This information paper provides a brief overview of the challenges faced by ports and terminals attempting to improve the working conditions of crane operators in terms of crane cabin ergonomics.
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INTRODUCTION

DOCUMENT PURPOSE
This information paper provides a brief overview of the challenges faced by ports and terminals attempting to improve the working conditions of crane operators in terms of crane cabin ergonomics. The paper describes how many of these concerns, despite considerable improvements in crane cabin design, remain unaddressed at container handling applications at ports and terminals. The paper considers the benefits of introducing a common set of specifications with a view to mitigating the health risks associated with crane cabins.

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1 | EXECUTIVE SUMMARY

The rise of containerisation has brought new challenges for ports and terminals concerned about the health of their operators. Despite a growing degree of focus on crane cabin and work station design, ergonomic issues such as awkward posture, and environmental factors including inadequate heating, ventilation, noise, and vibration, continue to impact crane operators’ wellbeing. Beyond its personal cost, poor employee health also has detrimental effects on wider operational safety and productivity.

However, the global ports and terminals industry currently lacks a basic, comprehensive list of cabin characteristics that could be used to mitigate the health risks associated with crane cabinets and work stations. The aim of this paper is to provide baseline specifications for work stations and crane cabinets in relation to ergonomic and safety features.

To make such moves effective, this paper suggests that these recommendations should be included in design tenders requested by crane customers, and furthermore that they should also be included as standard features in suppliers’ initial quotations, rather than being optional extras.

Although critics may raise concerns that such recommendations encroach upon the functioning of the crane cabinet market, if all equipment suppliers were to adopt these features as standard, it is not anticipated that competitiveness would be affected, nor should it significantly affect cranes’ base prices.

Furthermore, the likely improvement in safety would reduce staff injuries and equipment damage costs over the lifetime of equipment, and improve the reputation of the container terminal industry and equipment manufacturers in general through an increased focus on safety.

Fig. 1 Example of Gantry Cabin

Fig. 2 Wrong postures adopted by crane operators
For many years, crane cab and work station design focused almost entirely on mechanical structures and basic control layout, with little reference to their human operators. As early as the 1970s, industry studies highlighted concerns over the impact of poor cab design on musculoskeletal disorder (MSD) and other conditions. A study by Wicks et al., published in 1975, suggested that tower crane operators would often leave their jobs before they reached the age of 50 due to ill health.

A study by Zondervan, (1989), showed that 64 per cent of the crane operators it surveyed were suffering from back complaints; and 42 per cent from neck complaints. Burdorf et al., (1993), found that 50 per cent of crane drivers were prone to back problems.

In 2001, Ariens concluded that there is some evidence to suggest a clear relationship between neck pain and resultant work-related risk factors: neck flexion, arm force, arm posture, duration of sitting, twisting or bending of the trunk, hand-arm vibration, and workplace design. A study published in 2002 showed that between 44 and 77 per cent of crane drivers surveyed suffered neck complaints, and between 67 and 86 per cent complained of lower back pain. Further, Eger et al. (2006) analysed video recordings of container crane operations, finding that operators spent significant amounts of time with their necks and trunks rotated or unnaturally bent.

An ergonomics study on grab unloaders by Courtney and Chan, (1999), demonstrated that to look downward through the central lower front window – a necessity for around half of a typical shift of the cranes surveyed – operators’ main body parts were in awkward postures involving the neck, (81 per cent), the lower back (88 per cent), the mid-back (50 per cent), and shoulders (50 per cent). This resulted in static loading of the neck and back, with the trunk flexed 30 to 40 degrees forwards and the neck fixed about 60 to 70 degrees forwards from the vertical to ensure a proper view of directly below the cab.

A more recent research paper, based on European Standards EN 1005-3/4/5 and focused on biomechanical analysis by the EPM Research unit – Ergonomics of the body posture and movement and the Biomedical Technology Department of the University of Milan (2007-2008), in collaboration with PEMA member Brieda Cabins, used electrodes to accurately measure stressors on trunk, neck and limbs with the use of the electromyography.

These tests clearly showed that the awkward postures adopted by crane operators is the result of improper cabin design, and went further in demonstrating that a good ergonomic control station’s configuration and control layout will alleviate poor posture and resulting injury.

International Standard ISO 11226, Ergonomics – Evaluation of Static Working Postures, establishes ergonomic recommendations for different work tasks. This standard provides information to those involved in the design and redesign, of work, jobs and products that incorporate basic concepts of ergonomics and working postures in particular. Recommendations contained in the standard related to trunk inclination and head posture, in combination with the studies mentioned above, appear to support the need for specific equipment for crane drivers. This report provides a brief overview of the ISO recommendations.

Design also has an overall impact on safety, as it can improve the poor visibility typically associated with crane cabins, mitigate the forces required to operate joysticks, buttons and levers and, by helping to reduce fatigue, also help operators to remain alert.

Finally, in addition to the cost of chronic conditions among the workforce caused by poor crane cabin design, the detrimental effect of employees’ poor health on relationships between operators and port management should also be considered.

Fig. 3 Biomechanical Analysis based on Body-Electromyograph
3 | KEY CONSIDERATIONS

Several issues need to be considered when drawing up specifications for crane cabins and control stations. A more exhaustive list of possible specifications is included in this paper; see below; such stipulations do, however, fall into several broad categories.

In container cranes – Ship-to-Shore (STS) and Rubber Tyred Gantry (RTG) cranes – drivers are required to look downwards almost continuously. In addition, each type of container crane has its own specific characteristics.

STS crane cabins significantly accelerate and decelerate when moving backwards and forwards. Passing the boom junctions creates low frequency shocks. Due to the heights and speeds typical of container cranes, drivers need to be constantly highly focused. Drivers’ downwards viewing angle is relatively limited due to crane height.

RTG drivers have a different field of vision. Because the spreader is relatively close to the cabin, the viewing angle is wider. As a result, driver’s legs often obscure their vision. Looking around while driving the machine, and looking sideways under beams while searching for trucks causes awkward posturing. Sideways movement, in combination with RTG rubber tyres, creates a swinging motion in the cab and the driver when starting and stopping.

There are also structural points to consider such as 40mm safety laminate fixed floor glass. The development of glass of this thickness resolves some of the issues where thinner, removable glass was used to assist cleaning, the latter being protected inside and out by metal safety grills which lead to poor visibility.

The need for shock and vibration absorbers on cabins and their control stations has emerged due in part to reports from operators that the increased speeds of modern cranes have resulted in greater vibration levels inside cabs. ISO 2631-1 Mechanical Vibration and Shock, which provides guidance on human exposure to whole body vibration, should be considered a benchmark in this area when drawing up specifications for crane cabs. Comfort is one element here, but there is also the issue of effective control of items such as touch screens.

Similarly, correctly positioned handholds are necessary to help drivers climb in and out of crane cabs, as well as moving around inside the cabin.

Anecdotal evidence from drivers, and detailed research by the EPM Research unit – Ergonomics of the body posture and movement and the Biomedical Technology Department of the University of Milan (2007-2008), shows that seats and control stations need to be fully adjustable in all directions including tilt, with forearm rests to reduce pressure on the lumbar region.

Seats and control stations also need to support the body through periods of biomechanical stress caused, for example, by trolley acceleration and deceleration, while hand supports allow for precise control during joystick operations.

Related to this is the need for good quality, self-retracting safety belts – cabins are prone to sudden jolts and stops that can, in some cases, unseat operators. However, freedom of movement needs to be maintained both for ease of use and to prevent drivers simply abandoning seat belts that are felt to be unnecessarily restrictive.

The positioning of displays and lighting inside crane cabins is critical to effective crane operation. Experience and evidence from other industries where crane use is prevalent, shows that monitors need to be between 45° and 50° from the driver’s eye level to avoid strain. Further, key system indicators, including fault and overload lights, should be within drivers’ forward and downward field of vision, rather than set into side panels where operators risk failing to be alerted to important system information. Touch screens and other control tools also need to be adjustable.

Other important issues that need to be considered in crane cab design include adequate air conditioning and heating, with sufficient warmth being directed across the glass floor to keep this free from moisture. Furthermore, crane cabins must be positively pressurised with clean air to keep out pollutants.
## 4 | INDUSTRY RECOMMENDATIONS

The following is not intended to be a comprehensive source of cabin and control station safety items. Rather, it aims to provide terminals, operators and suppliers a solid minimum baseline of safety features that are practical and effective.

Based on experience, records and insurance claims analysis, the table includes systems, structures, features, equipment and technology that have been shown to reduce injury or damage that are currently not standard.

Table 1: Recommended list of cabin and driver control station minimum standard safety features

<table>
<thead>
<tr>
<th>ITEM</th>
<th>RISK</th>
<th>SAFETY FEATURE</th>
<th>FUNCTIONAL REQUIREMENT</th>
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<tr>
<td>7</td>
<td>Structural strength of glass floors.</td>
<td>LAMINATED, CERTIFIED FLOOR GLASS</td>
<td>Floor glass should be fixed, walk-on safety laminated glass, at least 40mm thick, with sliding and lockable footrest grids for optimal visibility of the working area below. Floor windows should resist a concentrated load of 2,500N/ft², and a divided load of 1,500N/ft² simultaneously.</td>
</tr>
<tr>
<td>8</td>
<td>Fall risk to drivers during operating phases due to cranes stopping suddenly.</td>
<td>FOUR-POINT SAFETY BELTS</td>
<td>It is advisable to have safety belts for the shoulder and waist, so the driver is held safely during operations, and blocked in the event of the trolley suddenly stopping.</td>
</tr>
<tr>
<td>9</td>
<td>Bending and tilting of drivers.</td>
<td>SAFETY BELTS</td>
<td>Safety belts for the shoulder and waist with type-approved roller to allow the free movement of the driver.</td>
</tr>
<tr>
<td>10</td>
<td>Failure to monitor and control visual indicators.</td>
<td>FRONT POSITIONING OF VISUAL INDICATORS</td>
<td>It is advisable to install all mission-critical indicators in the lower front frame of the horizontal position, in boxes of suitable size, to avoid obstructing visibility, thereby giving drivers all necessary information, (spreader lights, container weight, container height, hoist/trim position, twist lock locked/unlocked, crane faults, windspeed, sudden high winds, overload, anti-collision alarms etc.). These are located in the driver’s main working direction, which is the look through the front and floor glass. This enables the safe control of loading/unloading operations.</td>
</tr>
<tr>
<td>11</td>
<td>Failure to monitor and control visual indicators.</td>
<td>ANGULAR POSITIONING OF VISUAL INDICATORS</td>
<td>Display screens should be positioned between 45° and 50° to drivers’ eye level while seated, ensuring the safe control of information necessary during operations.</td>
</tr>
<tr>
<td>12</td>
<td>Difficulties related to the use and accessibility of auxiliary devices.</td>
<td>LATERAL POSITIONING OF AUXILIARY DEVICES</td>
<td>Auxiliary control panels and radio/transmitters should be designed according to cabin vibration; and should be placed on the right- or left-hand wall and should be within easy reach of the driver by hand when seated at the control station with a maximum rotation of the head of 90°. Main (turn on/off) switches and microphones should be positioned to allow drivers to maintain sight on driving the crane while using communication equipment.</td>
</tr>
<tr>
<td>13</td>
<td>Failure to use touch devices, noise and vibration.</td>
<td>INTERNAL NOISE DAMPERS, ISOLATION AND ABSORPTION MEASURES</td>
<td>No equipment installed in cabins should produce noise due to vibration of the cabin. Cabin structure and windows should be isolated to avoid unwanted noise entering the cabin. Cabins should be provided with sufficient sound absorbent material to reduce reverberation.</td>
</tr>
<tr>
<td>14</td>
<td>Lumbar spine, neck flexion and general driver overload.</td>
<td></td>
<td>It is advisable to lean the forearms while using joysticks to minimise lumbar overload. Leaning forward responsibly makes it possible to reduce neck flexion when looking downwards.</td>
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## About the Authors & PEMA

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This paper has been prepared by Siro Brieda of Brieda Cabins, with input from Daan Potters from BTG Special Products BV.

### About PEMA

Founded in late 2004, the mission of PEMA is to provide a forum and public voice for the global port equipment and technology sectors, reflecting their critical role in enabling safe, secure, sustainable and productive ports, and thereby supporting world maritime trade.

Chief among the aims of the Association is to provide a forum for the exchange of views on trends in the design, manufacture and operation of port equipment and technology worldwide.

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**APPENDIX 1:**

P Wicks, Ergonomic Analysis of Human Factors Affecting Optimum Performance of Mobile (Tower) Crane Drivers, University of Surry, 1975

Brieda Cabins, Ergonomic Solutions in designing workstation for operators of harbour cranes, 2007

**APPLICABLE STANDARDS** – Please note that behind PEMA statements there are international standards that impact equipment safety, and these must be reviewed, and their implications incorporated.

Applicable international, national or local regulatory standards should be respected in all cases.