Chapter 45 – Heavy-lift and Project Cargoes

Following a number of significant damage losses to ships and cargoes and a series of near-miss incidents in recent years, concerns have increased about the lack of expertise, skills and resources being deployed in this complex area of shipping.

The information in this publication is provided for guidance only and is not intended to replace, nor should it be used for, specific expert advice on the transportation of project/heavy-lift cargoes.

45.1 Project Cargo

Figure 45.1: Project cargo.

A wide range of cargoes fall within the definition of project cargo, from traditional breakbulk type cargoes to large single items such as cranes or oil and gas modules. It may be that large, heavy or out-of-gauge items require specialised stowage, lifting and handling, or there may be high value or critical items, or a quantity of goods connected to the same project, possibly loaded from different ports.

The cargo insurers will stipulate certain conditions (a warranty) for the purpose of insurance. If the cargo to be carried meets certain criteria (often referred to as 'critical items'), certain procedures will have to be followed under the warranty.

Critical items may fall under one (or both) of two broad headings:

1. Those that are critical because of the cost and difficulty of replacement.
2. Those that may require unusual provisions for safe loading, stowage, lashing and discharge.

The criteria for critical items take into account factors such as the replacement lead time, the value of the cargo (individually and/or in total), the size or footprint, weight, the centre of gravity and whether specialised transport, lifting and/or securing is required.

Cargo types that fall within the definition of a critical item may include:

- Oil and gas equipment for onshore and offshore infrastructure
- refinery and petrochemical plant equipment
- renewables equipment for onshore and offshore infrastructure
- modules and pre-assembled units
- port handling equipment

- port construction
- floating cargo
- rolling stock
- heavy machinery
- power plants and power generation equipment.

Critical items require special attention during transportation. Careful assessment and detailed planning is required for loading, stowage, securing and discharge.

Project cargo damages or loss can be very costly, often running into many millions of dollars. The risks involved can be largely mitigated with careful planning and attention, before the cargo is received for shipment.

The pressure to reduce costs is always high and, as the cost of shipment is essentially an overhead, there is a natural desire to reduce the shipping costs as far as possible. The use of unsuitable vessels to transport a cargo, poor quality or inadequate securing and dunnage, poorly trained crew and a lack of detailed planning can all lead to damage or loss.

Figure 45.2: Damage to project cargo during transportation.

Damage will likely lead to a claim against the cargo and/or liability insurance and, potentially, delays to the project (eg delay in start-up). With many other parties involved and the consequential costs high, these claims are often complicated and may result in lengthy and costly litigation.

45.2 Relevant Regulations, Codes and Guidelines

It is the Master's responsibility to ensure that all cargo is stowed, secured and handled (loaded/discharged) with care and in accordance with the requirements of the charterparty.

The charterparty may stipulate specific responsibilities of the vessel owner, charterer and shipper, such as the specific responsibility for stowage, lashing and securing of the cargo. There may be a requirement from the charterer and/or the cargo insurers for the appointment of an independent marine warranty surveyor (MWS) to review, approve and monitor all loading and sea fastening operations. These responsibilities should be carefully assessed as they can greatly affect the liabilities if the cargo is damaged or lost during the loading, voyage or discharge. It is important that all relevant persons are aware of these requirements and their responsibilities.

The following regulations are applicable and should be adhered to:

Flag State and Classification Society rules

These are always mandatory and, in particular, SOLAS Chapter VI: Carriage of Cargoes is relevant and must be complied with. Regulations for lifting gear and operations will be found within the flag State or Classification Society rules.

> The rules of a vessel's Classification Society will also set out the requirements for maintenance of the vessel, including equipment required for the loading, stowage and securing of project cargoes. If these requirements are not followed, the vessel's owners may be liable in the event of an incident.

Cargo Securing Manual (CSM)

The vessel's Cargo Securing Manual (CSM) is a key document in the shipment of project cargoes. The CSM is a required document under SOLAS Chapters VI and VII and sets out the types of cargo that the vessel is properly suited to carry, as well as how it should be loaded, stowed and secured. It will also document the vessel's cargo securing equipment (inventory) and its maintenance and inspection procedures.

The CSS Code (IMO *Code of Safe Practice for Cargo Stowage and Securing,* 2003, revised 2021) (Reference 22)

This Code has been amended several times by MSC Circulars (eg by References 69 and 70). It sets out the general principles for the safe stowage and securing of a range of cargoes, including project cargoes and non-standard, heavy units that may require special attention. Annex 13 of the CSS Code, as revised by MSC.1/Circ.1623 in 2020 (Reference 70) sets out the method for calculating the required lashing forces for abnormal loads. The CSM will be based on the principles set out in the CSS Code.

> One key aspect is that specialist knowledge and experience in the shipment of project cargoes is required to fully plan and engineer such cargo shipments safely. The CSS Code sets this out in Section 1.8, Special Cargo Transport Units:
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> *"The shipowner and the ship operator should, where necessary, make use of relevant expertise when considering the shipment of a cargo with unusual characteristics which may require special attention to be given to its location on board vis-a-vis the structural strength of the ship, its stowage and securing, and the weather conditions which may be expected during the intended voyage."*
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> In particular, the calculations involved often require specialist knowledge and appropriate expertise should be engaged.

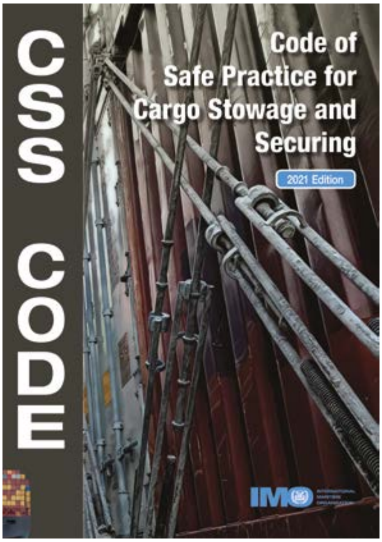

Figure 45.3: The IMO CSS Code is the main standard to be applied for the stowage and securing of project cargoes.

The IS Code (IMO *International Code on Intact Stability*, 2008, as amended) (Reference 27)
The IS Code contains both mandatory regulations and recommended provisions, setting out the minimum stability standards for all applicable vessels. MSC.1/Circ.1537/Rev.1 (Reference 27a) provides approved unified interpretations of the Code, agreed in 2019. Damaged stability standards should also be considered (SOLAS Chapter II-1).

The CTU Code (IMO/ILO/UNECE *Code of Practice for Packing of Cargo Transport Units*, 2014) (Reference 57)
This Code provides guidance and measures for ensuring the safe packing of cargo in containers and other cargo transport units (CTUs).

Guidance on best practice for the loading, stowage, securing and discharge of project cargoes may also be found in:

DNV *Rules for Planning and Execution of Marine Operations* (Reference 77)
The DNV Rules are mainly applicable to offshore operations, but there are sections on heavy lifts, lifting appliances, and loading and discharge operations that are relevant to project cargo shipments.

DNV-GL *Noble Denton Guidelines* (Reference 78)
The DNV-GL *Noble Denton Guidelines* provide the technical basis for marine operations, including the transportation of specialised cargoes. The guidelines include *Marine Transportation Guidelines, Marine Lifting Guidelines, Mooring Guidelines* and *Load-out Operations*.

All of these guidelines are specialist technical documents and appropriate expert advice on their content and implications should be sought before they are used.

45.3 Vessel Types and Suitability

Figure 45.4: Tweendecker.

A number of different vessel types are commonly used to carry project cargoes. These include:

- Tweendeckers: This old-style general or breakbulk cargo ship, with multiple hatches, fixed tween decks and cargo handling via derricks or cranes, has now largely disappeared
- general cargo ships: These carry a wide variety of cargoes, including industrial items, bagged cargoes, project cargoes, steel products, forest products, palletised cargoes, smaller breakbulk cargoes and containers. They are uncellular and have holds with movable/stackable tween deck pontoons
- multipurpose and heavy-lift vessels: These vessels usually have wall-sided (rectangular) holds and movable tween decks, providing efficient stowage for a range of cargoes using their own securing fittings. They are ideally suited to the carriage of project cargoes. Heavy-lift vessels are commonly defined as having cranes capable of a 100 T single lift. The cranes are usually sited to enable tandem working
- bulk carriers: These vessels have a number of holds designed to carry cargoes such as coal, grain, iron ore, etc. This type of vessel may vary in size from only a few hundred tonnes to around 200,000 T. The smaller sizes, up to around 50,000 T, may be fitted with cranes for self-discharge

Bulk carriers are sometimes chartered for project cargo transport, but are not well suited to this task as they do not have wall-sided holds, making safe and proper stowage difficult. The crews are often not familiar with the requirements for the stowage and securing of project cargoes.

Figure 45.5: General cargo ship.

Figure 45.6: Multipurpose vessel.

Figure 45.7: Bulk carrier holds are not designed for the carriage of project cargoes. The shape of the holds makes proper stowage and securing difficult and will require stacking and overstows. This can, and often does, result in cargo damage and sometimes damage to the ship.

- module carriers and semi-submersible heavy-lift vessels: These vessels have all accommodation forward and a broad, flat deck, designed for the carriage of large modules. Loading and discharging is via self-propelled trailers, skidding or, if semi-submersible, by float-on/off methods. The vessels are usually fitted with sophisticated and highly responsive ballast systems (sometimes with stability pontoons) to allow fine adjustment of draught, list and trim as heavy modules are loaded

Figure 45.8: A purpose-built heavy-lift ship.

Figure 45.9: The tween deck of a purpose-built multipurpose vessel.

- barges: A wide variety of barge types can be used for the transport of project cargoes, ranging from inland river barges to large ocean-going barges. Self-propelled, ballastable 'dumb' barges, requiring the use of pusher or tow tugs, are available in some regions. Some are equipped with holds and hatch covers. For larger project cargoes undergoing an ocean tow with a tug, a large 'classed' pontoon-type barge (with a flat watertight upper deck) would be utilised (spoon bow and raked stern with two box skegs). Careful consideration is required for the type of barge, tugs and towage arrangement. The condition of the barge should be carefully assessed, particularly the condition of the structure and essential systems (ballast system and manhole covers).

Figure 45.10: Loading heavy-lift cargo on to an inland barge.

45.4 Voyage Instructions

45.4.1 Summary of Master and Crew Responsibilities

The shipper's instructions may provide specific precautions that should be adhered to for the safe carriage of the cargo. These may be as simple as standard handling symbols indicating orientation or centre of gravity stencilled onto a packing case, or a large amount of information covering every aspect of carriage, from factory packing to onsite unpacking, and the conditions that must be met during transportation to ensure that a manufacturer's guarantee is honoured. Another aspect is the basis of design and design accelerations for heavy/project cargo (such as a transformer or module).

The cargo insurers may require the attendance and approval of a MWS during transportation and any recommendations made by the surveyor with respect to the transport must be adhered to. These do not remove or override the Master's ultimate responsibility for the safety of the crew, vessel and cargo.

Figure 45.11: A clear understanding of each party's responsibilities and good teamwork is key to the success of project cargo transportation.

45.4.2 Shippers' Instructions

The shippers may provide instructions for the safe and proper stowage and securing of the cargo. These instructions may refer to matters such as whether the cargo unit can be overstowed (ie whether other items may be stacked on top of it), the lashing and securing of the cargo (including the suitable lashing points on the cargo), the preferred stowage location (such as whether it can or cannot be stowed on deck) and the required packing to ensure the protection of any internal components and protection from the elements.

For more complicated shipments, particularly those for large, heavy items, a detailed transport manual or method statement should be provided. Owners should ensure that this is provided in a timely manner. It is normally provided by the shippers to all relevant parties and it should document all required procedures for the safe and proper shipment of the cargo, including:

- Management of the project, responsibilities and key contacts
- details of the cargo
- details of the vessel
- vessel strength and stability
- port details
- loading procedures, including any heavy lifts and, if necessary, any transportation to the loading berth
- stowage requirements
- lashing and securing requirements, including details of all lashing, securing and lifting gear
- voyage plan, including contingency procedures and ports of refuge
- discharge procedures.

The transport manual, or method statement, should be complied with as this defines the procedures for the entire shipment. It will have been reviewed by personnel with the specialist knowledge required for critical shipments, such as a MWS or cargo superintendent ('supercargo').

45.4.3 The Marine Warranty Surveyor (MWS)

The MWS is appointed on behalf of the cargo insurance underwriters, who insure the shipment of the cargo.

The MWS ensures that the terms of the warranty clause in the insurance policy are complied with and that the operations are carried out in accordance with the approved procedures, as defined in the transport manual or method statement.

Involvement of an MWS is common where shipment of the cargo forms a component of a larger project, including cargo comprising relatively small cases or cargo transport units (CTUs) through to complete modules for new infrastructure projects. In the latter case, the shipping operation will comprise a series of procedures, ie transport to point of shipment, lift plans and rigging calculations, sea fastening, and routeing of the ship or tow.

Subject to the approval of procedures and calculations, it is normal for the MWS to attend and observe loading, securing and possibly discharging operations, to ensure that approved procedures are adhered to and to be on hand to evaluate and approve any changes to procedures necessitated by the actual onsite conditions.

Where smaller quantities of cargo are being shipped on breakbulk or container 'liner' vessels, the MWS would typically consult with the chief officer and/or client's representative with respect to stowage position and method(s) of securing.

In cases where an MWS attends to approve loading and securing of cargo, it is usual for a certificate of approval (COA) or letter of approval (LOA) to be issued, on completion of operations, to confirm that the previously approved procedures have been adhered to or that the MWS is satisfied with onboard securing arrangements agreed with the ship's personnel or client's representative. The COA/LOA may have additional recommendations attached, such as specifying checks to be made on lashings, records to be noted in the vessel's log, etc.

45.4.4 The Client's Representative (Supercargo)

The supercargo, in many respects, plays a similar role to the MWS, but is usually appointed as the representative of one of the parties directly involved in the shipment such as the shipper, charterer or receivers.

45.5 The Cargo

Cargo group	Examples	Comments
Oil and gas equipment	Process modules, accommodation units, sub-sea equipment, topsides, decks, complete platforms/jack-ups	Can be very large units weighing thousands of tonnes
Refinery and petrochemical plant equipment	Cooling towers, flash towers, storage tanks, pipe-racks, reactors, towers and similar	May have large dimensions, often deck space intensive
Renewable energy equipment	Wind turbine blades (carried in racks), nacelles, foundations, mono-piles, tidal turbines, power cables (on non-specialist vessels)	Wind turbine blades (usually carried in racks) can be affected by longitudinal bending of the vessel due to their length. Careful stowage and securing are required to avoid this
Modules and pre-assembled units	Often for oil and gas installations or refinery/petrochemical plants, such cargoes may include living quarters, pre-assembled machinery, generator sets, large pipe racks	Often pre-assembled into large structural framework for which careful lashing, securing and bracing is required to avoid distortion

Cargo group	Examples	Comments
Port handling equipment	Typically, cranes and material handling equipment such as large container gantry cranes, ship-loaders, mobile harbour cranes, rubber tyre gantry (RTG) cranes, reach stackers	May consist of a framework, requiring careful lashing, securing and bracing to avoid distortion. Some units may have low lift stability
Port construction	May include pre-assembled items such as link-spans, jetty platforms, cat-walks, dolphins, single buoy moorings	
Floating cargo	A wide variety of vessels and craft, such as tugs, small ferries, yachts and super-yachts, small naval craft	Careful lifting sling positioning and restraint required
Rolling stock and heavy machinery	Locomotive engines and carriages, wheeled and tracked vehicles such as material handling lorries, excavators, trucked equipment such as mobile cranes, drilling rigs, etc. Mining equipment, factory equipment	Often included as breakbulk project cargo. Proper stowage and securing required
Power plants and power generation equipment	Large generators, conductors, transformers and similar	

Table 45.1: Different types of project cargo.

Project cargoes come in many different shapes and sizes.

Heavy lift

There is no standard definition of a heavy lift in weight terms, although the cargo insurance policy may set a weight figure as part of the critical item criteria (typically 50 T, but this may vary).

A 500 T lift on a specialised vessel, loaded/discharged at a safe berth, may present less risk than a 50 T lift at the limits of a vessel's safe handling capacity loaded/discharged at a berth not suited to handling such items.

Breakbulk cargo

Breakbulk cargo is a much broader group of cargo types and refers to cargoes that are loaded and stowed individually and not in containers or palletised. This includes certain project cargoes that are small enough to fit inside a vessel's holds, but which require individual loading, stowage and securing.

Problems often occur with breakbulk cargoes because there may not be a requirement for a surveyor to oversee and approve loading and securing. There has been a growing trend to use bulk carriers for such cargoes, which are ill-suited to the task and can result in extensive damage to the cargo.

Out-of-gauge

The term out-of-gauge refers to any cargo that has dimensions that exceed the normal dimensions of a standard shipping container.

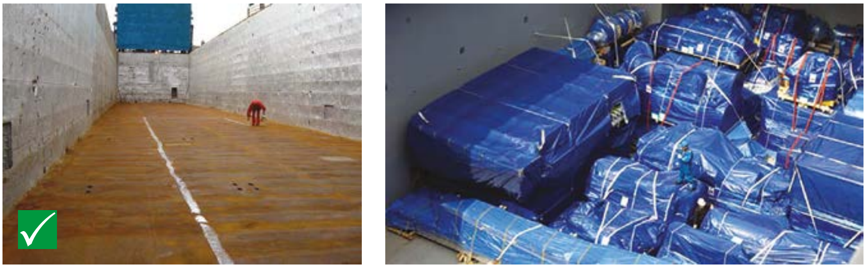

Figure 45.12: Project cargoes require clear positioning and stowage. Care is required to ensure that all units in the stow can be properly secured.

45.5.1 Aspects to Consider for Project Cargoes

'Footprint' of the cargo

Where and how cargo will be stowed on the vessel must be considered to minimise the risk of damage and/or loss. The three-dimensional space and position must be considered in relation to the vessel structure and other cargo units; the stowage of project cargoes (particularly those in a breakbulk format) can often resemble a 3D jigsaw and must be planned as such.

The stowage plan should consider the following:

1. Is shoring required to hold the unit in position?
2. Can enough lashings with sufficient scope be run to resist the forces that will be experienced?
3. How should the cargo be orientated, with regard to any principal axes of strength in the cargo to the largest forces that will be applied to it?
4. Can the cargo have other cargo stowed on top of it (overstow)? What is the weight limit for overstow?
5. Does the cargo need to be carried on deck? Does the charterparty or fixture specify whose responsibility and risk this is (as often owners will not wish to carry the risk for deck cargoes)?
6. If carried on deck, is there a risk of green seas affecting the cargo? Is forward on the deck the right position for the unit? Does it overhang the vessel's sides (significantly increasing the risk of cargo damage)?

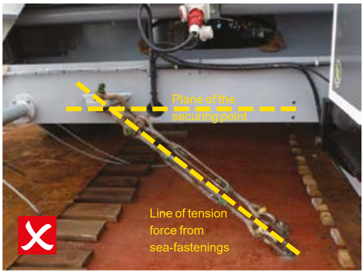

Figure 45.13: Lifting and securing lugs (pad-eyes) should not be subjected to forces out of plane of the eye as this will damage the eye and may lead to failure of the lashing.

Lifting and securing points

The cargo must be supplied with appropriate lifting and securing points, particularly for large and heavy items. If the cargo unit is not supplied with adequate lifting/securing points, attempts may be made to lift and secure the cargo in the best manner possible. However, if this is felt to present any risk of damage to the cargo (itself or surrounding), a note of protest should be issued at the time of loading. If the risk is felt to be significant (to the cargo unit, cargo as a whole or to the vessel), the cargo should be rejected.

The cargo lifting/securing points should be assessed to confirm that they are strong points and not merely attached to a protective cover, ie are they intrinsically part of the unit? They should also be checked to see that they are structurally sound and that they are in plane to the principal forces to which the cargo is going to be subjected, taking due account of the unit's position and orientation in the stow.

Figure 45.14: Cargo being lifted.

Cargo condition

The cargo unit, whatever its size, must be adequately packed and covered for its voyage to protect it from damage. If contained within an outer casing or protective packaging (eg a wooden box), the casing must be secure, well fixed to the cargo unit so it does not come loose, and cover all required parts of the unit. The unit should be well secured and packed within the casing.

Figure 45.15: Cargoes should be well packed and properly secured inside CTUs. Failure to do so can lead to extensive damage to the CTU, surrounding cargo and even the ship itself.

If shipped without an outer protective casing, careful packaging and covering of any vulnerable parts or components is necessary to prevent damage from impacts and corrosion.

Certain cargoes (such as coils, transformers, turbine components, etc) may be particularly liable to internal damage as they are sensitive to accelerations. These units must be properly packed, secured (including all internal components) and, if necessary, monitored during the voyage.

Advice from the manufacturer and/or relevant specialists should be sought.

Figure 45.16: Damage to the cargo observed on loading, even if only to packaging, should be noted and recorded.

Any project cargoes shipped inside containers or other cargo transport units (CTUs) should be adequately packed (stuffed), with appropriate shoring and internal securing, as with normal containerised transport (see Chapter 41).

The cargo should be inspected at loading and any damage recorded and noted, see Figure 45.16.

Cargo information
Heavy-lift and project cargoes tend to be more valuable than most and the consequence of their damage or loss proportionately more serious. Each cargo unit should be supplied with appropriate documentation that provides the necessary information to ensure safe transportation. The general standard for project cargo information should always be 'comprehensive and accurate'.

The documentation must include the accurate weight of the cargo unit, the accurate location of its centre of gravity (particularly important for heavy lifts and possible off-centre units), its dimensions, and details of the safe slinging, lifting and securing points, as well as the nature of the cargo.

The weight and centre of gravity should be marked on each side of the cargo unit such that it is immediately visible.

45.6 The Vessel

45.6.1 The Cargo Securing Manual (CSM)

All ships carrying cargoes other than solid or liquid bulk cargoes are required to carry and maintain a ship-specific Cargo Securing Manual (CSM). This is a mandatory requirement of SOLAS (Reference 18) and the CSS Code (Reference 22). The CSM must be approved by the vessel's flag State.

The purpose of the CSM is to set out the procedures and standards for the securing of cargo, taking into account the type of cargo, the characteristics of the vessel and the conditions that may be encountered. It is intended to provide relevant information and guidance to assist the crew in properly securing the cargo.

Guidelines for the production of the CSM have been published by the IMO (Reference 24) and various Classification Societies. In general, the CSM should provide information on:

- The securing devices carried on board (number, strength, inspection regime and maintenance) and their arrangement
- the stowage and securing of non-standardised cargo, including evaluation of the forces and the appropriate calculation methods for determining the required cargo securing capacity
- the stowage and securing of standardised cargo units (such as containers), including securing devices, stowage requirements and evaluation of the forces acting upon the cargo units.

45.6.2 Vessel Stability

The vessel must comply with the *International Code on Intact Stability* (IS Code, Reference 27) at all times, including during loading and discharge operations. For large, heavy cargoes, the vessel's stability should be checked at all key stages of the proposed loading/discharge sequences. This will include any lifting operations (cargo unit at furthest extension and highest crane boom position), 'drive-on' (using self-propelled modular trailers for example) or floating operations (with semi-submersible vessels).

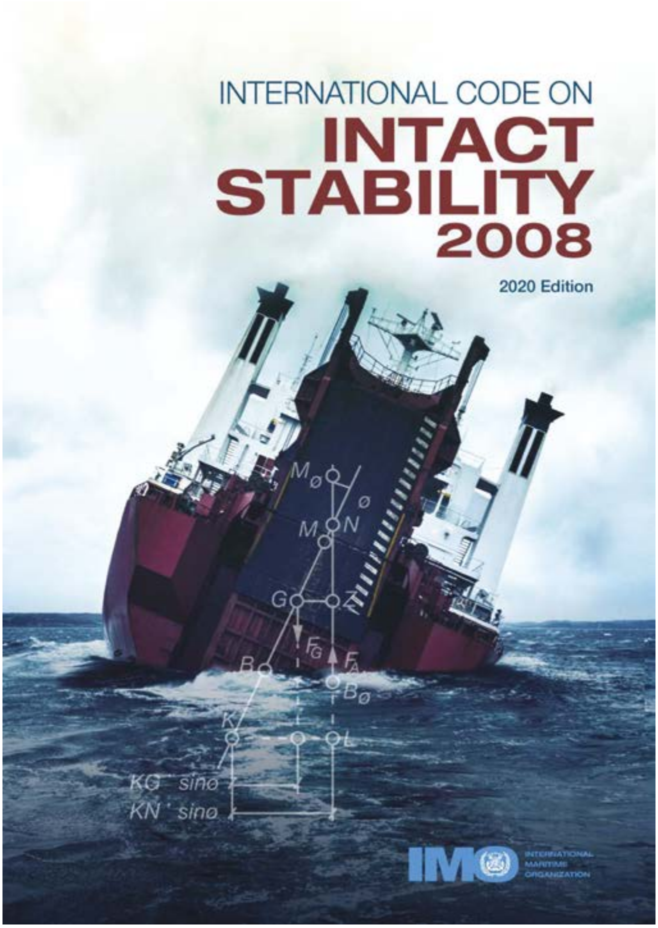

Figure 45.17: The IS Code, 2020.

Where relevant, the effect of a stability pontoon should be included in the calculations.

For high value/long replacement time cargoes and/or if the voyage route is deemed to be high risk, additional stability checks will be required for a damaged state (eg a one compartment flooded condition). Although a vessel may meet the IMO intact stability criteria, it may still be considered that the vessel has too little (tender) or too much (stiff) stability.

Vessels with heavy deck cargoes may have a high centre of gravity (CG) and a small metacentric height (GM). This will result in a slow roll period (tender) and the ship will linger at the maximum angle. The extended roll period increases the gravitational forces on the cargo and the securing devices.

Figure 45.18: Rough weather combined with a high GM can result in violent motions, which if not properly planned for, can result in damage to or loss of the cargo.

Vessels with heavy cargo stowed low in the holds may have a low CG and a large GM. This results in a fast roll period (stiff) and the ship may roll violently. This violent motion increases the dynamic forces acting on the cargo and the securing devices, due to the increased accelerations.

Project cargoes for the oil industry, loaded on conventional vessels, usually include a quantity of drill and casing pipe. This has to be bottom stowed in the holds and the result is always a high GM, with its associated short roll period, which in some cases is as low as seven to eight seconds, potentially resulting in violent rolling. High acceleration forces may be exerted on tween deck and deck cargo lashings and this should be taken into account during the planning and loading phase. Because project cargoes can be relatively light but have a high volume, there is usually insufficient deadweight in the whole consignment to bring the vessel down to a reasonable draught that will provide full propeller and rudder immersion. Therefore, some bottom ballast will still be needed, which further increases the GM. Pumping out this bottom ballast will make little difference to the roll period and will make the vessel difficult to handle in adverse weather.

With a lighter vessel, there is an added risk of main engine shutdown, as the governor will be working harder to avoid engine overspeed.

On conventional vessels, an ideal roll period would be in the region of 15 to 20 seconds. A longer roll period, resulting from a GM that is too low, will mean that the vessel will 'hang' at the maximum angle at the end of each roll and any shift of cargo could result in loss of GM and the vessel reaching angle of loll, with no prospect of recovery without resorting to ballasting bottom tanks.

The nature of the cargo will dictate the final GM, although consideration should be given during the planning phase to loading as many heavy units high up in the tween decks, or on deck if permitted, to counteract the effect of the drill and casing pipe consignments in the lower holds. This will not be possible in the case of bulk carriers being employed to load project cargoes, as the heaviest units will have to be stowed directly over the pipe stows, or on the remaining tank top areas in the holds, further increasing the GM.

Consideration should be given to the weather conditions that the vessel may experience on voyage. For exposed, open ocean voyages, where bad weather is a possibility, the effect of the loading condition (GM and draughts) on the vessel's motions should be considered and any negative effects mitigated as much as possible. It is important to minimise the motions of the vessel (including possible wind heeling) as far as practically possible.

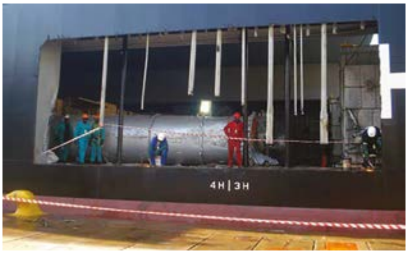

Figure 45.19: When sea fastenings fail under excessive vessel motions, the violent motion of large, heavy project cargoes can cause extensive damage to the vessel structure. Side-shell plating (in way of cargo holds), deck structures and hatch covers are particularly vulnerable to damage. The repairs can cause extensive delays.

45.6.3 Vessel Strength Considerations

The vessel will have defined weight limits for the tank top, tween deck and hatch covers (expressed in tonnes per square metre). It is important that these limits are adhered to, particularly with heavy cargoes, and they must be considered in the stowage planning.

Heavier cargo units should be placed over the frames of the vessel and additional load spreading may be required. Methods of load spreading can range from dunnage or wooden mats, to steel grillages for heavier units. These spread the load into the surrounding structure of the vessel. The grillage should be designed to take both the static weight of the cargo unit and the dynamic loads to which it will be subjected on voyage. In many cases, sophisticated software is used to determine 'hot spots' in the structural members of the vessel while stowing heavy-lift cargo. This approach is usually used by naval architects or structural engineers, who are either employed internally or externally.

Figure 45.20: Load-spreading 'mats' to protect the structure of the vessel.

Where structural reinforcements, grillages or any other welded modifications are required, the proximity to the vessel's bunker tanks or any other flammable source must be considered and the appropriate hot work procedures followed. All appropriate work permits should be in place.

The longitudinal strength of the vessel in terms of shear forces and bending moments must be checked at all key stages of the loading and discharge operations and for the voyage conditions. Project cargoes are typically limited by volume (rather than weight) and so the shear forces and bending moments are usually within the vessel's permissible limits.

45.6.4 Securing Points

The securing points fitted to the vessel, and the surrounding structure to which they are fitted, must be strong enough to withstand the loads (static and dynamic) imposed by the cargo during the voyage. This is particularly important in the case of 'hard' sea fastenings such as welded stoppers.

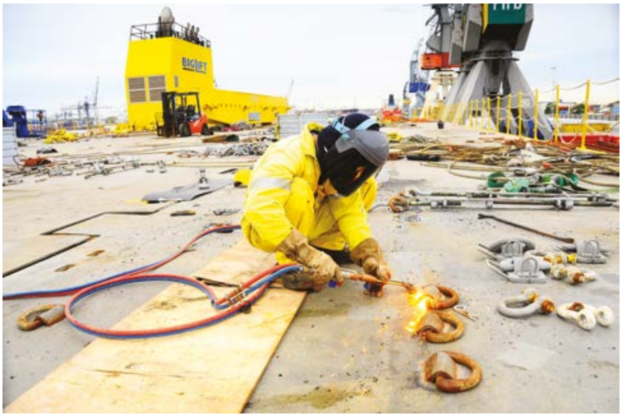

Figure 45.21: Adding securing points to the deck of a heavy-lift vessel.

Figure 45.22: Lashing wires with sufficient scope and clear working space.

The securing points should be located such that there is adequate room for the securing device to operate effectively. For wire lashings, the lashing should have a clear line between the cargo unit and the securing points on the vessel and must not run around corners of the vessel structure or other cargo units.

Figure 45.23: Examples of D-rings properly welded to the deck (left) and poorly welded onto a bulkhead (right).

45.6.5 Cranes and Lifting Devices

The vessel's cranes and lifting devices are of critical importance in the loading and discharge of project cargoes.

Maintenance of cranes and the operational procedures applied are critical to their safe operation. There are numerous examples of heavy lifts being dropped due to failures of cranes and/or poor operational practices. The manufacturer's recommendations for maintenance should be followed and full records kept. Defective wires must be replaced as necessary. The Classification Society inspection history and maintenance records (eg 'rocking' test results) are often requested for review.

Figure 45.24: The vessel's cranes are of critical importance to the safety of operations and all components should be thoroughly maintained and regularly inspected. A crane failure during a heavy lift could be catastrophic.

The manufacturer's recommended operating procedures should be followed and the crane operating limits adhered to.

A significant factor in incidents relating to cranes is the competence of the operators. Heavy lifts, particularly tandem lifts (using more than one crane at the same time to lift a unit), require experience and appropriate training.

Figure 45.25: Cargo being unloaded using a tandem lift.

45.7 Loading and Discharge

The responsibilities of each party must be agreed and documented prior to commencement of operations and should set out the chain of responsibility, persons in charge and contact details for all relevant persons.

Instructions/information from shippers
The shipping note provides details of the contents of a cargo consignment to carriers, forwarders and receivers.

Industry guidelines and best practice
For any cargo movement, in particular for loading and discharge operations, a full and detailed plan must be produced and adhered to. The plan should take account of the requirements and recommendations of industry best practice guidelines and rules.

Heavy-lift equipment and relevant requirements
Lifting gear may include wires, shackles, spreader beams and lifting blocks/hooks and should be documented on board the vessel, or with the crane (if shore-side). All lifting equipment should be certified and its safe working load (SWL) or working load limit (WLL) and minimum breaking load (MBL) documented and marked visibly on the item itself.

Figure 45.26: Safe lifting equipment.

Lifting lugs/eyes on the cargo unit should be located so as to provide a stable lift, accounting for any offset of the unit's centre of gravity. They must also be strong enough for the lift, including any dynamic lifting loads. All lifting gear and lifting points on the cargo should be inspected before commencing the lift.

Figure 45.27: Unsafe lifting equipment.

Lifting and rigging plans

For any heavy lift, it is essential to properly develop and document a lifting plan, which should define the procedures for the lift and provide accurate information on the centre of gravity of the unit, the proposed lifting spread to be employed and the calculation of the rigging stability (the lifting triangle). It should document the loads expected to be experienced and the safety factors used in selecting the lifting gear. It should also assess the need for centre of gravity corrections (eg the use of water bags) and/or possible test lifts required to ensure stability (insurance policy coverage should be checked in this case).

The lifting of units with a high centre of gravity (CG) can be challenging. An incident occurred on board a ship where the rigging arrangement for a heavy-lift item was incorrect, and this coupled with a strong gust of wind, caused the crane to list. As the stability of the lift was marginal to begin with, once the crane had started to list, there was no means to restore it to its upright position. The load fell to the deck of the vessel and the quayside, causing significant damage.

All crane lifts should be carefully assessed to ensure adequate clearances between the cargo unit itself, the vessel, and the port infrastructure. Tandem crane lifts must be planned in detail to ensure the correct synchronous movement of the cranes.

Limiting conditions and external influences

The lift should have limiting conditions imposed on it to ensure that the design loads for which it is rated are not exceeded. These will include limiting wind conditions and vessel motions (which may differ for in-harbour and offshore operations) and, where positional accuracy is important, the lift may be limited to daytime hours only.

Significant crane slewing (rotation) and other horizontal motions should be assessed to ensure that the dynamic loads imposed are within the capacity of the lifting system. Similarly, lifting into and out of water imposes additional loads on the lift and must be assessed.

Reference should be made to the relevant industry guidelines for the determination of these loads.

Loading sequence and trim, ballasting
During loading and discharge operations, it is important to carefully manage the vessel's draughts and trim. This is particularly important for drive-on/off and float-on/off operations. Careful ballasting is needed to ensure that the required draughts and trim are maintained during the course of the operation and this should be properly calculated and documented in advance. The ballast tank and pump capacity of the vessel should be checked to ensure that they are adequate, particularly for barge transports. In addition to ballast water loads, the impact on stability of the free surface effect from slack tanks should also be taken into account.

Other loading methods

- Float on/off: This method of loading and discharging is employed by semi-submersible heavy-lift vessels and submersible pontoon barges. Cargoes may include offshore platforms, jack-ups, other vessels (eg barges, tugs, etc) and large project cargoes that are suitable for wet loading/discharging. These vessels can be expensive to charter, but provide a safe and relatively fast option for transportation

Figure 45.28: A float on/off vessel with an offshore platform as its cargo.

- skid-on/off: pontoon barges, module carriers and semi-submersible heavy-lift vessels are commonly loaded by cargo being skidded into position. Large oil and gas units (eg topside modules) are often loaded by this method. These are typically bespoke operations allocated to a specialist contractor

Figure 45.29: Barge transports and loading/discharge by non-lifting methods require specialist expertise and knowledge.

- roll-on/off: Wheeled cargoes can be driven onto and off the vessel. Many project cargoes are loaded/discharged using self-propelled modular transporters (SPMTs). SPMTs provide a flexible loading/discharge method and are capable of dealing with inclined and uneven routes.

45.7.1 Other Operational Issues

Ground-bearing pressure
Consideration should be given to the ability of the load path (ashore) to withstand the weight passing over it without undue deformation, which might result in damage to the load path and/or a loss of stability of the load-transporting equipment. This can also be a factor with lifted loads, particularly where a high capacity mobile crane is utilised. The loading capacity of port facilities should be determined and account taken of any damaged or degraded areas. Repair and/or consolidation may be required to provide a usable load-path over which a heavy unit can be skidded or driven, or a crane safely located. The transport of the unit to the load port and onwards from the discharge port must also be considered. A route survey may be required.

Transshipments
Transshipment of cargo should, under ideal circumstances, be avoided as generally the cargo is at its most vulnerable when being handled. However, there are circumstances when it cannot be avoided. Transshipment operations, particularly ship to ship (STS), require detailed and careful planning.

Barge transport
While there are heavy-transport vessels capable of carrying modules of 2,000 to 3,000 T, towed barge transport is often the only reasonable solution to move heavy-lift cargo, particularly where extremely large and heavy structures are concerned. These may include container cranes, large tanks, or jackets and decks for offshore installation. Barge transport is inevitably slower than the use of an equivalent vessel. It will also require the attachment of a suitable towing vessel and may need more sophisticated voyage planning where the tow route is lengthy or transits known hazardous or adverse weather areas. Barge transports should be carefully planned as they are generally a higher risk method.

Management of operations

For any loading and discharge operation, the planning of the operation must include provision for hold points during the operation and toolbox talks. These help to ensure the safe progression of the operation and that all persons involved understand the next steps, responsibilities, etc.

Appropriate risk assessments, including hazard identification meetings, should be carried out. These should involve all relevant parties and be approved by all. They should include management of changes (any deviations from agreed procedures) to be documented and agreed by all parties.

Relevant authorities (such as the local Port Authority) should be informed of the operation and involved in the planning. There may be a need to restrict vessel movements nearby during an operation, for example, which will require the support and assistance of the port.

45.8 Stowage Requirements

All vessels have their specific advantages and disadvantages, but while specialist heavy-lift vessels will be more expensive to charter, they are generally better suited to the cargo types typically shipped, so the overall shipment is safer. Cheaper vessels, such as bulk carriers or general cargo vessels, are often employed for economic reasons. However, they are not designed to carry these types of cargoes and their use often ultimately leads to increased costs, either due to cargo damage claims or the extra design and work required to make the cargo shipment as safe as possible, which tends to nullify the perceived cost benefit.

Figure 45.30: Large cargo units will need to be carried on deck, requiring special planning of the stowage, required sea fastenings (to allow for the higher CG) and protection from the elements. Stowage on forward hatch covers is not advised unless absolutely necessary as vessel motions (in particular, pitch motions) are greater in this location and there is a higher risk of impact from seas shipped on deck.

Large cargo units require large amounts of deck space and this often dictates the choice of vessel. If the cargo can only be carried on deck and not in the holds, suitable protection from the elements is then required.

Deck cargoes will often be specified as being carried at the shipper's risk and it is important to note this and take action accordingly.

45.9 Cargo Securing

Cargo securing equipment
Cargo securing gear may include lashing wires, web lashings, chains, D-rings, turnbuckles and shackles. In project cargo terms, these are often referred to as 'soft' lashings. As with lifting gear, all of the equipment for cargo securing should be certified and have its SWL and MBL documented and marked visibly on the item. If carried by the vessel, the CSM should provide a full inventory of these items.

Figure 45.31: Turnbuckles.

Also applicable are 'hard' sea fastenings such as stoppers, braces, etc, which are often constructed from steel plating and/or beam sections and welded to the vessel. These are typically used for larger, heavier cargo units and are usually used only once.

Figure 45.32: 'Hard' sea fastenings.

As with lifting gear, securing equipment should be well maintained and regularly inspected. Records of the inspections and maintenance should be retained. Prior to use, all securing gear should be inspected and, if damaged, should not be used and should be replaced.

45.9.1 Types of Securing

Wire lashings (direct or looped)
Wire lashing are the most common form of cargo securing. They are easy to stow (but must be wound/unwound properly), are easily adaptable to the shape of cargo compared to deck/hold lashing points, and tension can be maintained on voyage (using turnbuckles or similar). The wires are susceptible to damage and require regular maintenance. Care must be taken to ensure the wires do not damage the cargo and

sheathing protection may be required. The wires must be rigged properly to get full load capacity and will need retensioning during the voyage. Large numbers of wires are required for larger, heavier items, and these can be difficult to handle. Separate wires should be used to counter sliding and tipping forces.

Figure 45.33: Wire lashings.

Web lashings

These are better suited to smaller/lighter cargo units and where the cargo unit does not have dedicated lashing points. They are re-usable, easy to stow and the soft material minimises damage to cargo. They tension with a ratchet and are easy to handle. They are prone to chafing damage and have limited strength so a large number are required, even for medium-sized units.

As a general rule, soft lashings have the greatest effect if attached close to the plane of the centre of gravity (CG) of the item (subject to the structure of the item being able to withstand the motion forces expected) with the angle of the lashings as close as possible to 45° to the deck.

Figure 45.34: Web lashings may sometimes be used for smaller, lighter project cargoes, typically because they are cheaper than wires. However, they do not provide the strength of wire lashings and are prone to chafing damage. Securing cargoes using web lashings as shown in the right-hand image will damage the webbing and reduce its effectiveness.

Chains
These can provide higher strength capacity and require less maintenance than wires but are harder to handle and stow, and difficult to keep taught. When using ratchet tensioners, the chain will loosen in steps (by link) rather than gradually, potentially resulting in loss of tension. They are suited to stronger securing points, with separate chains required for sliding and tipping resistance.

Figure 45.35: Lashing chains need to be properly tensioned and so need to be secured to appropriate securing points to enable the tension to be created. The chains shown provide good tipping restraint but minimal sliding restraint, due to their high angle.

Sea fastenings
These can include hard stoppers and braces, typically of steel construction and with welded connections to the decks. They can provide combined resistance to sliding and tipping and may be designed to resist very large forces. They are well suited to large, heavy units of non-uniform shape but require proper design and engineering. They will have a higher cost, require time to construct and will need qualified welding contractors and non-destructive testing (NDT). Care is required to ensure that the vessel's structure can withstand the imposed loads.

Figure 45.36: Sea fastenings.

Dunnage, shoring

Wooden dunnage must be placed on the decks underneath the cargo to provide greater friction between the cargo and the deck and to assist load spreading. Dunnage is not used where the cargo unit sits on a grillage or similar, which is designed to spread the load, but may be used as shoring or bracing to help position and maintain the cargo unit.

The dunnage should be of good quality solid wood and not of plywood or similar. Ideally, it should be of horizontal grain (and not curved) to minimise the risk of splitting.

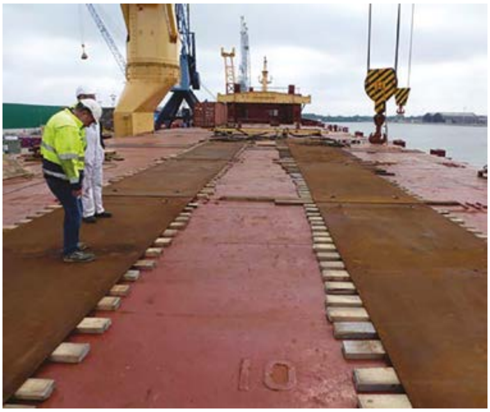

Figure 45.37: Wooden dunnage.

45.9.2 Securing Methods

The options for securing the cargo unit should be assessed and the most appropriate selected. This is typically undertaken by the charterers but is subject to the provisions of the charterparty. It is, therefore, important that each party understands their specific responsibilities. The Master should ensure that they are satisfied with the cargo securing and should note any defect or concern about the proposed arrangements.

Certain cargo types, particularly large heavy items or units that cannot absorb any stresses, will dictate that certain types of sea fastenings are required and whether 'hard' or 'soft' sea fastenings should be used.

Hard sea fastenings include welded stoppers, braces, etc that are connected to the vessel's decks and provide restraint of the cargo and spread loads into the surrounding structure of the vessel. Equally, if there is a direct connection between the vessel and the cargo unit (eg welds, pad-eyes, etc), stresses on the vessel may be transferred to the cargo unit. In particular, this can occur with cargo units of sufficient length that longitudinal bending and deflections of the vessel are imparted into the cargo unit. Careful design of the sea fastenings is required to ensure that this is avoided or, if unavoidable, that the stresses imposed on the cargo are within the capacity of its own structure. Hard sea fastenings will typically provide a greater restraining capacity and so are better suited to larger, heavier units.

Figure 45.38: Where cargo units may incur deflections due to the longitudinal bending of the vessel, the sea fastenings must be carefully designed to minimise the loads imparted into the cargo unit. More complex sea fastening designs are required, based on specialist expertise. It is, therefore, important that sufficient time is allowed in the project for the proper design process to be carried out.

Soft sea fastenings include wires, straps, etc which provide some restraint, but also have some 'give'. This 'give' is useful in avoiding the transfer of vessel stresses into the cargo unit, but also means that the tightness of the securing needs regular checking to ensure it does not come loose. Soft sea fastenings are generally cheaper and more convenient to use.

The design of the sea fastenings must provide restraint against sliding and tipping in both transverse and longitudinal directions as well as against uplift. The design philosophy for sea fastenings is such that hard and soft types should not be mixed in each mode of restraint, eg use of sea fastenings for sliding or tipping restraint can each employ different methods such as hard for sliding and soft for tipping, but a mixture of both types of fastening for one mode of restraint should be avoided.

For soft restraints, the optimum angle for sliding restraint is about 25 degrees to the deck, while for tipping restraint, the optimum angle is about 45 to 60 degrees. Hard sea fastenings should be designed considering all relevant forces and stresses (and not just one mode of force).

Bracing may need to be installed on the cargo unit to prevent distortion of the cargo unit under the loads experienced in a seaway. This is particularly relevant for frameworks (eg modules for oil and gas installations) and large gantry cranes (eg container cranes, RTGs, etc).

Where welding is required to construct the sea fastenings, it must be ensured that this is not over or against any fuel tanks and that hot work procedures are followed. The welding must be of a high standard and specialist, fully qualified welders are normally required to complete the welding of sea fastenings. The welds must be tested to ensure that there are no defects and non-destructive testing (NDT) inspectors are employed for this. The amount of NDT required varies, depending on the complexity and criticality of the project/cargo, but testing of a minimum of 20% of all welds is normally required and, in some cases, 100% of all welds may require testing. In addition to any NDT, there should always be a 100% visual inspection of all sea fastening welds.

Figure 45.39: Examples of welds, showing very poor quality welding (top), a sea fastening weld to the deck that failed the NDT inspection due to the presence of weld cracks (middle) and a D-ring after NDT inspection that was passed (bottom).

45.10 The Voyage

45.10.1 The Voyage Plan

The voyage plan should be critically assessed for the route, proximity to areas of navigation danger, exposure to weather conditions (duration and how open the area is and its effect on cargo stowage and securing) and areas of known piracy activity. Different criteria will apply for open ocean voyages, compared to sheltered voyages of limited duration. Weather routing should be used where possible. Adequate fuel reserves should be maintained on board the vessel for the duration of the voyage. The usual recommended minimum reserve is 20% or five days' fuel reserves.

The voyage route should include contingency plans in case of emergency events or forecasted weather exceeding the limits defined in the stowage and sea fastening calculations. Ports and areas of refuge should be identified and should ideally be reachable within a reasonable accurate weather forecast timeframe (usually two to three days' sailing).

Where an MWS is involved, the vessel will be required to provide daily reports of voyage progress and a report on the condition of the cargo. This is usually a small addition to the normal reporting process for owners and charterers.

45.10.2 Voyage Reporting

An MWS may provide a certificate or letter of approval to confirm that the vessel can depart and that all procedures have been complied with. The certificate/letter may contain a number of recommendations that must also be complied with, as a requirement of the warranty for the insurance policy. The recommendations will typically include limiting weather conditions for the voyage, the requirement to regularly check the sea fastenings and reporting requirements.

A certificate or letter of approval may also be provided for critical operations such as heavy lifts or load-out/load-off.

It is important to keep records of the operations, both for log entries and future reference. It is recommended that the crew make notes of the operations as they progress and while on voyage. Handwritten notes (or crew's notebooks) should be retained and, for more complicated cargoes, the notes should be extensive and represent a proactive approach.

Duty officers should be encouraged/instructed to take as many photos as possible, particularly during loading. Video clips of critical heavy-lift operations can also be taken. Photos and video clips are particularly helpful to investigators and experts in case of cargo loss or collapse, and could help protect interests in case of litigation.