

# Bulk Cargo Liquefaction

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## Introduction

The problems associated with cargo liquefying whilst onboard vessels are nothing new. However, there have been a number of very serious incidents over recent years where vessels have experienced liquefaction leading to loss of stability and capsizing. Cargoes such as iron ore fines, nickel ore, millscale, fluorspar, iron ore concentrates and others have all given rise to liquefaction associated problems.

The definitions, tests and precautions in the International Maritime Solid Bulk Cargoes (IMSBC) Code for cargoes that may liquefy are widely associated with metal ore concentrates, for which their application is relatively straightforward. However, any cargo containing fine material and moisture has the potential to liquefy and the properties of such cargoes should be queried with the shipper.

Intense pressure from shippers, mis-description of cargoes, inadequate testing methods and lack of crew awareness over the potential for liquefaction of some cargoes have all contributed to recent incidents. The purpose of this briefing is to inform and advise Members of the problems associated with liquefaction in general.

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# Bulk Cargo Liquefaction

## What is Liquefaction?

In a fine grained, moisture laden cargo the spaces between cargo grains are filled with both air and water. Whilst at sea the cargo is subject to forces due to the vibration and rolling of the vessel. These forces cause the inter-grain spaces to contract. The water in the spaces between grains is subject to a compressive force but as it is a liquid it cannot be compressed. This has the effect of reducing the inter-grain frictional force that holds the cargo in a solid state. Where enough moisture is present the reduction in inter-grain friction due to the ship's motion and vibration can be sufficient to cause the cargo to flow like a liquid.

## Consequences of Liquefaction

The most significant consequence for the vessel resulting from liquefaction is cargo shift leading to loss of stability. This may produce dangerous angles of list and in some instances the resulting loss of stability can be such that the vessel and the lives of those onboard are lost. It is therefore imperative that seafarers are aware of the types and condition of cargo that may give rise liquefaction.



## SOLAS Requirements

The International Convention for the Safety of Life at Sea (SOLAS) Chapter VI – Carriage of Cargoes - provides the general framework for the carriage of all cargoes.

### Shippers duties

In respect of cargoes with particular hazards, such as liquefaction, SOLAS is explicit in requiring the shipper to provide the master, or his representative, with the appropriate cargo information sufficiently in advance of loading to enable the necessary precautions for safe carriage to be put into effect. The format of such information is also provided in IMO MSC/Circ.663. A typical format for the shipper's declaration is included in the appendix.

Additionally there are specific provisions for additional information to be supplied for cargoes which may liquefy in the form of a certificate of moisture content and transportable moisture limit (TML).

As such shippers are obliged to provide appropriate cargo information to the master before loading commences.

### Masters duties

SOLAS Chapter VI, Part B, Regulation 6.2, states that

“Concentrates or other cargoes which may liquefy **shall only be accepted for loading** when the actual moisture content of the cargo is less than its TML.”

Therefore, a master should not accept such a cargo for loading without first receiving the appropriate documentation certifying the moisture content and TML of the cargo with the moisture content shown to be less than the TML.

### Terminal representatives duties

SOLAS Chapter VI, Part B, Regulation 7 deals with the loading, unloading and stowage of bulk cargoes and introduces the Code of Practice for the Safe Loading and Unloading of Bulk Carriers (BLU Code). The BLU Code is included as a supplement of the IMSBC Code.

The BLU Code, although primarily concerned with arrangements between the terminal and the ship to ensure safe and efficient cargo operations in port, does under section 3.3.3 state that:

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“The terminal representative should be satisfied that the ship has been advised as early as possible of the information contained in the cargo declaration as required by chapter VI of SOLAS 1974 as amended.”

A question confirming that the cargo information has been received is also included in the recommended ship shore safety checklist at Appendix 3 - question 12 - of the BLU Code.

Terminal representatives bringing commercial pressure on masters to load their vessels before receiving the shipper's cargo declaration are acting in contravention of the BLU Code and therefore SOLAS. Masters are urged to resist such pressures.

It is a master's responsibility to ensure that the vessel is safely loaded; and where the shipper's cargo declaration has not been received the master has no idea of the likely properties of the cargo to be loaded.

If such declaration is not forthcoming a master should not commence loading and should immediately notify owners. Members should contact North for advice in such circumstances.

## Liquefaction and the IMSBC Code

The main reference for any ship operator or master when considering whether or not a cargo is likely to liquefy is the IMSBC Code. The dangers associated with commonly shipped cargoes are listed within the Code – Group A cargoes are those that are likely to liquefy. Any cargo listed as Group A should be carried strictly in accordance with the provisions of the IMSBC Code.

However, the Code itself warns in Section 1.2.1 that the schedules for individual cargoes are not exhaustive. It may be that some cargoes which can liquefy are not included in the Code e.g. river sand. Ship operators and masters should not automatically assume there is no risk of liquefaction simply because a cargo does not appear in the IMSBC Code as a 'Group A' cargo. Ship operators and masters should not automatically assume there is no risk of liquefaction simply because a cargo does not appear in the IMSBC Code as a 'Group A' cargo.

**Any bulk cargo containing the correct proportion of fine particles and sufficient moisture may liquefy.**

It is essential that masters and ship operators are familiar with the IMSBC Code.

## Flow Moisture Point (FMP) and Transportable Moisture Limit (TML)

### Flow Moisture Point

The maximum water content, expressed as a percentage, at which a sample of cargo will begin to lose shear strength. Cargoes with moisture content beyond FMP may liquefy.

### Transportable Moisture Limit

This is defined as 90% of the FMP when used in conjunction with the Flow Table Test (FTT) and the Penetration Test and taken as equal to the critical moisture content at 70% degree of saturation according to the Proctor/Fagerberg test method.

From the ship operators and master's perspective the important figures for the laboratory to determine are the TML of a representative sample of the cargo to be loaded and its actual moisture content. It is a requirement of SOLAS that the average moisture content of a Group A cargo in any cargo space must not be higher than the TML. This is an important point; it is of little use to the vessel if an average moisture content of all cargo is provided. This may lead to dry cargo in some holds and cargo liable to liquefy in others which will put the vessel at risk.

In order to find the TML when using the Flow Table and Penetration Test the laboratory must first determine the FMP of the sample.

Loading a cargo above, at or near its FMP represents an unacceptably high risk for vessels and for this reason a safety margin is allowed – this gives the TML.

After determining the FMP, the moisture content of the cargo is obtained by drying samples of the cargo in accordance with Section 4.6.5 and Appendix 2 of the Code.

If the moisture content of the cargo sampled is below the TML then the cargo should be safe to load.

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*Figure 1: A flow table for determining FMP*

However, there is no way for the vessel's operators or master to determine whether or not the sampling and testing procedures used by shippers are adequate and/or accurate. In some cases such as with some nickel ore cargoes, the subject of their own briefing, not only can the techniques used for testing be deficient, but also the inhomogeneous nature of the cargo itself makes FMP determination using the techniques described in the IMSBC Code problematic as they are designed for more homogeneous cargoes.

## Shipper's declaration

Section 4 of the IMSBC Code requires the shipper of the cargo to provide the master with appropriate cargo information sufficiently in advance of loading to enable the precautions which may be necessary for the safe carriage of the cargo to be put into effect. The minimum information to be provided is listed in Section 4.2.2. This information includes both the TML of the cargo and its moisture content at shipment.

The vessel should receive this documentation well in advance of loading and masters should resist pressure from shipper or terminal representatives to begin loading in advance of receipt of the certificate. It is better to delay loading whilst awaiting the certificate than to have to discharge unsuitable cargo loaded without the appropriate documentation. Such a discharge may be highly

problematic due to the lack of suitable equipment, berth or due to local customs or other regulations. Terminals and shippers may simply be unwilling to accept the discharged cargo. For cargoes tested in accordance with the provisions contained in Appendix 2 of the IMSBC Code the shipper's cargo declaration should be accompanied by a signed certificate stating the cargo's TML and moisture content.

In addition, Section 4.3.2 of the Code states that 'the certificate of TML shall contain, or be accompanied by, the result of the test for determining the TML', which we understand to mean that the flow moisture point (FMP) where applicable, must also be included with the documentation. This should allow the master to calculate the TML to ascertain that it is stated correctly on the declaration and also provides useful evidence in the event of a dispute.

Unfortunately there have been many instances where the information provided by the shipper has stated that the cargo has been within the TML but which cargo has later proven to be liable to liquefy. This can come about through poor testing procedures (despite detailed advice as to the conduct of tests contained within the IMSBC Code), changes in circumstance since testing was carried out, such as heavy rain, or through lack of understanding by shippers' representatives of the potential dangers posed to the vessel by spurious figures.

As such, even where the certificate states that cargoes are safe to load, masters and their officers must always be vigilant in monitoring the condition of the cargo as it comes onboard. Different stockpiles of cargo can have different characteristics so vigilance throughout the duration of loading operations is necessary.

In the event of a dispute arising over the properties of the cargo intended for loading we would recommend that Members consider the employment of an independent surveyor/expert to assist the master. In such circumstances Members should contact North for advice.

## Sampling and testing of cargo

Sampling and testing procedures for bulk cargoes that may liquefy should be carried out in accordance with the test procedures approved by a competent authority in the country of origin when such test procedures exist. In their absence, properties of a solid bulk cargo shall be determined in accordance with the test procedures prescribed in Appendix 2 of the IMSBC Code.

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## Can test



Figure 2: Before



Figure 3: During



Figure 4: After - a failure on this occasion

In order that the vessel can make a “check test” on the condition of the cargo the IMSBC Code describes a shipboard method known as the “can test”. Master’s can refer to the IMSBC Code, Section 8, for details. The test involves filling a small can with the sampled cargo and repeatedly banging it on a hard surface. The appearance of the material at the end of the test can be used to form an opinion regarding the suitability of the material for shipment.

This test should not be a substitute for proper laboratory testing using an appropriate methodology. However, if can tests carried out on a cargo presented for loading indicate a propensity for liquefaction, this is a major warning sign that the cargo as a whole may be unsafe for carriage.

Expert advice should then be sought. If shippers present significant amounts of material that fails the can test, this is an indication that the cargo as a whole is unsafe, and that documentation provided may be flawed. It should also be borne in mind that a negative result from the can test (no free moisture or fluid condition is seen) does not necessarily mean that the cargo is safe for shipment.

## Advice to Owners and Masters on Loading

Although it is the shipper’s duty under SOLAS to test and certify that a cargo is safe to load experience has shown that in some cases this does not always occur. Therefore, the actions of owners and masters before arrival and, most importantly, at the load port are crucial in ensuring that a vessel is protected from loading a cargo that may liquefy.

Masters and ship operators should always bear in mind the possibility that the information contained within the shipper’s declaration, for whatever reason, may not accurately reflect the true condition of the cargo.

## Documentation and information

Members must ensure that cargo interests have provided the necessary cargo documentation, that the information is up to date (moisture content should be taken within 7 days of loading) and takes into account any recent events (e.g. heavy rain) that may change the characteristics of the cargo. The master should be made fully aware of the characteristics of the cargo to be loaded.

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The provision of the information to the vessel should ideally take place well in advance of loading to enable the master to prepare for the planned loading, including the appointment of surveyors and or cargo specialists to protect Member's interests if thought necessary. Members should endeavour to make the master aware of any known problems with a particular cargo or of any recent abnormal precipitation at the load port or point of origin of the cargo.

There are no circumstances in which it is considered prudent to load cargo liable to liquefy without first having received the appropriate cargo documentation relating to the cargo to be shipped on that vessel including a properly completed shipper's declaration, and a signed TML and moisture content certificate indicating that the cargo is safe to load.

## Decision to load

The master's decision to commence loading is critical in avoiding problems associated with cargoes that liquefy. High loading rates mean that vessels can have many thousands of tonnes of cargo loaded in just a few hours. To safeguard a vessel and its crew and to avoid the delays, disputes and other problems associated with discharging a cargo that is unsuitable for transportation the master must satisfy himself, as far as can be reasonably determined, as to the suitability of the cargo for loading.

If at all practicable the master should arrange to view the cargo stockpiles to be loaded onboard as the condition of the stockpiled cargo may indicate potential problems with liquefaction. Samples collected from these stockpiles may be Can Tested for signs of liquefaction before loading.

Where doubt exists as to the characteristics of the cargo to be loaded the master should delay the start of the loading operation and contact owners. In such circumstances it is advisable to appoint an independent surveyor or cargo specialist for advice. Always remember that removing unsuitable cargo from the vessel can be highly problematic.

In the case of cargoes known to liquefy and which have resulted in problems for vessels, such as iron ore fines from India during the south-west monsoon season, it will be to owners' advantage to appoint independent surveyors to sample and inspect the cargo to be loaded prior to a vessel's arrival and to assist the master throughout the load.

## Awareness during loading

As the first cargo comes aboard the vessel the master and his officers should endeavour to take samples and test them using the can test as described in Section 8 of the IMSBC Code. Ideally, further such testing should take place at regular and frequent intervals during loading to ensure that the condition of the cargo coming onboard is safe throughout the loading operation. The location of the sample may be critical. A wet cargo exposed to sunshine for a few days may be dry on the surface but still have high moisture content at the base or at intermediate layers. It is therefore important that a cross section of the cargo is sampled.

The characteristics of the cargo within the hold should also be monitored for signs of excess moisture. Cargo monitoring throughout the loading operation is necessary to stop cargo that may liquefy from being loaded.

When a master is in any doubt as to the suitability of the cargo for transportation, loading should be suspended, the owners informed, contact with the Club established and an independent surveyor or cargo specialist called in to assist the master with the further assessment of the cargo.

Weather conditions during the load may also require the suspension of the loading operation. Loading cargoes liable to liquefy during heavy rain is an unnecessary risk.

Where the vessel is engaged in carrying a cargo that is not listed in the IMSBC Code then Section 1.3 of the Code should be followed.

## Cargo unsuitable for shipment already on board

Suspect cargo should be sampled by an independent laboratory and, if found to have moisture content beyond its TML, then the safest option is to discharge the cargo. This sounds simple but unfortunately experience has shown that once a vessel has loaded wet cargo getting rid of it at the load port can be highly problematic. Commercial reluctance on the part of the shippers and ports to accept/unload unsafe cargo can lead to severe delays and extensive costs. In some cases these situations can drag on for months. There may also be damage to valuable commercial relationships should such a dispute arise. It is always best for the vessel's safety and in the owner's interest that unsafe cargo is identified before loading commences.

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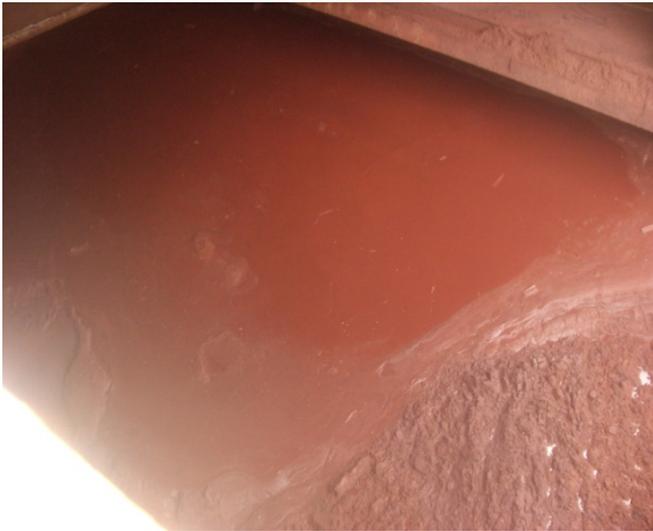


Figure 5: Liquefied iron ore fines in cargo hold

## Cargo Liquefying Whilst at Sea

Despite the provisions of SOLAS, the IMSBC and BLU codes it is still the case that cargo unsuitable for transportation is loaded and carried. In recent years there have been a number of incidents involving the loss of vessels and of life that have been attributed to liquefaction of the cargo onboard. There have also been numerous instances of vessels losing stability, but not capsizing, which are known to have been caused by liquefaction.

ISM Code amendments that came into force on 01 July 2010 require that potentially hazardous situations are risk assessed and have procedures in place to deal with the situation should it occur. Clearly liquefaction places the vessel in a hazardous situation and procedures to deal with liquefaction should be developed if not already in place.

Once liquefaction of a cargo has taken place at sea a vessel and its crew may be in very real danger.

Whilst every such situation will have its own unique set of circumstances as a minimum owners/vessels should:

- Ensure that detailed stability calculations are carried out before departure from the load port for every cargo loaded. The calculations will then serve as baseline data in the event of a liquefaction incident.
- The master must immediately notify owners. Owners should seek the advice of an expert in these

circumstances. The likely effect of ballasting the vessel to correct a vessel's list needs to be calculated and carefully considered before any such operation takes place. Incorrect ballasting may exacerbate the situation causing a further reduction in stability. Even where ballasting has taken place and is successful in returning a vessel upright, the cargo onboard is still in a dangerous state.

- The vessel may need to seek the nearest port of refuge.

## Protect Your Interests

The loading and carriage of cargoes that have the potential to liquefy takes place every day, all over the world and the vast majority of voyages pass off without incident. However, the potential consequences of loading a cargo that is unsuitable for carriage due to its moisture content are of such seriousness that vigilance when dealing with these cargoes can never be relaxed.

Familiarity with the IMSBC Code and awareness that its Annexes are not exhaustive is important. Always bear in mind that some cargoes do not appear in the IMSBC Code and that some of these cargoes may liquefy. The best way to protect both the crew and the owner's interests is by ensuring that the provisions and advice of the IMSBC Code are followed at all times and by being vigilant before, during and after loading.

# Cargo Liquefaction

## Appendix

### Exemplar shipper's cargo declaration

Shipper	Reference number(s)
Consignee	Carrier
Name/means of transport	Instructions or other matters
Port/place of departure	
Port/place of destination	
General description of the cargo (For solid bulk cargo - type of material/particle size)	Gross mass (kg/tonnes) <input type="checkbox"/> General cargo <input type="checkbox"/> Cargo unit(s) <input type="checkbox"/> Bulk cargo
Specification of bulk cargo (if applicable) Stowage factor Angle of repose Trimming procedures Chemical properties* if potential hazard  * e.g., IMO class, UN No. or BC No. and EmS No.	
Relevant special properties of the cargo	Additional certificate(s) (if required) <input type="checkbox"/> Certificate of moisture content and transportable moisture limit <input type="checkbox"/> Weathering certificate <input type="checkbox"/> Exemption certificate <input type="checkbox"/> Other (specify)
<b>DECLARATION</b>  I hereby declare that the consignment is fully and accurately described and that the given test results and other specifications are correct to the best of my knowledge and belief and can be considered as representative for the cargo to be loaded.	Name/status, company/organization of signatory   Place and date   Signature on behalf of shipper