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DIRECT REDUCED IRON BY PRODUCT FINES

A guide to shipping, handling and storage

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Disclaimer

The information presented in this guide is intended as general information only and should not be used in relation to any specific application without independent examination and verification of its applicability and suitability by professionally qualified personnel. Those making use thereof or relying thereon assume all risks and liability arising from such use or reliance.

Document history

This is Version 2 of IIMA's Guide for Shipping, Handling and Storage of Direct Reduced Iron Fines, Version 1 having been published in 2017.

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1. Introduction

1.1 Direct Reduced Iron

Direct reduced iron is produced by the reduction of iron ore by carbon monoxide and hydrogen, as illustrated in simplified form in the equations below:

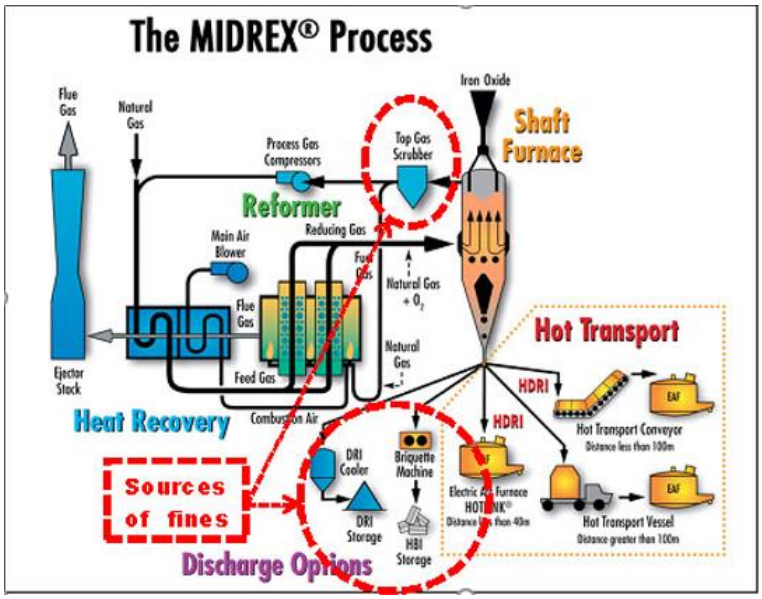
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

There are several processes for direct reduction of iron ore, principally gas-based shaft furnaces (Midrex and ENERGIRON processes) accounting for 76% and coal based rotary kiln furnaces (mainly in India) accounting for 24% of 2019 production (108.1 million tonnes).

Direct Reduced Iron is produced either in pellet/lump form (DRI, designated as DRI (B) in the IMSBC Code[1]) or as Hot Briquetted Iron (HBI, designated as DRI (A) in the IMSBC Code). The principal application for DRI (A) and DRI (B) is as metallic feedstock for electric arc furnace (EAF) steelmaking. DRI (A) or (B) typically contains 90-94% total Fe, of which 80-90% is metallic Fe (typical metallisation being 92-96%).

1.2 Generation and Processing of Direct Reduced Iron Fines

There are two principal sources of fines generation during the direct reduction process, as illustrated in the graphic below, based on the flowsheet of the Midrex process. In an ideal world these fines would be reprocessed and recycled back through the direct reduction process - indeed there are various technologies for doing so, such as cold briquetting and pelletising. However, this is not always the case and there is a significant trade in these fines.



Source: Midrex Technologies, modified by IIMA for sources of fines

It is inevitable that during the discharge of DRI (B) from the furnace and subsequent handling, including briquetting to produce DRI (A) and cooling, there will be some

[1] International Maritime Solid Bulk Cargoes Code (published by the International Maritime Organisation, IMO)

generation of fines through abrasion, etc. Users of DRI (A) and (B) require minimal content of fines in the product. Fines are undesirable in the EAF process as they have a high loss rate to the fume system (where they add unnecessarily to dust volume) and are also trapped in the slag which reduces the yield. Therefore DRI (A) and (B) are screened before shipment, thus generating Metallised DRI Fines. In the case of DRI (A), newly formed hot briquettes are dropped into a quench tank for cooling, a process which also generates some fines (so-called "quench tank fines") which are included with the Metallised DRI Fines.

In the shaft furnace it is inevitable that there will be some generation of dust due to decrepitation of iron ore during the reduction process and this dust is carried off with the off-gas and has to be separated from the gas stream via the off-gas scrubber(s). The dust particles are trapped by the water droplets in the scrubber and channelled as suspended particles, first to a classifier (which separates the larger agglomerated particles) and then to circular clarifiers (for pellet/lump-based processes) or directly to settling ponds and/or filter presses (for fines-based processes). In the case of clarifier equipped plants, flocculants are typically used to lump the finely suspended particles into larger and denser particles which settle more quickly and stably to the bottom of the clarifier and are then pumped to settling ponds or filter presses. This material, known variously as scrubber fines, slurry fines, pond fines, top gas fines, etc. is hereinafter referred to as "Off-gas Fines." Depending on where in the furnace it arises, off-gas fines can range from virtually unreduced oxide fines from the top of the shaft to metallised fines from lower down in the shaft - its metallic iron content thus has a lower and wider range than Metallised DRI Fines.

In gas-based shaft direct reduction furnaces, as in the blast furnace, the process involves a descending column of solids (the iron ore burden) and an ascending column of gas (the reducing gases). In order to ensure complete and uniform reduction of the iron ore, it is essential that the permeability of the iron ore burden is such that the ascending column of gases interfaces with the maximum surface area of the iron ore - the higher the content of iron ore fines in the feedstock, the lower the permeability of the burden. The iron ore feedstock (pellets and lump ore) is therefore screened to remove fines before being charged to the furnace. These screened Iron Oxide Fines can be recycled through an on-site pelletising or briquetting plant if one exists, or sold to third parties.

DRI Fines component	Total Fe %	Metallic Fe%	Carbon %	Gangue %	Moisture %
Metallised DRI Fines	80 - 90	35 - 85	0.5 – 4.0	4.5 – 9.0	2.0 – 9.0
Off-gas Fines	55 - 75	1 - 40	0.5 - 2.5	4.0 - 12.5	4 - 20
Iron Oxide Fines	62 - 68	0	0	2 - 5	2 - 5

Gangue = SiO_2 + Al_2O_3 + CaO + MgO

The preparation of Direct Reduced Iron Fines is as follows:

1. Collection of individual components


Metallised DRI Fines


Off-gas ines


Iron Oxide Fines

2. Screening of individual components to remove over-sized particles

3. Blending and stockpiling of the individual components to meet customer requirements

1.3 3 Shipment of Direct Reduced Iron Fines (DRI Fines)
Shipments can range from 100% Metallised Fines to 100% Off-gas Fines with a variety of blends of the two. Some blends also contain Iron Oxide Fines. Companies specialising in DRI Fines are able to tailor-make their products to suit customer requirements. IIMA member companies have safely shipped about 10 million tonnes of DRI Fines the past 13 years, shipment size being typically between 30,000 and 50,000 tonnes.

Until the current (2023) edition of the IMSBC Code, DRI Fines were designated as Direct Reduced Iron (C). When the DRI (C) schedule was first introduced, the assumption was that DRI (C) would behave like DRI (B) during handling and transportation. The schedule for DRI (C) therefore includes:

- a provision for carriage of a moisture content of <0.3%, a virtual impracticality given the nature of the material as well as the storage and handling processes involved;
- a requirement for the introduction of a dry, inert gas at tank-top level so that the inert gas purges the air from the cargo and fills the free volume above, nitrogen being preferred - such a precaution is appropriate for DRI (B) for which the principal hazard is self-heating, but not for DRI Fines for which the principal hazard is evolution of hydrogen.

From an ocean transportation perspective, DRI Fines with moisture content <0.3% are extremely rarely shipped, if for no other reason than the dust hazard. In practice, DRI Fines are shipped with a typical moisture content of about 5%. DRI Fines have therefore been shipped under exemptions to the above provisions, allowing moisture content ≥0.3% and requiring mechanical ventilation in order to remove hydrogen from cargo spaces.

Discussions at the IMO to introduce a new schedule for DRI Fines, designated DRI (D), have after many years been concluded. The new schedule is now included in the 2023 edition of the Code which becomes mandatory from January 2025 with the possibility of voluntary adoption from January 2024. At 10 pages, the DRI (D) schedule is one of the longest in the IMSBC Code.

The DRI (C) schedule remains in the IMSBC Code in order to cater for the very rare shipment of this cargo.

2. Description of DRI fines for Maritime Transportation

The Bulk Cargo Shipping Name (BCSN) for the proposed new schedule in the IMSBC Code for Direct Reduced Iron Fines has been designated as **Direct Reduced Iron (D) (By-product Fines with moisture content of at least 2%)**, abbreviated hereinafter to DRI (D). This schedule includes the following description:

DRI (D) is a porous, black/grey odourless metallic material generated as a by-product of the manufacturing and handling processes of DRI (A), hot-moulded briquettes and/or DRI (B) lumps, pellets and could-moulded briquettes, which has been aged for at least 30 days prior to loading.

Characteristics of DRI (D) are as follows:

Physical properties			
Size	**Angle of repose**	**Bulk density (kg/m³)**	**Stowage factor (m³/t)**
Fines and small particles with an average size less than 6.35mm, particles larger than 12 mm not to exceed 3% by weight.	Not applicable	1850 to 3,300	0.30 to 0.54
Hazard classification			
Class	**Subsidiary hazard(s)**	**MHB**	**Group**
Not applicable	Not applicable	SH and/or WF	A and B

DRI (D) is thus treated under the IMSBC Code as a Material Hazardous Only in Bulk (MHB), Group A and Group B cargo, but, until the schedule for DRI (D) becomes mandatory from January 2025 or is adopted voluntarily from January 2024, DRI Fines should be handled as prescribed in the relevant Exemption Certificates issued by the competent authorities of Trinidad and Tobago, Venezuela, USA, Canada, the Netherlands, Belgium, the Philippines and other countries as applicable. Exemptions granted by the National Competent Authorities under the provisions of section 1.5 of the IMSBC Code may specify

additional measures which should be implemented along with those in this guide. Applicable exemption certificates should be provided to ship masters.

3. Hazards Associated with DRI (D)

A temporary increase in temperature of about 30°C (86°F) over ambient, due to oxidation and consequent self-heating, may be expected after material handling in bulk.

There is a risk of overheating, fire and explosion during transport due to the fact that this cargo reacts with air, fresh water and seawater to produce hydrogen and heat. Hydrogen is a lighter than air, flammable gas that can form an explosive atmosphere when mixed with air in concentrations above 4% by volume.

Oxygen in cargo holds and in enclosed adjacent spaces may be depleted. Flammable gas may also build up in these spaces. All precautions shall be taken when entering cargo holds and enclosed adjacent spaces.

This cargo may be subject to liquefaction if shipped at moisture content in excess of its Transportable Moisture Limit (TML). Refer to sections 7 and 8 of the IMSBC Code.

3.1 Hydrogen Evolution

The primary hazard associated with DRI (D) is the accumulation of hydrogen in enclosed spaces, such as ships holds and adjacent spaces, because of the generation and release of hydrogen by the material. DRI (D) evolves hydrogen on a continuous basis because it contains moisture. The mechanism involved is the aqueous corrosion of iron. Hydrogen is a lighter than air, flammable gas which can form an explosive mixture in combination with air in concentrations above 4% by volume (the Lower Explosive Limit or LEL). Contact with saltwater will accelerate the rate of hydrogen evolution.

Industry experience suggests that there may be a relationship between cargo temperature (measured as the average readings of thermocouples on or soon after loading) and evolution of hydrogen. Data derived from temperature and gas monitoring of 132 holds carrying DRI (D) was analysed. Of the 132 holds monitored, 51 exhibited a temperature of ≥40°C and of these, 24 exhibited hydrogen concentration of ≥25% LEL. Temperature ≥40°C was the only common cargo parameter observed for the 24 holds which exhibited hydrogen concentration ≥25% LEL. Whilst this relationship is not conclusive, a temperature of ≥40°C is indicative of an approximately even chance that the hydrogen concentration will reach or exceed 25% LEL and should therefore be taken into account in the risk assessment (refer section 5.3.1 point 8).

3.2 Self-heating and Reactivity

Self-heating of DRI (D) on exposure to air (oxygen) and water is a secondary hazard, unlike for DRI (B) where self-heating is the primary hazard. Being a fine material, the permeability of a mass of DRI (D) to air is much less than for DRI (B), i.e. the surface area of material exposed to air is significantly lower and thus its reactivity is correspondingly lower. DRI (D) may exhibit a temporary increase in temperature of up to about 30°C (86°F) above ambient temperature after handling in bulk, for example after being loaded on board a ship. This is due to the temporary exposure of all surfaces of the material to air. The material will normally fall gradually to ambient temperature levels after handling.

3.3 Oxygen Depletion

Enclosed spaces containing DRI (D), e.g. a ship's hold, as well as enclosed adjacent spaces, may become oxygen-depleted, and all due caution should be exercised upon entering such spaces. In the case of maritime transport, the precautions for entry into enclosed spaces as specified by SOLAS[2], the IMSBC Code[3] and by the vessel's ISM[4] procedures must be strictly followed.

3.4 Dynamic Separation and Liquefaction

For the purposes of maritime transport, DRI (D) is effectively an IMSBC Code Group A cargo, i.e. a cargo which may liquefy if shipped at a moisture content in excess of its Transportable Moisture Limit (TML). The TML of DRI (D) varies but is typically in the 9-12% range.

3.5 Dust Emission

As with most bulk cargoes, handling DRI (D) has the potential to generate some dust. Refer sections 4.2 and 5.5 below for further information.

4. Handling and Storage of DRI (D) at Production Sites, Port Terminals and Stockyards

DRI (D) should be protected at all times from contact with water to the extent possible/practicable or as required by applicable regulations, unless as otherwise specified in this guide.

4.1 Handling Equipment

Whether at the production site, the port, intermediate terminal or the end-user's stockyard, handling of DRI (D) is essentially the same in that industry utilises standard bulk material handling equipment of various types, sizes and capacities. All types of conventional bulk material handling equipment can be used, including:

- bucket-wheel stacker-reclaimers
- cranes equipped with magnets or clamshell-type buckets
- front-end loaders, backhoes
- fixed or mobile conveyors and conveyor belt systems
- fixed or mobile bins and hoppers
- if at port terminal or at anchor for mid-streaming operations to barges, ship travelling bridge cranes, fixed cranes, floating cranes and belt systems
- self-release skips
- railcar straddle carriers and rotary dumpers

4.2 Handling of DRI (D) - Dust

Some fine dust may be generated during each stage of material handling and transfer and it is important to minimise the height and number of drops while transporting and handling DRI (D). It may be necessary to use a freshwater spray and/or dust-suppressant mist to supress dust, but this practice should be considered only on a case-by-case basis,

[2] SOLAS Chapter III Regulation 19. 3.6.2. Emergency training and drills
[3] IMO Resolution A.1050(27) 30 November 2011 / Revised recommendations for entering enclosed spaces aboard ships (copied under 'supplements' in the IMSBC Code) (currently undergoing further updating/revision)
[4] International Safety Management Code (published by the IMO)

as any resultant rusting will reduce product metallisation and thus adversely impact the value of the cargo.
Dust from DRI (D) is composed primarily of iron oxide, which if inhaled or in contact with the eye can cause irritation or eye damage. Therefore, in order to minimise the risk of injury to personnel from dust, appropriate personal protective clothing and equipment should be worn/used by personnel working in the vicinity of handling, loading and unloading of DRI (D), especially in a covered area.

4.3 Steaming

DRI (D) will release water vapor in the form of a visible plume after being heavily wetted by precipitation. This so-called "steaming" is often misinterpreted by materials handling personnel as overheating of the material, but is in reality only a normal reaction which poses no hazard to the personnel, material, or surroundings. The DRI (D) can warm up to around 65°C [149°F] or more as the steaming occurs but should normally cool down again to ambient temperature once the free water is driven off. It is not necessary to take any preventive action if the pile is steaming and the temperature does not exceed 100°C [212°F] in isolated pockets. DRI (D) does not overheat as a result of being wetted by precipitation, if properly stored.

4.4 Storage of DRI (D)

DRI (D) can be stored in the following areas or containers:

- stockyards / warehouses (covered or uncovered)
- silos, hoppers or other confined spaces

General guidelines for all forms of storage are to keep the area:

- clean and dry (with proper drainage)
- free of combustible materials: wood, coal, coke, etc.
- free of chlorides or past cargoes: avoid cement, lye, borax
- well-separated from other stored materials
- well-ventilated to avoid hydrogen accumulation

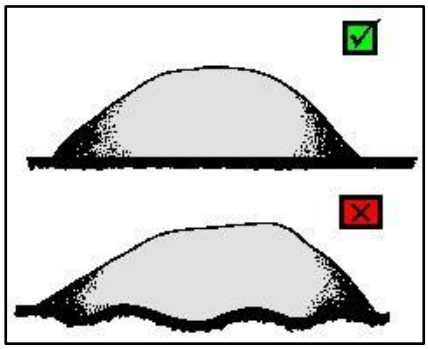
DRI (D) should normally be used or dispatched on a "first-in, first-out" basis. The content of metallic iron decreases over time as a consequence of re-oxidation in the presence of air and moisture, so that material used on a "first-in, last-out" basis will have variable metallic iron content which in turn will negatively affect end-use applications.

4.4.1 Stockyards

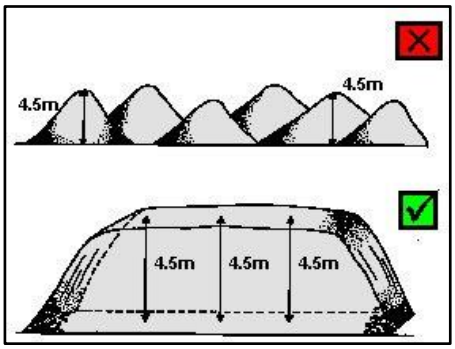
DRI (D) can be stored uncovered in open air without problem, provided that proper precautions are taken and subject to any requirements of the national administration of the port of loading. The storage area should be kept clean and free of any oxidants, combustible and non-compatible materials. Use of a storage pad with a concrete base for open yard storage of DRI (D) is preferable to one with a base of compacted dirt, fill, crushed rock or other materials, as front-end loader operators may accidentally dig into the base when loading the material, pick up unwanted base materials and intermix them with the DRI (D). The storage pad should have adequate drainage in order to prevent standing water.

During storage, the material should be piled such as to allow the greatest possible exposure to the atmosphere and thus facilitate its natural ageing.

As with HBI, it is generally most efficient to stack the DRI (D) in flat-topped, tent shaped piles, typically 4-6 meters high. Tented piles with overlapping bases are not recommended, as conical, tented piles can create a chimney-like effect for hot spots that might occur in the interior of the pile, which may in turn accelerate the heating of the pile (albeit less likely for DRI Fines than for DRI and HBI). Overlapping piles make it difficult for equipment to access and isolate potential hot spots and thereby mitigate increases in pile temperature, or to undertake emergency procedures effectively.



Storage base



Stacking

Diagrams courtesy of BHP

If possible and practical, DRI (D) piles should be covered in order to reduce the risk of rapid re-oxidation. All sources of ignition, such as welding, gas torches, grinding, smoking, etc., should be kept away from DRI (D) piles to reduce the risk of accidents and signs prohibiting such activities are recommended.

4.4.2 Silos, bins and hoppers

Some simple rules should be followed for the safe handling of DRI (D) in silos, bins and hoppers:

1. storage bins must be covered and protected against rain and flooding;
2. bins and hoppers must be designed for complete discharge, with slopes of the walls and bottom greater than 50° to avoid material stagnation/cohesion;
3. construction designs of storage silos, bins and hoppers should be such as to avoid creation of an air drafting effect during periods of strong wind with consequent additional internal air flow;
4. bins with capacities larger than 100 tons must be equipped with dust collectors at the upper areas;
5. bins and other bulk storage equipment/facilities should be equipped with thermocouples capable of activating an alarm system if the temperature exceeds 100°C [212°F) in any area;
6. the hydrogen concentration in the void space of an enclosed silo, bin or hopper should be monitored;
7. mechanical ventilation is highly recommended - experience from maritime transportation of DRI (D) indicates that natural ventilation may be insufficient to dissipate accumulated hydrogen in a large container such as a ship's hold, silo, hopper, etc. to safe levels (i.e. below 1% by volume or 25% LEL). Mechanical ventilation shall exhaust to a safe area. All inherent risk associated with the location of the ventilation discharge points shall be considered and risk mitigation measures taken to address any such identified potential risk as appropriate.

5. Maritime Transport of DRI (D)

The following types of ship have been used for ocean transport of DRI (D):

- dry bulk carriers: single-deck, handy-size, handy-max, supra-max, or Panamax with hydraulically or mechanically operated type or twin-fold type hatch covers of watertight construction;
- double-deck (tween deck) vessels are not recommended for shipment of DRI (D).

In writing this section, given that the IMSBC Code schedule for DRI (D) is very comprehensive, it was concluded that the most effective approach would be to reproduce the schedule itself, with one exception being that the information contained in the Appendix is incorporated into the main text for the sake of continuity. Some additional notes from IIMA have been added in blue text where appropriate, as have some explanatory footnotes.

Direct Reduced Iron (D)
(By-product fines with moisture content of at least 2%)

Description
Direct reduced iron (DRI) (D) is a porous, black/grey odourless metallic material generated as a by-product of the manufacturing and handling processes of DRI (A) hot-moulded briquettes and/or DRI (B) lumps, pellets and cold-moulded briquettes, which has been aged for at least 30 days prior to loading.

Characteristics

Physical properties			
Size	**Angle of repose**	**Bulk density (kg/m^3)**	**Stowage factor (m^3/t)**
Fines and small particles with an average size less than 6.35mm, particles larger than 12 mm not to exceed 3% by weight.	Not applicable	1850 to 3,300	0.30 to 0.54
Hazard classification			
Class	**Subsidiary hazard(s)**	**MHB**	**Group**
Not applicable	Not applicable	SH and/or WF	A and B

Hazard

- Temporary increase in temperature of about 30°C over ambient, due to oxidation and consequent self-heating, may be expected after material handling in bulk.
- There is a risk of overheating, fire and explosion during transport due to the fact that this cargo reacts with air, fresh water and seawater to produce hydrogen and heat. Hydrogen is a lighter than air, flammable gas, that can form an explosive atmosphere when mixed with air in concentrations above 4% by volume.
- Oxygen in cargo holds and in enclosed adjacent spaces may be depleted. Flammable gas may also build up in these spaces.
- This cargo may liquefy if shipped at a moisture content in excess of its transportable moisture limit (TML). See sections 7 and 8 of this Code.

Stowage and segregation

- "Separated from" goods of classes 1 (division 1.4S), 2, 3, 4 and 5, and class 8 acids in packaged form (see the IMDG Code).
- "Separated from" solid bulk materials of classes 4 and 5.
- Goods of class 1, other than division 1.4S, shall not be carried in the same ship.
- Boundaries of compartments where this cargo is carried shall be resistant to fire and passage of liquid.

Hold cleanliness

The cargo spaces shall be clean, dry and free of salt and residues of previous cargoes. Prior to loading, wooden fixtures such as battens, loose dunnage, debris and combustible materials shall be removed.

Weather precautions

Storage in the open air shall be permitted prior to loading, subject to any requirements of the competent authority of the port of loading. During storage, the material shall be piled such as to allow the greatest possible exposure to the atmosphere and thus facilitate its natural ageing.

When a cargo is carried in a ship other than a ship complying with the requirements in 7.3.2 of this Code, the following provisions shall be complied with:

1. the moisture content of the cargo shall be kept less than its TML during loading operations and the voyage;
2. unless expressly provided otherwise in this individual schedule, the cargo shall not be handled during precipitation;
3. unless expressly provided otherwise in this individual schedule, during handling of the cargo, all non-working hatches of the cargo spaces into which the cargo is loaded, or to be loaded, shall be closed; and
4. the cargo in a cargo space may be discharged during precipitation provided that the total amount of the cargo in the cargo space is to be discharged in the port.

Loading

- Prior to loading this cargo, the shipper shall provide the master with a certificate issued by a competent person recognized by the competent authority of the port of loading, stating that the cargo does not meet the criteria for class 4.2 materials.[5]
- As the density of the cargo is extremely high, the tank top may be overstressed unless the cargo is evenly spread across the tank top to equalize the weight distribution. Due consideration shall be given to ensure that the tank top is not overstressed during the voyage and during loading by a pile of the cargo.
- Prior to loading, the cargo shall be prepared and aged naturally for a minimum of 30 days. Prior to loading this cargo, the shipper shall provide the master of the ship with a certificate issued by a competent person recognized by the competent authority of the port of loading stating that the cargo has been prepared and aged naturally for a minimum of 30 days.
- Prior to loading, the temperature of the cargo in the stockpile to be loaded shall be measured by the shipper for three consecutive days and recorded in a log. Measurements shall be taken 20 to 30 cm below the surface and at 3-metre intervals over the length and width of the stockpile. The cargo shall not be loaded if its temperature is in excess of 65°C.
- Appendix**: Precautions to be taken by the shipper prior to and during loading**
  1. The cargo temperature shall be monitored by the shipper for the three days prior to loading to verify temperature stability. Measurements shall be recorded in a log

[5] Substances liable to spontaneous combustion.

detailing the temperature for each lot of cargo loaded, a copy of which shall be provided to the master prior to sailing.
2. Material exhibiting temperature instability beyond the temporary increase of up to about 30°C or with a temperature above 65°C shall not be loaded.
3. If necessary, once the pre-shipment moisture content has been determined, each pile of cargo to be loaded may be covered with tarpaulins and during loading, the tarpaulins progressively removed as the pile is loaded. In the event of precipitation during loading such that a pile becomes wet, loading from such a pile shall be suspended and, weather permitting, loading shall be resumed from a different pile which has been tested for moisture content. The wet material shall be resampled for moisture content pursuant to 4.5.2 of the IMSBC Code[6] and, such moisture content to be certified as suitable for loading by a competent person recognized by the competent authority of the port of loading.
4. Prior to loading and after loading has been stopped due to precipitation, the shipper shall ensure that the conveyor belts and all other equipment used for loading this cargo contain no accumulations of water or other substances.
5. Each time loading operations are commenced or resumed, all conveyor belts shall be operated unladen, but not over a cargo hold.[7]

- Care shall be taken by all parties concerned to ensure that particles coarser than 6.35 mm are, as far as is practicable, evenly distributed throughout the entire cargo, in order to avoid build-up of concentrations of coarse material.
- Trim in accordance with the relevant provisions required under sections 4 and 5 of this Code.
- The cargo temperature shall be monitored during loading and recorded in a log detailing the temperature of each lot of cargo loaded, a copy of which shall be provided to the master.
- Hatch covers shall, weather permitting and subject to the absence of precipitation, remain open after completion of loading of the respective holds and placement of thermocouples, in order to allow cooling of the cargo, stabilization of cargo temperature and natural ventilation of the hold. Otherwise, hatches shall be closed and sealed immediately upon completion of loading and placement of thermocouples. Monitoring of temperature and hydrogen concentration shall then be commenced.
- 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°C 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.
- If after loading and before sailing any cargo temperatures are found to be in excess of 65°C, the material so affected shall be allowed to cool naturally to 65°C or less, or be cooled by mechanical intervention prior to sailing, for example with a front end loader, subject always to proper monitoring and safety precautions being in place. Other measures may be specified by the competent authorities concerned.
- On completion of loading and before sailing, a certificate shall be issued by a competent person recognized by the competent authority of the port of loading, stating that:
  1. the proportion of material larger than 12 mm is no more than 3% by weight;
  2. the moisture content of the cargo loaded is at least 2% and below the TML[8]; and

[6] See Appendix 1.
[7] From IIMA: in addition to conveyor belts, this applies also to vessel loading gear and all other loading equipment.
[8] Re the TML, refer to sections 4.3 of the IMSBC Code and MSC.1/Circ.1454/Rev 2 (see Appendix 1). If the cargo is being loaded from barges, refer to section 4.3.4 in particular.

3. the temperature of the cargo loaded does not exceed 65°C.

Precautions

- It is recommended that an experienced cargo technician appointed by the shipper be on board the ship during loading and throughout the voyage.[9]
- Prior to loading, the shipper shall provide the master with comprehensive information on the risk of hydrogen evolution and the factors which may affect the rate thereof.
- Such risk assessment may include, but not be limited to:
  1. expected weather conditions;
  2. such information as is then available on the hydrogen evolution rate;
  3. planned speed of the ship;
  4. availability and accessibility of ports of refuge en route; and
  5. distance to the port of discharge.
- It is strongly recommended that weather routing be utilized in the above-mentioned risk assessment.
- Prior to shipment, the master, with the aid of the shipper and/or the cargo technician if appointed, shall ensure that all concerned crew members have been informed about and understand the potential risks associated with the carriage of this cargo. Such knowledge exchange shall be recorded in the ship-shore safety checklist.[10,11]
- The shipper shall ensure that expert advice is available at all times during the voyage and shall provide relevant contact details to the master prior to sailing.
- Any material that has become wetted, for example, due to precipitation, shall not be loaded unless such material has been rectified regarding its moisture content.
- In the event that a hold carrying this cargo has to be closed prior to completion, for example, due to precipitation, such hold shall be monitored for hydrogen concentration as frequently as required and ventilated to keep the hydrogen concentration less than 1% by volume (25% LEL).
- The ship's cargo holds shall be provided with the means of reliably measuring the temperatures at several points within the stow and the concentrations of hydrogen and oxygen in the cargo hold atmosphere during the voyage without entering the cargo holds.

[9] IIMA strongly recommends the appointment of a cargo technician. Experienced means qualified/trained in: basic maritime safety; understanding of direct reduced iron and its behaviour; ocean transport and storage of direct reduced iron; use of portable instruments for temperature and gas monitoring.

[10] From IIMA: Refer to section 4.2 of the IMSBC Code entitled "Provision of information" for full details of information to be provided.

[11] From IIMA: It is recommended that, as for all potentially flammable cargoes, prior to loading the Master with the aid of the shipper and/or the cargo technician shall ensure that all concerned crew members have been informed about and understand the potential risks associated with carriage of DRI (D). Such knowledge exchange shall be recorded in the ship-shore safety check list. Such information may include:

a) copy of this guide
b) material safety data sheet
c) copy of the IMSBC Code schedule for Direct Reduced Iron (D)
d) copy of the BLU Code 'Ship Shore Safety Check List' signed by both parties

Such measuring devices shall be suitable for use in an oxygen-depleted atmosphere and of a certified safe type for use in an explosive atmosphere.[12,13,14]

- Holds carrying this cargo and adjacent spaces may become oxygen-depleted. No person shall enter a loaded cargo space or enclosed adjacent space unless such space has been ventilated and the atmosphere tested and found to be gas-free and to have sufficient oxygen to support life.[3]
- Appendix: **Additional precautions to be taken**[15]
  1. Where practical, ballast tanks adjacent to the cargo holds containing this cargo, other than double-bottom tanks, shall be kept empty.
  2. Bilge wells shall be clean, dry and protected from ingress of the cargo with non-combustible material. Bilge wells shall be checked regularly for the presence of water. If water is found, it shall be removed by pumping or draining the bilge wells.
  3. The introduction of moisture and accumulation of condensation in the cargo holds shall be avoided.
  4. Appropriate precautions shall be taken to protect machinery and accommodation spaces from the dust of the cargo. Due consideration shall be given to protect sensitive equipment such as radars and exposed telecommunications equipment from the dust of the cargo.
  5. Persons who may be exposed to the dust of the cargo shall wear protective clothing, goggles or other equivalent dust eye-protection and dust filter masks, as necessary.
  6. During any handling of this cargo, "NO SMOKING" signs shall be posted on decks and in areas adjacent to cargo holds, and no naked light shall be permitted in these areas. Smoking, burning, cutting, chipping, grinding or other sources of ignition shall not be allowed in the vicinity of cargo holds containing this cargo at any time.
  7. All electrical equipment within any cargo hold in which this cargo is carried shall be of a certified safe type for use in explosive atmospheres or effectively isolated from the electrical supply.
  8. Prior to loading, an ultrasonic test or another equivalent method shall be conducted to ensure weathertightness of the hatch covers and closing arrangements, and all readings shall confirm weathertightness.
  - Appendix: **Duties of the cargo technician**
  - The cargo technician, if appointed, shall:
    1. Monitor the loading operations and provide advice as appropriate.
    2. Advise on and supervise the installation of thermocouples in the cargo holds for temperature monitoring, monitor the performance of the thermocouples, and keep the master informed accordingly; if a cargo technician is not appointed, the shipper shall advise on and supervise the installation of the thermocouples in the cargo holds.

[12] From IIMA: Gas monitors using catalytic bead or electrochemical (diffusion type) sensors should be fitted for reliable hydrogen detection. Sensors based on infrared technology do not warn against hydrogen explosion dangers and should therefore not be used. A minimum of two (three preferred) gas monitors equipped with the approved type of gas sensors should be on board the ship prior to loading DRI (D). The ship's hatch covers should be fitted with appropriate sampling points (minimum one, preferably two) for the measurement of gases in each cargo hold to contain DRI (D). Normally, a tube extends from the sampling point to approx. 2 metres below the weather deck level and at least the same distance above the cargo surface. All monitoring equipment shall be operational and properly calibrated at the commencement of loading.

[13] From IIMA: All monitoring equipment shall be operational and properly calibrated at the commencement of loading.

[14] From IIMA: The ship's cargo hold coaming shall be fitted with an appropriate sampling point for the measurement of hydrogen and oxygen gases in each hold. Normally, a tube extends from the sampling point to approximately two metres below the weather deck level and at least the same distance above the cargo surface.

[15] From IIMA: Prior to loading, the shipper shall ensure that conveyor belts and all other equipment used for loading DRI (D) contain no accumulations of water, snow or other substances.

3. Monitor and report on the cargo parameters, namely temperature and hydrogen and oxygen concentrations, as well as other data or information relating directly to cargo behaviour, such duty to include taking readings in conjunction with designated crew members and ensuring that readings are communicated on a regular and frequent basis to the master, or their designated representative, who shall forward them to the shipper to seek appropriate advice.
4. Assist and advise the master and crew in the development of the time-based gas prediction curve and the frequency of updating thereof.
5. Advise and coordinate with the master and crew, as appropriate, in connection with the operation of the ventilation systems.
6. Provide advice and assistance to and cooperate with the master and crew in case of an emergency pertaining to the cargo.

- In carrying out such duties the cargo technician shall act in an advisory capacity and be subject to the authority and decision of the master of the ship.
- In the absence of the appointment of a cargo technician, the master or their designated representative shall seek advice from the shipper or other competent person.

Ventilation

- During the voyage, mechanical surface ventilation shall be provided in each cargo hold carrying this cargo, in order to keep the hydrogen concentration less than 1% by volume (25% LEL). The mechanical surface ventilation system shall be of a certified safe type for use in an explosive atmosphere, capable of ventilating the cargo surface, as stipulated in 3.5 of this Code. Suitable wire mesh guards shall be fitted over inlet and outlet ventilator openings.
- Added by IIMA:
  Ventilators shall be non-sparking, in compliance with IACS URF29 Rev6.[16, 17]
  1. The air gap between the impeller and the casing shall be not less than 0,1 of the shaft diameter in way of the impeller bearing but not less than 2 mm. It need not be more than 13 mm.[18]
  2. Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet ventilation openings on the open deck to prevent the entrance of objects into the fan housing.
  3. The impeller and the housing in way of the impeller are to be made of alloys which are recognised as being spark proof by appropriate test
  4. Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials. Furthermore, the installation on board of the ventilation units is to be such as to ensure the safe bonding to the hull of the units themselves.
  5. Type tests on the finished product are to be carried out in accordance with the requirements of the Classification Society or an equivalent national or international standard
- Mechanical surface ventilation shall be available at all times, either by compliance with the Load Line Convention, Annex I, regulation 19(3), or by adopting measures to avoid a situation whereby the cargo hold mechanical ventilation system could not be used due to

[16] https://iacs.org.uk/resolutions/unified-requirements/ur-f
[17] IACS recognises either the NEC (Class 1, Division 1, Group B) or ATEX (Group 11C) certification as the bodies for which guidance is given on motors available to work in Hydrogen enriched environments.
[18] (a) The minimum air gap in the vicinity of the impeller bearing should be 0.1 times the shaft diameter; (b) however, this minimum gap should not be less than 2 mm; (c) on the other hand, there is no need for the air gap to exceed 13 mm. **Optimal Gap**: aim for the specified air gap (0.1 times shaft diameter or 2 mm, whichever is greater). **Regular Inspection**: regularly inspect and measure the gap to ensure it remains within the recommended range.

rough seas, such measures to be in keeping with good seamanlike practices[19] as for similar cargoes emitting intermittent combustible gases and advice from weather routing service providers.

- Ventilation shall be such as to provide surface ventilation and to avoid the possibility of the build-up of flammable gas/air mixtures. Ventilation other than surface ventilation shall not be applied and on no account shall air be directed into the body of the cargo.
- In order to minimize the possibility of the introduction of oxygen and moisture into the cargo holds, periods of surface ventilation shall be limited to the time necessary to remove hydrogen which may have accumulated in the cargo holds and maintain the hydrogen concentration below 1% by volume (25% LEL).
- Mechanical ventilation shall be such as to enable an airflow of at least 1.2 m^3 per hour per tonne of cargo in each hold carrying this cargo when needed, and in any case shall have an adequate capacity to ventilate down to a concentration of 0.2% hydrogen by volume (5% LEL) or less.
- Prior to loading, an inspection of the mechanical ventilation system shall be conducted to ensure that it is functioning properly.
- Two spare sets of ventilation equipment of a certified safe type for use in an explosive atmosphere shall be available on board the ship during the voyage. A crew member or other person with the ability to install the spare fans shall be available on board throughout the voyage.
- In addition, natural ventilation shall be provided in enclosed cargo holds intended for the carriage of this cargo.
- The operating period and frequency of the ventilation system shall be determined based on the measured hydrogen concentration and the indicated rate of increase/decrease thereof over time. It is therefore very important to establish a time-based gas prediction curve (see the appendix to this schedule). Such curve shall be first determined prior to sailing and, recognizing that conditions can change during the voyage, be updated from time to time during the voyage as may be appropriate, for example in the case of seawater intrusion into a hold carrying this cargo.
- Based on the time-based gas prediction curve(s), the risk assessment shall as soon as possible be updated accordingly, and the voyage plan shall be optimized to avoid a situation where the cargo hold mechanical ventilation system might not be able to be used due to rough seas for periods greater than the estimated time for the concentration of hydrogen to reach 1% by volume (25% LEL). The port authorities at planned ports of refuge shall be advised in advance and a confirmation that access would be granted shall be obtained prior to adding such port to the voyage plan.
- The risk assessment, voyage plan, and weather routing, if adopted, shall be updated as frequently during the voyage as updates on the weather become available, as well as actual hydrogen evolution rates.
- Gases in the cargo holds carrying this cargo shall be removed by extraction, rather than by blowing in the air from outside. Mechanical ventilation exhaust shall be directed to a safe location, away from personnel. All inherent risks associated with the location of the ventilation exhaust openings shall be considered and risk mitigation measures shall be taken to address any such identified potential risk, as appropriate. Ventilation shall be such that exhaust gases cannot enter living quarters in hazardous concentrations.
- In the event that mechanical ventilation cannot be operated for whatever reason (for example in the event of mechanical breakdown or electrical failure):
    1. continuous natural ventilation shall be applied until mechanical ventilation is restored; repairs to the non-functioning ventilator shall, if practicable and safe, be

[19] From IIMA: Good seamanlike practice is generally recognized as some act, precaution or measure taken by a reasonable and prudent mariner; using skill, experience and available resources, to help foster common sense solutions that ensure the safety and preservation of the crew, the ship, and the environment, as well as safeguarding cargo interests.

carried out away from cargo holds containing this cargo; a ventilator which cannot readily be repaired shall be replaced with a spare one;
2. if necessary and practicable, use other available means of forced ventilation, preferably in extraction mode;
3. weather routing advice, if available, shall be updated as soon as possible and, where appropriate, consideration shall be given to re-routing and/or adjusting speed to avoid heavy weather;
4. the frequency of monitoring of hydrogen concentration and cargo temperature shall be increased;
5. subject to the discretion of the master, during heavy seas, consideration shall be given to leaving open one or more of the natural vents on the leeward side that are situated in locations protected from the serious effects of the heavy weather, in order to provide some useful dissipation of hydrogen gas from the holds;
6. mechanical ventilation shall be restarted as soon as possible and operated continuously until the concentration of hydrogen falls to or below 0.2% by volume (5% LEL), and thereafter operated, as necessary, to sustain the hydrogen concentration below 1% by volume;
7. due care shall be exercised in restarting the ventilation, both mechanical and natural, so as not to create an ignition source; and
8. seek advice from the shipper or other suitably qualified expert, as appropriate.

- In all cases, mechanical ventilation shall be operated for an appropriate period of time prior to discharge.
- **Appendix**: **Development of time-gas gas prediction curve**
  A time-based gas prediction curve is an important tool for understanding the likely rate of evolution of hydrogen from this cargo. In order to develop such a curve, a cargo hold shall be ventilated until the hydrogen concentration falls to or below 0.2% by volume (5% LEL), then ventilation (both natural and mechanical) to such hold shall be stopped, and the hydrogen concentration measured every 2 hours thereafter for at least 24 hours or until it reaches 1% by volume, whichever occurs first. If the concentration reaches or exceeds 1% by volume, the respective cargo holds shall be ventilated and measurements continued to ensure that the concentration of hydrogen has stabilized and remains sustainably at or below 0.2% by volume (5% LEL). Based on this data, the length of time needed to reach a concentration of 1% by volume in the absence of ventilation shall be calculated and employed for updating the voyage plan and optimizing the weather routing.

Carriage

- The concentrations of hydrogen and oxygen and cargo temperature in holds carrying this cargo shall be measured daily during the voyage in the presence of or by the ship's designated crew member or representative, or by or under the supervision of the cargo technician, if appointed, and the results of such measurements shall be recorded in a log, given to the master, and kept on board for a minimum of two years.[20,21]
- The frequency of monitoring shall be determined on the basis of the information provided by the shipper, the advice of the cargo technician if appointed, and the information obtained through the analysis of the atmosphere in the cargo holds. Consideration shall be given to increasing the frequency of cargo monitoring following periods of bad weather or following mechanical breakdown of the ventilation system.
- As soon as the results of monitoring indicate that the hydrogen concentration is approaching or has reached 1% by volume (25% LEL), the following precautionary measures shall be taken:

[20] From IIMA: Any crew member responsible for operating monitoring equipment shall have been fully trained in its use.
[21] From IIMA: It should be understood that cargo heating may be localised and may not be immediately detected by the thermocouples. Thus, monitoring the levels of hydrogen and oxygen in the cargo holds is an important early stage indicator of heating.

1. verify proper operation of the mechanical and natural ventilation systems;
2. maintain, and if possible, increase mechanical and natural surface ventilation until the hydrogen concentration falls to or below 0.2% by volume (5% LEL);
3. take care to prevent any spark generation or other potential source of ignition in the vicinity of the cargo holds, adjacent spaces, or open decks; and

.1 increase the frequency of monitoring of the hydrogen concentration in the cargo holds with the proper equipment, preferably to hourly, provided always and to the extent that prevailing conditions permit.

- If the hydrogen concentration remains above 1% by volume after such increased monitoring and ventilation, seek expert advice. Other than in the case of last resort, opening the hatches for the purpose of additional ventilation shall be undertaken only following receipt of relevant expert advice. Personnel shall under no circumstances enter the affected cargo spaces.
- A cargo temperature of 65°C in a cargo hold is an indicator of a potential emergency situation and is, therefore, a trigger for increased monitoring and vigilance, as well as preparation for dealing with the emergency. In such cases, the following precautionary measures shall be taken:
  1. if possible, increase the rate of mechanical and natural ventilation to dissipate heat and any hydrogen;
  2. monitor temperatures every 2 to 3 hours and hydrogen concentration every hour if possible, but in any event not less frequently than every 4 hours, provided always and to the extent that prevailing conditions permit;
  3. do not use CO_2, water or steam on the cargo;
  4. monitor hydrogen and oxygen levels in adjacent cargo holds and spaces and if possible, ventilate them;
  5. if possible, check for bulkhead heating in adjacent cargo holds; if significant bulkhead heating is detected from within an empty cargo hold, spray with water from the empty cargo hold side, provided the bulkheads are mechanically sound (water shall not be allowed to enter into contact with this cargo);
  6. check for signs of abnormal heat in affected sounding pipes and air pipes; and
  7. if and when the temperature returns sustainably to 65°C or less, regular monitoring procedures shall be resumed.
- In the event that the cargo temperature reaches or exceeds 100°C, follow the emergency procedures given in the appendix to this schedule.
- Additional note by IIMA: If the integrity of the cargo holds or hatch covers is breached for any reason and the cargo of DRI (D) comes into contact with water[22]:
  1. hatches shall normally remain closed while at sea to prevent the entry of water into the cargo holds. Except in case of emergency, under no circumstances shall water be allowed to enter the cargo holds.
  2. first eliminate the source of water ingress if possible;
  3. maintain ventilation in accordance with section 5.3.1 above;
  4. increase the frequency of monitoring of hydrogen concentration, preferably to hourly, but no less than every four hours, provided always and to the extent that prevailing conditions permit.
  5. if the hydrogen concentration is approaching or has already reached or exceeded 1% by volume (25% LEL) on a sustained basis, refer to the above precautions in this section;
  6. monitor the temperature of the cargo every hour and if cargo temperature increases to >100°C (212°F) refer to the emergency measures immediately below.

[22] From IIMA: A likely consequence of significant water intrusion is evolution of steam and hydrogen. If there is free-standing water over the cargo surface, bubbling and/or steaming may occur, perhaps not until 16-24 hours after the intrusion. Changes in the colour of the cargo surface may be evident.

7. in the event of water intrusion, the affected hatches shall not be opened other than in the case of last resort and personnel shall enter the holds only in extremis, exercising extreme caution and following procedures for safe entry.

- **Appendix: Emergency measures in the case of high cargo temperature**
  - In the event that the cargo temperature in a hold reaches or exceeds 100°C, the first step is to seek expert advice, in order to determine the best course of action, taking into account the prevailing circumstances and history of the cargo in question; for example, the rate of temperature increase, the remaining sailing time to the scheduled discharge port, etc.
  - Depending on the expert advice received, the following two solutions may be considered:
    a) deviation to a port of refuge to discharge the affected cargo if the cargo temperature exceeds 120°C, in which case preparations should be made for grab discharge; and
    b) as a last resort and only if safe, flooding the affected cargo holds with water, always taking into account the stability and strength of the ship.
  - The temperatures mentioned in this section, i.e., emergency measures in case of high cargo temperature, are indicative only, and the advice of the appointed surveyor or expert shall be followed.
  - Additional note by IIMA: in all cases vents should be opened and, if available, mechanical ventilation started in order to remove any residual hydrogen.
- Bilge wells shall be checked regularly for the presence of water. If water is found, it shall be removed by pumping or draining the bilge wells.
- In the event that during the voyage the ship begins to exhibit motions indicative of cargo shifting, the appearance of the surface of this cargo shall be checked, subject always to the provisions for safe entry given in the section for "Precautions" hereof. If free water above the cargo or fluid state of the cargo is observed, the master shall take appropriate actions to prevent cargo shifting and potential capsize of the ship and give consideration to seeking emergency entry into a place of refuge.
- Additional note by IIMA: Crew shall watch for slumping of a cargo pile which may be indicative of dynamic separation processes (liquefaction). If flattening of the cargo pile occurs, or substantial free water appears at the 'corners' of the cargo hold, or water (slurry) appears above the flattened cargo, or any fluid state of the cargo itself is observed, the master shall seek advice and take appropriate actions to prevent cargo shifting and potential capsize of the ship. Appropriate actions may include: altering course to reduce rolling, reducing speed to minimize pounding and considerations for deviating to a Port of Refuge (sheltered waters), all the while with sea and weather forecasts considered. On board safety measures may include: increasing communications with owners and SAR (search and rescue), the general readying of survival craft and the lowering of side-launched survival craft to embarkation deck. Crew shall be made aware of a heightened safety alertness existing on board.
- Additional note by IIMA: In the event that heavy seas are forecast during the voyage, risk assessments should be updated as appropriate and consideration given to:

1. weather routing
2. altering course and/or speed in order to avoid such heavy seas such as to allow ventilation and allow crew's safe access on deck;
3. deviation to a place of safe refuge; and
4. advance preparation of the vessel for heavy seas, e.g. rigging life lines on deck, planning for necessary work on deck, always in accordance with good seamanlike practices.

Discharge

- The hydrogen concentration in the relevant cargo hold atmospheres shall be measured immediately before any action to open the hatch covers is undertaken. If the hydrogen concentration is greater than 1% by volume (25% LEL), hatch covers shall not be opened.

Additional ventilation shall be applied until the hydrogen concentration falls to or below 1% by volume. Special attention shall be given to the opening of hatch covers, in order to avoid sparks being generated. If in doubt, expert advice shall be sought.

- The cargo in a hold may be discharged during precipitation, provided that the total amount of the cargo in such hold is: (1) to be discharged in the port; and (2) not to be transferred to another ship. Otherwise, during precipitation, all cargo operations shall be suspended and hatches of holds containing this cargo shall be closed. Monitoring of the hydrogen concentration in those holds containing this cargo shall be resumed.
- **Additional note by IIMA with respect to high temperature contingency at the discharge port:**
  1. The master of the ship shall notify the competent port authorities if the vessel will arrive with cargo temperatures in excess of 100°C in holds containing DRI (D).
  2. The operations supervisor and the material handling operators are responsible for properly executing the action plan if a ship or barge arrives at the discharge port carrying DRI (D) at the temperature levels in sections A and B below. Discharging operations must be supervised by personnel familiar with the safety precautions and emergency procedures for handling DRI (D).
  3. The zone of the storage area designated for hot DRI (D) should be clean and free of debris and flammable material, such as coal, coke and wood.
  4. In all cases, before unloading the ship or barge, measure the DRI (D) temperature in each hold and record the measurements in the temperature logbook. This should be done every two hours while the contingency is in effect.
  5. While transferring hot DRI (D) by conveyor, inspect the belt transfer system regularly for any sign of overheating. In case of overheating, stop the loading and transfer, but keep the transfer belts in motion until they cool. Take special care to avoid ingress of water into hoppers, etc.
  6. In the designated zone of the storage area, hot DRI (D) should be spread out on the ground in a layer of about 0.5 m depth using a track-equipped bulldozer for cooling. Mix cooler with hotter material to lower the average temperature (do not use water).
  7. Elevated temperature in this context means in excess of 100°C. In essence, the hottest material should be unloaded first. Hot DRI (D) may be localised within the hold of a ship or barge (so-called hot spots).
     A. Temperatures above 150°C
        Starting with any hot spots, discharge DRI (D) with temperatures above 150°C, position it in the designated location and spray with pressurised water (in this case, there is no option other than to cool down the material before transfer to the designated zone of the storage area, as conveyor belts will burn at temperatures above 150°C. When the temperature has fallen to 150°C or below proceed immediately with transfer to the designated zone in the storage areas for cooling.

     B. Temperatures at or below 150°C
        1. Starting with any hot spots, first unload the holds containing DRI (D) with temperature between 100°C and 150°C in the designated area, immediately transfer the hot material to the designated zone in the storage area for cooling.
        2. Then, starting with any hot spots, unload the holds containing DRI (D) with temperature between 65°C and 100°C in the designated area and immediately transfer the hot material to the designated zone in the storage area for cooling.

Clean-up

Accumulations of dust from this cargo on deck or in proximity to cargo holds shall be removed as quickly as possible. Hosing with seawater shall be avoided. Consideration shall be given to carefully cleaning exposed radio communications equipment to which dust from the cargo might adhere, such as radar, radio aerials, VHF installations, AIS and GPS.

Emergency procedures

Additional note from IIMA: In case of any emergency contingencies, it is important that advice be sought as soon as possible from P&I Clubs, Owners, Charterers, Shippers or other expert as appropriate. Contact shall be maintained with any expert appointed by Owners (as recommended by P&I Clubs and/or Shippers) throughout the duration of the emergency and until normal readings are achieved. The Cargo Technician, if appointed, shall also be involved in the process and shall work closely with the Master throughout the emergency but may take decisions only in conjunction with the Master and/or Owners of the vessel and any other parties involved. At all times during an emergency, good seamanlike practice shall be followed.

Special emergency equipment to be carried Self-contained breathing apparatus
Emergency procedures As provided by the shipper. **Emergency action in the event of fire** The specific procedures provided by the shipper should be consulted and followed as appropriate. Do not use CO2. Do not use water. Do not use steam. **Medical first aid** Refer to the Medical First Aid Guide (MFAG), as amended.

6. Transportation of DRI (D) by Barge, Rail and Truck

6.1 Barge Transportation

6.1.1 Barge condition

Covered barges are recommended for transport of DRI (D), but open barges are also acceptable provided that the appropriate precautionary measures are taken. Barges must comply with the following conditions:

- Be clean and dry, with no accumulations of water, e.g. in bottom indentations
- Be free of chlorides and previous cargoes
- Be free of combustible materials
- bilge pumps must be operable (where applicable)
- access available to portable stripping pumps for removal of standing water
- covered barges should be fitted with vents adequate to provide natural ventilation

Prior to loading, the barges should be inspected to ensure that the cargo hold is dry and free of rags, wood or other contaminants and free from salt or residues from previous cargoes such as cement, lye, and borax, particularly those that might increase oxidation and thus self-heating. In the case of covered barges, the covers should be inspected for water-tightness prior to loading.

6.1.2 Barge loading

The precautions and procedures for loading barges are essentially the same as for loading ocean-going vessels (refer section 5 above). Barge loading operations should be supervised by personnel familiar with the safety precautions and emergency procedures associated with handling DRI (D). The loading operators should be trained in the appropriate safety precautions and emergency procedures for handling DRI (D).

1. DRI (D) should not be loaded if its temperature is >65°C (149°F).
2. DRI (D) should not be loaded in heavy precipitation. Covered barges should be closed during heavy precipitation.
3. Barges should be visually checked for water prior to loading, especially aft where water may accumulate from wash water and/or rain water.
4. The drop of the material should be minimised in order to reduce dust generation.
5. Loading operations should be carried out in a manner such as to reduce stress on the barge. Typically, loading would start at one end and continue along the length of the barge hopper.
6. DRI (D) should be loaded leaving room at the bow and stern for access to drain and pump standing water as deemed necessary.
7. DRI (D) should be evenly distributed in the barge, making the stow in small heaps.
8. Barges should be loaded in a manner so as to have a slight "trim by the stern" to enable easier water extraction.
9. Covered barges should be closed as soon as possible after completion of loading.

6.1.3 Barge shipment

During shipment, the following precautions should be taken:

1. If shipment is by sea or through saltwater, watertight hatch covers must be used to prevent ingress of saltwater into the barge.
2. Water from precipitation should not be allowed to accumulate in the bottom as this may lead to oxidation and associated hazards.
3. Covered barges should remain closed until unloading.
4. If at any time the cargo compartment of a loaded covered barge must be entered, the compartment must be checked for adequate oxygen concentration (minimum 21%). Before any personnel enter a cargo compartment containing DRI (D), the cover must be opened for a sufficient length of time to dissipate any accumulated gases.
5. When DRI (D) is transported by barge, a copy of any applicable permit should be on board the tug or towing vessel. When the barge is moored, the shipping document and a copy of such permit should remain on the barge in a suitably protected location.

6.2 Transportation by Truck and Rail

Truck and railcar beds should be clean to prevent contamination, the containers should not have any large-gapped openings that would allow spillage, and truck tailgates should be properly sealed.

In some situations, trucks and/or railcars may be loaded directly from a ship or barge using a variety of equipment combinations, but because time for vessel discharging is intended to be as short as possible (to avoid demurrage charges), it is common practice to discharge the product to a temporary storage, and later reclaim from the storage pile to whatever equipment is in place to effect the loading, e.g. conveyor belt system that discharges to large capacity hoppers, which then allow for controlled loading to rail ore truck.

To avoid loss during transport, trucks should not be overloaded. The bulk density of DRI (D) is high and has to be taken into account during loading. It is recommended that tarpaulins be used in order to suppress dust emission and to limit moisture pick-up en-route. Adhere to local regulations regarding use of tarpaulins.

Appendix 1: Provisions for Group A cargoes

IMSBC Code Section 4.3: Certificates of test

4.3.2 When a group A cargo is carried, the shipper shall provide the ship's master or their representative with a signed certificate of the TML, and a signed certificate or declaration of the moisture content, each issued by an entity recognized by the competent authority of the port of loading. The certificate of TML shall contain, or be accompanied by, the result of the test for determining the TML. The declaration of moisture content shall contain, or be accompanied by, a statement by the shipper that the moisture content is, to the best of their knowledge and belief, the average moisture content of the cargo at the time the declaration is presented to the master.

4.3.3 When a group A cargo is carried, procedures for sampling, testing and controlling moisture content to ensure the moisture content is less than the TML when it is on board the ship shall be established by the shipper, taking account of the provisions of this Code. Such procedures shall be approved and their implementation checked by the competent authority of the port of loading.* The document issued by the competent authority stating that the procedures have been approved shall be provided to the master or their representative.

4.3.4 If the cargo is loaded on to the ship from barges, in developing the procedures under 4.3.3 the shipper shall include procedures to protect the cargo on the barges from any precipitation and water ingress.

4.3.5 When a group A cargo is to be loaded into more than one cargo space of a ship, the certificate or the declaration of moisture content shall certify the moisture content of each type of finely grained material loaded into each cargo space. Notwithstanding this requirement, if sampling according to internationally or nationally accepted standard procedures indicates that the moisture content is uniform throughout the consignment, then one certificate or declaration of average moisture content for all cargo spaces is acceptable.

IMSBC Code section 4.5: Interval between sampling/testing and loading for TML and moisture content determination

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.

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 seven 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.

4.5.3 Samples of frozen cargo shall be tested for the TML or the moisture content after the free moisture has completely thawed.

MSC.1/Circ.1454/Rev.2 section 4: Development of procedures for controlling moisture content

4.1 The shipper should establish a procedure for controlling moisture content to ensure that the moisture content is less than the TML when it is on board the ship. Once the moisture content has been measured, it is important to ensure that the moisture content remains below the TML. This procedure should be based on an analysis of all factors that may influence the moisture content between the production/extraction area and the ship.

4.2 The procedure should, at least, include:

- a description of the geographic configuration of the production/extraction area;
- a description of the location of the stockpiling/storage area, when applicable; - a description of the method(s) to transport the consignment from the production/extraction area to the stockpiling/storage area or to the ship and, when applicable, from the stockpiling area to the ship and a description of the precautions taken during these transport operations to control moisture content of the consignment (such as: use of closed vehicles, suspension of certain operations and conveyor belts sloped and covered during rainfall);
- a description of the stockpiling/storage method(s), when applicable and of the precautions taken during stockpiling/storage (such as configuration of the pile to allow rain to run off) to control moisture content of the consignment;
- a description of the method(s) to load the cargo from shore to ship and precautions to protect the cargo from precipitation and water ingress (see 4.3.4 when loaded from barges);
- a description of the sampling operations between the production/extraction area and the ship to measure and report moisture content at different stages before being on board the ship (such as during stockpiling, conveyor transport, loading);
- a description of the conditions when the cargo is not authorized to be loaded and when the loading should be suspended on board the ship (moisture content greater than the TML, weather conditions);
- a description of the periodic internal control procedures to ensure that the procedure for controlling moisture content is applied; and
- a description of the human and material resources and of the awareness and training activities of the personnel involved to implement the procedure.

4.3 Records of the following activities addressed in the procedure for controlling moisture content should be kept and made available to the competent authority of the port of loading upon request:

- training;
- internal review to ensure that the procedure for controlling moisture content is applied correctly;
- weather conditions during which the procedure is applied; and
- any modification of the procedure for testing.

Records should be kept for a period of time established by the competent authority of the port of loading in the working language of the shipper. If the language or languages used are not English, French or Spanish, a translation into one of these languages should be included.