REDUCING THE RISK OF LIQUEFACTION

Operational guidance for vessels that carry cargoes which may liquefy

The London P&I Club

TMC MARINE
A BUREAU VERITAS GROUP COMPANY

BUREAU VERITAS

REDUCING THE RISK OF LIQUEFACTION

TABLE OF CONTENTS

4 GLOSSARY
5 INTRODUCTION
6 WHAT IS LIQUEFACTION?
8 WHAT ARE THE EFFECTS OF LIQUEFACTION?
10 THE "CAN TEST"
12 LOADING CARGOES WHICH MAY LIQUEFY
- **13** BEFORE LOADING
- **14** THE LOADING OPERATION
- **15** DURING THE VOYAGE

17 RECENT DEVELOPMENTS
18 APPENDIX 1 - GROUP A CARGOES WHICH MAY LIQUEFY

GLOSSARY

FLOW MOISTURE POINT

The Flow Moisture Point (FMP) means the percentage moisture content (wet mass basis) at which a flow state develops under the prescribed method of test in a representative sample of the material.

GROUP A

Cargoes which may liquefy if shipped at a moisture content in excess of the transportable moisture limit.

GROUP B

Cargoes which possess a chemical hazard which could give rise to a dangerous situation on a ship.

GROUP C

Cargoes which are neither liable to liquefy (Group A) nor to possess chemical hazards (Group B).

IMSBC CODE

The International Maritime Solid Bulk Cargoes (IMSBC) Code refers to requirements applicable to the transportation of solid bulk cargoes adopted according to the IMO resolution MSC.268(85).

MOISTURE CONTENT

Moisture Content (MC) means that portion of a representative sample consisting of water, ice or other liquid expressed as a percentage of the total wet mass of that sample.

TRANSPORTABLE MOISTURE LIMIT

Transportable Moisture Limit (TML) of a cargo which may liquefy means the maximum moisture content of the cargo which is considered safe for carriage in ships not complying with the special provisions of subsection 7.3.2 of the IMSBC Code. It is determined by the test procedures, approved by a competent authority, such as those specified in paragraph 1 of Appendix 2 of the Code. If the methods of flow table test or penetration test is used, the TML is determined as 90% of FMP.

REDUCING THE RISK OF LIQUEFACTION

INTRODUCTION

The purpose of this booklet is to provide general guidance and practical advice to masters, ship owners, shippers and charterers on the loading and the carriage of bulk cargoes which may liquefy, the risks associated with liquefaction and the precautions to minimize these risks. It is not intended to replace, in any way or form, the official IMO regulations and guidance notes or any document that forms part of a vessel's safety management system.

Millions of tonnes of cargo (iron ore fines, coal, manganese ore fines and nickel ore) that are known to be prone to liquefaction have been successfully transported without any incident. Despite an improvement in the awareness of carrying such cargoes, incidents where cargoes have been known to liquefy unfortunately continue and sometimes with catastrophic/tragic[1] results. Therefore the liquefaction phenomenon continues to be as relevant today in 2017.

While the main requirements for the safe carriage of solid bulk cargoes are enshrined in the IMSBC Code, this booklet outlines the precautions you should take before accepting cargoes for shipment and the procedures you should follow for the safe loading and carriage of the nominated cargo.

You will still need to consult the Code to check whether the cargo you are about to carry or carrying complies fully with the Code.

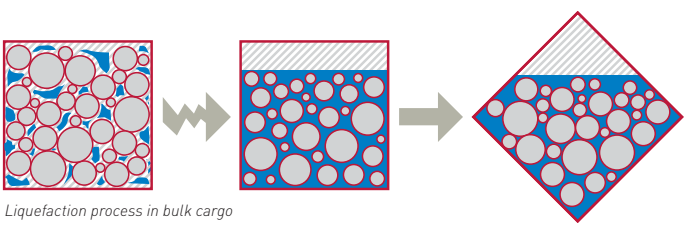
Please note that the IMSBC Code is mandatory under the provisions of the SOLAS Convention. However, some parts of the Code continue to be recommendatory or informative and therefore in the context of the language of the Code, the words "shall", "should" and "may", when used in the Code, should be taken to mean that the relevant provisions are "mandatory", "recommendatory" and "optional", respectively.

[1] *E.g. loss of Bulk Jupiter with 18 lives in January 2015*

WHAT IS **LIQUEFACTION?**

A solid bulk cargo consists of three main components: a solid component; a moisture component; and an amount of air (void space) in between. Vibration and the motion of a vessel will cause the cargo stowed in the holds to compact the moisture and small particles contained in the cargo. In certain conditions a cargo can compact to such an extent that there is no more void space (air) between solid and water particles.

When there is more water inside the cargo than there is space between the particles, and the water has nowhere to go, then the water pressure between the particles may rise and press the particles apart. This will either result in a sliding failure or the wet base of the cargo will transition from a solid state to a viscous fluid.



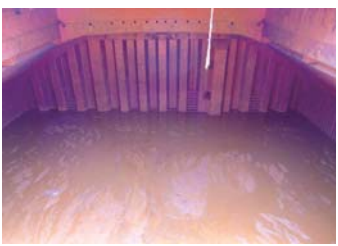
Liquefaction process in bulk cargo

KEY FACTS

Key fact: Liquefaction may occur without additional water content (e.g., from rainwater) if the inherent MC is already too high, yet undetected by improper checks/tests, in which case agitation alone will cause liquefaction as described.

- Space between particles reduces
- Air is expelled
- Water pushes particles apart
- Loss of shear strength
- Solid cargo becomes liquid
- Centre of gravity shifts
- Free Surface Effect
- Ships may capsize

In the liquefied form, the viscous state may unexpectedly flow from one side of the cargo hold to the other, which causes a shift in the centre of gravity of the vessel. This has a dramatic effect on the ship's stability. In heavy seas, the cargo can flow to one side in a roll, and not return with the roll the other way, which progressively leads to the vessel capsizing.



Liquefied cargoes

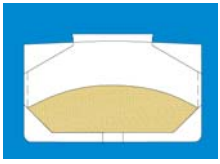
WHAT ARE THE EFFECTS OF **LIQUEFACTION?**

Free Surface Effect

The most significant consequence of cargo liquefying is the vessel's loss of stability (reduction or loss of GM), leading to the vessel listing at a dangerous angle to one side. In some instances, the angle of heel continues to increase, resulting in the vessel listing heavily, down flooding or even capsizing, leading to the loss of the vessel, its cargo and crew.

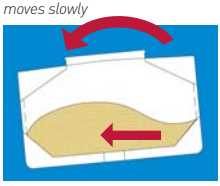
It is vital that the crew are fully aware and have a complete understanding of what happens when a cargo liquefies, and are able to spot warning signs at the earliest possible stage.

Step 1.1 *Liquefied cargo*



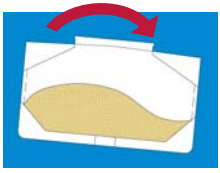
When a bulk cargo liquefies **(Step 1.1)**

Step 1.2 *Ship rolls to port, cargo moves slowly*



it may move towards the lower side of the hold when the ship rolls **(Step 1.2)**

Step 1.3

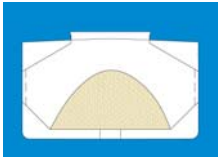


As the vessel rolls in the opposite direction the liquefied cargo may not however flow back, instead remaining towards the side of the hold to which it has already shifted **(Step 1.3)**

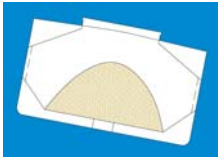
Cargo shift

Another effect is 'sliding'. Sliding is different from liquefaction and may occur when the moisture content is too high, in untrimmed cargoes. The cargo loses its cohesion and becomes less sticky.

Step 2.1 *Untrimmed bulk cargo with high moisture and low cohesion*



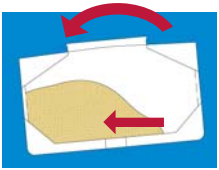
Step 2.2 *Ship rolls*



When a cargo liquefies, it starts to behave like a fluid. This means that it acquires a free surface. The detrimental effect of this free surface (reduction or loss of GM) can be very significant for two reasons:

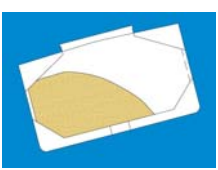
- Bulk carrier cargo holds are single compartments without the centerline bulkheads. Often with heavy cargo they are only half full. This creates the largest possible free surface in the cargo hold.
- Bulk concentrate cargoes are a lot denser than fluids, so the metacentric height reduction is high when the cargo liquefies. This can reduce the stability extensively.

Step 1.4



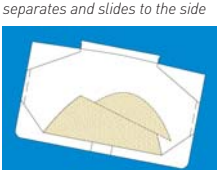
On each subsequent roll, the cargo (in a viscous state) may move further to the same side and build-up **(Step 1.4)**. The resulting cargo may flow to one side of the ship with a roll but not completely return with a roll the other way.

Step 1.5



This causes a rapid build-up of cargo on one side of the vessel and build-up of heavy cargo resting on the ship's side-plating **(Step 1.5)**. The vessel may progressively reach a dangerous angle of heel with down flooding and even capsize quite suddenly with little or no warning.

Step 2.3 *The top of the cargo separates and slides to the side*



Step 2.4 *The cargo has moved to the side resulting in a list*

When the ship rolls, the top part of the cargo can separate and slide to one side. This transposes the cargo and its vertical centre of gravity to one side and affects stability. Liquefaction can also occur along with sliding.

THE "CAN TEST"

Prior to loading a Group A cargo, the actual MC and TML have to be determined, as required by Section 4.2.2.9 of the IMSBC Code. These scientific (laboratory) tests are carried out ashore and more information can be found in paragraph 1.1.4.4 of appendix 2 of the Code.

Currently, the master or other members of the crew can carry out a complementary test (or check) on board, known as the "Can Test" in order to determine approximately whether the cargo they are about to load or loading has the possibility of flowing, i.e. whether the FMP is exceeded or not.

Cargo stockpile

How to do a can test?

Take a cylindrical can, preferably a tin can or similar container of about 0.5 or 1 litre capacity and half fill it with the cargo.

Half full can

After striking on deck

Upturned sample

Hold the can with one hand and bring it down sharply to strike a hard surface such as the deck or a bollard from a height of about 0.2 meters. You need to repeat this procedure 25 times at one to two-second intervals.

Examine the surface for free moisture or fluid conditions. Then turn the can upside down and shake it slightly to dislodge the sample. Examine this as well for free moisture or a fluid condition. In daylight, the surface will be glistening.

If possible, photograph each can test for your own records by marking on deck the location of the sample from where it was obtained (location in cargo pile and depth). Maintain a log of the tests that were carried out and their results.

During the course of loading, the master or a designated crew member is recommended to frequently 'Can Test' the cargo as it is being loaded. This should be from the cargo pile in the hold (tests on cargo piles in barges/ashore are additional but not as conclusive for the 'as loaded' state).

NOTE

Even if a sample remains dry after testing, the MC of the sample may still exceed the TML. The 'Can Test' does not demonstrate that the cargo moisture content is less than the TML but may indicate that the cargo has exceeded its FMP. Only a laboratory test can establish this.

Bauxite hold

LOADING CARGOES **WHICH MAY LIQUEFY**

Some of the known cargoes which may liquefy (Group A) are mineral concentrates that have been refined into ores by eliminating most of the waste materials. They are generally known to be fine-particled material with a moisture content. For example, copper, iron, lead nickel and zinc concentrates. A list of the 'Group A' cargoes extracted from the current IMSBC Code can be found at Appendix 1.

Following the tragic loss of Bulk Jupiter in 2015, bauxite has also been identified as a cargo which may liquefy and the IMSBC Code is in the process of being reviewed[2].

Any 'Group A' cargo whose MC is in excess of the TML can only be carried in specially constructed or fitted cargo ships that have been approved by the Administration. For this purpose, in December 2016 Bureau Veritas issued guidelines for the design of ships subject to bulk cargo liquefaction. See the Bureau Veritas Guidance Note NI 639 DT R00 E for further details on what constitutes a "specially constructed or fitted" cargo ship.

[2] *IMO circular CCC.1/Circ.2 dated 20 October 2015 "Carriage of Bauxite that may liquefy"*

BEFORE LOADING

It is important that the master should not accept concentrates or other cargoes which may liquefy for loading without being provided with the appropriate documentation certifying that the moisture content of the cargo is less than the TML.

Prior to the commencement of loading the master should satisfy himself and confirm that:

- The cargo holds are clean and dry, and the bilges have been tested.
- The hatch covers close correctly and are weathertight.

The following should also be carried out by the shipper and the master:

- The shipper should provide the master well in advance with the appropriate information on the cargo as per requirements found in Section 4.2.2 of the IMSBC Code.
- This information should be accompanied by a declaration by the shipper (Section 4.2.3).
- The master should check, based on the information provided on the cargo declaration, whether the cargo can be safely carried on board the vessel or whether additional information is required.
- The shipper should provide the master with a signed certificate of the TML, and a signed certificate or declaration of the MC issued by an entity recognized by the Competent Authority of the port of loading (Section 4.3.2).
- The master should check that the laboratory test undertaken ashore to determine the TML of a cargo has been conducted within six months of the date of loading the cargo[3] (Section 4.5.1).
- The master should check whether the testing of the MC of the cargo that is being presented is as near as practicable to the time of loading, and not more than seven days (Section 4.5.2).
- If there has been significant rain or snow between the time of testing and loading, check tests (laboratory tests, not can tests) should be conducted to ensure that the moisture content of the cargo is still less than its TML.

NOTE

It is a master's responsibility to ensure that his/her vessel is safely loaded. If a shipper's declaration has not been provided and has not been forthcoming, then the master should not start loading and immediately notify the vessel's owners.

[3] *Where the composition or characteristics of the cargo are variable for any reason, a test to determine the TML shall be conducted again after it is reasonably assumed that such variation has taken place.*

THE LOADING **OPERATION**

Although the carriage of 'Group A' cargoes takes place on a regular basis without incident, the potential consequence of loading an unsuitable cargo due to an unacceptable moisture content requires that the master and crew remain vigilant throughout the loading operation.

Loading should only commence when the shipper has fulfilled the requirements outlined above and the master is satisfied with the information he has been provided with. The master should also complete the ship shore safety checklist as recommended by the Code of Practice for the Safe Loading and Unloading of Bulk Carriers (BLU Code[4]).

The master and owners may consider the appointment of an experienced, independent cargo surveyor in order to check the shore-side stockpile and if necessary take samples. In most ports the master may not be allowed to go ashore to inspect the stock pile.

During loading the master should:

- Arrange for the deck to be adequately manned so as to carry out a visual inspection of the cargo being loaded.
- Be aware of the build-up of water pools or splatter on the bulkheads - this indicates excessive moisture.
- Continue to systematically carry out and record 'Can Tests' as described above.
- Restrict the ingress of water and not load during periods of rain fall.
- Make sure that the hatch covers of all non-working holds are kept shut.
- Ensure that, if the cargo is being loaded from barges, the barges are adequately covered during periods of precipitation and water ingress. If this is not the case, the master should not accept any cargo from these barges unless the moisture content has been re-established.
- If the vessel encounters prolonged periods of precipitation during the loading period, request check tests to ensure that the MC of the cargo is still less than its TML.
- Prior to completion of loading, ensure that the cargo is reasonably trimmed (as per dry bulk cargo good practice).
- On completion of loading, ensure that the hatch covers are closed and secured as required.

NOTE

If during loading the master has reason to suspect that the MC is in excess of the TML, he/she should stop loading the cargo and inform the owners. The master may issue a 'Letter of Protest' and seek further advice from the P&I Club.

[4] *The BLU Code can be found as a supplement to the IMSBC Code*

DURING **THE VOYAGE**

During the voyage the master and crew should continue to monitor the state of the cargo even if they are satisfied about the condition of the cargo they loaded. Some precautionary measures to minimise any potential incidents of cargo liquefaction are as follows:

Monitor the cargo holds regularly to check for any sign of accumulation of free water in the cargo. Although these inspections may not provide a true representation of the cargo condition, they may provide an indication of how the cargo has behaved since it was loaded. However, this should only be carried out if it is safe to enter the holds, as mineral cargoes tend to deplete oxygen levels. It should be remembered that several fatalities have occurred in recent years.

If it is not already part of the ship's routine, sound the cargo hold bilges on a daily basis. Although free water is expected to drain it can hold the moisture towards the bottom of the hold and develop a wet base.

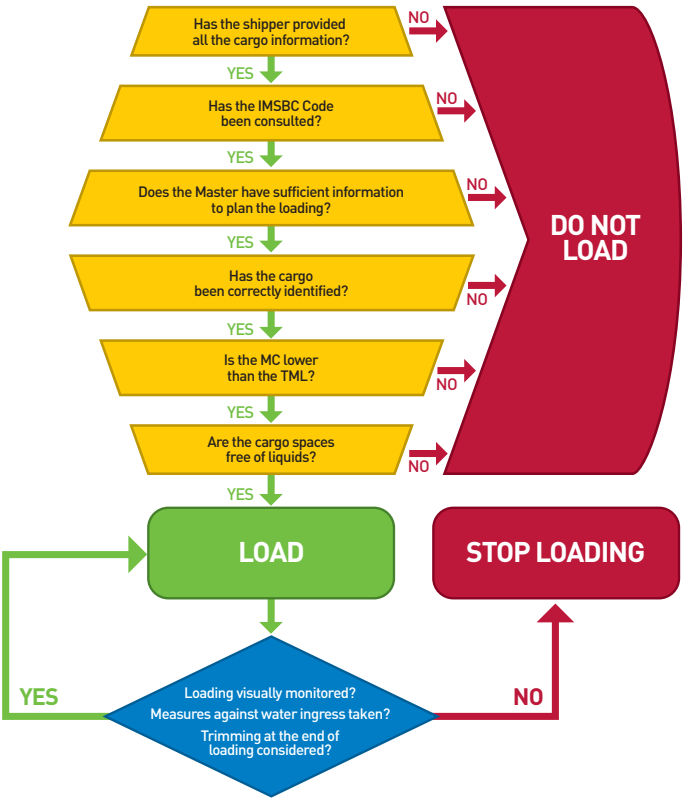
If necessary, consider ventilation of cargo as and when appropriate. This will depend on the advice contained in the IMSBC Code for that particular cargo loaded.

Monitor the vessel's motion, in particular the rolling period. A change in the rolling period may provide a warning of a reduction in the vessel's GM.

If the master or owner has any reason to suspect that the cargo is/has liquefied, they should immediately:

- Contact their P&I Club
- Contact the nearest coastal state authority
- Consider heading to the nearest port or place of refuge
- Consider measures to reduce the vessel's vibration/motion

FLOW DIAGRAM TO BE FOLLOWED **PRIOR TO AND DURING LOADING**



RECENT **DEVELOPMENTS**

On 1st January 2017, the latest amendment, 03-15, to the IMSBC Code entered into force.
The amendments are aimed at dealing with the latest advancements in the transport of cargoes, and are briefly summarised below.

There are 18 new individual schedules of solid bulk cargoes, a majority of which are for Group A cargoes. These schedules provide clarity on the carriage requirements for cargoes that in the past may have created uncertainty. A list of all Group A cargoes and the recent additions to the Group contained in the IMSBC Code can be found in Appendix 1 of this booklet.

The Code now provides new schedules for iron ore fines and scale generated from the iron and steel making process. In the past these Group A cargoes have been associated with a significant number of ship casualties and cargo disputes due to liquefaction.

The most noteworthy amendment to the existing cargo schedules is the replacement schedule for iron ore (Group C). Iron ore cargoes are now defined in terms of particle size and goethite content. The new section 1.4 of Appendix 2 includes a Modified Proctor/Fagerberg test procedure for iron ore fines. This method is used for determining the TML of iron ore fines.

For the purpose of incorporating the requirements of MARPOL Annex V that apply to the management of solid bulk cargo residues, a new regulation, Section 14, has been added which addresses the management of residues of solid bulk cargoes, in relation to the "2012 Guidelines for the implementation of MARPOL Annex V". As per MARPOL Annex V, the management of the residues of solid bulk cargoes depends primarily on the classification of a solid bulk cargo as either harmful to the marine environment (HME) or non-HME. The responsibility for classifying and declaring whether a solid bulk cargo is HME or non-HME lies with the shipper now. This classification will now be included in the cargo information provided by the shipper as per section 4.2.2.2.

A new Appendix 5 containing all the Bulk Cargo Shipping Names (BCSN) can be found in the IMSBC Code appendix under three languages.

APPENDIX 1
GROUP A CARGOES THAT MAY LIQUEFY[5]

- Aluminium fluoride*
- Alumina hydrate (can also be B)
- Aluminium smelting/remelting by-products, processed (can also be B)
- Blende (zinc sulphide)
- Calcined pyrites (can also be B)
- Cement copper
- Chalcopyrite
- Chemical gypsum*
- Clinker ash, wet (can be also B)
- Coal (can be also B)
- Coal slurry
- Coke breeze
- Copper concentrate
- Copper nickel
- Copper ore concentrate
- Copper precipitate
- Copper slag*
- Fish (in bulk)
- Fluorspar (can be also B)
- Fly ash, wet
- Galena (lead sulphide)
- Ilmenite clay
- Ilmenite sand (can be also C)
- Ilmenite (upgraded)
- Iron and steel slag and its mixture*
- Iron concentrate
- Iron concentrate (pellet feed)
- Iron concentrate (sinter feed)
- Iron ore (concentrate, pellet feed, sinter feed)
- Iron ore fines*
- Iron oxide technical*
- Lead and zinc calcines (mixed)
- Lead and zinc middlings
- Lead concentrate
- Lead ore concentrate
- Lead ore residue
- Lead silver concentrate
- Lead silver ore
- Lead sulphite
- Lead sulphite (galena)
- Manganese concentrate
- Manganese ore fines*
- Metal sulphide concentrates (can be also B)
- Mineral concentrates
- Nefeline syenite (mineral)

** New individual schedules of solid bulk cargoes as per amendment 03-15 of the IMSBC Code*

[5] Extracted from Appendix 4 of the IMSBC Code and includes the amendments in force on 1 January 2017

Nickel concentrate

Nickel ore

Nickel ore concentrate

Peat moss (can be also B)

Pentahydrate crude

Pyrites calcined (can be B)

Pyrites

Pyrites
(cupreous, fine, flotation or sulphur)

Pyritic ash (can be B)

Pyritic ashes (iron)

Pyritic cinders

Sand, heavy mineral

Scale generated from the iron and steel making process*

Silver lead concentrate

Silver lead ore concentrate

Slig (iron ore)

Spodumene (upgraded)*

Zinc and lead calcines (mixed)

Zinc and lead middlings

Zinc concentrate

Zinc ore, burnt

Zinc ore, calamine

Zinc ore, concentrates

Zinc ore, crude

Zinc sinter

Zinc slag*

Zinc sludge

Zinc sulphide

Zinc sulphide (blende)

Zircon kyanite concentrate*

NOTES

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