Cargo Liquefaction Risks

Introduction:

Cargo liquefaction can be a problem on bulk carriers as it can cause the ship to lose stability and increase the risk of capsizing, often without warning. This is particularly observed in commodity cargoes, such as iron ore, nickel ore and bauxite, The high-water content of these metals, as well as their fine particle size, means they can liquefy or dynamically separate and then shift, leading to a reduction in stability, which is known as the “free surface effect”.

Casualties:

According to INTERCARGO1, between 2012-2021, 27 bulk carriers of over 10,000 dwt were declared as total losses because of cargo liquefication, which included 70 lives lost in 5 casualties.

- Harita Bauxite (2013) – Sank due to cargo liquefaction, carrying nickel ore from Indonesia, with 15 lives lost.
- Trans Summer (2013) – Capsized and sank due to cargo liquefaction, carrying Nickel ore from Indonesia.
- Bulk Jupiter (2015) - Sank due to cargo liquefaction, carrying bauxite from Kuantan, Malaysia, with 18 lives lost.
- Emerald Star (2017) – Capsized and sank due to cargo liquefaction, carrying nickel ore from Buli, Indonesia, with 10 lives lost.
- Nurl Allya (2019) – Capsized and sank due to cargo liquefaction, carrying nickel ore from Weda Island, Indonesia, with 27 lives lost.

Liquefaction mechanism:

Cargo commodities are typically made up of small particles that stick together, with moisture and air filling the gaps between them, forming a stable solid mass.

On a vessel, the cargo is subject to vibrations and movement. This movement and vibration reduces the volume of the void spaces between the solid particles, pushing the water out from this space. This causes the water pressure between particles to increase.

When the water pressure becomes too high, the bonds between the particles weaken and break by stress, and the cargo begins to act as a liquid. This process is known as liquefaction. If the separated water can escape but cannot drain properly, it may collect on the surface of the cargo, forming a liquid slurry. This liquid slurry can also impair a vessel’s stability and is known as dynamic separation.

Step 1: Normal state of the cargo
Cargo is made up of small particles and there is a small amount of moisture in the void spaces between the particles.

Step 2: External vibration to cargo holds
During voyage, the cargo is subject to vessel vibrations and the movement of the vessel.

Step 3: Increase in water pressure
As the cargo consolidates/compacts by continuous vibrations, the gaps between the particles become tighter, pushing the water out. This increases the water pressure within these gaps.

Step 4: Delinking particles
When the water pressure becomes too high, the bonds holding the particles together weaken and start to break.

Step 5: Liquefication
Particles lose contact with each and move freely past each other in a fluid-like state.

Understanding the IMSBC Code:

The International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS Convention), deals with various aspects of maritime safety and contains, in Chapter VI, the mandatory provisions governing the carriage of solid bulk cargoes. These provisions are extended in the International Maritime Solid Bulk Cargoes Code (IMSBC Code).[2]

The primary aim of the IMSBC Code, which replaced the Code of Safe Practice for Solid Bulk Cargoes, is to facilitate the safe stowage and shipment of solid bulk cargoes, by providing information on the dangers associated with the shipment of certain types of solid bulk cargoes and instructions on the procedures to be adopted when the shipment of solid bulk cargoes is contemplated.[2]

The IMSBC code consists of a main body with several appendices that provide specific information on cargo properties and handling. The structure of IMSBC code is as follows:

- IMSBC Code (Principles)
- Appendices

  Appendix 1: Individual Schedules* of Solid Bulk Cargo
  - Group A (Cargoes with liquefaction or dynamic separation risk)
  - Group B (Cargoes with Chemical Hazards (MHB: Material Hazard only in Bulk))
  - Group C (Cargoes not applicable for A or B)

  Appendix 2: Laboratory Test Procedures, associated apparatus and standards

  Appendix 3: Properties of Solid Bulk Cargoes

  Appendix 4: Index of Materials

  Appendix 5: Bulk Cargo Shipping Names in three languages (English, French and Spanish)

*“Schedules” means detailed information for each solid bulk cargo, including its properties, hazards, handling procedures, and safety measures. Appendix 1 is the one of the most important references to conduct risk assessments of solid bulk cargoes.

Cargoes:

IMSBC Code Appendix 1 Group A deals with cargoes that pose a risk of liquefaction or dynamic separation.

Group A cargoes can only be accepted for loading when the actual moisture content of the cargo is less than its transportable moisture limit (TML).

The TML of a group A cargo means the maximum moisture content of the cargo which is considered safe for carriage in ships not complying with the special provisions of specially constructed or fitted cargo ships for confining cargo shift.[3]

Cargo information:

To check a cargo risk, it is necessary to check cargo information prior to a voyage.

The following are items to check from the shipper [4]:

- ☐ General description of the cargo
- ☐ Gross mass (kg/tons)
- ☐ Specifications of bulk cargo, if applicable
- ☐ Stowage factor
- ☐ Bulk density (as required by SOLAS regulation XII/10):
- ☐ Angle of repose, if applicable:
- ☐ Trimming procedures:
- ☐ Chemical properties if potential hazard*:
- ☐ Group of the cargo: ☐ Group A ☐ Group B ☐ Group C ☐ Group D
- ☐ Transportable moisture limit
- ☐ Moisture content at shipment
- ☐ Certificates ☐ Certificate of moisture content and transportable moisture limit
  ☐ Weathering certificate ☐ Exemption certificate ☐ Other (specify) _____
- ☐ Relevant special properties of the cargo (e.g. highly soluble in water)

Water contents test[5]:

Before loading, the following contents are to be checked in the cargo information, which is provided to the master as appropriate information on the cargo by the shipper.

1. TML and moisture content are stated on the cargo certificate.
2. Whether the test to determine TML of the cargo has been conducted within six months to the date of loading of cargo.
3. The interval between sampling/testing and loading is never to be more than seven days.
4. Whether proper cargo information has been individually provided for each cargo hold to be loaded. (Except in cases where the moisture content of the cargo is clearly uniform.)

The master should not accept the cargo for loading unless the moisture content of the cargo indicated in the cargo information has been confirmed as being less than its TML.

If the moisture content of the cargo is unclear due to significant rainfall between the time of testing and actual loading, the master is to carry out a complementary test (Can Test) or a check test of the moisture contents in the laboratory. However, it is to be noted that the Can Test may not indicate that the moisture contents of the cargo is less than TML, although it may indicate that the moisture contents of cargo exceeds the TML, it is to be considered only as a supplementary test. The letter of the Code is that if free moisture or a fluid condition appears, arrangements should be made to have additional laboratory tests conducted on the material before it is accepted for loading. The following parts of the Code are to be referred to for each test.

(1) Can Test (Paragraph 8.4, Section 8 of the IMSBC Code)

(2) Check Test in the laboratory (Appendix 2 of the IMSBC Code)

Concerns:

Inaccuracy of TML

The typical way to check the TML method is the Flow Table Test. However, this method has some problems. For cargo with fine particles, high moisture content or large grain size (7mm or more), the TML test often fails to accurately reflect the actual liquefaction risk, potentially compromising safety.[6]

Among Group A cargoes listed in the ISMBC code, nickel ore (especially from the Philippines and Solomon Islands as reported by some P&I clubs[7,8]), iron ore fines (Notably from Venezuela[9] and Sierra Leone[10]), bauxite, and direct reduce iron (D) (DRI(D)) have been identified as particularly prone to inaccurate TML measurement. These materials tend to consist of fine particles and high moisture content, which can reduce the reliability of standard testing methods like the Flow Table Test.

Also, FMP (Flow Moisture Point) which is used to calculate TML, can be overestimated. It can therefore cause the TML to be higher than the actual, which means that cargo might be judged as “safe” even when it is unsafe. Overestimated TML can reduce the safety margin and increases the risk of shipment.[6]

It should also be noted that even if a test has been carried out, if the person carrying out the test does not follow the correct procedures or if loading is carried out in the rain, there may be reduced accuracy in human factors or operational issues.

Inadequacies in laboratory test arrangement

Testing by a specialized, accredited surveyor or laboratory is recommended for shipments where the risk is increased by inaccurate moisture content. However, in Venezuela and the Solomon Islands[7,9,] authorized laboratories may be absent or scarce, necessitating remote testing, for example. There are also cases, such as in Sierra Leone[10], where the authenticity of the tests themselves may be questionable. In developing countries, or in countries or regions with a poor export record, inspection systems may be lacking, increasing the risks to cargo shipments.

Precautions:

Here are some focused precautions both on land (before loading) and at sea (after loading).

At cargo exporting origin

Precaution 1: Environment condition which is not suitable for sheltering from rain or humid condition.

Precaution 2: Inadequacies in laboratory test arrangement.

In developing countries that export such cargoes, logistics infrastructure can be inadequate. Transport vehicles may not be equipped to protect cargo from rain, and the distance from the mine to the port can be long, increasing the risk of exposure to rain and humid air. At the storage facilities and port side, there may also be a high possibility that the cargo handling and storage equipment are not sufficiently designed to shield cargo from rain. Even in a dry season, it should also be noted that even if the surface appears dry, the underlying layer may be wet.

This risk is particularly high in humid and rainy regions, such as those located in low latitudes, where intense rainfall can occur in short periods. Special attention is required if the shipper intends to load cargo during the monsoon season.

According to the IMSBC Code, moisture content of cargo samples must be tested within seven days prior to loading. Even if testing is conducted, it is important to note that the moisture content may change between the time of testing and loading due to exposure to rain or humid air. Cargo that has moisture content samples older than seven days should not be loaded.

Additionally, there could be inadequacies in laboratory test arrangements in some countries (see “Concerns”). Or there may have also been reported cases of pressure to change survey results “fit for loading” from the cargo exporting side.[11]

In case there is doubt on moisture contents of cargo or test records, the master of the loading vessel or consignee is advised to request re-testing or refuse loading cargoes until they are cleared of any suspicions since shippers are responsible for safe-cargo-condition.

The following are IMSBC Code cargo sampling interval requirements[4]:

> 4.5 Interval between sampling/testing and loading for TML and moisture content determination
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> 4.5.1 The shipper shall be responsible for ensuring that a test to determine the TML of a solid bulk cargo is conducted within six months to the date of loading the cargo. Notwithstanding this provision, where the composition or characteristics of the cargo are variable for any reason, the shipper shall be responsible for ensuring that a test to determine the TML is conducted again after it is reasonably assumed that such variation has taken place.
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> 4.5.2 The shipper shall be responsible for ensuring that sampling and testing for moisture content is conducted as near as practicable to the date of commencement of loading. The interval between sampling/testing and the date of commencement of loading shall never be more than 7 days. If the cargo has been exposed to significant rain or snow between the time of testing and the date of completion of loading, the shipper shall be responsible for ensuring that the moisture content of the cargo is still less than its TML, and evidence of this is provided to the master as soon as practicable.

During voyage

There are several potential risks of water ingress on board. The most common risk is the intrusion of water into the cargo hold due to rain or waves. If the cargo hatch is properly weathertight, such risks can be significantly mitigated. The weathertight integrity of the hatch can be verified through external condition surveys, with ultrasonic testing being the most accurate method.

Group A cargoes may, by their nature, contain moisture, which should freely drain via the bilges. It should be part of the ship’s daily routine that the cargo hold bilges are sounded daily.

Daily maintenance is also essential to ensure that equipment functions properly when needed. It is important to assess whether the shipowner or management company has the technical and financial capacity to perform such maintenance, and to conduct external condition surveys as needed.

Moreover, crew members must be capable of recognizing early signs of cargo liquefaction and responding appropriately. Nickel ore and iron ore fines are particularly hard to assess visually, making early signs easy to miss. Measures against liquefaction involve not only cargo handling but also proper voyage planning.

Encountering rough weather increases the risk of rainfall and vibration-induced liquefaction, so the use of weather routing is recommended.

Finally, understanding the vessel's trim and condition is essential. Without this knowledge, proper stowage may not be achieved, and inappropriate responses may be taken if liquefaction occurs.

Considerations and Recommended Actions for Shippers and Consignees

1. Understanding Cargo Characteristics and Risks

Shippers must verify whether the cargo falls under IMSBC Code Group A (cargoes that may liquefy or dynamically separate) and manage moisture content to ensure it stays below the TML. There may be other cargoes such as Olive Margine, which are not listed in the IMSBC Code, however, they are known to liquefy. In cases where there is no direct match within the IMSBC Code, Section 1.3 of the IMSBC Code ('Cargoes not listed in the IMSBC Code') must be followed.

Particular caution is required for cargoes such as nickel ore, iron ore fines, and bauxite, which have a high risk of liquefaction.

2. Ensuring Accurate TML Measurement

TML should be measured by a reliable testing facility, and certification proving that the cargo's moisture content is below TML must be issued by an authorized party.

In developing countries such as Solomon Islands or Venezuela, where testing facilities are limited, arranging a proper testing in advance is essential.

As required by the IMSBC Code, necessary documents such as moisture content certificates and TML certificates must be prepared and submitted to the ship's master. Ensuring document accuracy and avoiding false declarations is critical.

3. Cargo Treatment Environmental Management

Loading during rainy weather should be avoided, and measures must be taken to prevent the cargo from becoming wet. The crew should also carefully monitor the loading for any signs of cargo being liable to liquefy (such as splatter on the sides of the cargo hold) and if cargo is extremely wet before loading, then crew could conduct complementary can tests on the cargo for flow characteristics and determine its TML and moisture content, as the liquefaction risk very much remains.

It is recommended to recheck the moisture content before loading and perform drying treatments if necessary.

It is recommended to get verification that a vessel's hatches are weather tight, are in a satisfactory condition by an authorized surveyor. Arrange a condition surveyor if the vessel's condition is in question, if necessary.

4. Collaboration with the vessel's operator

Close collaboration with the vessel's operator, to provide to the master and crew, is crucial to share information about the cargo's characteristics and liquefaction risks by providing accurate and detailed information. In general, when loading Group A cargoes at ports unfamiliar to shippers, and if crew are not familiar with associated risks, transportation and precautions for loading these cargoes, it is recommended to appoint a surveyor.

Discussing and agreeing on cargo monitoring, management methods and emergency response measures in advance is advisable.

To avoid extreme conditions whilst sailing at sea, it is recommended to arrange external weather routing services. Recommended route and voyage progress should be shared among all stakeholders to double or triple check to mitigate the risk. If there is any doubt on one provider, a second opinion by shipper or consignee could be an option to ensure the vessel's safety.

Considerations and Recommended Actions for Underwriters

1. Risk Assessment

Underwriters should evaluate liquefaction risks by considering the cargo type, shipping region, and transportation route in detail.

Where testing facilities are limited and suspected to be inadequate, for example in cargoes from developing countries such as Solomon Islands or Venezuela, underwriters should ensure the reliability of cargo testing; testing method, surveying party, certificate readiness.

Hull risk must be surveyed either by desktop or physically, assessing the vessel's master and crew's skill and experience, owner, ship management company and operators' information, Class and P&I club. Take note that bulk carriers pose relatively higher total cargo loss risk once liquefaction incident occurs, therefore it is important that the P&I Club and vessel owners are reliable and financially heathy.

2. Verification of Shipper's Measures

Verify that the shipper has conducted appropriate TML measurements and moisture management, and request or arrange additional cargo and vessel condition survey or documents if needed.

Investigating the shipper's and consignee's past trading records and loss and/or incident history is crucial for risk assessments. It is favourable that the persons in charge of communication between the shipper and the consignee are closely available at the origin to respond swiftly in case of emergency.

3. Coverage

For cargoes with high liquefaction risk, setting cargo value limits and imposing tailored special conditions (e.g., Vessel condition survey warranty, cargo survey warranty, loading survey warranty, weather routing warranty, mandatory certificate requirement) may be considered.

Propose a conservative premium ideally without attaching a wavier of subrogation as it poses relatively higher total cargo loss risk, and consider tailored coverage design based on ICC(C).

4. Consulting with MRC

Close collaboration with MRC in liquefaction risks is recommended for accurate risk assessments.

Sharing best practices with the client to reduce liquefaction risks and encouraging their implementation is vital.

For further information, please contact your local Marine Risk Consulting team.

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3. IMO, International Maritime Solid Bulk Cargoes (IMSBC) Code, https://www.imo.org/en/OurWork/Safety/Pages/CargoesInBulk-default.aspx

4. IMSBC CODE (Amendment 07-23)

5. ClassNK, Carriage of cargoes which may liquefy (TEC-0845)

6. NorthStandard, Let it flow! The limitations of the flow table test, https://www.nepia.com/articles/let-it-flow-the-limitations-of-the-flow-table-test/

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9. Japan P&I Club, Venezuela - Reactivated Iron Pellets Production at San Felix, https://www.piclub.or.jp/en/news/12018

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11. Japan P&I Club, Indonesia and the Philippines – Safe Carriage of Nickel Ore Cargoes, https://www.piclub.or.jp/en/news/11294