AMPASafety Equipment Project

FORMAL SAFETY ASSESSMENT
Personal Protective Equipment in Marine Pilot Ladder Transfers

Part 1: Footwear

prepared by

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Important Note

The information in this report replaces the report ‘Preliminary evidence regarding footwear’ prepared under the AMPA Safety Equipment Project in April 2007. The report dated August 2008 provides extensive revisions and additions, and this report provides further minor revisions.

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Fiona and her associates specialise in applying ergonomics principles to develop tailored, evidence-based solutions that enhance human performance and reduce risk of injury and illness within industry.
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1. INTRODUCTION

1.1 Project aims

The aim of the AMPA Safety Equipment Project is to investigate the usability of selected personal protective equipment (PPE) and marine safety equipment used by marine pilots in Australia during the pilot ladder transfer between the pilot vessel and commercial vessels. This investigation follows a ‘human factors’ and ergonomics approach as it focuses on the application and use of equipment in a given context, with consideration for the users, the influence of the environment, the organization of the task, work systems, and the interaction with other equipment.

The results from these investigations will provide practical and evidence-based advice regarding PPE items that reduce risk, increase risk and/or have no effect on pilot safety during the pilot ladder transfer. Pilots and their employers can then use this information to contribute towards their own assessments in managing and reducing risk in their specific work environments and with their own pilots.

1.2 Project methodology

Formal Safety Assessments

The methodology used for these reports is based on both the ‘Formal Safety Assessment’ as used by the International Maritime Organization (IMO), and on the requirements under Australian legislation for Risk Assessment and Risk Management.

Both the Formal Safety Assessment and the Risk Management approach have the same key elements:

Hazard identification

This involves identifying hazards in tasks. In this project this step includes considering actual or potential hazards when the equipment is used in the pilot transfer and hazards when the equipment is not used.

Risk assessment

In this phase the likelihood and consequence of the hazards are assessed and the relative contribution of the different factors that impact on this risk are evaluated and compared.

Risk control

Risk ‘controls’ or risk mitigation strategies are provided to address the assessed risks. In these reports the control options have been evaluated by the users to reduce the risk of additional hazards being introduced and to ensure the advice is sound and acceptable to the users.

Cost Benefit Analyses

This issue is not often included in Risk Management models however it is included under the IMO Formal Safety Assessment. This step is also a useful part of the
process to compare and contrast the different control options as well as the potential cost of doing nothing.

**Assessment of ergonomics principles**

The methodology in this report also incorporates the requirements for selecting and comparing items of PPE as outlined in the European Standard ‘Personal Protective Equipment – Ergonomics Principles’ IS EN 13921:2007. As this Standard explains:

*"The application of ergonomics principles to PPE allows optimization of the balance between protection and usability."

PPE worn by marine pilots and other occupational groups is aimed at protecting the user from known hazards to their health and safety. However the PPE may also unintentionally create new hazards, as well as failing to counter the known hazards and to operate as intentioned. Maintenance methods and testing schedules for all equipment can also influence usability, and may serve to reduce or increase risk for the pilot.

These reports explore the ergonomics issues of the interaction of the PPE with the pilot’s body, including:
- biomechanical interaction
- anthropometric characteristics (human sizing and dimensions)
- thermal interaction
- interaction with the senses – eg vision, hearing, touch

The assessments include an examination of the interaction between the different items of PPE with each other and with typical functional tasks undertaken by the pilot. For example this includes the impact of helmet wearing while wearing a personal flotation device, or glove wearing when operating a marine radio.

**PPE selected for review**

In consultation with AMPA, a sample of PPE was selected for review. The rationale for this selection was as the PPE is commonly used by pilots in Australia, and/or has recently been proposed as being of potential benefit in the pilot ladder transfer (eg report by Weigall presented at Asia-Pacific Marine Pilotage Conference 2006).

Formal safety assessments have been prepared for each of the following items of PPE and equipment:

<table>
<thead>
<tr>
<th>Part</th>
<th>Item</th>
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<tbody>
<tr>
<td>1</td>
<td>Footwear</td>
</tr>
<tr>
<td>2</td>
<td>Gloves</td>
</tr>
<tr>
<td>3</td>
<td>Head Protection</td>
</tr>
<tr>
<td>4</td>
<td>Personal Flotation Devices, Wet Weather Jackets and Personal Locator Beacons</td>
</tr>
</tbody>
</table>

Prepared by Fiona Weigall, ©Health & Safety Matters Pty Ltd, August 2008
The project has been broken up into four chapters or ‘parts’, with each part providing a stand-alone report on the topic. The reports follow a similar format, and provide the reader with evidence-based material including data from peer-reviewed scientific journals plus information based on consultation with a wide range of users, subject experts, equipment manufacturers and equipment suppliers. The reports also provide user evaluation and performance testing of the PPE and other equipment where possible.

1.3 Using and applying this information and advice

The information from these assessments should contribute to an organisation’s own risk assessments and safety assessments, based on specific pilots and scenarios that are typical to the pilots’ work. The information in these reports should not replace these important port specific and pilot specific risk assessments.

For this project and the assessments, the use of PPE and marine safety assessment was restricted to the pilot ladder transfer task. Task analyses revealed the following typical methods used in the pilot boarding and disembarkation as:

Boarding
- Donning the relevant PPE (e.g., PFD, gloves, wet weather jacket)
- Walking around the deck of the pilot vessel to the ladder
- Reaching up then jumping or stepping onto the lower rungs of the ladder
- Climbing up the ladder, grasping and releasing the hands on manropes or side ropes
- Walking on the deck/within the commercial vessel

Disembarking
- Walking on the deck/within the commercial vessel
- Climbing down the ladder, most commonly sliding the hands down the manropes on the descent or less commonly holding the ladder’s side-ropes
- Jumping or stepping backwards off the ladder onto the pilot vessel

For this project it was therefore assumed that the pilot’s complete PPE is used for relatively short periods. Theoretically all the PPE could be removed once onboard the ship provided the footwear used during the transfer was replaced with alternative footwear. The PPE could also be removed once safely within the cabin of the pilot vessel.

If the above task analyses are not relevant to a pilot or if the ladder transfers are performed differently to those observed for these reports, other hazards may be present, with different risks and different control options.

1.4 Personal Protective Equipment as a ‘control’

PPE is routinely used in situations where a risk to health and safety has been identified. The preferred and optimal solution is of course to eliminate or to redesign the task to remove the risk or to minimize the risk. PPE should only be
used when the task has been improved as much as ‘reasonably practicable’ by other means. This hierarchical approach to risk control is also the law in each occupational health and safety (OHS) jurisdiction in Australia.

The use of PPE to reduce risks in the ladder transfer task is considered a very low level and relatively ineffective means of ‘controlling’ the risks associated with this task. However given that the most common transfer method and the internationally accepted method of undertaking pilot transfers is to use the pilot ladders, and most ports in Australia use this method, it is relevant that the pilots be provided with the most appropriate PPE to minimise risks wherever possible.

This PPE should be well suited to the task, the work environment and each specific user. Marine safety equipment is also important for the pilot as this can reduce the severity of the injury should a fall or other accident occur.
2. BACKGROUND

2.1 Policies and procedures regarding footwear

There are no national or state requirements regarding pilots’ footwear at work, but pilot employers generally require the pilots to wear some form of enclosed footwear when they undertake the ladder transfer task. In some cases the pilots select and purchase their own footwear using an ‘allowance’ from the employer, while in other cases the employer recommends footwear models from the company’s main supplier of personal protective equipment and other safety gear and pays for the footwear.

The Code of Safe Working Practice for Australian Seafarers provides the following advice to seafarers regarding footwear selection and use:

| 5.4.7.2 | All seafarers at work should wear safety footwear that complies with AS 2210.1 1994 (Occupational Protective Footwear, Guide to Selection and Use). Sandals and similar footwear must not be worn when working. |

The European Maritime Pilots’ Association (EMPA 2008) provides the following guidance specifically to pilots:

“Shoes or boots with non-slip soles providing a secure foothold on decks, pilot ladder and accommodation ladder steps. Some types of safety footwear incorporating toe protection may be also suitable.”

2.2 Footwear worn by pilots

Australian pilots currently wear a wide range of different footwear, including:

- Dress shoes – leather shoes with a soft “rubber” sole, such as Florsheim, Windsor Smith and Westport brands
- Walking and casual shoes – typically leather uppers with soft soles such as Rockport, Colorado, Rivers and Doc Marten brands
- Deck shoes – sailing type shoes with smooth, finely grooved soles such as Sperry Topsiders
- Boots – such as ankle height leather boots with elastic gussets or lace up
- Steel capped footwear – generally in an ankle height, boot style
- Sandals – in hot climates

According to pilots surveyed for this project, their choice of footwear was based on a combination of factors, including:

- Non-slip sole
- Comfort for wearing for long periods (including standing on the bridge)
- Water and/or oil resistant
• Easy to kick or push off in an emergency
• Neat appearance and/or to match their pilot uniform

Some pilots wore ‘safety shoes’ (ie fitted with a steel cap) which had been issued to them by their employer. While they stated they may not have chosen safety shoes and did not feel the cap was necessary the shoes were reportedly comfortable and did not restrict their climbing methods.

As with safety helmets, pilots issued with safety shoes are more likely to be required to walk through industrial sites where this form of footwear is required under the site’s occupational health and safety policies.

Interviews with pilots and pilot managers in Australia indicate that many pilots like to choose shoes that match their uniform or other work clothes.
3. HAZARD IDENTIFICATION

As with the hands, the feet are an important interface between the ladder and the pilot. Inappropriate or inadequate footwear may result in two main ‘mechanisms’¹ of injury for pilots in the transfer task – slips, trips and falls, and body stressing.

1. Slips, trips and falls, from:
   - Slipping or tripping on the deck
   - Slipping or tripping on a step on the ladder
   - Being unable to maintain balance as the vessels and/or ladder moves.

   Footwear can contribute to the risk of slips, trips and falls from:
   - Soles that are not compatible with the step materials and surfaces (rubber, timber and potentially wet and greasy) and slip
   - Thick or stiff soles that reduce flexibility and also reduce proprioception through the sole and from feeling where the ladder step is under the foot adding to risk of slips and trips
   - Tripping or catching the shoe on the step, such as when a piece of the footwear extends beyond the size and shape of the foot (e.g. footwear with soles that extend past the toe box, or with bulky heel counters)
   - Footwear with bulky fastenings that the ropes may become entangled on and contribute to falls

2. Body stressing, from
   - Muscular stress from jarring and strain when landing heavily on the deck after descending the ladder
   - Muscular stress due to restricted ankle and foot movement and requiring awkward postures
   - ‘Repetitive movement, low muscle loading’² with repeated climbing and walking tasks

   Footwear can contribute to the risk of injuries from body stressing when it:
   - Lacks cushioning and shock absorption capacities
   - Restricts movement at some joints and places excessive stress on others

Footwear that cannot easily be removed in an emergency situation and is heavy and bulky could provide an additional risk in the case of a fall into water, as it may make swimming and flotation more difficult.

While the footwear must suit the transfer task, it must also be suitable for walking along the deck, climbing stairs to the bridge, and standing for long periods. Other considerations for footwear are the areas dockside – including access to the wharf, the surface of the wharf and any contaminants or substances over these areas.

¹ Terms relating to injuries and injury causation are as defined in Type of Occurrence Classification System, Edition 2.1, National Occupational Health & Safety Commission, Canberra, 2002
² as above
4. RISK ASSESSMENT

4.1 Likelihood and consequence of injuries relating to footwear

Injury and incident data for pilot transfers

There is not enough data available from pilot services in Australia or overseas that provides detailed information regarding the influence of slips, trips and falls or body stressing relating to footwear and from which injury incidence rates can be determined.

Because of this lack of data from pilots, injuries from these events in related or similar environments are explored below.

Slips trips and falls - general

A major study across 11 countries surveyed almost 7,000 seafarers and found that slips trips and falls accounted for 43% of all injuries (Jensen et al 2005). Of those injured from slips, trips and falls 42% had sprains or fractures from the accident, compared with other injury types where only 17% caused these conditions.

Almost half of the seafarers injured from slips, trips and falls were unfit for duties for at least one day, and this was a greater proportion than for other mechanisms of injury. Complaints of discomfort and time off work were also greatest for those seafarers who had experienced a slip, trip or fall. Areas where most slip, trip and fall accidents occurred were on gangways, followed by the accommodation and deck.

An additional factor contributing to trips and falls is the vessel’s movements. This ‘motion induced interruption’ (MII) can cause people to lose stability and so make postural adjustments which may or may not be sufficient to prevent falls. When a person stumbles, these adjustments are rapidly effected by the feet and the trunk (MacKinnon et al 2006; Powell et al 1999).

Falls on the same level - impact of floor surfaces and friction

As with other accidents, there is generally not one isolated factor that causes the accident and fall, but rather a number of different risk factors (both direct and indirect) that contribute to the slip, trip or fall event (Leclercq 2006).

Slipping is a major cause of injury, and a key factor impacting on slipping is friction. Friction refers to the resistance to sliding between two surfaces and is necessary to prevent forward motion of the feet when walking (WorkCover 1998). Good friction between footwear and floor surfaces is essential for walking in a controlled manner, and is particularly critical at certain phases of walking such as when:

- the heel of the leading foot strikes the ground;
- the toe of the trailing foot pushes off the ground; and
- making a sudden change of direction.
Friction may be provided by:
- adhesion of one surface to another - such as a rubber heel on a dry surface;
- indentation of one surface indenting onto another - such as sharp particles indenting into a soft shoe sole.

Most slips occur in wet conditions. If a film of fluid covers the floor or other surface the adhesion can be lost and aquaplaning occurs. Some non-slip surfaces (such as those with sharp particles) can penetrate the film and provide sufficient friction, but this depends on how viscous the liquid is and the degree of indentation of the surface (Stevenson 1992). Very viscous fluids include oil and grease.

Flooring and different surfaces can be tested for slip resistance, where the coefficient of friction is measured. The coefficient of friction (COF) is defined as the friction force opposing sliding motion divided by the force at right angles to it (as illustrated in Figure 1), and the larger its value the better. Typical values of the COF used in walking are between 0.25 and 0.3, however more friction is required for walking quickly, walking with long strides and walking on a slope. The recommended minimum COF is 0.4 available between the shoe and the floor, where this is measured under realistic conditions (Stevenson 1992).

Figure 1. Determining the coefficient of friction of a floor surface (Stevenson 1992).

Table 1 provides examples of different floor surfaces and their slip resistance, with the larger numbers representing greater friction and a reduced risk of slipping.

Features improving the slip resistance of floor surfaces include:
- rough (at least 10 micrometers from peak to valley in the floor texture)
- sharp peaks, not rounded (eg rounded pebbles on top of concrete can be very slippery)

For example concrete finished with a trowel is much smoother and therefore more slippery than concrete finished with a wooden float or with a broom (WorkCover 1998).
Table 1. Comparison of coefficient of friction with different surfaces (WorkCover 1998)

<table>
<thead>
<tr>
<th>Floor surface</th>
<th>Coefficient of friction (wet with water)</th>
<th>Comparison with AS/NZS 3661.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>High polyurethane gloss on timber</td>
<td>0.09</td>
<td>Unacceptable to AS/NZS 3661.1</td>
</tr>
<tr>
<td>Polished marble</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Glazed ceramic tile</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Smooth vinyl</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>Quarry tiles, various</td>
<td>0.46 – 0.54</td>
<td>Acceptable to AS/NZS 3661.1</td>
</tr>
<tr>
<td>Concrete paver, coarse texture</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Timber deck, profiled finish</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>Vinyl, raised dot pattern, coarse grit</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Concrete, broom finish, old</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Concrete, broom finish, new</td>
<td>0.87</td>
<td></td>
</tr>
</tbody>
</table>

Many floor surfaces in ships are slippery, including decks, passageways and stairs. One study showed that of 13 common floor surfaces tested, 8 were rated as ‘slippery’, having a coefficient of friction of less than 0.14 (Gronqvist et al 1990). The lowest scoring and most slippery surface was ‘smooth painted deck’ at 0.05, and the highest scoring surface was a ‘3M’ brand ‘Safety Walk anti-slip Carpet’ at 0.64. Floor surface roughness was identified as the most important factor affecting slip resistance in this study.

**Falls from a height**

No published studies of ladder falls from rope ladders or from pilot ladders were located. As with falls on the same level, it is often not possible to determine the exact reason for a ladder fall, and the reason is often a combination of factors (Cohen & Lin 1991a & b; Bjornstig & Johnsson 1992; Christensen 2004). In a study of more than 9,000 ladder falls at work, ‘lost footing’ was identified as the mechanism of injury in approximately 22% of cases (Smith et al 2006).

From observing the pilot transfer task, interviewing pilots and reviewing available accident and incident data, the situations contributing to falls from the pilot ladder climbing task are:
- Transitioning onto or from ladder – moving to or from the pilot boat, or to or from the accommodation system, particularly as the accommodation ladder is also often moving
- Having to over-reach – such as to the accommodation ladder and at the head/top of the ladder and to the manropes
- Being thrown from the ladder – due to sudden twisting or jerking
- Slippery steps – due to water and/or grease
- Miss-stepping – through rushing to ascend or descend the ladder

Falls from elevations account for between 10 – 15 % of all work related fatalities in Australia and overseas (ASCC 2008; NIOSH 2000). Falls from ladders specifically account for approximately 650 injury claims per year in Australia, and the greatest number occur in the construction sector, followed by manufacturing and
agriculture/forestry and fishing. Falls by Sea Pilots have not been identified as a separate group in the Australian national fatality data sets and are included in the ‘Fishing’ sector.

Studies into ladder falls have identified that almost half of those injured suffered moderate or serious injuries (moderate = concussion or uncomplicated fracture, serious = femur fracture or spleen rupture). The fall height affects severity, and one study (Bjornstig & Johnsson 1992) noted:
- In falls of less than 3m - 59% of injuries were rated as ‘moderate’ or ‘serious’
- In falls over 4m - 86% of injuries were ‘moderate’ or ‘serious’ injuries.

Of the 114 falls analysed for this study, there were a total of 167 injuries - an average of 1.5 injuries per person. In addition to suffering superficial injuries, other injuries were fractures/luxations (40%); sprains/muscle ruptures (13%); and concussion and other injuries (6%).

Another study of almost 10,000 ladder fall cases also noted the high level of fractures, and the consequences of these fractures were more serious in terms of days off work and direct cost of medical treatments than all other consequences of ladder falls (Smith et al 2006). For example:
- almost half of the cases with fractures cost more than US$5,000 in the year 2000; as compared with
- 10% of other injuries costing more than US$5,000.

In addition:
- almost 60% of ladder fall fractures cases had more than 28 days of disability; as compared with
- just over 10% of other injury types that had more than 28 days of disability.

Falls into water have different effects, and impacts that were feet first produced less fractures and injury than those that were horizontal because of the longer deceleration experienced.

The seriousness of fall injuries and the risk of fatalities increases with age (eg Smith et al 2006; Bjornstig & Johnsson 1992; and NIOSH 2000). The high fall fatality rates in older workers are reportedly due to more medical complications and prolonged recovery periods. For example the study by NIOSH analysed more than 8,000 falls and found:
- 0.23 deaths per 100,000 workers for 16-19 year olds;
- 0.40 for 25-34 year olds;
- 0.86 for 55-64 year olds; to
- 1.57 for 65 year olds and above.

According to this data the older pilots are therefore at much greater risk of serious injury from a fall than their younger colleagues.

**High impact through the feet**

Any impact taken through the feet is translated to the legs and to the spine, and can create a jarring type injury from walking, running and jumping. This ‘impact loading’ is reported to be a major factor in the development of musculoskeletal injuries. Loading can be a particular problem for pilots with existing knee injuries
(such as damaged or compromised menisci) as the knee’s shock absorbing capacity is reduced.

High impacts through the spine contribute to injuries such as the development of back pain, and this impact will also exacerbate many back conditions – both discal and ligamentous (Rome et al 2005; Fauno et al 1993).

4.2 Risks and benefits of different footwear designs

**Background**

There are various standards that relate to different occupational protective footwear and footwear selection, but none relate specifically to tasks requiring ladder use. There are standards relating to fire officers’ work however these tend to be for a boot that is bulkier and heavier than a standard boot with characteristics designed to cope with intense heat and heavy impacts from falling items.

Scientific literature regarding the prevention of falls on the same level stress that the priority must be to design the walking surfaces and work environments to reduce slips, and footwear should be one of the last factors to alter or modify as it is less effective. However where floor or work surfaces cannot be altered or improved, footwear gains importance.

The complicating factor for pilots in footwear selection is that they need to transit and stand on different surfaces between their office and the ship’s bridge, and this can reportedly include:

- carpeted office areas
- gravel driveways/carparks
- wharves and dockside areas covered with contaminants such as mud, mined materials, dusts and chemicals (eg in bulk container wharves)
- concreted areas under various states of repair and covered in different contaminants
- internal ships stairs covered with linoleum type flooring with rubber nosings
- external ships stairs made with various chequer-plate and/or metal grate materials
- linoleum, rubber matting, timber and other coverings on the bridge
- carpet and/or linoleum-type flooring inside the pilot boat cabin
- anti-slip aggregate painted over the pilot boat deck – which may be a fibreglass, aluminium or steel deck
- hardwood timber and rubber steps of the pilot ladder

As well as the floor or ground surface, other factors affecting the likelihood of falls on the same level are:

- water and other liquids
- contaminants on the surface
- sudden changes in surfaces
- poor lighting (obscuring liquids, contaminants and other hazards)
- sloped floor surfaces
- worn areas of special coatings (such as worn anti-slip paint)
The pilot’s movements on the surface can further increase the risk through:

- rapid movements
- sudden changes of direction

Considering the pilot boat deck and task of moving on the deck just prior to a transfer, many of the above floor surface characteristics and human behaviours are evident.

A person’s gait and foot kinematics change significantly when they perceive a slippery and non-slippery surface, particularly the heel’s vertical velocity and the foot-floor angle at heel contact (Chambers et al 2003) which is why good lighting, good vision and familiarity with the surface also affect the task and slip risk.

**Cut and shape of footwear**

Footwear that extends too high up the leg or too low over the foot can both impact on safety and comfort in the ladder climbing task. For example in a study on firefighters’ footwear, long leather boots that extended over the ankles caused discomfort as well as restricting movements with dorsiflexion (bending the foot up at the ankle) (Marr 1990). High cut shoes or ankle boots (such as used for basketball) do however provide additional support for users who require increased lateral stability for their ankles.

Footwear that is cut too low over the foot can also be problematic with instances of peoples’ feet coming out of the shoe as they walk or climb, resulting in the person tripping (Marr 2007). Some of the sailing shoes are very low cut and lack grip around the heel and forefoot, allowing the feet to slip out.

**Sole grip**

Sole grip refers to a friction force generated between the footwear and the floor. Footwear that has the greatest coefficient of friction includes:

- rubber (especially nitrile rubber)
- polyurethane (especially microcellular polyurethane)
- PVC/nitrile (rather than pure PVC)

(WorkCover 1998; Stevenson 1992)

The grip on the sole and its ability to walk over wet and slippery areas is clearly critical, however the best sole pattern depends on the surfaces underfoot, and this is dependent on the pilot’s work environment/s.

Tread patterns have limited influence when walking over dry surfaces, but are important on wet surfaces and those with contaminants. The shoe sole pattern allows the heel to penetrate the contaminant and make direct contact with the floor. The leading edge of the raised pattern on the sole should be sharp to help sweep away any liquid, and the pattern should have distinct channels or grooves that go to the edge of the soles to let the lubricants escape.

The heel strike area requires either a beveled or rounded edge rather than a sharp corner, and this area also benefits from a grooved pattern where possible. For
example bevels of between 10 – 20 degrees have been found to reduce slips at the heel strike phase of walking (Stevenson 1992; SATRA 1989).

Features of slip resistant soles are illustrated in Figure 2.

**Figure 2. Characteristics of soles that are recommended to reduce slip (SATRA 1989)**

Note - Not all options would be present on one sole

In most situations the soles recommended to reduce slips and trips are ‘deep cleated’ as this allows for walking and moving over a range of surfaces that may have different contaminants such as gravel, mud, or rocks.

‘Sailing’ or ‘boat shoes’ have different tread patterns to the deep cleated footwear illustrated in Figure 2. These shoes have a large number of very small channels designed specifically for moving on wet decks and these are designed for dispersing water. A disadvantage of this tread pattern is if the shoes are also worn over rough ground that has substances or rocks etc that do not fit between the grooves the soles will be unable to penetrate and adhere to the surface and there is an increased likelihood of slipping.

Soles that are not recommended for wet and slippery areas have the features illustrated in Figure 3.
Another factor influencing the slip resistance of the sole is the condition of the sole. Treads become worn and damaged and the channels or grooves can develop a build up of solid material preventing liquids from escaping. Brand new shoes can also be a problem as new soles tend to be more slippery than slightly used ones (Gronqvist et al 1990), and it is recommended that new shoes are pre-roughened with wet-dry sandpaper to improve friction (Stevenson 1992).

**Sole flexibility**

Studies of climbing tasks have highlighted that they require excellent sole and shoe flexibility to allow ankle and forefoot movement, and a key area requiring good movement is at the big toe joint where dorsiflexion (upwards bending) of between 65-75 degrees is required (Marr 1990 & 1991).

Shoes that can restrict these movements are:
- long boots that extend past the ankle
- shoes with hard or rigid soles such as leather or hard plastics

A soft low density midsole is best as this conforms to the ground surface and so maximizes the contact area (SATRA 1989).

**Sole profile**

To compensate for lack of sensation felt through the shoe soles, some researchers have recommended use of shoes with definite heel areas for ladder climbing so that the wearer can use this heel as a locator and prevent forwards slip. However on the pilot ladder, the ladder steps are generally sitting against the hull. This position reduces the ability of the feet to slide forwards and allows only the first 115mm of the foot to be supported by the step (accounting for between half to
2/3rds of the length of the shod foot). Given the shape of the steps (being only 25mm thick and flat) the step edges are less defined than on a runged ladder.

Shoe profiles that are not recommended for climbing and foot movement are those with thick and stiff soles (Marr 1990). Shoes with raised heels should also be avoided as they reduce the contact area through the feet and increase the risk of slips (Stevenson 1992).

A wedge sole is recommended for indoor work and for sports and activities that do not require moving over rough ground (SATRA 1989).

**Shock absorption characteristics**

One approach to managing the problem of ‘impact loading’ is to attenuate the impact through footwear and/or orthotic devices such as special insoles that provide extra support and cushioning.

There is some evidence that a reduction in forces through the feet translates directly into improved comfort and reduced injury from stress fractures, injuries and pain in the calves, Achilles tendon problems and back problems (Rome et al 2005; Fauno et al 1993; Gillespie & Grant 2005). Studies of different insole characteristics have measured the forces from both heel-strike and from forefoot loading when subjects were are doing different activities, and there is evidence that these forces to the feet can be reduced by between 23 to 30% in walking and running (Windle et al 1999; Johnson 1988).

However the evidence is not consistent and other studies have had inconclusive results. For example there are 2 studies where significant differences were not seen when comparing ‘shock absorbing insoles’ with no insoles (Withnall et al 2006; Sherman et al 1996). A study of the effect of insoles on the forces in the lumbar spine when personnel were ladder climbing on a navy ship was also inconclusive (Pelham et al 2006).

According to Stevenson (2007) ‘running shoes’ are generally designed to provide the greatest level of shock absorption, and these are also lightweight, have motion control features and come in a wide number of styles. He also recommends dual density soles that provide both cushioning and resilience.

**Footwear weight**

The overall weight of the shoe also affects walking and climbing, with larger heavier materials requiring more effort to move in and creating greater levels of fatigue over a shift than lighter footwear. These shoes can also be more awkward and tiring to use when doing climbing and crouching tasks. In a NSW study of firefighter’s footwear half of the respondents complained of the boot being too heavy, restrictive and clumsy (Marr 1990).

Anecdotal evidence suggests that many people who work on ladders and scaffolding prefer to wear lightweight flexible footwear such as the ‘Dunlop’ brand ‘Volley’ model lace-up sandshoe or sports shoe (Marr 2007).
‘Safety’ boots

Footwear with steel toe caps is commonly worn in industrial settings. The caps are designed to protect the toes from crush injuries from objects falling on the toes (and meet the Australian and New Zealand Standard 2210.3). Safety boots are not generally a requirement for pilots, but some employers have requested they are used by pilots. There are also ‘safety shoes’ available now that use a plastic cap that also meets the standard for impact.

Australian studies conducted by an Occupational Podiatrist found that in many cases the use of ‘safety’ footwear with steel caps created injuries and problems for the wearers (Marr 1991; Marr & Quine 1993). From a survey across 321 users in NSW, Marr (1991) reported:

- 65% found the boots were too hot and made the feet sweat
- 34% found the caps were too shallow and pressed on their toes
- 44% found the caps prevented them from bending their feet easily
- 17% of females found the female safety shoes were too narrow, so they often opted for a male sizing

In addition, the study confirmed that safety footwear was not always available in fractional sizes resulting in the respondents being forced to wear ill-fitting shoes.

For participants who climbed ladders and scaffolding and needed to crouch and perform fast movements, the use of safety shoes was identified as hazardous, and often more hazardous than the work they were undertaking. For example some of the riggers surveyed reportedly refused to wear the safety shoes, even though this was a worksite requirement. For workers moving on wet and slippery surfaces a heavy work boot was also identified as posing a greater risk than the work practice.

The report concluded that the decision to wear steel capped shoes must be made on a case by case basis and with careful consideration of the work environment, the worker’s tasks and the shoe’s effects on their mobility and comfort. If the risk of crush injury is low, and if workers are required to climb, crouch, move rapidly and walk over slippery areas, a protective but non-steel capped safety shoe is likely to be the safer alternative.

The above study was undertaken more than 15 years ago and recommendations were made to the Standards committee working in this area, but it is not known if manufacturers have changed their designs on the basis of the recommendations.

Another study undertaken with firefighters and their footwear also found problems with the use of their steel capped boots (Marr 1990). Some firefighters had particular problems with the issued boots, namely those with foot types that were flat or high arched, had bunions, hammer toes, or enlarged great toe joints. These boots also restricted forefoot movements in tasks such as ladder climbing and undertaking tasks in crouched and stooped postures.

Based on the available advice it is recommended that pilots not be required to wear steel-capped safety shoes unless the risk of crush injuries is assessed as being greater than the risk of slips and falls, and provided the pilot can achieve good foot mobility for climbing.
Footwear uppers & air circulation

In the Marr study (1991) 25% of subjects had skin breakdowns on their feet, most commonly between their toes. Broken skin tends to result from being too hot and sweaty, and is often followed by skin infections such as tinea. The ability of the feet to 'breathe' and have air circulating around them reduces the development of maceration or broken skin. Ideally footwear provides uppers with some aeration.

Another problem for pilots is that their feet may get wet from water over the deck, sea spray, waves and rain.

Wearing clean socks each day that are made of a cotton-mix, wool-mix or sports type acrylic are all suitable to absorb sweat, aid cushioning, and reduce skin chafing (NOHSC c1996).

4.3 User evaluation and performance testing

Review by pilots

A convenience sample of 14 pilots (all male) from a large city and a nearby port was surveyed to rate the importance of specific design features in footwear. There was also opportunity for discussion.

In the survey pilots were asked to rate the relative importance of 11 design factors using a Likert scale including 0 = not desirable, 1 = not important, to 5 = very important. The survey results were analysed to determine the median (or most frequently occurring response) and these are listed in Table 2.

<table>
<thead>
<tr>
<th>Footwear – Design features</th>
<th>Median ratings below:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip resistant on cutter deck</td>
<td>5</td>
</tr>
<tr>
<td>Slip resistant on pilot ladder</td>
<td>5</td>
</tr>
<tr>
<td>Slip resistant on ship deck</td>
<td>5</td>
</tr>
<tr>
<td>Ability to feel edge of pilot ladder step under the shoe</td>
<td>4</td>
</tr>
<tr>
<td>Cushioning eg for standing at bridge and jumping down to pilot boat deck</td>
<td>4</td>
</tr>
<tr>
<td>Water resistant</td>
<td>4</td>
</tr>
<tr>
<td>An arch support</td>
<td>4</td>
</tr>
<tr>
<td>Suited to walking over rough ground</td>
<td>3</td>
</tr>
<tr>
<td>'Smart' appearance</td>
<td>3</td>
</tr>
<tr>
<td>Ease &amp; speed of removal</td>
<td>3</td>
</tr>
<tr>
<td>Steel capped</td>
<td>1</td>
</tr>
</tbody>
</table>

As the results show, the features of slip resistance and cushioning are rated as most important by this group. Responses to the value of having steel capped footwear varied from being ‘not desirable’ to ‘very important’, and this may reflect...
the different work environments and different cargos that are carried in the commercial vessels and/or in the port environment.

When asked for which brand or model of shoe they would recommend for their work, responses were typically walking style shoes (e.g., such as ‘Rockport’ or ‘Hush Puppies’ brands). They claimed these brands provided very comfortable and well-cushioned footwear that was also non-slip and hard wearing.

Pilots were also asked to rate a selection of footwear in order of their preferred appearance only. Results were added to provide scores, with the highest scores indicating the most popular appearance. The 14 surveyed pilots rated the following options as follows.

Table 3. Pilots’ reports of preferred footwear appearance from 6 options

Ratings from 1 = most desirable, to 6 = least desirable

<table>
<thead>
<tr>
<th>Shoe appearance ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Most desirable appearance</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Of the 14 pilots surveyed, 7 rated the dress shoe as having the best appearance, with 3 others rating it as having the second best appearance. There was a consistent dislike for the appearance of the boat shoe that looks like a casual, sports shoe or jogging shoe. The preference for the more formal looking footwear may reflect the city locations and/or the nature of the vessels that are piloted. Preferences from pilots located in more remote areas are not known.
**Performance testing – Slip resistance**

As slip resistance was the most important feature that the pilots’ required of their footwear, testing in slip resistance of typical footwear was arranged. The aim of the tests was to determine the slip resistance of common shoes under both wet and dry conditions on the pilot ladder.

Four pairs of shoes from a boating retailer were selected for slip resistance tests. The criteria for the selection were:
- current models
- designed for use on boat decks
- already worn by some pilots
- representing a range of sole designs (including two assumed to be a poor design and two assumed to be good designs)
- potentially appropriate for pilots to wear when using ladders at sea

In addition, two old, worn shoes were selected: one walking style shoe used by a pilot at work and in ladder transfers; and one sailing/boat shoe borrowed from a recreational sailor. These were selected for comparison and to assess the impact (if any) of wear on soles.

A single timber step from an old pilot ladder was borrowed so that the selected footwear could be tested on this surface to simulate a shod foot stepping on the pilot ladder. The ladder step and footwear were given to an expert assessor of slip resistance (Mr Neil Adams) with an outline of the test’s aims. His methodology and findings follow and are italicised.

**Methods**

*Measurement of the coefficients of friction between each of the shoe types and the timber ladder tread were made, using a manually operated force gauge. The measurement conditions included:*
- static coefficients of friction (COF) on the tread when it was dry, and
- dynamic coefficients of friction (COF) when the tread was saturated with water.

The tread was wiped clean after each set of measurements for each individual shoe. Three sets of wet condition measurements were made, including once in the presence of sea water, with the shoe order being randomised for the different sets.

The 6 shoe soles are illustrated in Table 4.
### Table 4. Shoe soles tested for slip resistance

<table>
<thead>
<tr>
<th>Shoe Identifier of those tested</th>
<th>Shoe sole pattern</th>
<th>Description of sole</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><img src="image" alt="Shoe A" /></td>
<td>A worn, walking style shoe with deep cleats</td>
</tr>
<tr>
<td>B</td>
<td><img src="image" alt="Shoe B" /></td>
<td>A very worn sailing/boat shoe, with worn areas across fine tread pattern</td>
</tr>
<tr>
<td>C</td>
<td><img src="image" alt="Shoe C" /></td>
<td>A new, leather boat shoe with both a fine tread pattern plus deep, lateral cleats</td>
</tr>
<tr>
<td>D</td>
<td><img src="image" alt="Shoe D" /></td>
<td>A new, leather boat shoe with a very fine tread pattern</td>
</tr>
<tr>
<td>E</td>
<td><img src="image" alt="Shoe E" /></td>
<td>A new synthetic boat shoe with both fine tread patterns plus deep, lateral cleats</td>
</tr>
<tr>
<td>F</td>
<td><img src="image" alt="Shoe F" /></td>
<td>A new synthetic boat shoe with an unusual, circular tread pattern plus some lateral cleats</td>
</tr>
</tbody>
</table>
Table 5 provides the average coefficients of friction obtained with the shoes. As slips are more likely to occur in wet conditions, the shoes are listed across the top of the table in decreasing order of their frictional performance in the presence of water.

Table 5. Coefficients of Friction (Shoe on timber ladder tread)

<table>
<thead>
<tr>
<th>Shoes</th>
<th>E</th>
<th>C</th>
<th>A</th>
<th>B</th>
<th>F</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>COF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static - Dry</td>
<td>0.74</td>
<td>0.87</td>
<td>0.68</td>
<td>0.50</td>
<td>0.72</td>
<td>0.56</td>
</tr>
<tr>
<td>Dynamic - Wet</td>
<td>0.50</td>
<td>0.48</td>
<td>0.43</td>
<td><strong>0.35</strong></td>
<td><strong>0.33</strong></td>
<td>0.29</td>
</tr>
</tbody>
</table>

All shoes produced satisfactorily high (or slip resistant) coefficients of friction in dry conditions. However, three of the shoes (the three shaded and italicised figures in Table 5) produced coefficients of friction that were below a level that could be regarded as adequately slip resistant in wet conditions (ie below 0.4).

On the basis of these results, shoes B, F and D would be considered unsuitable for the task, and the best scoring soles are E, C and A, as illustrated in Table 6 below.

Table 6. Shoes rated as slip resistant on wet surfaces (COF > 0.4)

<table>
<thead>
<tr>
<th>Shoe Identifier \ COF</th>
<th>Shoe sole of the 3 best soles for slip resistance in wet conditions (of 6 tested)</th>
<th>Description of sole</th>
</tr>
</thead>
<tbody>
<tr>
<td>E COF 0.5</td>
<td><img src="image1.png" alt="Image" /></td>
<td>A new synthetic boat shoe with both fine tread patterns plus deep, lateral cleats</td>
</tr>
<tr>
<td>C COF 0.48</td>
<td><img src="image2.png" alt="Image" /></td>
<td>A new, leather boat shoe with both a fine tread pattern plus deep, lateral cleats</td>
</tr>
<tr>
<td>A COF 0.43</td>
<td><img src="image3.png" alt="Image" /></td>
<td>A worn, walking style shoe with deep cleats</td>
</tr>
</tbody>
</table>
It is relevant to note that the frictional performance of the shoes may have been affected by their respective conditions. For example, shoe B in particular was significantly worn, and may have produced a lower result than would a newer shoe of the same type. Conversely, in other studies the slip resistance of some shoes has been found to improve after an initial wear period.

It is likely that the frictional performance of the tested shoes that were new will change over time, with a probable initial increase being followed by a gradual decline as the shoes become increasingly worn. Only repeated testing over time can establish whether or not this expected change occurs with each of the shoes, and to what extent any such changes affect the suitability of the respective shoes.

**Performance testing – Other design features**

In addition to slip resistance, other features were identified in the literature and by the pilots as being important in the ladder climbing task. Each of the shoes used for the slip resistance testing plus 2 additional shoe types were then compared against most of these factors, as summarized in Table 7.

Water testing and resistance to water was not assessed due to risk of marking the shoes as 4 pairs of the shoes were brand new and had to be returned for sale. There are however a range of footwear materials currently on the market claiming various qualities relating to preventing the feet from becoming wet, while allowing some ventilation, such as the ‘Gortex’ brand material, and similar materials. There are also shoes specifically for water sports that allow the water to drain from the shoes and allow the foot to dry, however these were not assessed as it is reportedly not common for pilots to have their feet immersed in water.

In assessing the factors in the table a mixture of objective and subjective measures was used to conduct these evaluations. The information is provided as a general guide to illustrate the range of considerations and to highlight the differences between the different styles and models of shoes.

**Table 7. Comparison of design features between 6 shoe types**

<table>
<thead>
<tr>
<th>Features</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G*</th>
<th>H*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of one shoe (grams)</td>
<td>500</td>
<td>460</td>
<td>410</td>
<td>460</td>
<td>380</td>
<td>375</td>
<td>640</td>
<td>620</td>
</tr>
<tr>
<td>Feel ladder step edge under sole?</td>
<td>1=no, 3=yes a bit, 5=easy to feel</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Cushioning?</td>
<td>1=no, 3=yes a bit, 5=very cushioned</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Flexible midsole?</td>
<td>1=no, 3=yes a bit, 5=very flexible</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Secure on the foot</td>
<td>1=no, 3=yes a bit, 5=very secure</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Heel cup support</td>
<td>1=no, 3=yes a bit, 5=very supportive or stiff</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Ease/speed of removal</td>
<td>1=not easy, 3=very easy</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Slip resistant in previous test?</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Note- Shoes of the same size were not available for the assessment
* = Not assessed for slip resistance, but included for additional comparison.
G= Walking shoe, popular brand-name shoe
H= Leather work boot with elastic gussets (not steel capped)

One feature that is common to shoes B, C and D was identified as a potential issue. Each of those shoes has a large opening, and a short lace-up section. That combination facilitates wearers slipping the shoes on and off while leaving the laces permanently tied. Considering the demands of the task, footwear that is more securely attached to the foot is considered desirable.

The table also illustrates that while a shoe may rate well in one area (eg cushioning), it may not rate well for slip resistance, and vice versa. Using this evaluation together with the slip resistance measures from the earlier testing, shoes A, E & C appear to rate well for most features. These shoes are: A – a walking shoe; E – a synthetic boat shoe with fine tread and deep tread patterns; and C - a leather boat shoe with fine tread and deep tread patterns.

The use of the above ratings depends on which features are considered desirable by individual pilots. For example some pilots are more concerned about removing their shoes quickly than they are about their foot falling out of their shoe. Others require deep footwear to secure orthotics that they need for support.

4.4 Cost benefits in footwear selection

There is a great variation in pricing of footwear. The 4 new pairs of shoes selected from a retail boating shop for the slip resistance tests were priced between $120 - $180.

Paying a high price for footwear does not always provide the best features for the ladder climbing task, and footwear needs careful selection. For example in the slip resistance tests, the shoes that rated the best for slip resistance were the $130 shoes, and the worst of the new shoes cost $140.

From looking at footwear prices in boat shops and in shoe shops, a pilot should expect to pay retail prices of between $100 - $300 for shoes with the necessary characteristics to aid safety, comfort, and overall usability. Footwear that claims to provide water proof yet breathable fabrics tend to be in the upper end of this price range.

There is a health benefit and a safety benefit in selecting footwear that is well suited to the pilots’ feet. Poorly fitted footwear or footwear that lacks cushioning can contribute to spinal loading and fatigue and may also contribute to the risk of the pilot slipping on the pilot ladder or on the deck.
5. RISK CONTROL

5.1 Conclusions

Based on this review of the standards, existing scientific literature, assessments of the physical demands of the transfer task, user evaluation and performance testing, it is clear that there is not one ‘perfect’ shoe that will suit all pilots and all ports. The choice of footwear depends on the pilot’s work environments and the surfaces that they traverse both before and after their pilotage work, and the climate at the site.

As well as site differences impacting on footwear selection, the pilot’s feet and any relevant injuries or abnormalities with their feet, legs and back should also be considered.

When selecting footwear it is important to consider how all the different features impact on usability and on comfort, and to check a range of different footwear styles for the desired features. For example some ‘dress’ shoes have good cushioning and good soles, while others that may look the same at a glance have inappropriate soles and minimal cushioning.

5.2 Recommendations

The characteristics of footwear that appear to best suit the pilot transfer task have these characteristics:

- Slip resistant sole material (such as nitrile rubber)
- Tread pattern that allows water or other fluids to be quickly dispersed
- Tread pattern that also suits any other contaminants and ground surfaces that the pilot walks over
- Flexible midsole area
- Rounded or bevelled heel edge with good contact area
- Non-slip tread pattern extending to toe area
- Cushioned sole or insole
- Close fitting, ideally with adjustments possible
- Lightweight
- Water resistant (and resistant to chemicals as required by environment)
- Generally not steel-capped, unless this does not impact on forefoot movements and does not make the shoe too bulky (and this depends on other hazards in the pilot’s work environment)

Footwear that has the above characteristics and is versatile would appear to be suitable for most pilots – so neither a traditional deck shoe nor a very deep cleated work boot, but a shoe that has some features of each. For example a well cushioned walking shoe or a deck shoe with cushioning and with at least 4 rows of eyelets would have many desirable features.

The best way to select a shoe is to consider all these features, try the shoes on with typical socks, and try crouching, standing on tip toes, and walking at different
speeds. Any usual aids such as orthotics that are to be worn with the shoes should also be trialled for fit.

It is also recommended that pilots wear clean socks each day that are made of a cotton-mix, wool-mix or sports type acrylic as all are suitable to absorb sweat, aid cushioning, and reduce skin chafing (NOHSC c1996).

Shoes that are **not** well suited to the pilot transfer have these design characteristics:
- Hard, patternless heels
- Not well secured and may slip off during the transfer
- Poor slip resistance to wet or oily conditions
- Lack cushioning to impact and prolonged standing
- Very heavy boots
- Rigid soles, reducing flexibility
- Thick soles, reducing feeling of steps and controls
- Bulky fastenings that could become caught or undone

Footwear with the recommended features will allow pilots to transfer as safely as possible using the pilot ladder, and will also provide them with comfort in their feet, legs and spine throughout their shift.

Illustrations highlighting the various design features follow.

**Table 8. Features to look for in a shoe for the ladder transfer and related tasks**

<table>
<thead>
<tr>
<th>Feature illustrated</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Heel" /></td>
<td>Heels of these 2 different shoes have soft, bevelled edges rather than a distinct 90 degree corner with a hard sole material.</td>
</tr>
<tr>
<td><img src="image2.png" alt="Tread Pattern" /></td>
<td>This tread pattern is suited to water and slightly larger contaminants, with the pattern over the whole sole, including the toe and heel areas.</td>
</tr>
</tbody>
</table>
## Feature illustrated

<table>
<thead>
<tr>
<th>Description</th>
<th>Feature illustrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>This shoe with 4 rows of eyelets provides a secure fit around the upper part of the foot. Laces allow adjustments to suit different socks and to allow feet to expand etc.</td>
<td></td>
</tr>
<tr>
<td>The front toe areas of these shoes have non-slip soles extending over the nose.</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 4. Walking shoe

The shoe illustrated to the left is one example of a shoe with a good tread pattern, even when well worn, plus a cushioned midsole, beveled toe and heel, arch support, and flexible midsole.

This style of shoe was rated second by the sample of pilots in the user evaluation, after the black dress shoes. Many sports shoes also have these characteristics, and some dress shoes may also have some of these characteristics.

The figures over the page illustrate the sole patterns that are recommended for slip resistance, and those that are not recommended for slip resistance.
Figure 5. Characteristics of soles that are recommended to reduce slip (SATRA 1989)
Note- Not all options would be present on one sole

![Recommended Sole Features]

Figure 6. Characteristics of soles that are NOT recommended to reduce slip (SATRA 1989)
Note- Not all options would be present on one sole

![Not Recommended Sole Features]
6. FOOTWEAR REFERENCES

Standards

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AS/NZS 2210.2:2000
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AS/NZS 2210.4:2000
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AS/NZS 2210.5:2000
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AS/NZS 2210.6:2001
Occupational protective footwear - Additional requirements and test methods

AS/NZS 2210.7:2001
Occupational protective footwear - Additional specifications for safety footwear

AS/NZS 2210.8:2001
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