KISH P&I CLUB

موسسه بیمه متقابل کیش

## *KISH P & I LOSS PREVENTION CIRCULAR KPI-LP-06-2012*
## *(Information Leaflet for Nickel Ore & DRI Cargoes)*

# NICKEL ORE MATTERS

The main problem with Nickel Ore is behaving like a liquid (so called liquefaction).The consequences of liquefaction for a vessel can be:

►Delays at the load port from rejecting cargo or problems with certification of cargo already loaded,

►Stability problems on voyage from loss of metacentric height (GM) due to free-surface effect leading to a list, angle of loll or capsize,

►Delays at the discharge port or port of refuge making the ship safe and discharging a cargo in a fluid state.

The definitions, tests and precautions in the International Maritime Solid Bulk Cargoes (IMSBC) Code for cargoes that may liquefy are widely associated only with metal ore concentrates, for which their application is relatively straightforward. But any cargo with fine material and moisture could potentially liquefy and should be queried with the shipper.

The high price of minerals in recent years has made some trading viable which would otherwise be uneconomic. One such trade is the shipment of unprocessed nickel ore from various remote islands in Indonesia and the Philippines. If the moisture content of the ore is too high then it can liquefy just like concentrates and display the same liquid behaviour.

Serious problems have been experienced with ocean transport of these cargoes. The IMSBC Code certification requirements apply to nickel ore but the test methods do not always give well-defined results. Several laboratories have obtained widely differing results on samples supposedly representing the same cargo.

The following informative notes are devised to clarify the associated problems:



1- Liquefaction :

In solid state the particles of the material are held together by friction and the cargo has the characteristic of a solid. Cargo on loading appears 'normal' – like slightly damp sand. However, if there is sufficient moisture in the cargo, external agitation can increase the pore water pressure to the 'flow moisture point' (FMP), where water pushes the particles apart. The material then undergoes a sudden transition to the flow state where it loses the friction between particles. The cargo begins to behave like a liquid.

The 'flow moisture point' (FMP) of any cargo that may liquefy is absolutely critical – even the *slightest excess* of moisture above the FMP could lead to liquefaction.

2-IMSBC Code :

Cargoes that may liquefy will contain moisture and at least a proportion of small particles. This includes a wide range of mineral cargoes other than concentrates, with widely differing physical and chemical properties. The International Maritime Solid Bulk Cargoes (IMSBC) Code certification requirements apply to all cargoes which may liquefy regardless of whether or not the cargo is specifically identified as posing a liquefaction risk.

*Never assume there is no risk of liquefaction simply because a cargo is not identified as 'Group A' in the IMSBC Code.*

3-Transportable Moisture Limit (TML):

*Sections 4, 7 and 8 of the IMSBC Code* deal with assessment of acceptability of consignments for safe shipment and production of test certificates showing the 'transportable moisture limit' (TML) and actual moisture content of cargoes. Any ship operator contemplating carrying fine-grained mineral cargoes should carefully read these sections of the IMSBC Code.

On voyage the cargo can be agitated by wave impact and engine vibration and, if there is sufficient moisture present, the cargo will reach FMP and liquefy. This may result in loss of GM from free-surface effect, sudden cargo shifts and structural impact damage from sloshing. For this reason the master must be completely satisfied that *testing* has been carried out strictly according to the procedures *set out in Appendix 2 of the IMSBC* Code.

Because of the severe consequences of exceeding the FMP, the safety margin provided by the lower TML is critical and should not be compromised.

The IMSBC Code describes a number of tests. For the Flow Table Test and Penetration Test the *TML is defined as 90% of the FMP*. The TML of a cargo determined using the Proctor/Fagerberg test is taken as equal to the critical moisture content at 70% degree of saturation. It is a requirement of the International Convention for the Safety of Life at Sea (SOLAS) that the average moisture content of any type of granular cargo in any cargo space must not be higher than the TML.

The difference between the TML and the FMP is intended as a safety margin to protect against uncertainties in testing – such as laboratory errors, sampling errors and variations in moisture content in the cargo. Shippers must certify the TML and the moisture content of the cargo before start of loading. No cargo should be accepted for loading without valid certificates. If the actual moisture content at any location in the cargo is greater than the FMP then the cargo can liquefy at any time without warning.

There are *no 'safe' weather conditions* or routings *for carrying a cargo above its TML*. If masters have doubts about the testing procedure and appearance of the cargo then they should conduct a 'can' test as described in the IMSBC Code section 8.4.

Nickel ores have relatively low nickel content and have been shipped on shorter voyages to Australia and Japan for many years. The high price of minerals has resulted in the shipment of unprocessed nickel ore from various remote islands in Indonesia and the Philippines on long ocean voyages.

As with many finely particulate minerals, including mineral ore concentrates, these ores have the propensity to liquefy and shift if their inherent moisture level is too high. There have been a number serious instances of cargo liquefaction of nickel ore, including total losses and near-misses.

## *SYSTEMATIC DEALING WITH NICKEL ORE*

A) Nickel Ore Background :

Nickel laterite is an inhomogeneous low-grade ore consisting of very fine clay-like particles and larger rock-like particles. There are two different types, limonite and saprolite, which differ in their chemistry and their physical appearance, but present similar problems in bulk shipping due to their high moisture content.

The nickel ore in question is simply dug out of the ground, sorted for size, stored in stockpiles and then shipped. Apart from the drying effect of the sun – which is of unquantifiable benefit – there is no further processing involved.

Because of the way the ore is mined the composition and physical behaviour can differ greatly from mine to mine, from shipment to shipment, from the same mine, and even within a single cargo.

Assessing whether cargo is safe as described earlier, assessing whether a cargo is safe to ship requires the transportable moisture limit (TML) to be calculated. The TML is then compared to the moisture content of the cargo, and provided the TML is the higher figure, the cargo should be safe to load.

There are problems with both the determination of TML (which for nickel ore needs to be determined by a competent laboratory separately for every single cargo) and moisture content (which must be of the cargo offered for shipment), which the IMSBC Code requires shippers to provide prior to commencement of loading. The ore is not found in a homogeneous form. Much of the material is very fine clay-like particles but there are also larger rock-like particles, some of which can be very large indeed.

The FMP testing methods in the IMSBC Code have been developed with concentrates in mind and rely on uniform physical and chemical properties throughout the cargo. For cargoes that consist of a wider range of particle sizes – from rocks through pebbles to sand or soil-like material – the IMSBC Code tests become less reliable. It may not always be possible to certify the FMP of these types of cargo using the test procedures in the Code. It may also be difficult to find qualified laboratories that are willing to certify the FMP of materials other than concentrates.

B) Sampling of Nickel Ore :

Various problems arise with sampling for moisture content and FMP/TML testing. Some stem from the actual manner in which the stockpiles are physically sampled. In a recent case, it was found that the mine did not routinely sample the stockpiles prior to shipment, but rather sampling was conducted during the course of loading. As this was too late to comply with the requirements of the IMSBC Code, their practice was to present the master with *information relating to the cargo loaded onto a previous unrelated vessel*.

In turn, the results of the analysis of the cargo loaded onboard the subject vessel would then be presented to the next ship and so on. By the time the subject consignment had actually been characterised in terms of its suitability for carriage, it had already been loaded, making it more difficult to resolve any issues arising. The master would have been totally unaware of the fact that he was carrying a potentially dangerous cargo.

The shippers in this case (which is not exceptional) were in *breach* of the requirements of the IMSBC Code for a number of reasons. *Firstly,* the moisture content data on the cargo certificates related to a different cargo and not the actual one due to be carried. *Secondly,* the stockpiles intended for loading onboard the subject vessel had not been sampled in accordance with the requirements of the IMSBC Code. This details the frequency and extent of sampling for a given stockpile size, and states that sampling should be conducted no more than one week prior to shipment if the ore is stored uncovered - as most nickel laterite stockpiles are. Should there be significant rain between the time of testing and loading check tests should be conducted to ensure that the material is still in a safe state to load.

C) Moisture content determination:

The in-homogeneity of lateritic nickel ore means that the proportion of the fine clay-like and larger stone-like fractions in different samples can vary significantly. As the clay material typically has higher moisture content (30 to 50%) compared to the larger stony fraction (about 20%), the actual moisture content determined will be an average. As a consequence, the actual moisture content of the clay-like fraction, which is the one prone to liquefaction, will typically, be higher than the declared value.

Preparation of samples for moisture content and FMP determination using the Flow Table Test can be a lengthy process involving samples being spread out on a floor in hot environments. One can therefore expect moisture loss due to evaporation and contact with a dry surface. Although this is not critical for FMP determination (providing testing is carried out correctly), it will result in an underestimation of moisture contained in the actual cargo to be loaded, from which there will be no such moisture loss.

D) Flow moisture point testing:

*Appendix 2 of the IMSBC* Code provides three methods for determining the FMP of commodities. One of these methods, the Flow Table Test (FTT), is the method of choice of the nickel ore mines. However, the FTT was developed for measuring the FMP of relatively homogeneous mineral concentrates. The IMSBC Code states that the method is

primarily for materials with grain sizes up to 1mm, but “may also be applicable to materials with a maximum grain size up to 7mm”. The IMSBC Code also warns that the method may “not give satisfactory results for some materials with high clay content”. Lateritic nickel ore is inhomogeneous, comprising a mixture of fine and larger particles (> 7mm), and has a high clay content. This does not preclude the application of the method to nickel ore, but it does mean that great care is required in performing the test.

The FTT method involves preparing a sample on a flow table in the form of a truncated cone. The flow table top is then raised and allowed to fall sharply through a defined vertical distance. This simple procedure is repeated up to 50 times and the behaviour of the sample cone observed to see if “*plastic deformation*” has occurred. The construction of the flow table and the test methodology is described in great detail in the IMSBC Code. However, it is the experience of the authors that neither the set-up or test method described is being adhered to by the nickel ore mines, with the potential for inaccurate FMP and TML information being declared to the vessel.

Before we can address these issues, we first need to discuss another area of debate, the identification of plastic deformation.

E) Identification of a flow state:
The IMSBC Code does not provide any definite criteria for identifying a flow state (Appendix 2, Section 1.1.4.2.3), but instead lists a number of physical observations that indicate plastic deformation, and suggests procedures for measuring this deformation. The physical signs include: "*moulded sides of the sample may deform*"; "*cracks may develop on the top surface*" of the sample cone; "*the sample cone begins to show a tendency to stick to the mould*"; and there may be "*tracks of moisture on the table*" following the test.

As regards measuring the extent of deformation, "an increase in diameter of up to 3mm in any part of the cone is a useful guide". An alternative approach is to measure the increase
in diameter (if any) following additions of water to the sample. If in the first instance there is 1 to 5mm increase, followed by 5 to 10mm increase, a flow state is indicated.
While some of the Philippine mines rely solely on identifying a subjective change in shape of the sample cone, the Indonesian mines tend to rely only on measuring the extent of the deformation (typically 3mm). These vastly different approaches can lead to a great variance in the declared FMP. No consideration is given to the overall behaviour of the sample, and the key indicators referred to in the IMSBC Code may simply be ignored.

F) Construction of the flow table:
According to the IMSBC Code the metal frame of the flow table is to be attached to a metal base plate, which in turn is securely fixed to a concrete plinth that is isolated from the floor by cork matting. This arrangement is designed to provide a known constant force to the sample during testing.
Typically, the mines do not comply with the IMSBC Code, and frequently utilize a free standing table on various surfaces. FMP determination at a Philippine mine for a limonite ore when the table was (a) loosely fixed to a wooden desk, and (b) when securely fixed to a concrete plinth showed that A much smaller deformation was obtained with the flow table mounted on a flimsy wooden desk, due to dissipation of energy into the structure of the support, compared to the deformation observed with a similar sample when the flow table was securely fixed to a rigid platform. This would result in a higher FMP being declared for an incorrectly fixed table.

G) Effect of tamping pressure:
Before the FMP of nickel ore can be determined it needs to be prepared in the form of a truncated sample. The sample mould is filled in three distinct phases, each layer being compacted by a defined number of actions with a tamper.
This is to simulate the packing of the material in the cargo hold. The tamping pressure used is calculated from the bulk density of the cargo (at loaded moisture content) and maximum depth of the cargo in the hold. In the case of nickel ore such tamping pressures can be difficult to apply, and as a consequence, the mines apply incorrect technique and reduced tamping pressure. In effect, the sample is simply spread around to fill the mould, rather than compacted. By using a lower tamping pressure you are underestimating the FMP.

H )Determining moisture content at flow point :

The FMP is determined by adding water to a stock sample of nickel ore until a flow state is determined. At the mines there is no control of the laboratories' environment, and moisture loss can be expected. The IMSBC Code is specific in requiring that "the whole moulded sample should be placed in a container, weighed immediately and retained for moisture determination".
This is not done at many of the mines. Instead, they start with a known weight of sample that is fully utilized in the sample mould, and use the declared moisture content of the cargo as the baseline moisture content. If the sample passes the FTT the whole of the sample is removed and water added, with the test being repeated. The new moisture content is then calculated based on the original sample weight and the volume of water added. The failure to determine the moisture content of the samples experimentally will result in an overestimation of the moisture content, and consequently, FMP.

I ) Advice to Ship Owners :

In all recent instances shippers of nickel ore have issued certificates based on sampling and testing carried out by the respective mine's in-house laboratory.
Regrettably, extensive audits of the sampling and testing methods used by these mines have in every instance so far revealed serious deficiencies, which have rendered the values certified by shippers effectively meaningless. This presents ship owners with a serious dilemma. They are faced with a choice of either accepting the values certified by shippers at face value, despite the high probability of these certificates being flawed, or of becoming actively involved in an (inevitably acrimonious and time-consuming) investigation of the safety of the cargo being offered for shipment.

J) Responsibility of the Master & crew:

It is imperative for the safe operation of the vessel that officers involved in cargo operations understand the characteristics of the cargo to be loaded. Owners and managers have a responsibility to ensure that prior to presenting the vessel for loading the master is fully informed of the characteristics of the intended cargo. This will enable him to take action in a timely manner, especially if concerns require the appointment of a cargo specialist, many load ports are isolated and the appointment and arrival of a cargo specialist can be time consuming.

K) Accuracy of information provided:

Cargo documentation provided for this cargo is ***often inadequate*** and does not alert the crew to the potential of the cargo to liquefy. There are many examples of insufficient information being presented by shippers to the master and a few cases of documentation for cargo loaded on an entirely different vessel being handed over. Ore cargo characteristics and moisture content in particular can change during seasonal climate variations, shippers have a responsibility to ensure cargo information provided is recent, relevant and accurately determined. For nickel ore cargoes that may liquefy this must include the moisture content and the transportable moisture limit (TML).
The composition of some nickel ore cargoes can often be of an inhomogeneous nature. Testing methods for cargoes that are prone to liquefy described in Appendix 2 of the IMSBC Code were designed to assess the suitability of ore cargoes with a maximum granular size of 7mm and are described as not necessarily giving satisfactory results for material with a high clay content. Nickel ore and lateritic nickel ore in particular have both. Testing can still be carried out, however the process and results often give values of

moisture content below the actual value of the intended cargo. Values of TML and moisture content should therefore be treated with caution.

L) Recent matters:

Ship-owners should be aware that in recent cases in the Philippines, there were across certificates similar to those encountered during our first involvements with nickel laterite ores being shipped from Indonesia. These certificates state simply that the material has been tested in accordance with the IMSBC Code Flow Table Test method and found to pass. No figures for the FMP and TML are stated although average moisture content, which is valueless without a TML, is provided.

Needless to say, it is not possible to assess the safety and suitability for carriage of a material based on such an incomplete declaration.

M) Inspection of cargo prior to shipment:

This can be very difficult for the master if cargo is being transhipped by barge as is usually the case. If the cargo is stored in uncovered stockpiles and has standing water, moisture content may be high, especially during the wet season. If possible a comparison of appearance between stockpiles and cargo loaded on barges should be conducted to determine if they are from the same stockpile.

The IMSBC Code describes a shipboard method (the "*can test*") for checking whether a cargo may be suitable for shipment. This involves filling a small can with the material and repeatedly banging it on a hard surface. The appearance of the material at the end of the test can be used to determine form an opinion about the suitability of the material for shipment. This test should not be a substitute for proper laboratory testing using an appropriate methodology. However, if can tests carried out on a cargo presented for loading indicate a propensity for liquefaction, this is a major warning sign that the cargo as a whole is unsafe for carriage.

Expert advice should then be sought. If shippers present significant amounts of ore that fails the can test, this is an indication that the cargo as a whole is unsafe, and that any certification to the contrary is flawed.

During loading nickel ore cargoes with high moisture content can often be detected by the way the cargo splatters and liquefies when it enters the hold, evidence of free water in the hold would reinforce the master's suspicion.

# DIRECT REDUCED IRON (DRI) MATTERS

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

**A) DRI and its derivatives:**
Initially, most DRI was shipped in the form of pellets. This form was found to be most at risk of heating and methods of treating DRI were tried in order to reduce the danger.

1- Passivated pelle**ts :**
These are ordinary DRI pellets coated with a substance which is intended to protect the iron from air and moisture. Producers in different countries use different forms of coating, some of which are more effective and durable than others. However, no coating renders the DRI entirely safe. The coating can chip off and it will break down over time.

2- Cold moulded briquettes:
These are DRI pellets which have been compressed into the shape of a cake of soap, the intention being to reduce the accessible surface area of the pellets in order to reduce the area available for reacting with air and moisture. The briquettes can also be passivated. The problem with this cargo is that the briquettes are relatively fragile as they are compressed when cool. They can fracture during normal cargo operations, which increases the amount of surface area available for reaction with air and moisture and the cargo becomes dangerous in a similar way to pellets.

3- Hot moulded briquettes or hot briquetted iron (HBI) :
The pellets and lumps can be compressed at temperatures exceeding 650°C to form coherent briquettes that are less porous than the original materials. As such, the briquettes are less fragile and, therefore, less prone to breaking up during cargo handling and have less surface area available for oxidation. They can also be passivated. This is possibly one of the safer forms of DRI but, even so, is still prone to heating and giving off hydrogen in certain conditions.

4- DRI fines:
The DRI production process (and the hot-briquetting process if HBI is being produced) generates copious quantities of dust or ‘fines’. These fines are usually stored separately from the finished DRI or HBI product, but, as they have commercial value for steel making, there is a market for shipping them. Fines are not normally compressed into large cohesive briquettes and remain porous like DRI pellets. As fines they also exhibit an extended surface area. Consequently they can exhibit self-heating qualities. They may have also generated hydrogen in sufficient quantities to form explosive atmospheres, even in holds

that have been subject to natural ventilation through conventional cargo hold vents, or hatch cover openings.

**B) Hazards of DRI and derivatives:**
The principal hazards of all cargoes of DRI and its derivatives are twofold.

1- Reaction with air:
Firstly, they will react with the oxygen present in the air, thereby producing heat. This effect can run away in spectacular fashion, leading to auto-oxidation (burning) of the iron, in which the stow becomes incandescent as the temperatures approach 1,000oC. This tendency is successfully prevented in most practical applications by densifying the DRI pellets at temperatures exceeding 650oC to produce HBI. Whereas self-heating is dangerous and alarming, it is a gradual and progressive event that can often be diagnosed early, affording masters time to obtain advice from ashore and institute suitable safety measures.

2-Reaction with moisture:
The second hazard is again related to the reactivity of iron, this time with moisture or water. The result is the generation of hydrogen gas, which is explosive over a very wide range of concentrations & in practical situations, displays an alarming readiness to be ignited. Explosions of hydrogen in air are extremely violent and rapid and an unfortunate master has no time in which to react to an explosion.

**C) Misleading descriptions of DRI:**
Shippers may offer a material for bulk shipment that is clearly a DRI product, but is claimed to be safe for bulk carriage by sea without the usual precautions. This particularly applies to DRI fines. The most common approach is to call the fines 'HBI Fines' or 'Metallic HBI Fines' and thereby claim the relaxation in precautions afforded to HBI. Fines have also been described as 'Iron Fines' or 'Iron Remet Fines', the term 'remet' probably being a shortening of the word 'remetalised', signifying it is metallic rather than the ore.
Despite the foregoing, not all cargoes with 'DRI' in the description are hazardous. For example, cargoes described as 'direct reduced iron ore'. By referring to the typical material composition supplied by the shippers, it could be seen that this was indeed iron ore that was destined for the direct reduction process, and therefore a cargo that posed no special hazards. However, this is difficult for a master to determine and expert advice should always be sought.

**D Exemptions at Port of Loading :**
There have recently been further attempts by shippers of DRI to persuade ship owners to carry DRI Fines using precautions different to those described in the IMSBC Code. These are usually accompanied by an exemption from the country of shipment. The carriage described in the documentation provided by shippers for DRI (C) with moisture in excess of the limits in the IMSBC Code for DRI (C), uses ventilation rather than inerting the holds. In addition carriers may be faced with large amounts of technical data produced by the shippers to support their case for carriage under ventilation and not as per the IMSBC Code. The background to this latest attempt to have DRI (C) shipped under provisions different to those of the IMSBC code is a failed attempt to have a new class of DRI cargo, called Iron Fines (blend),

approved for inclusion into the IMSBC Code at IMO DSC 15 during September 2010. If requested to ship cargoes described as DRI(C) under conditions other than those described in the IMSBC Code expert advise should be requested. Such cargoes will almost certainly fall under the description of DRI(C) in the IMSBC Code and should be carried strictly in accordance with the Code

**E) Regulatory developments :**
Following a number of investigations into accidents associated with the carriage of DRI, the International Maritime Organization (IMO) revised the relevant schedules for this cargo when it published the International Maritime Solid Bulk Cargo (IMSBC) Code, which is in force now.

**F) Safe carriage of DRI :**
*The common factor to both hazards mentioned above is the oxygen present in the atmosphere. It is clear that the exclusion of oxygen, or its reduction to a suitably low level, will eliminate the possibilities of self-heating or of a hydrogen explosion occurring. It follows that carrying a cargo of DRI or its derivatives under an inert gas blanket, and maintaining that blanket throughout the voyage, is an acceptable method to carry the product safely. The IMSBC Code recommends that both DRI (B) and DRI (C) cargoes are carried under an inert blanket.*



***IMSBC EXTRACTED GUIDELINES***

***Summary of IMSBC Code schedules for DRI and its derivatives :***
The following summary has been produced to assist in decision making process and for t general information. If a vessel is fixed to load a DRI or related cargo; she should refer to and comply with the more detailed advice contained within the IMSBC Code.

**1) All Types of DRI :**
**• Fines are now defined as particles up to 6.35mm (¼") in size.**
**• Cargo spaces shall be clean, dry and free from salt and residues of previous cargoes. Wooden fixtures and combustible materials shall be removed.**
**• The carrier's representative is to have reasonable access to stockpiles and loading installations for inspection.**
**• Prior to loading, the shipper shall provide the Master with a certificate issued by a competent person stating the cargo is suitable for shipment and that it conforms with the requirements of the Code in terms of particle size, moisture content and temperature.**
**• A similar certificate shall be provided after loading relating to the whole consignment.**
**• The shipper shall provide comprehensive information on the cargo and safety procedures to be followed in the event of an emergency.**
**• No cargo shall be loaded or transferred during precipitation and non-working hatches shall be kept closed.**

• The cargo shall not be accepted when its temperature is in excess of 65oC, or its moisture content exceeds the permitted value, or if the quantity of fines exceeds the permitted value, where appropriate.
• The cargo temperatures shall be monitored during loading and recorded in a log.
• The cargo shall be trimmed in accordance with the relevant provisions of the Code.
• Adjacent tanks other than double bottom tanks shall be kept empty during the voyage.
• Weather tightness shall be maintained throughout the voyage.
• The bilge wells shall be clean and dry and protected from ingress of cargo.
• Precautions shall be taken to protect personnel, equipment etc. from the dust of the cargo.
• During handling of the cargo, "NO SMOKING" signs shall be posted and no naked lights or other ignition sources permitted.
• Suitable precautions shall be taken before entering cargo spaces, which be depleted of oxygen and/or contain a flammable atmosphere.
• The ship shall be provided with a detector suitable for measuring hydrogen in an oxygen depleted atmosphere and for use in a flammable atmosphere.
• Cargo temperatures and hydrogen concentrations in hold atmospheres shall be measured at regular intervals during the voyage.
• If the hydrogen concentration exceeds 1% or the cargo temperature exceeds 65oC, appropriate safety precautions shall be taken. If in doubt, expert advice shall be sought.
• Bilge wells shall be checked regularly for the presence of water.
• All records of temperature, hydrogen and oxygen measurements, where appropriate, are to be retained on board for 2 years.
• The hydrogen concentration shall be measured in the holds prior to opening the hatch covers.
2) DRI (A), Briquettes, hot-moulded :
• The moisture content shall be less than 1%.
• The cargo shall comprise essentially whole briquettes and the addition of fines shall be prohibited.
• Fines shall comprise no more than 5% by weight.
• Weather deck closures and hatch covers shall be inspected and tested to ensure integrity and weather tightness.
• Surface ventilation only shall be conducted as necessary and air shall not be directed into the body of the cargo. When mechanical ventilation is used, the fans shall be certified as explosion-proof and shall prevent spark generation. Wire mesh guards shall be fitted over inlet and outlet ventilation openings, and the escaping gases shall be unable to enter living quarters.
• During discharge, the application of a fine spray of fresh water is permitted only when the cargo is to be stored in an open area.

3) DRI (B), Lumps, pellets, cold-moulded briquettes :
• The average particle size shall be from 6.35mm to 25mm, with fines no more than 5% by weight.
• The shippers' certificate shall state the date of manufacture for each lot of cargo.
• The certificate issued after loading shall confirm that the moisture content has not exceeded the permitted value.
• The cargo shall be certified as having been aged for at least 3 days, or treated so as to achieve the same reduction in activity.

**• The cargo shall be kept dry at all times. Any cargo that has been wetted, or known to have been wetted, shall not be loaded.**

**• Loading conveyors shall be dry.**

**• Prior to loading, an ultrasonic test or another equivalent method with a suitable instrument shall be conducted to ensure weather tightness of the hatch covers and closing arrangements.**

**• The moisture content shall less than 0.3% by weight and shall be monitored during loading.**

**• Any cargo that has already been loaded into a cargo space and which subsequently becomes wetted, or in which reactions have started, shall be discharged without delay.**

**• The breakage of briquettes and lumps shall be minimised and the addition of fines shall be prohibited.**

**• Carriage is only permitted under an inert gas blanket.**

**• Prior to loading, provision shall be made to introduce a dry inert gas at tank top level. Nitrogen is preferred. All vents and openings shall be sealed to prevent the loss of the inert atmosphere.**

**• On completion of loading of a cargo space it shall be immediately closed and sufficient inert gas introduced to achieve an oxygen concentration of less than 5% throughout the cargo space.**

**• The ship shall be provided with the means of reliably measuring the temperatures at several points within the stow, and determining the concentrations of hydrogen and oxygen in the cargo space atmosphere on voyage whilst minimizing the loss of the inert atmosphere.**

**• The oxygen concentration shall be maintained at less than 5% throughout duration of voyage. The ship shall be provided with the means to ensure that this requirement can be achieved throughout the voyage. Consideration shall be given to topping up with additional supplies of inert gas: the ship's fixed CO2 fire-fighting system shall not be used for this purpose.**

**• The ship shall not sail until the master and a competent person recognised by the national administration of the port of loading are satisfied that:**

**- All loaded cargo spaces are correctly sealed and inerted;**

**- The cargo temperatures have stabilised at all measuring points and are less than 65oC; and**

**- The concentration of hydrogen in the free space has stabilised and is less than 0.2% by volume (i.e. 5% LEL).**

**• The cargo spaces shall remain tightly sealed and the inert condition maintained throughout the voyage.**

**• The ship shall be provided with a detector suitable for measuring oxygen in a flammable atmosphere.**

**• Oxygen concentrations shall be measured at regular intervals during the voyage.**

**• During precipitation, all cargo discharge operations shall be suspended and holds containing cargo shall be closed.**

**4) DRI (C), By-product fines :**

**• The average particle size shall be less than 6.35mm, and there shall be no particles greater than 12mm in size.**

**• "The reactivity of this cargo is extremely difficult to assess due to the nature of the material that can be included in the category. A worst-case scenario should therefore be assumed at all times."**

**• The cargo shall be kept within the permissible moisture content at all times.**

• The carriage requirements are identical to those for DRI (B), including the 0.3% limit on moisture, with the following exceptions:- The shippers' certificate does not need to state the date of manufacture of each lot of cargo;

The cargo shall be certified as having been aged for 30 days.

- Any cargo that has already been loaded and which subsequently is exposed to additional fresh water or seawater over its natural moisture content and becomes wetted, or in which reactions have started and its temperature has exceeded 120 Degrees C, shall be discharged without delay.

KPI Loss Prevention Team
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