Chapter 5

FATIGUE

Fatigue is a threat to aviation safety because it can have a negative effect on performance. Perhaps one of the most insidious aspects of fatigue is that when we are fatigued, we are often unable to recognise that we are fatigued, that our performance is deteriorating, and that we should act accordingly. For engineers, who are often shift workers, fatigue is an important issue. We use the word fatigue all the time, but what exactly does it mean? This chapter looks at the symptoms of fatigue, its effects and some strategies for managing it.

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Fatigue cannot be prevented by personality, intelligence, education, training, skill motivation, size, strength or professionalism.

Ron Heselgrave
What is fatigue?

We use the word fatigue all the time, but what exactly does it mean? There are several different meanings of the word:

- Tiredness after hard physical work
- Emotional fatigue
- Short-term effects of intense concentration on a task
- An overwhelming need to sleep.

This chapter deals mainly with the last type of fatigue. As we will show, fatigue can have a major effect on your safety and the quality of your work when you are maintaining aircraft.

We can distinguish between two types of sleep-related fatigue:

- Acute—this is generally only short term and can be remedied with a good night’s sleep
- Chronic—a longer-term problem, as there is usually a build-up of sleep deprivation.

Fatigue can act like a toxin accumulating in our body. We can generally deal with a small amount of it, and work it out of our system by catching up on a night’s sleep, but chronic fatigue accumulates and can have increasingly dangerous effects.

Case study

The maintenance was AOG* and was carried out and completed in a straight 36-hour shift. The aircraft was expected to be on line first thing in the morning and no back-up aircraft was available. At about 5.30am, a ground run was carried out with no defects evident. The aircraft was then released for a maintenance flight, which was uneventful. On the post-flight release to service, a rag was found caught on the main driveshaft and had shredded itself by about 50 per cent, hitting the aircraft structure during the flight. I was very tired and failed to notice the rag before the ground run and the maintenance flight. No company policies were in place regarding working periods.

* AOG = aircraft on ground: the aircraft could not be flown until maintenance complete
The effects of fatigue

One obvious hazard of fatigue is that the fatigued person loses the fight to stay awake while at work. Clearly this is most dangerous when the person is operating equipment or driving a vehicle. A sleep episode can take the form of a microsleep, which is a brief moment (generally between two and thirty seconds) when the person starts to enter the first stage of sleep, possibly with their eyes still open, sometimes for less than a few seconds before regaining consciousness. The person is typically unaware that they have experienced a microsleep, and may continue to perform simple repetitive tasks while asleep. When truck drivers volunteered to wear sleep-monitoring equipment while they worked, researchers were amazed to find that some drivers were showing signs of the first stage of sleep while driving on interstate highways²².

Sleep deprivation can produce effects very similar to those produced by alcohol. An Australian study found that people who were given a simple vigilance task in the early hours of the morning, after being continuously awake for 17 hours, performed as badly as if they had a blood alcohol concentration of 0.05 per cent. Seven or more hours of wakefulness can produce impairment similar to that produced by a blood alcohol concentration of 0.10 per cent²³. In other words, conducting a complex maintenance task when you are fatigued is like drinking on the job.

Think about it!

Consider these two imaginary scenarios:

Scenario 1
You are about to take your first parachute jump. You are handed your newly packed parachute by your instructor, Bob. He proudly tells you that he has just prepared your chute for you. You notice that Bob is leaning a little unsteadily on the rigging table. You also smell alcohol on his breath. When you ask Bob about this, he shrugs and tells you that he always likes to have a few shots of vodka to steady his hand before he starts rigging chutes.

Scenario 2
You are about to board a Cessna 172 for a brief flight. The aircraft has just come out of major maintenance. You speak with your colleague, Jim, who is also a LAME. He is normally a cheerful and talkative person, but on this day he has bags under his eyes and does not have much to say, except that he is looking forward to going home and having a good sleep. He tells you that he has just worked 24 hours straight and is exhausted. He says his last job was a routine task, but for some reason he had trouble focusing on it. This last job involved replacing the aileron control cables on the aircraft you are about to board.

Is there a difference between these two scenarios?

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The above scenarios suggest that the performance of both Bob and Jim is impaired, the difference being what has caused that impairment—alcohol or fatigue. Just like someone who is intoxicated, if you are fatigued you will react more slowly, have trouble paying attention, be prone to memory lapses, and can show impaired judgment. You may also become withdrawn and uncommunicative. Boring tasks requiring close attention (such as some inspection jobs) are most affected by fatigue. Just as a drunk person may think they are sober, fatigued people often don’t realise just how impaired they are.

Society does not tolerate drunk drivers or intoxicated workers. There is increasing awareness that the impairment resulting from severe fatigue is also no longer acceptable in safety-critical environments such as aircraft hangars. Therefore, there should be no difference in the way we view and take action on the behaviour of Bob and Jim described above—both are unsafe.

The effects of fatigue on performance are summarised in the table below:

<table>
<thead>
<tr>
<th>Performance category</th>
<th>Effects</th>
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</thead>
<tbody>
<tr>
<td><strong>Attention: reduced</strong></td>
<td>Leave out steps in tasks</td>
</tr>
<tr>
<td></td>
<td>Preoccupation with single tasks or steps</td>
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<tr>
<td></td>
<td>Tunnel vision, less likely to notice the unexpected</td>
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<tr>
<td></td>
<td>Less aware of poor performance</td>
</tr>
<tr>
<td></td>
<td>Concentration requires more effort</td>
</tr>
<tr>
<td><strong>Memory: diminished</strong></td>
<td>Poor memory for tasks completed or underway</td>
</tr>
<tr>
<td></td>
<td>Forget to perform task steps</td>
</tr>
<tr>
<td></td>
<td>Revert to ‘old habits’</td>
</tr>
<tr>
<td></td>
<td>More likely to forget to return to interrupted tasks</td>
</tr>
<tr>
<td><strong>Mood: withdrawn</strong></td>
<td>Reduced communication</td>
</tr>
<tr>
<td></td>
<td>More irritable, frustrated by minor difficulties</td>
</tr>
<tr>
<td></td>
<td>Temptation to shortcut tasks</td>
</tr>
<tr>
<td><strong>Reaction time: increased</strong></td>
<td>Slower to notice problems</td>
</tr>
<tr>
<td></td>
<td>Less smooth control of equipment or vehicles</td>
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Fatigue can affect all maintenance tasks, whether it is because of impaired judgement, difficulty in focusing attention, or other performance deficiencies. Two common types of fatigue-related errors in maintenance are:

- **Memory failures**
  
  Fatigued engineers are more likely to forget to perform routine actions, such as replacing oil caps and are more susceptible to distraction and resulting memory lapses.

- **Failures to notice defects or problems**
  
  Fatigued engineers have more difficulty detecting defects during inspections, and may be less likely to notice problems in their own work, or the work of others, as a result of inattention or poor concentration.

The reduced performance caused by fatigue imposes a burden on the aviation industry not only in terms of flight safety, but also in financial costs through delays, the need for re-work, and other inefficiencies. For example, an air turnback of an airline aircraft caused by a relatively simple error such as a gear lock pin left in place, as outlined on the next page, can cost tens of thousands of dollars.
Case study

As the wing upper forward mount bolts and nuts were being torqued, the torque wrench being used broke. Another torque wrench was obtained, but it was noticed that it was out of calibration. Myself and the technician who was performing the work discussed this and rationalised that ‘it was only out of calibration by a month or two’. We decided to continue the procedure using the out-of-calibration torque wrench. When it was brought to my attention last night, I immediately arranged to have the aircraft grounded and a torque check done. I don’t want to sound like I’m making excuses, but I believe this occurrence is a result of fatigue and stress. During the previous seven days, both myself and the other technician had worked many long hours. Over the previous 30 days I have had three days off … in hindsight, I should have recognised then that I was badly in need of some rest. Instead, I pressed on.

Aviation Safety Reporting System report

Are we the best judges of our level of fatigue?

People are notoriously bad judges of their own level of fatigue. Asking a fatigued person if they are OK to keep working is like asking someone who is drunk if they are OK to drive. Even if we are not good judges of how tired we are, we can still keep track of how long we have been awake, how much sleep we have had recently, and the quality of that sleep. Before starting work, you could ask yourself these questions:

- How much sleep have I been getting over the last few nights?
- How long have I been awake?
- Will I be working at a time when I would rather be sleeping?
- Have I had good-quality sleep?

Your answers to these questions can help you to assess how likely you are to be at risk because of fatigue.

The impact of fatigue in the workplace

Some people in the aviation industry see fatigue as a normal and unavoidable part of aviation maintenance. They consider that with enough effort, a tired worker can continue to perform their job effectively. Increased effort or concentration might help for a few minutes, but it cannot compensate for fatigue over an entire shift. Fatigue has a very real detrimental impact on safety in aviation and in many other industries. Here are some myths about sleep and fatigue:

<table>
<thead>
<tr>
<th>Myth</th>
<th>Reality</th>
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<tbody>
<tr>
<td>‘Five or six hours sleep a night is generally enough.’</td>
<td>Very few people can manage on this amount of sleep without being seriously affected.</td>
</tr>
<tr>
<td>‘Daytime sleep is just as good as nighttime sleep.’</td>
<td>Shiftworkers who have to sleep during the day generally get lower-quality sleep, and less of it.</td>
</tr>
<tr>
<td>‘We can judge how fatigued we are accurately.’</td>
<td>Studies have shown that fatigued people often don’t realise that their abilities are impaired by fatigue.</td>
</tr>
<tr>
<td>‘We need less sleep as we get older.’</td>
<td>We still need the same amount of sleep, but our sleep becomes more fragmented, and we tend to wake earlier.</td>
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</table>
Human error is recognised as a causal factor in the majority of industrial and transport accidents. Fatigue, in turn, is one of the major causes of human error. Here are some facts about the role of fatigue in industrial and transport accidents:

- Industrial and engineering disasters, including those involving nuclear power, tend to occur in disproportionate numbers in the early hours of the morning
- Shift workers have twice the number of highway accidents as workers on day schedules
- Fatigue is involved in 31 per cent of truck accidents resulting in the death of the driver
- Driving while sleepy is as dangerous as driving while intoxicated. In some parts of the world, a driver can be charged with motor vehicle homicide if they cause a fatality and have not slept in 24 hours. In Australia, road safety legislation now views motor vehicle accidents involving fatigue as ‘voluntary impairment’—in other words you make a conscious choice to drive when tired
- Fatigue is the largest identifiable and preventable cause of incidents in Australian transport operations. Twenty to thirty per cent of road accidents involve driver fatigue. The figure is 5–15 per cent for fatal road accidents
- Australian road statistics show that sleep-deprived individuals are 4–7 times more likely to have an incident driving to and from work.

The causes of fatigue

Fatigue is caused by a combination of two processes—sleep debt and circadian rhythms.

Sleep debt

Adults generally sleep between seven and eight hours per night, although the need for sleep varies between people, with some individuals needing up to 10 hours of sleep to remain alert. A century ago, before the widespread use of electric lighting, people typically slept around nine hours per night. Today, family demands, work commitments and even television viewing habits combine to limit the opportunities for nighttime sleep. In our busy world, many people are suffering from sleep deprivation without being aware of it. Extreme sleep deprivation has severe health effects, but even mild sleep deprivation can affect health and our ability to perform tasks in our work and personal lives.

If we obtain less sleep than we need, we build up a sleep debt. Each successive night of inadequate sleep adds to the debt. Even reducing our sleep by just one hour each night over several nights (e.g. getting seven hours when we really need eight) can reduce our mental efficiency.

Shift workers, who sleep during daylight hours, also build up a sleep debt because daytime sleep tends to be briefer and of poorer quality than sleep obtained at night.24

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Obviously, a sleep debt may build up when a person’s work and family commitments do not allow them to sleep for as long as their body needs. But sleep debts can also occur when sleep is disrupted by alcohol and other drugs, and medical conditions. Medical conditions that can cause sleep disruption include the following:

- **Insomnia** An inability to get to sleep, or a difficulty staying asleep. In many cases, insomnia is a symptom of another problem, such as medical conditions, side effects of medicines, or sleep disorders. Insomnia can also be caused by worry or emotional upsets.

- **Restless legs syndrome (RLS)** A disorder that causes a strong urge to move your legs. This urge to move often occurs with strange and unpleasant feelings such as creeping, tingling or burning. Moving your legs relieves the urge and the unpleasant feelings.

- **Periodic limb movements (PLM)** Involuntary leg movements while asleep. The movements often disrupt sleep and may cause the person to wake up.

- **Sleep apnoea** A disorder in which breathing pauses or becomes shallow during sleep (see below).

If you think you may be experiencing any of these conditions, see your doctor immediately.

### Sleep apnoea

Sleep apnoea is one of the more common medical conditions related to sleep disturbance. It is a condition in which breathing stops for ten seconds or longer during sleep. This reduces the level of oxygen to the brain, and results in disturbed sleep. The condition is often associated with snoring. During a typical episode of sleep apnoea snoring stops as the person ceases breathing. After a period of silence, they wake up, gasp or snort, and then return to snoring.

Sleep apnoea affects between two and five per cent of the population. However, the condition is more common in men who are overweight and/or have a large neck size.

Sleep apnoea typically results in excessive daytime sleepiness. It also causes forgetfulness, clumsiness on tasks requiring careful movements, and may lead to reduced sex drive and/or impotence.

The good news is that effective treatments are available for sleep apnoea. As well as weight loss, your doctor may recommend surgery, or the use of a device that will keep your airway open while you sleep.

**When to see a doctor**

Consult a medical professional if you experience, or if your partner observes, the following:

- Snoring loudly enough to disturb the sleep of others or yourself
- Shortness of breath that awakens you from sleep
- Intermittent pauses in your breathing during sleep
- Excessive daytime drowsiness, which may cause you to fall asleep while you’re working, watching television, or even driving.

*Mayo Clinic*
Circadian rhythms

Our bodies have very steady 24-hour rhythms in their physiology, biochemistry and behaviour. Alertness, body temperature, sleep tendency and human error have also been shown to follow a 24-hour pattern. These rhythms are known as circadian rhythms, the word circadian being Latin for ‘about a day’. Our body’s internal clock is kept on correct time by exposure to light, particularly early morning light. Our circadian rhythms are so reliable that even if we are removed from the 24-hour rhythm of night and day (such as wintering in Antarctica) the rhythms continue to run. Without regular exposure to a daily cycle of light and dark, circadian rhythms eventually begin to ‘free run’ and will no longer align closely with the 24-hour day.

Circadian rhythms have an important role in regulating sleep patterns. Chemical changes occur in the body as it prepares for sleep, typically between 8pm and midnight. Body temperature reaches a low point at around 3am, and then begins rising steadily, apparently as our body gets ready for the day ahead, even before most people are naturally awake.

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Do shift workers adapt to permanent night shifts?

Not usually! Research shows that fewer than 30 per cent of permanent night shift workers actually adjust their rhythms to a nighttime schedule. In most cases, they remain on a typical daytime pattern. As a result, even workers on regular nightshifts will still experience a strong drive for sleep during the night, and will find it more difficult to obtain good quality rest during daylight hours.

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Beware the WOCL!

The period from around 2am–5am when we would normally be asleep, is often referred to as the window of circadian low (WOCL), and is a time when mental functioning is generally at its worst. The WOCL is a high-risk time for human error. Even people without a sleep debt find that their work performance is affected by fatigue during the WOCL, but a sleep debt will intensify the negative effects of the WOCL.

Studies of thousands of industrial errors have shown that although they can occur at any time of day or night, a large proportion of errors occur at around 3am. There is often a second, although smaller, risk period at around 3pm. That afternoon period is sometimes called the ‘post-lunch dip’, but it happens regardless of whether people eat lunch or not.

In a recent study, hundreds of errors reported anonymously by LAMEs and AMEs were examined to see how they varied throughout the 24-hour day. Nearly all the errors were minor and were quickly corrected. Most of these several hundred errors were absent-minded ones made during routine or monotonous tasks such as re-fitting caps and covers, removing tools, and positioning stands and equipment. Problem-solving mistakes such as mis-diagnosed faults were less common. To control for the possibility that the 24-hour pattern of errors might just reflect the number of people working at each hour of the day and night, the number of errors reported at each hour was adjusted to even out any effects of staffing level changes.

The results showed that absent-minded errors showed a strong circadian rhythm, with a big peak between 2am and 3am. Problem-solving mistakes, on the other hand, happened at all times of the day and night. Although the cases came from airlines, the same pattern was observed in general aviation (GA), even though overnight work is generally less common in GA.

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These results remind us to be alert to the dangers of fatigue. Everyone involved in maintenance, whether LAMEs or AMEs, needs to be aware that it is harder to focus your attention during the window of circadian low. This in turn may increase the odds of errors, particularly absent-minded slips and memory lapses, as indicated in the following case study:

**Case study**

Six ... mechanics were ... sent to ZZZ to accomplish the engine change [#2 engine on a B737-300]. These mechanics had worked 24-plus hours straight to complete the engine change. When the aircraft left XXX on a revenue flight to ABC, the flight crew was unable to retard #2 engine below 90 per cent N1 and had to do an in-flight shutdown on final approach into ABC. It was discovered that a 10-32 nut was left in the throttle box, and that prevented the flight crew from retarding #2 engine throttle.

*Aviation Safety Reporting System report*

**Tips for dealing with the WOCL (window of circadian low: 2–5am)**

- If possible, avoid the most safety-critical tasks during the WOCL. For example, if you have a choice of rigging flight controls or checking the expiry dates on life jackets, leave the flight controls until later.
- If you can, keep the lights bright and the temperature slightly cool.
- Try to avoid monotonous or tedious tasks.
- Ask someone to check your work.
- Stretch, walk around. Get some fresh air. But don’t expect this to help for more than a few minutes.
- If you can, take a brief nap. Even a few minutes will help.
- Use caffeine carefully, and be aware that it may make it more difficult to sleep when you get home.
Factors that increase the impact of fatigue

Certain conditions in the workplace can make the effects of fatigue more severe. These include:

- **Low light.** A work environment with low illumination reduces alertness and makes it harder for a fatigued person to fight the urge to sleep.

- **Passive activities.** Tasks that do not involve physical activity, or are performed while seated, are more likely to be affected by fatigue.

- **Boring or monotonous tasks.** Tasks requiring continuous monitoring or long tedious inspections tend to be more susceptible to fatigue-related errors.

- **Warm temperature.** A fatigued person will find it even harder to stay alert if their work environment is warm.

Case study

Two of us worked together that night on the fan lube. My partner cleaned and re-sprayed the dampers. Unknown to him, one damper fell off the shelf where he was working, and landed on a lower portion of the work table, out of sight. Upon reassembly, I sat in the inlet installing blades and dampers. Apparently I missed installing a damper under #20 fan blade. This occurs occasionally, and you’ll have an extra damper left over after all the fan blades are installed. Then you spin the fan slowly and find where the missing damper is, and install it. But in this case, we had no ‘extra’ damper because, unknown to us, it had fallen to a lower shelf on the work table. Inspection looked over the blade installation (they don’t look at dampers) and gave us an OK to install front spinners. The aircraft left the station on a revenue flight the next morning, and upon reaching XXX, the pilot wrote up a vibration on #2 engine … I think the major factor in this instance was alertness. The human body is not designed to work [nightshift]. I cannot function at my best during the night. I routinely get four hours of restless sleep a day, and I’m constantly tired and irritable.

*Aviation Safety Reporting System Report*
How tired are you?

 Epworth sleepiness scale
 Developed by Dr Murray Johns of Epworth Hospital in Melbourne

 How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life over recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

<table>
<thead>
<tr>
<th>Situation</th>
<th>Chance of dozing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting and reading</td>
<td></td>
</tr>
<tr>
<td>Watching TV</td>
<td></td>
</tr>
<tr>
<td>Sitting inactive in a public place (e.g. a theatre or a meeting)</td>
<td></td>
</tr>
<tr>
<td>As a passenger in a car for an hour without a break</td>
<td></td>
</tr>
<tr>
<td>Lying down to rest in the afternoon when circumstances permit</td>
<td></td>
</tr>
<tr>
<td>Sitting and talking to someone</td>
<td></td>
</tr>
<tr>
<td>Sitting quietly after a lunch without alcohol</td>
<td></td>
</tr>
<tr>
<td>In a car, while stopped for a few minutes in traffic</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>no chance of dozing</th>
<th>slight chance of dozing</th>
<th>moderate chance of dozing</th>
<th>high chance of dozing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

1 – 6. Congratulations, you are getting enough sleep!
7 – 8. Your score is average
9 and up. Seek the advice of a sleep specialist without delay!
Managing the risks of fatigue in aviation maintenance

Over 40 per cent of adults in the general population report that daytime sleepiness is affecting the quality of their work.\textsuperscript{26} Maintenance workers tend to be even more fatigued than the general population. In fact, 82 per cent of maintenance personnel worldwide consider that fatigue is a safety issue in aircraft maintenance.\textsuperscript{27}

In 2001, a study using sleep monitoring equipment showed that maintenance personnel:

- Sleep an average of only five hours per 24-hour period
- Tend to over-estimate the amount of sleep they are getting
- Work an average of 48 hours per week
- Ten per cent say they have fallen asleep at the wheel while commuting.

A survey of Australian aircraft maintenance engineers found:

- Fifteen per cent had worked a shift longer than 18 hours in the previous 12 months
- Some LAMEs had worked for 24 hours or longer at a stretch.\textsuperscript{28}

Sleep inertia (AKA ‘sleep drunkenness’)

In the few minutes after waking up, we may experience a brief period of confusion, poor memory and grogginess. This effect, which can last up to 15 minutes, is known as sleep inertia. It can be an issue in workplaces where people have to wake up shortly before they get to work, for example pilots who sleep in onboard crew-rest facilities, or ambulance officers. It can also be an issue in maintenance if you are on call during the night, or if you nap at work. Be aware that after waking from a deep sleep it might take 15 minutes or so before you are alert enough to get to work.

Fatigue cannot be eliminated, but the risks associated with it can be managed through a partnership between employer and employee. Some of the causes of fatigue originate with company policies and practices; for example, hours of work, the extent to which work is performed during the night, and the predictability of work schedules. Other causes stem from the employee’s personal situation, including commuting time, family responsibilities, and the demands of second jobs. The diagram opposite shows some of the main sources of fatigue. Employer and employee share responsibility for managing fatigue to the best of their abilities.


Responsibilities of the employer

- Schedule work hours and time off to give the employee sufficient opportunity for restorative sleep
- Manage workload and breaks.

Responsibilities of the employee

- Manage their personal time to make sure they are rested and fit for duty
- Not to put other people in danger by performing maintenance when excessively fatigued
- When reporting incidents, to note if fatigue was a factor.

Employer and employee responsibilities for managing fatigue

Adapted from Australian National Transport Commission
Some strategies to deal with fatigue

In this section, we consider some actions that can be taken to manage fatigue. Some of these might be considered common sense, but others may not be as obvious.

Get more sleep!

The first and most obvious way to prevent fatigue is to get more good-quality sleep. This is easier said than done, of course, particularly if you work irregular hours, have a second job, or have young children. Here are some tips on getting better sleep:

Tips for better sleep

- Set, and stick to, a sleep schedule as much as possible. Try to go to bed and wake up at the same times each day
- Expose yourself to bright light in the morning, but avoid it at night. Exposure to bright morning light energises us and prepares us for a productive day. Alternatively, dim your lights when it’s close to bedtime
- Exercise regularly. Exercise in the morning can help you get the light exposure you need to set your biological clock. Avoid vigorous exercise close to bedtime if you are having problems sleeping
- Establish a relaxing bedtime routine. Allow enough time to wind down and relax before going to bed
- Create a cool, comfortable sleeping environment, free of distractions. If you are finding that entertainment or work-related communications are creating anxiety, remove these distractions from your bedroom
- Treat your bed as your sanctuary from the stresses of the day. If you find yourself still lying awake after 20 minutes or so, get up and do something relaxing in dim light until you are sleepy
- Keep a ‘worry book’ next to your bed. If you wake up because of worries, write them down with an action plan, then forget about them until morning
Avoid caffeinated drinks, chocolate and tobacco at night
Avoid large meals and beverages right before bedtime
No nightcaps—drinking alcohol before bed can rob you of deep sleep and cause you to wake up too early
Avoid medicines that delay or disrupt your sleep. If you have trouble sleeping, ask your doctor or pharmacist if your medications might be contributing to your sleep problem
No late afternoon or evening naps, unless you work nights. If you must nap, keep it under 45 minutes and before 3.00 pm
Place a ‘Do not disturb’ sign on your door. Ask all family members to be as quiet as possible while you are sleeping
Make sure that your room is dark. Blackout curtains can help
Use an answering machine or voicemail for phone calls. Turn down the ringer.

Controlled naps
Numerous research studies have shown that even a brief nap can result in performance improvements. Napping used to be widely discouraged by employers, but now pilots, air traffic controllers and others are being allowed to take brief controlled naps when workload permits. Here are two types of naps:
- Preventive nap—a brief sleep before you report for work, particularly before starting a night shift
- Restorative nap—a brief sleep during a break at work can sharpen your performance for the next couple of hours.

There are two problems to watch out for with naps:
1. Avoid taking naps in the hours before you go to bed so as not to interfere with your main sleep period
2. Naps lasting more than about 40 minutes may produce sleep inertia, (a feeling of grogginess and disorientation that may persist for up to ten minutes after awakening), and may impair performance. The best nap duration appears to be about 20-25 minutes (Also known as the ‘NASA nap’).

Caffeine
Caffeine is one of the most widely used stimulants, and if used carefully and in moderation, can be part of an overall fatigue management strategy. Caffeine has a half-life in the body of around five hours, so shiftworkers should be careful to avoid caffeine in the hours leading up to sleep. If you use caffeine to stay alert at work, use it selectively, and cut down on caffeinated drinks at other times. If you develop a tolerance to caffeine, it will not be as effective in keeping you alert.

Breaks
If the situation allows it, a brief break or a stretch can help to focus your attention and provide temporary relief from fatigue. Do not be afraid to call time out for a few minutes to clear your head. Breaks, however, only provide a short-term benefit. The only real remedy for fatigue is sleep.

Progressive restrictions
One way to deal with fatigue in maintenance is to keep those who are most fatigued away from the most safety-critical tasks, an approach sometimes called ‘progressive restrictions’. Some companies have internal policies progressively limiting the tasks an engineer can perform the longer they have been at work. For example, a LAME who has been on duty for longer than 12 hours might not be permitted to certify for the work of others, or may not be permitted to perform engine runs or other critical tasks. If they have been working for longer than 16 hours, they might be prevented from working on critical systems such as flight controls.
A general illustration of the progressive restriction approach in maintenance is shown below.

In your own operations:

- Where would you draw the line between low and moderate fatigue?
- What would you define as ‘unacceptable fatigue’?
- What tasks would you want to keep out of the hands of very fatigued engineers?

**Example of the progressive restriction approach**

**Level of fatigue**

- **Low**: Work in accord with normal privileges and limitations.
- **Moderate**: All work must be dual inspected. Operational/Functional checks must be carried out whenever a critical system has been disturbed.
- **Extreme**: Previous restrictions and: No sign-off authority. May not interact with critical systems such as flight controls. May not work on ETOPS tasks.
- **Unacceptable**: No maintenance tasks may be performed.

Fatigue risk management systems (FRMS)

Around the world, safety-critical industries such as railways, road transport and airlines are beginning to introduce scientifically based risk management approaches to dealing with fatigue-related hazards. These approaches are known as fatigue risk management systems (FRMS), and are often part of an organisation’s overall safety management system (SMS). If your organisation does not have an SMS, it can still have an FRMS. A typical FRMS includes education and training for staff, incident reporting systems, and work schedules that take into account current knowledge of human fatigue.

A fatigue risk management system (FRMS) can be part of a safety management system (SMS)

CASA defines an FRMS as: ‘A scientifically-based, data-driven, documented management system used to identify, record, track and manage the risks to aviation safety that may arise from fatigue. This may form part of an operator’s safety management system (SMS).’

Worldwide progress towards FRMS in maintenance has been slow. In an FAA survey of the worldwide airline maintenance industry in 2007:

- Most maintenance personnel recognised that fatigue had an impact on safety.
- Fewer than 25 per cent worked for an organisation with a fatigue management system.
- Most organisations did not provide any training on fatigue management.29

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An FRMS can often include the use of commercial computer software systems to design shift rosters. Software models take into account the sleep a person is estimated to have obtained, as well as circadian variations in alertness, to produce an estimate of the fatigue level that might result from a particular shift pattern. Commonly used models include the following:

- Fatigue audit InterDyne (FAID)
- Fatigue avoidance scheduling tool (FAST)
- Circadian alertness simulator (CAS).

Even though computer software is widely used to design shift rosters, maximum limits on duty times are still an important part of managing fatigue in maintenance. In 2003, the UK Civil Aviation Authority asked a sleep expert (Professor Simon Folkard) to develop duty time guidelines for maintenance engineers. The guidelines he developed have been widely accepted as reasonable and are included at the end of this chapter. Key items from Folkard’s guidelines are:

- There should be a 12-hour limit on shift duration
- No shift should be extended beyond 13 hours by overtime
- A break of at least 11 hours should occur between shifts
- There should be a work break every four hours.

The following elements are common to most formal FRMS. In some cases, an organisation’s fatigue risk management interventions involve only some of these elements, such as training or work schedule re-design.

- Organisational policies
  - Commitment from management and staff
  - Safety reporting culture policy to enable staff to report incidents
- Education and training
  - For front line staff, as well as managers, supervisors and scheduling personnel
- Risk assessment
  - Identifying tasks at greatest risk from fatigue
  - Developing strategies to reduce the risk to these tasks
  - Determining how much fatigue can be tolerated to get the job done
- Changes to work schedules to reduce fatigue
  - Applying maximum duty time limits
  - If necessary, using software modeling to fine-tune schedules and estimate fatigue levels
- Continual monitoring and assessment of fatigue and fatigue-related events
  - Incident and event reporting system
- Periodic evaluation and continuous improvement of the FRMS program
Key points

- Fatigue is not only a threat to aviation safety, but can also put the health and safety of aircraft maintenance personnel at risk. Fatigue seriously impairs work performance and increases the chances of human error.

- With no legally imposed duty time limits for LAMEs and AMEs, maintenance personnel are often pressured to work extremely long hours, and almost certainly experience greater levels of fatigue than most other sectors of the aviation industry.

- In the past there was a common attitude that people should just tough it out, but it is now increasingly recognised that fatigue can produce performance impairments comparable to those produced by alcohol. Drink driving is no longer tolerated by society, and there are signs that social attitudes are also shifting in the same direction when it comes to fatigue. In the near future, performing a safety-critical task while fatigued may be seen as a reckless act, akin to drink-driving.

- There is a worldwide move towards comprehensive fatigue risk management systems (FRMS) in maintenance operations. These systems typically include awareness training for personnel, incident reporting systems, risk assessment and controls to limit the impact of fatigue. Even without a full FRMS, maintenance organisations can still take steps to manage fatigue through simple steps such as company duty time limits.

Further information

The U.S. Federal Aviation Administration maintains a website devoted to resources on fatigue in aircraft maintenance, including regular newsletters on maintenance fatigue:


- *Grounded* is an entertaining video about maintenance fatigue. As the DVD notes say: “There is trouble on the home front and fires at work! Gregg is an airline manager who needs some rest. Can he get the aircraft back in the air and also correct his poor sleep habits? Or, will he go through life grounded?” This video is about sleep but is not a sleeper. Available free of charge at: https://hfskyway.faa.gov/HFSkyway/FatigueEducation.aspx

- The report *Fatigue Risk Management in Aviation Maintenance: Current Best Practices and Potential Future Countermeasures* summarises the world’s best practices (details above) on fatigue management in maintenance. The report is available on the FAA fatigue website.

You can find Information on fatigue modeling software on the following websites:

- Fatigue Audit InterDyne (FAID) www.faidsafe.com
- Fatigue Avoidance Scheduling Tool (FAST) www.fatiguescience.com
- Circadian Alertness Simulator (CAS) www.circadian.com

If you are concerned that you might be suffering from a sleep disorder, speak to your doctor. You can find information on sleep and sleep disorders at:

- Australia’s Health Direct Website: http://www.healthinsite.gov.au/topics/Sleeping_Well
- U.S. National Sleep Foundation
- http://www.sleepfoundation.org/
Folkard’s recommendations on aircraft maintenance hours of service

a) No scheduled shift should exceed 12 hours.

b) No shift should be extended beyond a total of 13 hours by overtime.

c) A minimum rest period of 11 hours should be allowed between the end of a shift and the beginning of the next, and this should not be compromised by overtime.

d) A maximum of four hours work before a break.

e) A minimum break period of ten minutes, plus five minutes for each hour worked since the start of the work period or the last break.

f) Scheduled work hours should not exceed 48 hours in any period of seven successive days.

g) Total work, including overtime, should not exceed 60 hours or seven successive work days before a period of rest days.

h) A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime.

i) To comply with the European Union working time directive, four weeks annual leave should be allowed.

j) A span of successive night shifts should be limited to six for shifts of up to eight hours long, four for shifts of 8.1 to 10 hours long, and two for shifts of 10.1 hours or longer. These limits should not be exceeded by overtime.

k) A span of night shifts involving 12 or more hours of work should be immediately followed by a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off) and this should be increased to three successive rest days (i.e. 83 hours off) if the preceding span of night shifts exceeds three or 36 hours of work. These limits should not be compromised by overtime.

l) The finish time of the night shift should not be later than 08.00.

m) A morning or day shift should not be scheduled to start before 06.00, and wherever possible should be delayed to start between 07.00 and 08.00.

n) A span of successive morning or day shifts that start before 07.00 should be limited to four, immediately following which there should be a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime.

o) Wherever possible aircraft maintenance engineers should be given at least 28 days notice of their work schedule.

p) Employers of aircraft maintenance personnel should consider developing risk management systems similar to those required by Western Australia’s code of practice for commercial vehicle drivers.
q) Educational programs should be developed to increase aircraft maintenance engineers’ awareness of the problems associated with shiftwork. In particular, it is important to draw their attention to the objective trends in risk, with a view to increasing their vigilance at points where risk may be high despite the fact that fatigue may not be. It is also important to provide information on how to plan for night work, and to give guidance on the health risks which seem to be associated with shift work, particularly at night.

r) Aircraft maintenance personnel should be required to report for duty adequately rested.

s) Aircraft maintenance personnel should be discouraged or prevented from working for other organisations on their rest days, and hence from exceeding the proposed recommendations on work schedules, despite their implementation by their main employer.


When you are ready, please turn to page 33 of the Workbook for Engineers and complete the exercises.