

Case study on reducing manual handling and ergonomics related incidents in the offshore wind industry



G+ Global Offshore Wind
Health & Safety
Organisation

In partnership with



CASE STUDY ON REDUCING MANUAL HANDLING AND ERGONOMICS
RELATED INCIDENTS IN THE OFFSHORE WIND INDUSTRY

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FOREWORD

Offshore wind industry operators are at risk of musculoskeletal injuries and disorders when performing manual handling (MH) activities, and in particular when those are uncontrolled. These activities can include handling heavy items (tooling, equipment, kit bags and personnel bags), repetitive tasks, working in restricted spaces and working above shoulder height.

The Energy Institute (EI) and the G+ Global Offshore Wind Health and Safety Organisation (G+) have produced this first edition case study on preventing MH and ergonomics (MH&E) related incidents in the offshore wind industry.

The primary audience for this document are those involved in the design, specification and procurement of both offshore and onshore renewable assets. Those involved with the assessment and management of health and safety at work, namely managers, and health and safety (H&S) specialists, may also find the task-based scenarios of particular interest.

The case study is based on analysis of offshore wind industry incidents, assessment of a sample of offshore wind industry activities, a systematic review of regulatory requirements, observation of good practice and stakeholder engagement, including peer review by G+ members.

1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides support and practical examples to help reduce MH&E related incidents in the offshore wind industry.

The requirement for support and guidelines to reduce MH incidents in the offshore wind industry originates from:

- Reporting that indicates that MH injuries are one of the largest causes of lost working day incidents within the offshore wind industry.
- The fact that MH tasks potentially involve handling very heavy items (often as team handling operations).
- The nature of working conditions that increase MH risks, e.g. working in restricted space within the asset, dragging bags/items onboard crew transfer vessels (CTV) and working in adverse environmental conditions.
- The fact that the offshore wind industry is expanding, creating a larger workforce and therefore more opportunities for incidents to occur.

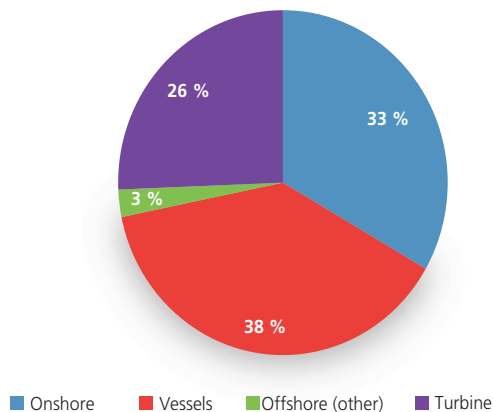


Figure 1: Lost work day incidents in 2018

The primary audience for this document are those involved in the design, specification and procurement of both offshore and onshore renewable assets. Those involved with the assessment and management of H&S at work, namely managers and H&S specialists, may also find the task-based scenarios of particular interest:

- project designers/engineers (the individuals responsible for designing or procuring new wind turbines, ensuring they are easy to operate and maintain);
- managers (decision makers that establish the organisational culture, and develop and enhance management procedures), and
- members of the H&S team (those responsible for protecting the health, safety and wellbeing of people who work, conducting risk assessments and enhancing safety management arrangements, e.g. training, developing procedures).

This document should also be used as a source of valuable experience by companies to inform internal guidance and training for senior technicians and supervisors (those who manage and oversee how work is carried out, and also provide support with MH risk assessment).

1.2 SCOPE OF THE DOCUMENT

The document is aimed at organisations working in the offshore wind industry involved in both construction and operations and maintenance (O&M), but with a specific focus on O&M. The information covered is likely to be relevant for all offshore wind farms, whether their operations are in an early stage of construction or existing operational sites.



Figure 2: Offshore wind industry: construction and O&M

The information provided within this document considers:

- MH issues across a range of areas from shore (warehouse, port/quayside) to vessel to asset (substation/foundation/transition piece (TP)/nacelle), and
- type of MH injuries, including acute (occurs suddenly during activity, often a sprain or strain) and chronic (i.e. pain and injury that develops slowly and is persistent, long-lasting or recurring).

The document does not consider:

- Other types of incidents or injuries that might be associated with construction or O&M tasks in the offshore wind industry, such as injuries relating to electrical shock (e.g. burn, cardiac arrest), falls from height or injuries from dropped tooling and equipment.
- Climbing ladders and working with items at height, which is covered by the *G+ Good practice guideline working at height in the offshore wind industry*.

1.3 DEFINITIONS

1.3.1 MH

The European Council (EC) Directive 90/269/EEC on the minimum H&S requirements for the manual handling of loads where there is a risk particularly of back injury to workers defines MH as:

'...any transporting or supporting of a load, by one or more workers, including lifting, putting down, pushing, pulling, carrying or moving of a load, which, by reason of its characteristics or of unfavourable ergonomic conditions, involves a risk particularly of back injury to workers.'

According to the Manual Handling Operations Regulations (MHOR), a manually handled item may be moved or supported by the hands or any other part of the body; for example, the shoulder. MH also includes supporting an item in a static posture, and the dropping or throwing of an item.

Using human effort for a purpose other than to transport or support an item (e.g. using a spanner to loosen a bolt) is not strictly considered to be an MH operation under the EC directive. However, for the purposes of this case study such activities are also considered where incident data indicate the activity to be a risk for injury for technicians carrying out maintenance work in the asset.

MH activities are regulated through EC Directive 90/269/EEC on the minimum health and safety requirements for the MH of items where there is a risk particularly of back injury to workers (fourth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC).

1.3.2 MH Injuries

According to guidance on the UK MHOR:

'Manual handling injuries are part of a wider group of musculoskeletal disorders (MSDs). The term 'musculoskeletal disorders' covers any injury, damage or disorder of the joints or other tissues in the upper/lower limbs or the back.'

1.3.3 Chronic and acute injuries

MH can cause both acute and chronic injury.

An acute injury occurs suddenly during an activity. These are typically sprains, such as overstretching a ligament connecting bones by overstretching a knee, or a strain of a muscle or tendon, such as due to overstretching and tearing the muscle or tendon.

A chronic injury is typically due to overuse of a part of the body or from long-standing conditions. Typical examples include tendonitis, arthritis, lateral epicondylitis (tennis elbow) and repetitive strain injury (RSI). Repeated acute injuries may also contribute to chronic injuries.

1.3.4 Ergonomics

The International Ergonomics Association (IEA) defines ergonomics as:

'The scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance.'

In the context of this document, ergonomics is considered to relate to design, such as the physical layout of the work environment (e.g. nacelle, vessel, etc.) and the design of equipment and tooling.

The European Directive 2006/42 provides additional advice on the importance of considering ergonomic principles (e.g. when designing machinery, it is important to allow for variability in the technician's physical capability, and to provide sufficient space for technicians to move around and use tooling).

1.3.5 Performance influencing factors (PIFs)

PIFs are defined by the Health and Safety Executive (HSE) as: characteristics of the job (e.g. the working environment); the individual (physical capability to do the work), and the organisation (e.g. time pressure) that influence human performance.

These factors can impact performance in different ways; for example, a wet and windy working environment can make it harder to grip items securely, increasing the risk of MH injuries, as discussed in HSE INDG143 *Manual handling at work. A brief guide*.

Having an understanding of what the PIFs are and how they shape performance can inform ways to minimise the risk of MH injuries, such as through providing appropriate training on MH techniques. This could also potentially enhance performance.

2 TASK-BASED EXPERIENCE

The following section collates the combined G+ members' experience in over 10 years of offshore wind construction, O&M. The sections provide real life scenarios, observations and techniques for dealing with issues presented.

Greenstreet Berman were appointed to produce this document. They started with a project initiation workshop, where experts were gathered, and the work programme agreed. They then reviewed the G+ incident data to investigate the MH&E related incidents that had historically occurred on member sites. A documentation review was undertaken to see what was already in the public domain that might be useful. Once this knowledge was collated, Greenstreet Berman presented this back to industry experts and started to draft this document, with input from industry. This development process is illustrated in Figure 3.



Figure 3: Document developing process

Items 1 to 8 cover access to the asset and typical work activities during the O&M phase. Items 9 and 10 deal with construction:

1. Preparation of items in the warehouse.
2. Movement of items between warehouse and CTV loading area.
3. Movement of items between shore and CTV.
4. Movement of items between CTV and asset.
5. Movement of items between TP and other areas of the asset (e.g. foundation, nacelle, yaw section and hub).
6. Working on an offshore asset – foundation, TP or tower levels.
7. Working on an offshore asset – yaw deck.
8. Working on an offshore asset – nacelle/blade hub.
9. Construction task – bolt insertion and torquing.
10. Construction task – attaching the rigging for lifting.

These scenarios are not intended to be comprehensive and they do not cover all aspects of MH activity associated with the offshore wind industry.

Each scenario is presented in the same manner using the following sub headings:

- Scenario: describes the general overall work scenario along with the more specific MH tasks associated with this scenario.
- Problem area: a general discussion of the unique issues/problems associated with MH and possible PIFs that can affect behaviour and error occurrence.
- How to tackle MH issue: advice on tackling the issues/problem is summarised (in table form):
 - typical task performed as part of the overall scenario;
 - the common PIFs that shape performance and behaviour and make the risk of MH more or less likely – further information and a more comprehensive list of PIFs is presented in 1.3.5;
 - likely hazards associated with these tasks (e.g. item and postural constraints that can lead to injury);
 - possible interventions (relevant to the task and PIFs) to help reduce MH risk:
 - eliminating hazards entirely (e.g. removing the need to undertake the MH activity through mechanisation or some other means), and
 - reducing or mitigating the risk through a number of interventions (e.g. reducing the items to be handled).

Where available, examples of recordable incidents are provided in text boxes to illustrate where a particular hazard has led to injury. Note that the examples are not exhaustive.

2.1 PREPARATION OF ITEMS IN THE WAREHOUSE

2.1.1 Scenario



Figure 4: Warehouse

There is a requirement to store, locate, retrieve and pack up the items necessary for working offshore (e.g. equipment/tooling/components/consumables), for transportation to an offshore asset.

In most cases, this will be done as an MH activity supported by mechanised material handling equipment (MHE) (e.g. forklift truck).

Although likely to vary, the fundamental aspects of this task remain the same, namely:

- items are initially stocked into defined locations; this may include the breaking down of packages or even decanting of certain liquids;
- the items are then located and retrieved from storage, normally kept on pallets on warehouse racking but also in lifting bags;
- items are moved to a packing or loading area, and
- items are packed into appropriate 'lifting bags' for transportation.

This section does not include an analysis of loading the racking (in stores) in the first place, i.e. deliveries onto site. In many instances, materials come to site that have to be decanted from the transport, frames, containers and packaging onto the site's stores racking. This in itself creates a risk to the team, and one that could be completely avoidable by thorough planning, discussions with the supplier and their delivery company.

2.1.2 Problem areas

In larger warehouses, storage is likely to be palletised and retrieved from racking using forklift trucks, although the design of the warehouse may prevent their use in all areas. Where mechanical MHE cannot be used or is not available then items will need to be accessed manually. The weight of the item and placement in the warehouse will therefore affect the ease of handling operations.

The warehouse environment can also affect MH performance, for example:

- Temperature: the ability to grip and hold an item securely.
- Noise: affects communication and team handling.
- Lighting: readability of labels.

Stocking or retrieving items from racking or moving them around the warehouse may also be physically demanding, particularly if items are heavy. In some situations, tasks to prepare items might be highly repetitive. Evidence from the MH data review indicates that the associated task can lead to both acute and cumulative injury risk.

Depending on the size of the wind farm stores, teams can be packing more than three tonnes of parts and components for a day's service and then unpacking a similar weight from the previous day's servicing. Time pressures may also be present to work quickly to ensure items are delivered to the CTV in good time. This can lead to workers not always following MH procedures and good practice guidelines on lifting and carrying.

2.1.3 How to tackle MH issues

Table 1: Summary of key tasks, hazard, PIFs and risk control measures for preparation of items in the warehouse

Task	Likely PIFs	Potential hazards	Task-specific risk controls
Identify items	Labelling – if unclear, an item might need to be moved to enable identification	Adopting an awkward posture to view and/or move items so they can be correctly identified	Prevention Mechanise the process for retrieving items from storage either using a forklift and/or overhead crane/hoist
Retrieving items from the racking/shelving	Design – racking design (e.g. depth of racking, height of racking) Housekeeping – cluttered shelving or cluttered work area causes items to be moved unnecessarily; spillages may affect safe movement of items	Dragging items that might be heavy, reaching into racking away from the body in a potentially awkward posture to reach and retrieve items	Mitigation <i>Design</i> Ensure the sizing and depth of the racking is appropriate e.g. items can be placed on shelves within a zone of comfortable reach ¹
Lowering items (e.g. from the racking/shelving to warehouse floor)	Environment – warehouse lighting (difficult to see), temperature (i.e. cold affects grip), floor surface (smooth/rough), noise – impacts on communication	Carrying items in an awkward posture (e.g. items difficult to grasp) or lowering item away from body to floor or to another person causing them to twist or hold items at a distance	Ensure there is enough space between racking/shelving to allow fork lifts to operate to limit manual handling <i>Planning</i> Develop a plan/written procedure for the storage of items (e.g. grouping related items together, placing heavier items on lower racking) and ensure that the plan is implemented, and procedures followed
Team handling – passing items from one person to another potentially at height		Miscommunication during team handling causing an unexpected movement of items and excessive transfer of weight to an individual	Good practice to rotate the work between personnel <i>Labelling</i> Ensure items are clearly labelled so they can be easily identified, consider colour coding labels/bags by weight (e.g. heavier to lightest black, purple, red, yellow, green) or based on suitable lifting method (e.g. suitable for one-person MH, two-person MH or only to be lifted by mechanical aid)

¹ Zone of reach – tasks requiring only fingertip pressure on a pushbutton could be located at or near the outer limits of arm reach; however, a task requiring a full grasp of a handle to pull an item requires a closer arm reach. Reach envelopes, therefore, need to be developed for actual working positions and for explicit purposes.

Table 1: Summary of key tasks, hazard, PIFs and risk control measures for preparation of items in the warehouse (continued)

Task	Likely PIFs	Potential hazards	Task-specific risk controls
<p>Other general warehouse tasks (e.g. moving/dragging items for loading to transport)</p>	<p>Time pressure – organising and preparing items quickly, to ensure maintenance activities are carried out as planned</p> <p>Nature of item – size, shape and weight of items lifted in and out</p> <p>Competence – knowledge of good MH techniques</p> <p>MH policies and procedures – not comprehensive/unclear</p> <p>Physical capacity – not physically able to complete the tasks in a safe manner</p>	<p>Dragging or lifting items that are heavy, bulky or unwieldy in a stooped position</p> <p>Lifting and Lowering items out of boxes and into bags, often away from the body</p> <p>Loading items from a pallet into a lifting bag can be a repetitive action which could lead to injury</p>	<p><i>Workspace</i></p> <p>Ensure the warehouse is designed to create an effective working environment, e.g.:</p> <ul style="list-style-type: none"> – Well lit, so labels can be read and hazards more easily identified – Provide a suitable ambient temperature – Slip/trip obstacles are reduced/removed (e.g. free of wet surfaces, lubricant) – Create set down areas, ideally close to racking to reduce double handling <p><i>Housekeeping</i></p> <p>Reduce/remove clutter to enable mechanised lifting devices to access more areas and introduce clear routes and walkways</p> <p><i>Items</i></p> <p>Reduce the weight of items to be handled, e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held.</p> <p>Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH (ideally tailored to task and work environment) and on communication protocols for team handling (e.g. effective communication when lowering an item to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p> <p>Physical fitness testing and training</p>

2.2 MOVEMENT OF ITEMS BETWEEN WAREHOUSE AND CTV LOADING AREA

2.2.1 Scenario

Once prepared in the warehouse, items will need to be moved to a location from which they can be loaded onto the CTV.



Figure 5: CTV loading area

The way in which items are moved will depend on the nature of the site and whether items can be carried directly from the warehouse. Most frequently, bags will be transported by assisted means, for example: lorry, light commercial vehicle or other motorised vehicles; trailers towed by electric tugs; motorised push or pull trolleys (with sides or flat-bed), and manual push or pull trolleys (with sides or flat-bed).

Loading the transport system will most often be carried out manually, although some sites will have warehouse cranes and other mechanised MHE (such as forklift trucks) to aid this. Some of the common tasks when carrying out this scenario include:

- locating and positioning the transport system;
- loading bags/containers and other items into a transport system, ordered by asset and CTV;
- movement of manual transport system (e.g. push/pull trolley) to CTV loading area, and
- unloading items.

2.2.2 Problem area

The key problem area with this scenario concerns manually loading and unloading the transport, and then, if required, moving it by manual pushing/pulling.

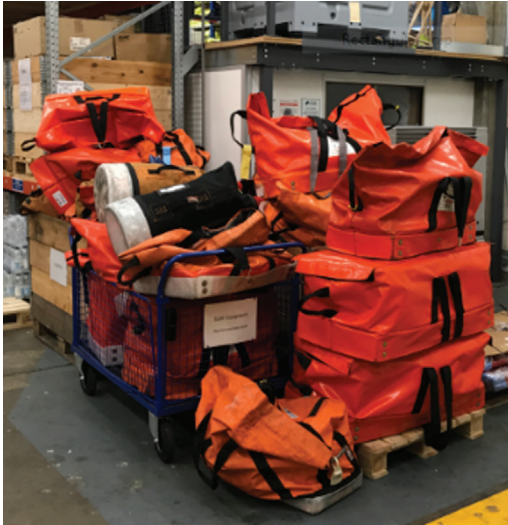


Figure 6: Loading and unloading

Example of incident:

Loading bag into transport: during the morning, equipment and bags are lifted onto Bradshaws for transit to the vessel. The injured person bent down to lift his personal bag of a confirmed weight of 14 kg when he felt a sharp pain.

The risk associated with loading the transport will be impacted primarily by the design of the transportation; for example, a trolley with high sides might be more difficult to load, requiring items to be lifted and either thrown or lowered into the trolley, although one without sides might be less stable and items might shift or fall as it is moved. Light commercial vehicles, which are opened at one end, might be easier to load, but they will require items to be positioned at the back and stacked as more items are introduced. Other design features of the transport will also affect how easy it is to move e.g. wheel design, handles, brake, etc.

The performance of transport systems will also be affected by the prevailing weather conditions and the nature of the road or walkway. For example, inclines down to or up from the dock area will increase the push force required to move a manual transport system (e.g. for every 100 kg of weight a 10-degree incline will increase the push force required by 17 kg) (MHOR).

2.2.3 How to tackle MH issues

Table 2: Summary of key tasks, hazard, PIFs and risk control measures for movement of items between warehouse and CTV loading area

Task	Likely PIFs	Potential hazards	Task-specific risk controls
Lifting into or retrieving items from a high-sided transport system	Equipment design – e.g. manual transport system is easy to push/pull, load, unload etc Workplace design – such as road, walkway surface, slope incline Environment – weather conditions e.g. extremes of temperature or humidity, gusts of wind, lightning and rain	Holding or manipulating items at distance from the body (e.g. reaching away from the body with extended arms to place or retrieve an item from a transport system. This might include adopting an awkward posture e.g. stooping) Items to be dragged or lifted whilst inside the transport system can lead to excessive pushing or pulling of items whilst in an awkward posture e.g. bent over	Prevention Introduce a device that can transport items by conveyor (overhead or at ground level) from the warehouse directly to the CTV Move all items by a flat-bed motorised vehicle, which can be loaded by warehouse crane and unloaded again by crane located on the dockside or CTV Mitigation <i>Planning</i> Avoid requirement for repetitive MH where possible, if not rotate workforce and provide adequate resource <i>Workplace</i> Where possible, ensure road and walkway surfaces are smooth and of a good quality (free of gaps, potholes, etc.) which can affect the free movement of manual transport systems, and that the incline of road and walkways used to move items is kept to a minimum <i>Equipment</i> Ensure manual transport systems are designed to be stable, keep items well secured and support ease of pushing and pulling, for example: – Manual transport system are designed to limit the weight or number of items to be moved – The sides of manual transport systems are designed so that their height does not require technicians to lift items to an awkward height (e.g. away from the trunk and above waist height) nor adopt an awkward posture e.g. twist the trunk or sideways bending;
Moving items to the back of a transport system	Time pressure – moving items quickly to ensure items are loaded onto the CTV in a timely fashion such that maintenance activities are carried out as planned Competence – knowledge of good MH techniques Nature of item – size, shape, weight and centre of gravity of item to be lifted	Potentially high force required to get a heavy manual transport system moving (particularly if overloaded) on a rough (e.g. uneven, slippery, stepped) or inclined floor surface, which might cause content to be unstable and shift Repetitive manual lifting	
Pushing/pulling manual transport system			

Table 2: Summary of key tasks, hazard, PIFs and risk control measures for movement of items between warehouse and CTV loading area (continued)

Task	Likely PIFs	Potential hazards	Task-specific risk controls
Pushing/pulling manual transport system (continued)	MH policies and procedures – not comprehensive/unclear		<ul style="list-style-type: none"> – Manual transport systems can be easily stopped (e.g. brakes are adequate to control a trolley being moved on different surfaces and in different weather conditions) – Manual transport systems roll easily when fully laden, wheels are suitable for rough surfaces (e.g. larger wheel diameter/fatier tyres) – A manual transport system's handles support grip strength and allow for a good posture (e.g. torso upright, not twisted, handles are between hip and shoulder level) – Manual transport systems need to be able to deal with the Inclines of Links spans between shore and the pontoons; these can be steep, which requires the units to be down rated during certain tidal periods – Manual transport systems should be regularly inspected and serviced in order to maintain their integrity
			<p><i>Items</i></p> <p>Reduce the weight of items to be handled e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians and boat crew do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH, ideally tailored to task and work environment</p> <p>Provide training and guidance on communication protocols when MH involves team handling operations</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>

2.3 MOVEMENT OF ITEMS BETWEEN SHORE AND CTV

2.3.1 Scenario

Once items are at the dockside, there is a requirement for them to be moved on board the CTV, for transfer to the asset. Normally, items are lifted using the CTV, dockside or pontoon crane, but where a crane is unavailable items will be MH directly onto the CTV. The same activity occurs in reverse, when returning from an asset back to shore.

There are a number of common steps when completing this task:

- prepare boat/harbour crane for lifting, for example remove any covers, and move crane into position;
- perform the transfer of lifting bags to appropriate area of the CTV (either manually, with the use of a crane, or a combination of both), and
- carry out additional transfer of items on the CTV if required.

2.3.2 Problem area



Figure 7: Transfer from shore to CTV

Example of incident:

Detaching items from a crane: attempting to remove a sling after an item had been landed on the quayside. The item (tent bag with components) was resting on the slings. As the injured person was attempting to remove the sling, he felt a muscular spasm in his back.

When transferring items between the shore and vessel there are a number of potential problem areas that can increase MH risk:

1. No crane or inadequate crane movement/coverage leads to potentially heavy items being MH onto the CTV.
2. Attaching items to CTV or quayside crane.
3. Technicians boarding the CTV with backpacks and personal belongings.

Should a gang-way between the shore and vessel be unavailable, personnel will be required to step across the gap between the vessel and pontoon whilst also potentially undertaking MH activities.

4. Deck hands often have to manoeuvre bags on the vessel decks to make room for oncoming cargo.
5. Last minute changes to manifest or 'firefighting' response to issues in the field can result in rushing, lack of resource and non-optimised loading, leading to potential for MH injury.
6. On return to shore, the following additional factors could further increase MH risk:
 - end of shift, physical and psychological fatigue;
 - weather conditions, i.e. wet bags could result in mishandling or wet vessel surface could result in slipping;
 - bags with equipment are on other vessels (wrong vessels) and are needed and crew are not available to crane off kit;
 - time pressure to finish as crew could be outside their allotted working hours;
 - carriers (e.g. trolley/trailers) not available, so bags unloaded to the quayside and not directly onto carriers;
 - no mechanical support aids available at the end of the day;
 - poor lighting;
 - vessels moored in wrong orientation, preventing the vessel crane or other cranes from reaching the quayside, and
 - tidal restrictions resulting in vessel having to wait outside port for long periods and heavy weather.

Example of incident:

CTV loading: during vessel loading two heavy orange bags were lifted onto the vessels using the quayside crane. As the crane boom does not extend to the cargo storage area, the deck hand pulled the bags across the vessel deck. As a result of this pulling, the deck hand has suffered a muscular strain to his left shoulder/arm and was in pain.

2.3.3 How to tackle MH issues

Table 3: Summary of key tasks, hazard, PIFs and risk control measures for movement of items between shore and CTV

Tasks	PIF/risk factors	Hazard	Task-specific risk controls
Lifting items manually onto the vessel	Equipment design – the crane might not provide full coverage Workplace design – the pontoon/quayside can impact on the ability of the vessel to manoeuvre up close, resulting in a gap between the vessel and pontoon Lack of pontoon area may result in vessels having to moor alongside each other resulting in vessel-to-vessel transfer and MH of bags at arm's length across the gap Environment/weather – bad weather, wind/rain, poor lighting, cold or darkness in winter/night shift, surface movement	Heavy or bulky items. Floor of CTV and dock/pontoon might be slippery. There may be variation in floor levels. The movement of the CTV against the dock or pontoon could cause an unexpected movement of items and excessive transfer of weight to an individual Should the item not be aligned with the crane then dragging/pulling heavy or bulky items. Uncoupling items from crane shackle attachment may result in finger or hand entrapment	Prevention Ensure the CTV, dock and pontoon crane include coverage that provides a lifting capability across the whole vessel deck Mitigation Workplace Design the dockside so the CTV can be positioned without leaving a gap between vessel and dockside or floating pontoon/quayside Provide a suitably designed gangway (e.g. low slip floor surface, handrails) that is always used for personnel movement between shore Equipment Bags designed so they can be carried as a backpack, if still within MH guidelines (e.g. < 20 kg) Boat design Avoid or limit the use of CTVs with different levels in the deck storage and lifting area, such that items do not need to be lifted and/or carried Equipment Provide a scissor lift or equivalent to help raise items to different deck levels (the lift should be designed to enable bags to be dragged onto it to avoid unnecessary lifting) Provide ramps rather than steps so items can be more easily loaded in conjunction with a cart truck
(Un)coupling items from crane		Guiding items once attached might require manipulating an item at distance from body (e.g. above head height). There is a risk of a sudden movement of items if communication between technicians is poor Boarding the vessel with personal bags, PPE and climbing equipment could result in a slip/trip/fall due to variation in floor levels, the movement of the CTV against the dock or pontoon or poor weather (e.g. gusting winds)	
Lifting items using crane			
Personnel boarding vessel with personal protective equipment (PPE) and/or other carry items	Fatigue – may adversely impact concentration and attention, especially when performing task at the end of a shift		

Table 3: Summary of key tasks, hazard, PIFs and risk control measures for movement of items between shore and CTV (continued)

Tasks	PIF/risk factors	Hazard	Task-specific risk controls
Moving items on the CTV	<p>Time pressure – offshore tasks are reliant on an accurate understanding of changing metocean conditions (e.g. tide times etc.), which can create time pressure to transport the CTV to the asset within set periods of time, challenging adherence with MH good practice</p> <p>Nature of item – size, shape, weight and centre of gravity of item to be lifted</p> <p>Competence – knowledge of good MH techniques</p> <p>MH policies and procedures – not comprehensive/unclear</p> <p>Effective planning – managing vessel logistics so heavy items are loaded on the vessel closest to mooring. Ensuring adequate time is built into the process to ensure there is no requirement to rush</p>	<p>Moving (dragging or lifting) heavy items. Movement of items where there are variations in floor levels. Space constraints in areas inside the CTV</p>	<p><i>Items</i></p> <p>Reduce the weight of items to be handled e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians and boat crew do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH (ideally tailored to task and work environment)</p> <p>Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>

2.4 MOVEMENT OF ITEMS BETWEEN CTV AND ASSET

2.4.1 Scenario



Figure 8: Movement of items between CTV and asset

This scenario comprises the transfer of items from the CTV to an asset, using a crane mounted on the TP external platform. Items are moved in approved lifting bags, from the CTV foredeck to the outdoor setdown area on the TP platform. The task is likely to require physical handling on the CTV and asset. Common tasks include, for example:

- manoeuvre items to appropriate area of CTV foredeck for transfer as the TP cranes have limited reach
- prepare TP crane for lifting, for example mounting the hoist so it can be stored within the WTG or remove any weather covers, and move crane into position;
- attach lifting bags to TP crane;
- perform the transfer of items which on some sites may require manoeuvring the load over the handrails;
- manual slewing of davit crane often required with the potential for MH injury, and
- the same activities occur in reverse when returning to shore.

2.4.2 Problem area

Technicians may be required to move/drag very heavy items (>50 kg) and potentially to different levels (i.e. the CTV foredeck is often on a raised platform at the front on the CTV) and the davit crane does not have the reach to lift from all areas.



Figure 9: CTV foredeck

Example of incident:

Moving items around the CTV: technician strained back whilst moving equipment around on deck.

It is also common for a CTV to transfer a number of teams to different assets. Consequently, there can be a large number of bags on board, and CTV crew and/or technicians will need to sort through and move bags. If space on board is limited, items may need to be moved and lifted over other bags. This 'double handling' also increases the frequency of the lifts made. The movement of the vessel at sea can also throw people off balance, which can make MH more challenging.

Bags and items are also likely to range in terms of weight, shape and size, which might cause a technician to move an item that is much heavier than expected.

Once on the TP platform, items will also need to be moved away from the 'set down area' and, where applicable, manually moved into the tower to make room for other items to be raised. This may again require heavy items to be lifted or dragged. This leads to poor behaviours and the dragging of suspended loads at low level in an attempt to reduce deck movements. As mentioned previously, there may be time pressure to move items from the CTV to the asset quickly (e.g. time to travel to other assets and also move away from the asset to reduce fuel burn and wear to the CTV especially in rough sea conditions).

2.4.3 How to tackle MH issues

Table 4: Summary of key tasks, hazard, PIFs and risk control measures for moving items between the CTV and asset

Tasks	PIF/risk factors	Hazard	Task-specific risk controls
Handling items around the CTV	Equipment design – the design/location of the crane/davit might not provide full coverage over the vessel deck and the TP laydown area Environment – bad weather, wind/rain, poor lighting or darkness in winter/night shift, surface movement etc	Moving (dragging or lifting) heavy items. Movement of items where there are variations in floor levels. Space constraints in inside areas of the CTV Moving suspended loads across the deck	Prevention Increase the range of the TP crane or consider deck design, such that whilst the vessel is pushing on and creating a stable platform, safe lifting and deck work can be undertaken. This could be achieved by using more than one TP crane with different ranges or one with a telescopic arm, although it is recognised that this would be an expensive intervention
Preparing items for lifting (e.g. coupling items to crane)	Fatigue – this may adversely impact concentration/attention, when performing the task in reverse (e.g. back to shore) Health – people and the way they handle equipment can be affected when unwell, as well as impacting their physical abilities and performance	Should the items not be aligned with the crane then heavy or bulky items will need to dragged/pulled Coupling items from crane shackle attachment may result in finger or hand entrapment Grouping items and slinging ready for a single lift – demand on wrists and hands if items are bulky and unwieldy and need to be held in position whilst attached	Mitigation <i>Boat design</i> Avoid or limit the use of CTVs with different levels in the deck storage and lifting area, such that items do not need to be lifted and/or carried. Create demarcated areas so items for one asset can be grouped easily <i>Equipment</i> Provide a scissor lift or equivalent to help raise items to different deck levels (the lift should be designed to enable bags to be dragged onto it to avoid unnecessary lifting). Provide slip ramps so items can be more easily pulled up stairs or used in conjunction with a cart truck
Lifting items	Management and time pressure – this may be a direct PIF or a mediating factor, for example in the relationship between sea conditions and human performance. Such pressure can increase non-compliant behaviour	Guiding items once attached might require manipulating an item at distance from body (e.g. above head height). There is a risk of a sudden movement of items if there is poor communication between technicians	<i>Planning/work organisation</i> Ensure careful work planning when visiting multiple assets such that items to be moved are in the correct order, and ensure that technicians and CTV crew adhere to the recommended plan

Table 4: Summary of key tasks, hazard, PIFs and risk control measures for moving items between the CTV and asset (continued)

Tasks	PIF/risk factors	Hazard	Task-specific risk controls
Lifting items (continued)	<p>PPE (immersion suits) – restrict movement and reduce ability to grip securely</p> <p>Housekeeping – cluttered areas of CTV means items might need to be moved unnecessarily. Particularly an issue on larger services as more equipment is required</p> <p>Nature of item – size, shape, weight and centre of gravity of item to be lifted. With the potential that it does not clear the handrail and needs manual manoeuvring</p>	<p>Manipulating items once suspended from the crane and guiding up and down. Likely performed initially by upper limbs at extension, possibly above head height, and thereafter using a tag line</p>	<p><i>Items</i></p> <p>Reduce the weight of items to be handled, e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow green) to indicate different weights to ensure that technicians and boat crew do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH (ideally tailored to task and work environment). Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>
Handling items on the asset (uncoupling items from crane)	<p>Nature of item – size, shape, weight and centre of gravity of item to be lifted. With the potential that it does not clear the handrail and needs manual manoeuvring</p>	<p>Moving (dragging or lifting) heavy items. Movement of items where there are space constraints as the footprint of the TP area might be small or limited with items</p> <p>Uncoupling items from crane shackle attachment may result in finger or hand entrapment</p>	
Moving item away from the 'set down area' and, where applicable, manually moved into the tower	<p>Competence – knowledge of good MH techniques</p> <p>MH policies and procedures – not comprehensive/unclear</p>	<p>Poor communication between the crane operator and the slinger/banksman, resulting in the slinger/banksman undertaking additional manual handling tasks</p>	

2.5 MOVEMENT OF ITEMS BETWEEN TP AND OTHER AREAS OF THE ASSET

2.5.1 Scenario

Once on the TP platform, items (e.g. equipment, tooling, components, consumables) will be moved to other areas such as the: tower yaw section, nacelle, hub or blades.

Items are typically lifted to and from the TP platform using the external or internal nacelle crane but can also be manoeuvred into the tower section directly via the tower door. For some assets, the cranes lift over the top of the open roof allowing the nacelle 360 degrees (yawed) manual movement to align over items on the TP platform.



Figure 10: Movements on the TP platform

This task comprises the following general activities:

- prepare bags for lifting, using appropriate sling and connectors;
- yaw the nacelle to align the crane, if required;
- manoeuvre items in bags into position for lifting with the nacelle crane;
- undertake lift, and
- disconnect items from crane and manoeuvre to suitable location.

The same activity occurs in reverse when items are transferred from the asset to shore.

2.5.2 Problem area

Example of incident:

TP cleaning with high pressure cleaning: technician (contractor) has ended job and has packed fish box on TP with high pressure cleaner, pump and tools. Approximate weight of fish box is 100 kg. As the fish box does not stand directly under the crane, the technician pulls the fish box on TP about 50 cm to get the box under the crane for correct hoisting. He felt his right shoulder hurting.

Despite the fact that the nacelle can be moved, technicians may still be required to lift or drag very heavy items (>50 kg) because:

- On some occasions, it might not be possible to position the nacelle in the right orientation (e.g. it cannot be yawed to align with items to be lifted due to a fault disabling the yaw system).
- Many items are stored in the lifting area on the TP and items might need to be dragged into position under the nacelle crane.
- There is also the limitation of space in the nacelle, which can reduce the potential laydown and increase the MH risk.

In certain circumstances, the work area might be restricted, meaning technicians are required to adopt an awkward or difficult posture whilst carrying out the handling operation. Team handling can be used to move very heavy items and moderate the restrictive nature of the workplace (e.g. relatively small footprint on the TP platform which might be cluttered with other items). The task may also be performed in challenging weather (e.g. cold, windy, wet), and on rare occasions possibly wearing restrictive PPE.

2.5.3 How to tackle MH issues

Table 5: Summary of key tasks, hazard, PIFs and risk control measures for moving items between the TP and other areas of the asset

Tasks	PIF/risk factors	Hazard	Task-specific control measures
<p>Dragging items to position under the nacelle crane</p>	<p>Environment (e.g. weather) – bad weather, wind/rain, poor lighting or darkness in winter/night shift Equipment – crane zone of reach, design of lifting gear</p>	<p>Moving (dragging or lifting) heavy items on the TP platform</p>	<p>Prevention Working on the asset and MH heavy items presents some obvious challenges. One solution is to manually yaw the nacelle for each lift but, as discussed previously, this might not always be possible Additional lifts might also be carried out with the TP crane, to reposition items although this might require adapting the TP crane, or providing more than one TP crane to provide complete coverage of the TP platform area</p>
<p>Preparing items for lifting (e.g. coupling items to crane)</p>	<p>Work area – size of TP platform Housekeeping – cluttered TP platform Labelling – item dragged in error as mistaken for wrong item, weight of item unknown PPE (immersion suits) – restrict movement and reduce ability to grip securely</p>	<p>Should the item not be aligned with the crane then heavy or bulky items will need to be dragged/pulled Coupling items from the crane shackle attachment may result in finger or hand entrapment Grouping items and slinging ready for a single lift – demand on wrists and hands if items are bulky and unwieldy and need to be held in position whilst attached</p>	<p>Adapt/specify nacelle cranes that can lift directly from the vessel decks thus reducing handling MH between the vessel and nacelle Finally, slings and pulleys, combined with lifting points (where practical attached to the TP railing or tower) might be used to help move very heavy or bulky items Mitigation <i>Equipment</i> Specialist equipment can be used to help make team handling of heavy items easier (e.g. the offshore oil industry uses a clamp with jaws and handles to make lifting easier (e.g. enables 43 kg valves to be lifted with less MH risk) (HSE Well handled offshore manual handling solutions)</p>

Table 5: Summary of key tasks, hazard, PIFs and risk control measures for moving items between the TP and other areas of the asset (continued)

Tasks	PIF/risk factors	Hazard	Task-specific control measures
Lifting items	<p>Nature of item – size, shape and weight of item to be lifted (some items by their design, such as replacement components, will be very heavy and difficult to move)</p> <p>Competence – knowledge of good MH techniques</p> <p>MH policies and procedures – not comprehensive/unclear</p> <p>Time constraints – (e.g. metocean conditions) can create time pressure to complete works quickly and may encourage poor MH behaviour (e.g. move items by hand rather than use the crane which might take longer. Or rush attaching a load which increases risk)</p>	<p>Guiding items once attached might require manipulating an item at distance from body (e.g. above head height). There is a risk of a sudden movement of items if there is poor communication between technicians</p> <p>Manipulating items once suspended from the crane and guiding up and down. Likely performed initially by upper limbs at extension, possibly above head height, and thereafter using a tag line</p>	<p><i>Items</i></p> <p>Reduce the weight of items to be handled e.g. <20 kg.</p> <p>Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH (ideally tailored to task and work environment). Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>
Handling items (uncoupling items from the crane)		<p>Uncoupling items from the crane shackle attachment may result in finger or hand entrapment</p>	

2.6 WORKING ON AN OFFSHORE ASSET – FOUNDATION, TP OR TOWER LEVELS

2.6.1 Scenario

Service and maintenance work may be required within the tower levels, either to plant/equipment or to the tower structure itself (e.g. torquing bolts at the flanges connecting tower sections).



Figure 11: Working inside the tower

The internal asset layout will vary between sites. Some towers will house only the electrical switch gear, but others may include converter and transformer units. Irrespective of these differences, there are core tasks likely to remain consistent across all assets, including:

- movement of necessary tooling, parts and equipment to the work area;
- preparation of work area;
- performance of service or maintenance task, and
- clean-up and transfer of items back to TP or to next task area.

2.6.2 Problem areas



Figure 12: Lifting items through the tower door

Items, such as parts tools and consumables (i.e. lubricants, nuts, bolts etc.) will need to be moved from the TP platform to the work area, typically through the tower door, and then for transfer to other areas. The tower door is seldom at the same level as the TP platform and technicians will often need to climb a small number of steps up to the door. To make this easier, bags might also be opened, and individual items carried into the tower one at a time. In some rare occasions, very heavy items (around 100 kg) that cannot be broken down may be suspended on the nacelle crane and dragged laterally into the tower. The force required to bring the item into the correct position can be physically demanding.

Once inside the tower, items may need to be transferred to a number of other areas, usually by the service lift, although again the service lift might not be on the same level as the tower door. Maintenance work within the foundation/TP may also present an MH risk. For example, access to tower flange bolts is not always within easy reach and technicians may be required to adopt extreme postures whilst using heavy tooling (e.g. stretching at full reach whilst leaning forward, with wrist at a position of 45 degrees).

The lighting can also be bad within the foundation, TP or tower levels so it may take longer to carry out work, which in turn may mean that technicians may need to adopt awkward postures for a longer period of time.

Example of incident:

Dragging item on TP platform: we had been sent out to fix the cables in the tower. During the work we had to make space between the tower cables... The next day, the injured person had some pain in the shoulders, and the employer office decided to keep him onshore for two days on restricted work.

2.6.3 How to tackle MH risk

Table 6: Summary of key tasks, hazard, PIFs and risk control measures for maintenance activities in the foundation, TP or tower levels

Tasks	PIF/risk factors	Hazard	Task-specific control measures
<p>Movement of items (e.g. necessary tooling, parts and equipment) to work area</p> <p>Preparation of work area</p> <p>Performance of service or maintenance task</p> <p>Clean-up and transfer of items back to TP platform or to next task area</p>	<p>Lifting equipment – absence of lifting equipment (or overhead gantry) to move items laterally into the TP and thereafter within the TP</p> <p>Task design – whether individuals perform a high number of tasks requiring use of equipment at extreme postures or with repeated twisting actions</p> <p>Physical access – affects postures, visual feedback, requirement for problem solving etc. all increase possibility of error and increase time</p> <p>Equipment – weight of equipment may pose an accumulative risk of injury</p> <p>Working environment – restricted space on platforms, working across multiple levels, access, extreme postures/weights of equipment, lighting</p> <p>Nature of item – size, shape and weight of item to be lifted</p> <p>Competence – knowledge of good MH techniques</p> <p>MH policies and procedures – not comprehensive/unclear</p>	<p>Breaking down bag/items to smaller items and carrying them, or pulling suspended loads, manually into the TP through door thresholds, up stairs etc. to the work area increases tripping causing sudden movement of items</p> <p>Positioning equipment in small work space causing an awkward posture (stooping, over reaching, twisting etc)</p> <p>Performing tasks using tooling at an awkward posture (e.g. holding or manipulating items at distance from the body)</p> <p>Tasks might require frequent repetition of a movement (e.g. using a wrench to torque a bolt)</p> <p>Moving tooling consumables out of tower section or to next work area carrying items potentially up/down ladders causing an awkward posture (e.g. items difficult to grasp) passing items back to other technicians reaching upwards</p>	<p>Prevention</p> <p>Ensuring lift access to work areas. Providing lifting points (i.e. pad eyes) hoists and lifting equipment to lower/raise equipment within the TP</p> <p>Mitigation</p> <p><i>Workspace design</i></p> <p>Workspaces can be designed to enable safe access for maintenance. In the case of existing wind turbine generators (WTGs), an option is to consider where improvements might be made (e.g. removing redundant equipment) or develop bespoke equipment/tooling that is easier to use (e.g. lighter, extendable)</p> <p><i>Items</i></p> <p>Reduce the weight of items to be handled e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH, ideally tailored to task and work environment. Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>

2.7 WORKING ON AN OFFSHORE ASSET – YAW DECK

2.7.1 Scenario

Common tasks in this area include maintenance of equipment such as brakes, replacement of consumables such as friction pads, and tasks such as bolt tightening.

In some situations, items can be transferred first to the nacelle via the nacelle crane and then down into the yaw deck or brought up from inside the tower either manually or via the lift, if available.

Similar to other task areas, there are common stages to working in this area:

- accessing the yaw deck;
- movement of necessary tooling, parts and equipment to the yaw deck;
- preparation of work area;
- performance of service or maintenance tasks, and
- clean-up and transfer of items back to nacelle as required.

2.7.2 Problem area



Figure 13: Yaw deck workspace

The yaw deck workspace has some unique challenges, such as whole body physical access.

Access to the yaw deck can be physically demanding for personnel, as it often requires passing through ladder hatches, especially on older WTG types. This in turn can make it difficult to bring in items and equipment or to use tooling. Limited space and obstructions (e.g. equipment and building structure) may also require technicians to adopt uncomfortable working postures.

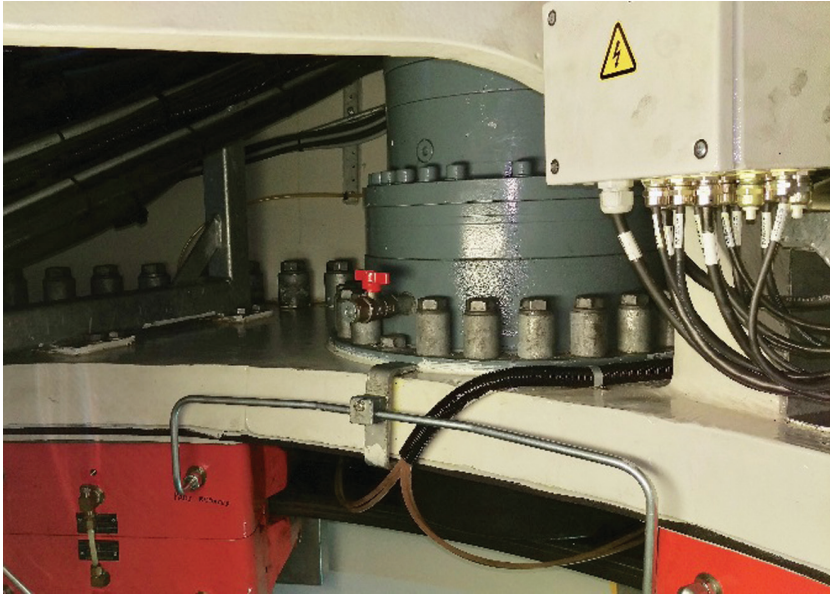


Figure 14: Work at the brake unit

The 'brakes' for example, are often fixed to the underside of the flange which can be difficult to get close to. This may require technicians to work from below the plant, to ensure they can see what they are working on and to use tooling. If a brake unit has to be removed for repair or exchange, this involves moving a unit weighing at least 50 kg, often working above shoulder height.

When a yaw caliper, which can weigh up to 160 kg, is changed, then specialist tools have been devised that help in the direct lifting and lowering of the caliper into place. This requires a trolley being moved into the yaw section via the nacelle crane.

It is also possible that many bolts must be undone to remove a brake, which may require a technician to adopt an awkward and uncomfortable posture for a prolonged time, affecting the back, neck and shoulders.

2.7.3 How to tackle MH

Table 7: Summary of key tasks, hazard, PIFs and risk control measures for working in the yaw deck

Tasks	PIF/risk factors	Hazard	Task-specific risk control
Accessing the yaw deck	Lifting equipment – absence of lifting equipment to move items into the yaw deck Task design – whether individuals perform a high number of tasks requiring use of equipment at extreme posture or repeated twisting actions	Narrow or difficult access and space constraints preventing good posture	Prevention At the design stage, it may be possible to ensure that the combination of nacelle crane and yaw access enables the nacelle crane to be used to hoist items directly to the yaw deck. Additional temporary lifting equipment may be needed for moving heavy items, such as yaw brakes, to and from the nacelle
Movement of necessary tooling, parts and equipment to work area	Physical access – affects postures, visual feedback, requirement for problem solving etc. all increase possibility of error and increase time Equipment – weight of equipment may pose an accumulative risk of injury Working environment – restricted space on yaw deck platforms, limited access to maintained items, extreme postures/weights of equipment, lighting, slippery floor due to oily floor plates e.g. working in yaw section Nature of item – size, shape and weight of items to be lifted. This may require the lifting of floor plates on occasion which introduces further risks	Lifting items into and out of the yaw deck which might be heavy, bulky or unwieldy Lowering items away from body to floor or to another person causing them to twist or hold items at a distance Moving/dragging heavy items on the yaw deck platform Narrow or difficult access and space constraints preventing good posture Performing tasks using equipment at extreme postures (e.g. holding or manipulating items at distance from the body)	Mitigation <i>Design</i> Improving access to the yaw deck, widening openings. Workspaces can be designed to enable safe access for maintenance. In the case of existing WTGs, an option is to consider where improvements might be made (e.g. removing redundant equipment) or develop bespoke equipment/tooling that is easier to use (e.g. lighter, extendable) <i>Reduce task frequency</i> Design of bolted connections to reduce maintenance requirements, such as maintenance-free connection design, or the use of tension-monitoring systems to enable tension to be checked without having to apply a physical force. Distributing maintenance tasks to different members of the team so that no one person has a high rate of task repetition
Preparation of work area			
Performance of service or maintenance task			

Table 7: Summary of key tasks, hazard, PIFs and risk control measures for working in the yaw deck (continued)

Tasks	PIF/risk factors	Hazard	Task-specific risk control
<p>Clean-up and transfer of items back to TP or to next task area</p>	<p>Competence – knowledge of good MH techniques MH policies and procedures – not comprehensive/unclear; the absence of procedures may prompt improvised ways of working</p>	<p>Moving tooling consumables out of yaw deck or to next work area, carrying items up ladders or passing items back to the nacelle reaching upwards</p>	<p><i>Items</i> Reduce the weight of items to be handled e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians do not try to drag heavy items in error</p> <p><i>Training</i> Provide training on safe MH, ideally tailored to task and work environment. Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i> MH policies and procedures are comprehensive, cover all the tasks required and are developed in line with good practice guidelines and appropriately communicated</p>

2.8 WORKING ON AN OFFSHORE ASSET – NACELLE/BLADE HUB

2.8.1 Scenario

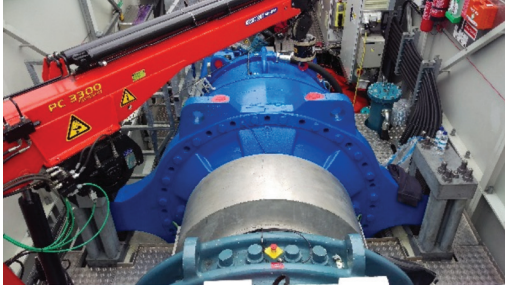


Figure 15: Work in the nacelle

The majority of service and maintenance activity is performed in the nacelle and blade hub; for example, routine servicing, inspection tasks, replacement of consumables such as oils, and major or minor component replacement.

Despite the range of WTG tasks, many are likely to be similar, such as:

- movement of necessary tooling, kit bags, consumables (including oil containers), parts and equipment from crane set down area to work area and then within the work area;
- preparation of work area;
- performance of service or maintenance task, and
- clean-up of area, pack away for transfer back to O&M base, or to the next task.

Retrofitting equipment after the initial installation can be difficult to complete, due the location of some of the retrofits within the yaw and turbines sections.

2.8.2 Problem area



Figure 16: Working in confined space

Example of incident:

Maintaining equipment in the nacelle: while a technician was working in the nacelle and unfastening the bolts on the brake callipers, the bolt released suddenly and the technician struck his head against the high-speed shaft cover.

The available workspace is generally limited (often occupied with equipment/plant, etc.) although the newer, larger turbines generally have more space and better access. Whilst some walkways exist, these do not provide physical and visual access to all areas. The limited space also means items may be stored anywhere there is room, such as walkways. The lack of clear walkways can make it difficult to maintain a stable and secure posture. There are also often oil spills on to floor plates, making surfaces slippery underfoot. Situation risk assessment should always cover workspace inspection and clean-up before commencing task activity.

In some turbines, the floors are not level, but on an incline (e.g. around five degrees). This can affect posture and make manoeuvring heavy items (e.g. dragging kit bags) more difficult.

In some WTGs, it is possible to use the nacelle crane to move items such as components directly into place and suspend them whilst they are fitted; however, coverage is never 100 %.

The limited space can also make it difficult to use tooling and can increase the risk of cuts and bruises. The hub is an area of particularly restricted and difficult access. Whilst the weight of items moved in and out of the hub may normally be manageable e.g. ~10 kg, the small spaces to move through and tight angles whilst carrying items can mean technicians will often need to adopt awkward postures. A common task in the hub is torquing bolts around the blade root. Reaching these bolts can be very difficult, with technicians working with arms outstretched and away from their bodies. Hubs generally contain grease lubrication systems, so surfaces can become contaminated, increasing the risk of items being dropped or mishandled.

Example of incident:

Working in the hub: operator was tightening a bracket 3.5 m down a shaft using a long T bar with an Allen key at the end. The small tight area required the task to be done with arms extended upwards through the gap from the hub to the shaft. The operator reported tingling sensation in his hand.

2.8.3 How to tackle MH

Table 8: Summary of key tasks, hazard, PIFs and risk control measures for working in the nacelle/hub

Tasks	PIF/risk factors	Hazard	Task-specific risk factors
Accessing the nacelle/hub	Workplace access – space and hatch size constraint Lifting equipment – absence of lifting equipment to move items into or within the nacelle/hub. Note that the nacelle crane may not be able to provide 100 % coverage of the area	Narrow or difficult access and space constraints preventing good posture Nacelle hatch closing itself onto technicians may result in finger or hand entrapment	Prevention Options include installing additional lifting points and methods such as fleeting items with chain blocks Mitigation <i>Designing for access/layout</i>
Movement of necessary tooling, parts and equipment to work area	Task design – whether individuals perform a high number of tasks requiring use of equipment at extreme posture or repeated twisting actions	Lifting items into and out of the nacelle/hub which might be heavy, bulky or unwieldy	At the design stage, sizing the nacelle/hub so that people have sufficient access to nacelle/hub equipment Ensure items with a known failure rate or high service requirement are positioned and located in an area where access is better and/or it is easier to use lifting aids if required
Preparation of work area	Physical access – affects postures, visual feedback, requirement for problem solving etc. all increase possibility of error and increase time Equipment – weight of equipment/tooling may pose an accumulative risk of injury	Narrow or difficult access and space constraints preventing good posture Performing tasks using equipment at extreme postures (e.g. holding or manipulating items at distance from the body) Repetition of tasks creating cumulative handling risk Fatigue builds up after hours of work Manually handling heavy maintained items of equipment	Installing dampers on hatches to prevent sudden closure on people whilst passing through <i>Housekeeping</i> Having a system of work that requires cleansing of oily surfaces so as to minimise the risk of oil contamination of PPE. Where persistent leakage occurs, such as beneath bearings, the use of suitable catch trays can prevent wider contamination <i>Equipment</i> Where a crane is not available, alternative systems such as ropes and pulleys may have to be set up, and generally involve some level of manual effort to move components <i>Planning</i> Due note taken of weather extremes regarding temperature, lightning, rain and night working
Performance of service or maintenance task			

Table 8: Summary of key tasks, hazard, PIFs and risk control measures for working in the nacelle/hub (continued)

Tasks	PIF/risk factors	Hazard	Task-specific risk factors
<p>Clean-up of area, pack away and transfer of items back to O&M base, or to next task</p>	<p>Working environment – restricted space in nacelle/hub, limited access to maintained items, extreme postures/weights of equipment, poor lighting. Even though working in the nacelle or hub, weather can still be a factor resulting in wet surfaces along with working at night with inadequate lighting or extreme temperatures</p> <p>Housekeeping – storage of items in walkways, spillage of lubricants</p> <p>Nature of item – size, shape, weight and centre of gravity of items to be lifted</p> <p>Competence – knowledge of good MH techniques</p> <p>MH policies and procedures – not comprehensive/unclear; the absence of procedures may prompt improvised ways of working</p>	<p>Moving tooling consumables out of nacelle/hub or to next work area (e.g. holding or manipulating items at distance from the body)</p> <p>Moving items back to the TP platform (e.g. attaching items to the nacelle crane) may result in finger or hand entrapment</p> <p>Guiding items once attached might require manipulating an item at distance from body (e.g. above head height)</p>	<p><i>Workspace</i></p> <p>Workspaces can be designed to enable safe access for maintenance. In the case of existing WTGs, an option is to consider where improvements might be made (e.g. removing redundant equipment) or to develop bespoke equipment/tooling that is easier to use (e.g. lighter, extendable)</p> <p><i>Items</i></p> <p>Reduce the weight of items to be handled, e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH, ideally tailored to task and work environment. Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>

2.9 CONSTRUCTION TASK – BOLT INSERTION AND TORQUEING

2.9.1 Scenario



Figure 17: Bolted connections

Bolted connections are used between tower sections, at some monopile (MP)/TP joints, at the tower/TP joint and between the nacelle and the tower.

Blades also have many bolted connections, literally hundreds; each has to be MH into position and the problem is exacerbated by poor access and egress during assembly.

Assembling these connections is a key activity during WTG assembly (onshore tower assembly or offshore installation), and currently inserting and tightening the bolts is carried out as an MH activity. This work will involve:

- lifting components (i.e. bolts and nuts) by crane to the required platform level within the structure;
- bringing tooling, such as a hydraulic power pack and one or more bolt tightening tools to the required location, which will generally be at the connection above where it was last used, so may need mechanical lifting within the tower;
- lifting bolts from their storage/transport packaging and inserting them onto the flange;
- fitting and initial tightening of nuts, using nut runners or similar power tools, and
- final tightening, generally using a hydraulic torque or tensioning tool.

2.9.2 Problem area



Figure 18: Tightening bolts

Each connection typically consists of 100 to 180 bolts. The bolts to be inserted can vary in size (~10 kg each) although the largest bolts (found on MP/TP connections) can weigh up to 20 kg each.

Each bolt has to be inserted into the flange by hand, then a nut fitted and tightened, usually involving the use of a hydraulic torque or tensioning tool.

Technicians involved in the assembly of the WTG may assemble several bolted connections over the course of a shift, as each connection will take about two hours. Tightening the bolts on each flange is a repetitive task using the same movements and groups of muscles.

Larger bolts will have an outside diameter of over 70 mm, making them more difficult to grip. This can lead to temporary hand cramp which can affect grip strength but may also be linked to other longer-term conditions such as focal hand dystonia, as discussed in HSE INDG171 *Managing upper limb disorders in the workplace: A brief guide*. Bolts also have smooth machined surfaces on their unthreaded shanks and may also have lubricant on their threads. If technicians lose grip strength whilst handling these bolts, this could lead to them being dropped, causing injury to feet/lower limbs; or if dropped to a lower level in the WTG, there is a risk of significant damage to WTG components and/or potentially fatal injury to any personnel below.

Example of incident:

Preparing flange bolt: at about 8 a.m, the injured person was preparing the flange bolts and as he lifted a bolt to reinsert into the flange on the airtight platform, the bolt twisted due to the weight and resulted in twisting his left wrist.

2.9.3 How to tackle MH

Table 9 provides a summary of risk factors by sub-tasks.

Table 9: Summary of key tasks, hazard, PIFs and risk control measures for bolt insertion and torquing

Tasks	PIF/risk factors	Hazard	Task-specific risk controls
<p>Movement of tooling and plant</p>	<p>Design – restricted access to flange due to lift/ladder/other obstructions, meaning that technicians may need to adopt an awkward posture to position and tighten bolts</p> <p>Equipment/tooling – weight of tool (e.g. hydraulic bolt tightening tools) especially if a technician needs to work from beneath the flange, meaning the tool is held in an awkward posture. When using nut runners for initial tightening, the user generally also has to support the reaction from the torque applied by the tool</p> <p>Environment/weather – bad weather, wind/rain, poor lighting or darkness in winter/night shift</p>	<p>Moving (dragging or lifting) heavy items</p>	<p>Prevention</p> <p><i>Bolt insertion</i> – use some form of jig/fixture that should be pre-loaded with the full set of bolts that allows bolts to be pre-positioned above the holes in the upper flange into which they will be inserted. The jig would need to be mechanically lifted to the tower section, and located securely above the upper flange, prior to assembly onto the section below</p> <p><i>Bolt tightening</i> – use a device to fit nuts and carry out initial tightening, without the technician having to support the weight of the device and nut, or apply any torque to the nut. After insertion and initial tightening of all bolts, either this device or another tool should then carry out the final tightening</p> <p><i>Eliminate</i> – Develop a design that is bolt-free. Robotic welding techniques could be possible</p> <p>Mitigation</p> <p>There are a number of possible options for reducing the risk associated with both insertion and torquing; in summary they include:</p> <p><i>Planning</i></p> <p>Recognise the repetitive requirements of the task and plan in sufficient resource/time for frequent breaks and rotation of personnel</p> <p><i>Equipment/tooling/components</i></p> <p>Use a specially designed trolley to support weight of tightening tool and ease movement between bolts – this should allow a single lift to position/remove the tool, with movement between bolt positions involving sliding/rolling or an assisted lift</p>

Table 9: Summary of key tasks, hazard, PIFs and risk control measures for bolt insertion and torquing (continued)

Tasks	PIF/risk factors	Hazard	Task-specific risk controls
<p>Lifting bolts from storage box and inserting into holes in flange</p>	<p>Task – requires repetitive movement Nature of item – size, shape and weight of items lifted – large bolt diameters (can be >70 mm) are harder to grip in the hand, as well as being heavier. Item may be required to be held in position for a longer period of time Competence – knowledge of good MH techniques MH policies and procedures – not comprehensive/unclear Fatigue – this may adversely impact concentration and attention</p>	<p>Lifting from floor level to around waist height stooping. Turning around while lifting, twisting the trunk Repetitive task – about 150 bolts to insert on each flange frequently leading to insufficient rest or recovery periods between lifts Should the items not be aligned with the crane then heavy or bulky items will need to dragged/pulled Coupling items from crane shackle attachment may result in finger or hand entrapment If bolts are inserted from underside of flange (to make tightening easier), they have to be supported in position until the nuts have been fitted, with prolonged physical effort Awkward position, reaching upwards working below waist height, e.g. stooping</p>	<p><i>Insert bolts from top of flange</i> Less precise handling required, no need to hold them in position for fitting of nuts, however this only works if the tightening tool can be used from beneath the flange <i>Use stud bolts</i> Threaded at both ends, with a nut on each end to allow insertion from above, fitting the nut from below, then tightening from above <i>Equipment/tooling</i> Use tools that react against the tower wall/flange/adjacent bolts, in order to eliminate reaction forces on the technician during initial tightening <i>Workplace</i> Provide safe access around full circumference of flange – this may include temporary covers to enable operators to stand safely over openings such as the lift aperture Minimise height differential for lifting bolts – if inserting manually, store bolt boxes on tables/trolleys to avoid bending down to pick the bolts up <i>Items</i> Reduce the weight of items to be handled e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow green) to indicate different weights to ensure that technicians do not try to drag heavy items in error <i>Training</i> Provide training on safe MH, ideally tailored to task and work environment. Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below) <i>Procedures/policy</i> MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>
<p>Manipulation of rigging and lifting equipment</p>			
<p>Holding bolts in position prior to fitting nuts</p>			
<p>Initial and final tightening</p>		<p>Use of tools such as nut runner, hydraulic torque tool, hydraulic tensioning tool may require prolonged physical effort to hold in place</p>	

2.10 CONSTRUCTION TASK – ATTACHING THE RIGGING FOR LIFTING

2.10.1 Scenario



Figure 19: Lifting operation

During WTG assembly, the main components are lifted into position, both during onshore pre-assembly and offshore final assembly.

Although the size and weight of these components means that are lifted by crane and/or other mechanical device, technicians involved in the construction phase may still be required to manually position the lifting equipment used in the lifting operations, such as crane hooks, shackles or wire slings. While some items of lifting equipment such as spreader beams are too heavy to move manually, and are therefore lifted directly by the crane, other lighter items will be positioned and attached manually.

In summary this work will involve:

- rigging the system of lifting equipment between the crane hook and the item;
- manoeuvring the lifting equipment into the required position for attaching to the item, through a combination of crane positioning and manual guiding, and
- attaching and then de-attaching the lifting equipment after the move is complete, which may include the removal and reinsertion of items such as shackle pins.

2.10.2 Potential problem area

Lifting equipment such as crane hooks, shackles or wire slings can weigh 10 – 50 kg but may need to be lifted into place and held whilst the item is attached.

If ropes or slings are at an angle from vertical, then when connecting to or disconnecting from the item, the lifting equipment will tend to swing back to a vertical orientation. This places additional demands on the technician, as it will be necessary to apply a horizontal force on the lifting equipment in order to maintain its position, and then guide it after releasing from the item. This requires the technician to hold the item in a static position whilst administering a lateral force to prevent uncontrolled swinging, which would create a risk of injury or equipment damage.

In addition to MH injuries, the handling of heavy items whilst suspended can also lead to other compression and contact injuries if a person is struck by the item being moved, potentially caused by situations such as the sudden release of a stuck item, or wind causing an item to swing unexpectedly.

Example of incident:

Winching operations: while a crew member was rearranging entangled rope on a cape stand, the winch operator commenced winching operations, causing a broken finger.

2.10.3 How to tackle MH

Table 10: Summary of key tasks, hazard, PIFs and risk control measures for attaching the rigging for lifting

Tasks	PIF/risk factors	Hazard	Task-specific risk factors
Lifting slings, chains, hooks, etc.	Workplace design – relative positions of where lifting equipment attaches to items, and where technicians can safely stand	Lifting heavy bulky items. Weight of items	Prevention Use lifting equipment that does not require manual attachment. Standard lifts that are repeated in each assembly sequence present the greatest opportunity for development of automatic systems; these may include systems such as automatic slinging equipment, remotely operated hydraulic shackles or other connectors that engage directly with items. The design of such systems should ensure that it is obvious if the connection has not been made correctly, and such systems should be failsafe, so that they cannot release unintentionally when under load. As well as improving safety, such systems can improve efficiency. Clearly any mechanised or remotely controlled systems need to be of failsafe design, so that they do not introduce a risk of the item being released unintentionally, or technicians injured by the movement of pins/grips
Attaching/detaching lifting equipment to items	Lifting equipment design – extent and ease of actions that need to be taken in order to attach to items Environment/weather – bad weather, wind/rain, poor lighting or darkness in winter/night shift Nature of item – size, shape and weight of items to be lifted Competence – knowledge of good MH techniques MH policies and procedures – not comprehensive/unclear	Coupling items from crane shackle attachment may result in finger or hand entrapment Manipulating items once suspended from the crane, and guiding up and down. Likely performed initially by upper limbs at extension, possibly above head height (e.g. reaching upwards, and thereafter using a tag line) Dragging items laterally because of restricted movement of lifting equipment such as wire rope slings, which are heavier and less flexible (and hence harder to position) than textile slings, means that items are manipulated at distance from the body Rain soaked synthetic slings can become heavy and therefore more difficult to handle when wet	Mitigation <i>Design for lifting</i> At the design stage, if a requirement to lift an equipment item is foreseen, then a suitable method should be devised. This should include considering where lifting equipment will be attached, and how these positions will be accessed. Any locations where access may be needed for adjustments, such as using chain blocks to distribute items/adjust the angle of components, should also be considered, particularly as these will be higher up than where the lifting equipment attaches to the item. Safe access needs to be provided to any such locations, taking account of the forces that the technician may need to apply

Table 10: Summary of key tasks, hazard, PIFs and risk control measures for attaching the rigging for lifting (continued)

Tasks	PIF/risk factors	Hazard	Task-specific risk factors
Attaching/detaching lifting equipment to items (continued)			<p><i>Design of lifting equipment</i></p> <p>Aim to have vertical connections, to minimise lateral forces and reaching out when attaching to or detaching from the item. For example, a spreader beam in the form of an H (in clear view) can allow vertical slinging to each corner of an item, whereas a simple straight beam would involve off-vertical slinging if connecting to the same points</p> <p><i>Items</i></p> <p>Reduce the weight of items to be handled e.g. <20 kg. Ensure items to be handled can be easily gripped/securely held. Equipment bags have correct labelling. Colour code bags (black, purple, red, yellow, green) to indicate different weights to ensure that technicians do not try to drag heavy items in error</p> <p><i>Training</i></p> <p>Provide training on safe MH, ideally tailored to task and work environment. Provide training and guidance on communication protocols when MH involves team handling operations (e.g. an item is being lowered to another person standing below)</p> <p><i>Procedures/policy</i></p> <p>MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated</p>

3 CONCLUSION

The reduction of MH risk should be achieved proactively, by identifying potential risks, assessing them and implementing appropriate measures to minimise risk. Good practice includes having an MH policy and minimising MH risks through a suitable set of organisational and management arrangements.

This document provides a case study which is based on analysis of offshore wind industry incidents, assessment of a sample of offshore wind industry activities, a systematic review of regulatory requirements, observation of good practice and stakeholder engagement, including peer review by G+ members.

General key learnings across the presented cases can be summarised as follows:

- MH risks can be prevented and mitigated by introducing appropriate design solutions (e.g. enough space in warehouses, widening openings for easier access, improved design for lower maintenance).
- Good planning practice is required, for instance to remove requirements for repetitions where possible, to rotate work between personnel, to facilitate proper recovery between demanding tasks.
- Use of appropriate specialist equipment is recommended to help mitigate MH risks.
- Appropriate training on MH techniques is provided and ideally tailored to task and work environment.
- MH policies and procedures are comprehensive, developed in line with good practice guidelines and appropriately communicated.

Effective prevention of MH injuries further requires:

- A specific safety management policy and set of procedures for MH to ensure risks are systematically managed with a commitment to continuous improvement.
- A focus on eliminating and reducing MH risks by design.
- Where MH cannot be eliminated, to apply a task risk assessment and task-specific solutions.
- The use of a dynamic risk assessment approach, as there are many infrequent tasks, potentially unforeseeable tasks, and circumstances may differ to those cited in safe systems of work (SSOW).
- Occupational health (OH) surveillance and management specific to MH, especially to identify people at risk of musculoskeletal injuries, to identify additional safeguards specific to individuals, and to enable rapid detection and management of musculoskeletal injuries and chronic conditions.
- A supportive safety culture with respect to MH, especially as compliance with safe systems of work and use of dynamic risk assessment depends on the behaviour of people working remotely.

Consistency across the industry would be encouraged by good practice guidance which provides task-specific recommendations to offshore wind operators for current WTG designs on how to reduce the likelihood of manual handling incidents.

ANNEX A

ACRONYMS AND ABBREVIATIONS

ART	assessment of repetitive tasks of the upper limbs
CTV	crew transfer vessel
EC	European Council
EI	Energy Institute
G+	Global Offshore Wind Health and Safety Organisation
H&S	health and safety
HSE	Health and Safety Executive
IEA	International Ergonomics Association
MAC	manual handling assessment charts
MH	manual handling
MH&E	manual handling and ergonomics
MHE	material handling equipment
MHOR	Manual Handling Operations Regulations
MP	monopile
MSD	musculoskeletal disorder
OH	occupational health
O&M	operations and maintenance
PIF	performance influencing factor
PPE	personal protective equipment
RAPP	risk assessment of pushing and pulling
REBA	rapid entire body assessment
RSI	repetitive strain injury
RULA	rapid upper limb assessment
SSOW	safe systems of work
TP	transition piece
WTG	wind turbine generator

ANNEX B REFERENCES

Ergo Plus (www.ergo-plus.com)

A step-by-step guide: rapid entire body assessment (REBA)

A step-by-step guide: rapid upper limb assessment (RULA)

European legislation (www.eur-lex.europa.eu)

Council Directive 90/269/EEC of 29 May 1990 on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (fourth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

Council Directive 2006/42/EC of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)

G+ Global Offshore Wind Health and Safety Organisation (G+) (www.gplusoffshorewind.com)

G+ 2016 incident data report

G+ 2017 incident data report

G+ 2018 incident data report

Health and Safety Executive (HSE) (www.hse.gov.uk)

HSE48 Reducing error and influencing behaviour

INDG143 Manual handling at work: A brief guide

INDG171 Managing upper limb disorders in the workplace: A brief guide

INDG383 Manual handling assessment charts (the MAC tool)

INDG438 Assessment of repetitive tasks of the upper limbs (the ART tool): Guidance for employers

INDG478 Risk assessment of pushing and pulling (RAPP) tool

L113 Safe use of lifting equipment Lifting Operations and Lifting Equipment Regulations 1998. Approved code of practice and guidance

Performance Influencing Factors (PIFs)

RR01 Human factors integration: Implementation in the onshore and offshore industries

Well handled offshore manual handling solutions

Miscellaneous

'Definition and domains of ergonomics', International Ergonomics Association, www.iea.cc

Pheasant, S., *Ergonomics and the design of work*. Bodyspace anthropometry

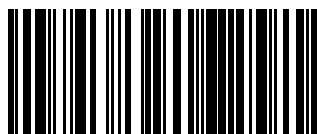
UK government (www.legislation.gov.uk)

Manual Handling Operations Regulations



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