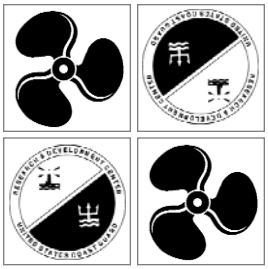
Crew Endurance Management System

(CEMS)



One of AWO's ongoing priorities is to improve crew alertness. AWO has worked with the Coast Guard to develop educational tools to inform companies and crewmembers about this topic. The Coast Guard Research and Development Center has developed a Crew Endurance Management System (CEMS) to help companies introduce a holistic program addressing endurance factors. The following is adapted from materials supporting the CEMS.

For further information on resources available for CEMS, please contact the Coast Guard's Human Element & Ship Design Division at (202) 267-2997.

What is Crew Endurance In Maritime Operations?

Maritime crews generally work 12 hours per day, seven days a week, in cycles varying from 15 to 30 days. The cycle, or crew shift, depends on environmental factors, crew travel frequency to and from assigned vessels, and industry and operational constraints. The 24/7 working environment of the maritime industry can subject crews to a number of operational risk factors such as sustained wakefulness, temperature variations, and uneven work demands that can affect crew endurance (stamina and alertness).

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

While the endurance of a vessel is a function of how long the vessel can support operations underway without replenishment or maintenance, the endurance of its crewmembers is a function of a combination of environmental, operational, physiological and psychological factors.

These factors include the internal state of crewmembers (e.g., emotional state, stress level), physical conditioning, motion-discomfort level, quality and duration of sleep periods, diet, and the stability of the body's internal timing system (the biological clock). Each of these factors affects a crewmember's endurance level by exerting a direct influence on his or her energy and alertness levels. Therefore, a crewmember's performance and safety levels depend on his or her level of endurance.

One key to maintaining a high level of performance and safety in maritime operations is crew endurance management.

Factors:

- **Environmental**: Effects of ambient temperature, noise and vibration on the human body.
- **Operational**: Effects of company and boat policies.
- **Physiological**: Effects of sleep, diet, exercise and shift work on the body and performance.
- **Psychological**: Effects of stress and working conditions on performance.

What is Crew Endurance Management?

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

- **Environmental**: Effects of ambient temperature, noise and vibration on the human body
- **Operational**: Effects of company and boat policies
- **Physiological**: Effects of sleep, diet, exercise and shift work on the body and performance
- **Psychological**: Effects of stress and working conditions on performance

Crew endurance can be managed by controlling the major risk factors affecting crewmember alertness and stamina. These risk factors are called performance stressors and can affect crewmember performance individually and/or collectively. Some examples can be seen in the box to the right.

These are external risk factors affecting crewmembers that can be managed by mitigating the stressors. For example, drinking additional fluids can minimize dehydration and mineral loss during high heat working conditions.

There is also an internal risk factor related to a person's "body clock." Within an individual's body clock is a period known as the "Red Zone." The Red Zone can also be managed to affect crewmember alertness and stamina.

Performance Stressors:

Environmental

- Heat illness, caused by dehydration and the loss of minerals needed to maintain normal body function
- Cold illness, caused by heat and energy loss, resulting in hypothermia and frostbite

Physiological

- Excessive caffeine use, which is an energy drain that can cause anxiety and sleep loss
- Improper use of over-the-counter medications, which can cause drowsiness and reduced alertness

Operational

- Company and boat policies that define the parameters of crewmember work practices

Psychological

- Stress caused by flight-or-fight anxiety or burnout

What is The "Red Zone"?

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

Crew endurance can be managed by controlling the major challenges or risk factors affecting crewmember alertness and stamina. These risk factors are called performance stressors and can affect crewmember performance individually and/or collectively.

These are external risk factors affecting crewmembers that can be managed by mitigating the stressors. For example, drinking additional fluids can minimize dehydration and mineral loss during high heat working conditions.

There is also an internal risk factor related to a person's "body clock." Within an individual's body clock is a period known as the "Red Zone."

The body's biological clock is a physiological mechanism composed of neural networks and hormonal outputs that regulate the timing of energy production and the timing of sleep onset and wake-up. 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.

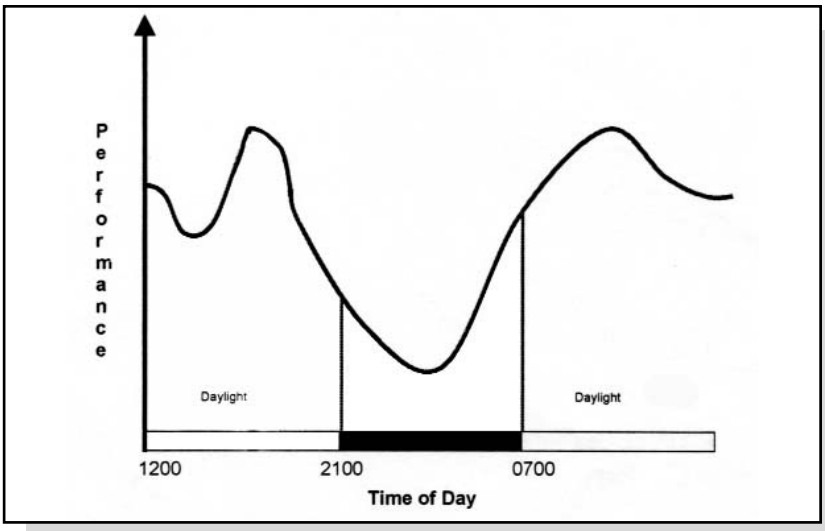
The biological clock regulates energy cycles so that alertness increases after wake-up time, peaks in the mid-morning hours, dips in the afternoon hours, peaks again in the early evening hours, and begins to decrease in the early night, reaching all time lows in the middle of the night.

As illustrated in the figure below, performance (energy) dips after noontime, reaching a mild low at about 1300, increases to a daily peak at about 1800, and then decreases steadily until reaching a daily low between 0200 and 0400. It then increases steadily, reaching another daily peak at about 1000, and then decreases through the late morning. The "Red Zone" is defined as the daily period of lowest energy and alertness that typically spans from roughly sundown to sun up; in this case, from 2100 until 0700.

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.

The Red Zone can be managed to affect crewmember alertness and stamina.

The "Red Zone"



How can The "Red Zone" Be Managed?

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

Crew endurance can be managed by controlling the major challenges or risk factors affecting crewmember alertness and stamina. There are external risk factors affecting crewmembers that can be managed by mitigating the stressors, like insulation from the cold and damp. There is also an internal risk factor related to a person's "body clock." Within an individual's body clock is a period known as the "Red Zone."

The body's biological clock is a physiological mechanism that regulates the timing of energy production and the timing of sleep onset and wake-up. 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. The "Red Zone" is defined as the daily period of lowest energy and alertness that typically spans from roughly sundown to sun up; in this case, from 2100 until 0700.

Staying out of the Red Zone is a matter of energy management. If the body does not produce sufficient energy, the brain and the nervous system cannot function efficiently, causing one to:

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

Regardless of how hard people might try to compensate for lack of energy, their ability to carry out both physical and mental tasks is reduced. This reduction in energy compromises their safety as well as the safety of those around them.

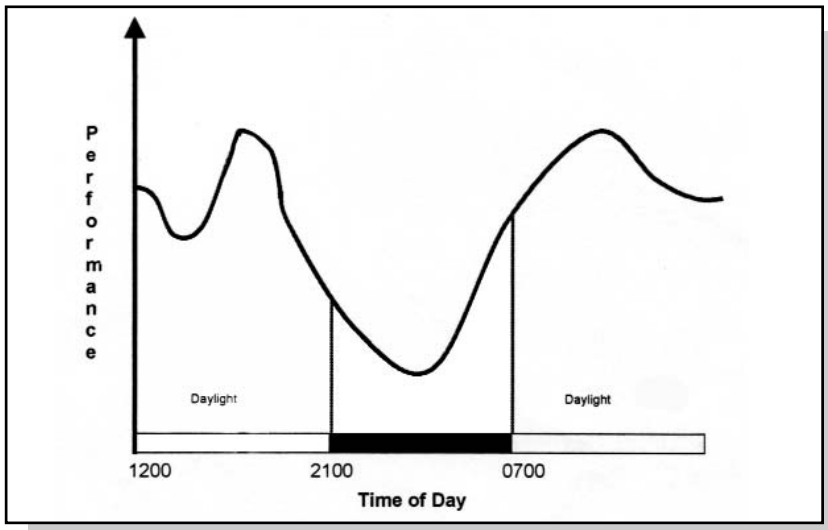
Be cautious of products that claim to boost energy resources. These products can provide dietary input to the energy-producing machinery (body), but they cannot produce energy. The only way to produce energy is through adequate sleep, sufficient water intake, a balanced diet, a stable body clock and regular exercise.

Here are a few tips on how to control your daily energy level:

- Exercise daily. Any simple form of regular exercise helps: a 20-minute walk, running, weight lifting, 10-minute aerobic workouts, etc.
- Consume a balanced diet: low sugar, low fat, low starch, high in green and yellow vegetables, chicken, turkey and fish
- Get adequate sleep
- Manage stress, using relaxation methods to reduce stress at the individual level

It is important to understand how energy is produced, how it affects endurance, and how it can be increased or decreased in certain situations.

The "Red Zone"



How is Energy Produced?

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

Crew endurance can be managed by controlling the major challenges or risk factors affecting crewmember alertness and stamina. There are external risk factors affecting crewmembers that can be managed by mitigating the stressors, like insulation from the cold and damp. There is also an internal risk factor related to a person's "body clock." Within an individual's body clock is a period known as the "Red Zone." The "Red Zone" is the daily period of lowest energy and alertness that typically spans from roughly sundown to sun up.

Staying out of the "Red Zone" is a matter of energy management. An important part of managing the "Red Zone" is understanding how energy is produced, how it affects endurance, and how it can be increased or decreased in certain situations.

What Is Energy and How Is It Produced?

The production of energy is dependent upon the production of molecules called adenosine tri-phosphate (ATP). ATP is found in all cells of the body. The amount of ATP produced by the body depends on good nutrition, adequate hydration (water intake), oxygen, and sufficient sleep. (See figure at right.)

How the Body Turns Food into Energy

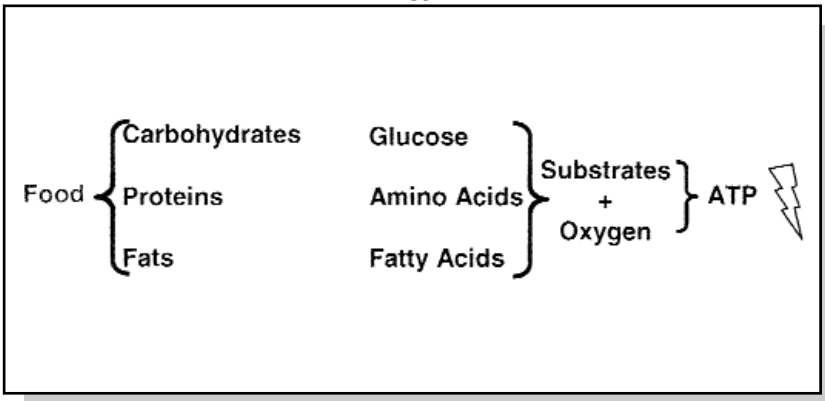
The digestive system breaks food down into carbohydrates, proteins, and fats, which are then converted by enzymes into energy substrates: glucose (sugar), amino acids and fatty acids. These substrates are then processed within individual cells into ATP (energy).

The Role of Sleep

Energy production generally takes place when energy is not being expended, i.e., during sleep cycles. The "Red Zone," the daily period of lowest energy and alertness, is also the time of greatest energy production. That is why sufficient sleep is necessary to maintain adequate energy and performance levels.

Since the "Red Zone" is triggered by the body's internal clock, simply shifting the timing of sleep is not sufficient. Hormones that regulate the body clock, like melatonin, are affected by several factors. One of these factors -- the amount of light to which the body is exposed -- has an impact on when the body produces energy. Understanding how light affects the "Red Zone" is key to "Red Zone" management.

Food is Broken Down into Energy Substrates



How does Light Affect The "Red Zone"?

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

Crew endurance can be managed by controlling the major challenges or risk factors affecting crewmember alertness and stamina. There are external risk factors affecting crewmembers that can be managed by mitigating the stressors, like insulation from the cold and damp. There is also an internal risk factor related to a person's "body clock." Within an individual's body clock is a period known as the "Red Zone."

The "Red Zone" is the daily period of lowest energy and alertness that typically spans from roughly sundown to sun up. Since the "Red Zone" is triggered by the body's internal clock, simply shifting the timing of sleep is not sufficient. Hormones that regulate the body clock, like melatonin, are affected by several factors. One of these factors -- the amount of light to which the body is exposed -- has an impact on when the body produces energy.

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 system schedule in synchronization with local sunrise and sunset and the duration of daylight hours.

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 production and decrease endurance.

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 increase endurance during nighttime work is to reverse the biological clock's synchronization from daytime to nighttime orientation. This is known as "shifting the 'Red Zone'."

How can The "Red Zone" Be Shifted?

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

Crew endurance can be managed by controlling the major challenges or risk factors affecting crewmember alertness and stamina. There are external risk factors affecting crewmembers that can be managed by mitigating the stressors, like insulation from the cold and damp. There is also an internal risk factor related to a person's "body clock." Within an individual's body clock is a period known as the "Red Zone."

The "Red Zone" is the daily period of lowest energy and alertness that typically spans from roughly sundown to sun up.

Controlling Shiftwork Adaptation

Adapting to nighttime or daytime work requires synchronizing physiological and cognitive resources with the biological clock. Maladaptation results if the body clock is not adjusted to the watch schedule. To adapt the biological clock, crewmembers must see daylight (or bright artificial light of at least 1,000 lux) on awakening and throughout their active periods (e.g., during work hours). Light management is a critical part of the process of adapting to new watch schedules.

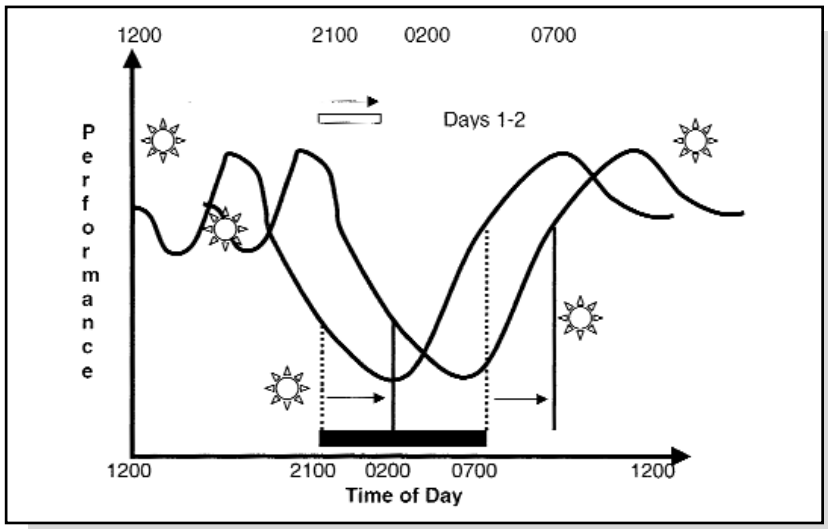
The only way to fully adapt to night watch schedules is to reset the biological clock so that energy peaks during nighttime. Work must take place under artificial light (of at least 1,000 lux) that mimics daylight. Sleep must take place in a dark and noise-reduced environment. Lacking control of daylight and/or light exposure is a significant contributor to fatigue and shiftwork maladapation.

Using Light Management Techniques

A strategic use of light management can help crewmembers to function optimally during nighttime rather than daytime hours. For example, exposing the human eye to artificial light during the period between sunset and 0200 can shift the "Red Zone" for after-watch duty. See Figure 1.

(continued on page 10)

Figure 1



How can The "Red Zone" Be Shifted?

(continued from page 9)

Figure 2 shows the "Red Zone" being shifted into full daylight hours. The three arrows indicate the amount of relative shift realized by applying light management techniques over three different periods of time. (Note that if sunrise occurs prior to 0700, natural light may be used for light management once daylight is of sufficient intensity.)

Also note that it takes about five or six days of consistent light management to shift the "Red Zone" fully from a nighttime orientation over to a daylight (morning) orientation. Light management in this case could consist of closely replicating a daylight environment during nighttime hours, and a nighttime environment during morning hours.

This "reverse" light management regimen is illustrated in Figure 3. Since wheelhouse personnel cannot generally work in bright artificial light at night, special "green" lights have recently been developed to provide the 1,000 lux needed to simulate daytime brightness.

Now that the science of crew endurance management has been examined, the implementation of a Crew Endurance Management System can be discussed.

Figure 2

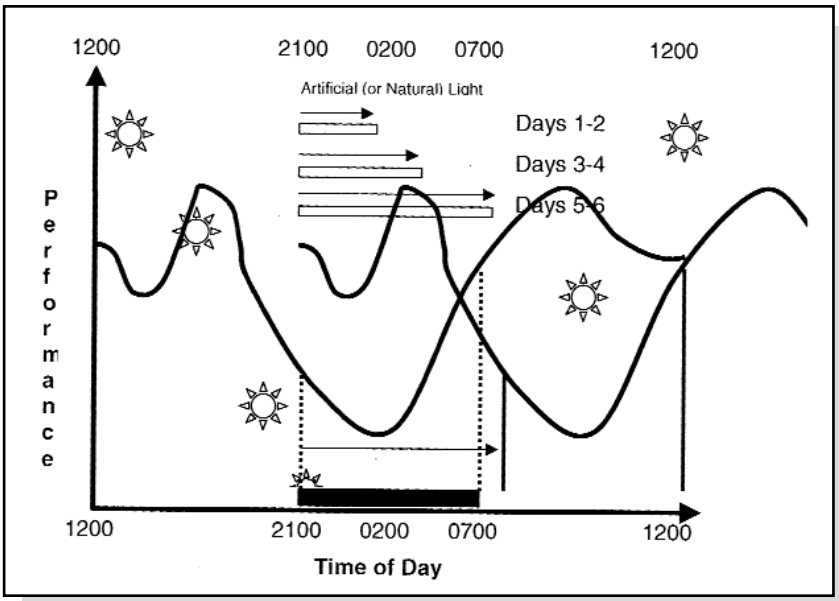
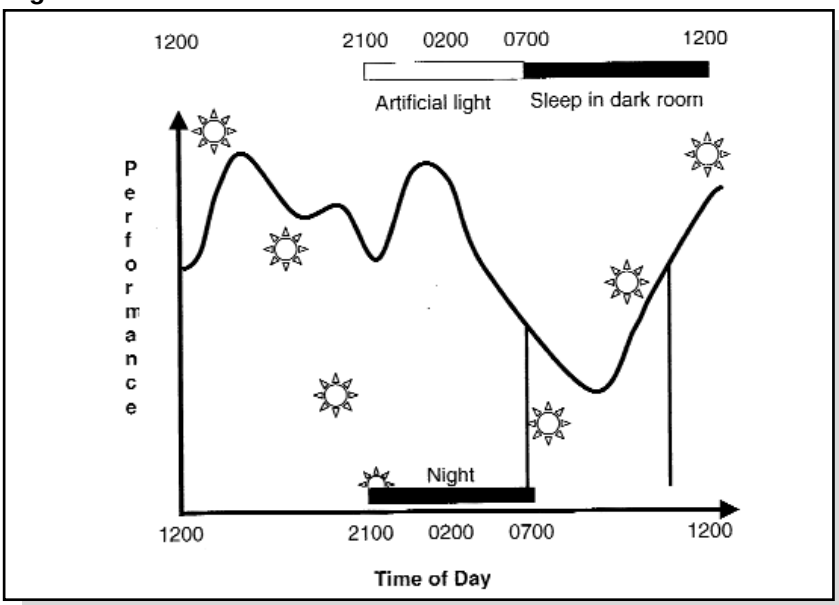


Figure 3



The Structure Of A Crew Endurance Management System

Now that the science of crew endurance management has been explained, the next half of this series will describe the Crew Endurance Management System developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented into a company's operations.

History of the Crew Endurance Management System

Dr. Carlos Comperatore, the senior scientist heading this effort for the Coast Guard, began his work on endurance management with the U.S. military. Working with elite teams in special forces applications, he developed ways to improve mission performance during short-term, 24-hour-a-day operations. The U.S. Coast Guard initially tapped Dr. Comperatore to help its own maritime operations and saw how other segments of the maritime industry could benefit from this initiative. The Crew Endurance Management System (CEMS) discussed here has been tested in a variety of maritime environments, including marine shipping companies, towing vessel operations, U.S. Coast Guard cutters, small boat stations and aviation units.
Dr. Comperatore is continuing to introduce CEMS to other maritime segments, most recently the Washington State ferry system.

How Can Crew Endurance Management Affect Company Performance?

Mental and physical stress factors have an impact on 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, crewmembers must dedicate a larger part of their mental resources to the immediate task at hand and focus less on advance planning. Planning ahead before a task allows crewmembers to anticipate specific risks and maintain operational safety. However, when stress factors are not controlled proactively, crewmembers 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 Phases of Developing a Company-Specific Crew Endurance Management System

Implementing a CEMS into a company's operations involves three phases:

- **Phase I**: Program Development
- **Phase II**: Program Deployment
- **Phase III**: Program Assessment

Two critical elements of Phase I are 1) setting up a Crew Endurance Working Group; and, 2) setting up and maintaining a Final Common Path.

CEMS
PHASE I

Program Development

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented in a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment and Program Assessment.

Phase I: Program Development

As with any project, development is the crucial first step. Despite some misperceptions, CEMS does not mean simply changing a watch schedule. CEMS is a field-tested system with concrete phases and steps that must be undertaken in a logical way to be successfully integrated into a company's operations. Many facets of a company's operations and structure must be considered and resources tapped to ensure that CEMS is fully explained to all employees involved, both crewmembers and shoreside staff. Once a company commits to implementing CEMS, education about elements of the program must be undertaken. CEMS relies on the communication between, and support of, all areas of company operations -- management, shoreside support and crewmembers -- to achieve the desired goals.

Phase I consists of several steps, each with specific elements.

Developing a CEMS program involves the following:

- Setting up and training a Working Group;
- Analyzing the current situation; and,
- Drawing up a CEMS plan.

Setting Up and Training a Working Group

The Crew Endurance Working Group (CEWG) is responsible for all aspects of implementing a CEMS aboard a maritime vessel, including:

- Identifying the endurance risk factors relevant to the vessel;
- Creating a collaborative network to facilitate implementing CEMS aboard the vessel; and,
- Devising and deploying a CEMS plan specific to the vessel.

To be effective, a CEWG must include or represent all those individuals who stand to be affected by the implementation of CEMS aboard a particular vessel. A CEWG typically consists of the following individuals:

- One or two company officers;
- Company operations manager;
- Captain/pilot/mate of the vessel;
- Engineer of the vessel; and,
- One or more deckhands of the vessel.

To control factors affecting crew endurance requires the development of a supporting organizational infrastructure. Without management support, individual crewmembers cannot effectively implement endurance management practices.

The members of the CEWG must receive training as needed in identifying and managing crew endurance risk factors; creating collaborative networks to facilitate CEMS implementation; and, devising and deploying CEMS.

Typically, the goal of a CEWG is to develop a CEMS for a particular situation -- in most cases, a specific vessel; however, CEMS can also be set up to apply to an entire company.

Successful working groups avoid personal or organizational agendas, and seek improvement of policies and crew management practices that will help crewmembers maintain endurance.

CEMS
PHASE I

Program Development -- Analyzing The Situation

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented into a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment and Program Assessment. The first step in program development is setting up and training a Crew Endurance Working Group -- the CEWG.

The three elements of CEMS Program Development are:

- Setting up and training a working group;
- Analyzing the current situation; and,
- Drawing up a CEMS plan.

Before drawing up a CEMS plan, the working group must analyze the current situation.

Analyzing the Current Situation

- **Step 1**: Review crew endurance management information.
- **Step 2**: Identify crew endurance performance factors.
- **Step 3**: Identify elements affecting endurance during maritime operations.
- **Step 4**: Analyze relationships between elements; determine modifications.

1st Step: Receiving Training in CEMS Principles and Practices

The CEWG meets initially to receive specific training in CEMS practices and procedures. The objective for this meeting is for all members of the CEWG to reach the same level of knowledge concerning identifying and managing crew endurance risk factors; creating collaborative networks to facilitate CEMS implementation; and, devising and deploying CEMS plans.

The CEWG must also choose a leader at this stage. In this regard, it is critically important that the CEWG choose a leader who is respected by all stakeholders and who is capable of guiding the group away from individual agendas.

2nd Step: Identifying Endurance Risk Factors

The process of controlling endurance risk factors requires an analysis of the entire operational system of the vessel. This analysis consists of identifying the various areas of risk, such as workload, onboard environment, weather and company policy, as well as the relationship between these areas of risk.

This analysis should be conducted during at least a 15- to 30-day period in order to properly document duty hours, workload and crew rest associated with periods of low and high workload. Depending on the geographical location, workloads may be directly affected by seasonal changes; thus, some analyses must be conducted during both winter and summer seasons.

Information collected during this analysis helps CEWG members identify endurance risk factors of organizational as well as operational origin. Identifying all these risk factors is fundamental to developing a CEMS plan for a specific real-world operation, as one size DOES NOT fit all. As the relevant risk factors are identified, the CEWG can then develop a specific plan to control the impact of these risk factors on performance and safety.

3rd Step: Identifying Contributing Elements

The third step consists of analyzing the operational risk areas to identify specific risk elements (activities, environmental conditions, policies, operational situations) that appear to be affecting crew endurance. For example, in the area of diet, consumption of large amounts of caffeine may affect the quality and duration of sleep. Typically, risk factors in more than one area are identified.

4th Step: Identifying Possible Modifications

The fourth step consists of suggesting modifications that affect the risk elements identified in the analysis. Frequently, these types of possible modifications include changing crewmember dietary practices and exercise habits, modifying the use of caffeine, and making physical changes to crewmember sleeping quarters. More sophisticated modifications may involve changing the watch schedule and introducing light management techniques.

CEMS
PHASE I

Program Development -- Drawing Up A CEMS Plan

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented into a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment and Program Assessment. The first step in program development is setting up and training a Crew Endurance Working Group. The second step in program development is analyzing the situation.

The three elements of CEMS Program Development are:

- Setting up and training a Working Group;
- Analyzing the current situation; and,
- Drawing up a CEMS plan.

Once the Crew Endurance Working Group (CEWG) has been established and the current situation has been analyzed, the final element of CEMS Program Development can be conducted. This element, drawing up a CEMS plan, consists of two components:

1. Agreeing on and prioritizing modifications; and,
2. Setting up a Final Common Path.

The process involved in arriving at a plan for implementation requires dedication, cooperation and self-discipline. If individual agendas are allowed to take precedence, a meaningful CEMS plan cannot be achieved.

It is recommended that the CEWG focus on identifying changes (no matter how small) that all stakeholders can support. Other changes, which may require budgetary or manpower resources that have an impact on those other than vessel crewmembers, may be considered for long-term projects.

Agreeing On and Prioritizing Modifications

The CEWG must agree on and prioritize the system modifications suggested in Step 4 of the analysis process. The process of prioritizing system modifications involves placing them into one of three possible categories:

- Those that can be implemented easily;
- Those that can be implemented with more effort; or,
- Those that cannot be implemented.

It is recommended that the CEWG place an initial emphasis on small or inexpensive modifications that yield relatively large benefits. Larger or more expensive changes can then be phased in over time. It is paramount that the CEWG make its modification recommendations on the basis of information gathered during the analysis, rather than on the basis of personal choice or preference.

Setting Up a Final Common Path

In order for a CEMS to succeed, a Final Common Path must be established and maintained. A Final Common Path consists of the following key elements:

- Setting up a team of onboard coaches to train crewmembers on the science and practices of CEMS, and to serve as program models and monitors. The team of coaches typically consists of the captain, the pilot, and the mate.
- Training the coaches in the science and practices of CEMS. Training for coaches is provided by company management, typically using resources available from the U.S. Coast Guard Human Element and Ship Design Division.
- The coaches train the crewmembers in the science and practices of CEMS, model the required practices, and monitor crew adherences to these practices.

CEMS
PHASE I

Program Development -- Setting Up A Team of Coaches

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented into a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment and Program Assessment. The first step in program development is setting up and training a Crew Endurance Working Group. The second step in program development is analyzing the situation. The final step in program development is drawing up a CEMS plan.

Setting Up a Team of Coaches

One of the most critical elements of a company's CEMS is the team of coaches. As mentioned in the last article, the team of coaches typically consists of the captain, the pilot, and the mate. Coaches are trained in the science and practices of CEMS, typically using resources available from the U.S. Coast Guard Human Element and Ship Design Division. The coaches then train crewmembers in the science and practices of CEMS, model the required practices, and monitor crew adherence to these practices.

Effective crew endurance management requires constant encouragement and reinforcement. Coaches accomplish this by:

- Supporting the overall implementation of CEMS by modeling endurance management practices for crew emulation, actively encouraging crewmembers to follow these practices themselves, and monitoring/enforcing adherence to the policies and procedures of the CEMS plan.

- Providing information to crewmembers on the science of CEMS: diet, exercise, caffeine use, environmental stressors, psychological conditions and, sleep and body clock management.

- Providing information to crewmembers on how to maximize the benefits of rest opportunities.

- Implementing crew-rest protocols that document 1) the timing and number of rest opportunities made available to crewmembers and, 2) crewmember efficiency in taking advantage of rest opportunities.

Along with adequately trained coaches, the successful implementation of CEMS to improve endurance requires an active education campaign. The education campaign must be designed to instruct company managers, wheelhouse personnel, department heads, and crewmembers on their contribution to the coordination and execution of the various elements of the CEMS plan. Coaches, once trained, can help spearhead this campaign.

CEMS
PHASE 2

Program Deployment

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented into a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment and Program Assessment. The first step in program development is setting up and training a Crew Endurance Working Group. The second step in program development is analyzing the situation. Drawing up a CEMS plan is the final step in program development. Another crucial step in program development is setting up a team of coaches.

This article explores Phase II of CEMS -- program deployment -- the implementation of CEMS on board a vessel.

Program Deployment

The process of deploying the company-specific crew endurance management plan consists of training the full crew and implementing the CEMS plan.

Training the Crew

The team of coaches trains the vessel crew in sleep and body-clock management, as well as stress management and other crew endurance practices. This can be done in a workshop format, typically lasting a day-and-a-half. Vessel coaches can carry out additional crewmember training onboard during normal operations.

Implementing the Plan

The process of implementing the plan is accomplished through three interlocking methods:

- Enlisting the support of the full crew
- Making the recommended system modifications
- Coaching the crew toward consistency

Enlisting the Support of the Crew

Crewmembers are provided with key information and training on crew endurance (benefits, factors, procedures, etc.) and are presented with the company Crew Endurance Working Group's (CEWG) plan, together with the rationale underlying each of its features.

Crewmembers are invited to make suggestions toward improving the plan and asked to support the final plan toward the mutual benefit of all concerned. Crewmember buy-in is critical to the success of the CEMS plan and including their input in tailoring the plan can help make the plan their own. No buy-in, no success.

Making the Recommended System Modifications

The CEWG, together with company management and the vessel's coaches, ensure that all of the system modifications recommended in the final plan are made. These modifications potentially include physical changes to crew quarters, dissemination of new onboard policies, and requests to the crew for changes in personal choice (for example, modifying the use of caffeine or other stimulant drugs). Watch schedule changes may also be included in these modifications but are generally not the first, and usually not the only, modification to be implemented.

Coaching the Crew

The coaches are responsible for training individual crewmembers in endurance management practices. Coaches serve as models for emulation and actively encourage crewmembers to help achieve the success of the plan.

At various times during the implementation phase, the CEMS plan should be assessed.

CEMS
PHASE 3

Program Assessment

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented in a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment, and Program Assessment. The first step in program development is setting up and training a Crew Endurance Working Group. The second step in program development is analyzing the situation. Drawing up a CEMS plan is the final step in program development. Another crucial step in program development is setting up a team of coaches. Phase II of CEMS -- program deployment -- is the implementation of CEMS on board a vessel.

Program Assessment

The final phase of CEMS is Program Assessment. The purpose is to evaluate how well a newly deployed CEMS plan is working under real-world conditions. It is usually conducted over a 30-60 day period (depending on hitch schedules and other factors) and during high operational tempo. As in Phase I analysis, it is necessary to document the impact of watch, work and training schedules on crew rest and stress levels.

The Coast Guard Research and Development Center has used wrist monitors to provide accurate information on the quality and duration of the wearer's sleep. A logbook, possibly electronic, can also be used in the field. The data should document whether crewmembers' 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 crew endurance plan.

These observations can help determine the need for further modifications to the crew endurance plan. This type of information is of great value to the Crew Endurance Working Group (CEWG) members because it helps identify endurance risk factors, both organizational and operational, and possible ways to mitigate them.

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

Now that CEMS has been explained, a real-world example can illustrate how CEMS can work at an AWO member company.

CEMS
PHASE 3

Quick Example of CEMS Implementation

Part II of this series describes the Crew Endurance Management System (CEMS) developed by the Coast Guard Research and Development Center in Groton, CT, and how it can be implemented into a company's operations. There are three phases of developing a company-specific crew endurance management system: Program Development, Program Deployment and Program Assessment. The first step in program development is setting up and training a Crew Endurance Working Group. The second step in program development is analyzing the situation. Drawing up a CEMS plan is the final step in program development. Another crucial step in program development is setting up a team of coaches. Phase II of CEMS -- program deployment -- is the implementation of CEMS on board a vessel. Phase III is program assessment.

Quick Example

Now that CEMS has been fully explained, an example of a CEMS program tailored to a specific vessel will help illustrate CEMS elements. This example was derived from a vessel invited to participate in a CEMS demonstration project.

Phase I: Program Development

Once the vessel was accepted into the demonstration program, a Crew Endurance Working Group (CEWG) was assembled, consisting of the company safety manager, company operations manager, and the entire crew of the vessel. Before beginning its work, the CEWG was trained in the science of crew endurance and in the process of crew endurance management.

Once trained, the CEWG analyzed the current situation by studying the vessel's operational system and its major components. The CEWG identified the relationships between these major components and isolated specific factors within each component that were affecting crew endurance.

Operational Component	**Factors Affecting Crew Endurance**
Diet	Crewmembers were eating large meals immediately before going to bed after watch. Crewmembers were consuming large quantities of caffeine.
Individual Choices	Crewmembers were being kept awake by noises associated with crews handling rigging near the vessel; slamming doors or banging manhole covers; and using TVs, radios, handheld VHF radios, etc. at high-volume levels.
Towing Vessel Environment	Crewmembers were being awakened by sudden movements of the vessel. Crewmembers were being kept awake by light coming into crew quarters through window ports and the air filter in the door.
Company Policies	Crewmembers were being delayed from sleep time by having to take their showers after watch and meals. Crewmembers were being delayed from sleep time by having to wait to be relieved for meals.

On the basis of their analysis, the CEWG drew up a list of specific recommendations, both operational and environmental.

Operational

Policy: Early showers will be allowed. However, crewmembers will be expected to discuss any work to be completed before taking early showers. An early shower does

(continued on page 19)

CEMS
PHASE 3

Quick Example of CEMS Implementation

(continued from page 18)

not relieve anyone of any duties to be performed on watch.

Policy: Early meals will be allowed, provided they do not interfere with the cook.

Policy: Crewmembers coming on watch will be given priority seating at meal times.

Environmental

Policy: Pilothouse personnel will actively avoid rapid changes in throttle settings whenever practicable.

Policy: Deck crew will actively minimize noise associated with the performance of their duties. This will include handling rigging with care near the vessel.

Policy: Crewmembers will avoid slamming doors or banging manhole covers.

Policy: Crewmembers will keep TVs, radios, handheld VHF radios, etc. to mutually acceptable volume levels.

Physical: Install baffles on stateroom doors that allow airflow while restricting noise and light.

Physical: Install slide panels over exterior stateroom windows to restrict light.

Phase II: Program Deployment

Once the CEWG's recommendations were approved, the CEMS was deployed. Endurance coaching training was provided, as well as information on diet and stress management, in a daylong workshop. The vessel's own crew endurance coaches then carried out additional crewmember training onboard during normal operations.

Crewmembers were invited to make suggestions toward improving the plan and helped to ensure that all of the system modifications recommended in the final CEMS plan were made. Vessel coaches served as models for crew emulation and monitored adherence to the new policies and procedures.

Phase III: Program Assessment

At various times during the implementation phase, the program was assessed through sleep monitors, saliva specimens and a psychomotor vigilance task to measure alertness. Alternate measurements may also be used. Crewmembers showed indications of a well-adapted body clock and experienced minimal lapses in alertness.

CEMS in a Nutshell

Endurance and Science

Crew endurance refers to the ability of a crew to maintain performance within safety limits while coping with job-related environmental, operational, physiological and psychological challenges (factors or stressors).

Since the human body clock is timed for individuals to sleep at night, measures can be taken to improve the performance of those who work at night, in the "Red Zone." The "Red Zone" is the daily period of lowest energy and alertness that typically spans from roughly sundown to sunup. All mariners, whether working daylight or nighttime shifts, can benefit from education on ways to mitigate the effects of stressors on their performance.

A Methodical Program to Manage Crew Endurance

Dr. Carlos Comperatore, U.S. Coast Guard Research & Development Center, has developed a program known as the Crew Endurance Management System (CEMS). CEMS is a program to help maritime companies introduce into their operations an integrated way to address crew endurance factors. Because there are so many factors affecting crew endurance -- weather, workload, watch schedule, nutrition/hydration, and rest, for example -- there is a need for an integrated system to fully address the vessel operational model. CEMS is a field-tested system with concrete phases and steps that must be undertaken in a logical way to be incorporated successfully into a company's operations.

CEMS in a Nutshell

- Phase I: Program Development
  - Analyzing the Situation
  - Drawing Up a CEMS Plan
  - Setting Up a Team of Coaches
- Phase II: Program Deployment
- Phase III: Program Assessment

The Future

The Coast Guard and AWO are working in tandem to develop resources to assist the tugboat, towboat and barge industry to integrate CEMS into its operations. The Coast Guard-AWO Crew Endurance Management Working Group has been charged with developing a plan to do so. The success of CEMS, a nonregulatory solution to address factors critical to the industry's operations, depends on the commitment of government and industry, from management to deckplate. All AWO members are encouraged to explore its benefits.