Hot Briquetted Iron Association (HBIA) Ltd. presents

HOT BRIQUETTED IRON (HBI)*
Guide for Handling, Maritime Carriage, and Storage

* described as Direct Reduced Iron (A) – Briquettes, hot-moulded in the International Maritime Solid Bulk Cargoes (IMSBC) Code published by the International Maritime Organization (IMO)
HOT BRIQUETTED IRON (HBI)*

Guide for
HANDLING, MARITIME CARRIAGE, AND STORAGE

Published by
HBI Association Ltd.

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DISCLAIMER

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

The purpose of the HBI Association Ltd. (HBIA) is threefold:

- To promote HBI as steel's most versatile metallic
- To inform ship owners/operators, charterers, and terminal operators of the handling, shipping, and storage benefits of HBI
- To assist iron and steel producers in the effective use of HBI

Therefore, the HBIA has sponsored the preparation of this guide to better inform those involved in the use, transport, handling, and storage of steelmaking metallics of the characteristics and benefits of HBI.

The guide is divided into the following sections:

1.0 Definitions
2.0 Characteristics of DR Products
3.0 HBI Loading Procedures
4.0 HBI Ocean Carriage
5.0 HBI Inland Transport, Handling, and Storage
6.0 Emergency Contingencies

The guide draws from the collective experience of Venezuelan producers of Direct Reduced Iron (DRI) and HBI who have manufactured, used, and exported these products and their byproducts for more than 35 years plus the experiments carried out by recognized laboratories and recommendations made by shipping insurance organizations during the period.

Much of this experience is embodied in the schedules for the various direct reduction products in the new International Maritime Solid Bulk Cargoes (IMSBC) Code published by the International Maritime Organization (IMO), as well as in US Coast Guard shipping documents.

The IMSBC Code includes schedules for Direct Reduced Iron (A) – Briquettes, hot-moulded, or HBI, Direct Reduced Iron (B) – Lumps, pellets, and cold-moulded briquettes, and Direct Reduced Iron (C) – By products, including fines.

We hope that you find this guide for the safe handling, shipping, and storage of HBI, or DRI (A), to be both informative and helpful.

Respectfully,

Alberto Hassan
President
HBI Association Ltd.
PREFACE

The existing, generally accepted knowledge of the physical and chemical characteristics of direct reduction products is derived from the collective experience of the industry since the 1970s. This knowledge provides the basis for the wording of a variety of written rules and proceedings in use today.

Despite this wealth of knowledge, there is still a lack of understanding and acceptance of the proper methods and techniques for safely handling, shipping, and storing these products, as well as the unique safety-related benefits of HBI, or DRI (A).

Direct reduction products include Direct Reduced Iron (DRI), or DRI (B), Hot Briquetted Iron (HBI), and DRI/HBI Fines (metalized fines), or DRI (C) By-product fines. These are manufactured products or products derived from the manufacturing process (in the case of DRI/HBI Fines), which means they have consistent and uniform characteristics that generally follow the Laws of Nature.

However, there is a “human factor” in every process, be it production, handling, shipping, or storage. In order to control how direct reduction products perform in a given situation, the “human factor” must be addressed.

Over the past 35 years, there have been some accidents involving direct reduction products. Many of these were the result of human carelessness or negligence when handling, shipping, and storing these materials. In most of these cases, if the proper procedures had been followed, the accidents would not have occurred.

In other words, most hazardous situations can be avoided when the hazardous factors are fully identified, understood, and controlled in a timely manner.

The aim of this guide is to gather the experience-based knowledge from the last 35 years and present it in a manner that can be easily referenced and understood in real world situations. We hope that those involved in any aspects of handling, shipping, and storing HBI, or DRI (A), will become more knowledgeable of its characteristics in order to better understand how to be safe and better prepared to manage the risks associated with this product.

Together, we can act responsibly in complying with the spirit of the SOLAS, the new IMSBC Code, and the BLU Code.

Oscar Dam G.
PhD, Met. Eng., MSc. Imperial College, University of London
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PART I
Section 1 - DEFINITIONS

This section provides clarification of technical terms commonly used when discussing direct reduction products and the methods/procedures for handling, shipping, and storing these products.

1.1. BLU Code

Code of practice for the safe loading and unloading of bulk carriers published by the International Maritime Organization (IMO).

1.2. Contingency

A consideration or alternative when the possibility of a hazardous situation exists (implied risk).

1.3. Contingency Plan

The mechanism for implementing (putting into action) a set of considerations or alternatives when the possibility of a hazardous situation exists (implied risk).

1.4. DR Feedstock

Pellets (DR-grade) - iron ore concentrate that has been formed into round balls (agglomerated), fired, and indurate at a temperature of about 1360° to 1400° Celsius. Total iron content is typically 66 to 67 percent, and particle size ranges from 9 to 16 mm diameter.

Lump - natural iron ore chunks as mined, having a particle size between 9 to 25 mm and a total iron content of 63 to 65 percent.

Fines - natural iron ore particles as mined or as produced during the crushing of large particles of natural, coarser particles. Fines are classified as pelletizing fines or sintering fines. The former has a particle size between 0 and 12 mm and is used in fluidized bed direct reduction processes.

1.5. Direct Reduced Iron (DRI)

The product of iron oxide pellets, lump ores, and/or fines that have been reduced (i.e., oxygen removed) in a direct reduction process at temperatures in excess of 900° Celsius, thereby increasing the percentage (by weight) of total iron in the reduced product. All other oxides in the ore remain in their natural state.

The International Maritime Organization (IMO) describes direct reduced iron as DRI (A) Hot-moulded briquettes, DRI (B) Lumps, pellets, and cold-moulded briquettes, and DRI (C) By-product fines.

1.6. Direct Reduced Iron (A) or DRI (A) Briquettes, hot-moulded

IMO classification for Hot Briquetted Iron (HBI) – see Definition 1.11.
1.7. Direct Reduced Iron (B) or DRI (B) Lumps, pellets, cold-moulded briquettes

IMO classification for pellet and lump DRI – see Definition 1.5.

1.8. Direct Reduced Iron (C) or DRI (C) By-product fines

IMO classification for DRI fines and other byproducts from the production and handling of DRI (A) and (B) – see definition 1.9.

1.9. DRI Fines

This is the result of physical degradation of the particle size distribution of pellets, lumps, and fines during the reduction process caused by the action of rubbing, crepitation, shear stresses, etc. Fines also can be generated during the processing, handling, and screening of DRI (A) and DRI (B) prior to use in iron and steel production processes. Normal size distribution depends on the feedstock and a range from 0 to 12 mm. Metallic iron content is in the range of 1.0 to 75.0 percent by weight.

Mixtures of fines sometimes are prepared. The water present in some of these mixtures will accelerate the natural passivation process and result in total iron content similar to sinter feed quality iron ore.

DRI fines have been known by various names when traded, such as HBI Fines, Orinoco Remet, Orinoco Concentrate, Settling Pond Fines, Quench Tank Fines, Metallized Fines, Remet, Process Fines, Sedimentation Fines, Chips, etc. These different names are used to identify the source of the fines (i.e., how they were generated or collected).

1.10. Hazardous Situations

DRI (A) and (B) are neither inert materials nor pyrophoric materials; therefore, hazardous situations, such as overheating and hydrogen gas evolution, can occur if proper precautions are not taken.

1.11. Hot Briquetted Iron (HBI)

The name given to the form of DRI that has been compacted at a temperature greater than 650° Celsius at the time of compaction and has a density greater than 5.0 grams per cubic centimeter (g/cm³). Its higher density and pillow shape provide superior handling, shipping, storage, and melting characteristics.

1.12. Hygroscopic Cargoes

These are cargoes having a moisture content that can interact with air. (Source: “Cargo Ventilation” published by North England P & I Association Ltd.)

1.13. Ignition Temperature

The point at which the heat of reoxidation exceeds the heat losses in a DRI (A) or (B) storage pile (from 150° to 230° Celsius). In this temperature range, DRI B, and DRI (A) to a lesser extent, could ignite and burn.
1.14 **IMSBC Code**

The International Maritime Solid Bulk Cargoes Code, as published by the International Maritime Organization (IMO), which contains the amplified provisions governing the carriage of solid bulk cargoes and the carriage of dangerous goods in solid form in bulk. It will supersede the IMO Code of Safe Practice for Solid Bulk Cargoes (BC Code), 1994 Edition, on January 1, 2011. Until then, use of the IMSBC Code is voluntary.

1.15 **Overheating**

The effect when a heavily wetted pile of DRI (A) or (B) exceeds 150° Celsius. The pile should be spread out and allowed to cool naturally. Do not spray water on a steaming pile of DRI (A) or (B).

1.16 **Partial Briquettes/HBI Chips**

Pieces ranging from 6 to 25 mm particle size that are produced during DRI (A) processing, handling, and screening operations. This material is considered DRI (A) for shipping purposes.

1.17 **Passivation (natural air)**

The process whereby DRI (A) and (B) are allowed to react with the oxygen in the air following quenching or cooling after discharge from the reduction furnace or briquetting machine. The temperatures are about 44° Celsius and less than 100° Celsius for DRI (B) and DRI (A), respectively.

The fresh products are placed into piles in the storage yard and allowed to react with the oxygen in the air. After about five days, the DRI (A) or DRI (B) might show some steaming. Temperatures readings should be taken on a regular basis or daily if in a climate subject to frequent heavy rain.

In the case of DRI fines, or DRI (C), natural air passivation normally is acceptable for a period of 30 to 120 days.

1.18 **Pyrophoric**

Defined as: 1. Igniting spontaneously or 2: Emitting sparks when scratched or struck especially with steel. **DRI is not pyrophoric.**

1.19 **Reactivity**

It is the natural tendency of DRI (A) and (B) to react with oxygen in the air and in water to form iron oxide. The loss of iron is slow in the presence of oxygen in the air. However, oxygen in water causes more rapid reoxidation and the release of hydrogen gas. This effect is accentuated when seawater comes into contact with DRI (B) and to a lesser extent with DRI (A).

1.20 **Risks and Consequences**

The possible results of careless handling, shipping, and storage of DRI (A) or (B):

- Injury to people
- Damage to the environment.
Damage to the quality of the material.
Damage to installations and equipment.

1.21. **Steaming**

The effect when a pile of DRI (A) or (B) has been heavily wetted. Heat from the process of reoxidation generates water vapor, which is released into the air.

1.22. **Sweat**

The condensation that forms in a ship’s hold, either on the cargo or on the ship’s steelwork. (Source: “Cargo Ventilation” published by North England P&I Association Ltd.)
PART I
Section 2 – CHARACTERISTICS OF DR PRODUCTS

This section includes a brief analysis of existing data on the reactivity of the various types of Direct Reduced Iron (DRI), as defined in the IMO IMSBC Code. Available data from technical literature and reports submitted to IMO by DRI producers in the late 1970s and more recently from 2006 to 2009 were reviewed under the UN concepts and industry testing procedures.

2.1. DRI Production

HBI and DRI, classified by IMO as DRI (A) and DRI (B), respectively, are produced in either shaft furnace or fluidized bed processes. Shaft furnace processes use as feedstock 100 percent iron oxide pellets or a mixture of pellets and lump iron ores. The fluidized bed process uses iron ore fines (<1 to 12 mm particle size). The reduction temperature of both is about 900° Celsius. The product of both processes is metallized to 93 to 94 percent and has 1.5 to 2.0 percent carbon. The HBI temperature after quench cooling is below 100° Celsius. DRI is cooled prior to discharge to below 50° Celsius.

During the reduction process, some physical degradation of the pellets, lumps, and iron ore fines takes place. This action produces small pieces of the original feedstock (>6.35 mm) that have been metalized (i.e., metalized fines).

Fines also can be produced during handling, screening, and carriage of HBI and DRI. The particle size distribution depends on the feedstock and will range from <1 to 12 mm.

Broken pieces and chips of HBI can be produced during handling, screening, and carriage. The normal size distribution depends on the feedstock and will range from 6.35 to 20 mm (see Figure 1 below). Partial briquettes and chips are shipped as HBI according to the IMO IMSBC Code schedule for DRI (A).

The particle size ranges of all direct reduction products are shown in Figure 1.

All direct reduction products undergo natural air passivation prior to temporary storage or vessel load out.

2.2. DRI Product Descriptions

DRI is a highly porous, black/grey metallic material formed by the reduction (removal of oxygen) of iron ore at temperatures below the fusion point of iron.

HBI is an enhanced form of DRI that has been compacted at temperature at or above 650° C and has a density greater than 5.0 grams per cubic centimeter (g/cm³).

DRI Fines are a highly porous, metallic material generated as a by-product of the manufacturing and handling processes of DRI and HBI having a density of less than 5000 kg/m³.
Figure 1
Particle Size Range for Direct Reduction Processes and Their Products

Figure 2 shows the typical chemical and physical characteristics of HBI. Actual chemical and physical characteristics may vary from shipper to shipper. A preliminary certificate of analysis of the product should be supplied to the Master before sailing.

<table>
<thead>
<tr>
<th>Typical Chemical Characteristics</th>
<th>(%)</th>
<th>Physical Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Iron (T Fe)</td>
<td>90 - 94</td>
<td>Bulk density (kg/m³) 2,500 - 3,300</td>
</tr>
<tr>
<td>Metallic Iron (Fe)</td>
<td>83 - 88</td>
<td>Approximate Stowage factor (m³/mt) 0.3 to 0.4</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.6 - 2.0</td>
<td>Size: Length: 50 to 140 mm</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.02 - 0.11</td>
<td>Width: 40 to 100 mm</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>0.003 - 0.03</td>
<td>Thickness: 20 to 50 mm</td>
</tr>
<tr>
<td>Total Gangue (SiO₂, Al₂O₃, CaO, MgO, MnO)</td>
<td>1.95 - 5.10</td>
<td>Weight: 0.2 to 3.0 Kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finest: under 6.35 mm</td>
</tr>
</tbody>
</table>
2.3. DRI Product Classifications

HBI is classified by IMO in the IMSBC Code as Direct Reduced Iron (A) – Briquettes, hot-moulded and as such is suitable for sea carriage without the use of inert gas or other special equipment. A copy of the schedule pertaining to HBI, or DRI (A), in the IMSBC Code schedule is included in this guide as Annex 1.

HBI also conforms to the requirements of the U.S. Coast Guard Special Permits issued to shippers pursuant to 46 CFR 148.01-9 of the U.S. Coast Guard (USCG) Carriage of Solid Hazardous Materials in Bulk Regulations.

DRI is classified by IMO as Direct Reduced Iron (B) – Lumps, pellets, and cold-moulded briquettes. Cold-moulded briquettes are defined as briquettes that have been formed at a temperature less than 650° Celsius or which have a density of less than 5000 kg/m$^3$.

DRI Fines are classified by IMO as DRI (C) – By-products, including fines.

2.4. DRI Reactivity\(^{(2, 3, 4)}\)

Direct reduction products have an affinity for oxygen, which is known as reactivity. In early days of exporting DRI, the product showed a strong tendency to react with water, especially sea water.

HBI was introduced in 1976 as a response to the safety issues of shipping DRI in pellet and lump form. HBI has the same low residual chemical characteristics of DRI but is much safer to transport as a bulk cargo due to its compacted physical structure, which makes it less reactive with water and much less prone to self-heating. More than 80 million metric tons (tonnes) of merchant HBI have been shipped worldwide, more than 65 million tonnes of which by water, with an outstanding safety record.

For this reason, prior to loading DRI classified by IMO as DRI (B), a dry, inert gas must be introduced at tank top level to purge the air from the cargo and fill the free volume above. Nitrogen is preferred for this purpose. All vents, accesses, and other openings that could allow the inert atmosphere to be lost from the cargo spaces must be closed and sealed, and the ship must have the means to maintain the oxygen concentration in the cargo spaces below 5.0 percent throughout the voyage.

Figure 3 shows that HBI is the least reactive of all direct reduction products.
2.5. DRI Reactivity Stages.

Industry experience has shown that the DRI reactivity mechanism consists of the following stages:
1. Reoxidation
2. Steaming
3. Water Effects
4. Auto Ignition

The reactivity stages are similar for all direct reduction products. However, the following description of the stages will focus on HBI, or DRI (A), which is the subject of this guide.

2.5.1. Reoxidation

HBI will slowly re-oxidize in storage in the same way as scrap. The HBI weatherability test shown in Figure 4 was conducted over an 8-month period in tropical conditions (27° C and 70 percent relative humidity). The average metallization loss was measured at the pile surface and at 0.5 m in the pile.

![Figure 4: Metallization Loss for HBI Stored in Open Yard](image)

Because any direct reduction product will react with water, HBI should be stored in an area with adequate drainage to avoid standing water. However, it is not necessary to cover storage piles because the relatively inert characteristics of HBI prevent rapid reoxidation.

Metallization losses can be minimized when stockpiled in an open yard by following these recommendations:
• Build tent-shaped piles up to 6 meters high
• Build piles slightly above ground level to provide a slope for better water drainage

2.5.2. Steaming

When rain falls on HBI piles, the material will absorb some water (about 3 percent by weight) due to capillary effects on the exposed surfaces and will release water vapor. This effect is called “steaming.”

At a temperature above 50° Celsius, HBI will re-oxidize when heavily wetted and create heat, which in turn results in evaporation of the water. HBI piles will steam until the water is evaporated, the reoxidation reaction stops, and the material cools to ambient temperature. Therefore, water should not be sprayed on steaming piles of HBI.

2.5.3. Water Effects

When water is present during or after reoxidation, corrosion (i.e., “rusting”) occurs. This effect is stronger when seawater is in contact with HBI. Hydrogen gas can evolve when water is present during oxidation reactions. This gas is highly explosive and detrimental to breathing in enclosed spaces.

2.5.4. Auto Ignition

HBI is classified in the IMO IMSBC Code as MHB (material hazardous only in bulk). An MHB classification is given to a substance that is neither Class 4.2 (substances that can self-heat or are liable to spontaneous combustion) nor Class 4.3 (substances that emit flammable gases after contact with water) and therefore, not considered dangerous.

However, HBI piles can reach the ignition point under certain conditions:

• Sustained re-oxidation
• Excessive fines content in the pile
• Briquetting density below 5.0 gm/cm³
• Accumulated hot product
• Presence of excess water

Under such conditions, the pile will ignite locally if the temperature of the pile exceeds 200° C (ignition temperature).

The auto ignition tendency should be monitored closely because hydrogen can be generated under wet conditions, especially in the presence of seawater, and there will be no flame present.

2.6. Hazards

HBI is not a pyrophoric material, but neither is it an inert material. Therefore, hazardous situations, such as overheating and hydrogen gas evolution, can occur if proper precautions are not taken.

The schedule for HBI or DRI (A) in the IMO IMSBC Code lists the following under the heading “Hazards”:
- Temporary self-heating of about 30°C Celsius may be expected after material is handling in bulk.
- Material may slowly evolve hydrogen after contact with water. Hydrogen is a flammable gas that can cause explosions when mixed with air in concentrations above 4 percent.
- Liable to cause oxygen depletion in cargo spaces.
- This cargo is non-combustible or has a low fire risk.
PART II
Section 3  HBI LOADING PROCEDURES

This section provides information about the HBI loading procedures commonly used during the last 35 years including flow sheets that are easy to understand and follow.

The following general procedures are presented in this section:
- Vessel Acceptance
- Handling and Storage at the Port
- Preloading Vessel Inspection
- Loading Procedure

3.1. Vessel Acceptance

Before the first briquette is loaded, it must be determined that the ship is suitable for the cargo and is in possession of a valid IMO Certificate of Compliance (see Figure 5).

The vessel acceptance flow sheet for an HBI cargo is shown in Figure 6.

3.1.1. Vessel Type

The following types of vessels have been used for ocean transport of HBI:
- 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
- OBO with similar hatch covers as above

Double-deck vessels are not recommended for this type of cargo.

3.1.2. Ventilation System Types

Direct reduction products are hygroscopic cargoes because they have a moisture content that can interact with air and condensation (i.e., sweat), can form on the steelwork in a ship’s hold. For this reason, surface ventilation, either natural or mechanical, is recommended by the IMO for carriage of HBI, or DRI (A).

According to the IMO IMSBC Code, air should not be directed into the body of the cargo. When mechanical ventilation is used, the fans must be certified as explosion-proof and equipped to prevent spark generation, thereby avoiding the possibility of igniting any hydrogen gas that might be present in the cargo hold. Suitable wire mesh guards must be fitted over the inlet and outlet ventilation openings, and care must be taken to prevent any escaping gases from entering living quarters in hazardous concentrations.
CERTIFICATE OF COMPLIANCE

Recommendations of the "Code of Safe Practice for Solid Bulk Cargoes". Appendix B Cargoes.

Issued under the authority of the Government of

**Particulars of ship**
- **Name of ship**: 
- **Distinctive number of latters**: 
- **Port of registry**: 
- **Gross tonnage**: 
- **Deadweight of ship (metric tons)**: 
- **IMO number**: 

THIS IS TO CERTIFY
That the subject ship is found to comply with the recommendations of Appendix B of IMO's "Code of Safe Practice for Solid Bulk Cargoes", Res.A434(XI) for the carriage of dangerous bulk cargoes as listed in this certificate, provided that stowage requirements together with other provisions of the Code of Safe Practice for Solid Bulk Cargoes (BC Code) has been observed.

<table>
<thead>
<tr>
<th>Cargo</th>
<th>IMO Class</th>
<th>Cargo Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct reduced iron, briquettes, hot moulded</td>
<td>MHB</td>
<td>All cargo holds 3/4</td>
</tr>
</tbody>
</table>

This certificate is valid until __________________________

Issued at __________________________ On __________________________

**RENEWAL OF CERTIFICATE**

THIS IS TO CERTIFY that at the periodical survey required for renewal of the Certificate, the ship was found to comply with the relevant provisions and that this Certificate is reinstated with validity until: (maximum five months), pending the issuance of the new certificate

Plase __________________________ Date __________________________

Surveyor's signature __________________________ Stamp __________________________

Figure 5
IMO Certificate of Compliance
Figure 6
Vessel Acceptance Flow Sheet
There are two types of surface ventilation systems available on bulk cargo ships: natural and mechanical (fan-assisted)

3.1.2.1. Natural Ventilation System

Natural ventilation systems typically consist of a pair of ventilators at each end of the hold. However, some ships employ only a single, center line ventilator at each end.

The effect of natural ventilation is assisted considerably by the presence of strong, relative winds. When the relative wind is zero, very little air will enter the ventilators, thereby greatly limiting their effect.

A typical arrangement of natural ventilation on the hatches is shown in Figure 7.

For natural ventilation, it is recommended \(^{(4, 9)}\) to equip the hatches of the holds with gravity ventilators (see Figure 7). This would be sufficient to dissipate hydrogen at a sufficient rate to prevent accumulation in an amount that would approach the explosive limit. Hydrogen content in the holds should be less than one percent.

![Figure 7 - Natural Ventilation Device on Hatch Covers](image)

3.1.2.2. Mechanical (Fan-Assisted) Ventilation System

Mechanical surface ventilation means power-assisted ventilation and ventilation only of the space above the cargo, as derived from the definitions in Section 3 of the IMO IMSBC Code. A typical arrangement of “mushroom” electric ventilators located on deck between hatch covers is shown in Figure 8.
3.1.3. Arrangement of the Ventilation System

- Vents should be installed on the upper part of the hatch covers.
- Vents and ducts should restrict the ingress of water as much as possible.
- Gases should be extracted from the holds as much as possible rather than blowing in humid air from the atmosphere.

3.1.4. Type of Fan Drive (in Case of Mechanical Ventilation)

Ventilators must have the following characteristics:

- Certified marine explosion-proof in compliance with requirements of classification societies of ships
- Axial flow
- Reversible
- Non-sparking blades
- Variable speed
- Drive mechanisms:
  - Air
  - Water
  - Electrical

3.2 Handling and Storage at Loading Port

The flow sheet for handling and storing HBI at the port shown in Figure 9 was developed from actual operations at Compañía Operadora del Puerto de Palúa (COPAL) in Palúa, Venezuela. COPAL is the largest and most experienced port in the world for handling, storing, and loading direct reduction products.

Additional information on standard port operations and emergency procedures is available by contacting COPAL management (ggcopal@cantv.net).
Figure 9
Handling and Storage at Port Flow Sheet
3.3. Preloading and Vessel Inspection

The shipper should provide details regarding the nature of the material to the carrier, and a thorough inspection of the vessel must be carried out following the steps shown in the pre-loading flow sheet shown in Figure 10.

Prior to loading, the shipper or his appointed agent should provide the safety precautions and emergency procedures associated shipping HBI to the Master of the ship. Details of the characteristics and properties, such as chemical hazards (i.e., toxicity and corrosiveness), stowage factor, angle of repose, etc. should be provided so all necessary safety precautions can be put into effect.
The potential for HBI to generate hydrogen gas after contact with water, especially seawater, should be pointed out and extensively discussed in the instructions provided to the carrier. Proof that the instructions were furnished to the carrier, such as a signed receipt from the Master, should be obtained by the shipper.

3.4 Cargo Documentation

When shipping HBI, the following instructions are normally given to shipping companies and shipmasters prior to loading:

- Maritime guide for transportation of HBI, or DRI (A)
- Material Safety Data Sheet for HBI, or DRI (A)
- Material Compliance Certificate:
  - Issued by shipper
  - Issued by a competent person recognized by the national administration of the port of loading
- Quantity to be loaded
- Copy of relevant pages of the IMO IMSBC Code
- US Coast Guard Special permits when applicable

3.5 Loading Procedure

The following general information and guidelines are derived from experience during the last 35 years regarding the steps to follow for the safe loading of HBI, or DRI (A). See Figure 11 for the vessel loading procedure flow sheet.

HBI, in general, should not be loaded if temperature is in excess of 65° Celsius or during periods of heavy rain.

3.5.1 Moisture Content

Even though the moisture content of the cargo complies with the recommended levels in the IMO IMSBC Code (< 1.0%), condensation might occur in the ship holds as a result of water lost as water vapor by the steaming effect. However, if water vapor is released and either natural or mechanical ventilation is used, no condensation will occur.

Therefore, although the moisture content of the material at the time of shipment is important, precautions taken by using ventilation will diminish the risks of the cargo.

For this reason, care must be taken to ensure a clean cargo hold before loading. The cargo hold should have no residual chlorides (often present if the cargo hold was last cleaned with seawater) or past cargoes (particularly those that may increase oxidization, such as cement, lye, and borax).

3.5.2 Temperature Measurements

As noted in the previous paragraphs, steaming can occur at time of loading, and temperatures can approach 85° Celsius. Therefore, the temperature of the material at the time of shipment must not exceed 65° Celsius.

The lowest obtained temperature for HBI was with natural ventilation, and the results were in agreement with the temperature readings of recent commercial shipment temperature readings in actual conditions.
3.5.3. Hydrogen Emission Measurements

Experiments confirm that hydrogen gas is evolved during re-oxidation only if water is present, and that hydrogen evolution occurs after approximately 16 hours. During the voyage, hydrogen gas concentrations can leak to other areas of the ship if the holds are not maintained in a gastight condition. Mechanical and natural ventilation show the lowest hydrogen content when compared to inert and air hermetic conditions.
3.6. Barge Top-Off Operations

In the case of top-off operations with barges, the same precautions taken for loading ocean-going vessels should be followed plus these specific precautions and steps:

Barge cargo hoppers should be clean, dry, and free from salt and residues of previous cargoes. The cargo hold should have no residual chlorides or past cargoes, particularly those that might increase oxidization, such as cement, lye, and borax.

Top-off operations should not be performed during heavy rain.

HBI shall not be loaded if its temperature is in excess of 65° Celsius.

Barges for top-off operations should be provided with covers or the HBI should be covered with appropriate material, such as canvas or tarpaulin, in order to limit water absorption during transfer from the loading dock to the topping-off area.

Additionally, great care should be taken to minimize the entrance and accumulation of water in the hoppers. Barge operators should have portable bilge pumps to remove any water accumulated in the hoppers to avoid excessive wetting of HBI.

Barges should be loaded in such a way as to have adequate trim by the stern (0.3 m minimum) so water accumulates in the aft part of the barge hopper for easier extraction.

HBI should be loaded in the central part of the barge, leaving free space on port and starboard sides for easy drainage of water to the stern and towards the bilge well. There should be about 2 meters of free space from the aft to avoid wetting the cargo with accumulated bilge water.

The HBI should be evenly distributed in small piles as flat as possible. The drop of the briquettes should be minimized to reduce breakage and fines generation.

The loading operations should be started in one end of the barge and continued along the length of the barge hopper.

Once the cargo is evenly distributed in the hoppers, loading personnel should have available space for inspection purposes.

The loading operations should be supervised by personnel familiar with the safety precautions and emergency procedures associated with handling HBI. The loading operators should be trained in the appropriate safety precautions and emergency procedures for handling this product.

Unmanned covered barges used to transport HBI should be fitted with adequate vents to provide natural ventilation.

If the cargo compartment of a covered barge must be entered, first the compartment should be checked for adequate oxygen concentration. Before anyone enters a covered cargo compartment containing HBI, the hatches should be opened for a sufficient length of time to dissipate any accumulated gas.
A photo of a top-off operation is shown in Figure 12.

Figure 12
Barge Top-Off Operation in Orinoco River
PART II
Section 4 – HBI OCEAN CARRIAGE

This section provides information about safe carriage of HBI, or DRI (A), developed from actual experiences during the past 35 years. The information includes procedures in flow sheet form that are easy to understand and follow. The following general procedures are presented in this section:

- During the voyage
- Seawater intrusion into holds

Provisions stated in the IMO IMSBC Code for the carriage of this product should be followed.

4.1. General Safety

During the voyage, no smoking, burning, welding, cutting, chipping or other source of ignition should be allowed in the proximity of a loaded hold or on or near barges containing DRI (A). The crew should be familiar with confined space rescue safety.

During carriage, ventilation and routine checks and monitoring of the cargo should be given due consideration. Hatches should remain closed while at sea to prevent the entry of seawater into the holds. Under no circumstances should seawater be allowed to enter the holds.

The flow sheet with procedures during the voyage when transporting HBI is show in Figures 13.

4.2. Ventilation

Surface ventilation only, either natural or mechanical, should be conducted, as necessary, during the voyage for HBI, or DRI (A). On no account should air be directed into the body of the cargo. When mechanical ventilation is used, the fans should be certified as explosion-proof to prevent any spark generation, thereby avoiding the possibility of ignition of a hydrogen air mixture. Suitable wire mesh guards should be fitted over inlet and outlet ventilation openings. Care should be taken that escaping gases do not enter living quarters in hazardous concentrations. During unfavorable weather and sea conditions, surface ventilation should be conducted as practically and safely as possible.

Ventilation should be closed during heavy seas to keep seawater and moisture out.
Once holds are closed, no one is to enter them without proper life maintenance equipment. The surface ventilation system should be open.

1. Always keep cargo holds closed at sea.
2. Surface ventilation system must be open throughout the voyage at any time during favourable weather conditions.
3. Do not allow seawater into the holds.
4. Do no smoke, weld, burn, cut, chip or carry out spark producing work on deck.
5. Sound bilges everyday and pump out any extra water as practical as possible.
6. Monitor the temperature of the cargo during the voyage and report to shipper.
7. Once the voyage is over, the Captain is advised to send a report on the material monitoring if necessary.

Is hydrogen content above 2% or temperature above 65°C at any time?

Yes

1. Ensure effective surface ventilation and keep hatch covers closed.
2. Use the temperature and gas monitoring equipment if available.
3. Check for temperature, hydrogen and oxygen content in cargo holds.
4. Check for bulkhead heating in adjacent holds.

No

Continue normal monitoring and surface ventilation, and send daily information to shipper.

Is there bulkhead heating?

No

Keep surface ventilation in troubled holds

Yes

Spray with water from the empty hold side, providing bulkheads are mechanically sound to avoid ingress of water in troubled hold.

Does temperature inside the hold continue above 65°C?

No

Continue normal procedure for temperature and hydrogen content readings.

Yes

Did water enter the hold?

No

Yes

1. Call the shipper and report temperature readings of troubled holds if available.
2. Do not open the troubled hold unless the expert tells you to do it.
3. See the procedure on what to do if water enters the holds.

Figure 13
Voyage Procedure Flow Sheet
4.3  Routine Checks

Personnel should not be permitted to enter cargo spaces at any time during the voyage. Suitable signs should be displayed at all access points, and where possible, access points to cargo spaces should be locked.

Bilges should be sounded twice a day and any excess water pumped out.

Enclosed spaces adjacent to cargo spaces, such as storerooms, carpenter shop, passageways, tunnels, etc., should be monitored regularly for the presence of hydrogen. Such spaces should be adequately ventilated, and in the case of mechanical ventilation, only equipment safe for use in an explosive atmosphere should be used. Testing is especially important prior to permitting personnel to enter such spaces or activating any equipment located in such spaces.

Before entry by any personnel, enclosed adjacent spaces should be thoroughly ventilated and the atmosphere tested and found to be hydrogen gas-free and to have adequate oxygen for breathing. If this is not possible, only trained personnel wearing self-contained breathing apparatus and under the supervision of a responsible officer should undertake emergency entry into such spaces. In addition, special precautions should be taken to ensure that no source of ignition is carried into the space.

4.4  Monitoring

Various measurements of the cargo should be taken at least once every shift during the voyage. The readings should be recorded and kept onboard and made available upon request for a minimum of two years. Results of monitoring during the voyage should be sent to the shipper as soon as possible but no later than at voyage end.

The vessel should have the means of determining qualitatively and quantitatively the oxygen and hydrogen content of the cargo spaces without requiring entry into the cargo spaces. It also should be fitted with or carry onboard adequate equipment for remotely recording temperatures of the cargo in each hold.

All monitoring equipment should be operational and properly calibrated at the commencement of loading. The vessel’s crew should be properly trained in the use of this equipment.

4.4.1.  Procedure for Monitoring Hydrogen

For quantitative measurements of hydrogen, a suitable detector should be onboard. The detector should be suitable for use in an atmosphere without oxygen and of a type certified safe for use in explosive atmosphere. Ingress of moisture into the instrument should be restricted in order to get accurate results, and it should be properly calibrated, as per manufacturer’s instructions.

The ship’s hatch covers should be fitted with appropriate sampling points (minimum one, preferably two) for the measurement of hydrogen gas in each cargo hold.

The concentration of hydrogen in the cargo spaces should be kept below 1 percent, which is lower than the LEL (Lower Explosivity Limit) of hydrogen by volume in air (4 percent). If this value is exceeded, immediate measures for dissipating hydrogen should be taken as per the Emergency Contingencies section of this guide (PART III, Section 6).
Throughout the voyage, hydrogen gas measurements should be taken as frequently as necessary but at least once per shift. In case the LEL exceeds 1 percent, additional ventilation procedures should be undertaken. Refer to the Emergency Contingencies section of this guide (PART III, Section 6).

4.4.2. Procedure for Monitoring Oxygen

For quantitative measurements of oxygen, a suitable detector should be onboard. The detector should be of a type certified safe for use in explosive atmosphere. Ingress of moisture into the instrument should be restricted in order to get accurate results, and it should be properly calibrated, as per manufacturer's instructions.

The ship's hatch covers should be fitted with appropriate sampling points (minimum one, preferably two) for the measurement of oxygen gas in each cargo hold.

4.4.3. Procedure for Monitoring Temperature

Temperature of the cargo shall be taken regularly during the voyage and a record kept on board for a minimum of two years.

It is advisable that adequate equipment for remote temperature monitoring within different parts of the cargo is incorporated at approximately half depth. At least four spots in the cargo should be monitored per hold.

There may be a steady rise in the cargo temperature for the first 24 to 36 hours after loading due to disturbances caused by material handling. A gradual temperature decline towards ambient should follow.

In warm latitudes, the ambient temperature of the cargo spaces above the stowage may rise during the day due to solar warming combined with accompanying condensation. This should not significantly affect the temperature within the cargo.

If the temperature rises above 65° Celsius, refer to the Emergency Contingencies section of this guide (PART III, Section 6).

4.5 Seawater Intrusion into Holds

A flow sheet with procedures to follow during the voyage in case of seawater intrusion into the vessel's holds is show in Figures 14.
Figure 14
Seawater Intrusion into Holds Procedure Flow Sheet

At sea, do not open the troubled hold.

Did seawater enter the hold?

No

Initiate temperature and gas monitoring if equipment is available and keep surface ventilation open.

Yes

Bubbling, vaporization and hydrogen generation will occur.
Temperature of the cargo could tend to increase.

1. Keep the surface ventilation open.
2. Monitor on an hourly basis the temperature of the cargo and hydrogen generation in the troubled holds if equipment is available.
3. If the hydrogen content is equal to or above 2%, keep the available ventilation system permanently working.
4. Call the shipper.
5. Follow the instructions of the expert.

WARNING
DO NOT USE EITHER FRESH WATER OR SEAWATER TO COOL DOWN HOT MATERIAL in enclosed spaces such a cargo hold on a ship, unless strictly necessary to keep integrity of vessel and under Master’s expertise. If water must be used: i) use large amount of water to completely flood the material and ii) provide adequate ventilation to let Hydrogen gas generated escape to atmosphere. Be prepared to jettison cargo if very high temperatures (over 120 °C) are recorded, or make arrangements to get to the nearest safe and suitable port for discharging the hot cargo. Hydrogen concentration should be kept below 1% and the surface ventilation system should be open continuously to lower the concentration of hydrogen gas inside the cargo hold. Consider the solutions with the following priorities as follows:

1. unload the troubled cargo at nearest port
2. jettison of cargo
3. flood the hold with water
PART II
Section 5 – HBI INLAND TRANSPORT, HANDLING, AND STORAGE

5.1. Equipment for Unloading and Handling HBI

All types of conventional bulk material handling equipment can be used to unload and handle HBI:

- Front-end loaders (Figure 15)
- Scrap yard magnets (Figure 16)
- Cranes with magnet/clamshell-type bucket (Figure 17)
- Conveyor belts (Figure 18)
5.2. Barge Transport

In the case of inland barges, the same precautions should be taken as for barge top-off operations (see PART II, Section 3.6). It is very important that the barge hold is dry and should have no residual chlorides (often present if the cargo hold was last cleaned with seawater) or residue from past cargoes (particularly those that may increase oxidization, such as cement, lye, and borax).

Unloading can be conducted under all weather conditions as long as the HBI is outdoors, not in a confined space, and does not have a confined space directly above.

Some hydrogen gas may evolve in the cargo hold during the voyage if the HBI is contacted by water or moisture from previous cargoes. Therefore, it is absolutely essential that the hydrogen gas is ventilated prior to commencing unloading operations.

5.3. Truck and Railroad Transport

Truck and railroad transportation of HBI should be carried out in the same way as with other bulk materials. Local transportation regulations should be followed. The recommended way to load HBI in a truck to avoid material spillage is shown in Figures 19 and 20.

Hydrogen gas can evolve during transport if the HBI is in contact with water or residue from a previous cargo. Therefore, the cargo box or freight car should be clean and dry, and the tailgate or car doors/hatches should seal properly. Once loaded, the temperature of the cargo should be checked at several points in the load.

In case a hot spot is located in any area of the cargo box or freight car, that area should be unloaded immediately. HBI with a temperature above 65º Celsius should not be transported except to a nearby area for cooling. Hot HBI should not be loaded into trucks under any conditions.

Trucking companies should not wet the material as it leaves the storage yard to reduce dust generation. Instead, a tarpaulin should be used to cover the cargo box of the truck, which also helps avoid spillage.
5.4. Yard Storage

HBI can be handled by front end loaders and other standard bulk materials handling equipment and systems. When using front end loaders, care should be taken to minimize running them on top of the material to avoid breakage.

The storage area should be easily accessible by loading equipment. Although the HBI has high impact strength, the storage area should be as close as possible to the melt shop to avoid double handling of the product, breakage, and fines generation.

Yard storage of HBI is not affected by water picked up (HBI will pick up only about 3 percent water by weight). However, it is good practice to avoid standing water by providing adequate drainage.

The storage area should be kept reasonably clean, which means free of wood debris, coal or coke residues, and any other combustible material or source. Due to its relatively inert characteristics, it is not necessary to cover HBI storage piles to prevent rapid reoxidation.

The most effective way to pile HBI is shown in Figure 21.
When heavily wetted by rain, HBI will release water vapor. This is called “steaming.” The HBI will increase in temperature to about 60º Celsius without overheating. An HBI pile must exceed 100º Celsius before overheating occurs.

The procedure to handling HBI that has overheated is shown in Figure 22.

Figure 22

Caution: Water should not be sprayed on an overheated pile of HBI. If water is added to the pile, an aggressive oxidation reaction can develop, causing complete or partial melt down of the HBI.

Fines generated during production and handling of HBI will reoxidize much faster than whole briquettes. A conservative number is 15 percent loss for 6.35 mm fraction after exposed storage for a month. FeO content will vary with the size of the fines. This increase of FeO in the 6.35 mm fraction is similar to -25.4 mm material.
PART III
Section 6 – EMERGENCY CONTINGENCIES

This section provides information about contingency procedures commonly used during the past 35 years.

Basically, there are two types of contingencies:
- Self-heating
- Hydrogen accumulation over the LEL in confined cargo or adjacent spaces

6.1. During Storage and Loading Operations

The following are instructions developed and implemented by the Port of Palúa, which handles and loads all of the HBI exported by Venezuela.

6.1.1 General Contingencies

The loading operations must be supervised by personnel familiar with the safety precautions and emergency procedures for handling HBI, or DRI (A). The loading operators must be trained in the appropriate safety precautions and emergency procedures.

6.1.2 Action Plan for HBI at Elevated Temperatures

The Operations Supervisor and the Material Handling Operators are responsible for properly executing the action plan if a train or truck arrives at the reception quay of the port carrying HBI at the following temperature levels:

6.1.2.1 Greater Than 65° Celsius but Less Than or Equal to 80° Celsius

Proceed with the following actions:
- Before unloading rail cars or trucks, measure the HBI temperature in each rail car/truck and record the measurements in the temperature log book.
- Unload the HBI in the client’s assigned quay and immediately transfer the HBI to the storage yard zone indicated by the client and store it as suggested in PART II, Section 5.4 of this guide.

6.1.2.2 Greater Than 80° Celsius but Less Than or Equal to 150° Celsius

Proceed with the following actions:
- Before unloading the rail cars or trucks, measure the HBI temperature in each rail car/truck and record the measurements in the temperature log book. This should be done every two hours while the contingency is in effect.
- Unload the rail cars/trucks with HBI at temperature less than 65° Celsius first, then those containing HBI between 65° and 100° Celsius. Continue unloading HBI with temperatures between 100° and 150° Celsius in the first vibrating feeder, using the movement sense of the belt as a reference.
- Transfer the HBI from the quayside to the storage yard indicated by the client in the following manner:
  - Transfer the HBI during a maximum of three-minute intervals, and dose (i.e., mix the hotter with the cooler material to have an average
temperature lower than the hottest one – no water to be used) the DRI that is at temperatures between 100° and 150° Celsius for a maximum of two minutes. Stop the vibrating feeders for about five minutes, but keep the conveyor belts in motion. Repeat these steps until finished with HBI removal.
- While transferring the HBI, inspect the belt transfer system for any sign of overheating. In case of belt overheating, stop the HBI dosing and transfer but keep the transfer belts in motion until they cool. Take special care to avoid pouring water into hoppers and other equipment.
- Use a front-end loader to spread the HBI to a level of approximate 30 centimeter height to stop the reoxidation, as suggested in PART II, Section 5.4 of this guide.
- Verify that the belts are cooled down, and resume HBI transfer per the previous instructions.

6.1.2.3. Greater Than 150° Celsius

Proceed with the following actions:
- Before unloading the rail cars or trucks, measure the HBI temperature in each rail car/truck and record the measurements in the temperature log book. This should be done every two hours while the contingency is in effect.
- Position the rail cars/trucks containing HBI with temperatures greater than 150° Celsius at the end of the reception area and spray with pressurized water. In this case, there is no option but to momentarily cool down the HBI before being discharged into the quay and then into the conveyor belt system. Otherwise, the belts will burn. Afterward, the HBI is piled in the yard. It then can be spread out for further cooling.
- When the temperature is reduced to between 80° and 150° Celsius proceed with the steps described in 6.1.2.2.

6.2. During the Voyage

Over the years, there have been some incidents involving reoxidation and overheating of DRI where inexperience, carelessness, or negligence exposed the vessels, their crews, and the cargoes to extreme conditions. By following the relevant precautions, HBI can be safely transported throughout the world.

A combination of several factors is necessary to create a hazardous condition during ocean transport of any form of DRI. Therefore, the entire crew of the vessel must be familiar with and closely follow the guidelines contained in the IMO IMSBC Code for shipping HBI, or DRI (A).

During the voyage, if the temperature of the cargo shows signs of exceeding safe levels, the ship should head for the nearest suitable port (i.e., one equipped with shore cranes or other bulk cargo handling equipment) and discharge its cargo.

In extreme cases (temperatures greater than 200° Celsius), the affected hold should be flooded with water as quickly as possible to prevent serious damage to the ship, and vents should be opened to remove remaining hydrogen \(^8\). Flooding of cargo spaces should be conducted as a last resource keeping the integrity of the ship as per Master’s expertise.
Some hydrogen gas is expected to evolve during the voyage. Therefore, it is absolutely essential that this gas is ventilated from the holds whenever weather conditions allow. Natural surface ventilation will suffice to accomplish this. Additionally, great care must be taken to prevent any seawater from entering the holds, as wetting the HBI with saltwater could accelerate the rate of hydrogen emission beyond what is expected when fresh water is present.

6.3. During Unloading Operations (10)

Unloading can be conducted under most weather conditions, as long as the HBI remains well ventilated, is not in a confined space, and does not have a confined space directly above.

6.3.1 General Contingencies

The unloading operations must be supervised by personnel familiar with the safety precautions and emergency procedures for handling HBI, or DRI (A). The unloading operators must be trained in the appropriate safety precautions and emergency procedures.

6.3.2 Action Plan for HBI at Elevated Temperatures

The Master of the ship must notify the port authorities if hydrogen gas is detected in the ship holds or if abnormal temperatures are measured in the HBI cargo holds.

The Harbor Master and qualified personnel are responsible for executing the action plan when a ship or barge arrives with HBI at the following temperature levels:

6.3.2.1. Greater Than 65° Celsius but Less Than or Equal to 80° Celsius

Proceed with the following actions:
- Before unloading the vessel, measure the HBI temperature in each hold and record the measurements in the temperature log book.
- Unload the holds in the assigned zone and immediately transfer the HBI to the storage yard zone as described in PART II, Section 5.4 of this guide.

6.3.2.2. Temperature Greater Than 80° Celsius and Less Than or Equal to 150° Celsius

Proceed with the following actions:
- Before unloading the vessel, measure the HBI temperature in each hold and record the measurements in the temperature log book. This should be done every two hours while the contingency is in effect.
- Unload the holds with HBI at temperature less than 65° Celsius first, then those containing HBI between 65° and 100° Celsius. Continue unloading HBI with temperatures between 100° and 150° Celsius in the first transfer station, using the movement sense of the belt as a reference.
- Transfer the HBI from the unloading zone clean and free of debris and flammable material, such as coal, coke and wood to the storage yard indicated by the client as follows:
  - Transfer the HBI during a maximum of three-minute intervals, and dose (i.e., mix the hotter with the cooler material to have an average temperature lower than the hottest one – no water to be used) the HBI that is at temperatures between 100° and 150° Celsius with cooler material for a maximum of two minutes. Stop the vibrating feeders for
about five minutes, but keep the conveyor belts in motion. Repeat these steps until finished with HBI removal.

- While transferring the HBI, inspect the belt transfer system for any sign of overheating. In case of belt overheating, stop the HBI dosing and transfer but keep the transfer belts in motion until they cool. Take special care to avoid pouring water into hoppers and other equipment.
- Use a front-end loader to spread the HBI to a level of approximate 30 centimeter height to stop the reoxidation, as suggested in PART II, Section 5.4 of this guide.
- Verify that the belts are cooled down and resume HBI transfer per the previous instructions.

**Caution:** Do not spray water on hot HBI that is steaming (i.e., emitting water vapor).

### 6.3.2.3. Greater than 150° Celsius

Proceed with the following actions:

- Before unloading the holds, measure the HBI temperature in each hold and record the measurements in the temperature log book. This should be done every two hours while the contingency is in effect.
- Position the HBI with temperatures greater than 150° Celsius at the end of the reception area and spray with pressurized water. In this case, there is no option but to momentarily cool down the HBI.
- When the temperature is reduced to between 80º and 150° Celsius proceed with the steps described in 6.3.2.2.

### 6.4. Hydrogen Gas Contingency

Although HBI has the lowest tendency to reoxide when contacted by fresh water or seawater, the ultimate rule is to keep all forms of water from entering the cargo holds. Reoxidation tends to generate hydrogen gas but does not cause spontaneous ignition of the gas unless an ignition source is present.

In case of seawater intrusion into the cargo holds, follow the procedure flow sheet in Figure 14 (see paragraph 4.5 of this guide).

**Procedure If Hydrogen Concentration Is Over 1% (25% LEL):**

- Inform the shipper immediately and seek expert advice.
- Keep the natural surface ventilation open at all times
- Monitor LEL in the holds continuously until level drops to less than 25 %.
- Avoid any possible ignition source on the vicinity.
- Care shall be taken as to prevent any spark generation.
- Monitor the hydrogen concentration in the holds and keep the surface ventilation (either natural or mechanical) until values fall below 1%.
- When hydrogen levels are within safe values, proceed as normal.
- On the contrary, additional ventilation should be applied to the space if available and re-testing should be conducted after a suitable interval.
- Contact the P & I Club and Shipper and follow the instructions of the appointed expert or surveyor.
- At sea, do not open the troubled hold without explicit instructions from the shipper or appointed expert or surveyor.
- Ensure there are no possible sources of ignition near the cargo spaces, adjacent spaces or open decks.
PART IV
Section 7 – REFERENCES


PART IV
Section 8 – BIBLIOGRAPHY


10. COPAL Briquettes Reception and Unloading Procedures.

11. Fior de Venezuela Fact Sheets Leaflet.


PART IV
Annex 1 – IMSBC CODE SCHEDULE FOR DIRECT REDUCED IRON (A)

DIRECT REDUCED IRON (A)
Briquettes, hot-moulded

DESCRIPTION

Direct reduced iron (A) is a metallic grey material, moulded in a briquette form, emanating from a densification process whereby the direct reduced iron (DRI) feed material is moulded at a temperature greater than 650°C and has a density greater than 5,000 kg/m³. Fines and small particles (under 6.35 mm) shall not exceed 5% by weight.

CHARACTERISTICS

<table>
<thead>
<tr>
<th>ANGLE OF REPOSE</th>
<th>BULK DENSITY (kg/m³)</th>
<th>STOWAGE FACTOR (m³/t)</th>
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</thead>
<tbody>
<tr>
<td>Not applicable</td>
<td>2500 to 3300</td>
<td>0.3 to 0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>To be verified by the shipper</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIZE</th>
<th>CLASS</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate size:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length 50 mm to 140 mm</td>
<td>MHB</td>
<td>B</td>
</tr>
<tr>
<td>Width 40 mm to 100 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness 20 mm to 50 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Briquette weight 0.2 to 3.0 kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fines and small particles: under 6.35 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HAZARD

Temporary increase in temperature of about 30°C due to self-heating may be expected after material handling in bulk. The material may slowly evolve hydrogen after contact with water (notably saline water). Hydrogen is a flammable gas that can form an explosive mixture when mixed with air in concentration above 4% by volume. It is liable to cause oxygen depletion in cargo spaces. This cargo is non-combustible or has a low fire-risk.

STOWAGE & SEGREGATION

“Separated from” goods of class 1 (division 1.4S), 2, 3, 4 and 5 and class 8 acids in packaged form (see IMDG Code).

“Separated from” solid bulk materials of classes 4 and 5.

“Separated longitudinally by an intervening complete compartment or hold from” goods of class 1 other than division 1.4S.

Boundaries of compartments where this cargo is carried shall be resistant to fire and passage of liquid.

HOLD CLEANLINESS

The cargo spaces shall be clean, dry and free from salt and residues of previous cargoes. Prior to loading, wooden fixtures such as battens, loose dunnage, debris and combustible materials shall be removed.
WEATHER PRECAUTIONS
This cargo shall be kept as dry as practicable during loading and the voyage. Open storage is acceptable prior to loading. This cargo shall not be loaded onto ships or transferred between ships or barges during precipitation. During loading of this cargo all non-working hatches of the cargo spaces into which this cargo is loaded or to be loaded shall be kept closed. Only when weather permits may non-working hatch covers be left open for a minimum of 1 hour after completion of each pour to allow cooling after cargo handling in bulk.

LOADING
Prior to loading this cargo, the shipper shall provide the master with a certificate issued by a competent person recognized by the National Administration of the port of loading stating that the cargo, at the time of loading, is suitable for shipment and that it conforms with the requirements of this Code; that the quantity of fines and small particles (up to 6.35 mm in size) is no more than 5% by weight; the moisture content is less than 1.0% and the temperature does not exceed 65°C.

This cargo shall not be loaded when the temperature is in excess of 65°C, if its moisture content is in excess of 1.0% or if the quantity of fines and small particles (up to 6.35 mm in size) exceeds 5% by weight.

Appropriate precautions shall be taken during loading in order to have a cargo composed of essentially whole briquettes. The cargo shall be loaded in such a way so as to minimize breakage of briquettes and the additional generation of fines and small particles and concentration of fines in any area of the cargo. The addition of fines and particles less than 6.35 mm or dust in homogenous cargoes of briquettes shall be prohibited.

Trim in accordance with the relevant provisions required under sections 4 and 5 of the Code. Due consideration shall be given to evenly spreading the cargo across the tanktop to minimize the concentration of fines.

The cargo temperature shall be monitored 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. After loading, a certificate, confirming that throughout the whole consignment the fines and small particles (under 6.35 mm in size) are less than 5% by weight, shall be issued by a competent person recognized by the National Administration of the port of loading.

PRECAUTIONS
The carrier’s nominated technical persons or other representatives shall have reasonable access to stockpiles and loading installations for inspection.

Shippers shall provide comprehensive information on the cargo and safety procedures to be followed in the event of emergency. The shipper may also provide advice in amplification of this Code but the advice shall not be contrary thereto in respect of safety.

Where practicable, ballast tanks adjacent to the cargo spaces containing this cargo, other than double-bottom tanks, shall be kept empty. Weather deck closures and hatch covers shall be inspected and tested to ensure integrity and weather tightness which shall be maintained throughout the voyage.
Appropriate precautions shall be taken to protect machinery, equipment and accommodation spaces from the dust of the cargo. Radars and exposed radio communication equipment of the ship shall be protected from the dust of this cargo. Bilge wells of the cargo spaces shall be clean, dry and protected from ingress of the cargo using non-combustible material. 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.

During handling of this cargo “NO SMOKING” signs shall be posted on decks and in areas adjacent to cargo spaces, and no naked lights shall be permitted in these areas.

Cargo spaces containing this cargo and adjacent spaces may become oxygen-depleted. Flammable gas may also build up in these spaces. All precautions shall be taken upon entering the cargo and adjacent spaces.

VENTILATION
Surface ventilation only, either natural or mechanical, shall be conducted, as necessary, during the voyage for this cargo. On no account shall air be directed into the body of the cargo. When mechanical ventilation is used, the fans shall be certified as explosion-proof and shall prevent any spark generation thereby avoiding the possibility of ignition of hydrogen air mixture. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings. Ventilation shall be such that escaping gases cannot enter living quarters in hazardous concentrations.

CARRIAGE
For quantitative measurements of hydrogen, a suitable detector shall be on board while this cargo is carried. The detector shall be suitable for use in an oxygen depleted atmosphere and of a type certified safe for use in an explosive atmosphere. The concentrations of hydrogen in the cargo spaces carrying this cargo shall be measured regularly during the voyage, and the results of the measurements shall be recorded and kept on board for a minimum of two years. When the monitored hydrogen concentration is higher than 1% (> 25% LEL) by volume, appropriate safety precautions shall be taken in accordance with those procedures provided by the shipper in case of emergency. If in doubt, expert advice shall be sought.

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.

Temperature of the cargo shall be taken regularly during the voyage and a record kept on board for a minimum of two years. If the temperature in the cargo space exceeds 65°C, appropriate safety precautions shall be taken in accordance with the procedures provided by the shipper in case of emergency. If in doubt, expert advice shall be sought.

DISCHARGE
The hydrogen concentration in the cargo space shall be measured immediately before any opening action of the hatch covers. If the hydrogen concentration is greater than 1% (> 25% LEL) by volume, all appropriate safety precautions in conformity with the procedures provided by the shipper or the recommendations of the competent authority shall be taken. If in doubt, expert advice shall be sought.
During discharge, a fine spray of fresh water may be applied to this cargo for dust control only when the cargo will be stored in an open area. It is not recommended to apply a fine spray of fresh water to this cargo when it will be stored in an enclosed space or is to be transshipped.

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

EMERGENCY PROCEDURES

<table>
<thead>
<tr>
<th>SPECIAL EMERGENCY EQUIPMENT TO BE CARRIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EMERGENCY PROCEDURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EMERGENCY ACTION IN THE EVENT OF FIRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not use water. Do not use steam. Do not use CO₂.</td>
</tr>
<tr>
<td>Batten down.</td>
</tr>
</tbody>
</table>

The specific procedures in the event of emergency provided by the shipper should be consulted and followed, as appropriate. If in doubt, expert advice should be sought as quickly as possible.

Preparations should be made for grab discharge if serious heating occurs.

<table>
<thead>
<tr>
<th>MEDICAL FIRST AID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refer to the Medical First Aid Guide (MFAG), as amended.</td>
</tr>
</tbody>
</table>
PART IV
Annex 2 – TYPICAL MATERIAL SAFETY DATA SHEET FOR DRI (A)

ATTACHMENT

MSDS

Material Safety Data Sheet

for

HBI (IMO DRI A)
MANUFACTURER'S MATERIAL SAFETY DATA SHEET

SECTION I – PRODUCT AND COMPANY IDENTIFICATION

Product Identification

Product Name: Hot Briquetted Iron (HBI)
Trade Name: Hot Briquetted Iron (HBI)
Chemical Name: Iron
Product Use: Iron and Steel Production

Description as per IMO IMSBC Code Appendix 1:

Proper Shipping Name: Direct Reduced Iron (A), Briquettes, hot-molded Material Hazardous only in Bulk (MHB)
IMO Class: B
Group:

US Coast Guard Special Permits: Issued to each shipper pursuant to 46 CFR 148.01-9 of the U.S. Coast Guard (USCG) Carriage of Solid Hazardous Materials in Bulk Regulations.

Date of MSDS: April 2008

Company Identification

Manufacturer’s Name: 
Address:

Phone Numbers: 
Fax Numbers: 
Emergency Numbers:
SECTION II – Composition/Information on Ingredients

CHEMICAL DATA: (percentages by weight)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Iron (TFe)</td>
<td>90 - 94 %</td>
</tr>
<tr>
<td>Metallic Iron (MFe)</td>
<td>83 - 88 % Minimum</td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>0.8 - 2.0 %</td>
</tr>
<tr>
<td>Sulfur (S) as sulphide</td>
<td>0.003 – 0.03 %</td>
</tr>
<tr>
<td>Phosphorus (P) as P_2O_5</td>
<td>0.02 – 0.13 % Maximum</td>
</tr>
<tr>
<td>Gangue</td>
<td>1.95 – 5.10 % Maximum</td>
</tr>
</tbody>
</table>

INGREDIENTS

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>National Institute of Standards and Technology Chemical Abstract System (CAS) Number</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBI (Iron Furnace)</td>
<td>65996-67-0</td>
<td></td>
</tr>
<tr>
<td>IRON</td>
<td>7439-89-6</td>
<td>81-88%</td>
</tr>
<tr>
<td>IRON (II) OXIDE</td>
<td>1345-25-1</td>
<td>4-8%</td>
</tr>
<tr>
<td>IRON (III) OXIDE</td>
<td>1309-37-1</td>
<td>2-8%</td>
</tr>
<tr>
<td>METAL OXIDE</td>
<td>Not Available</td>
<td>&lt;4%</td>
</tr>
<tr>
<td>CARBON</td>
<td>7440-44-0</td>
<td>0.4-2.0%</td>
</tr>
</tbody>
</table>

SECTION III – Hazards Identification Including Emergency Overviews

HAZARD INFORMATION

<table>
<thead>
<tr>
<th>Class</th>
<th>Not Classified as Dangerous. Material Hazardous only in Bulk (MHB) as per IMO IMSBC Code.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients</td>
<td>No known hazardous ingredients</td>
</tr>
<tr>
<td>Poisons Schedule</td>
<td>Not scheduled</td>
</tr>
</tbody>
</table>

HEALTH EFFECTS

<table>
<thead>
<tr>
<th>Acute Ingestion</th>
<th>If swallowed, dust or small pieces may cause gastrointestinal disturbances. An overdose of iron may cause irritation to the mouth, esophagus and stomach. Symptoms may include nausea, vomiting, abdominal pain, bloody diarrhea and shock.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive Eye contact</td>
<td>Dust and small pieces may cause mechanical irritation, redness and pain in contact with the eyes, which can result in redness and lacrimation. May cause conjunctivitis.</td>
</tr>
</tbody>
</table>
Acute Skin Contact

Dust and small pieces may cause mechanical irritation in contact with the skin, which can result in slight redness.

Excessive Inhalation

Inhalation of dust may cause irritation to the respiratory tracks. Symptoms may include coughing, sneezing, soreness of the throat and breathing difficulties.

Chronic

Repeated or prolonged exposure to this material may result in skin irritation in individuals with sensitive skin. Chronic exposure to iron dust has been associated with benign pneumoconiosis, not affecting lung function. Persons with impaired respiratory functions may be more susceptible to the effects of the substance.

Decomposition

May produce toxic iron fumes when heated to decomposition (1,535 °C)

SECTION IV – First Aid Measures

FIRST AID

If Swallowed
Induce vomiting immediately. Seek medical attention.

Inhalation
Remove person to fresh air. Get medical attention in case of breathing difficulty.

Eyes
If contact with eye(s) occurs, wash with copious amounts of water for approximately 15 minutes holding eyelid(s) open. If irritation develops and persists seek medical attention.

Skin
Wash gently and thoroughly with water and soap. Ensure contaminated clothing is washed before re-use or discard. If irritation develops and persists seek medical attention.

First Aid Facilities
Eye wash fountains and normal wash room facilities

ADVICE TO DOCTOR

Advice to Doctor
Treat symptomatically or consult a Poison Information Center

SECTION V – Fire Fighting Measures

FIRE AND EXPLOSION HAZARD DATA

Material may slowly evolve hydrogen after contact with water and reacts more rapidly with salt water. Proper surface ventilation shall be provided for material in enclosed spaces. Temporary small increase in temperature may be expected after material handling in bulk. Maximum allowed shiploading temperature 65°C. If temperature exceeds 65°, provide adequate surface ventilation to remove any hydrogen gas generation. Do not allow any hot work/spark
generation on deck or surroundings.

- Non-flammable when correctly piled. May self-heat if piled incorrectly. In fire situation, evacuate area and contact emergency services. Remain upwind and notify those downwind of hazard.

FIRE FIGHTING PROCEDURES

- Wear fire protective clothing
- Wear self-contained breathing apparatus when entering enclosed spaces with HBI.
- Wear non-sparking footwear.
- Avoid all sources of ignition.
- Remove the hot material from the stack. On a ship, a clamshell bucket may be used.
- Divide hot material into small piles and spread it out to less than 0.5 m deep. The material will quickly cool below the ignition point.
- In case it is not practical to spread the material over a wide area such as in a hold of a ship, coverage using a non-oxidant material (e.g. sand, and finely crushed slag) could be used, for smothering the fire and hindering the air supply. This technique would need to be decided depending on the emergency because it would contaminate the material.
- Do not use CO₂ as CO may be formed. Do not use dry chemical.
- DO NOT USE EITHER FRESH WATER OR SEAWATER TO COOL DOWN HOT MATERIAL in enclosed spaces such as a cargo hold on a ship, unless strictly necessary to keep integrity of vessel and under Master’s expertise. If water is used: i) use large amount of water to flood the material and ii) provide adequate ventilation to let hydrogen gas generated escape to atmosphere.
- In fire situation, evacuate area and contact emergency services
- Emergency Schedule to follow for packaged material: GOLF, as per IMDG Code

SECTION VI – Accidental Release Measures

<table>
<thead>
<tr>
<th>Material in bulk:</th>
<th>Broken pieces and dust generated during loading and unloading should be collected and dispose adequately.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material in packaged form: e.g. samples</td>
<td>Ventilate area if spilled into enclosed space. Use protective equipment specified in Section 8. Pick-up and place in a suitable container for reclamation or disposal. Avoid contact with strong oxidizers.</td>
</tr>
<tr>
<td>Emergency Schedule to follow for Spillage for packaged material:</td>
<td>November / Oscar / Papa, as per IMDG Code</td>
</tr>
</tbody>
</table>
SECTION VII – Handling and Storage

Storage Precautions  
Store in cool, dry, well ventilated area removed from oxidizing agents, flammable materials (e.g. coke, wood), sources of heat (e.g. steam lines) and foodstuffs. The HBI can be stored in open yards uncovered.

Handling  
The HBI can be handled substantially the same as scrap. It can be moved from one side to another, stored and transported safely in all types of weather due to its density and good physical and chemical stability.

SECTION VIII – Exposure Controls, Personal Protection

Respirator Type (NIOSH N95)  
During handling dust is generated; and if ventilation is inadequate, the use of an N95-type respirator is advisable.

Eye Protection  
During handling dust is generated, e.g. loading, unloading, cutting or sanding; the use of safety goggles is advisable.

Hand Protection  
Use of canvass gloves is advisable.

Head Protection  
During handling, material can spill and use of helmet is advisable.

SECTION XIX – Physical and Chemical Properties

<table>
<thead>
<tr>
<th>Physical State</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>From Light Gray to Gray Black</td>
</tr>
<tr>
<td>Odor</td>
<td>Odorless</td>
</tr>
<tr>
<td>Apparent Density (gm/cm³)</td>
<td>5.0 Minimum</td>
</tr>
<tr>
<td>Bulk Density (MT/m³)</td>
<td>Range 2.5 – 2.8</td>
</tr>
<tr>
<td>Stowage factor (m³/MT)</td>
<td>0.35 – 0.40</td>
</tr>
<tr>
<td>Angle of Repose</td>
<td>38°</td>
</tr>
<tr>
<td>Fines under 6.35 mm</td>
<td>5% max.</td>
</tr>
<tr>
<td>Porosity</td>
<td>15 % Maximum</td>
</tr>
<tr>
<td>Water Pick-up</td>
<td>3.0 % Maximum</td>
</tr>
<tr>
<td>Dimensions (mm)</td>
<td>110 x 50 x 30</td>
</tr>
<tr>
<td>Solubility in water</td>
<td>Insoluble</td>
</tr>
<tr>
<td>Melting Point</td>
<td>APPROX. 1500 DEGREES CENTIGRADE</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>APPROX. 3000 DEGREES CENTIGRADE</td>
</tr>
<tr>
<td>Vapour Pressure</td>
<td>NOT AVAILABLE</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>APPROX. 5 (WATER = 1)</td>
</tr>
<tr>
<td>Flash Point</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td>Flammable Limit LEL</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td>Flammable Limit UEL</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>INSOLUBLE</td>
</tr>
</tbody>
</table>
### OTHER PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosiveness</td>
<td>NOT CORROSIVE TO ALUMINIUM</td>
</tr>
<tr>
<td>Stability</td>
<td>STABLE UNDER NORMAL CONDITIONS OF USE</td>
</tr>
<tr>
<td>Hazardous Polymerization</td>
<td>WILL NOT OCCUR</td>
</tr>
<tr>
<td>Materials to Avoid</td>
<td>STRONG ACIDS AND OXIDIZING AGENTS</td>
</tr>
</tbody>
</table>

### SECTION X – Stability and Reactivity Data

#### STABILITY AND REACTIVITY DATA

<table>
<thead>
<tr>
<th>Exposure Limits</th>
<th>No exposure standards have been established for this material.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactivity</td>
<td>Stable in dry air and under normal conditions but oxidizes in fresh water and more readily in seawater forming rust and generation of hydrogen gas. Incompatible with oxidizing agents, e.g., acids, hydrogen peroxide and nitrogen dioxide.</td>
</tr>
</tbody>
</table>

### SECTION XI – Toxicological Information

<table>
<thead>
<tr>
<th>Toxicology</th>
<th>No toxicity data is available for this material</th>
</tr>
</thead>
</table>

### SECTION XII – Ecological Information

This material is not considered a contaminant to the environment. It can be recycled. HBI or any dust generated during handling if left in the atmosphere will oxidize and eventually return to its natural state: Iron oxide. Avoid spillage in land or water. Local environmental regulations should be followed.

### SECTION XIII – Disposal Consideration

<table>
<thead>
<tr>
<th>Waste Disposal</th>
<th>Recycle where possible. Alternatively, it can be traded as a raw material for iron or steel production.</th>
</tr>
</thead>
</table>
### SECTION XIV – Transport Information

**Truck and Rail Road Transportation**

It should be transported in the same way as with other bulk materials. Local transportation regulations should also be followed.

**Maritime Transport**

Classified as MHB, Briquettes Hot Molded under the regulations for ocean transport contained in the International Maritime Organization publication "International Maritime Solid Bulk Cargoes Code (IMSBC Code)"

US Coast Guard Special Permits pursuant to 46 CFR 148.01-9 of the U.S. Coast Guard (USCG) Carriage of Solid Hazardous Materials in Bulk Regulations.

### SECTION XV – Regulatory Information

**OSHA / EPA**

Not provided

### SECTION XVI – Other Information

**Others**

Not provided