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ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ: Παπαλεωνίδα Παρασκευή

***ΘΕΜΑ:*Seafarers fatigue: Causes, effects, management**

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Abstract

In this dissertation I look at seafares' fatigue. In the first chapter we look at the definition of fatigue and the fact that it is considered to be physical or mental. The second chapter contains the main causes of fatigue, with the greater being the lack of sleep. In addition, information is included about the correct way of sleep and the sleep stages that we pass during our sleep sessions. In the third chapter, I speak about the effects that the fatigue can have on our bodies and our brain. Some maritime accidents are included where the fatigue was the primary contributory factor. Finally the last chapter contains information on how to reduce fatigue or how to manage it when it already exists in order to mitigate its' effects.

1. What is the fatigue?

The word fatigue is used to describe a range of disorders and sufferings, varying from a general state of lethargy to a specific work-induced burning sensation within one's muscles.

"Physiologically, "fatigue" describes the inability to continue functioning at the level of one's normal abilities." (Hawley et al 1997)

"Interest in fatigue, including lack of sleep, as a factor in accidents at sea has in recent years grown". (IMO, STW37/INF.5, NOV 2005)

1.1. <u>Definition of fatigue</u>

International Maritime Organization (IMO) guidelines define fatigue as: “A reduction of physical and/or mental condition, resulting from physical stress. It may impair almost all psycho-physical abilities including: power, speed, reaction time, coordination, decision making, and/or emotional balance”. Fatigue is the consequence of long working days with work shifts, insufficient number of personnel, and inadequate qualification of the subordinate crewmembers. Work shifts and unpredictability, which are typical features of life at sea, may lead to fatigue and therefore to a high risk of accidents, also of psycho- emotional nature.

Fatigue (which is also called exhaustion, tiredness, languidness, languor, lassitude, and listlessness) is a subjective feeling of tiredness which is distinct from weakness, and has a gradual onset. Unlike weakness, fatigue can be alleviated by periods of rest. Fatigue can have physical or mental causes. Physical fatigue is the transient inability of a muscle to maintain optimal physical performance, and is made more severe by intense physical exercise Mental fatigue is a transient decrease in maximal cognitive performance resulting from prolonged periods of cognitive activity. It can manifest as somnolence, lethargy, or directed attention fatigue

Medically, fatigue is a non-specific symptom, which means that it has many possible causes. Fatigue is considered a symptom, rather than a sign because it is a subjective feeling reported by the patient, rather than an objective one that can be observed by others. Fatigue and 'feelings of fatigue' are often confused

Often, the symptom of fatigue has a gradual onset and the person may not be aware of how much energy they have lost until they try to compare their ability to complete tasks from one time frame to another. They may presume that their fatigue is due to aging and ignore the symptom. This may lead to a delay in seeking care.

1.2. <u>Types of fatigue</u>

1.2.1 <u>Physical Fatigue</u>

Physical fatigue, or muscle fatigue, is the temporary physical inability of a muscle to perform optimally. The onset of muscle fatigue during physical activity is gradual, and depends upon an individual's level of physical fitness, and also upon other factors, such as sleep deprivation and overall health. It can be reversed by rest. Physical fatigue can be caused by a lack of energy in the muscle, by a decrease of the efficiency of the neuromuscular junction or by a reduction of the drive originating from the central nervous system. The central component of fatigue is triggered by an increase of the level of serotonin in the central nervous system. During motor activity, serotonin released in synapses that contact motoneurons promotes muscle contraction. During high level of motor activity, the amount of serotonin released increases and a spillover occurs. Serotonin binds to extrasynaptic receptors located on the axon initial segment of motoneurons with the result that nerve impulse initiation and thereby muscle contraction is inhibited.

Muscle strength testing can be used to determine the presence of a neuromuscular disease, but cannot determine its etiology. Additional testing, such as electromyography, can provide diagnostic information, but information gained from muscle strength testing alone is not enough to diagnose most neuromuscular disorders.

People with multiple sclerosis experience a form of overwhelming lassitude or tiredness that can occur at any time of the day, for any duration, and that does not necessarily recur in a recognizable pattern for any given patient, referred to as "neurological fatigue".

1.2.2 Mental Fatigue

Mental fatigue is a temporary inability to maintain optimal cognitive performance. The onset of mental fatigue during any cognitive activity is gradual, and depends upon an individual's cognitive ability, and also upon other factors, such as sleep deprivation and overall health. Mental fatigue has also been shown to decrease physical performance. It can manifest as somnolence, lethargy, or directed attention fatigue. Decreased attention is known as ego depletion and occurs when the limited 'self-regulatory capacity' is depleted. It may also be described as a more or less decreased level of consciousness In any case, this can be dangerous when performing tasks that require constant concentration, such as operating large vehicles. For instance, a person who is sufficiently somnolent may experience microsleep. However, objective cognitive testing can be used to differentiate the neurocognitive deficits of brain disease from those attributable to tiredness.]

The perception of mental fatigue is believed to be modulated by the brain's reticular activating system (RAS).

Causes of fatigue

2.1 Fatigue on a seagoing ship

Fatigue is a problem for all 24-hour a day transportation modes and industries, the marine industry included. However, there are unique aspects of seafaring that separate the marine industry from the others.

It must be recognized that the seafarer is a captive of the work environment. Firstly, the average seafarer spends between three to six months working and living away from home, on a moving vessel that is subject to unpredictable environmental factors (i.e. weather conditions). Secondly, while serving on board the vessel, there is no clear separation between work and recreation. Thirdly, today's crew is composed of seafarers from various nationalities and backgrounds who are expected to work and live together for long periods of time. The operational aspects associated with shipping become more complex compared with standard industries, for reasons such as: variety of ship-types, pattern and length of sea passage, port-rotation, and length of time a ship remains in port. All these aspects present a unique combination of potential causes of fatigue.

The most common cause of fatigue known to seafarers (and not only) is the lack of good quality and quantity of sleep. Of course and there are plenty more facts that can cause one person to feel tired all the time, such as stress, excessive workload and environmental factors.

There are many ways to categorize the causes of fatigue. To ensure thoroughness and to provide good coverage of most causes, they have been categorized into 4 general factors.

- Crew-specific Factors
- Management Factors (ashore and aboard ship)
- Ship-specific Factors

- Environmental Factors

<u>2.1.1 The Crew-Specific Factors:</u> are related to lifestyle behavior, personal habits and individual attributes. However, fatigue varies from one person to another and its effects are often dependent on the particular activity being performed. The Crew-specific Factors include Sleep and Rest, Quality/ Quantity and Duration of Sleep, Sleep Disorders/Disturbances, Rest Breaks, Fear, Monotony and Boredom, Diet, Illness, Skill, knowledge and training as it relates to the job, Personal problems, Interpersonal relationships. Only sleep can maintain or restore performance level of the crew. When the crew does not get enough sleep, fatigue will set in and alertness will be impaired. Poor quality of sleep also may cause fatigue. Apart from sleep, rest (taking a break) between works periods can contribute to restoring performance levels. Insufficient rest periods or postponing assigned rest times (to finish the job early) can cause fatigue. Disturbances while resting such as being woken up unexpectedly, on call (during port operations), or unpredictable work hours (when arriving in port) can cause fatigue. Stress can be caused by personal problems (family), problems with other shipmates, long work hours, work in general, etc. A build up of stress will cause or increase fatigue. Boredom can cause fatigue. You may become bored to the point of fatigue when your work is repetitive and monotonous and/or bodily movement is restricted. To work with an international crew who belongs to various nationalities, speaking in different languages is a difficult task to deal with, when it comes to a situation where you find a communication barrier to make others to understand what your requirements and needs are. Sometimes the crew has to deal with uneducated and inexperienced staff where one may find it stressful to carry out day today operations, in giving instructions and making them to understand what one really require out of a staff member. It is unbearable for a crew member when he realizes that his family needs his presence to help the family members in difficult situations. Being away from the loved ones and the family for a long period is very stressful. It is very unfortunate to note that most of the senior officers are compelled to manipulate the ILO regulations with regard to the rest hours for the crew.

2.1.2 The Management Factors: related to how ships are managed and operated. These factors can potentially cause stress and an increased workload, ultimately resulting in fatigue. These factors include: Organizational Factors such as Staffing policies and Retention, Role of riders and Shore personnel, Paperwork requirements, Schedules-shift, Overtime, Breaks, Company culture and Management style, Rules and Regulations, Upkeep of vessel, Training and Selection of crew. Seafarers are compelled to work more than the specified number of hours, sometimes in excess of 20 hours due to various reasons, such as scarcity of man power, long pilotage and during long manoeuvring hours in canals, fairways, transits etc. which affect the physical and mental stability and efficiency of the crew. Nowadays, for most of the ships, port stays are very short especially in Japanese, Chinese and European ports. Most of the times vessels shift from port to another within a very short period and as a result short spells of loading/unloading, frequent arrival/departure and continuous ship operations cause lot of stress and fatigue to crew members on board ship. Voyage and scheduling factors such as frequency of port calls, time between ports, routing, weather and sea condition on route, traffic density en route and nature of duties/workload while in port cause stress and fatigue.It is being reported that it is very stressful for the crew when the Port State Control (PSC) officers and other Inspectors visit the ship for inspections such as wetting and safety inspections, when the crew is busy with the cargo operations and the administrational work/paper work simultaneously. Most of the ship Masters are autocratic and very demanding. In some instances when you analyze some of the Masters' behaviour is questionable and unacceptable. Due to this fact the crew has to go through lot of hardships during their contract on board. There are some ship design features that can affect/cause stress and fatigue.

2.1.3 Ship-specific Factors: Some ship design features such as automation, equipment reliability affect work load. Some affect the crew's ability to sleep, and others affect the level of physical stress on the crew (i.e. noise, vibration, accommodation spaces, etc.). The following list details ship-specific factors: ship design, Level of Automation, Level of Redundancy, Equipment reliability, Inspection and Maintenance, Age of vessel and Physical comfort in work spaces, Location of quarters, ship motion and Physical comfort of accommodation spaces. Noise or vibration can affect one's ability to sleep/rest, and it can affect the level of physical stress thus causing fatigue. The ship's movement affects the ability to maintain physical balance. Maintaining balance requires extra energy, which can then cause fatigue. A ship's pitching and rolling motions would need 15-20% extra effort to maintain the balance.

2.1.4 Environmental factors: can also be divided into factors external and internal to the ship. Within the ship, the crew is faced with elements such as noise, vibration and temperature (heat, cold, and humidity) and social life among the crew members. External factors include port condition and weather condition and vessel traffic. Exposure to excess levels of environmental factors, e.g. temperature, humidity, excessive noise levels, can cause or affect stress and fatigue. Long-term exposure may even cause harm to a person's health. Furthermore, considering that environmental factors may produce physical discomfort as the temperatures at the northern edge can be totally different to that on the southern edge, same time it defers from continent to continent and country to country. Extremes of temperature are experienced between very short periods by the seafarers if a ship sails from Africa to Europe, the warmest usually ranging from 30^0 C to 35^0 C and the coldest usually ranging from -17^0C to -25^0C respectively. Therefore, every seafarer will find it difficult to acclimatize to these extreme conditions. Excessive noise levels can also cause or contribute to the disruption of sleep. Ship motion is also considered an environmental factor. Motion affects a person's ability to maintain physical balance. This is due to the extra energy expended to maintain balance while moving, especially during harsh sea conditions. There is a direct relationship between a ship's motion and a person's ability to work. Excessive ship movement can also cause motion sickness.

By analyzing the sleep factor we come with that some of the sleep issues that the seamen have to face:

2.2 Sleep factors

2.2.1 Sleeping disturbances

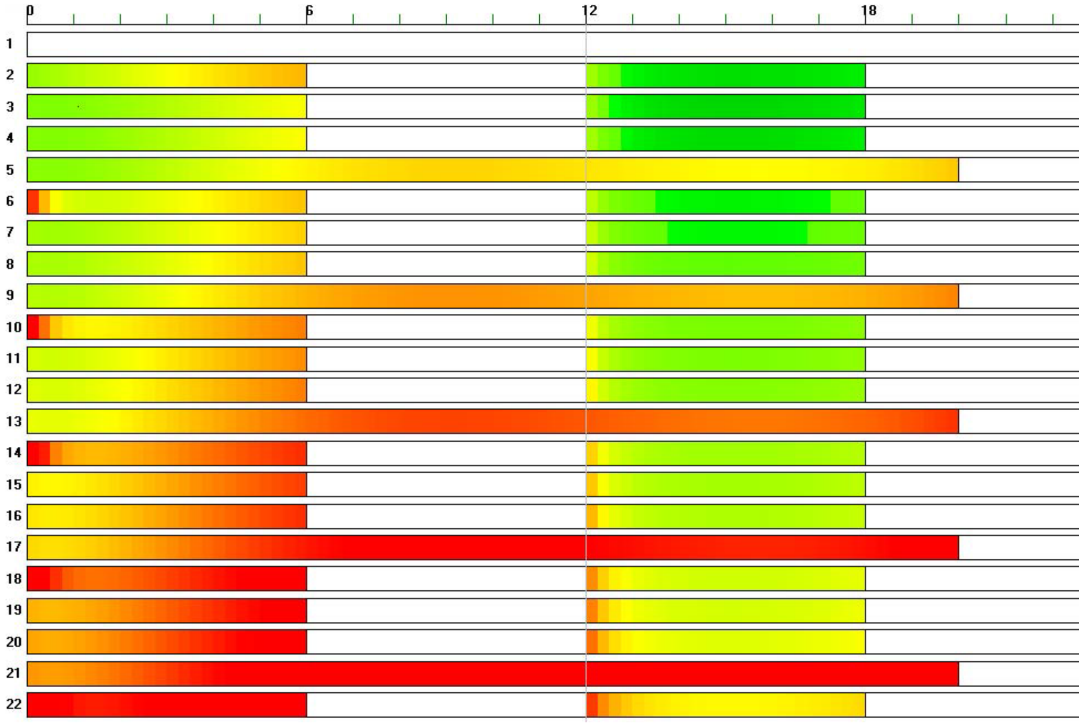
Sleep of enough duration and quality is necessary for psychological wellbeing. Sleep is based on circadian rhythms according to an approximately 24-hour cycle. If this rhythm is impaired it is possible to feel sleepy when it is necessary to be awake or to feel awake at the sleeping time. A large proportion of seafarers refer to not sleeping well and to having rest continuously interrupted. This phenomenon, similar to the so-called “jet lag”, is experienced primarily by seafarers sailing on board of ships rapidly crossing several time zones. Seafarers working on transoceanic ships complain of having 2 or even 3 episodes of awakening during sleep and they show a circadian predicted dip in alertness in the nighttime. A pronounced dip of alertness is also noticeable in the afternoon with an increase of accident risk. Seafarers’ work requires a shift system, which has a negative impact on circadian rhythms. Working on 24-hour shift patterns on a moving vessel poses a number of obstacles to gain sufficient restorative sleep. Crew may have to work additional hours, sleep when their bodies feel naturally awake, and face disturbances from vessel activity. In a recent interview, fatigue effects were investigated in a sample of seafarers. Participants worked on a 6-on, 6-off watch system or on 4-on, 8-off watch system. Sleepiness was higher in those working with the 6-on, 6-off system, and also fatigue increased during the watch. The effect in the 4-on, 8-off system was, inversely, less evident. A trend was also found toward short sleep episodes in the 6-on, 6-off system where sleep was more often split in two episodes. Environmental factors of the ship such as noise, vibration, and adverse weather conditions can impair sleep quality. Sleep disturbances related to noise may vary depending on the place in which the seafarers sleep and on their age. Younger people are more sensitive to noise and therefore more prone to sleep complaints. Sleep disturbances can also lead to mood, cognitive and perceptive abilities disorders. These situations increase the risk of accidents

2.2.2 Irregular Schedules

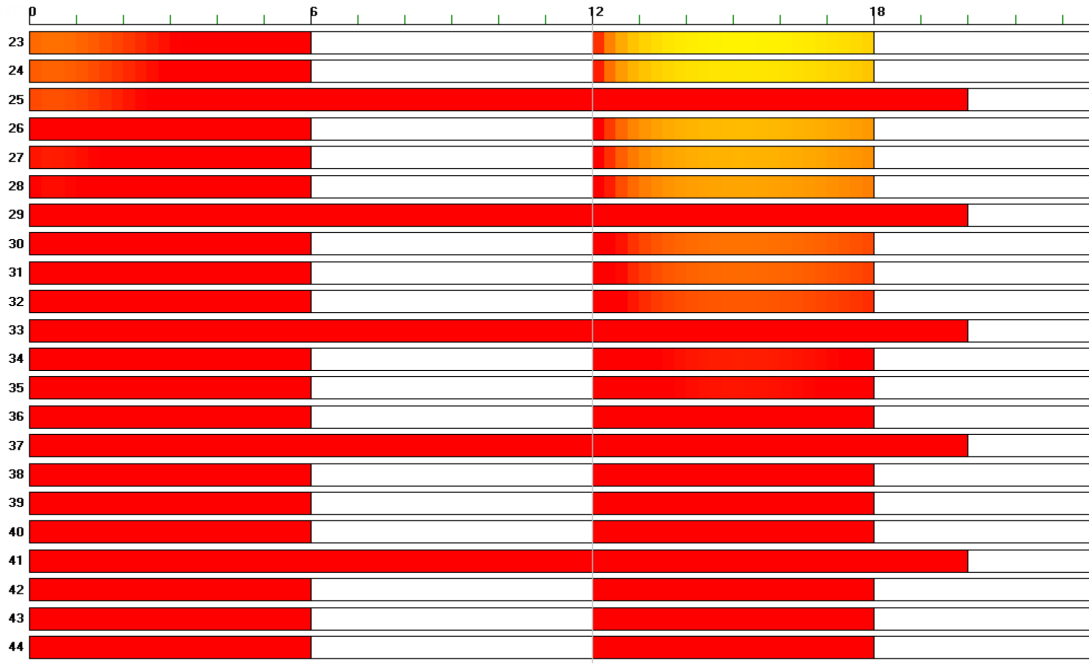
Those mariners who work at night and sleep during daytime has a reduced alertness during their work due to the natural tendency of the body (circadian rhythm).

In this case the day time sleeping is not restorative since the body tries to stay awake during day time. The body can adjust to a change in schedule, but it takes a few days for the adjustment. If there is an abrupt change in the shift schedule it puts the body out of synchronization with body's circadian rhythm.

All these problems exist in almost every vessel but their effects are more visible in vessels that do costal navigation or have only two watching officers.



This slide shows that cumulative fatigue that develops over a three week period for the chief mate working 6 on 6 off on a ship that is in port every 4 days. Fairly artificial scenario – many ships that operate around our coasts are in port more often and the ability of this officer to get his rest is even less. However, even under these conditions, fatigue accumulates overtime such that by day 22 its impact is critical



If you extend the period a further 3 weeks you can see that , using a tool designed for airline personnel, the situation becomes very bad indeed….if this officer were an aviator he would not be permitted to fly!

In addition plenty mariners although they have sufficient quantity of sleep they do not feel rested, because their sleep is disturbed. In order for the body to rest properly it require restorative sleep to be alert, restorative sleep has four elements:

1 .Duration; an average adult requires 7 to 8 hours sleep in a 24 hour period.

2. Continuity; the sleep period must be continuous and without interruptions.

3. Quality; five stages of any sleeping cycle must be complete as each stage provides a different benefit.

4. Time of day; sleeping during the night has higher quality than during the day.

During the sleeping session the human body cycles through different levels of sleep According to various researches there are two types of sleep.

All the informations come from http://www.howsleepworks.com

2.3 Stages of sleep

2.3.1 Non-REM sleep, which is perhaps best defined negatively as any sleep not recognizable as **REM sleep**, consists of three separate stages (stage1, stage 2 and stage 3), which are followed in order upwards and downwards as sleep cycles progress. Formerly, four stages of non-REM sleep were distinguished, and most older hypnograms therefore usually show four stages of non-REM sleep, rather than three; the distinction can be quite useful at times, and is still quite widely used, even though three stages is now the "official" categorization. It should be noted that the distinctions between these sleep stages are somewhat arbitrary anyway, and the physiological boundaries between them are necessarily blurred and continuous.

Stage 1 (NREM1 or N1) is the stage between wakefulness and sleep, sometimes referred to as somnolence or drowsy sleep, in which the muscles are still quite active and the eyes roll around slowly and may open and close from time to time. In more scientific terms, stage 1 is the period of transition from relatively unsynchronized beta and gamma brain waves (with a frequency of 12-30 Hz and 25-100 Hz respectively), which is the normal range for the awake state, to more synchronized but slower alpha waves with a frequency of 8-13 Hz, and then to theta waves with a frequency of 4-7 Hz. It is difficult to pinpoint the actual point of sleep onset (falling asleep), as the process is a continuum as brain wave activity gradually slows down.

During stage 1 sleep, breathing gradually becomes more regular and the heart rate begins to slow. Dreaming is relatively rare during this stage, but sudden twitches or hypnic (hypnagogic) jerks (sudden short micro-awakenings often accompanied by a falling sensation) are quite common, the last gasps of waking control before sleep takes over. During this short period of very light, easily disrupted sleep, usually lasting less than 10 minutes, the sleeper may be aware of sounds and conversations, but feels unwilling, rather than unable, to respond to them. A person awakened during this period will often believe they have never slept at all. Typically, this stage represents only about 5% of the total sleep time.

Stage 2 (NREM2 or N2) is the first unequivocal stage of sleep, during which muscle activity decreases still further and conscious awareness of the outside world begins to fade completely. If any sounds are heard, the sleeper is not able to understand their content at this point. Brain waves during stage 2 are mainly in the theta wave range (as in stage 1 sleep), but in addition stage 2 is also characterized by two distinguishing phenomena: sleep spindles (short bursts of brain activity in the region of 12-14 Hz, lasting maybe half a second each, also known as sigma waves) and Kcomplexes (short negative high voltage peaks, followed by a slower positive complex, and then a final negative peak, with each complex lasting 1-2 minutes) - see the diagram at right. Together, these serve to protect sleep and suppress response to outside stimuli, as well as to aid in sleep-based memory consolidation and information processing. Because sleepers pass though this stage several times during the night, more time is spent in stage 2 sleep than in any other single stage, and it typically constitutes about 45%-50% of total sleep time for adults (or even more in young adults).

Stage 3 (NREM3 or N3) is also known as deep or delta or slow-wave sleep (SWS), and during this period the sleeper is even less responsive to the outside environment, essentially cut off from the world and unaware of any sounds or other stimuli. Stage 3 sleep occurs in longer periods during the first half of the night, particularly during the first two sleep cycles, and represents around 15%-20% of total adult sleep time. Stage 3 is characterized by delta brain waves with a frequency of around 0.5-4 Hz, along with some sleep spindles, although much fewer than in stage 2. Historically, what is now usually described as stage 3 (following the guidelines of the American Academy of Sleep Medicine) was split into two stages, stage 3 and stage 4, depending on the frequency of delta waves (stage 4 was initially defined as when delta waves exceeded 50% of the total).

As well as neuronal activity, other physical indicators such as brain temperature, breathing rate, heart rate and blood pressure are all at their lowest levels during stage 3 sleep. Dreaming is more common during this stage than in the other non-REM sleep stages, although not as common (nor as vivid and memorable) as during REM sleep. This is also the stage during which parasomnias like night terrors, sleep-walking, sleep-talking and bedwetting occur. Information processing and memory consolidation (particularly of the declarative memory) also takes place during this period, as it also does to some extent during the stage 2 and REM stages. It is much more difficult to wake a person during stage 3 sleep, and if awakened at this stage they will often feel very groggy and may take up to 30 minutes before they attain normal mental performance (known assleep inertia). Children and young adults tend to have more slow-wave stage 3 sleep than adults, and the elderly may experience little or no stage 3 sleep at all.

2.3.2 REM sleep occurs in cycles of about 90-120 minutes throughout the night, and it accounts for up to 20-25% of total sleep time in adult humans, although the proportion decreases with age (a newborn baby may spend 80% of total sleep time in the REM stage). In particular, REM sleep dominates the latter half of the sleep period, especially the hours before waking, and the REM component of each sleep cycle typically increases as the night goes on.

As the name suggests, it is associated with rapid (and apparently random) side-to-side movements of the closed eyes, a phenomenon which can be monitored and measured by a technique called electrooculography (EOG). This eye motion is not constant (tonic) but intermittent (phasic). It is still not known exactly what purpose it serves, but it is believed that the eye movements may relate to the internal visual images of the dreams that occur during REM sleep, especially as they are associated with brain wave spikes in the regions of the brain involved with vision (as well as elsewhere in the cerebral cortex).

Brain activity during REM sleep is largely characterized by low-amplitude mixed-frequency brain waves, quite similar to those experienced during the waking state - theta waves, alpha waves and even the high frequency beta waves more typical of high-level active concentration and thinking. These show up as the typical "saw-tooth" brain wave pattern on an electroencephalogram (EEG) and, because of these similarities with the waking state, REM sleep has earned the moniker "paradoxical sleep". The brain's oxygen consumption, reflecting its energy consumption, is also very high during this period, in fact often higher than when awake and working on a complex problem.

Breathing becomes more rapid and irregular during REM sleep than during non-REM sleep, and the heart rate and blood pressure also increase to near waking levels. Core temperature is not well regulated during this time and tends towards the ambient temperature, in much the same way as reptiles and other cold-blooded animals. Sexual arousal is also common during REM sleep and the male penis and female clitoris become aroused and erect for substantial periods during this sleep stage, regardless of whether or not any dreams in progress are of an erotic nature.

Although the muscles become more relaxed during non-REM sleep, they become completely paralyzed and unresponsive during REM sleep. This virtual absence of muscle tone and skeletal muscle activity is known as atonia, and it occurs because the brain impulses that control muscle movement are completely suppressed (other than those controlling the eye movements and one or two other essential functions, like the heart, diaphragm, etc, that allow us to breathe and remain alive). The source of these inhibitory signals (which utilize the neurotransmitter norepinephrine) is in a specific part of the pons region of brainstem called the locus coeruleus.

The majority of dreams - certainly the most memorable and vivid dreams - occur during REM sleep, and it is thought that the muscular atonia that accompanies it may be a built-in measure to protect us from self-damage which could occur while physically acting out these vivid REM dreams. This hypothesis is borne out by Michel Jouvet's early experiments on cats in which the muscle inhibition nerves were severed, leading these cats to physically stalk invisible prey and run and jump around wildly during the dreams of REM sleep.

Neurologically, REM sleep is activated by secretion of the neurotransmitter acetylcholine and inhibited by the neurotransmitter serotonin, and this effect is principally generated in the pons region of the brainstem. In experiments on animals, it has been shown that the surgical destruction of a particular group of nerve cells in the pons can eliminate REM sleep completely, suggesting that the active function of these cells (rather than merely the deactivation of wakefulness mechanisms) is necessary for REM sleep.

of REM sleep leads to surprisingly few negative effects on behaviour, it has been shown to impair the ability to learn complex tasks, suggesting that REM sleep is a vital component of our sleep patterns, particularly during early childhood development, when REM sleep makes up a much larger percentage of total sleep. This is backed up by the fact that, if REM sleep is repeatedly interrupted or shortened, then longer REM "rebound sleep" tends to occur at the next opportunity in compensation (instead of slowly moving through the various stages of non-REM sleep first, the sleeper slips quickly into REM sleep, and stays there longer than usual).

Some memory consolidation, particularly of procedural and spatial memory, also takes place during this stage, although perhaps not to the same extent as during the deeper, later stages of non-REM sleep. It has been noted that people tend to spend more time than usual in REM sleep following days when they have been in unusual situations requiring them to learn a lot of new tasks.

Although most people do not tend to wake after each cycle of REM sleep, as some animals do, we are more likely to wake from REM sleep than from non-REM sleep. Usually, these "micro-awakenings" are of a few seconds only, and the sleeper does not normally remember them. If over-stimulated, though, a person may wake up fully, and it may take the length of an entire sleep cycle (1.5 - 2 hours) to get back to sleep.

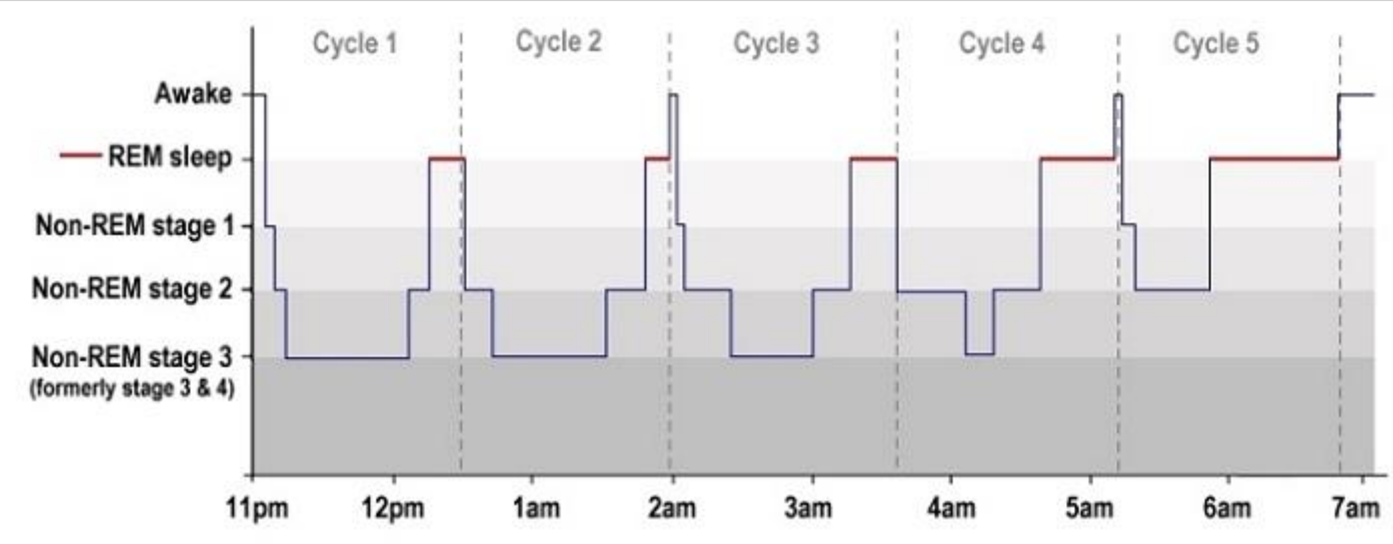
Although it is usually assumed that REM sleep (and the dreams that go with it) is a physiological necessity, recent findings have muddied the waters somewhat. For example,in cases of REM sleep deprivation, individuals tend to compensate by dreaming more during non-REM sleep. Animals deprived of REM sleep for as long as two months seem to be able to continue with very little perceptible behavioural or physiological injury, and humans taking certain antidepressant medications that result in little or no REM sleep also show few apparent negative consequences.

It has been known that sleep goes in cycles since as early as 1937, and the distinction between REM and non-REM sleep was established in 1953. Since then, the various sleep stages have been defined and redefined until we have the breakdown of types and stages we know today, as has been described in the preceding sections.

The particular sleep architecture of an individual over the course of an average night - the overall sleep time, the structure and pattern of sleep stages and phases, the time spent in non-REM and REM sleep, the timing and organization of sleep cycles, etc - is best illustrated by means of a hypnogram (see example below), a simplified graphical representation of the results obtained from a more detailed polysomnogram over a complete sleep period.

Sleep progresses in a series of four or five more or less regular sleep cycles of non-REM and REM sleep throughout the night, sometimes referred to as ultradian rhythms ("ultradian" meaning within a day). The first sleep cycle is typically around 90 minutes in length, with the succeeding cycles averaging around 100-120 minutes, although some individuals may have longer or shorter average cycles, and they are usually shorter in children. Each cycle follows the stages of non-REM sleep (stage 1 -

stage 2 - stage 3) and then, after a period in deep stage 3 slow-wave sleep, back through the stages (stage 3 - stage 2 - stage 1). Then, instead of waking, the sleeper may enter a short period of REM sleep, before going back through the stages (stage 1 - stage 2 - stage 3) in a new cycle (see the hypnogram below). As the night progresses, the time spent in deep stage 3 sleep decreases and the time spent in REM sleep increases, so that there is a greater proportion of stage 3 sleep earlier in the night, and a greater proportion of REM sleep later in the night, particularly during the final two sleep cycles.



A typical hypnogram showing sleep stages and cycles in adult sleep (image by Luke Mastin)

Generally speaking, the deeper the level of sleep, the slower, stronger and more synchronized the brain waves become, so that a sleep cycle can also be thought of as a progression from the beta and gamma waves of wakefulness, through alpha and theta waves, to the delta waves of slow-wave sleep (and back again). Also, the deeper the level of sleep in the cycle, the higher the arousal threshold, so that it is quite difficult to wake someone in stage 3 sleep, but relatively easy in stage 1 or REM sleep. There is also a general tendency towards decreased muscle tone as deeper and deeper sleep stages are achieved, although in this case REM sleep is anomalous in that muscle tone is at its lowest during that stage (despite its relatively high brain wave activity and low arousal threshold).

Each sleep stage in any particular sleep cycle fulfills a distinct physiological and neurological function, each of which appears to be necessary for the health of the body and mind, to the extent that, if sleep is interrupted or if certain stages are missing for any reason, their physiological functions are not fully executed, and the person may feel tired or groggy even after an apparently sufficient sleep period, a phenomenon known as "sleep inertia”. In recent years, special alarm clocks have become available which purport to monitor a person’s sleep stages and cycles and only wake them during periods of light sleep, when the deleterious effects of this sleep inertia are least acute.

When our sleep is disturbed or when someone works night hours for example the watch officers of the 00:01-04:00 and 04:00 – 00:08 their circadian rhythm is getting disturbed and is harder for them to get enough and proper rest.

Our internal circadian biological clocks regulate the timing of periods of sleepiness and wakefulness throughout the day. The circadian rhythm dips and rises at different times of the day, so adults' strongest sleep drive generally occurs between 2:00-4:00 am and in the afternoon between 1:00-3:00 pm, although there is some variation depending on whether you are a “morning person” or “evening person.” The sleepiness we experience during these circadian dips will be less intense if we have had sufficient sleep, and more intense when we are sleep deprived. The circadian rhythm also causes us to feel more alert at certain points of the day, even if we have been awake for hours and our sleep/wake restorative process would otherwise make us feel more sleepy.

In addition to the stages of sleep that if they are disturbed the person will not feel fully rested another important thing that we must consider is the circadian rhythm or biological clock.

2.4 Circadian rhythm

All the informations come from http://www.howsleepworks.com

All animals and plants have a built-in circadian rhythm, which is adjusted or entrained to the environment by external cues, known as Zeitgebers (a German word meaning “time-givers"), the most important of which is daylight. The brain’s internal circadian clock (also known as the biological clock, body clock, circadian pacemaker, circadian system, circadian oscillator, etc), which is centred in the hypothalamus region of the basal forebrain, uses these Zeitgebers to naturally synchronize or reset itself each day to within just a few minutes of the Earth’s 24-hour rotation cycle (the word “circadian” comes from the Latin words meaning “about a day”).

Early research in the 1960s and 1970s (including some famous experiments in caves) had concluded that the natural “free-running” circadian period of human beings was around 25 hours, not the expected 24 hours. However, later research (like that of Charles Czeisler *et al* in 1999) showed that these experiments were flawed, and that even the presence of electric lighting was enough to skew the results. It is now clear that, although individual circadian periods do vary - ranging between 23.5 and 24.5 hours in humans, dependent on variations in the person’s PER or period gene - they have a mean of around 24.2 hours, just slightly more than the Earth’s rotation. About 25% of people have a circadian period which is slightly less than the 24-hour day, and 75% have a circadian period slightly more than 24 hours.

The brain’s circadian clock regulates sleeping and feeding patterns, alertness, core body temperature, brain wave activity, hormone production, regulation of glucose and insulin levels, urine production, cell regeneration, and many other biological activities. The most important hormones affected by the circadian clock, at least insofar as they affect sleep, are melatonin (which is produced in the pineal gland in the brain, and which chemically causes drowsiness and lowers body temperature) and cortisol (produced in the adrenal gland, and used to form glucose or blood sugar and to enable anti-stress and anti-inflammatory functions in the body).

Growth hormone, essential to the repair and restoration processes of the body, is also secreted during sleep, particularly during deep non-REM sleep, as are other hormones like testosterone. Thyrotropin (or thyroid-stimulating hormone), on the other hand, is actively inhibited or suppressed during sleep. However, unlike melatonin and cortisol (which are almost entirely dependent on the circadian clock, regardless of whether an individual actually sleeps or not), these hormonal effects appear to be regulated by actual sleep and not by circadian rhythms *per se*.

Humans are diurnal animals, naturally active during the daytime, and our circadian rhythms reflect this. Generally speaking, for sleep to occur in the "right" part of the circadian cycle, the time of minimum core body temperature and maximum melatonin concentration should occur towards the end of the sleep period. As a rough guide, core temperature usually reaches its minimum around 4:30-5:00am in the morning in human adults, and melatonin (normally completely absent during daylight hours) typically begins to be produced around 8:00-9:00pm at night and stops around 7:00-8:00am in the morning (see diagram below). The deepest tendency to sleepiness occurs in the middle of the night, around 2:00-3:00am, along with a shorter and shallower period of sleepiness (often referred to as the "post-lunch dip") about twelve hours later, around 2:00-3:00pm in the afternoon.

Physically, the circadian clock is located in the suprachiasmatic nucleus (SCN) in the hypothalamus of the brain, one in each brain hemisphere. The SCN is a tiny pinhead-sized area, containing just 20,000 or so very small neurons, but it has the responsibility for sending signals to several other parts of the brain to regulate the daily sleep-wake cycle, body temperature, hormone production and other functions. In fact, the individual neurons that make up the SCN have been found to exhibit a near-24-hour rhythm of activity, suggesting that the clock mechanism actually works on a sub-cellular level. When dissociated from the SCN, the individual cells follow their own intrinsic 24-hour rhythms, but, when incorporated into the SCN, they all fire in synchrony. In experiments on mice where the SCN is completely removed, the mice (which are normally much more active during the nighttime and sleep more during the day) show little or no preference for their active time and sleep time, and their activity is sporadic and apparently random throughout the day and night.

The circadian clock checks its accuracy each day using external Zeitgebers, principally the light-dark cycle. Exposure to natural daylight stimulates a nerve pathway from special photoreceptive ganglion cells in the retina of the eye, cells that are totally separate from the rods and cones our eyes use to generate our everyday image of the world. These cells contain a unique light-sensitive pigment called melanopsin, and are most sensitive to short wavelength “blue light”. Even many blind people can respond to these light-dark cues, as the photoreceptive cells in their eyes can usually recognize daylight, even through closed eyelids. The light-dark signals are sent via the optic nerve to the suprachiasmatic nucleus, which uses them to reset its own circadian clock each day.

The biological clock does not actually require light to function, and the circadian cycle persists quite accurately even when individuals are completely cut off from daylight. The light-dark cycle (in concert with other Zeitgebers like meals, ambient temperature, etc), merely acts as an external cue to resynchronize or entrain the timing of biological rhythms, and to prevent small timing errors from accumulating. Without this important check, the circadian system can become seriously unbalanced. For example, the much dimmer illumination of artificial lights is not usually sufficient to trigger this reset of the circadian clock, which is why night shift workers never really fully adapt to their unnatural sleep patterns (see the section on Shift Work). It has been shown that simply increasing day-time lighting intensity in workplaces and care homes for the elderly can significantly improve their sleep regimes, reduce cognitive decline and improve mood disorders.

The irregular sleep patterns of newborn babies occur because circadian rhythms take some to develop, and most infants have established a more or less regular sleep-wake cycle by three to six months of age. Interestingly, some Arctic animals only show evidence of circadian rhythms during the times of year with more or less regular sunrises and sunsets (spring and fall), while others have been shown even to maintain their circadian rhythms through extended periods of sunlight or darkness. For people living in far northern locations, other Zeitgebers such as meal times, alarm times, house lights, etc, become relatively more important, so that people living in Alaska or northern Sweden can still function more or less normally during the long darkness of winter.

As well as regulating hormone production, body temperature, etc, the SCN also sends out an alerting pulse throughout the day (sometimes referred to as the circadian alerting system) which counteracts the increasing homeostatic sleep pressure. These alerting pulses from the SCN reach their peak about 2-3 hours before one's habitual bedtime (sometimes referred to as the "wake maintenance zone"), which serves to offset the homeostatic drive that has been continually accumulating throughout waking hours, allowing for continued alertness late into the evening. As the evening progresses, though, the SCN's alerting pulses start to weaken, melatonin production in the pineal gland increases (also under the direction of the SCN), and the "sleep gate" (also known as the primary sleepiness zone or sleep onset zone) opens, and the urge to sleep increases dramatically.

There are also other secondary or peripheral biological clocks throughout the body, such as in the liver, heart, pancreas, kidneys, lungs, intestines, and even in the skin and lymphocytes, all of which show natural daily oscillations. These organs are largely entrained independently by factors like the timing of meals, ambient temperatures, etc, rather than by the light-dark cycle, but the central coordination and synchronization of these secondary body clocks is still carried out by the suprachiasmatic nuclei. The main circadian system in the SCN in turn receives multiple feedbacks from these various organs, in a complex system of reciprocal interactions. Chronobiology, the relatively new science of timing medical attention to various organisms of the body depending on the most propitious time of day for those particular organs, has shown very good results in improving the effectiveness of treatments.

In recent years, particular genes have been identified as being involved in the circadian cycle, and it is no surprise to find that these genes are particularly active within the cells of the suprachiasmatic nuclei, as well as within the cells of other body tissues. Scientists now estimate than between 8% and 15% of the genes in the human body operate on a 24-hour cycle. The very similar sleep architecture of closely-related individuals (especially identical twins) demonstrates the strong genetic element in sleep, and certain genes - including CLOCK, BMAL, PER, TIM and CRY, among others - have been specifically identified as being involved in the sleep process, although the exact mechanism through which they regulate sleep is still being explored. Mutations in these genes have been associated with several different sleep disorders.

Circadian rhythms may be adjusted by up to two hours or so either way according to an individual's chronotype. Some people (often known as "larks" or morning people) tend to wake up early and are most alert during the first part of the day. Others ("night owls" or evening people) are most alert in the late evening and prefer to go to bed late. By some estimates, as many as 20% of people fall into one of these two categories. In these people, the timing of their circadian period is shifted completely (an effect that is at least partly encoded in their genes), so that morning people wake at a later stage in their circadian day, and are therefore much more alert on waking; evening people, on the other hand, wake too early in their circadian day, and so are less alert and perform poorly in the morning. Typically, this variation is limited to a couple of hours earlier or later than the average; those with extreme body clocks may have difficulty participating in normal work, school or social activities, and are considered to suffer from circadian rhythm sleep disorder .

Effects of fatigue

3.1General effects of fatigue

In the previous chapter we talked about the causes that they will make us feel fatigued.

In this chapter we will talk about the effects that fatigue has on our bodies and the accidents that can occur when the officers and the ratings are fatigue and are called to carry over various tasks.

Fatigue can affect your mind, emotions and body (e.g. your capacity for tasks involving physical exertion and strength, as well as your ability to solve complex problems or make decisions, etc). Your level of alertness is dependent on fatigue, and therefore, human performance can be impaired.

In the upcoming table we will describe some of the possible effects of fatigue by listing the performance impairments and the symptoms associated with them. These signs and symptoms of fatigue may be used to identify an individual's level of alertness. It must be noted, however, that it is difficult for an individual to recognize the symptoms of fatigue within him/herself, because fatigue impairs judgment.

1	Inability to concentrate	• Unable to organize a series of activities • Preoccupied with a single task • Focuses on a trivial problem, neglecting more important ones • Reverts to old but ineffective habits • Less vigilant than usual
2	Diminished decision-making ability	• Misjudges distance, speed, time, etc. • Fails to appreciate the gravity of the situation • Overlooks items that should be

		included • Chooses risky options • Difficulty with simple arithmetic, geometry, etc.
3	Poor memory	• Fails to remember the sequence of task or task elements • Difficulty remembering events or procedures • Forgets to complete a task or part of a task
4	Slow response	• Responds slowly (if at all) to normal, abnormal or emergency situations
5	Loss of control of bodily movements	• May appear to be drunk • Inability to stay awake • Affected speech e.g. it may be slurred, slowed or garbled • Feeling heaviness in the arms and legs • Decreased ability to exert force while lifting, pushing or pulling • Increased frequency of dropping objects like tools or parts
6	Mood change	• Quieter less talkative than usual • Usually irritable • Increased intolerance and anti-social behavior • Depression
7	Attitude change	• Fails to anticipate danger • Fails to observe and obey warning signs • Seems unaware of own poor

		performance • Too willing to take risks • Ignores normal checks and procedures • Displays a “don’t care” attidute • Weakness in drive or dislike for work

In addition to the behavioral changes listed in the table (symptoms), there are also a number of other changes associated with fatigue that will manifest as physical discomfort, such as:

- Headaches
- Giddiness
- Heart palpitations / irregular heart beats
- Rapid breathing
- Loss of appetite
- Insomnia
- Sudden sweating fits
- Leg pains or cramps
- Digestion problems

When an officer or rating acknowledge these symptoms to him/her or to others and just ignores them the results can be catastrophic. There are plenty marine accidents that one of the many causes that leaded to the accident was the fatigue.

3.2 Accidents due to fatigue

We will talk about some accidents that happened due to fatigue.

3.2.1 Shen Neng 1

First we have the grounding of Shen Neng 1.

At 1705 on 3 April 2010, the Chinese registered bulk carrier *Shen Neng 1* grounded on Douglas Shoal, about 50 miles north of the entrance to the port of Gladstone, Queensland. The ship's hull was seriously damaged by the grounding, with the engine room and six water ballast and fuel oil tanks being breached, resulting in a small amount of pollution.

Watch keepers on the bulk carrier Sheng Neng 1 were so fatigued after supervising the loading of coal at Australia's Gladstone port that they were not fit to carry out a navigational watch, concludes the Australian Transport Safety Board's investigation into the subsequent grounding.

No fatigue management was in place and the grounding occurred because the chief mate did not alter the ship's course at the designated course alteration position. "His monitoring of the ship's position was ineffective and his actions were affected by fatigue", says Australia's Transport Safety Bureau (ATSB).

The ship's hull was seriously damaged by the grounding, with the engine room and six water ballast and fuel oil tanks being breached, resulting in a small amount of pollution.

The ATSB investigation found that the grounding occurred because the chief mate did not alter the ship's course at the designated course alteration position. His monitoring of the ship's position was ineffective and his actions were affected by fatigue.

The ATSB identified four safety issues during the investigation: there was no effective fatigue management system in place to ensure that the bridge watch keepers were fit to stand a navigational watch after they had supervised the loading of a cargo of coal in Gladstone; there was insufficient guidance in relation to the proper use of passage plans, including electronic route plans, in the ship's safety management system; there were no visual cues to warn either the chief mate or the seaman on lookout duty, as to the underwater dangers directly ahead of the ship; and, at the time of the grounding, the protections afforded by the requirement for compulsory pilotage and active monitoring of ships by REEFVTS, were not in place in the sea area off Gladstone.

The ATSB has issued two safety recommendations to *Shen Neng 1*'s management company regarding the safety issues associated with fatigue management and passage planning and acknowledges the safety action taken by the Australian Maritime Safety Authority in relation to the extension of REEFVTS coverage to include the waters off Gladstone.
Fatigue remains a major contributor to maritime accidents, with overworked officers on under-manned ships little little support or understanding from shore-based personnel. Efforts to improve the situation consistently meet opposition from flags of convenience, and some not-so flags of convenience.

3.2.2 Thor Gitta

Not all the marine accidents come with no human fatalities. At the 21st of May 2009 one crew member of the Thor Gitta died.

At about 09301 on 21 May 2009, a crew member on board the general cargo ship Thor Gitta was fatally injured while attempting to secure lashing bins in the cargo hold. At the time, the ship was about 390 miles2 northwest of Fremantle, Western Australia. The investigation found that a risk analysis had not been undertaken before the bins were introduced into service and that the bins had been inadequately secured in an area where there were no dedicated lashing points. It also found that the crew member was probably affected by fatigue as a result of the duty roster and the ship's movement in the heavy seas.

As a result of this accident, the ship's manager has implemented a range of measures on all its vessels to improve the security of bin lashing arrangements and manage the risks of carrying out tasks associated with operation of the bins. The company has also introduced a different rostering system to better manage the fatigue of watchkeepers when the ship is at sea. The ATSB has issued one safety recommendation to the Danish Maritime Authority relating to the use of the 6 hour on/6 hour off work routine and the effect that that work routine has on a crew member's level of fatigue.

The accident

At about 2345 on 18 May 2009, Thor Gitta commenced loading a cargo of mining equipment in Fremantle, Western Australia. The cargo included a number of trucks which were loaded into the lower hold and secured to the tank top using ratchet webbing straps.

At about 1100 on 19 May, all cargo operations were completed. The ship’s departure draughts were 3.47 m forward and 5.97 m aft. Its departure GM was 1.75 m. At 1440, a Fremantle harbor pilot boarded Thor Gitta and shortly afterwards, the ship departed its berth. At 1510, the pilot disembarked and Thor Gitta began its planned passage, which was to take the ship on a direct rhumb line track across the Indian Ocean, passing to the north of Madagascar and then onto Dar es Salaam, Tanzania. While Thor Gitta was in Fremantle, the master had been monitoring a low pressure weather system (low) in the southern Indian Ocean, to the southwest of Western Australia, which was moving eastwards. At 1900, the Australian Bureau of Meteorology (BoM) issued a forecast, valid for 24 hours, which contained a gale warning for an area within 600 miles of the low. Winds were forecast to be north-westerly to south-westerly at 15 to 25 knots, increasing to about 35 knots. Seas were forecast to be moderate to rough on a moderate to heavy swell. Thor Gitta’s passage initially took the ship just within this area, as the low moved eastward. On the morning of 20 May, in preparation for the expected rough weather, the cargo lashings in the hold were inspected. The cargo was secure but additional lashings were put on the bins containing unused lashing equipment (lashing bins) which had been secured at the forward end of the ship’s tween deck. Water ballast was also discharged from the after peak and numbers 18 and 19 water ballast tanks to reduce the ship’s GM to 1.43 m. As the day progressed, the weather and sea conditions deteriorated. At about 2100, the master reduced the main engine speed to 112 rpm to lessen the pounding being experienced at the time. By the morning of 21 May, the weather and sea conditions had worsened, with the seas now confused and the waves averaging about 8 m in height. The chief mate wanted to check the lashings in the cargo hold again and the main engine speed was further reduced to 90 rpm, giving Thor Gitta a speed through the water of about 3 knots. The ship then took up a slight to moderate pitching motion in the head seas. The chief mate, an AB and an ordinary seaman (OS) donned their usual personal protective equipment, including hard hats and portable radios. Because there was no access to the lower hold from aft, the crew members made their way to the hold's forward entrance. They then climbed down the 8 m vertical ladder to the lower hold. At about 0900, the three men started to move from forward to aft through the lower hold, checking the lashings. At 0920, the chief mate reported to the master, who was on the bridge, that all the lashings were secure. The ship was pitching slightly and when the men were at about midships on their return to the ladder, they heard some movement on the tween deck. The chief mate looked up and, between the gap in the tween deck pontoons, could see that three lashing bins were sliding about 2 m from side to side across the deck. The men climbed the ladder to the tween deck, confirmed that the lashings on the bins had worked loose and at 0925, began to resecure the bins using ratchet webbing straps. They quickly secured the after two bins against the inboard side of the port water ballast tank. They then began to position the next lashing bin when the ship suddenly rolled to starboard. As the ship rolled, the bin began to slide across the tween deck pontoon. The chief mate yelled 'be careful, be careful!' and the OS jumped backward, seeking protection aft of the starboard water ballast tank. The chief mate also jumped clear of the sliding bin, moving to the hold's forward bulkhead, on the starboard side. However, the AB grabbed hold of the port side of the lashing bin and appeared to be trying to stop its slide to starboard. Shortly afterwards, the ship rolled heavily to port and the lashing bin started to slide back to port. The AB lost his balance and fell onto the pontoon, into the path of the bin. He was unable to get to his feet before the bin slid into him, hitting him heavily in the torso and pinning him against the side of the port water ballast tank . The chief mate tried to pull the bin off the AB but at about 0929, as the ship again rolled heavily to starboard, the bin came away from the AB and the chief mate's left foot was pinned between the bin's leg and the side of the starboard water ballast tank. When he was able, the chief mate jumped onto the top of the starboard ballast tank and clear of the moving bin. As the lashing bin slid away, the AB jumped to his feet and ran for the relative safety of the ladder recess. The chief mate, concerned that the AB had suffered internal injuries after being hit by the lashing bin, contacted the master using his portable radio and requested urgent medical assistance and that oxygen be brought to the hold. At about 0930, a few seconds after the AB made his way to the ladder recess, the chief mate and the OS saw him lose his grip on the ladder rung and fall down the recess onto the tank top, about 6 m below. At about the same time, the ship's rolling stopped and its pitching motion resumed. As a result, the lashing bin's movement stopped and the chief mate and OS were able to run to the ladder and make their way down to the AB, who had blood coming from his mouth, appeared groggy and was trying to sit up. The chief mate told the OS to try to keep the AB conscious while he went to seek assistance. In the meantime, the master had told the second engineer to get some crew and go forward. He called the second mate to relieve him on the bridge so that he could go forward. At 0940, when the other crew members arrived at the accident site, the AB's vital signs were checked. His pulse and breathing were both very weak. A resuscitation bag and mask were used to assist his breathing and a neck brace was applied. At about 1000, the AB lapsed into unconsciousness. The master returned to the bridge and at about 1030, contacted the Danish Medical Advisory Service by satellite telephone. The doctor instructed the master to check the dilation of the pupils of the AB's eyes. The master returned to the hold and both he and the second engineer witnessed that the AB's pupils were nonresponsive to light. The master then returned to the bridge and reported back to the doctor. At 1045, the doctor told him to stop any attempts to revive the AB and pronounced him deceased. The chief mate's injuries, his swollen left foot and a 10 cm laceration down to the bone on his lower right leg, were treated by the master and second engineer when they returned to the accommodation from the hold. At 1200, after a discussion between the master and the ship's managers, the decision was made for the ship to return to Fremantle where the AB's body could be landed and further medical attention provided to the chief mate. At 0510 on 23 May, a Fremantle harbour pilot boarded Thor Gitta and by 0606, the ship was all fast alongside its berth.

ATSB Finding

Using fatigue assessment software, FAID, on the seafarer's work routine, 6 on 6 off, ATSB noted a score of 111 on the morning prior to the accident: "This score is considered to be in the very high range (of fatigue)".

Says ATSB: "Article 5 of ILO 180 prescribes the maximum hours per day that a crew member, regardless of duties and not including emergency situations, is permitted to work… This convention was ratified by Denmark in 2003 and the Danish Maritime Authority has chosen to use the option provided for in Article 3 to regulate11 seafarers' hours of rest in a 24 hour period and a 7 day period (1(b) above). In doing so, the Authority permits seafarers to work up to 91 hours in any 7 day period.

“However, the effect that a 6 hours on/6 hours off roster has on a crew member’s level of fatigue has been considered at length in a number of studies undertaken since the STCW and ILO requirements were introduced. These include several conducted by the Cardiff University, the United Kingdom’s Marine Accident Investigation Branch, the International Transport Workers Federation and the University of Wellington for Maritime New Zealand. It is reasonable to say that all these reports comment on the inability of this type of roster to effectively manage the fatigue levels of those working the roster, and that other systems of rosters (such as the 4 hours on/8 hours off) should be considered. Both the 6 hours on/6 hours off work routine for watchkeepers and the modified work routine for deck ratings used on board Thor Gitta, while complying with the ILO 180 and STCW requirements for rest, probably resulted in a cumulative level of fatigue in the crew.”

The combination of jetlag and fatigue can lead to serious accidents. As we can see from the accident at the French-flagged cableship Ile De Sein.

Jetlag and fatigue may have led to a fire aboard the French-flagged cableship *Ile De Sein,* suggests France’s maritime accident investigation agency, BEAmer. Long-haul flights can lead to mistakes with serious consequences if efforts are not made to reduce their effects.
In the case of *Ile De Sein,* bunkering operations were underway in Honolulu. The engineering team carrying out the operation had arrived the previous day on a flight from France. By 1930 on 5 May 2015 the marine diesel oil tank nu,ber two was nearly full. After sounding, the cadet closed the ball-valve actuated by a counterweight but omitted to close the cap.
Soon after an engineer was preparing, from the control cabin, the shifting of the filling from the MDO tank number two starboard to the MDO tank number one centre. An operator error during the filling valve opening – closing sequence on the tanks, resulted in the tank venting pipe and sounding circuit overpressure.

Without the cap fuel vapour was able to escape through the sounding tube and, as flammable vapours will, found an amenable source of ignition.

A well-drilled firefighting team tackled the blaze appropriately and extinguished it. Says BEAmer: “The most important damages were located on electrical bunched cables (6600 volts), control organs and cabinets for DA1 and 2. Restarting of the mooring generating set after repair of its power supply.”

Although BEAmer says: “The engineer team who was coordinating the bunkering operation joined at Honolulu on the day before. The fatigue, due to the joining travel from France and to the jet lag, had probably contributed to the operating error in controlling the MDO tank filling valves” it offers no recommendation regarding mitigation of the effect of jetlag and travel fatigue and limits itself to “The crew’s attention should be drawn to the fact that the closure of a fuel tank sounding pipe, only by the ball-valve, do not provide vapour tightness.”

Unfortunately, the report does not determine whether a checklist was required by onboard procedures. Checklists, although much derided, are a tool designed to reduce the chances of error in sequential tasks.

Honolulu is 11 hours behind France and the more than 15 hour flight crosses a dozen time zones. Such long flights disrupt the body and brain’s natural cycle, the circadian rhythm, and the engineers’ bodies would still have been operating on ‘Paris time’. Such long flights incur fatigue, even if one sleeps during the flight.

To put that into context it would take between five and ten days to recover from jetlag and travel fatigue. Some recommendations say allow a day’s rest for each time zone crossed, but this may not be possible in a real world setting. The engineers aboard *Ile De Sein* had, at most, 24 hours.

The report of the France’s maritime accident investigation agency shows as everything that happened before and after the accident.

FACTUAL INFORMATION (Local time TU-10) Weather conditions (Source: maritime incident report written by the master) : NNE wind force 2 (4 to 6 knots), smooth sea state.

The vessel sailed from Makassar (Indonesia) on 17 March 2015 for a Trans-Pacific cable recovery (with a view to recycling).

On 4 May, she moored at Honolulu for a technical call and for the relief of a part of the crew. 1412 km of cables were already on board.

On 5 May, beginning of the bunkering operation at quay nr30 in the afternoon. The generating set nr2 was operating (DA2).

Soon before 7.30 pm the Marine Diesel Oil tank Nr2 was nearly full. The level curve indication displayed on the control panel was confirmed by a manual sounding (SD23). After sounding, the cadet closed the ball-valve (actuated by a counterweight) but omitted to close the cap.

Soon after an engineer was preparing, from the control cabin, the shifting of the filling from the MDO tank nr2 starboard to the MDO tank nr1 centre. An operator error during the filling valve opening - closing sequence on tanks nr1 and nr2, resulted in the tank venting pipe and sounding circuit overpressure.

The pressurized MDO depletion was done through the tank overflow circuit and triggered an alarm. But MDO vapours were already leaking from tank nr2 starboard sounding pipe and were projected on DA2 exhaust. The vapours ignited quickly and, at 7.35 pm, the fire alarm rang out. Simultaneously, flames melted the cables of the control circuit of DA2 which stopped, causing thus a black-out. The generating sets on standby mode started, among which DA1. Located beside DA2, its turbo-blower inhaled flames. Once the fire alarm had sounded, the master joined the engine control cabin. A white smoke entered the control cabin when the adjoining door to the engine room had been opened by an engineer. At 7.37 pm, the general alarm was sounded, as well as the call for firefighting stations. The bunkering operation was interrupted. At 7.38 pm Honolulu harbourmaster was informed by a VHF channel 12 call. At 7.40 pm, mustering signal just prior to the release of CO_2 . All the safety measures had been taken and CO_2 released in the generating set compartment at 7.49 pm. At 7.55 pm the master informed the owner LDA of the situation. At 7.56 pm a team of firefighters from the port was on the quay and began to cool the vessel's hull. From 8.00 pm to 8.06 pm gathering of firefighting teams and means on the deck forward the shed. At 8.08 pm no hot spot detected on the port hull with a thermal camera. From 8.14 pm to 8.20 pm a vessel's firefighter team entered the engine room through the control cabin and reported the presence of a light smoke and the absence of flame. The area of origin of the fire seemed to be located between DA1 and 2 (fuel leak, floor plates torn by the heat, burnt electric panel). The hull cooling operation, the investigation of the engine room and the monitoring of temperature evolution had been carried on until 9.45 pm, when the ventilation flaps were opened. New investigation after a 20 minute natural ventilation.

At 9.47 pm three harbour tugs ready to operate were in the vicinity of the vessel. At 10.21 pm the oxygen content was measured. Absence of harmful gas. At 10.35 pm VDR data back-up. At 10.36 pm setting up a watch to monitor the areas at risk. At 11.24 pm the master, on the quay, reported the situation to the coastguards. At 11.50 pm freedom of manoeuvre given to the three tugs. On 6 May at 1.57 am the mooring generating set (DA5) was started. At 2.05 am installation of an anti-pollution boom.

CONSEQUENCES

The most important damages were located on electrical bunched cables (6600 volts), control organs and cabinets for DA1 and 2. Restarting of the mooring generating set after repair of its power supply. The vessel should be back to service at the end of July 2015 to resume her mission to recover the Trans-Pacific cable.

OBSERVATIONS - ANALYSIS

The overflow alarm of the MDO 2 starboard tank went off (no time-lag), but it was probably masked by the fire alarm. The ball-valve of the sounding pipe prevented an important MDO overflow, but only the cap could provide vapour tightness. Tests and calculations done aboard a sister ship showed that: - The pressure at the sounding pipe cap was 1.56 bar; - Fuel vapours travelled to the exhaust area where the temperature was 270°C (measured by a thermal camera); - This area is accessible only by vapours. The engineer team who was coordinating the bunkering operation joined at Honolulu on the day before. The fatigue, due to the joining travel from France and to the jet lag, had probably contributed to the operating error in controlling the MDO tank filling valves.

<u>3.2.3 Mv Lernix</u>

Last but not least we have the case of “cozy captain” (as called from the marineaccident.org)

Report on the investigation into the grounding of

MV Lerrix

off the Darss peninsular, Baltic Sea

Germany 10 October 2005

SYNOPSIS

All times are ships time (UTC +1)

At 2342 on 10 October 2005, the British registered general cargo vessel Lerrix ran aground off the Darss peninsular in the Baltic Sea. The single hold vessel was carrying a cargo of second hand vehicles destined for Klaipeda in Lithuania. Twenty five minutes later the master re-floated the vessel using astern propulsion, narrowly avoiding a second grounding as he did so.

It was the master's first full command with the company. Earlier the same day, the vessel had transited the Kiel Canal, and the master reported that his rest period between midnight and 0600 had been disturbed by nervous tension brought on by the vessel's approach to, and navigation down the River Elbe. During the afternoon, the master suffered a second disturbed rest period while transiting the canal, making several visits to the bridge to check progress and, finally, to pilot the vessel outbound from the canal lock to sea.

At about 2230, the lookout requested and was granted permission to proceed below to complete cleaning the galley. A short while later, the master fell asleep in the bridge chair. As a result, the vessel missed a planned alteration of course at 2242 within the TSS and continued on a 090 heading at 10.5 knots until grounding at 2342. The vessel's movements were monitored by Warnemunde VTS and, when it became apparent that the vessel was not following the prescribed route, the VTS operators made several attempts to contact Lerrix by VHF, but received no response.

When the mate arrived on the bridge at midnight the master, who had woken seconds before, was seen at the engine control lever with maximum astern power set. The general alarm was sounded, soundings were taken and at about 0007 the vessel floated free and proceeded to anchor close by. The master was breath alysed for alcohol consumption – the test proved negative.

Analysis:

Although the individual voyages onboard Lerrix were about 3 to 4 days long, and the time in port between voyages 1 and 3 days, fatigue was a contributory factor in the accident. Working a 6-on/6-off routine, the master was unable to fully carry out his command obligations without disruption to his 6 hours of rest time. Furthermore, the poor quality of rest achieved in the master's two previous designated rest periods directly contributed to this particular grounding.

Although a lookout had been present on the bridge earlier in the evening, it was standard practice onboard Lerrix for the OOW to determine at the commencement of a lookout's watch whether his presence was required. Had the lookout remained on the bridge in accordance with STCW instructions, interaction between the two would have made it unlikely that the master would have fallen asleep, and ultimately the grounding could have been avoided.

A watch alarm, fitted to comply with a previous flag administration's requirements, was found to be inoperative. Had the watch alarm been available to the OOW, and set by him when the lookout departed from the bridge, this accident could probably have been avoided.

During the investigation, it emerged that the master was using a portable GPS connected to a personal laptop computer, running a pirated navigation package as his primary source of navigation information. The pirated programme, obtained from the internet in 1999, had not been updated and the alarm functions were inoperative.

Conclusions:

Lerrix grounded because the master, who was alone on the bridge, had fallen asleep and missed an alteration of course.

It is likely that the master was fatigued at the time of the grounding. He was one of two watchkeeping officers working 6-on/6-off, and his rest periods prior to the accident had been disturbed.

His decision to allow the lookout to leave the bridge, removed the single most important barrier to prevent the accident occurring. However, having made the decision, the grounding could still have been avoided if the watch alarm had been fully functional and utilised.

Sequence of events

Lerrix sailed from Alexandra Dock, Hull, at 2100 on 8 October 2005, bound for Klaipeda, Lithuania via the Kiel Canal. She had a cargo of used vehicles and containers, and sailed with a draught of 2.9 metres forward, and 4.1 metres aft. On departure, the master was the OOW, and he employed the services of a local pilot who assisted navigating the vessel downriver to the Spurn light float. The pilot disembarked at about 2300, thereafter the master set course toward the River Elbe and the Kiel Canal in Germany.

The 27 hour passage across the North Sea was uneventful. Wind and sea conditions were good, and although the visibility had varied between 1 and 2 miles, the master had not deemed it poor enough to commence a fog routine

The master completed his watch at midnight on 9 October, handed over to the mate, and then went down below to sleep. At this time, the vessel was navigating in an adopted TSS and was approaching the congested waters of the River Elbe. There was no legal requirement for the master to embark a pilot for the passage from seaward to the Kiel Canal, and his intention was for the mate, as the OOW, to navigate Lerrix along the Elbe toward the canal pilot embarkation point.

Although the master reported having total confidence in the mate’s watchkeeping ability, he found it difficult to achieve continuous rest during his sleep period between midnight and 0600. On at least three occasions, the master recalled waking, observing the traffic density and navigational situation from his porthole, smoking a cigarette, and then returning to his bed in an attempt to rest.

At 0600, the master took the watch from the mate, and at 0700 he embarked the pilot for the Kiel Canal, passing through the lock at 0745. The canal transit throughout the master’s watch was uneventful; he was relieved by the mate at 1200 and then went below for lunch.

During the afternoon, the master rested lightly in his cabin with his 'feet up'. There were two occasions, at about 1300 and 1400, when he visited the bridge to check on the vessel's progress. At 1500, he returned to the bridge to take over the con from the pilot before entering the final lock. The canal pilot disembarked at 1515, and at 1535 the master conned Lerrix out of the lock and commenced passage to Klaipeda. Traffic around the exit from the canal was moderate, and the master remained on the bridge until 1645, when he handed the con back to the mate and then went below for supper.

When the master returned to the bridge at 1800 to relieve the mate, sea conditions were good, the wind was south south east force 3 to 4, and visibility remained similar to that experienced during the north sea crossing, at between 1 and 2 miles. The master assumed his preferred position sitting in the port side bridge seat where he had space to place his laptop computer, and where he considered it offered him a better view to starboard. The logbook shows that GPS positions were recorded at 1831, 1930 and 2120, with each position corresponding to a planned alteration of course.

At 1945 the AB/cook, who was the designated lookout for the 2000 to 2400 watch, reported to the master on the bridge. Usual practice on Lerrix was for the lookout to report to the OOW at commencement of the night watch, when a decision would be taken on whether lookout duties or other employment away from the bridge was undertaken. On this particular occasion, the master reported that he felt the lookout's presence was necessary, and consequently the AB/cook remained on the bridge.

The lookout sat in the starboard bridge seat and, for a while, talked quite happily to the master, who, he reported, was showing no outward signs of fatigue and was behaving in a rational and logical manner. 6 The lookout was due to leave the vessel the following day, and was keen to ensure that his galley was thoroughly clean and tidy prior to his relief taking over. He asked permission from the master to be excused from lookout duties and be allowed below to complete cleaning the galley area and to pack his suitcases. The exact time of this request was reported as being 2300. However, evidence from radar coverage and electronic plotting shows that in all probability it was around 2230. The master agreed to the request and the lookout left the bridge. He did not return before the grounding occurred.

The master was not aware the vessel was equipped with a watch alarm, albeit a defective one, and therefore made no attempt to activate it when the lookout left the bridge.

Once the lookout had gone below, the master reported pacing the bridge for about 5 to 10 minutes, after which he returned to his chair on the port side. As a heavy smoker, the master always ensured that he had the leeward wheelhouse door open. He had consumed three mugs of coffee since coming on watch at 1800. Shortly after returning to his seat, the master fell asleep. The vessel was in autopilot, steering 090 at 10.5 knots through the east bound lane of the Kadetrenden TSS. Twelve miles ahead was the Darss peninsular, a designated environmentally sensitive area.

Lerrix had been acquired on radar by the local traffic routing service based at Warnemunde, 13 miles south of the Kadetrenden TSS; AIS had provided the necessary vessel particulars. With the master now asleep and no lookout present on the bridge, the vessel missed the scheduled alteration of course to 036 which, by EP, should have occurred around 2242. At about 2250, it became apparent to the traffic routing operator that Lerrix was not complying with Rule 10 of the International Regulations for the Prevention of Collisions at Sea. The vessel had departed the traffic lane eight cables right of her intended track on a course of 090 and was heading directly toward the land at 10.5 knots.

The Kadetrenden TSS is a fully adopted IMO TSS but there is a high rate of vessel non compliance. As a result, the German Waterways and Shipping Administration programme the patrol vessel Arkona to monitor and identify vessels not complying with IRPCS Rule 10. The Warnemunde traffic routing operator and the patrol launch Arkona made a succession of 19 VHF calls in a 16 minute period before the grounding in an attempt to establish contact with Lerrix. They both failed to raise any response from the vessel. As the seriousness of the situation developed, Arkona was tasked to investigate the movements of Lerrix.

Passing one cable south of the west cardinal buoy, in position latitude 54 24.9N longitude 012 24.6 E, Lerrix finally grounded on the Darss coastline at 2342. Both Arkona and traffic routing services continued to call Lerrix by VHF; still withno response. With the master asleep and oblivious to the grounding, the vessel’s engine continued to drive the vessel further up the beach at maximum power. No other crew member onboard Lerrix felt the vessel take the ground.

It was standard practice for the master, mate and lookouts to organise their own call before going on watch. The mate awoke as normal at 2345, three minutes after the grounding, and proceeded up to the bridge at midnight. The 2000 to 2400 lookout was still below and later found to be showering.

Seconds before the mate entered the bridge, the master awoke to find the small Koden radar in front of him (set on the 6 mile range scale) showing land very close to the centre spot, there were no shore lights visible. Not fully appreciating whether the vessel had grounded or was about to ground, he immediately grabbed the engine control lever and pulled it back to the full astern position. As the mate entered the bridge at midnight, the main engine alarms were sounding due to the intensity of the engine manoeuvre. Believing the vessel was about to ground, the master ordered the mate to sound the general alarm.

<u>Hours of rest records.</u>

The hours of rest records obtained from the master, mate, and lookout for the months of September and October, until the time of the grounding, can be found at Annex D. Despite the vessel’s operating programme for September outlined at paragraph 1.3.1, the hours of rest records for the master and mate showed a precise 6-on/6-off routine. Logbook extracts showing the time spent alongside, the time of arrival and departure, and personal work conducted outside of watchkeeping hours, show the rest hours records were inaccurate and did not reflect the actual hours of rest achieved. The AB/cook’s record of rest, although different to that of the master and mate's, was also inaccurate, and did not reflect the vessel’s programme.

The master forwarded records of rest hours for the crew to the company’s DPA at the end of the month. However, the DPA only reviewed the ‘total hours of rest’ column, which did not reveal that the records were inaccurate.

The rest hour records for October, obtained during the investigation and produced retrospectively by the individuals, showed a more realistic and accurate account, which supported other documentary evidence. Using logbook entries for September, it was possible to estimate the working hours for that month which, together with the more accurate October hours, provided usable data to calculate the possible effects of fatigue.

Working hours.

The master had been employed on the vessel for just under 3 months. Before this, he had spent 85 days on leave. He reported that throughout the period spent onboard Lerrix, the 6-on/6-off watchkeeping structure had suited him, although on the occasions when entering or leaving port had coincided with his 15 off-watch time, fatigue was an issue; particularly on departures. The master was content, however, that a period of 1 or 2 days in port, working a day routine, was sufficient for his body to fully recover from the sleep loss experienced at sea. The investigation discovered that the death of a close colleague 2 weeks previously had been causing the master some distress, and was an issue he was still coming to terms with. This, together with some of the navigational responsibilities of command, contributed to the fatigue that the master was suffering from. He had, on a number of occasions, confided to the mate during the watch changeover that he was tired, and was himself aware that the death of his colleague was causing a degree of stress-related fatigue.

The company's ISM procedure (Annex E) Section 11 - Preparation for Sea (Deck), addressed issues concerning the composition of a watch, and issues of fatigue, referring to the regulations laid down in STCW 78/95 which determine the minimum rest periods required. A schedule of working arrangements, which was signed by the previous master, had been drawn up for the vessel by the company's managers. Theoretically, the agreement allowed the master and mate 12 hours rest per day at sea, and 13 hours rest per day in port. The AB/cook's rest hours differed slightly, in that he was allowed 11 hours rest per day at sea. The agreement recognised that working hours may have to vary in port for shifting berth and late working of cargo, and at sea for arrival and sailing times, and prevailing weather conditions.

To assist the master assess the crew's hours of work and rest before sailing, in accordance with STCW 78/95 regulations, the company produced a rest hours flow chart (Annex E). Under the company's ISM system, masters were instructed to use the flow chart prior to sailing, to determine whether vulnerable personnel might be suffering from inadequate rest. The company was clear in its mind that if, because of the crew's inadequate rest, a vessel became unseaworthy and the master requested additional time in port, this would be conceded. Historically, there had been cases when other vessels in the fleet had delayed sailing in order to recoup rest deficiencies.

Chapter 4 How to Reduce Fatigue

In this final part we will see how we can mitigate the effects of fatigue on our bodies our even how to prevent the onset of it.

4.1 Sleep

The most effective strategy to fight fatigue is to ensure that you get the very best quality and quantity of sleep. Sleep loss and sleepiness can degrade every aspect of human performance such as decision-making, response time, judgment, hand-eye coordination, and countless other skills.

4.1.1 Sleep criteria

In order to be effective in satisfying your body's need, sleep must meet three criteria:

- Duration Everyone's sleep needs are unique; however, it is generally recommended that a person obtains on average 7 to 8 hours of sleep per 24-hour day. A person needs the amount of sleep that produces the feeling of being refreshed and alert. Insufficient sleep over several consecutive days will impair alertness; only sleep can maintain or restore performance levels.

- Continuity Sleep should be uninterrupted. Six one-hour naps do not have the same benefit as one six-hour period of sleep.

- Quality People need deep sleep. All sleep is not of the same quality and does not provide the same fully recuperative benefits.

4.1.2 Sleep habits

Here are some general guidelines on developing good sleep habits:

- Develop and follow a pre-sleep routine to promote sleep at bedtime (e.g. a warm shower, reading calming material, or just making a ritual of pre-bed preparation can provide a good routine).
- Make the sleep environment conducive to sleep (a dark, quiet and cool environment and a comfortable bed encourages sleep).
- Ensure that you will have no interruptions during your extended period of sleep.

- Satisfy any other physiological needs before trying to sleep (e.g. if hungry or thirsty before bed, eat or drink lightly to avoid being kept awake by digestive activity and always visit the toilet before trying to sleep).
- Avoid alcohol and caffeine prior to sleep (keep in mind that coffee, tea, colas, chocolate, and some medications, including cold remedies and aspirin contain alcohol and/or caffeine). Avoid caffeine at least six hours before bedtime.
- Consider relaxation techniques such as meditation and yoga, which can also be of great help if learnt properly.

4.1.3 Rest Issues

Another important factor that can affect fatigue and recovery is rest. Rest, apart from sleep, can be provided in the form of breaks or changes in activities. Rest pauses or breaks are indispensable as a physical requirement if performance is to be maintained. Factors influencing the need for rest are the length and intensity of the activities prior to a break or a change in activity, the length of the break, or the nature or change of the new activity.

4.2 Guidelines for maintaining performance

Here are some general guidelines that can help you maintain performance:

- Get sufficient sleep, especially before a period when you expect that time for adequate sleep will not be available.
- Ensure continuous periods of sleep.
- Take strategic naps (the most effective length of time for a nap is about 20 minutes).
- Take breaks when scheduled breaks are assigned.
- Develop and maintain good sleep habits, e.g. develop a pre-sleep routine.
- Monitor and effectively manage hours of work and rest by maintaining individual records of hours rested or worked.
- Maintain fitness for duty including medical fitness.
- Eat regular, well-balanced meals.
- Exercise regularly.

4.3 What can mitigate the effects of fatigue?

The most powerful means of relieving fatigue is to get proper sleep and to rest when appropriate. However, a number of countermeasures have been identified as potentially providing some short-term relief. It must be emphasized that these countermeasures will not restore an individual's state of alertness; they only provide short-term relief, and may in fact, simply mask the symptoms temporarily. The following list captures some of the short-term countermeasures:

- Interest or opportunity An interesting challenge, an exciting idea, a change in work routine or anything else that is new and different may help to keep you awake. If the job is boring or monotonous, alertness fades.
- Environment (light, temperature, humidity, sound, and aroma) Bright lights, cool dry air, obtrusive or loud music or other annoying irregular sounds, and some invigorating aromas (such as peppermint) may temporarily increase alertness.
- Food and consumption of chemicals
- Caffeine (encountered in coffee and tea and to a lesser extent in colas and chocolate) may combat sleepiness in some people for short periods. However, regular usage over time reduces its value as a stimulant and may make you more tired and less able to sleep. Muscular activity Any type of muscular activity helps to keep you alert; running, walking, stretching or even chewing gum can stimulate your level of alertness.
- Social Interaction Social interaction (conversation) can help you stay awake. However, the interaction must be active to be effective.
- Job Rotation Changing the order of activities, where personnel are assigned tasks that include variety in the nature of tasks, can be beneficial in breaking up job monotony. Mixing tasks requiring high physical or mental work with low-demand tasks can be beneficial.

- Strategic Napping Research has identified “strategic napping” as a short-term relief technique to help maintain performance levels during long periods of wakefulness. The most effective length of time for a nap is about 20 minutes. This means that if you have the opportunity to nap you should take it. However, there are some drawbacks associated with napping. One potential drawback is that naps longer than 30 minutes will cause sleep inertia, where situational awareness is impaired (grogginess and/or disorientation for up to 20 minutes after waking. A second is that the nap may disrupt later sleeping periods (you may not be tired when time comes for an extended period of sleep).

4.4. What can be done to reduce crew fatigue on board ship?

There are a number of steps that can be taken to prevent fatigue. Many of the measures that reduce fatigue are unfortunately beyond a single person’s ability to influence, such as voyage scheduling, ship design, and work scheduling. Steps such as the following are important in the prevention of fatigue on board ship, and are within the Ship Officer’s ability to influence and implement:

- Ensuring compliance with maritime regulations (minimum hours of rest and/or maximum hours of work)
- Using rested personnel to cover for those traveling long hours to join the ship and whom are expected to go on watch as soon as they arrive on board (i.e. allowing proper time to overcome fatigue and become familiarized with the ship)
- Creating an open communication environment (e.g. by making it clear to the crew members that it is important to inform supervisors when fatigue is impairing their performance and that there will be no recriminations for such reports)
- Scheduling drills in a manner that minimizes the disturbance of rest/sleep periods
- Establishing on-board management techniques when scheduling shipboard work and rest periods, and using watchkeeping practices and assignment of

duties in a more efficient manner (using, where appropriate, IMO and ILO recommended formats – “Model format for table of shipboard working arrangements” and “Model format for records of hours of work or hours of rest of seafarers”)

4.5 What rules and regulations are in place to prevent and deal with fatigue?

Each individual Flag Administration is responsible for the development, acceptance, implementation and enforcement of national and international legislation (conventions, codes, guidelines, etc.) that deal with the various fatigue aspects: work hours, rest periods, crew competency and watchkeeping practices.

The following international organizations have issued various conventions and other instruments that address fatigue:

International Labor Organisation (ILO) Convention Concerning Seafarers’ Hours of Work and the Manning of Ships – ILO Convention No.180;
International Maritime Organisation (IMO) International Convention on Standards of Training Certification and Watchkeeping for Seafarers, 1978, as amended in 1995 (STCW Convention) **(**Mandatory instrument); Seafarer’s Training, Certification and Watchkeeping Code (STCW Code) Parts A (
Mandatory instrument) and B (Recommendatory guidance.); International Safety Management Code (ISM Code) (Mandatory instrument.); and various guidelines/recommendations.

4.6 How does fatigue relate to the ilo and imo instruments?

The following ILO instruments contain guidance on fatigue related aspects:

Convention No. 180 This convention introduces provisions to establish limits on seafarers’ maximum working hours or minimum rest periods so as to maintain safe ship operations and minimize fatigue. The text from the Convention is provided in the Appendix.

Other Conventions Other ILO Conventions related to fatigue include the following convention numbers: 92, 133, 140, 141 and 147. Each introduces minimum habitability requirements (e.g. noise control and air conditioning) on board ships.

The following IMO instruments contain guidance on fatigue related aspects:
• ISM Code This Code introduces safety management requirements on shipowners to ensure that conditions, activities, and tasks (both ashore and afloat) that affect safety and environmental protection are planned, organized, executed and verified in accordance with company requirements. The fatigue related requirements include: manning of ships with qualified and medically fit personnel; familiarization and training for shipboard personnel; and issuance of necessary support to ensure that the shipmaster's duties can be adequately performed.
STCW Convention and STCW Code The STCW Convention requires that Administrations, for the purpose of preventing fatigue, establish and enforce rest period requirements for watchkeeping personnel. In addition, the Convention sets minimum periods and frequencies of rest. Part A of the Code requires posting of the watch schedules. Part B of the Code recommends that record keeping is useful as a means of promoting compliance with the rest requirements.

Resolution A.772(18) (Resolutions are not binding on governments, however their content is in some cases implemented by government through incorporation in domestic legislation.) – Fatigue Factors in Manning and Safety This Resolution provides a general description of fatigue and identifies the factors of ship operations which may contribute to fatigue.

Other Instruments The Appendix contains a list of IMO instruments identified as having some applicability to crew fatigue.

4.7 How can owners/operators/managers ensure that fatigue prevention is practised onboard?

- Management should consider the following in developing fatigue management policies and systems:

- ISM Code requirements for clear, concise guidance on operational procedures on board
- The need for joining crews to be adequately rested before assuming duties
- Scheduling time for proper hand over on crew change
- Voyage length, time in port, length of service and leave ratios
- Multicultural issues; language barriers, social, cultural and religious isolation
- Interpersonal relationships, stress, loneliness, boredom, social deprivation and increased workload as a result of small crew numbers
- Provision for shore leave and onboard recreation, family communication
- Watchkeeping arrangements
- Job rotation
- Improved sleeping berths and accommodation
- Adequate quality and quantity of food for proper nutrition
- Read Modules 2-4 for additional potential managerial mitigation tools
- Modification of present ship design or future designs

As noted in the previous section, an effective fatigue management system requires training. Ensuring the crew understands the necessity of getting regular rest and the implications of being fatigued (both to themselves and to the safety of the ship and/or those working with them) should be part of the education process. This process, as with any other training, needs to be ongoing in nature and may be assessed as part of management's supervision of the ship and its crew.

This training occurs in a system where the results of implementing mitigating strategies can be assessed. This implies that an information system should be established between management and the crewmembers of the ship. Such a system would provide feedback regarding hours- of-work by each crewmember. Such information would allow management to assess the status and effectiveness of work arrangements and confirm that work arrangements are being adhered to.

It may be impractical and unpopular to require crews to report exactly what they did during their time off work. Even though this will affect the precision and accuracy of tallied sleep accumulation results, the feedback on work/sleep still provides the basis by which management can monitor the effectiveness of their risk mitigation strategy.

4.8 What tools are available for designing/building a fatigueresistant ship?

Unfavourable environmental conditions can be instrumental in causing fatigue. Environmental conditions include noise levels, vibration, ship motion, seakeeping qualities of the ship, lighting, temperature and ventilation. These environmental conditions affect crewmembers within their workplace (bridge, engine room, etc.) and accommodation quarters, (including dining, food preparation and storage areas, hygiene and medical support areas.)

These environmental conditions extend across structural design, propulsion, hull forms and several other aspects of design. Often, constructive solutions may be employed to improve environmental conditions. For example, the transmission of noise can be dampened by the insertion of acoustic insulation; similarly, resilience techniques can be used to alleviate vibration problems.

There are a variety of tools such as Finite Element Analysis (FEA) which can assist the ship designer in ensuring that the limits specified by shipowners are not exceeded. These tools can be used for:

Calculating noise limits

Calculating vibration limits

Calculating seakeeping qualities/quality of ride

Analysing ventilation flows

Performing model tests

The use of ergonomic standards is also considered to be a major tool for improving the working environment, particularly those that deal with environmental conditions (such as temperature, vibration, ventilation, etc.).

Another tool used during design is the electronic model. These models are increasingly being used to assess both the impact of environmental conditions as well as ergonomics of workplace. With increasing frequency, electronic models — including virtual reality and three-dimensional computer aided design — are allowing early evaluation of various aspects of design.

4.9 What rules are available for designing/building a fatigueresistant ship?

There are a number of rules, regulations, standards and guidelines designed to enhance environmental conditions, which can be used by the ship designer who wants to reduce seafarer fatigue. As this is a developing area, many of the measures referenced here are provisional.

Accommodation

Crew accommodation is usually located in a far from ideal location. It is built around the operation of the ship, being placed directly over the engine room. This area does not give the best quality of ride. In addition, it can be noisy. Acoustic insulation could be used to reduce noise in this area, but it must also be considered in conjunction with measures to increase sleep disturbances that must be heard, i.e. fire alarms.

Consideration could be given to ensure that the accommodation area is restful and that it aides in recovery from fatigue, e.g. in terms of decor, easy to clean. Some aspects of crew accommodation, for instance minimum size and acoustic insulation, are subject to regulation such as the International Labour Organisation (ILO) Conventions. The ILO Conventions that address crew accommodation are as follows:

- Convention No. 92 concerning crew accommodation on board ship (Revised 1949)

- Convention No. 133 concerning crew accommodation on board ship (supplementary provisions)
- Convention No. 147 concerning minimum standards in merchant ships
- Protocol of 1996 to Convention No. 147
- Recommendation 155 of 1976, recommendation concerning the improvement of standards in merchant ships
- Recommendation No. 140 concerning Crew Accommodation (Air Conditioning)
- Recommendation No. 141 concerning Crew Accommodation (Noise Control)
  - Crew accommodation is also subject to National Standards such as The Ministry of Maritime Affairs and Fisheries of Korea, Ship Safety Act: Crew accommodation.

Environmental conditions in crew-only spaces

Some Classification Societies have rules, most of them being optional rules, for aspects of environmental conditions (i.e. noise and vibration)for certain ship types:

- Passenger (e.g. cruise, Ro-Ro ferries) High speed craft (e.g. Surface Effect Ships, wave piercing catamarans, hydrofoil)
- Yachts. However, these rules could form the basis for an assessment of any ship type. The variance that lies between the different schemes operated by different classification societies. A number of these Rules include crew-only spaces as well as passenger spaces. Crew-only spaces are defined as the following:
- accommodation spaces (e.g. cabins, corridors, offices, mess rooms, recreation rooms)
- work spaces
- navigation spaces

These Rules are contained in:

Comfort Class: Tentative Rules for Classification of Ships. Part 5, Chapter 12. Det Norske Veritas. July 1995 Provisional Rules for Passenger and Crew

Accommodation Comfort. February 1999. Lloyd's Register of Shipping Rules for the Evaluation of Noise and Vibration Comfort on Board Passenger Ships. January 1999. Registro Italiano Navale

<u>Noise</u>

Several IMO requirements and Resolutions aim to protect the seafarer from unacceptable levels of noise:

IMO, Res. A.468(XII) (1981), Code on noise levels onboard ship fixes permissible maximum limits of noise depending on the type of space. (Recommendatory Guidance)

SOLAS Regulation II-1/36 Protection against noise.

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