AMP A Safety Equipment Project

FORMAL SAFETY ASSESSMENT
Personal Protective Equipment in Marine Pilot Ladder Transfers

Part 2: Gloves

prepared by

Fiona Weigall
Certified Professional Ergonomist
Accredited Occupational Therapist
Health & Safety Matters Pty Ltd
PO Box 707, Gymea, NSW 2227
Ph: +61 2 9501 1650

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Important Note

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

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- Alison Bell, Certified Professional Ergonomist
Report Author

Fiona Weigall
MasterPubHealth, BAppSc(OT), GradCertAppErg, GradCertAdultEd

Fiona Weigall is a Certified Professional Ergonomist and Branch Secretary of the Human Factors and Ergonomics Society of Australia (NSW). She is also an Accredited Occupational Therapist with a clinical background in occupational rehabilitation and injury management including in the areas of traumatic brain injury, spinal injury, musculoskeletal and cumulative trauma disorders.

Fiona has advised on human factors and ergonomics in the public and private sectors for 20 years, including with an occupational health and safety regulatory body, WorkCover NSW. She was a founding director of Health & Safety Matters Pty Ltd in 2000, and has been accepted as a consultant researcher for the Australian Safety and Compensation Council's 'OHS Expert Research Panel' since 2004.

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 ergonomic 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.”

IS EN 13921:2007, page 5

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 ergonomic 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 and equipment selected for review

In consultation with AMPA, a sample of PPE and equipment was selected for review. The rationale for this selection was as the PPE or equipment 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 1</th>
<th>Part 2</th>
<th>Part 3</th>
<th>Part 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footwear</td>
<td>Gloves</td>
<td>Head Protection</td>
<td>Personal Flotation Devices, Wet Weather Jackets and Personal Locator Beacons</td>
</tr>
</tbody>
</table>

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 steps in the pilot boarding and disembarkation as:

Boarding
- Donning the relevant PPE (eg 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 done 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 gloves

None of the pilot stations surveyed reported having a policy for the pilots to wear or not to wear gloves, and glove use was optional. One pilot manager did however believe that pilots should be “encouraged” to wear gloves, believing this enhanced safety as well as protecting their hands from dirt and grease.

The Code of Safe Working Practice for Australian Seafarers provides the following general guidelines for seafarers:

5.4.7 HAND AND FOOT PROTECTION

5.4.7.1 Gloves should give protection from the particular hazard of the work being carried out and must be appropriate to that type of work. For example, leather gloves are generally better for handling rough or sharp objects, heat resistant gloves for handling hot objects, and rubber, synthetic or PVC gloves for handling acids, alkalis, various types of oils, solvents and chemicals.

The European Maritime Pilots’ Association (EMPA 2008) also provides advice regarding glove use. They advise pilots:

“Gloves, if worn, should not interfere with a secure grip on deck rails or the side ropes of pilot ladders”

2.2 Pilots use of gloves

Number of pilots using gloves

In a sample of 14 pilots from one pilot organisation, 5 wore gloves to ascend the pilot ladder (36%) and 8 wore gloves to descend the ladder (57%) (Weigall & Simpson 2005). Glove use at other ports appears to be more common, with pilots estimating that “most” or “all” pilots wore gloves. Anecdotal information from discussions with different pilots suggests that older and/or more experienced pilots are less likely to wear gloves than newer or younger pilots. Pilots working in cool climates are also more likely to wear gloves.

Pilots’ beliefs regarding glove use

Pilots who wear gloves reportedly do so for the following reasons:
- reduced chafing and risk of ‘rope burns’;
- reduced hands from becoming dirty or greasy from the ropes; and
- increased warmth in cold weather.
Pilots choosing not to wear gloves report:

- reduced grip from wearing gloves;
- problems with the gloves “swelling” if they become wet, thereby affecting their ability to grip with the gloves; and
- reduced sensation when wearing gloves.
3. HAZARD IDENTIFICATION

The interface between the hands and the ladder and associated ropes is a critical aspect of the ladder transfer task. The hands need to grip and hold ropes and the ladder during both the embarkation and disembarkation, but in slightly different ways. These two different tasks and the demands on the hands are described below.

Ascending the ladder / Embarkation

- Reaching arms overhead and holding onto the manropes (28mm diameter) while watching the deck and lower ladder rungs
- Adjusting the hands on the manrope, up and down, while waiting for the swell and conditions to be suitable
- Using near maximum grip force on the manropes while quickly stepping up and onto rungs
- Continuing to hold manropes using near maximum force exertion and repeatedly grasping and releasing hands as they move up the ladder (maximum climb 9 metres) OR
- Transferring the hands to the side ropes (2 x 18mm diameter) and repeatedly grasping and releasing with the hand.

If using the manropes for ascending, the body is in a more suspended and backwards leaning posture than if using the sideropes, and as a result has greater loading on the hands and requires greater force exertion. In this situation the ability of the hands to grip is more critical than for siderope users.

Descending the ladder / Disembarkation

- Holding the manropes, generally at or above shoulder level
- Holding a rope in each hand and controlling the release of tension in the grip to allow the rope to slide through the hand at varying rates to allow a fairly rapid but controlled descent
- At the last few steps, letting the ropes slide rapidly through the hands as the pilot pushes themselves backwards and drops, jumps or takes a large step down onto the pilot boat deck OR
- Gripping the side ropes, not the manropes, and coming more slowly down the ladder by repeated grasp and release

A vertical ladder poses a much higher risk of slip and fall accidents than a ladder angled at 70 degrees from horizontal due to the higher forces on the hands and feet. For example the force on one hand has been assessed as nearly 30% of body weight for vertical ladder users as compared with less than 10% of body weight for a 70 degree from horizontal (20 degree slant from vertical) (Bloswick & Chaffin 1990). These researchers also identified that hand torque required on vertical ladders is 60% of maximum hand torque capability.

The task demands and the grip forces on the hands can significantly increase if the ladder or associated ropes are suddenly jerked, pulled or twisted, requiring the pilot to rapidly increase grip and take other steps to reduce the risk of falling.

The hazards identified for the pilot in this aspect of the ladder transfer task include:

- Using unnecessary force and fatiguing the hand and arm musculature, contributing to the development of cumulative trauma disorders;
- Abrading the skin on the hands; and
- Losing grip, and slipping or falling

If the pilot's grip is compromised or in any way restricted the result can be a loosened or poor grip on the ladder. In the best case scenario this sudden loss of grip may cause the pilot to make rapid and jarring movements to re-establish grip, balance and control (posing risk of a strain injury), and in the worst case scenario the pilot will be unable to regain grip and will fall.

As outlined in a past review of the pilot transfer task and ladder falls (Weigall 2006a), falls from even relatively low heights (less than 3 metres) can result in serious injuries including fractures and head injuries (eg Bjornstig & Johnsson 1992; Helling et al 1999). As the fall height can be up to 9 metres, fatal injuries can occur (Helling et al 1999; Christensen & Emmanuel 1999).
4. RISK ASSESSMENT

4.1 Likelihood and consequence of problems from gloves and/or gripping

*Injury and incident data for pilot transfers*

Injury and accident data show that falls from a height are uncommon, yet are the primary mechanism for fatalities. The more common effects expected from the activity of repeatedly grasping the ropes on the ladder and holding the body weight in this posture are different cumulative trauma disorders in the wrist and forearm, such as carpal tunnel syndrome and epicondylitis.

Anecdotal reports indicate that injury from skin abrasions has occurred to pilots when they have not worn gloves, and this seems to be more common if the pilot is usually a glove wearer.

There have been incidents in Australia where pilots have reportedly ‘lost their grip’ and fallen. The exact reasons for these incidents are not clear, and can often only be guessed as many factors can contribute to the unconscious/unplanned ‘loss’ or reduction in grip.

The impact of a gloved hand is investigated in this report as gloves alter the interface between the hand and the rope and have a direct and often significant effect on grip ability.

4.2 Glove designs

The following Standards are most relevant to glove selection for pilots:

- AS/NZS 2161.1:2000 Occupational protective gloves Part 1: Selection, use and maintenance
- AS/NZS 2161.2: 2005 Occupational protective gloves Part 2: General requirements

From surveying pilot organizations it appears that the most commonly worn gloves are the commercially available ‘riggers gloves’. Another popular glove type is a thinner cotton drill glove with PVC beads on the palm and fingers. Some pilots are now also trialling the sailing style of gloves and according to personnel responsible for high-rise maintenance tasks and rock climbers, fingerless gloves are also popular with these groups.

A sample of these gloves and other gloves with characteristics reportedly suited to aspects of the pilot ladder climbing tasks are described in Table 1.
### Table 1. Glove designs and their characteristics

<table>
<thead>
<tr>
<th>Type of glove</th>
<th>Features/design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Riggers gloves</strong></td>
<td>Design features</td>
</tr>
<tr>
<td>$6.60</td>
<td>• Leather</td>
</tr>
<tr>
<td></td>
<td>• Full finger</td>
</tr>
<tr>
<td></td>
<td>• May be elasticized at back of wrist</td>
</tr>
<tr>
<td></td>
<td>Protection</td>
</tr>
<tr>
<td></td>
<td>• From abrasions</td>
</tr>
<tr>
<td></td>
<td>• From dirt, oil etc</td>
</tr>
<tr>
<td></td>
<td>Relevance to pilots:</td>
</tr>
<tr>
<td></td>
<td>• Designed for rope use</td>
</tr>
<tr>
<td></td>
<td>Limitations</td>
</tr>
<tr>
<td></td>
<td>• Not suited to very wet conditions, becomes slippery</td>
</tr>
<tr>
<td></td>
<td>• Not well fitted at wrist – slides up</td>
</tr>
<tr>
<td></td>
<td>• Variable lifespan with pilot use</td>
</tr>
<tr>
<td></td>
<td>• Poor sensation on finger tips</td>
</tr>
<tr>
<td><strong>Fingerless and half finger gloves</strong></td>
<td>Design features</td>
</tr>
<tr>
<td>Eg Ronstan, Musto, Burke $30</td>
<td>• 3 full fingers, and index and thumb with tips exposed; or all half fingers</td>
</tr>
<tr>
<td></td>
<td>• Pliable fabric</td>
</tr>
<tr>
<td></td>
<td>• Use of synthetics</td>
</tr>
<tr>
<td></td>
<td>• Double thickness palm and fingers for protection and grip</td>
</tr>
<tr>
<td></td>
<td>• Mesh panels on back of hand for flexibility, comfort and quick drying</td>
</tr>
<tr>
<td></td>
<td>• Low cut neoprene wrist band for secure fit and clear access to watch</td>
</tr>
<tr>
<td></td>
<td>Protection</td>
</tr>
<tr>
<td></td>
<td>• Main protection in the palm</td>
</tr>
<tr>
<td></td>
<td>Relevance to pilots:</td>
</tr>
<tr>
<td></td>
<td>• Able to touch and grip with index and thumb, allowing sensation</td>
</tr>
<tr>
<td></td>
<td>• Allows good dexterity</td>
</tr>
<tr>
<td></td>
<td>• Hard wearing/abrasion resistant palm</td>
</tr>
<tr>
<td></td>
<td>• Very well fastened at wrist (Velcro)</td>
</tr>
<tr>
<td></td>
<td>Limitations</td>
</tr>
<tr>
<td></td>
<td>• Does not protect whole hand from grease/dirt etc</td>
</tr>
<tr>
<td></td>
<td>• No protection for finger tips</td>
</tr>
<tr>
<td><strong>Cotton drill with PVC dot grip</strong></td>
<td>Design features</td>
</tr>
<tr>
<td>$1</td>
<td>• Lightweight</td>
</tr>
<tr>
<td></td>
<td>• Pliable</td>
</tr>
<tr>
<td></td>
<td>• Relatively good grip</td>
</tr>
</tbody>
</table>

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## Type of glove | Features/design
--- | ---
| **Protection** | - From soiling  
- From minor abrasion  

**Relevance to pilots:**  
- Allows good dexterity if well fitted  
- Good grip  
- Better sensation on finger tips than leather  

**Limitations**  
- Not suited to very wet conditions  
- Very limited lifespan  
- Not well fitted at wrist  

“Almost disposable – use for about a dozen climbs, then throw them out” according to a pilot who routinely wears these.

**Dipped natural rubber, cotton/poly shell**  
- eg Skinny Dip®

**Design features**  
- Close fitting  
- Reported superior dexterity

**Protection**  
- Some abrasion  
- Soiling

**Relevance to pilots:**  
- Allows good dexterity – including fine motor  
- Good sensation  
- Good grip  
- Fitted around wrist

**Limitations**  
- Unknown  
- May create too much friction/grip for pilots who slide the manropes through their hands?

**Kevlar gloves with rubber coating**  
- eg Skinny Dip Aramid®  
- Approx $12 per pair

**Design features**  
- Flexible natural rubber coating  
- 100% Kevlar seamless liner prevents skin irritation  
- Special finger-tip protection  
- Superior dexterity and comfort  
- Excellent lightweight grip

**Protection**  
- Good abrasion resistance  
- Excellent cut, tear and puncture resistance  
- Good grip
<table>
<thead>
<tr>
<th>Type of glove</th>
<th>Features/design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PVC coating on continuous-knit cotton liner</strong>&lt;br&gt;eg KPG®</td>
<td><strong>Relevance to pilots:</strong>&lt;br&gt;• Allows good dexterity&lt;br&gt;• Good grip&lt;br&gt;• Fitting around wrist&lt;br&gt;&lt;br&gt;<strong>Limitations</strong>&lt;br&gt;• Unknown&lt;br&gt;• May create too much friction/grip for pilots who slide the manropes through their hands?</td>
</tr>
<tr>
<td><strong>Seamless Nylon Machine Knit with HPT Coating</strong>&lt;br&gt;Eg P4001 Ninja Palm Coated gloves&lt;br&gt;packet of 12 - $3.11 per pair or single pair - $4.25</td>
<td><strong>Design features</strong>&lt;br&gt;• Breathable&lt;br&gt;• Cool, flexible and durable&lt;br&gt;• Texturized coating for strong grip&lt;br&gt;• Launderable&lt;br&gt;• Seam-free liner reportedly enhances comfort and eliminates the potential for seam failure&lt;br&gt;&lt;br&gt;<strong>Protection</strong>&lt;br&gt;• Abrasion-resistant&lt;br&gt;• Minimizes absorption of water, oil and grease&lt;br&gt;&lt;br&gt;<strong>Relevance to pilots</strong>&lt;br&gt;• According to the supplier this glove outwears and replaces cotton, lightweight leather, plastic-dot and similar, competitive gloves.&lt;br&gt;&lt;br&gt;<strong>Limitations</strong>&lt;br&gt;• Unknown&lt;br&gt;• May create too much friction/grip for pilots who slide the manropes through their hands?</td>
</tr>
<tr>
<td>Type of glove</td>
<td>Features/design</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------</td>
</tr>
</tbody>
</table>
| General Utility Glove | **Design features**  
Eg Ironclad Icon General Utility Glove  
$39.95 (cheaper in bulk)  
- Double stitched synthetic leather reinforcements on palm, saddle and fingers.  
- Padded inner palm with Ironclad’s patented flex pattern.  
- Secure wrist enclosure  
- Rubberised knuckle impact protection  
**Protection**  
- Heavy abrasion  
- Dirt and grease  
**Relevance to pilots**  
- Good, secure fit  
- Good general dexterity  
- Very secure at wrist – velcro fastener  
**Limitations**  
- May be slippery when wet  
- Some reduction in sensation (but not as much as leather rigger gloves as these are better fitted) |

| General Utility Gloves (continued) | Design features  
Eg ProTek Glove  
$18 (cheaper in bulk)  
- One piece synthetic leather palm with reinforcing  
- Reinforced foam padded inner palm  
- Integrated terry cloth sweat wipe |

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<table>
<thead>
<tr>
<th>Type of glove</th>
<th>Features/design</th>
</tr>
</thead>
</table>
|              | • Reinforced stitching on fingers  
|              | • Neoprene knuckle panel provides increased flexibility  
|              | • Velcro strap for snug fit  
|              | • This non-slip grip is ideal for use for hand and power tools in dry, wet or oily conditions  
|              | Designed for (according to manufacturer):  
|              | • Hand and power tool users in dry, wet or oily conditions  
|              | Protection  
|              | • Heavy abrasion  
|              | • Dirt and grease  
|              | Relevance to pilots  
|              | • Good, secure fit  
|              | • Good gross dexterity  
|              | • Very secure at wrist – velcro fastener  
|              | Limitations  
|              | • May be slippery when wet?  
|              | • Further reduction in sensation at finger tips as they have extra coating, and extra coating in palm  
|              | • Limited sizes: Sizes M,L,XL  

**General Utility Gloves (continued)**

Eg P8174 Contego  
12 Pairs per Packet = $11.50 per pair  

<table>
<thead>
<tr>
<th>Design features</th>
</tr>
</thead>
</table>
| • 0.8mm Clarino® synthetic leather  
| • Neoprene padded reinforcement  
| • Perforated fourchettes  
| • Black nylon / lycra, foam back  
| • Black neoprene knuckle bar  
| • Elastic cuff & velcro fastener  
| Designed for (according to manufacturer):  
| • Shipping, Automotive, Power tool use, Rescue operations, General handling, Mining, Metal handling  
| Protection  
| • Heavy abrasion on palm  
| • Dirt and grease  
| Relevance to pilots  
| • Heavy abrasion  
| • Dirt and grease  
| Limitations  
| • May be slippery when wet  
| • Slight reduction in sensation  
| Available in sizes Small - 2XL  

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<table>
<thead>
<tr>
<th>Type of glove</th>
<th>Features/design</th>
</tr>
</thead>
</table>
| Heavy Utility Glove  | Design features  
                      ● Duraclad reinforcement areas with recessed, double stitched seams.  
                      ● Rubberised knuckle impact protection  
                      ● One piece synthetic leather palm and finger sidewalls  
                      Designed for (according to manufacturer):  
                      ● Cable and Wire Work, Lumberyards, Construction, Material Handling, Demolition, Landscaping, Forestry/ Arborists  
                      Protection  
                      ● Heavy abrasion  
                      ● Dirt and grease  
                      Relevance to pilots  
                      ● Good, secure fit  
                      ● Very secure, low profile wrist enclosure  
                      ● Good gross dexterity  
                      ● Very secure at wrist – velcro fastener  
                      Limitations  
                      ● May be slippery when wet  
                      ● Further reduction in sensation at finger tips as they have extra coating, and extra coating in palm |

4.3 Risks of glove use in the transfer

*Increase in grip effort*

There are numerous studies showing how glove use leads to significant reductions in the maximum force that can be exerted by the hands (Chang & Shih 2007; Willms & Wells 2006; Sawyer & Bennett 2006; Kovacs et al 2002; Tsaousidis & Freivalds 1998 etc). Reductions range from 7% for cotton gloves to up to 20–30% for leather and rubber gloves (Putz-Andersson 1988; Tsaousidis & Freivalds 1998; Willms & Wells 2006).

This effect on grip force increases the effort required to perform tasks requiring grip, and excessive grip force exertion has been identified as one of the most important factors contributing to the development of cumulative trauma disorders (Eksioglu 2004). For example forceful and/or repetitive gripping fatigues the wrist flexors and extensors, with the extensors fatiguing most rapidly as they co-contract in order to stabilize the wrists (Mogk 2003).

Factors contributing to the reduction in grip ability appear to be a combination of one or more of the following factors:
• Thickness and pliability of the gloves - with the hands required to overcome this resistance
• Loss of tactile sensitivity and information
• Changes in the shape and posture of the hand and fingers and interference with the hand closing around objects or loads
• Reduction in friction at the interface between the hand and the glove (depending on the glove material)

While the exact scientific rationale for the reduction in grip remains unclear, one explanation is:

“It is possible that as compression forces increase, some of the work done by the hand is stored as elastic energy in the creases of the glove”
(Tsaousidis & Freivaldi 1998, p360)

The effect of gloves on grip force is strong at maximal exertions and only marginal at submaximal exertions or “just holding” types of grip exertion (Buhmann et al 2000; Bishu et al 1994). When using the manropes to ascend the exertion would be described as near maximum.

**Slippery when wet**

Pilots have reported leather gloves can become slippery and swollen when wet. A glove manufacturer confirmed this finding, and advised against using leather and cotton for the pilot’s task, stating that both could become slippery when wet, with leather becoming particularly slippery once it became saturated. He also advised against nitrile based gloves explaining that in wet conditions a soapy substance used in their manufacture leaches out and can make the glove surface slippery (Lockerbie 2007). While there was an anecdotal claim that ‘synthetic leather’ was less slippery when wet than real leather, no evidence was located on this topic.

**Slippery when contaminated**

Pilots are exposed to a range of dusts, oils and other contaminants in the course of their work and this depends on their work environment and the cargo carried in commercial vessels and stored at ports. For example at coal terminals the coal dust on the ropes and other fixtures can transfer to the gloves to make them slippery and greasy. While the hands can be washed, some gloves develop a build-up of different contaminants and this reduces any frictional advantages. If the gloves tolerate being washed without damaging the material and someone is prepared to wash the gloves, this may reduce problems with contaminants.

**Glove pliability, thickness and effort**

There is a linear association between the increasing thickness of a glove fabric and the reduction in force output and forces to handle an object. For example a study compared subjects grip strength with bare hands with ‘powerline maintainers’ electrical rubber gloves of 3 different thicknesses. A reduction was seen in the
gloved hands as compared with the bare hand, with grip force reducing as the glove thickness increased, as illustrated in Table 2. The reductions in forces were measured at:

- 1mm thick gloves – grip strength reduced by 10%
- 2mm thick gloves – grip strength reduced by 20%
- 3mm thick gloves – grip strength reduced by 30%

(Willms & Wells 2006).

Table 2. Grip force decrements from increasing glove thickness (1, 2, & 3mm)
(copied from Willms & Wells 2006)

<table>
<thead>
<tr>
<th>Glove Thickness</th>
<th>Grip Force Decrements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1mm</td>
<td>10%</td>
</tr>
<tr>
<td>2mm</td>
<td>20%</td>
</tr>
<tr>
<td>3mm</td>
<td>30%</td>
</tr>
</tbody>
</table>

Other studies have also found similar results, with Kovacs et al (2002) describing how the thicker and less elastic gloves cause a greater decrease in peak force than the thinner more elastic glove types, with the bare-hand or surgical glove being most recommended of those tested.

As well as thicker gloves consistently resulting in reduced grip, they also cause greater perceived discomfort in the wearer (Batra et al 1994). In addition, thicker gloves reduce manual dexterity, though performance in gloved hands can be improved with practice (Bensel 1993).

Poor glove fit

There is strong evidence that illustrates how poor fitting glove increase effort and increase error rates in manual tasks, as well as causing the user discomfort. While some gloves claim ‘One size fits all’, this is not the case and an inappropriate size for the hand and/or of the digits will limit their effectiveness and result in hazards for the user. For example a study comparing glove types and glove sizing found that the ‘better-fitting’ gloves that were best suited to the users’ hand sizes resulted in better transmission of muscular force to measured grip force (Kovacs et al at 2002).
The fitting of the glove at the wrist is a particular area identified by marine pilots. The traditional leather riggers gloves have only a row of elastic stitching, if anything, at the wrist area, and no fastening. Pilots have demonstrated how the front, palm side of the glove tends to become caught and bent towards the fingers, and can even come off during the ladder transfer. Glove security is particularly important for pilots wishing to use manropes for the descent. Another issue with leather gloves, and possibly others, is that they can stiffen with age and also if not properly washed, and sea salt can add to this stiffening effect.

A ‘mismatched glove’ that has material that is not suited to the task or a size that is not suited to the user’s hand size causes the user’s grip force to be higher than necessary, and tends to result in increased repetition. Repeated grasping and forceful grasping are both well documented risks in the development of cumulative trauma disorders in the hands and arms (for example tendonitis, carpal tunnel syndrome etc). Even just one size too large impacts on the length-strength relationship of the flexor and extensor tendons (Kovacs et al 2002).

The traditional riggers gloves often have a limited sizing (eg 3-4 sizes) and are not a close fitting design, and a pilot with smaller hands who was interviewed for this study has difficulty finding ones that fit him.

**Tactile sensitivity and dexterity**

There is a linear relationship between increasing glove thickness and reducing tactile sensitivity, with the bare hand being most sensitive, followed by very thin gloves (eg surgical gloves) to gloves of increasing thickness (eg Willms & Wells 2006; Shih et al 2001).

Impaired sensation directly affects motor control as more grip and load force is generated when participants were wearing multiple glove layers, and this use of force is increased if the gloves are more slippery than bare skin (Shih et al 2001; Willms & Wells 2006). This effect of increasing grip force is believed to be a direct result of sensory deprivation. Having visual feedback of the gripping task can slightly reduce this force (Willms & Wells 2006).

Tactile information is very important for tasks requiring high levels of manual dexterity (Tsaousidis & Freivalds 1998) such as manipulating small items. For example some pilots reported wanting to be able to operate instruments such as their radio and plotter etc with gloved hands, in which case fine finger dexterity is required. However for tasks requiring maximum strength, such as grasping the manropes, fine dexterity is less important.

**Changes to hand and finger posture**

Using gloves changes the hand’s natural posture and can particularly impact on web space. As well as having the potential to cause discomfort in the webspaces the glove’s fabric can also slightly alter and limit the movements at the different joints. For example many protective gloves have been found to reduce the ranges of abduction, adduction, extension and flexion movements in the hand and wrist when used in manual tasks (Bellingar & Slocum 1993).
In mid range grips the end sections of the fingers (distal phalanges) contribute most to grip force, with the middle finger providing most force (Kong 2005). It is therefore important that these joint movements are not restricted by very stiff fabrics or rigid coatings on either the backs or the palm sides of the gloves.

4.4 Benefits of glove use in the transfer

New glove designs

There is a lack of scientific studies and evaluation into the more modern glove types and of gloves not routinely used in industries. For example the literature located and reviewed in this report did not provide any analyses of gloves designed for tasks such as sailing, rock climbing, and other leisure or sports activities.

From reviewing sporting and other equipment catalogues there are numerous styles and designs of gloves. The manufacturers make various product claims but it is not known how accurate and objective these claims are, and testing by independent parties would be helpful. Some of the gloves in these catalogues that appear to provide advantages for the pilots transfer task are those with the following characteristics:

- Various palm coatings that aim to improve grip and reduce slip
- Gloves with mix of half and full fingers – allowing the ends of the fingers or of the index and thumb to remain bare and so enhance the hand’s sensation
- Mesh panels or other soft material on the back of the hands to permit maximum flexibility and movement in the hand and fingers
- Velcro fastening at the wrist
- Use of ‘Kevlar’ and other thread reported to be more durable than other natural fibres
- Fast-drying fabrics
- Constructed in a ‘pre-curved’ grip shape to reduce flexion effort
- Waterproof liners
- Breathable materials to reduce sweat build up

A glove manufacturer strongly recommended either a PVC glove or a rubber based glove for pilots, claiming that both provide superior grip, comfort and movement over leather or cotton gloves (Lockerbie 2007), however this may not be suitable for use with manropes on the descent and testing is required.

Improved frictional characteristics

As described above, gloves can be designed to provide more friction than is possible with the bare palm, so creating less slip than would otherwise happen. The palm and finger surfaces must be well suited to the surface of the item being handled to ensure an appropriate coefficient of friction. For example in tests with gloves in knife use (handle diameter 18 – 22mm), the users were able to achieve significantly higher torque values wearing thin Kevlar fibre protective gloves than when the handle was gripped with the bare hand. (The glove thickness was not stated in the report). The researchers concluded that the Kevlar glove significantly increased the friction between the hand and the knife handle (Claudon 2006).
One potential problem with the pilot’s task is that when ascending added friction is an advantage, but for descending if they wish to use the manropes and let the ropes slide through their hands a ‘sticky’ palm may limit this movement.

**Reduced skin abrasion**

The primary reason for pilots choosing to wear gloves is to reduce chaffing and abrading the hands from the rope, such as rope ‘burns’. The most suitable gloves should therefore withstand a specific level of ‘abradement’ – measured in both pressure and cycle movements over the glove surface (as per AS/NZS 2161.3:2005). The key area tested to withstand this abradement is in the middle of the palm.

According to the Standard, typical materials used in gloves that protect the hand from abrasion are leather or pigskin, neoprene and nitrile. However a wide range of new materials – such as synthetic leathers - are now also widely used.

**Protection from contaminants**

Wearing gloves provides the pilot with some protection against contaminants such as oils, chemicals, grease, splinters etc on the ropes and on the ladders. These contaminants can have an immediate effect or may irritate the skin or other organs over time. Contaminants can impact on the pilot’s health as well as soiling the hand and this affects the pilot’s ability to touch and grip other items including greeting the ship’s master and officers with handshakes. (Admittedly some pilots considered that a handshake with a dirty hand was a useful strategy for encouraging the ship’s master and crew to keep the pilot ladder cleaner and better maintained).

**Warmth**

Gloves provide the wearer with some protection from the cold, and warm hands and fingers have better sensation and are more dexterous than cold, stiff hands – both an advantage for gripping ropes.

**4.5 Other factors affecting grip ability**

The ability of the hand to grip and to determine the force required to maintain a safe grip is not only affected by wearing gloves or having the hands covered by other fabrics, but is also affected by arm posture, age, gender, hand dominance, hand and finger size, strength, vision of the task, and injuries and illnesses.

Each of these factors is briefly explored.
Arm postures

Data regarding wrist positions – such as flexed versus neutral versus extended - is inconclusive, however gripping with extreme wrist deviation, flexion or extension can all reduce the grip strength (Mogk & Keir 2003; Marley & Fernandez 1995).

Age

Studies generally show that grip force follows a bell-shaped curve, with maximum force tending to be achieved in the 30s and 40s, declining after this (Nicolay & Walker 2005).

Gender

Women’s grip strength is less than males, with studies finding women typically had between 50 – 75% the strength of males (Nicolay & Walker 2005; Kong & Lowe 2005; Mogk & Keir 2003).

Finger pinch strength is also higher in males, with women’s average finger force capability between 58 – 69% of that of males (Kong & Lowe 2005; Boatright et al 1997; Nicolay & Walker 2005).

However for endurance – the ability to maintain a constant force output - women generally have greater endurance than men at submaximal levels, although this advantage reduces as forces increase (Nicolay & Walker 2005).

Hand dominance

In right-handed people, the right hand is on average 10% stronger than the left non-dominant hand, and in men the difference is less than in women. Left dominant people also have less difference between their hands than right dominant people (Schmidt et al 1970).

Studies have also found that although the dominant hand was significantly stronger, it also fatigued more rapidly than the non-dominant hand (Nicolay & Walker 2005).

Hand and finger size

Each person has a hand grip posture and a hand span size where they can achieve their maximum grip strength and this is affected by their overall hand size and the length and strength of each digit. If an item such as a rope requires a grip that falls above or below the diameter suited to the individual’s hand they will be unable to achieve their maximum grasp (Kong & Lowe 2005).
Strength

Weaker individuals need to use a greater percentage of their maximum grip force than a stronger individual who can achieve the same grip with less or minimal effort. This additional workload required of weaker individuals can increase their muscle fatigue more rapidly than in the stronger individuals (Mogk & Keir 2003).

Vision of the task

Use of force exerted on a load is affected by visual feedback, and where the handling or gripping task is not observed subjects apply more force than when some visual feedback is possible. In one study subjects could accurately maintain a submaximal grip while still holding or grasping the load when they could see it, but they increased their grip when visual feedback was not available (Willms & Wells 2006). The impact of this phenomenon is that greater and unnecessary power is used when visual feedback is not possible or is reduced which would occur on the pilot ladder.

Injuries and illnesses

Past and current injuries and illnesses can affect an individual's strength and endurance with gripping tasks. For example injuries can affect active range of movement at joints, pain, and the ability to generate power. Injuries with a sensory component may also impact on grip ability (Armstrong 1998).

4.6 Glove trials

User evaluation

A convenience sample of 16 pilots from 3 ports was visited to check their current glove use and to display a range of gloves. Thirteen pilots completed a survey on glove use and preference. In the survey pilots were asked to rate the relative importance of 6 design factors using a Likert scale including 0 = not desirable, 1 = not important, to 5 = very important. The survey results indicate the design features of most importance to pilots are in this order:

- Improved ability to grip ropes/manropes – median score 5
- protect skin from being chaffed or abraded – median score 5
- protect from dirt and grease etc – median score 3

The requirement for gloves that kept hands dry and gloves that kept hands warm in cold times had the most variable responses, each with median scores of 3. Given the surveys were taken in NSW and the pilots wear the gloves for very short periods (just the ladder climb) the issues of having wet or cold hands are not as relevant as they may be at other ports.
Performance testing

Pilots were also asked to rate the current glove provided to them (in each case a leather rigger glove) for its functional performance on a range of tasks that may be undertaken by pilots around the time of the ladder climb, so when they are most likely to have gloved hands. Most pilots reported only using the gloves for the climb and for gripping ropes and not expecting or requiring the gloves to be used for any other task. Other pilots reported being annoyed that they were unable to manage other tasks when wearing the gloves.

Pilots rated their ability to perform 6 functional tasks when wearing the rigger gloves, as summarized in Table 3. Pilots in these groups who also wore sailing gloves (n=3) were asked to rate these gloves for the same tasks, and one pilot was asked to choose his preferred glove from a selection of synthetic leather full finger utility gloves and to rate these gloves (n=1).

Table 3. Comparison of ability to perform tasks with different gloves

<table>
<thead>
<tr>
<th>Functional tasks</th>
<th>Leather rigger glove (n=12)</th>
<th>Sailing glove – synthetic leather, 2 finger tips exposed (n=3)</th>
<th>General Utility Glove – Ironclad brand (n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sign their name (however writing is reportedly rarely required)</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Operate their radio/a radio</td>
<td>1.5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Pull their hands in and out of their pockets without the gloves slipping</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Tie ropes (ie a figure 8 in the end of a rope)</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Fasten and unfasten buckle or harness</td>
<td>2.5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Comfort in producing a strong grip*</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note. The literature has already demonstrated that grip force is limited with gloves such as leather rigger gloves, and thinner gloves allow significantly improved grip capacity as outlined in this report in the section on ‘Risks of glove use in the transfer’

The findings from these assessments suggest that a replacement for the traditional leather rigger glove would provide superior function for the user, providing a more secure fit and better dexterity. As the evidence on grip strength highlights, a well fitted glove made in the thinnest possible material will also allow the best grip.

One pilot has been trialling a Seamless Nylon Machine Knit with HPT Coating called the Ninja. This pilot does not use the manropes for either the ascent or descent, so does not need to have rope running over his fingers and palms. His preliminary feedback has been very positive, reporting the gloves to provide him
with the necessary protection as well as “gripping very well with their non-slip surface”. This trial will continue.

4.7 Cost benefit analysis

The key to gaining a cost-benefit from gloves is to purchase gloves that fit the users and their chosen tasks. While this appears self-evident, glove fit is difficult to achieve, particularly if a limited number of sizes and glove shapes are offered or made available to the pilot. Also if a pilot prefers not to wear a glove for the ladder transfer task for fear of having a reduced grip, they should not be forced to do so.

As previously outlined in ‘Glove Fit’ a ‘mismatched glove’ causes the user’s grip force to be higher than necessary, and results in repeated and forceful grasping, and so increases the risk of the user developing cumulative trauma disorders in the hands and arms. Even just one size too large impacts on the length-strength relationship of the flexor and extensor tendons (Kovacs et al 2002).

For example a pilot fall occurred about 2 years ago when the pilot reported his hand “gave way” when he was on the ladder. This sudden and unexpected weakness is a common sign of a cumulative trauma disorder that develops as a result of the hands being exposed to tasks that require forceful and/or repetitive gripping. This pilot required a significant period off work to recover from the fall.

When considering the cost of purchasing appropriate gloves, pilots and employers should also consider the ‘cost’ of incorrect gloves in contributing to these cumulative trauma and musculoskeletal disorders. While these conditions are not fatal they remain the main cause of Workers Compensation claims in Australia, with the largest number of days away from work. For example in NSW they typically account for 64% of all workplace injuries, and are also the most expensive injury group, accounting for 70% of all costs (WorkCover NSW 2002).

Added to these known costs are the many hidden costs of staff replacement, roster changes, personal distress from the injury, and the very real possibility that the pilot may be permanently unfit to return to work. Common injuries relating to use of the wrists and hands in grasping activities include tendonitis, tenosynovitis, carpal tunnel syndrome and epicondylitis. These conditions can all become chronic, long term problems and can result in permanent disability, restricting work activities as well as basic activities of daily living and leisure pursuits requiring the hands.

Poor gloves can also affect grip and could lead to the hands slipping and letting go of ropes during a ladder climb. In this scenario the consequence can be very serious.

To reduce injury risk careful glove selection is critical, and paying a higher price for a glove is money well spent if the product is superior and more suitable than the existing glove. However price should not be confused with quality, as choosing the right glove is the most important thing.

The prices of gloves currently provided to pilots who were surveyed cost between $1 for cotton beaded gloves to $6.60 for leather riggers gloves. While these gloves are very inexpensive to purchase, according to the pilots’ self reports and experiences, the gloves do not last very long. Data in Table 4 is based on pilot
reports; however purchasing officers may be able to provide more accurate data from which to make a more accurate comparison.

Table 4. Estimated cost per wear of selected gloves

<table>
<thead>
<tr>
<th>Type of glove</th>
<th>Estimated average number of wears or jobs*</th>
<th>Price per pair (if only buying one pair)</th>
<th>Cost per wear or job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leather rigger</td>
<td>12</td>
<td>$6.60</td>
<td>$0.55</td>
</tr>
<tr>
<td></td>
<td>50**</td>
<td></td>
<td>$0.13**</td>
</tr>
<tr>
<td>Cotton with beading</td>
<td>12</td>
<td>$1</td>
<td>$0.08</td>
</tr>
<tr>
<td>Sailing type fingerless glove</td>
<td>275</td>
<td>$30</td>
<td>$0.10</td>
</tr>
<tr>
<td>General Utility glove made of synthetic leather</td>
<td>Not yet tested.</td>
<td>$14</td>
<td>$0.05</td>
</tr>
<tr>
<td>(Eg Contego)</td>
<td>Estimated to be similar to synthetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>leather sailing gloves</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seamless Nylon Machine Knit with HPT Coating</td>
<td>Not yet tested.</td>
<td>$4.25</td>
<td>?</td>
</tr>
<tr>
<td>(Eg Ninja)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Number of ‘jobs’ is very variable at different ports and these figures are based on one pilot organization
**The figure of 50 wears for a leather glove was not reported by anyone but was inserted solely for comparative purposes to see how the price per wear changed with an increased lifespan.

The data in the table suggest that a glove that is more expensive to purchase than the current rigger glove may prove to be inexpensive when comparing ‘price per wear’, as well as reducing injury risk to the pilot. For example the synthetic leather glove is 2-3 times more expensive than the leather rigger glove to purchase, but is a far superior product. Even if this product only lasts 4 times as long as the leather glove (ie 48 wears) the price per wear is still much cheaper than the leather riggers gloves.

As the user trials and evaluation also rated the leather rigger gloves poorly as compared to other glove styles, new style gloves should be sourced and trialled and based on the recommendations of this investigation.
5. RISK CONTROL

5.1 Conclusion

Glove use in the pilot ladder transfer can either increase the risk of injury such as cumulative trauma disorders and from the hands slipping, or can reduce the risk of these events. Gloves should not be recommended as a blanket or essential requirement because of the potential problems with the reduction in grip force with most gloves, but should be assessed for each work environment and for the pilot’s preferred ladder climbing method.

5.2 Recommendations

The evidence presented in this report shows that in most cases the hands will be better able to grip when they are bare, however the risks with this are the hands being soiled, and the pilot may also sustain rope burns depending on their chosen climbing method. Each pilot’s method of climbing and ladder use should dictate which glove type they choose, should they choose to wear a glove at all.

For manrope users who both ascend and descend the ladder using these ropes, a glove should have the following properties:

- Thin material
- Very close fitting on hands and wrist
- Not water affected - ie does not swell or lose grip with water
- Abrasion resistant
- Soft material on the back of the hands to permit maximum flexibility and movement, such as mesh, nylon, or lycra
- Constructed in a ‘pre-curved’ grip shape to reduce flexion effort
- Firm fastening at the wrist that allows for fine adjustments, such as velcro
- Fastening at the back of the wrist to avoid becoming caught in ropes etc
- Soft palm and finger material to allow an unresisted grip
- Water proof or quick drying
- Provide protection from soiling

Some pilots like the sailing style gloves, and these have each of the features above so should be permitted where pilots are happy to have their thumb and index finger tips exposed.

Synthetic leather gloves appear to be a substitute for the current leather riggers gloves due to the superior fit, dexterity and wrist fastenings that most models provide, however their use when wet is not known. Further trials are recommended to assess the impact of water and how well they work in a rapid descent of the ladder by manrope users.

For pilots who use the side ropes and do not let the rope run through their hands the glove does not need to be as thick and robust as for manrope users, and this provides the benefits of permitting the hands to have better grip and improved dexterity. These pilots can use a much thinner glove, and possibly the newer synthetic materials that have different non-slip coatings (eg such as the Ninja, currently under trial).
All glove users should avoid gloves that have the following properties as each can increase the risk of hand injury and/or increase the risk of the hands slipping from the rope:

- Loose or incorrect fitting gloves
- Thick materials
- Leather in wet conditions (and possibly synthetic leather too)
- Nitrile based gloves*
- Gloves that lack wrist fastenings
- Gloves with thick, stiff materials on the back of the hand
- Very absorbent gloves

*The advice regarding nitrile based gloves was provided by a glove manufacturer who claimed that in wet conditions a soapy substance used in their manufacture leaches out and can make the glove surface slippery (Lockerbie 2007).

To ensure that glove users either choose or are provided with the best fitting gloves they should measure their hands to determine their specific requirements. As many brands of gloves come in limited sizes alternative brands will need to be available to pilots who do not fit those provided.

The Australian Standard regarding glove selection (AS/NZS 2161.1:2000) outlines how to measure the hands to determine glove sizing using measurements of the hand length and the hand circumference as illustrated in Figure 1. Glove users and glove purchasers will need this data to ensure the best fit possible and so ensure the pilots’ hands can work with maximum performance and comfort.

![Figure 1. Method of measuring hand dimensions for glove selection (AS/NZS 2161.1:2000, Appendix B)](image)
6. REFERENCES

Standards

AS/NZS 2161.1:2000
Occupational protective gloves - Selection, use and maintenance

AS/NZS 2161.2:2005
Occupational protective gloves - General requirements

AS/NZS 2161.3:2005
Occupational protective gloves - Protection against mechanical risks

AS/NZS 2161.10.2:2005
Occupational protective gloves - Protective gloves against chemicals and micro-organisms - Determination of resistance to penetration

AS/NZS 2161.10.3:2005
Occupational protective gloves - Protective gloves against chemicals and micro-organisms - Determination of resistance to permeation by chemicals

AS/NZS 2161.5:1998
Occupational protective gloves - Protection against cold

General references

Armstrong T, 1998, Upper limb musculoskeletal disorders and force, University of Michigan, at University of Michigan website: www.personal.engin.unimich.edu


Lockerie P, 2007, Manager Best Gloves Australia, personal communications


