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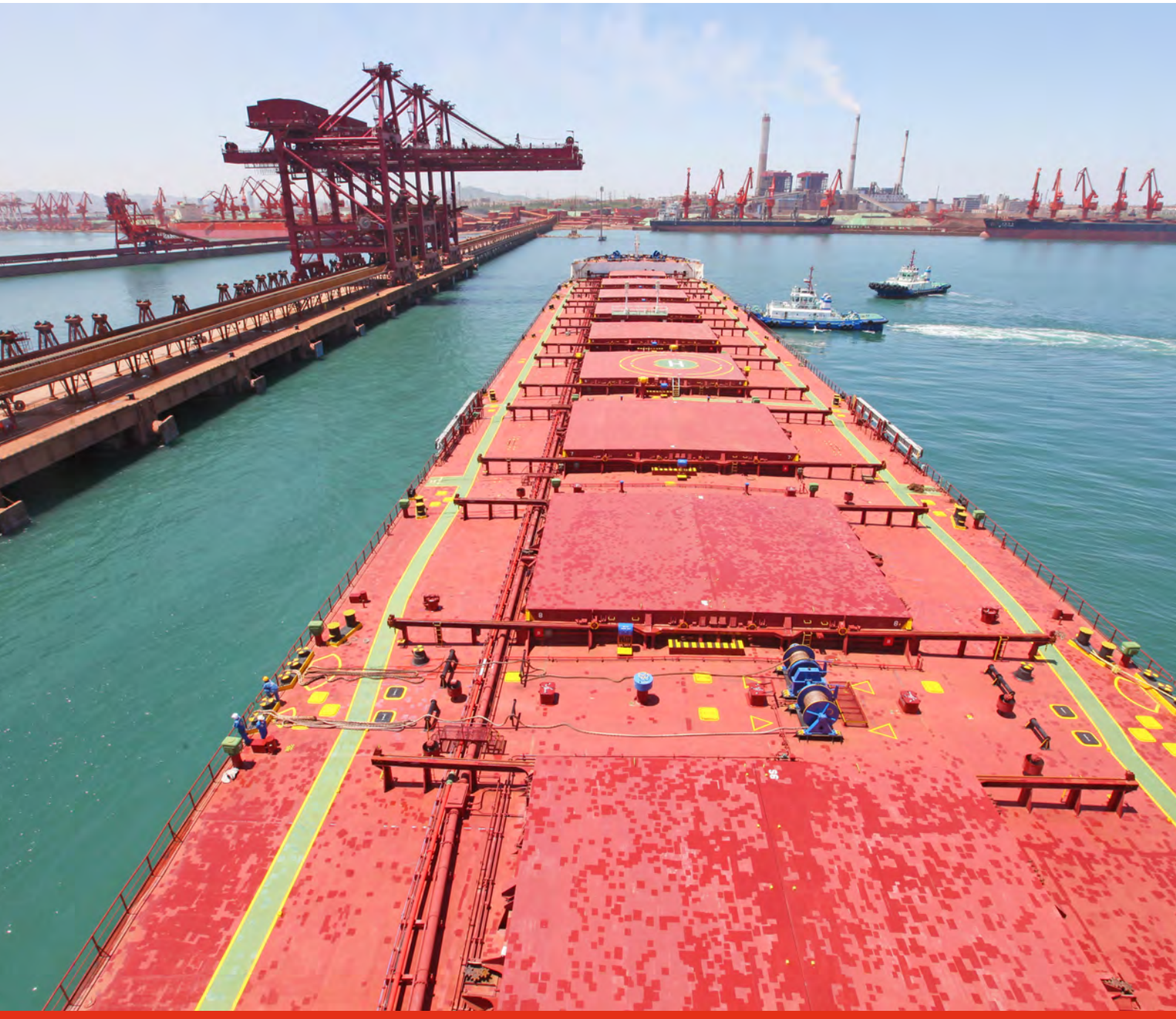
Iron Metallics Association

Direct Reduced Iron By-Product Fines (DRI D): A Guide to Handling, Storage & Shipping

October 2020



GUIDE FOR HANDLING, STORAGE AND SHIPPING OF DIRECT REDUCED IRON BY-PRODUCT FINES DRI (D)

October 2020

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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:

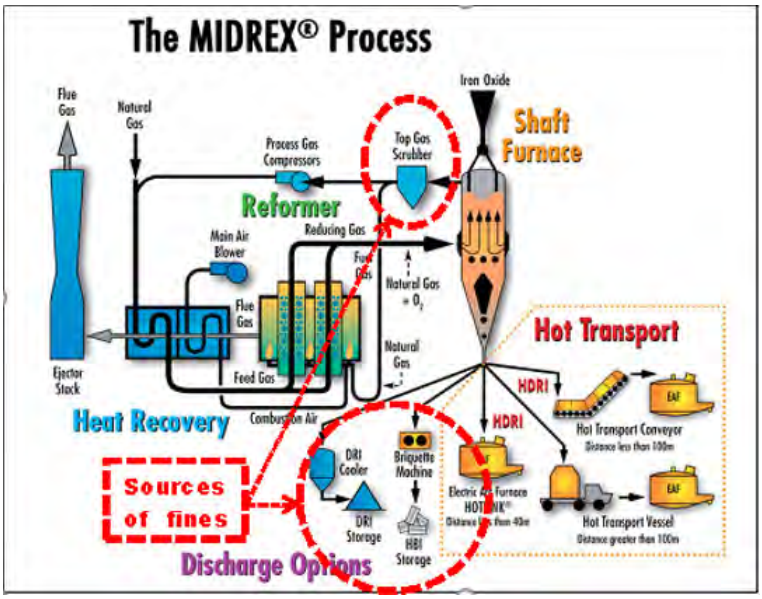
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

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 generation of fines through abrasion, etc. Users of DRI (A) and (B) require minimal content of fines in the product. Fines are undesirable

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

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

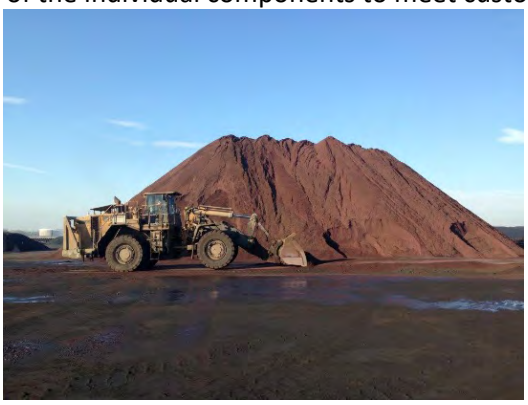
Metallised DRI Fines

Off-gas Fines

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 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.

In the IMSBC Code DRI Fines are designated as DRI (C). However, the schedule for DRI (C) 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.

DRI (C) is therefore shipped under exemptions to these provisions, allowing moisture content ≥0.3% and requiring mechanical ventilation in order to remove hydrogen from cargo spaces. Discussions are ongoing at the IMO to introduce a new schedule for DRI Fines, designated DRI (D), which would in all likelihood render the existing DRI (C) schedule redundant.

2. DESCRIPTION OF DRI FINES FOR MARITIME TRANSPORTATION

The Bulk Cargo Shipping Name (BCSN) for the proposed new schedule to 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 Hot Briquetted Iron (known as "HBI" or "DRI (A)") and/or Direct Reduced Iron (known as "DRI" or "DRI (B)") which has been aged for at least 30 days prior to loading. The density of (DRI) (D) is less than 5,000 kg/m³.

Angle of repose	**Bulk density (kg/m^3)**	**Stowage factor (m^3/t)**
Not applicable	1850 to 3300	0.30 to 0.54
Size	**Class**	**Group**
Fines and small particles with an average size less than 6.35 mm, particles larger than 12 mm not to exceed 3% by weight[2]	MHB[3] (WF) (SH) (OH)	A[4] and B[5]

DRI (D) will be treated under the IMSBC Code as a Material Hazardous Only in Bulk (MHB), Group A and Group B cargo, and, until the proposed IMSBC Code Schedule for DRI (D) is adopted or the schedule for DRI (C) amended accordingly, is 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.

[2] The characteristics of Direct Reduced Iron (C) in its IMSBC Code schedule state: "….. no particles to exceed 12 mm." This is not considered practical by industry, hence the max. 3% oversize tolerance.
[3] WF = Solids which evolve flammable gas when wet; SH = Self-heating solids; OH = Other hazards.
[4] Group A cargoes may liquefy if shipped at a moisture content in excess of their transportable moisture limit.
[5] Group B cargoes possess a chemical hazard which could give rise to a dangerous situation on a ship.

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).

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 $\geq$40°C and of these 24 exhibited hydrogen concentration of $\geq$25% LEL. Temperature $\geq$40°C was the only common cargo parameter observed for the 24 holds which exhibited hydrogen concentration $\geq$25% LEL. Whilst this relationship is not conclusive, a temperature of $\geq$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[6], the IMSBC Code[7] and by the vessel's ISM[8] 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.

[6] SOLAS Chapter III Regulation 19. 3.6.2. Emergency training and drills

[7] IMO Resolution A.1050(27) 30 November 2011 / Revised recommendations for entering enclosed spaces aboard ships (copied under 'supplements' in IMSBC) – copied in IMSBC Code supplements

[8] International Safety Management Code (published by the IMO)

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 to handle it. 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, 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

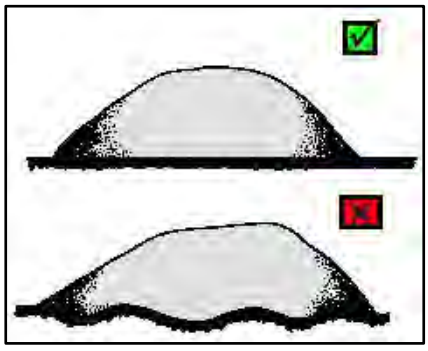
DRI (D) should normally be used or dispatched on a "first-in, first-out" basis. The content of metallic iron decreases over time as a consequence of re-oxidation in the presence of air and moisture, so that material used on a "first-in, last-out" basis will have variable metallic iron content which in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

4.4.1 Stockyards

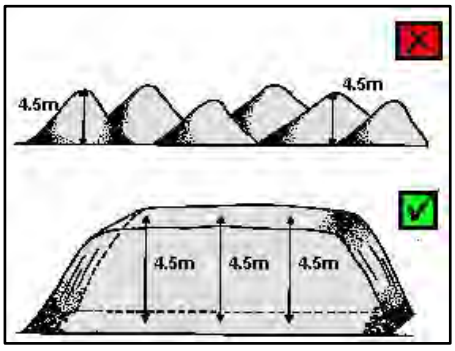
DRI (D) can be stored uncovered in open air without problem, provided that proper precautions are taken and subject to any requirements of the national administration of the port of loading. The storage area should be kept clean and free of any oxidants, combustible and non-compatible materials. Use 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;
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 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)

In writing this section we have endeavoured to avoid any inconsistencies with what is proposed for the DRI (D) schedule of the IMSBC Code and to follow one aspect of the IMO vernacular which is the use of the word "shall" in the imperative or mandatory sense.

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).

5.1 Preparation for Loading

5.1.1 Cargo and Shipper

1. DRI (D) for shipment shall be prepared and aged naturally for a minimum of 30 days prior to shipment. Storage in the open air is permitted prior to loading, subject to any requirements of the national administration of the port of loading. During storage DRI (D) shall be piled such as to allow the greatest possible exposure to the atmosphere and thus facilitate its natural ageing.
2. The Carrier's nominated technical personnel or representative shall have reasonable access to the stockpiles of cargo to be loaded for inspection thereof.
3. The cargo temperature shall be measured by the Shipper for the three consecutive days prior to and during loading to verify temperature stability and recorded in a log detailing the temperature for each lot of cargo loaded, a copy of which shall be provided to the Master of the vessel. Measurements shall be taken 20-30 centimetres below the surface and at 3 metre intervals over the length and width of the stockpile. Cargo with temperature in excess of 65°C (149°F) or which exhibits unstable temperature shall not be loaded.
4. In accordance with section 4.2 of the IMSBC Code, "the Shipper shall provide the Master or his representative with appropriate information on the cargo and its properties sufficiently in advance of loading to enable the precautions which may be necessary for proper stowage and safe carriage of the cargo to be put into effect." The Shipper or his appointed representative shall provide to the Master of the carrying vessel information about the nature of DRI (D) and the potential hazards associated with shipping it, (such hazards include the potential for DRI (D) to self-heat and generate hydrogen gas after contact with water, especially saltwater), together with the relevant on-board safety precautions (for example with respect to hot works), emergency procedures and first aid measures. Such information may be in amplification of the IMSBC Code, but shall not be in conflict therewith with respect to safety. Information provided to the Master should also include the length of time the material has been stored in preparation for shipment and its temperature history during that period.
5. 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[9] 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) (if finalised)
   d) copy of the BLU Code 'Ship Shore Safety Check List' signed by both parties

[9] See section 5.3.2 and footnote 14.

6. Prior to loading DRI (D) the shipper shall provide the Master of the ship with a certificate issued by a competent person recognised by the national administration of the port of loading verifying that the cargo has been prepared and aged naturally for a minimum of 30 days prior to loading.
7. As DRI (D) is a Group A cargo, valid, approved procedures shall be used by the Shipper for sampling, testing and control of moisture content in order to ensure that the moisture content of the cargo is below the TML.[10]
8. The interval between sampling/testing for TML and determination of the moisture content of the cargo shall be in accordance with section 4.5 of the IMSBC Code (see Appendix 1).
9. The shipper shall provide the Master of the ship with a certificate issued by a recognised laboratory stating the actual moisture content and TML of the cargo.
10. Unless otherwise expressly provided otherwise in this guide, DRI (D) should not be handled or loaded during precipitation. In some jurisdictions, local regulations may require DRI (D) to be stored under cover prior to loading.
11. If necessary, once the pre-shipment moisture content has been determined, each pile of cargo to be loaded may, where practicable and appropriate, 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 wetted, loading from such pile shall be suspended and, weather permitting, loading shall be resumed from a different pile which shall have first been tested for moisture content. The wetted material shall in due course be resampled for moisture content, such moisture content to be approved by a competent person recognised by the national administration of the port of loading before such material can be loaded.
12. In accordance with section 4.3, paragraph 4.3.4 of the IMSBC Code, when a vessel is being loaded from barges, the procedures for sampling, testing and controlling moisture content (see point 7 above) shall include procedures to protect the cargo on the barges from any precipitation and water ingress.
13. When shipment is made under an exemption to the IMSBC Code schedule for Direct Reduced Iron (C) issued in accordance with the provisions of section 1.5 of the IMSBC Code, the shipper shall provide the Master with copies of the applicable Exemption Certificates issued by the competent National Authorities.
14. 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.
15. The Shipper shall provide and install all required equipment and thermocouples for measuring the temperature of the cargo. The Shipper shall also provide suitable detectors for quantitative measurements of hydrogen and oxygen, without requiring entry into the holds, which shall be on board while DRI (D) is carried. Such measuring devices shall be suitable for use in an oxygen-depleted atmosphere and of a type certified for use in an explosive atmosphere. See section 5.3.2 below for further information on monitoring equipment and monitoring.
16. The shipper shall ensure that expert advice is available at all times during the voyage and shall provide relevant contact information to the Master prior to sailing.
17. Shore personnel involved with loading of DRI (D) shall be adequately trained in the appropriate safety precautions and emergency procedures to be followed for this cargo.
18. Refer to section 5.3.2 below for temperature and gas monitoring equipment that must be available on-board ships carrying DRI (D).

5.1.2 Vessel

1. Prior to loading, an ultrasonic test or other equivalent method shall be conducted to ensure the integrity and weather tightness of the hatch covers and weather-deck closing arrangements and all readings shall confirm weather tightness.

[10] In this context, refer to section 4.3 of the IMSBC Code and MSC.1/Circ1454/Rev.1 – see Appendix 1 hereof

2. Vessel's holds 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.
3. Bilge wells shall be clean, dry and covered with non-combustible material, to prevent ingress of the cargo. The bilge system of a hold to which DRI (D) is to be loaded shall be tested to ensure that it is working properly, and test results documented.
4. Appropriate precautions shall be taken to protect machinery, sensitive equipment such as radars and exposed telecommunications equipment and accommodation spaces from the dust of the cargo. Wrapping sensitive hatch fittings, such as exposed hydraulic cylinders, with plastic-stretch food wrap and/or aluminium foil provides a fast and economic means to secure equipment and is easily and quickly removed as needed.
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. All electrical equipment within any cargo space in which DRI (D) is carried shall be of certified safe type for use in explosive atmospheres or effectively isolated from the electrical supply.
7. All tools, bilge sounding devices, lines, tethers, weights and caps shall be of non-sparking materials.
8. Ensure electrical isolation of cargo hold lights if fitted as well as ensuring mast houses and common areas to the cargo holds are electrically isolated.
9. Prior to loading of DRI (D), care shall be taken to prevent water from entering holds into which DRI (D) are to be loaded.
10. Prior to loading, an inspection of the mechanical ventilation system shall be carried out to ensure that it is functioning properly (refer section 5.3.1 for details of ventilation).
11. Two spare sets of mechanical ventilation equipment of a type certified for safe use in an explosive atmosphere shall be available on board during the voyage. A qualified electrician or technician with knowledge of and experience in installing the spare fans in case of need shall be available on board during the voyage.
12. In addition, natural ventilation shall be available in enclosed cargo holds intended for the carriage of DRI (D).
13. Mechanical ventilators shall be capable of ventilating the cargo surface as stipulated in sub-section 3.5 of the IMSBC Code and have the following characteristics:
    a) Certified marine explosion-proof
    b) Axial flow
    c) Reversible operation
    d) Non-sparking blades
    e) Drive mechanisms: air (pneumatic), water (hydraulic), electrical
    f) Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

5.2 Vessel Loading Procedures

Pre-stowage plans and loading sequence programs are the responsibility of the vessel. A loading form and individual hold loading sequence form should be prepared prior to arrival for the presentation to Shipper upon berthing.

Loading of bulk cargoes, including DRI (D), is governed by the BLU Code i.e. the Code of Practice for the Safe Loading and Unloading of Bulk Cargoes, issued by the International Maritime Organisation[11]. section 2 of the BLU Code addresses the suitability of ships and terminals. Section 2.2 deals with ships and section 2.3 deals with terminals.

[11] latest (2010) edition published in 2011 by the International Maritime Organisation

The IMSBC Code has standard language for loading of heavy cargoes, such as DRI (D): "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 equalise the weight distribution. Due consideration shall be paid to ensure that the tank top is not overstressed during voyage and during loading by a pile of the cargo."

1. During any handling of DRI (D) "NO SMOKING" signs shall be posted on decks and in areas adjacent to cargo holds. No naked lights shall be permitted in these areas.
2. During the period of loading, carriage and discharge of DRI (D) smoking, burning, welding, cutting, chipping and/or other source of ignition shall not be allowed in the proximity of a cargo hold loaded with DRI (D), including mast houses and areas common to the cargo holds.
3. Loading operations shall be monitored by a qualified Cargo Technician[9] familiar with the characteristics, safety precautions and emergency procedures for DRI (D). The loading operators shall be trained in the appropriate safety precautions and emergency procedures.
4. Where practicable, ballast tanks adjacent to the cargo spaces carrying DRI (D), other than double-bottom tanks, shall be kept empty. Weather tightness shall be maintained throughout the voyage. The introduction of moisture and accumulation of condensation in the cargo spaces shall be avoided.
5. The cargo shall not be loaded onto ships or transferred between ships or barges during ANY precipitation. In case precipitation occurs during loading, the loading/transfer operation shall be halted and the hatches closed until the precipitation stops. Unless expressly provided otherwise in this guide, during the loading of DRI (D), the hatches of all non-working holds into which DRI (D) has been or will be loaded shall be kept closed.
6. The moisture content of the cargo shall be maintained at a minimum of 2% and below its TML at all times. Material with moisture content less than 2.0% and greater than the TML shall not be loaded. Any material that has been wetted, for example due to precipitation, shall not be loaded unless such material has been retested for moisture content, such moisture content to be approved for loading by a competent person approved by the national administration of the port of loading before such material can be loaded.
7. During loading of DRI (D), care shall be taken to prevent moisture from entering holds into which DRI (D) will be, is being or has been loaded.
8. After loading has been stopped due to precipitation, 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. Each time loading operations are commenced or restarted, particularly after rain or washing down, all conveyor belts shall first be operated unladen, but not over a cargo hold.
9. The drop of the material should be minimised in order to minimise dust generation.
10. Care shall be taken to ensure that particles coarser than 6.35 mm are as far as is practical evenly distributed throughout the entire cargo in order to avoid build-up of concentrations of coarse material.
11. The cargo temperature shall be monitored frequently (refer section 5.3.2 point 8 for definition of "frequently") during loading and recorded in a log detailing the temperature for each lot of cargo loaded, a copy of which shall be provided to the Master.
12. DRI (D) exhibiting temperature instability beyond the temporary increase of up to about 30°C (86°F) referred to in section 3.2 or with a temperature above 65°C (149°F) shall not be loaded.
13. DRI (D) shall be stowed separated from goods of classes 1 (division 1.4S), 2, 3, 4 and 5 and class 8 acids in packaged form (see IMDG Code)[12] and separated from solid bulk materials of classes 4 and 5. Goods of class 1, other than division 1.4S, shall not be carried on the same ship. Boundaries of compartments where DRI (D) is carried shall be resistant to fire and passage of liquid.
14. Trim in accordance with the relevant provisions required under section 5 of the IMSBC Code (Trimming procedures).

[12] International Maritime Dangerous Goods Code (published by the International Maritime Organisation)

15. On completion of loading and before sailing a certificate shall be issued by a competent person recognised by the national administration of the port of loading verifying:
    a) that the proportion of material above 12 mm is no more than 3% by weight;
    b) that the moisture content of the cargo loaded is at least 2% and below the TML;
    c) that the temperature of the cargo loaded does not exceed 65°C.
16. After loading, hatch covers shall, weather permitting and as may be advised by the Cargo Technician, remain open after completion of loading of the respective holds and placement of thermocouples in order to allow cooling of the cargo, stabilisation 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 and monitoring of temperature and hydrogen concentration commenced.
17. In the event that a hold carrying DRI (D) has to be closed prior to completion, for example due to precipitation, such hold shall be monitored for hydrogen concentration and ventilation applied such that hydrogen concentration does not exceed 1% by volume (25% LEL).
18. Once a hold has been loaded with DRI (D) and its hatch closed, mechanical surface ventilation shall be applied in accordance with section 5.4.1 below.
19. Immediately after completion of loading and sealing of holds for weather-tightness, the deck and vessel's structure shall be thoroughly cleaned using an environmentally friendly method in order to remove DRI (D) or dust that may have accumulated (pressure washing using fresh water and an environmentally acceptable acid-based cleaner have been found to be effective).
20. On completion of loading the ship shall wait for 24 hours (or longer as may be required) before sailing in order that the Master and Cargo Technician can ensure that:
    a) all loaded cargo holds are correctly closed and sealed;
    b) the temperature of the cargo at all measuring points is stable and does not exceed 65°C (149°F) for at least 12 consecutive hours;
    c) that the concentration of hydrogen in the head space of the holds has stabilised and does not exceed 1% by volume (25% LEL) for at least 12 consecutive hours.
21. If after loading and before sailing any cargo temperatures are found to be in excess of 65°C (149°F) the material so affected shall be allowed to cool naturally to 65°C (149°F) 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.
22. On completion of loading and before sailing a certificate shall be issued by a competent person recognised by the national administration of the port of loading verifying that:
    a) that the proportion of material above 12 mm is no more than 3% by weight;
    b) that the moisture content of the cargo loaded is at least 2% and below the TML;
    c) that the temperature of the cargo loaded does not exceed 65°C.

5.3 During the Voyage

5.3.1 Ventilation

1. During the voyage, mechanical surface ventilation shall be provided in the head spaces above the cargo in each hold carrying DRI (D) in order to prevent accumulation of dangerous levels of hydrogen in the holds. The mechanical surface ventilation system shall be of an explosion-proof type, capable of ventilating the cargo surface as stipulated in sub-section 3.5 of the IMSBC Code. Suitable wire mesh guards shall be fitted over inlet and outlet ventilator openings.
2. The mechanical surface ventilation shall be available at all times and as needed, either by compliance with the Load Line Convention, 1966, Regulation 19(3) or by adopting measures to avoid a situation whereby the cargo hold mechanical ventilation system could not be used due to

rough seas, such measures to be in keeping with good seamanlike practices[13] and advice from weather routing service providers.

3. Ventilation shall be such as to provide surface ventilation and avoid the possibility of build-up of flammable gas/air mixtures. Ventilation other than surface ventilation shall not be applied and on no account should air be directed into the body of the cargo. The concentration of hydrogen in the cargo hold atmosphere shall not exceed 1% by volume (25% LEL).
4. Mechanical ventilation shall be such as to enable an air flow of at least 1.2 m^3 per hour per tonne of cargo in each cargo space carrying DRI (D) when needed and in any case shall have an adequate capacity to ventilate down to a hydrogen concentration of 0.2% by volume (5% LEL) or less.
5. In order to minimise the possibility of 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).
6. The detected hydrogen concentration and the indicated rate of increase/decrease over time should be the determining factors in any decision as to the operating period and frequency of the ventilation system. The rate of hydrogen evolution from DRI (D) can vary from cargo to cargo and it is therefore very important to establish a time-based gas prediction curve as soon as gas evolution stabilises. The time-based gas prediction curve is an important tool for understanding the likely rate of evolution of hydrogen from the cargo.
7. In order to develop such a curve, a cargo hold has to 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 two hours thereafter for at least 24 hours or until it reaches 1% by volume (25% LEL), whichever first occurs. 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 stabilised and remains sustainably at or below 0.2% by volume (5% LEL). Based on these data, the Master should be able to accurately and reliably determine the length of time needed to reach a concentration of 1% by volume in the absence of ventilation and use this information for updating the voyage plan and optimising the weather routing.
8. Based on the time-based gas prediction curve, a risk assessment shall be carried out as soon as possible, such risk assessment to include, but not be limited to:
   a) expected weather conditions;
   b) actual hydrogen evolution rates;
   c) cargo temperature (refer section 3.1)
   d) speed of vessel;
   e) availability and accessibility of ports of refuge;
   f) distance to the port of discharge.

   Voyage planning shall take into account such risk assessment, including weather routing optimised 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 shall be updated as frequently during the voyage as updates on the weather become available as well as actual hydrogen evolution rates.
9. Gases in the cargo holds shall be removed by extraction, rather than by blowing in moist air from outside. Mechanical ventilation shall exhaust to a safe area. All inherent risk associated with the

[13]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 ensures the safety and preservation of the crew, the ship, and the environment as well as safeguarding cargo interests.

location of the ventilation discharge points shall be considered and risk mitigation measures taken to address any such identified potential risk as appropriate. Ventilation shall be such that escaping gases cannot enter living quarters in hazardous concentrations.

10. In the event that mechanical ventilation cannot be operated for whatever reason (for example in the event of mechanical breakdown or electrical failure):
    a) continuous natural ventilation shall be applied until mechanical ventilation has been restored; repairs to the non-functioning ventilator shall if practicable be carried out away from cargo holds containing this cargo; a ventilator which cannot readily be repaired shall be replaced with a spare one;
    b) if necessary and practicable use other available means of forced ventilation;
    c) weather routing advice 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;
    d) the frequency of monitoring of hydrogen concentration and cargo temperature shall be increased;
    e) 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;
    f) 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 (25% LEL);
    g) due care shall be exercised in restarting the ventilation, both mechanical and natural, so as not to create an ignition source;
    h) seek advice from the shipper or other suitably qualified expert as appropriate.
11. In all cases, mechanical ventilation shall be operated for an appropriate period of time prior to discharge (see also discharge section 5.4 below).

5.3.2 Cargo monitoring

1. A suitably qualified[14] Cargo Technician shall board the vessel at the loading port and remain on board the vessel for the duration of voyage. The Cargo Technician shall be appointed by the Shipper and shall have the following duties on board the vessel:
    a) to monitor the loading operations;
    b) to advise on and supervise the installation of thermocouples in the cargo holds for temperature monitoring, to monitor the performance of the thermocouples and to keep the Master informed accordingly;
    c) to monitor and report on the cargo/hold 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 (who shall forward them to the Shipper and/or applicable competent authority which should respond with appropriate advice in case of need);
    d) to assist and advise the Master and crew in the development of the time-based gas prediction curve;
    e) to advise and coordinate with the Master and crew as appropriate in connection with the operation of the ventilation systems; and
    f) to provide advice and assistance to and cooperate with the Master and crew in case of an emergency pertaining to the cargo.

[14] This 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.

2. The Shipper shall provide and install all required equipment and thermocouples for measuring the temperature of the cargo. Thermocouples shall be placed at several points within the body of the cargo for the purpose of temperature monitoring. The number and placement of the thermocouples shall be determined by the Cargo Technician in conjunction with the Shipper and shall be communicated to the Master in diagrammatic form. Set-up of the thermocouples shall be such that temperature readings can be taken without entry into cargo spaces or endangering personnel. 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. It should also be understood that thermocouples can fail or give incorrect readings in which respect the Cargo Technician shall interpret temperature readings and advise the Master accordingly.
3. As mentioned in section 3.2 above, there may be a steady rise in the cargo temperature of up to about 30°C (86°F) above ambient temperature for the first 24 to 36 hours after loading. A gradual temperature decline towards ambient should follow.
4. Suitable detectors for quantitative measurements of hydrogen and oxygen without requiring entry into the holds shall be on board while DRI (D) is carried, provided by the Shipper. The detectors shall be suitable for use in an oxygen-depleted atmosphere and of a type certified safe for use in explosive atmospheres. Because sensors based on catalytic or infrared technology do not warn against hydrogen explosion dangers, gas monitors using electrochemical (diffusion type) sensors should be fitted for reliable hydrogen detection.
5. All monitoring equipment shall be operational and properly calibrated at the commencement of loading.
6. 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.
7. The concentrations of hydrogen and oxygen and cargo temperatures in holds carrying DRI (D) shall be measured daily during the voyage by or under the supervision of the Cargo Technician in the presence of the ship's representative 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. Any crew member responsible for operating monitoring equipment shall have been fully trained and be familiar with its use to the satisfaction of the Cargo Technician.
8. The frequency of monitoring shall be determined on the basis of the information provided by the shipper, the advice of the Cargo Technician and the information obtained through the measurement of cargo temperature and analysis of the atmosphere in the cargo holds as well as the time-based gas prediction curve described in section 5.4.1 above. Consideration shall be given to increasing the frequency of cargo monitoring following periods of bad weather or following mechanical breakdown of the ventilation system.
9. 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 should be taken:
    a) verify proper operation of the mechanical and natural ventilation systems;
    b) maintain and, if possible, increase mechanical and natural surface ventilation until the hydrogen concentration falls to or below 0.2% by volume (5% LEL);
    c) take care to prevent any spark generation or other potential source of ignition in the vicinity of the holds, adjacent spaces, or open decks;
    d) 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.
10. If the hydrogen concentration remains above 1% by volume after such increased monitoring and ventilation, seek expert advice follow the emergency procedures in section 7.1 below.

11. A cargo temperature of 65°C in a cargo hold is an indicator of a potential approaching emergency situation and is therefore a trigger for increased monitoring and vigilance, as well as preparation for dealing with the emergency, should it eventuate. Precautionary measures that should be taken:
    a) if possible, increase the rate of mechanical and natural ventilation to dissipate heat and any hydrogen
    b) monitor temperatures every two to three hours and hydrogen concentration every hour if possible, but in any event not less than every four hours, provided always and to the extent that prevailing conditions permit;
    c) do not use CO_2, water or steam on the cargo;
    d) monitor hydrogen and oxygen levels in adjacent cargo holds and, if possible, ventilate them;
    e) 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 must not be allowed to enter into contact with DRI (D));
    f) check for signs of abnormal heat in affected sounding pipes and air pipes;
    g) if and when temperature returns sustainably to 65°C or less, regular monitoring procedures should be resumed.
12. If the temperature continues to increase, establish with the Shipper or the assigned expert 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. If the temperature in a hold shows signs of approaching, reaches or exceeds 100°C (212°F), refer to the Emergency Procedures in section 7 of this guide.

5.3.3 Other precautions during the voyage

1. Where practical, ballast tanks adjacent to the holds containing DRI (D), other than double-bottom tanks, shall be kept empty. Weather tightness shall be maintained throughout the voyage and introduction of moisture and accumulation of condensation in the holds shall be avoided.
2. 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[15]:
    a) first eliminate the source of water ingress if possible;
    b) maintain ventilation in accordance with section 5.3.1 above;
    c) 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;
    d) if the hydrogen concentration is approaching or has already reached or exceeded 1% by volume (25% LEL) on a sustained basis, refer to the emergency procedures in section 7.1 below;
    e) monitor the temperature of the cargo every hour and if cargo temperature increases to >100°C (212°F) refer to the emergency procedures in section 7.2.1 below.
3. 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 (refer section 3.3 of this guide).

[15] 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. This footnote is given as background information only.

4. 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.
5. 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.
6. In the event of significant evolution of hydrogen in a hold, enclosed spaces adjacent to that hold, such as storerooms, mast houses, carpenter's shop, passageways, tunnels, etc., should where practical be locked shut and warning notices prohibiting access posted. Electrical devices therein shall be isolated. Such spaces shall be monitored regularly for the presence of hydrogen and adequately ventilated and, in the case of mechanical ventilation, only equipment certified as a type safe for use in an explosive atmosphere shall be used. Atmosphere testing is especially important prior to permitting personnel to enter such spaces or activating any electrical equipment located therein.
7. Before entry by any personnel:
   a) enclosed adjacent spaces shall be thoroughly ventilated and the atmosphere tested and verified to be safe for entry with respect to the levels of oxygen (which should be at least 21% by volume) and flammable gas (all provisions of the vessel's ISM Code covering entry into enclosed spaces shall be followed);
   b) ensure adequate time to ventilate as a precautionary measure before entering mast houses and common areas to the cargo holds;
   c) before entering mast houses and common areas to the cargo holds and prior to restoring electrical services and lights, the compartment shall be ensured safe by use of a gas monitor for the detection of hydrogen
   d) Mast houses and common areas to the cargo holds should have their ventilation covers / flaps left open so far as is practicable to lessen risks of hydrogen pockets going undetected.
8. Holds containing DRI (D) and adjacent spaces may become oxygen-depleted. No person shall enter a loaded cargo hold or an enclosed adjacent space unless the space has been ventilated and the atmosphere tested and found to be gas-free and to have sufficient oxygen to support life (which should be at least 21% by volume). Suitable signs shall be provided at all access points and where possible, access points to cargo holds should be locked. Notwithstanding this, emergency entry may be permitted only in accordance with IMO Resolution A.1050 (27).
9. Periodically during the voyage, or at any time should the ship begin to exhibit movements indicative of cargo shifting (list or irregular rolling motion), the appearance of the surface of this cargo should be checked; subject always within the to the provisions for safe entry given provided in the Precautions section hereof. 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.
10. In the event that heavy seas are forecast during the voyage, risk assessments should be updated as appropriate and consideration given to:
    a) weather routing
    b) 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;

c) deviation to a place of safe refuge; and
d) 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.[13]

5.4 Vessel Discharge

5.4.1 Actions prior to unloading

The following actions should be taken prior to unloading a vessel carrying DRI (D):

1. Check the hydrogen concentration before opening cargo holds containing DRI (D). If the hydrogen concentration in a cargo hold is 1% or more by volume (25% LEL), ventilate the affected hold(s), continue to monitor the hydrogen concentration and do not open the hatches until the hydrogen concentration is less than 1% by volume.
2. Measure the cargo temperature in cargo holds containing DRI (D). If the temperature readings are stable and <100°C (212°F), it is safe to unload in the normal manner. If the temperature is ≥100°C (212°F), refer to the emergency procedures given in section 7.2 below.
3. Before any personnel enter a cargo hold containing DRI (D), measure (a) the oxygen concentration (which should be at least 21% by volume), (b) the hydrogen concentration which should be no more than 1% by volume (25% LEL) and (c) the temperature of the cargo which should be no higher than 65°C (149°F) before entry. Otherwise entry shall be permitted only in accordance with IMO Resolution A.1050 (27).
4. Where possible, provide electrical grounding/earthing in the cargo holds in order to reduce sparking potential from any electrical sources.
5. Sensitive equipment, such as radars should be protected against dust. Wrapping sensitive hatch fittings, such as exposed hydraulic cylinders, with plastic-stretch food wrap and/or aluminium foil provides a fast and economic means to secure equipment and is easily and quickly removed as needed.
6. Shore personnel involved with discharge of DRI (D) shall be adequately trained in the appropriate safety precautions and emergency procedures to be followed for this cargo.
7. Appropriate personal protective clothing and equipment should be worn/used by personnel working in the vicinity of handling, loading and unloading of DRI (D).
8. When it is safe to do so, open the hatches and inspect the condition of the cargo. Such inspection should include the following:
   a) the presence of wetted material on top of the cargo, indicating that water has seeped in via the hatch covers
   b) entry of water through the double bottom of the hull, indicated by wetted material at the edges of the bottom of the pile
   c) the presence of hot spots - defined as areas where the temperature is ≥100°C (212°F).

5.4.2 Discharging operations

1. During discharge of DRI (D), no smoking, burning welding, cutting, chipping and/or other activity which might create a source of ignition shall be permitted in proximity to a hold containing DRI (D).
2. Special attention shall be paid to the opening of hatch covers in order to avoid sparks being produced. If in doubt, expert advice shall be sought.
3. Only the holds being unloaded should be open when there is the threat of precipitation is in the area.
4. DRI (D) in a hold may be discharged at a port during precipitation, provided that the total quantity of cargo in such hold is:

a) to be discharged at the port in question, and
b) not to be transferred to another ship or covered/enclosed barge, and that
c) the express permission of the receivers has been given and a 'rain letter' issued by the Shipper.

5. Otherwise during precipitation all cargo operations shall be suspended and hatches of holds carrying DRI (D) closed and monitoring of the hydrogen concentration in such holds shall be resumed.
6. It is a recommended practice to discharge the cargo hold(s) with the highest cargo temperatures first, always in keeping within the ship's required trim and hull stresses.

5.5 Clean-up Procedures

1. Accumulations of dust from DRI (D) on deck or in proximity to holds shall be removed as quickly as possible. Contact with saltwater through hosing or other means shall be avoided.
2. 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 (Automatic Identification System) and GPS.
3. Dust evolved during handling and unloading of DRI (D) can accumulate over the ship's surface. In a marine environment, the dust rapidly rusts to form iron hydroxide, which has a reddish-brown colour. Laboratory testing has shown that such dust does not damage the integrity of the ship's paint system. However, to prevent staining, the following precautions should be taken:
   a) prior to loading ensure that cargo holds are fresh water rinsed in order to remove sea salt residues;
   b) remove the dust periodically during and immediately on completion of loading by sweeping/vacuuming;
   c) on completion of loading emphasis should be on 'dry-cleaning' of cargo holds, by brush or air, to remove as much dust as possible, removing dust accumulation on flat surfaces and pipes;
   d) then thoroughly wash down the affected surfaces of the ship, using fresh water as far as possible before using saltwater.
4. Specialised barrier coats may help minimize the extent of dust-related cleaning, especially on horizontal surfaces. Dry-cleaning by crew during loading and discharge helps reduce dust. Use of air to knock down dust from pipes and hatch channels/bars helps final cleaning.
5. Wrapping sensitive hatch fittings, such as exposed hydraulic cylinders, with plastic-stretch food wrap and/or aluminium foil provides a fast and economic means to secure equipment and is easily and quickly removed as needed.
6. Top-coat type paint coatings on main deck and accommodation (cosmetic - urethane based paints) may fail when using muriatic acid (hydrochloric acid). Not all ships have a top-coat. Friendlier acids may reduce coatings damage albeit at a cost increase.
7. Sometimes misconceptions by owners and industry attribute the rust-coloured residues (that remain hardened if not fully cleaned) as being due to corrosion of the hull. In fact, this is generally only the oxidation of the DRI (D) residues and has no ill-effect upon the ship's steel structure.

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:

- clean and dry, with no accumulations of water, e.g. in bottom indentations
- free of chlorides and previous cargoes
- free of combustible materials
- bilge pumps must be operable (where applicable)
- access 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 5.1 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 is 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.

7. EMERGENCY PROCEDURES

This section covers the two principle types of emergency contingency:

1. hydrogen accumulation exceeding 1% by volume (25% of the Lower Explosive Limit) in confined cargo hold or adjacent spaces on a sustained basis after additional ventilation has been applied;
2. sustained temperature ≥100°C (212°F);

For incidents of water intrusion and ship movements indicative of cargo shifting, please refer to section 5.3.3: for water intrusion points 2 and 3 and for cargo shifting point 9.

In case of one of these, or any other emergency, it is important that advice be sought as soon as possible from P&I Clubs, Owners, Charterers, Shippers or other expert as appropriate. This is implicit in each of the following sections 7.1 to 7.5 and contact must 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 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[13] shall be followed.

For all emergency contingencies, do not open the hatch covers without first having sought expert advice.

7.1 Action Plan for Hydrogen Gas Contingency - procedures if hydrogen concentration exceeds 1% by volume

1. As soon as the results of monitoring indicate that the hydrogen concentration is approaching or has already reached or exceeded 1% by volume (25% of the Lower Explosive Limit) and has not responded to the measures specified in section 5.3.2 point 10, inform interested parties such as Owners, Shippers, Charterers and P&I Clubs immediately and seek expert advice, taking into account the prevailing circumstances and history of the cargo in question, for example the rate of hydrogen evolution and ventilation applied, sea conditions, etc. Follow the instructions of the appointed expert or surveyor.
2. Other than in the case of last resort, lifting of the hatch covers for the purpose of additional ventilation should be undertaken only following receipt of relevant expert advice and personnel shall enter the affected cargo spaces only in extremis, exercising extreme caution and following procedures for safe entry.

7.2 Action Plans for High Temperature Contingency – procedures if cargo temperature exceeds 100°C (212°F)

7.2.1. During the Voyage

During the voyage, in the event that the cargo temperature level reaches or exceeds 100°C (212°F) and does not reduce after applying the measures given in section 5.3.2 point 12, the first step is to seek expert advice from the Shipper, Owner, Charterer, P&I Club or other appointed surveyor or expert 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 advice of the appointed surveyor or expert, the following two solutions may be considered:

1. 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;
2. as a last resort, flooding the affected cargo holds with water, always taking into account the stability and strength of the ship.

The temperatures mentioned in this section 7.2.1 are indicative only and the advice of the appointed surveyor or expert should be followed.

NOTE: in all cases vents should be opened and, if available, mechanical ventilation started in order to remove any residual hydrogen.

7.2.2 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 (212°F) 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 [212°F]. 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 [302°F]

Starting with any hot spots, discharge DRI (D) with temperatures above 150°C [302°F], 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 [302°F]). When the temperature has fallen to 150°C [302°F] or below proceed immediately with transfer to the designated zone in the storage areas for cooling.

B. Temperatures at or below 150°C [302°F]

1. Starting with any hot spots, first unload the holds containing DRI (D) with temperature between 100°C (212°F) and 150°C (302°F) 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 (149°F) and 100°C (212°F) in the designated area and immediately transfer the hot material to the designated zone in the storage area for cooling.

Appendix 1: Provisions for Group A cargoes

IMSBC Code Section 4.3.3

When a concentrate or other cargo which may liquefy 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 his representative.

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.1 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 paragraph 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.