

Hot Briquetted Iron (HBI): A Guide to Shipping, Handling & Storage

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GUIDE TO SHIPPING, HANDLING, AND STORAGE OF HOT BRIQUETTED IRON (HBI)

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

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CHAPTER 1 - INTRODUCTION TO HOT BRIQUETTED IRON (HBI)



*Figure 1: Hot Briquetted Iron
(Image courtesy of Metalloinvest)*



Hot Briquetted Iron (HBI) is the densified briquette form of Direct Reduced Iron (DRI). DRI is discharged hot from the reduction furnace and screw-fed into the nip between two counter rotating rollers. Pockets in the synchronously rotating rollers form the briquettes. This process occurs at high temperatures (at least 650°C [1202°F]) and high pressing forces. The continuous string of briquettes leaving the rollers is guided by a heavy chute and is separated into mostly single briquettes, for example by a rotor with impact bars as illustrated in Figure 2.

*Figure 2: Schematic of HBI manufacturing process
(Image courtesy of Maschinenfabrik Köppern)*

DRI, also known as Sponge Iron, is the product of the direct reduction of iron ore or other iron-bearing materials while in the solid state, i.e. without melting, using “reducing agents” carbon monoxide and hydrogen, derived from reformed natural gas, syngas or coal. It is a porous iron material which, due to its highly reduced state, is very reactive and easily reoxidised back to the oxide form in the presence of oxygen (air) and moisture. This reoxidation reaction is exothermic, i.e., heat is generated, which can lead to self-heating which in turn, if not controlled, can cause ignition and fires. In the presence of water (especially sea water) aqueous corrosion of iron can occur, leading to the generation of hydrogen, an explosive gas which is lighter than air.



*Figure 3: Modern HBI plant
(Image courtesy Midrex Technologies)*

HBI was developed in response to the difficulties in shipping DRI and is much safer to transport as a bulk cargo. The compaction of DRI into a dense briquette reduces its porosity and thus the surface area available to oxygen and water, meaning that HBI has a much lower reactivity and tendency to reoxidise and self-heat, therefore does not require the rigorous safety precautions required for safe shipment of DRI, principally inerting of the cargo with a blanket of nitrogen. Maintaining the apparent density of HBI at greater than 5 g/cm³ is key to an acceptable level of reactivity.

CHAPTER 2 - HANDLING & STORAGE AT PRODUCTION PLANTS, PORT TERMINALS AND STOCKYARDS

2.1 EQUIPMENT FOR HANDLING HBI AT PLANTS, PORTS & YARDS



Figure 4: Travelling conveyor-stacker and bucket wheel reclaimer at HBI Plant yard
(Image courtesy of Metalloinvest)

All types of conventional bulk material handling equipment can be used with HBI for yard storage, reclaiming, loading and/or unloading):

- Bucket-wheel stacker-reclaimers
- Cranes equipped with magnets or clamshell-type buckets
- Front-end loaders, backhoes
- Fixed or mobile conveyors and conveyor belt systems
- Fixed or mobile bins and hoppers
- If at port terminal or at anchor for mid-streaming operations to barges, ship travelling bridge cranes, fixed cranes, floating cranes and belt systems
- Self-release skips
- Railcar straddle carriers and rotary dumpers

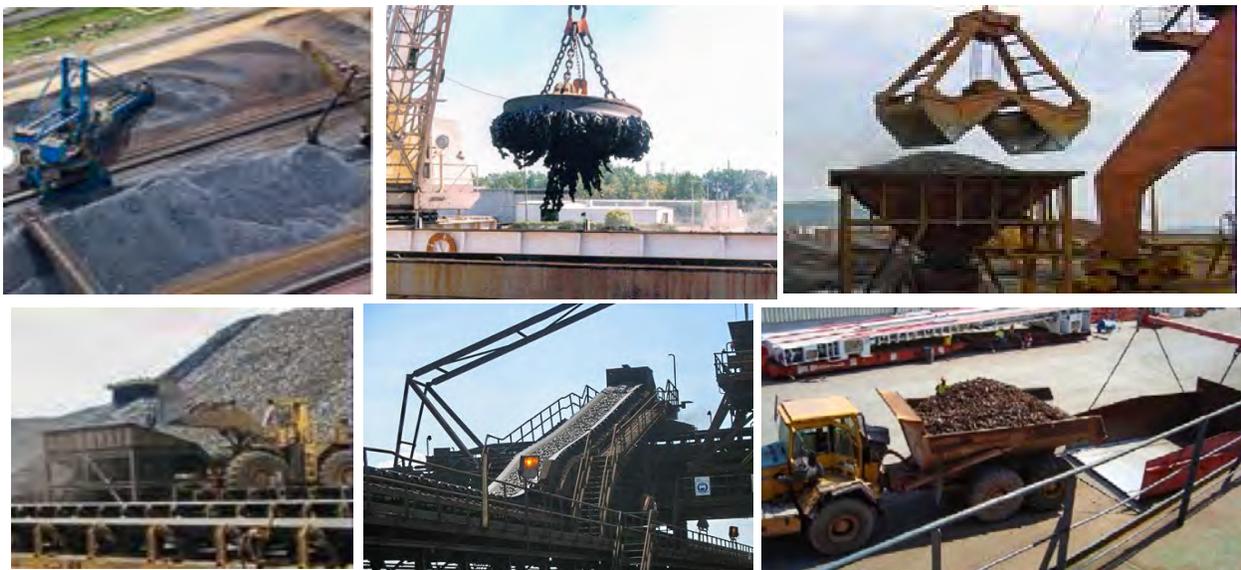


Figure 5: Photo collage of stacking, reclaiming and handling equipment
(Images courtesy of IIMA)

Whether at the production plant, the port, intermediate terminal or the end-user's stockyard, handling of HBI is similar in that industry utilises standard bulk material handling equipment of various types, sizes and capacities to handle HBI.

At the point of production, HBI is transferred from the briquetting units to plant storage and, after sufficient cooling, reclaimed for loadout (to vessel, barge, rail or truck). Discharge of HBI can be by self-discharging vessels on board crane systems or by shore-based cranes for vessels not equipped with their own cranes.

At port terminals, various types of handling systems may either transport the HBI to temporary ground storage, or convey it to hoppers for controlled re-loading to barges, railcars, or trucks. Many terminals make flexible combinations possible.

A key focus with HBI handling from production site to end user is the need to minimise briquette breakage and the generation of chips and fines, by minimising the height and number of free fall drops and the number of transfer points along the entire chain. Use of gentle lay down practice or "soft-loading" is recommended. While the number of transfer points may not be controllable, the choice of equipment and operator-controlled drop heights usually are (see Figure 6). All operators of material handling and transport equipment should be alerted to use soft handling techniques to minimise breakage and fines generation. Although HBI is intrinsically strong, rough or careless handling will contribute to product degradation.



*Figure 6: Railcar loaders having "soft-loading" capability (to minimise drop height)
(Images sourced from: left - Hub-4.com; right - PiercePacific.com)*

2.2 STORAGE OF HBI

HBI can be stored in the following areas or containers:

- Stockyards (covered or uncovered)
- Silos, hoppers or other confined spaces

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

- clean and dry (with proper drainage)
- free of combustible materials: wood, coal, coke, etc.
- free of chlorides or past cargoes: avoid cement, lye, borax
- sufficient distance from other stored materials

2.2.1 Stockyards

HBI can be stored uncovered in open air without problem, provided that proper precautions are taken. The storage area should be kept clean and free of any combustible and non-compatible materials. Yard storage of HBI is not affected by water pick-up, which is typically limited to about 3% by weight. However, it is good practice to avoid standing water by providing an even surface with moderate slope along with adequate drainage. It is recommended not to allow the piles to be wetted by anything but rainwater or snow, so they should not be located in areas subject to condensation, for example downwind from cooling towers. In addition, the piles should not be located close to heat sources such as steam lines or hot process gas ducts. Briquettes should not be contaminated with possible ignition sources such as, coke, wood or plastics (also direct reduced iron (DRI) in pellet/lumpy form).



Figure 7: Open stockyard storage of HBI
(Image courtesy of Tenova HYL)

Use of a storage pad with a concrete base is preferable to one with a base of compacted dirt, fill, crushed rock or other materials, as front-end loader operators may accidentally dig into the base when loading the HBI, pick up unwanted base materials and intermix them with the HBI (see Figure 8). Tramp materials or residues in the cargo may negatively impact the steelmaking process and thus the value of the HBI. When using front-end loaders and other mobile plant with HBI, care should be taken to minimise running them on top of piles so as to avoid breakage and fines generation. Likewise, multiple handling should be minimised.

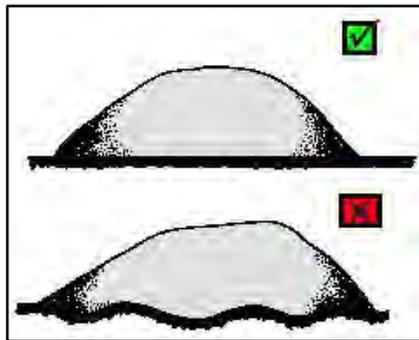


Figure 8: Correct storage base for HBI
(Diagram courtesy of BHP)

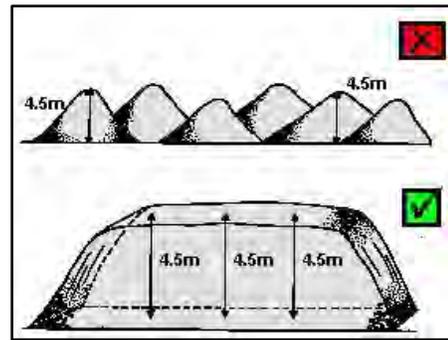


Figure 9: Proper stacking of HBI
(Diagram courtesy of BHP)

It is generally most efficient to pile the HBI in flat-topped tent shaped piles, typically 4-6 metres high, using a stacker, as illustrated in Figure 9 which shows incorrect and correct ways of stacking HBI. Tented piles with overlapping bases is not the recommended method, as conical, tented piles can create a chimney-like effect for hot spots that might occur in the interior of the pile, which may in turn accelerate the heating of the pile toward ignition. Overlapping piles make it difficult for equipment to access and isolate potential hot spots and thereby mitigate increases in pile temperature, or to undertake emergency procedures effectively.

2.2.2 Silos, bins and hoppers

There may be certain situations where HBI is moved temporarily into sheds, silos, bins or hoppers, for example in steel plant feedstock charging systems. If the HBI is to be continuously charged to the electric arc furnace, the receiving hopper should be equipped with a screen to remove large pieces of tramp materials or occasional oversized plates of multiple briquettes. While large plates of multiple briquettes do not pose any problem within the furnace, they may impede steady flow rates from a bin to a belt or launder that charges the furnace. Removal of oversized plates of multiple briquettes should not normally be an issue when fed to a blast furnace or basic oxygen furnace.

If the storage silos or bins discharge directly onto conveyor belts, there should be sufficient clearance between the discharge and the conveyor belt to avoid jamming of briquettes in the discharge, which may result in damage to the belts.

Care should be taken not to mix lime with HBI in storage silos or bins. If the lime has been wetted in any way, it will heat up and may instigate overheating of the HBI up to a hazardous level.

It is strongly recommended to monitor the hydrogen concentration in silos or bins containing HBI.

2.2.3 Inventory control and storage

HBI should normally be used or dispatched on a “first-in, first-out” basis. As pointed out in the reactivity section of Chapter 1, the content of metallic iron decreases over time as a consequence of re-oxidation in the presence of oxygen and moisture, so that material used on a “first-in, last-out” basis will have variable metallic iron content which in turn will affect steel plant yield as well as furnace operation.

2.2.4 Quality Loss in Storage

HBI metallisation loss can occur in the first 60-90 days of open storage, up to a level of about 3% in the first 20 cm (8 inches) depth into the pile, and to a lesser extent deeper into the pile where exposure to air is less. Metallisation losses can be minimised by following these recommendations:

- build flat-topped tent-shaped piles typically 4-6 metres high (as shown in Figure 9)
- avoid standing water by providing an even surface with moderate slope, along with adequate drainage

Fines and chips are more prone to re-oxidation than whole briquettes, since they have more surface area per unit volume, another reason to minimise generation thereof. Figure 10 illustrates the progressive metallisation loss of various size fractions of a sample of HBI over a period of 7 months.

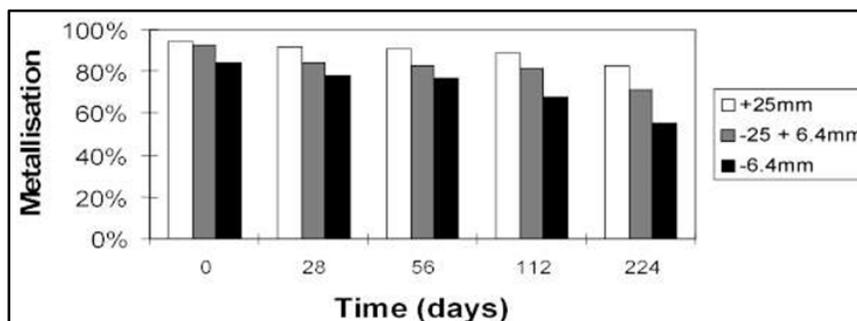


Figure 10: Metallisation of various size fractions of HBI over time (samples from stockpile outer layer)
(Chart courtesy of BHP)

2.2.5 Dissipation of water from precipitation (Steaming)



HBI will release water vapor in the form of a visible plume after being heavily wetted by precipitation (see Figures 11 and 12). This so-called “steaming” is often misinterpreted by materials handling personnel as overheating of the HBI, but is in reality only a normal reaction which poses no hazard to the personnel, material, or surroundings. The HBI can warm up to around 60°C [140°F] as the steaming occurs, but should normally cool down again to ambient temperature once the free water is driven off. It is not necessary to take any preventive action if the pile is steaming and the temperature in isolated pockets does not exceed 100°C [212°F]. If properly stored HBI does not overheat as a result of being wetted by precipitation.

Figure 11: Minor vapour plume as hot material meets atmospheric moisture
(Image courtesy of Tenova-Energiron)

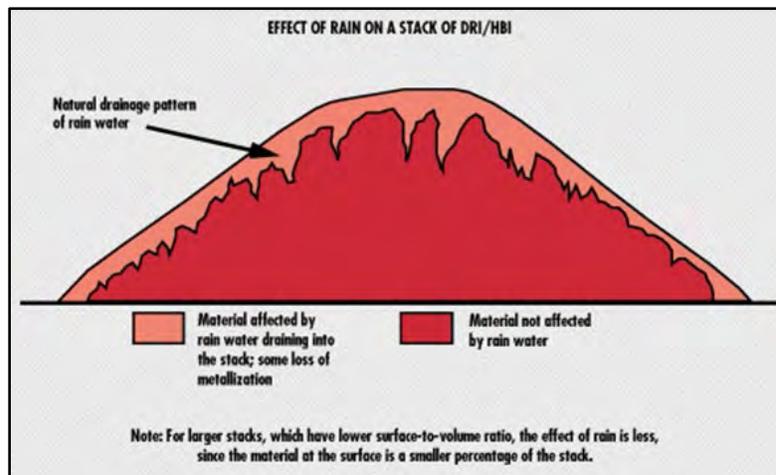


Figure 12: Effect of precipitation on surface of HBI stockpile
(Diagram courtesy of Midrex Technologies)

Covering the stockpiles with plastic sheets and spraying the stockpiles with liquid latex also helps to minimise re-oxidation and wetting.

2.2.6 Self heating and auto-ignition

Self heating can be detected by measuring temperatures at the top of the pile - temperatures in excess of 100°C [212°F] are a serious indication of material overheating. At this stage, no flame will be present. If wet material is present in the centre of a stockpile, the heat cannot readily escape and the temperature may rise, leading to ignition (see Figure 13). Conditions indicative of self-heating and auto-ignition are:

- sustained re-oxidation
- elevated temperatures (approaching 100°C [212°F])
- presence of water in the centre of a pile (particularly salt water)
- excessive (greater than 5% fines by volume) fines in the pile, particularly when segregated in the centre
- low HBI quality, i.e. poorly compacted, density <5,000 kg/m³.

Caution: under these conditions and due to the low thermal conductivity of HBI stockpiles, the pile will ignite if the temperature of the pile exceeds ignition temperature (reported to be greater than 750°C)

[1382°F] for HBI²). The pile should be monitored closely for hydrogen emission as hydrogen can be generated in wet conditions, especially in the presence of seawater, resulting in the risk of explosion.

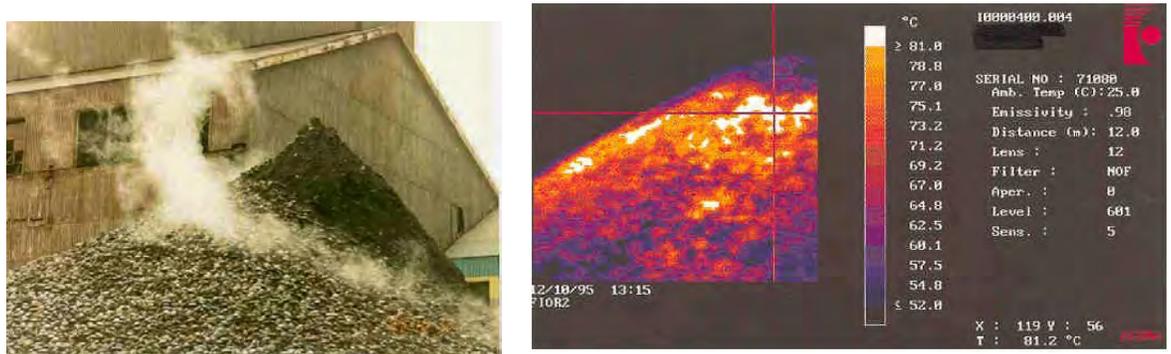


Figure 13: HBI pile self-heating incident, with thermal profile
(Images courtesy of BHP)

If hot-spots develop in the pile (i.e. localised temperatures exceed 100°C [212°F]), the affected material should be removed from the pile and spread out on the ground in a layer of about 0.5 m depth using a track-equipped bulldozer (see Figure 14). Use of rubber-tired front-end loaders may cause tire damage, depending on the temperature, size and location of the hot spot.

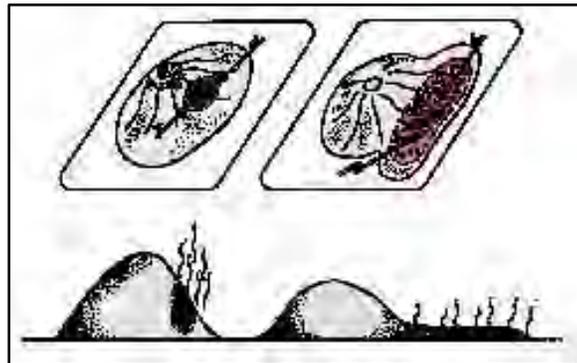


Figure 14: Controlling hot spots in an HBI pile
Top: View from overhead;
Left: >100°C (212°F) hot spot identified, Right: HBI spread out to dissipate heat build-up
(Diagram courtesy of BHP)

Another method is to bury the pile under sand or other suitable non-reactive fine-sized material in order to cut off oxygen supply. With this method, safety is the primary objective, but the trade-off is that when reclaimed, the HBI will have to be screened to remove the added material if the latter is not to end up in the steel furnace.

In case these measures or other alternatives are not practical or effective, the material can be flooded with water. However, this should be a last resort because it will result in a significant loss of HBI metallisation.

² Reoxidation and ignition behaviour of DRI to improve safety (Grabke et al, Final Report, Directorate General for Research, European Commission, technical steel research, Primary Steelmaking, 2003 EUR 20632)

Caution: water should not be sprayed on an overheated pile of HBI, as an aggressive reaction can develop, causing hydrogen gas generation, ignition, explosion, and/or meltdown of the HBI.

It should be emphasised that where HBI has overheated in piles, the material has been cooled and stabilised simply by lowering the height of the pile and allowing the heat to dissipate.

2.2.7 Dust suppression

Simply spraying water, as is done to control dust for many bulk commodities, has been found to be ineffective for suppression of HBI dust. Nevertheless, fine water sprays (using fresh, not salt water), can be used sparingly for suppression of dust during handling of HBI. Fine water sprays are best applied at the point of dust generation. Water in excess of 0.5% by mass may pose a safety hazard by increasing the potential for self-heating and hydrogen generation, and may also lead to metallisation loss through re-oxidation.

One practice that has been found to be effective during handling on conveyor belts is to apply a fine spray of water to the surface of the conveyor belt near the "tail" pulley of the conveyor, before the point on the belt where the HBI is added. This is shown in Figure 15 below. During conveying the fines naturally fall through the briquettes and settle on the conveyor belt. By wetting the belt, the fines stick to the belt and can be removed using a scraper or belt washing system at the head pulley, thereby eliminating the majority of the dust from entering into the storage piles, vessels, barges, railcars or trucks. Removed scrapings should be properly disposed of or recycled in accordance with applicable regulations or practices.

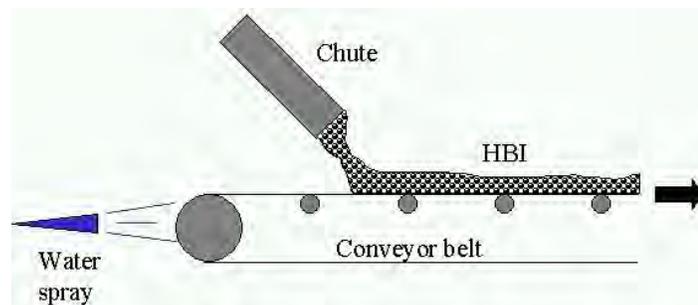


Figure 15: Illustration of use of water spray to suppress dust
(Diagram courtesy of BHP)

CHAPTER 3 – HANDLING AND SHIPMENT BY OCEAN-GOING VESSEL

3.1 PREPARATIONS FOR LOADING

3.1.1 Vessel type and equipment

The following types of vessel 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. Double-deck (tween deck) vessels are not recommended for shipment of HBI.

The IMSBC Code schedule for Direct Reduced Iron (A)³, the Bulk Cargo Shipping Name (BCSN) for HBI, includes the following requirements for Ventilation and Carriage respectively:

Ventilation

Surface ventilation only, either natural or mechanical, shall be conducted, as necessary, during the voyage for this cargo.

Carriage

- For quantitative measurements of hydrogen, a suitable detector shall be on board while this cargo is carried.
- Temperature of the cargo shall be taken regularly during the voyage and a record kept on board for a minimum of two years.

Thus, vessels for carriage of HBI must be capable of natural or mechanical ventilation of the holds and have equipment for monitoring the content of hydrogen and the temperature of the cargo in the holds.

The IMSBC Code requirements for flammable atmospheres and ventilation (Section 3, Safety of Personnel and Ship, clauses 3.4 and 3.5) are quoted in full in Annex 2.

Arrangement of ventilation system

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

Type of fan drive (In case of mechanical ventilation)

Ventilators must have the following characteristics:

- Certified marine explosion-proof in compliance with requirements of ship classification societies
- Axial flow
- Reversible
- Non-sparking blades
- Variable speed
- Drive mechanisms: air, water, electrical

³ See Annex 1 for the full schedule which has been reproduced with the kind permission of the IMO.



Figure 16: Photo collage of typical ventilators on hatch covers

Left: single natural gravity vent

Centre: single mushroom style fan-assisted vent

Right: dual mushroom style fan-assisted

(Images courtesy of IIMA)

3.1.2 Steps to be taken prior to loading HBI

1. The Carrier's nominated technical persons or other representatives shall have reasonable access to stockpiles and loading installations for inspection.
2. In accordance with section 4.2 of the IMSBC Code, "the Shipper shall provide the master or his representative with appropriate information on the cargo sufficiently in advance of loading to enable the precautions which may be necessary for proper stowage and safe carriage of the cargo to be put into effect." In particular, the Shipper or his appointed representative shall provide to the Master of the carrying vessel information about the nature of HBI and the potential hazards associated with shipping it, together with the relevant safety precautions and emergency procedures. Such hazards include the potential for HBI to self-heat and generate hydrogen gas after contact with water, especially seawater. The Master should be requested to convey such information to crew members. Proof that such instructions were so provided, such as a signed receipt from the Master, should be obtained by the Shipper. Such information may include:
 - a. copy of this guide
 - b. material safety data sheet
 - c. copy of the IMSBC Code schedule for Direct Reduced Iron (A)
3. 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 dust.
4. Hold inspection shall be carried out on each hold to carry HBI. Weather deck closures and hatch covers/coamings shall be inspected and tested to ensure integrity and weather tightness which shall be maintained throughout the voyage (hose testing, ultrasonic testing or equivalent).
5. Ensure that holds to carry HBI shall be clean, dry and free from salt and residues of previous cargoes.
6. Wash down deck surfaces, etc. to remove any salt present.
7. Prior to loading, wooden fixtures such as battens, loose dunnage, debris and combustible materials shall be removed.
8. Ensure that bilge wells of the holds shall be clean, dry and protected from ingress of the cargo, using non-combustible material. The bilge system of a hold to which HBI is to be loaded shall be tested to ensure that it is working properly and such tests documented.

9. Ensure that each hold has an adequate ventilation system.
10. Ensure that equipment suitable for quantitative monitoring of hydrogen and temperature without the need to enter cargo holds is on board.
11. Equipment for quantitative monitoring of hydrogen concentration shall be suitable for use in an oxygen depleted atmosphere and of a type certified safe for use in an explosive atmosphere. The instruments should be of durable field use design which prevents moisture ingress (which might affect results). Approved types of hydrogen sensors include Thermal Conductivity (TC) and Palladium Thin Film (PT) sensors. Catalytic bead combustible gas sensors and infrared sensors should not be used for hydrogen monitoring. A minimum of two (three preferred) gas monitors equipped with the approved type of gas sensors should be on board the vessel prior to loading HBI. The ship's hatch covers should be fitted with appropriate sampling points (minimum one, preferably two) for the measurement of gases in each cargo hold to contain HBI.
12. All monitoring equipment should be operational and properly calibrated at the commencement of loading, in accordance with manufacturer's instructions. The vessel's crew should be properly trained in the use of this equipment.
13. Any pre-loading inspections or procedures required by or on behalf of competent authorities shall have been carried out.
14. Following sampling and testing of the cargo to be loaded, the Shipper shall provide the Master with a certificate issued by a competent person recognised 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 the IMSBC Code, i.e. 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%⁴ and the temperature does not exceed 65°C.
15. The Master shall be in possession of all applicable permits, etc. from competent authorities.

3.2 VESSEL LOADING PROCEDURES

3.2.1 BLU Code

Loading of bulk cargoes, including HBI, is governed by the BLU Code i.e. the Code of Practice for the Safe Loading and Unloading of Bulk Cargoes, issued by the International Maritime Organisation⁵. Section 2 of the BLU Code addresses the suitability of ships and terminals: section 2.2 deals with ships and section 2.3 deals with terminals.

⁴ Exemptions to the provisions of the IMSBC Code DRI (A) schedule for HBI with moisture content above 1% and up to 5% have been granted. For such HBI the primary hazard is the accumulation of hydrogen in enclosed spaces (such as the ship's holds and adjacent spaces) generated by the aqueous corrosion of iron, due to the moisture contained in the HBI. Mechanical ventilation is the preferred method for removal of hydrogen. Such ventilation shall be operated so as to extract hydrogen from the affected holds to safe levels. Thus, vessels carrying HBI with elevated moisture content shall be equipped with mechanical ventilation. For further information, seek expert advice.

⁵ latest (2010) edition published in 2011 by the International Maritime Organisation

3.2.2 Loading and pre-voyage procedures and precautions

1. "Hot work" permits should be required on both the jetty and the ship when HBI is being loaded. Masters are advised to ensure a hot work permit is in place for any relevant maintenance or other work on deck while the ship is being loaded, unloaded, or underway.
2. HBI shall not be loaded when its temperature is in excess of 65°C [149°F], if its moisture content is in excess of 1%⁴ or if the quantity of fines and small particles (up to 6.35 mm in size) exceeds 5% by weight.
3. In the event that pockets of material with temperature in excess of 65°C [149°F] (hot spots) are found in a hold following loading and before sailing, if such material does not cool down naturally within a reasonable period of time, it should be dug out and turned over in the hold to facilitate cooling or if necessary discharged and cooled before reloading. What constitutes "a reasonable time" depends upon the circumstances on the spot: is the temperature stable or continuing to rise? What equipment and resources are available on the vessel/at the port? If in doubt, seek expert advice.
4. HBI shall not be loaded during precipitation. During loading of HBI 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 one hour after completion of each pour to allow cooling after cargo handling in bulk.
5. 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 minimise breakage of briquettes and the additional generation of fines and small particles and concentration of fines in any area of the cargo.
6. The deliberate addition of fines and particles less than 6.35 mm or dust in HBI cargoes shall be prohibited.
7. 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 and the Shipper. Infrared thermal guns are typically used to measure the temperatures via the hatch coaming.
8. Persons who may be exposed to the dust of the cargo shall wear protective clothing, goggles or other equivalent eye-protection and dust filter masks, as necessary.
9. During handling of this cargo "NO SMOKING" signs shall be posted on decks and in areas adjacent to cargo spaces, including mast houses and areas common to the cargo holds, and no naked lights shall be permitted in these areas.
10. Trim in accordance with the relevant provisions required under sections 4 and 5 of the IMSBC Code. Due consideration shall be given to evenly spreading the cargo across the tanktop to minimise the concentration of fines.
11. Loading of HBI against sources of heat should be avoided unless such heat sources can be isolated (for example in the case of bunker fuel tanks if the heating coils can be isolated when tanks are empty).
12. On completion of loading and at all times when closing hatch covers, hatch coamings and gaskets should be thoroughly cleaned and inspected to ensure that coamings are free of cargo debris and that an adequate hatch to coaming seal is made.
13. 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 recognised by the National Administration of the port of loading.

3.2.3 Effects of loading on ship and HBI

The IMSBC Code has standard language for loading of heavy cargoes, such as HBI:

“The tank top may be overstressed unless the cargo is evenly spread across the tank top to equalise the weight distribution. Due consideration shall be paid to ensure that the tank top is not overstressed during voyage and during loading by a pile of the cargo.”

The crucial factor in managing HBI size degradation during handling is the drop height which should be kept to a minimum. Once the initial HBI has begun to create a pile in the hold, the impact of subsequent material is cushioned (and drop heights diminish) as the pile builds in the hold.



Figure 17: Photos of “soft-loading” devices

*Left & center: adjustable, rotatable slide chutes minimise drop height to 10m during vessel loading
Right: skip used for loading scrap, pig iron, DRI, HBI, here with ship’s gear (load capacity 25 tonnes)*

(Images courtesy of Maschinenfabrik Köppern, Orinoco Surveying and Oldendorff)

3.2.4 Dust

HBI briquettes are inherently strong, nevertheless some will fracture, resulting in chips and fines and generation of dust. Some fine dust will be generated during each stage of material handling and transfer and, as already mentioned above, it is important to minimise the height and number of drops while transporting and handling HBI.

It may be necessary to use a freshwater spray mist to suppress dust, but this practice should be considered on a case-by-case basis, as moisture serves to reduce product metallisation and thus adversely impacts cargo value.

HBI dust is composed primarily of iron oxide, which if inhaled or in contact with the eye can cause irritation or eye damage. Therefore, eye protection should always be worn when working in the vicinity of HBI handling operations. A face mask should also be used to avoid inhalation in dusty conditions.

Dust evolved during handling/unloading of HBI can accumulate over the ship's surface (see Figure 18). In a marine environment, the dust rapidly rusts to form iron hydroxide, which has a reddish-brown colour. Laboratory testing has shown that such dust does not damage the integrity of the ship's paint system.



- prior to loading and being deemed load ready, ensure cargo holds are fresh water rinsed to remove sea salt residues, with any pools of standing water to be properly dried. Cargo hold bilges should be pumped dry and isolated when complete.
- remove the dust periodically during and immediately on completion of loading by sweeping/vacuuming
- on completion of loading emphasis should be on 'dry-cleaning' of cargo holds, by brush or air, to remove as much dust as possible, removing dust accumulation on flat surfaces and pipes. Then thoroughly wash down the affected surfaces of the ship.

*Figure 18: Staining of ship deck from HBI dust
(Image courtesy of BHP)*

Specialised barrier coats may help minimise the extent of dust-related cleaning, especially on horizontal surfaces. Dry-cleaning by crew during loading and discharge helps reduce dust. Use of air to knock down dust from pipes and hatch channels helps final cleaning.

Sensitive equipment, such as radars should be protected against dust (see Figure 21 below). Wrapping sensitive hatch fittings, such as exposed hydraulic cylinders, with plastic-stretch food wrap and/or aluminium foil provides a fast and economic means to secure equipment and is easily and quickly removed as needed.

Top-coat type paint coatings on main deck and accommodation (cosmetic - urethane based paints) may fail when using muriatic acid (hydrochloric acid). Not all ships have a top-coat. Friendlier acids may reduce coatings damage albeit at a cost increase. Preference should be given to 500bar HP wash when in doubt. Most epoxy type coatings used in cargo holds are rated to 60°C (140°F) and resist chemical damage from common acids used for cleaning HBI dust.

Sometimes misconceptions by owners and industry attribute the rust-coloured residues (that remain hardened if not fully cleaned) as being due to corrosion of the hull. In fact, this is generally only the oxidation of the HBI residues and has no ill-effect upon the ship's steel structure.

3.3 DURING THE VOYAGE

1. The cargo shall be kept as dry as practicable during the voyage.
2. Bilge wells shall be checked regularly for the presence of water. If water is found, it shall be removed by pumping or draining the bilge wells.
3. Hatches should remain closed while at sea in order to prevent the entry of seawater into the holds. Under no circumstances should seawater be allowed to enter the holds.
4. Consideration should be given to use of hatch-tape for centre hatch joints as a precautionary measure. Use of hatch tape should be confirmed to the ship's master by the shipper or vessel operator as the case may be. NB: some types of hatch-tape are more suitable than others.
5. The concentration of hydrogen in the holds carrying HBI shall be measured regularly during the voyage, and the measurements recorded, sent to the Shipper no later than at the end of the voyage and kept on board for a minimum of two years.

6. **CAUTION:** hydrogen gas is evolved during reoxidation of HBI when water is present, normally after approximately 16 hours.
7. Enclosed spaces adjacent to cargo holds containing HBI should be monitored regularly for the presence of hydrogen. Such spaces should be adequately ventilated and, in the case of mechanical ventilation, only explosion-proof equipment should be used. Testing is especially important prior to permitting entry to such spaces or activation of any equipment located therein.
8. During the voyage, surface ventilation only, either natural or mechanical, shall be conducted as necessary, i.e. to maintain the hydrogen concentration below 1% by volume (25% of the lower explosive limit [LEL]). 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 a 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.
9. **CAUTION:** even though the moisture content of the cargo may be less than 1%, condensation may occur in the ship holds as a result of the steaming effect. However, use of either natural or mechanical ventilation should normally prevent condensation and thus diminish the risk of occurrence of the hazards inherent in the cargo.
10. During unfavorable weather and sea conditions, surface ventilation should be conducted as safely as practically possible. Ventilators should be closed during heavy seas in order to prevent ingress of seawater and moisture.
11. Detailed and timely recording of cargo hold temperature and gas concentration helps to establish a 'trend' which ship's command can use in determining when to ventilate. The interval and duration of ventilation can be guided by the established trend, with due regard to weather and sea state, in keeping with good seamanlike practice, as with other similar cargoes.
12. **CAUTION:** when the monitored hydrogen concentration appears to be approaching, reaches or exceeds 1% by volume (25% of the lower explosive limit), appropriate safety measures shall be taken in accordance with the emergency procedures provided by the Shipper (see Chapter 5 hereof). If in doubt, expert advice shall be sought.
13. Temperature of the cargo shall be measured regularly during the voyage and a record sent to the Shipper no later than at the end of the voyage and kept on board for a minimum of two years.
14. **CAUTION:** A temporary increase of up to about 30°C in the cargo temperature due to self-heating may be expected after material handling in bulk. A gradual temperature decline towards ambient should follow. In warm latitudes, the ambient temperature in the cargo holds above the stow may rise during the day due to solar warming, accompanied by condensation. This should not significantly affect the temperature within the cargo.
15. A cargo temperature of 65°C (149°F) in a cargo hold is an indicator of a potential approaching emergency contingency (see point 17 below) and is therefore a trigger for increased monitoring (every two to three hours and not less than every four hours, provided always and to the extent that prevailing conditions permit) and vigilance, as well as preparation for dealing with the emergency, should it eventuate.
16. The best and most practical indicator of cargo temperature is the temperature on the top surface of the cargo in the hold which can be measure with an infrared thermal gun (spot pyrometer) or thermal imaging camera. Another indicator is the temperature in the head space above the cargo which can be monitored by sensors attached to the tank top. An isolated hot spot is less of a concern than multiple

hot spots which would be indicative of more general heating of the cargo. If in doubt, expert advice shall be sought.

17. Other precautionary measures that should be taken:

- a. if possible, increase the rate of mechanical and natural ventilation to dissipate heat and any hydrogen
- b. if possible, check for bulkhead heating in adjacent cargo spaces; if significant bulkhead heating is detected from within an empty cargo space, spray with water from the empty cargo space side, provided the bulkheads are mechanically sound
- c. check for signs of abnormal heat in affected sounding pipes and air pipes

18. If the temperature continues to increase, establish with the Shipper or the assigned expert the best course of action, taking into account the prevailing circumstances and history of the cargo in question, for example the rate of temperature increase, the remaining sailing time to the scheduled discharge port, etc. If the temperature in a hold shows signs of approaching, reaches or exceeds 100°C (212°F), appropriate safety measures shall be taken in accordance with the emergency procedures provided by the Shipper (see Chapter 5 hereof).

19. During or at the termination of the voyage, no smoking, burning, welding, cutting, chipping or other source of ignition should be allowed in the proximity of a hold containing HBI.

20. Masters should ensure a hot work permit is in place for any relevant maintenance or other work on deck while HBI is on board.

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

22. No person shall enter an enclosed space adjacent to a cargo hold containing HBI unless such adjacent space has been ventilated and the atmosphere tested and found to be gas-free and have sufficient oxygen to support life.

23. Notwithstanding the provisions of the previous point 18, emergency entry may be permitted without ventilation, testing, or both, provided that:

- a) the entry into the space is undertaken only by trained personnel wearing self-contained breathing apparatus
- b) the entry to the space is under the supervision of a responsible officer
- c) no source of ignition is introduced into the space
- d) the crew should be familiar with confined space rescue safety.

3.4 SEAWATER INTRUSION INTO HOLDS

The effects of seawater ingress into a cargo hold containing HBI can be the following

- generation of hydrogen
- increase in temperature
- steaming

In the event of seawater ingress into a cargo hold containing HBI, the following guidelines and procedures should be followed:

- first eliminate the source of water ingress to the extent possible
- maintain temperature and gas monitoring in affected cargo holds and increase the frequency of measurements to hourly
- maintain ventilation on a continuous basis, provided that weather and sea conditions are such that it is safe to do so
- seek advice from the Shipper or other expert, explaining the circumstances and follow the advice and/or instructions received
- in the event that after implementing these measures the cargo temperature reaches and does not fall below a temperature of 100°C (212°F) and/or the hydrogen concentration in the affected hold(s) reaches and does not fall below 1% by volume (25% of the lower explosive limit), refer to the procedures given in Section 3.3 points 15-18 above and the emergency procedures in Section 5 of this guide.

3.5 VESSEL UNLOADING PROCEDURES

In addition to the guidelines below, during unloading attention should be paid to the risks posed by hydrogen gas evolution and the depletion of oxygen in enclosed spaces. HBI should not be unloaded if temperature is in excess of 65°C [149°F] or during periods of heavy precipitation without expert advice (see Section 5).

3.5.1 Actions prior to unloading

The following actions should be taken prior to unloading a vessel carrying HBI:

1. Check the hydrogen concentration before opening cargo holds containing HBI. If the hydrogen concentration in a cargo hold is 1% or more by volume (25% of the lower explosive limit), ventilate the affected hold(s), continue to monitor the hydrogen concentration and do not open the hatches until the hydrogen concentration is less than 1% by volume.
2. Measure the cargo temperature in cargo holds containing HBI. If the temperature readings are stable and at or below 65°C, it is safe to unload in the normal manner. If the temperature exceeds 65°C [149°F], refer to the emergency procedures given in Chapter 5 (section 5.3).
3. Before any personnel enter a cargo hold containing HBI, measure the oxygen concentration which should be at least 21% by volume before entry. Otherwise entry shall be permitted only by trained personnel wearing self-contained breathing apparatus and under the supervision of a responsible officer and provided that no source of ignition is introduced into the space.
4. Where possible, provide electrical grounding/earthing in the cargo holds in order to reduce sparking potential from any electrical sources.
5. Protect radar, RDF scanners and other sensitive equipment from dust and fines.
6. When it is safe to do so, open the hatches and inspect the condition of the HBI cargo. Such inspection should include the following:
 - a. the presence of wetted briquettes on top of the cargo, indicating that water has seeped in via the hatch covers

- b. entry of water through the double bottom of the hull, indicated by wetted briquettes at the edges of the bottom of the pile
- c. the presence of hot spots - defined as areas where the temperature exceeds 100°C [212°F].

3.5.2 Vessel unloading

Vessels carrying HBI are normally discharged:

- at shore-based terminals with unloading by shore-based or on-board cranes directly to stockyard via the terminal conveyor system or to barges or smaller vessels (see Figure 19 below)
- in midstream to barge or smaller vessel with unloading by on-board or floating cranes, e.g. as practised in the US Gulf area (see Figure 20 below)

Almost any vessel or dockside system used for discharge of bulk materials can be used for HBI, including on-board handling systems designed for iron ore, scrap, or pig iron. For example:

- magnets (briquettes are magnetic)
- overhead bridge crane with grab buckets, clamshells or magnets, or independent mobile or fixed position cranes with grabs
- small front-end loader in hold discharging into buckets or skips (normally used for small piles and final clean-up of the ship's cargo holds)
- systems to transfer briquettes onto belts, trucks, railcars or barges.

Some midstreaming operations may use a floating terminal, just offshore, equipped with conveyor systems, in which case barges are moved beneath hoppers which directly load to barge holds.

Because of the relatively high bulk density of briquettes (~2.8 tonnes/cubic metre, or ~175 pounds/cubic foot), care must be taken that materials handling equipment is not overloaded. HBI is inherently strong and can therefore be handled using conventional bulk materials handling techniques. To optimise handling, drop heights should be minimised to reduce size degradation and the evolution of dust.

Ships crew should avoid 'pressing-up' ballast tanks during discharge and hold off on ballasting operations so far as practical.



Figure 19: Simultaneous transfer to barges and port storage using vessel floating cranes
(Image courtesy of Marine Inspection, LLC)



Figure 20: "Midstreaming": discharging cargo to barges using floating cranes on both sides of the vessel
(Image courtesy of CBG)

3.5.3 Dust suppression during unloading

Generation of dust and fines during handling of HBI was described in section 3.2.4 above. Measures to protect equipment and deal with dust during unloading and transfer to the stockyard of a shipment of HBI are essentially the same as those applicable during loading:

- minimise the number and height of drops between vessel and stockyard
- use a freshwater spray mist to suppress dust, but this practice should be kept to a minimum, as any resultant product rusting will reduce product metallisation and thus adversely impact the value of the cargo
- eye protection should always be worn when working in the vicinity of HBI handling operations and a face mask should also be used to avoid inhalation in dusty conditions
- to deal with dust accumulations on the ship, remove the dust periodically during and immediately on completion of unloading by sweeping/vacuuming and on completion of unloading thoroughly wash down the affected surfaces of the ship with fresh water so far as practical. Use of sea water should be avoided.
- Protect sensitive fittings and equipment, such as exposed hydraulic cylinders, radars, etc. See examples in Figure 21 below.



Figure 21: Protecting vessel equipment from HBI dust
(Images courtesy of Maschinenfabrik Köppern)

CHAPTER 4 - TRANSPORTATION OF HBI BY BARGE, RAIL AND TRUCK

4.1 BARGE TRANSPORTATION

4.1.1 Barge condition

Covered barges are recommended for transport of HBI, but open barges are also acceptable provided that the appropriate precautionary measures are taken.

Barges must comply with the following conditions:

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

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

4.1.2 Barge loading

The precautions and procedures for loading barges are essentially the same as for loading ocean-going vessels (see Chapter 3 above). Barge 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 HBI.

1. HBI should not be loaded if its temperature exceeds 65°C [152°F].
2. HBI should not be loaded during precipitation. Covered barges should be closed during precipitation.
3. Barges should be visually checked for water prior to loading, especially aft where water may accumulate from wash water and/or precipitation.
4. The drop of the briquettes should be minimised, to reduce breakage and the generation of fines.
5. Loading operations should be carried out in a manner such as to reduce stress on the barge. Typically, loading should start at one end and continue along the length of the barge hopper.
6. HBI should be loaded leaving room at the bow and stern for access to drain and pump standing water as deemed necessary.
7. HBI should be evenly distributed in the barge, making the stow in small heaps (see Figure 22).
8. Barges should be loaded in a manner so as to have a slight “trim by the stern” to enable easier water extraction.
9. Covered barges should be closed as soon as possible after completion of loading.

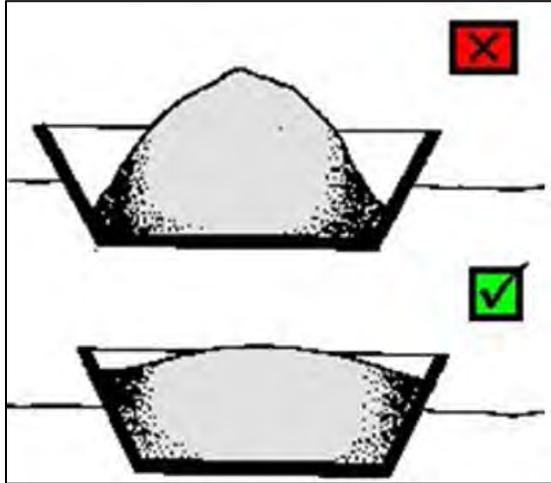


Figure 22: Correct loading of HBI to barges
(Diagram courtesy of BHP, imageo courtesy of Marine Inspection)



Figure 23: Open and covered barge operations
(Images sourced from: top left Creative Commons-Tim Kiser; Marine Inspection, LLC)

4.1.3 Barge shipment

During shipment, the following precautions should be taken:

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

4.2 TRANSPORTATION BY TRUCK AND RAIL

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

In some situations, trucks and/or railcars may be loaded directly from a ship or barge using a variety of equipment combinations, but because time for discharging is intended to be as short as possible (to avoid demurrage charges), it is common practice is send the product to a temporary storage, and later reclaim from the storage pile to whatever equipment is in place to effect the loading, e.g. conveyor belt system that discharges to large capacity hoppers, which then allow for controlled loading to rail or truck (see Figure 24 below). HBI should be loaded uniformly along the length of the railcar or truck.



Figure 24: Transfer from hopper to truck
(Photo courtesy of Port of Corpus Christi, TX)

To avoid loss during transport, trucks should not be overloaded (see Figure 25). The bulk density of HBI is high (at least 2.8 g/cm^3 or 175 lbs/cf) and has to be taken into account during loading. It is recommended that tarpaulins be used in order to suppress dust emission and to limit moisture pick-up en-route to the customer's yard. Adhere to local regulations regarding use of tarpaulins.

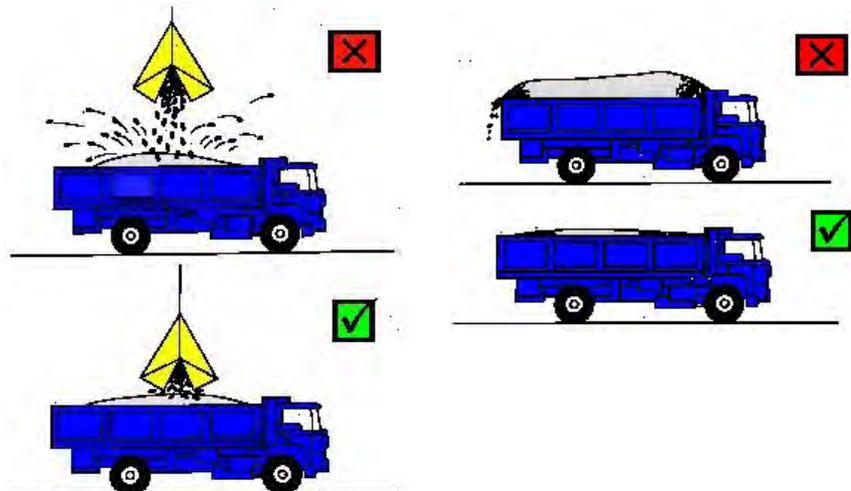


Figure 25: Keep drop heights low and avoid overloading railcars and trucks
(Diagrams courtesy of BHP)

CHAPTER 5 - EMERGENCY PROCEDURES

This section provides information about emergency procedures commonly used in shipping, handling and storage of HBI. There are two principal potentially dangerous situations (contingencies) with HBI cargoes and piles which can arise:

- self-heating to elevated temperatures in excess of 100°C [212°F] and as high as the ignition temperature (above 750°C [1382°F]²)
- hydrogen accumulation in excess of 1% by volume or 25% of the lower explosive limit (LEL) in confined spaces like holds or in covered storage sheds, and spaces adjacent to them.

5.1 ACTION PLAN FOR HBI AT ELEVATED TEMPERATURES DURING TRUCK AND RAILCAR UNLOADING

Unloading of HBI from trucks and railcars can be conducted under most weather conditions. At the general level:

1. The Operations Supervisor and the Material Handling Operators are responsible for properly executing the action plan if a train or truck arrives at the point of reception carrying HBI at the temperature levels shown in sections 5.1.1 and 5.1.2 below. Unloading operations must be supervised by personnel familiar with the safety precautions and emergency procedures for handling HBI.
2. In all cases, before unloading railcars or trucks, measure the HBI temperature in each railcar or truck, and record the measurements in the temperature log book. This should be done every two hours while the contingency is in effect.
3. The zone of the storage area designated for hot HBI should be clean and free of debris and flammable material, such as coal, coke and wood.
4. While transferring hot HBI by conveyor, inspect the belt transfer system regularly for any sign of overheating. In case of overheating, stop the HBI transfer, but keep the transfer belts in motion until they cool. Take special care to avoid ingress of water into hoppers and other equipment.
5. In the designated zone of the storage area, hot HBI should be spread out on the ground (separately from the main stockpile) in a layer of about 0.5 m depth using a track-equipped bulldozer for cooling (see Figure 14 in section 2.2.6). Mix cooler HBI with hotter material to lower the average temperature (do not use water).
6. In essence, the hottest material should be unloaded first.

5.1.1 Material at temperature above 150°C [302°F]

Position the railcars/trucks containing HBI with temperatures above 150°C [302°F] in the designated location in the reception area and spray with pressurised water (in this case, there is no option other than to cool down the HBI before discharge and transfer to the designated zone of the storage area for cooling, as conveyor belts will burn at temperatures above 150°C [302°F]).

5.1.2 Material at temperature up to 150°C [302°F]

1. First unload any railcars/trucks with HBI at temperature above 100°C [212°F] in the designated location and immediately transfer to the designated zone in the storage area for cooling.

2. Then unload HBI with temperatures between 65°C and 100°C (149°F and 212°F) in the designated location and immediately transfer to the designated zone in the storage area for cooling.

5.2 ACTION PLAN FOR HBI AT ELEVATED TEMPERATURES DURING THE OCEAN VOYAGE

During the voyage, if the temperature of any cargo hold shows signs of approaching or exceeding 100°C [212°F], taking into account the trend of temperature increase (refer point 11 in section 3.3 above), the first step is to seek expert advice from the Shipper, Owner, Charter, P&I Club or other appointed surveyor or expert. Depending on the advice of the appointed surveyor or expert, the following solutions may be considered:

1. deviation to a port of refuge to discharge the affected cargo if the cargo temperature exceeds 120°C [248°F] in which case preparations should be made for grab discharge;
2. as a last resort, flooding the affected cargo holds with water, always taking into account the stability and strength of the ship.

The temperatures mentioned in this section 5.2 are indicative and the advice of the appointed surveyor or expert should be followed.

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

5.3 ACTION PLAN FOR HBI AT ELEVATED TEMPERATURES DURING UNLOADING OF SHIPS AND BARGES

Unloading of HBI 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. At the general level:

1. The Master of the ship must notify the competent port authorities if elevated temperatures are measured in holds containing HBI.
2. The Operations Supervisor and the Material Handling Operators are responsible for properly executing the action plan if a ship or barge arrives at the discharge port carrying HBI at the temperature levels in sections 5.3.1 and 5.3.2 below. Discharging operations must be supervised by personnel familiar with the safety precautions and emergency procedures for handling HBI.
3. The zone of the storage area designated for hot HBI should be clean and free of debris and flammable material, such as coal, coke and wood.
4. In all cases, before unloading the ship or barge, measure the 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.
5. While transferring hot HBI by conveyor, inspect the belt transfer system regularly for any sign of overheating. In case of overheating, stop the HBI loading and transfer, but keep the transfer belts in motion until they cool. Take special care to avoid ingress of water into hoppers and other equipment.
6. In the designated zone of the storage area, hot HBI should be spread out on the ground in a layer of about 0.5 m depth using a track-equipped bulldozer for cooling (see Figure 14 in section 2.2.6). Mix cooler HBI with hotter material to lower the average temperature (do not use water).
7. Elevated temperature in this context means in excess of 65°C [149°F]. In essence, the hottest material should be unloaded first. Hot HBI may be localised within the hold of a ship or barge (so-called hot spots).

5.3.1 Temperatures above 150°C [302°F]

Starting with any hot spots, discharge HBI with temperatures above 150°C [302°F], position it in the designated location and spray with pressurised water (in this case, there is no option other than to cool down the HBI before transfer to the designated zone of the storage area, as conveyor belts will burn at temperatures above 150°C [302°F]). When the temperature has fallen to 150°C [302°F] or below proceed immediately with transfer to the designated zone in the storage areas for cooling.

5.3.2 Temperatures at or below 150°C [302°F]

1. Starting with any hot spots, first unload the holds containing HBI with temperature between 100°C (212°F) and 150°C (302°F) in the designated area, immediately transfer the hot HBI to the designated zone in the storage area for cooling.
2. Then, starting with any hot spots, unload the holds containing HBI with temperature between 65°C (149°F) and 100°C (212°F) in the designated area and immediately transfer the hot HBI to the designated zone in the storage area for cooling.

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

5.4 HYDROGEN GAS CONTINGENCY

If the hydrogen concentration is 1% by volume or more (25% or more of the lower explosive limit), adopt the following procedure:

1. Inform the Shipper and other interested parties such as Owners, Charters and P&I Clubs immediately and seek expert advice. Follow the instructions of the appointed expert or surveyor.
2. Maintain the natural surface ventilation and, if available mechanical ventilation, open/in operation at all times for the duration of the contingency, i.e. until the hydrogen concentration falls below 1% by volume.
3. Monitor the hydrogen concentration in the affected holds continuously until it drops to 1% by volume or below.
4. Ensure there are no possible sources of ignition near the cargo spaces, adjacent spaces or open decks.
5. Take great care to prevent any spark generation.
6. When hydrogen is stable below 1% by volume, proceed as normal.
7. At sea, do not open the affected hold(s) without explicit instructions to do so from the expert or surveyor appointed by the Shipper, Owner, Charterer or P&I Club as may be the case.

ANNEX 1: DIRECT REDUCED IRON (A) SCHEDULE OF THE IMSBC CODE⁶**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

Angle of repose	Bulk density (kg/m³)	Stowage factor (m³/t)
Not applicable	2500 to 3300	0.3 to 0.4 To be verified by the shipper
Size	Class	Group
Approximate size: Length 50 mm to 140 mm Width 40 mm to 100 mm Thickness 20 mm to 50 mm Briquette weight 0.2 to 3.0 kg Fines and small particles: under 6.35 mm	MHB	B

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

⁶ Reproduced with the kind permission of the International Maritime Organisation

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 recognised 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 minimise 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 minimise 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 recognised 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 transhipped.

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

<p>Special emergency equipment to be carried</p> <p>Nil</p>
<p>Emergency procedures</p> <p>Nil</p> <p>Emergency action in the event of fire</p> <p>Do not use water. Do not use steam. Do not use CO₂.</p> <p>Batten down.</p> <p>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.</p> <p>Preparations should be made for grab discharge if serious heating occurs.</p> <p>Medical First Aid</p> <p>Refer to the Medical First Aid Guide (MFAG), as amended.</p>

ANNEX 2: IMO PROVISIONS FOR FLAMMABLE ATMOSPHERES AND VENTILATION (SECTION 3, SAFETY OF PERSONNEL AND SHIP)

3.4 Flammable atmosphere

- 3.4.1 Dust of some solid bulk cargoes may constitute an explosion hazard, especially while loading, unloading and cleaning. This risk can be minimised by ventilating to prevent the formation of a dust-laden atmosphere and by hosing down rather than sweeping.
- 3.4.2 Some cargoes may emit flammable gases in sufficient quantities to constitute a fire or explosion hazard. Where this is indicated in the cargo schedule in this Code or by the cargo information provided by the Shipper, the cargo spaces shall be effectively ventilated as necessary. The atmosphere in the cargo spaces shall be monitored by means of an appropriate gas detector. Due consideration shall be paid to the ventilation and monitoring of the atmosphere in the enclosed spaces adjacent to the cargo spaces.

3.5 Ventilation

- 3.5.1 Unless expressly provided otherwise, when cargoes which may emit toxic gases are carried, the cargo spaces shall be provided with mechanical or natural ventilation; and, when cargoes which may emit flammable gases are carried, the cargo spaces shall be provided with mechanical ventilation.
- 3.5.2 If maintaining ventilation would endanger the ship or the cargo, it may be interrupted unless this would produce a risk of explosion.
- 3.5.3 When continuous ventilation is required by the schedule for the cargo in this Code or by the cargo information provided by the Shipper, ventilation shall be maintained while the cargo is on board, unless a situation develops where ventilation would endanger the ship.
- 3.5.4 Ventilation openings shall be provided in holds intended for the carriage of cargoes that require continuous ventilation. Such openings shall comply with the requirements of the Load Line Convention as amended for openings not fitted with means of closure.
- 3.5.5 Ventilation shall be such that any escaping hazardous gases, vapours or dust cannot enter the accommodation or other interior spaces in hazardous concentrations. Due consideration shall be given to prevent escaping hazardous gases, vapours or dust from reaching enclosed work areas. Adequate precautions shall be taken to protect the personnel in these work areas.
- 3.5.6 When a cargo may heat spontaneously, ventilation other than surface ventilation shall not be applied. On no account shall air be directed into the body of the cargo.