Direct Reduced Iron

Introduction:

Direct Reduced Iron is an iron product made by reducing iron ore with reducing gases, widely used in electric furnace steel making. During ocean transport, they have serious risks such as self-heating, oxidation hazards and liquefaction risk.

Direct Reduced Iron:

Direct Reduced iron (DRI), also called sponge iron, is produced from direct reduction of iron ore (in the form of lumps, pellets or fines) by a reducing gas produced from natural gas or coal[1].

The reducing gas is a mixture majority of hydrogen (H2) and carbon monoxide (CO) which acts as reducing agent. This process of directly reducing the iron ore in solid form by reducing gases is called direct reduction[1].

DRI is produced by passing hot reducing gases such as hydrogen, methane and carbon monoxide over iron ore (oxide), which is usually in the form of pellets or lumps. Although the process is conducted at high temperatures, these are still substantially below the melting point of iron. This means that the lumps and pellets retain their original shape but are considerably lighter owing to the removal of oxygen from the ore. Therefore, the pellets and lumps have a hugely porous structure, which makes the material extremely reactive and prone to re-oxidation on contact with air and/or moisture[1].

Types of Direct Reduced Iron:

DRI is a steel raw material and is available in Cold DRI(CDRI), Hot Briquetted Iron(HBI) and Hot DRI(HDRI).

Cold DRI (CDRI)

CDRI, which is cooled to nearly room temperature after reduction, has many pores formed by the removal of oxygen, and has the property of reoxidizing when exposed to air during long-term storage[2].

Hot Briquetted Iron (HBI)

To resolve CDRI's weak points, HBI is molded without cooling. Instead, the high-temperature reduced iron is compressed and molded into briquettes immediately after the heating process, which reduces the pores. As a result, HBI has reduced properties of reoxidation and solves storage and maritime transport issues, which leads to reduced losses due to powdering during handling2.

Hot DRI (HDRI)

When using DRI produced in a direct reduction plant with an adjacent electric furnace factory, the DRI is immediately transported to the waiting electric arc furnace reducing melting energy required significantly.

Developing transporting and using DRI after the heating process directly to the electric furnace contributes to improved productivity in electric furnaces and reduced CO2 emissions.

Understanding IMSBC Code:

The International Convention for the Safety of Life at Sea, 1974 (SOLAS Convention), as amended, 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)[3].

The primary aim of the International Maritime Solid Bulk Cargoes Code (IMSBC Code) 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].

IMSBC code is consisted of the main body and 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 risk)
  - Group B (Cargoes with Chemical Hazards (MHB: Material Hazard only in Bulk))
  - Group C (Cargoes not applicable for A nor 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)

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

Categories of Direct Reduced Iron[3]:

For ocean transportation, DRI is organized into one of four categories, A to D, according to shape and molding method after refining and moisture content.

DRIs exhibits chemical hazards. They are prone to self-heating and the generation of flammable gases upon contact with water. Therefore, it must be handled in accordance with the IMSBC Code, particularly under the Group B (MHB) schedule. See table 1 for a comparison of the different DRI schedules.

IMSBC Schedule	IMSBC Group	Trade Names	Typical Form	Hazards	Ventilation Requirements	Precautions
DRI (A)	B	HBI	Briquettes	Hydrogen evolution, self-heating	Conducted as necessary	Sealed holds, temp/gas monitoring, cargo loaded in such a way that briquettes do not break and create dust, proper trimming of cargo due to density, no handling in wet conditions, holds to remain open 1 hour after loading, weather permitting. No loading of cargo if cargo's temperature exceeds 65 degrees Celsius or its moisture content is in excess of 1.0% or if the quantity of fines and small particles (up to 6.35 mm in size) exceeds 5% by weight.
DRI (B)	B	DRI	Highly porous briquettes	Self-heating, reacts with air and water to produce hydrogen and heat, oxygen depletion	Do not ventilate. Maintain inert condition.	Cargo shall be aged for at least 3 days prior to shipment, or treated with an air-passivating technique, no hot work near cargo, holds to be kept inerted, cargo loaded in such a way that briquettes do not break and create dust, proper trimming of cargo due to density, no handling in wet conditions No loading of cargo if cargo's temperature exceeds 65 degrees Celsius or its moisture content is in excess of 0.3% or if the quantity of fines and small particles (up to 6.35 mm in size) exceeds 5% by weight, or known to have been wetted.
DRI (C)	B	HBI fines, Metallic HBI fines, Iron Remet fines	Dust/fines	Self-heating, reacts with air and water to produce hydrogen and heat, oxygen depletion	Do not ventilate. Maintain inert condition.	Cargo shall be aged for at least 30 days prior to shipment, no hot work near cargo, holds to be kept inerted, proper trimming of cargo due to density, no handling in wet conditions No loading of cargo if cargo's temperature exceeds 65 degrees Celsius or its moisture content is in excess of 0.3% or if the quantity of fines and small particles (up to 6.35 mm in size) exceeds 5% by weight, or known to have been wetted.
DRI (D)	A & B	DRI fines	Fines	Self-heating, reacts with air and water to produce hydrogen and heat, oxygen depletion, liquefaction	Conducted as necessary	The cargo is extremely complex and hazardous and therefore it is recommended that the shipper appoints a cargo superintendent for the duration of loading, carriage and discharge to ensure all aspects of the complex schedule are met.

Table 1.

Precautions

Above risks are exacerbated by conditions such poor weathertightness and inadequate ventilation (whether ventilating or not). It must also be reminded that the risks are exacerbated by cargo condition and operation such as moisture content, cargo operation during rain, poor storage management and regional factors.

It is essential to maintain a dry condition throughout the entire operation – from loading to discharge - to minimize the risks of self-heating or liquefaction. Careful attention must also be paid to the potential for hydrogen accumulation and subsequent explosion if ignited by accident.

Loading

For DRI (B) and DRI (C), this schedule outlines the following requirements to be fulfilled prior to departure:

The ship shall not sail until the master and a competent person recognized by the competent authority of the port of loading are satisfied:

1 that all loaded cargo spaces are correctly sealed and inerted;

2 that the temperature of the cargo has stabilized at all measuring points and that the temperature does not exceed 65°C; and

3 that at the end of the inerting process, the concentration of hydrogen in the free space of the holds has stabilized and does not exceed 0.2% by volume

In case of DRI (D), even stricter requirements are imposed.

On completion of loading, the ship shall wait for 24 hours (or longer as may be required) before sailing, in order to ensure that:

1 all loaded cargo holds are correctly closed and sealed;

2 the temperature of the cargo at all measuring points is stable and does not exceed 65℃ for at least 12 consecutive hours; and

3 that the concentration of hydrogen in the head space of the holds has

stabilized and does not exceed 1% by volume (25% of the lower explosive limit (LEL)) for at least 12 consecutive hours.

During voyage

Hatch covers shall be kept closed during the voyage to prevent ingress of water.

For DRI (D), there are stricter ventilation management requirements, including the provision of a time-based gas prediction curve and the preparation of backup ventilation equipment.

All DRIs are required to undergo regular monitoring of hydrogen and oxygen concentration and temperature.

As these cargoes are highly sensitive to moisture, bilge wells must be sounded regularly to monitor water levels, and any accumulated water should be pumped out by bilge pumps or other appropriate means.

For DRI (D), the use of weather routing advisory is strongly recommended to prevent liquefaction due to motion and to ensure the stability of the ventilation system.

Unloading

During unloading operations, DRI(B) and DRI (C) explicitly prohibit cargo operation during rain, whereas DRI(D) may permit it under certain conditions, such as in-port operations and non-transshipment.

Extreme caution shall be taken when opening the cargo hatch to avoid any sparks that could ignite accumulated hydrogen and cause an explosion.

Considerations and Recommended Actions for **Shippers and Consignees**

1. **Cargo treatment environmental management**

   DRIs possesses hazardous properties that can lead to serious incidents such as explosions, self-heating, and liquefaction. To mitigate these risks, careful handling is essential, starting from pre-loading storage and ending with post-discharging storage. It is crucial to keep the cargo as dry as possible and in an inert atmosphere to prevent explosion. Cargo operations should never be conducted during rainy conditions, and weather forecasts at the ports must be taken into account.

   The vessel's condition is a key consideration. Condition surveys can be undertaken to verify sufficient weathertight integrity, such condition could be screened through open-source information, or through physical surveys. Use of weather routing could also be considered.

2. **Cargo condition verification**

   Monitoring moisture levels and measuring the atmosphere within the cargo holds are also critical. If signs of danger are reported from the vessel, such as heat generation, accumulation of moisture, or hydrogen and oxygen concentrations approaching or exceeding explosive limits, immediate action and external assistance is required.

3. **Accurate documentation and information sharing**

   Moisture content and the aging condition of the cargo must be certified by an independent inspection body. Accurate information about the cargo, including potential risks, must be communicated to all relevant parties. A contact list of relevant parties involved in the cargo should also be prepared to ensure that prompt action can be taken in case of an emergency.

4. **Reference to the IMSBC code is essential.**

   Collaboration with 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 risks by providing accurate and detailed information. In general, when loading such 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.

Considerations and Recommended Actions for **Underwriters**

1. Risk assessment

First and foremost, it is absolutely essential not to misidentify the type of DRI. Careful verification should be made to ensure that the cargo name provided is accurate. Based on that, all associated risks should be thoroughly assessed.
Where possible, it is recommended to obtain cargo certificates through independent third-party inspection bodies. When such an inspection is conducted, it is also important to evaluate whether the inspection body is trustworthy and to consider any limitation in their testing capabilities.

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 a 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

Sufficient handling capability is required to ensure the condition of the cargo being loaded. It is essential to ensure that the cargo is in a properly dried condition prior to loading in order to guarantee safety. During cargo operations, measures should be taken to prevent rain water from entering unused cargo holds by keeping unnecessary hatch covers closed. Cargo handling should be suspended during rainfall, and a system for continuous weather monitoring should be in place. It should be ensured that loaded cargo remains in an acceptable state. 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

Each DRI has slightly different risks, therefore 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.

Especially, DRI (D) has higher risk than the other three types due to its liquefaction risk. Underwriters should take this risk into account.

Propose a conservative premium ideally without attaching a waiver 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 cargo 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.

1） Cargo Handbook.com, Direct Reduced Iron (DRI),
https://cargohandbook.com/Direct_Reduced_Iron_(DRI)
(Accessed 2025/04/10)

2） Junichi SHIINO*, Tsuyoshi MIMURA and Hiroshi SUGITATSU, MIDREX® Process Challenge for Carbon Neutral,
https://www.rpsj.org/wp-content/uploads/2022/05/G140_07_Shiino.pdf

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