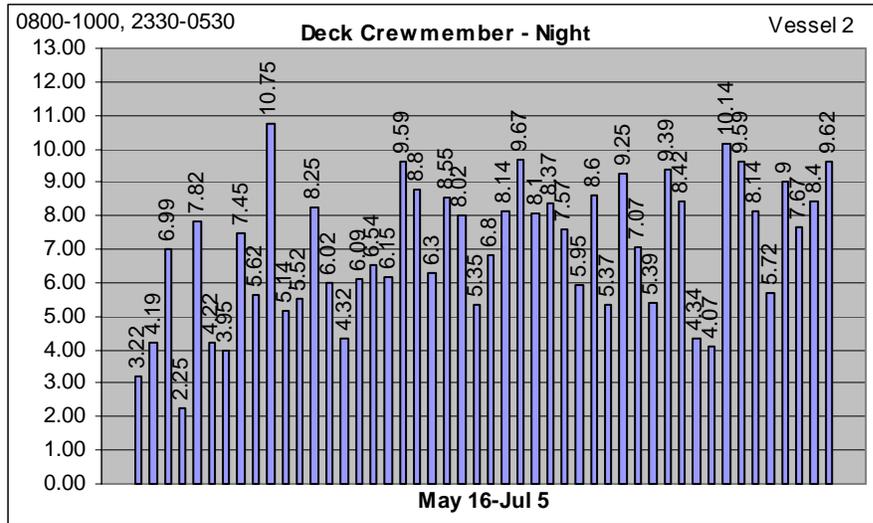
---

**Phase III — Follow-up Evaluation  
Endurance Plans Effectiveness Tests  
Crew Sleep Duration**

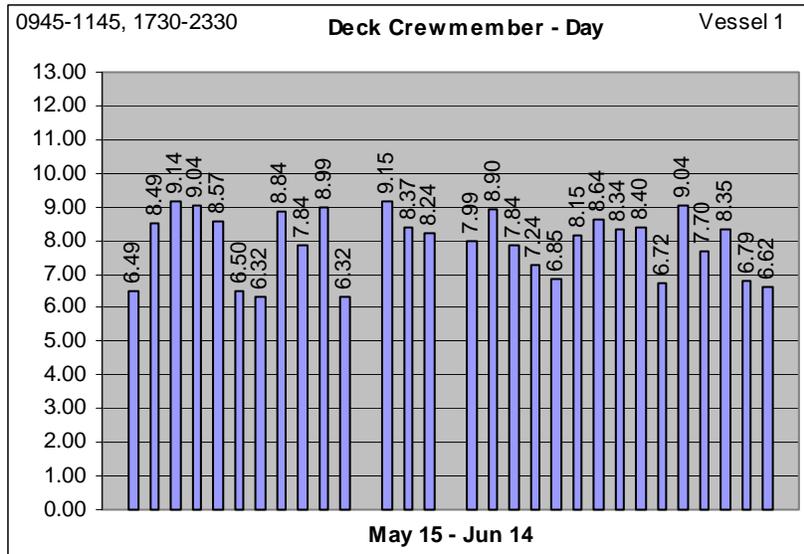
[This page left intentionally blank.]



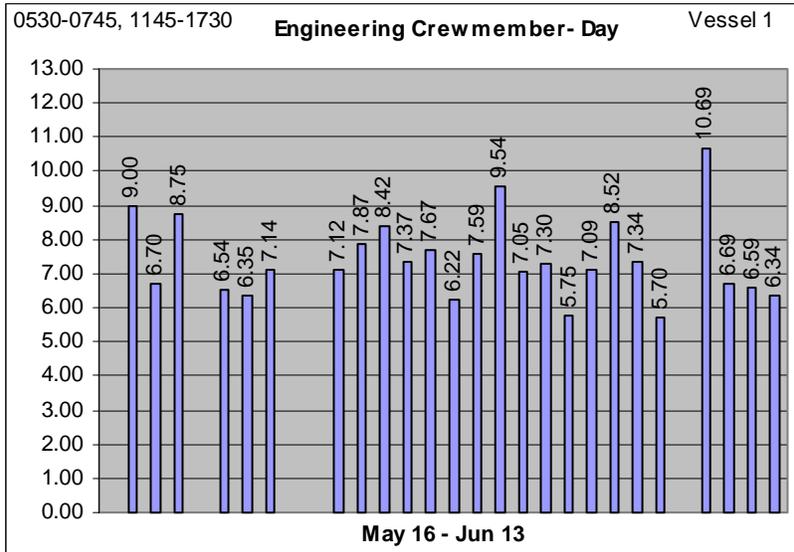
**Figure B-1.** Daily sleep duration plotted in hours over 27 days during the months of May and June 2000. This crew member stood a six-hour watch during the night and a two-hour watch during the day. See watch schedule on top left of illustration. In addition, this crewmember conducted repairs as needed from 2330-1130.



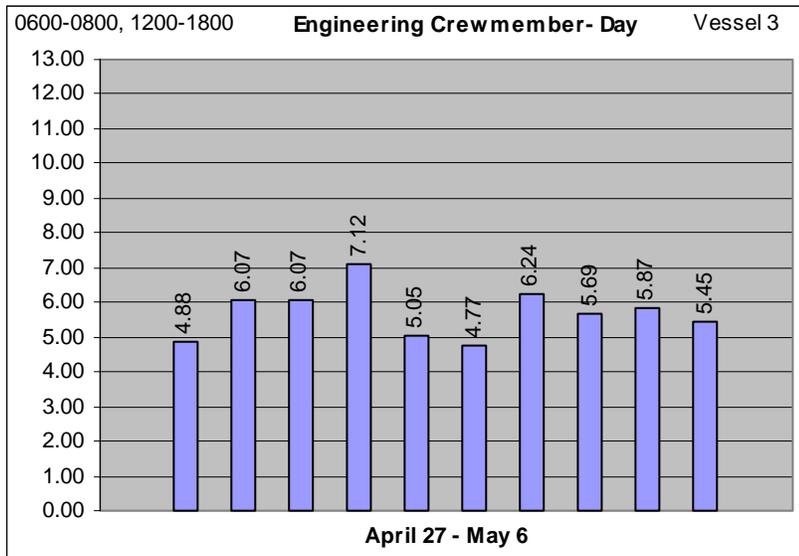
**Figure B-2.** Daily sleep duration plotted in hours over 48 days during the months of May through July. This crew member stood six consecutive hours of night watch and two more hours of day watch. See watch schedule on top left of illustration. Note that in most days (66%), sleep was maintained above six hours in duration.



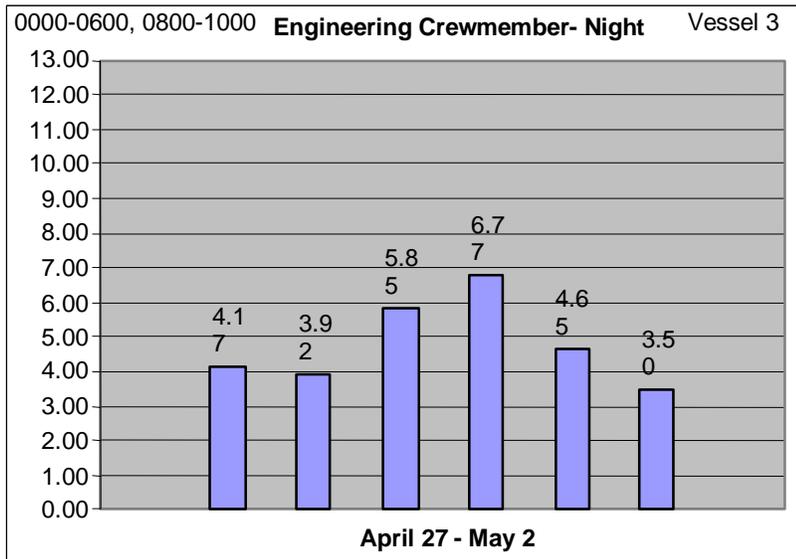
**Figure B-3.** Daily sleep duration plotted in hours over 29 days during the months of May and June 2000. This deck crew member stood a six-hour and a two-hour watch during the day throughout the study. See watch schedule on top left of illustration. Note that daily sleep duration was maintained above seven hours in 80% of all cases, and above six hours 100% of the time.



**Figure B-4.** Daily sleep duration plotted in hours over 25 days during the months of May and June 2000. This engineering crew member stood a six-hour and a two-hour watch during the day throughout the study. See watch schedule on top left of illustration. Note that sleep duration was maintained above seven hours in duration 64% of all cases, and above six hours in 92% of all cases.



**Figure B-5.** Daily sleep duration plotted in hours over 10 days during the months of April and May 2000. This engineering crew member stood a six-hour and a two-hour watch during the day throughout the study. See watch schedule on top left of illustration. Note that sleep duration reached six hours in only 40% of all cases. The implementation of the “alternate” watch schedule was discontinued due to increasing sleep debt and fatigue.



**Figure B-6.** Daily sleep duration plotted in hours over 6 days during the months of April and May 2000. This engineering crew member stood a six-hour watch during the night and a two-hour watch during the day. See watch schedule on top left of illustration. Note that sleep duration reached six hours in only one case. The implementation of the “alternate” watch schedule was discontinued due to increasing sleep debt and fatigue.

**List of Supporting Documents**

[This page left intentionally blank.]

## REFERENCES

Bell, D.S., and Donev, S. (1993). *Curing Fatigue*. Berkley Books, New York, NY.

Brown, G.(1999). *The Energy of Life*. The Free Press, New York, NY.

Caldwell, J. (1996). Sleep Deprivation, in Crowley, Newton, Davidson, Lindsey, and Marcum (Eds.), *Leader's Guide to Crew Endurance*. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory and U.S. Army Safety Center.

Caldwell, L. (1996). Stress and Fatigue, in Crowley, Newton, Davidson, Lindsey, and Marcum (Eds.), *Leader's Guide to Crew Endurance*. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory and U.S. Army Safety Center.

Comperatore, C.A. (1996). The Systems Approach to Crew Endurance, in Crowley, Newton, Davidson, Lindsey, and Marcum (Eds.), *Leader's Guide to Crew Endurance* (pp21-25). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory and U.S. Army Safety Center.

Comperatore, C. A., Bloch, C., Ferry, C. (1999). Incidence of sleep loss and wakefulness degradation on a U.S. Coast Guard cutter under exemplar crewing limits. (CG-D-14-99) Groton, CT: United States Coast Guard Research and Development Center.

Comperatore, C.A., Carvalhais, A., Rivera, P.K. (2000). Implementation of the U.S. Coast Guard Endurance Management System (CGEMS) at Air Station Miami. (In progress), United States Coast Guard Research and Development Center, Groton, CT.

Comperatore, C. A., Carvalhais, A., Della Rocco, P., Schaab, B., Bloch, C. (1998). Development of an endurance management plan for US Coast Guard air stations – phase I. (CG–D–28–98) Groton, CT: United States Coast Guard Research and Development Center.

Comperatore, C. A., Kirby, A., Bloch, C., and Ferry, C. (1999). Alertness degradation and circadian disruption on a U.S. Coast Guard cutter under paragon crewing limits. (CG-D-23-99) Groton, CT: United States Coast Guard Research and Development Center.

Forgey, M.D., William W., Editor. (2001). *Wilderness Medical Society: Practice Guidelines for Wilderness Emergency Care*, Second Edition, The Globe Pequot Press, Guilford, CT.