



THE 4TH ANNUAL DRY BULK SHIPPING MARKET OUTLOOK CONFERENCE

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Technical Report on the Reactivity, Safe Handling and Carriage of DRI Products (Safety Issues)



Oscar Dam / Ido Gibellini

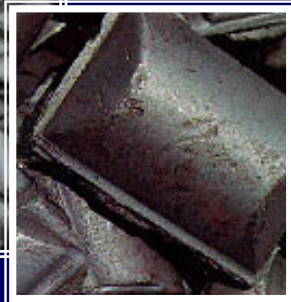
Hot Briquetted Iron Association (HBIA)
Technical Committee and Transportation Committee

- **Introduction.**
- **DR Products:**
 - ✓ **Definition.**
 - ✓ **Generation, volumes shipped.**
 - ✓ **Worldwide Forecast for the DRI Fines generation**
 - ✓ **Hazards.**
 - ✓ **Characterization – new research.**
 - ✓ **Ventilation or inerting - Safety Index.**
- **BLU Code**
 - ✓ **Relevant industry information on Safe Handling and carriage of DRI Fines**
- **Safety Recommendations.**
- **Advised Actions.**
- **Emergency procedures.**
- **Conclusions.**

- **Concern about safety issues on handling and transportation of DR products.**
- **DRI Chain supply: from producers to users via traders, shipowners, insurance companies and terminal operators.**
- **Industry to supply relevant information: aim to do so for shipowners as one of the main link of the distribution chain.**

DRI (A) Briquettes, hot-moulded (HBI)

- A material emanating from a densification process whereby the DRI feed material is at a temperature greater than 650°C (1200°F) at time of molding and has a density greater than 5.0 g/cm³.
- Weight from 0.5 to 1.5 kg, 1 to 3 ½ lb.
- Size:
 - ✓ L=90 to 130 mm, 3 ½ to 5 in
 - ✓ W=80 to 100 mm, 3 to 4 in
 - ✓ T=20 to 50 mm, ¾ to 1 ½ in



DRI (B) pellets, lumps or cold-moulded briquettes

- It is a metallic material of a manufacturing process formed by the reduction (removal of oxygen) of iron oxide at temperatures below the fusion point of iron. Cold-moulded briquettes should be defined as those which have been moulded at a temperature under 650°C or which have a density of less than 5 g/cm³ .
- Diameter of a typical pellet is about 12 mm ...
- ... its volume is about 0.9 cm.
- The mass of a typical pellet is about 3 g.
- So, its density is approximately 3.5 g/cm³ .
- A lot of the volume of that typical pellet is not iron ...
- ... it's air.

Physical Comparison between DRI Pellets and HBI

➤ DRI (B)



DRI

➤ DRI (A)



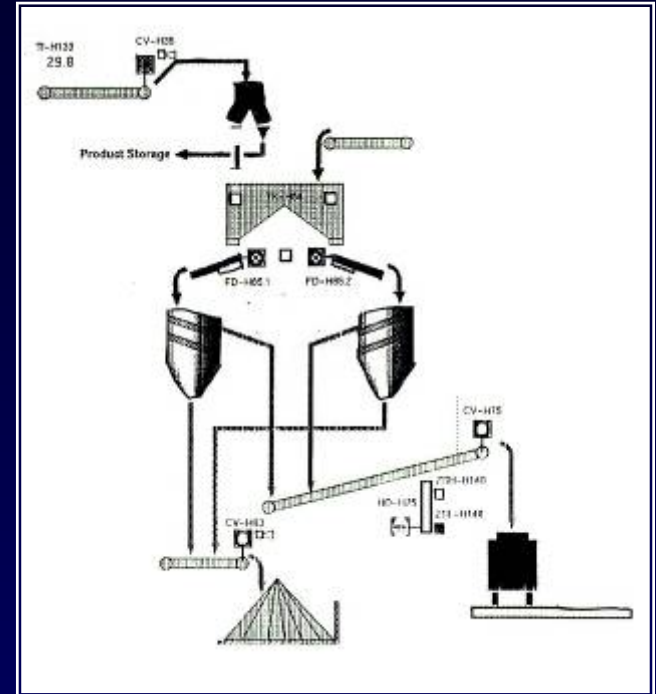
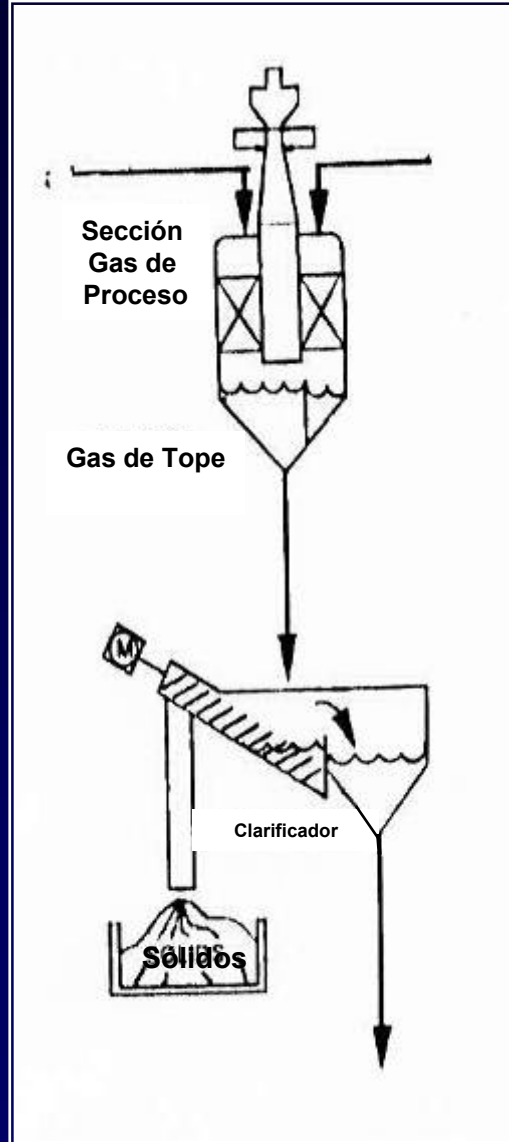
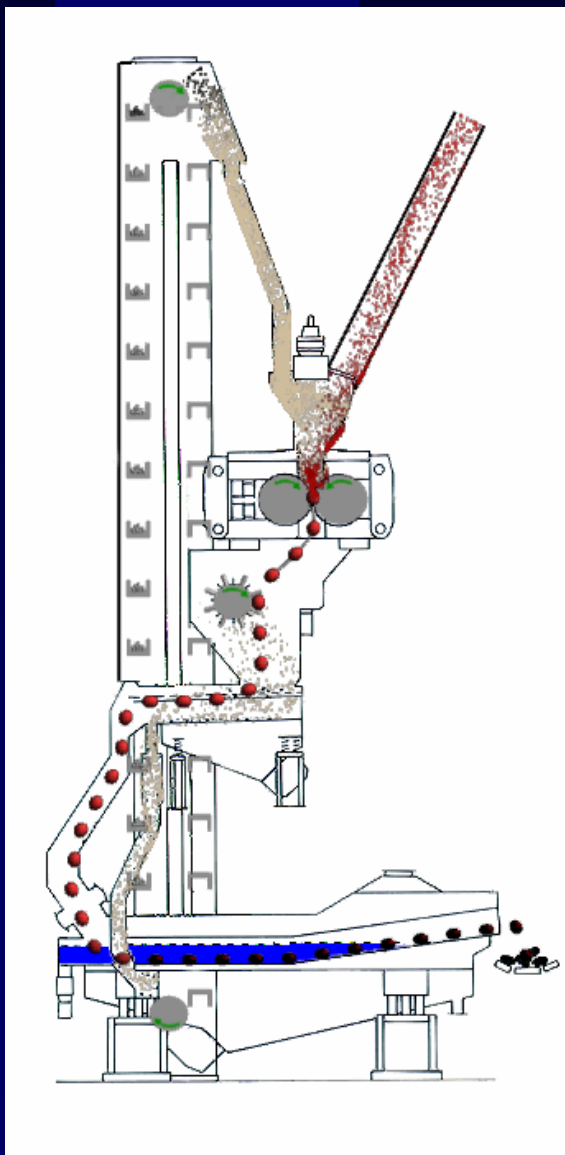
HBI

- An undersize particulate material.
- By-product during the production and handling of DRI (A).
- Temperature below 100°C after the cooling stage.
- Apparent density of less than 5.0 g/cm³.
- Stored outdoors.
- Natural ageing.
- Temperature below 65°C.
- Moisture content of up to 12%
Metallic iron content: 1% - 75%.



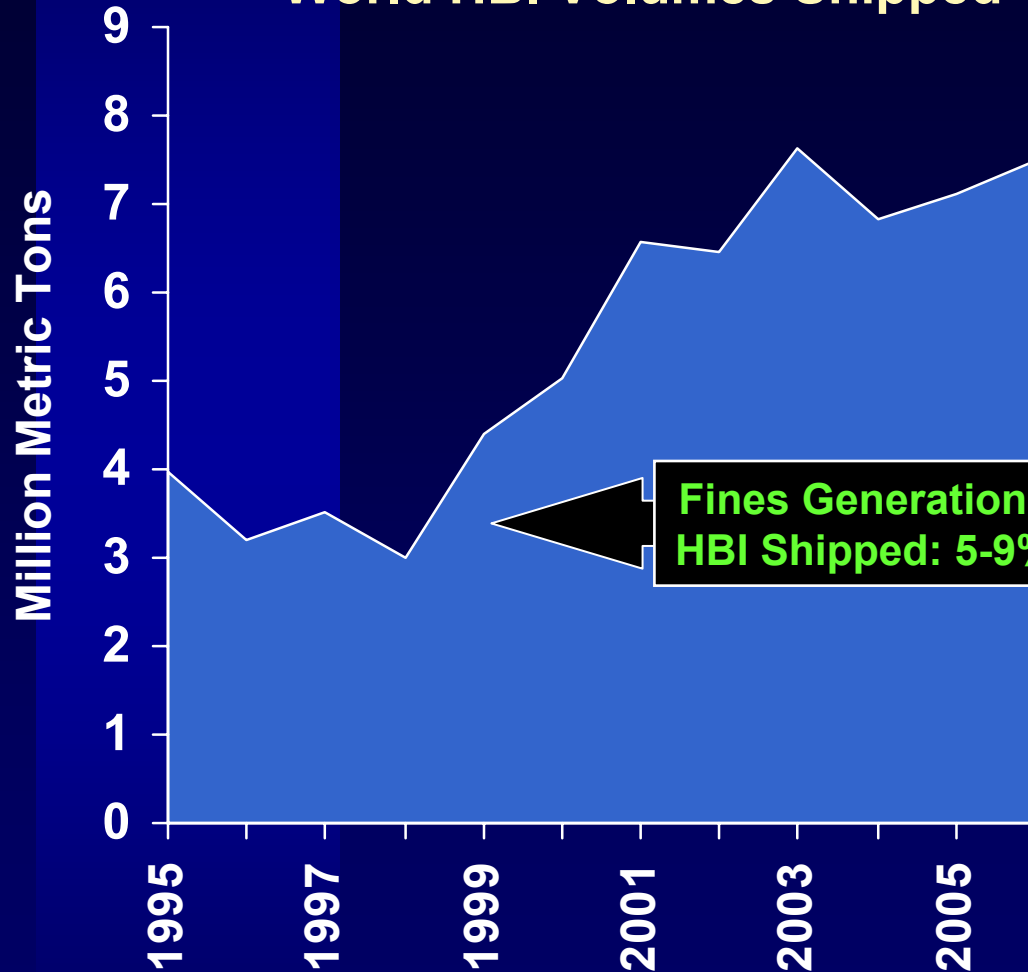
DRI FINES SOURCE OF GENERATION

DRI FINES SOURCES OF GENERATION



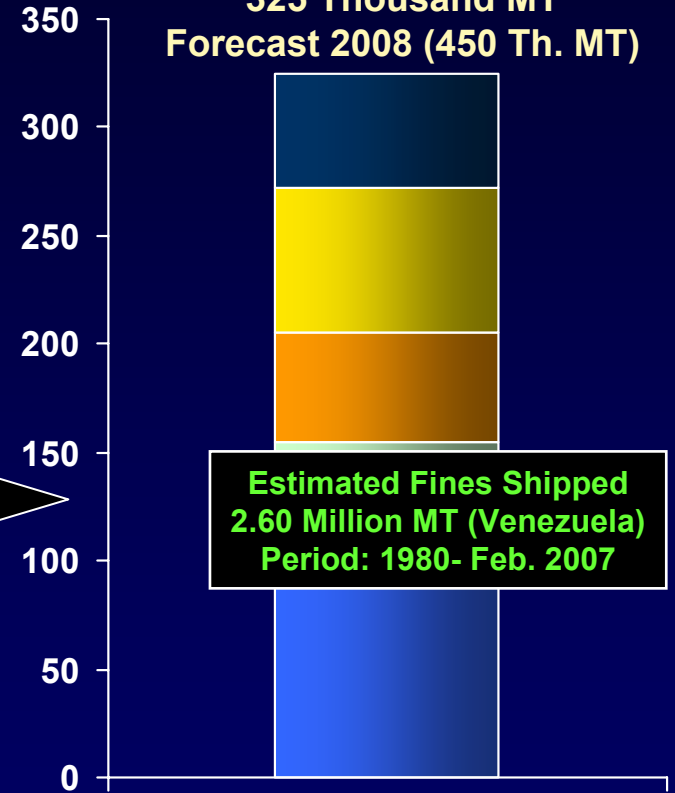
HBI Volumes Shipped & DRI Fines Generation from Venezuela

World HBI Volumes Shipped



Fines Generation / HBI Shipped: 5-9%

Venezuelan Fines Generated
325 Thousand MT
Forecast 2008 (450 Th. MT)



Estimated Fines Shipped
2.60 Million MT (Venezuela)
Period: 1980- Feb. 2007

- ORINOCO IRON
- VENPRECAR
- MATESI
- OPCO
- COMSIGUA

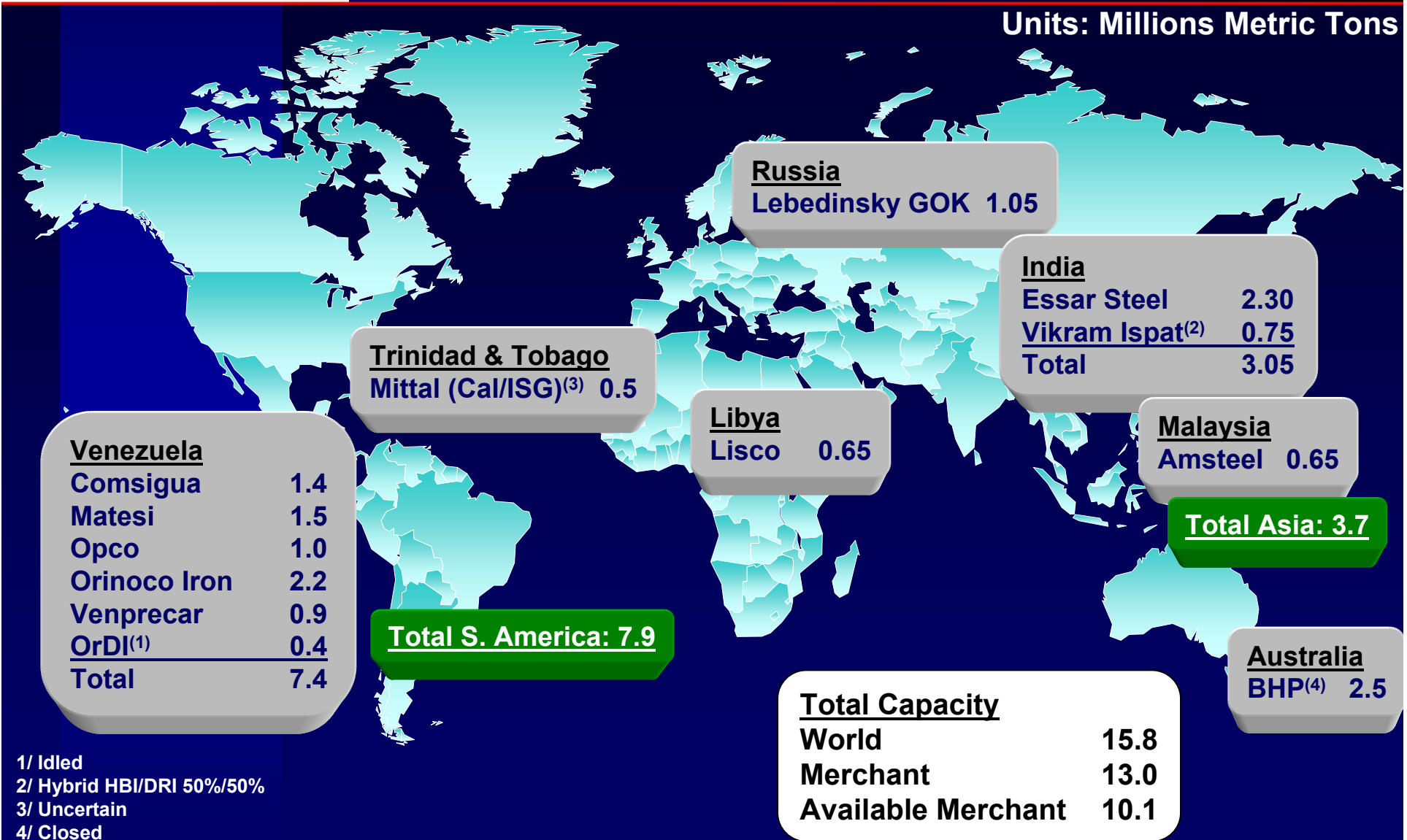
Source: Midrex & HBIA

Source: HBIA estimated

WORLDWIDE FORECAST FOR THE DRI FINES GENERATION

World HBI Producers

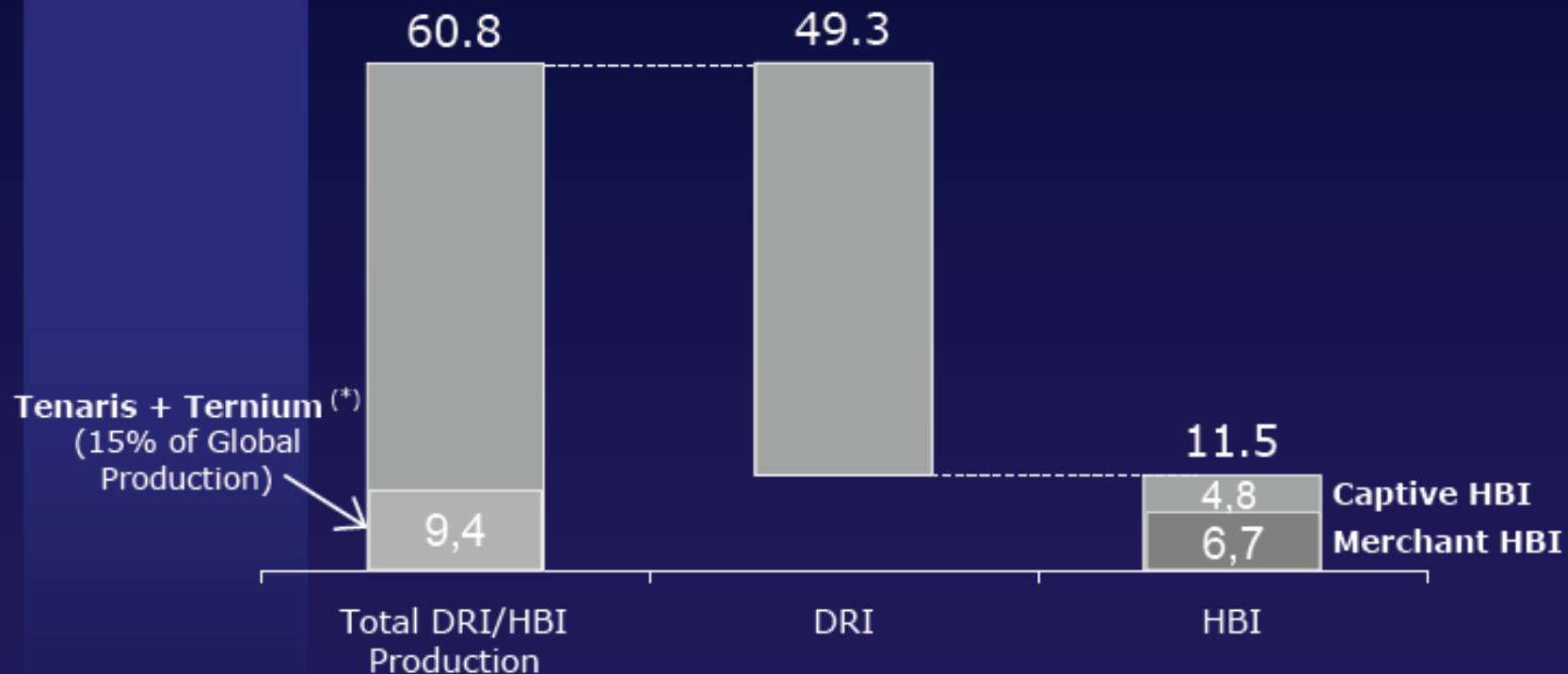
Units: Millions Metric Tons



1/ Idled
2/ Hybrid HBI/DRI 50%/50%
3/ Uncertain
4/ Closed

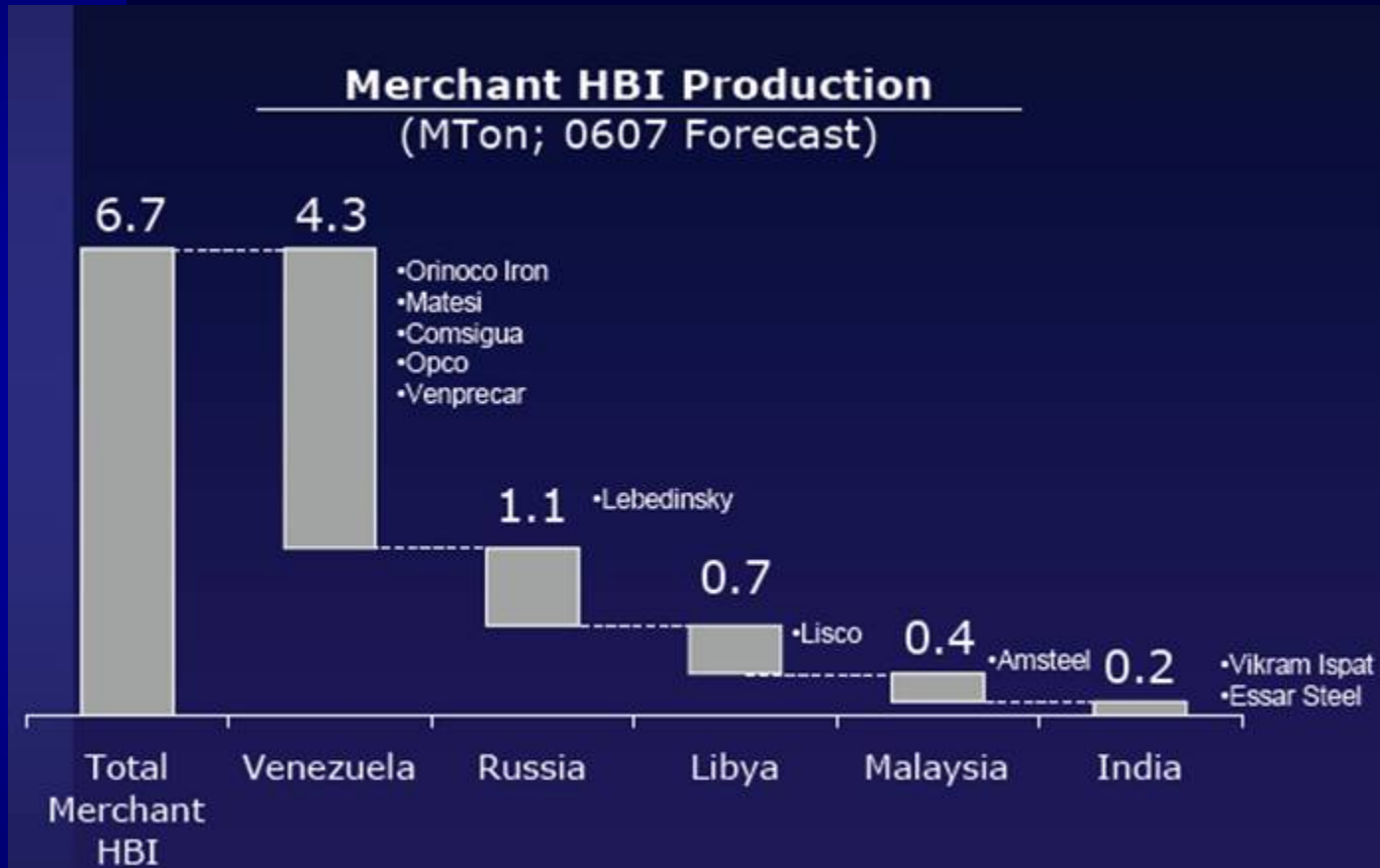
- Merchant HBI represents a small percentage of the global DRI/HBI production

DRI/HBI Global Production
(Mton; 2006 Estimation)



(*) Both companies are part of the Techint Group
Source: CRU, Exiros estimations

➤ Venezuela is the main producer of merchant HBI



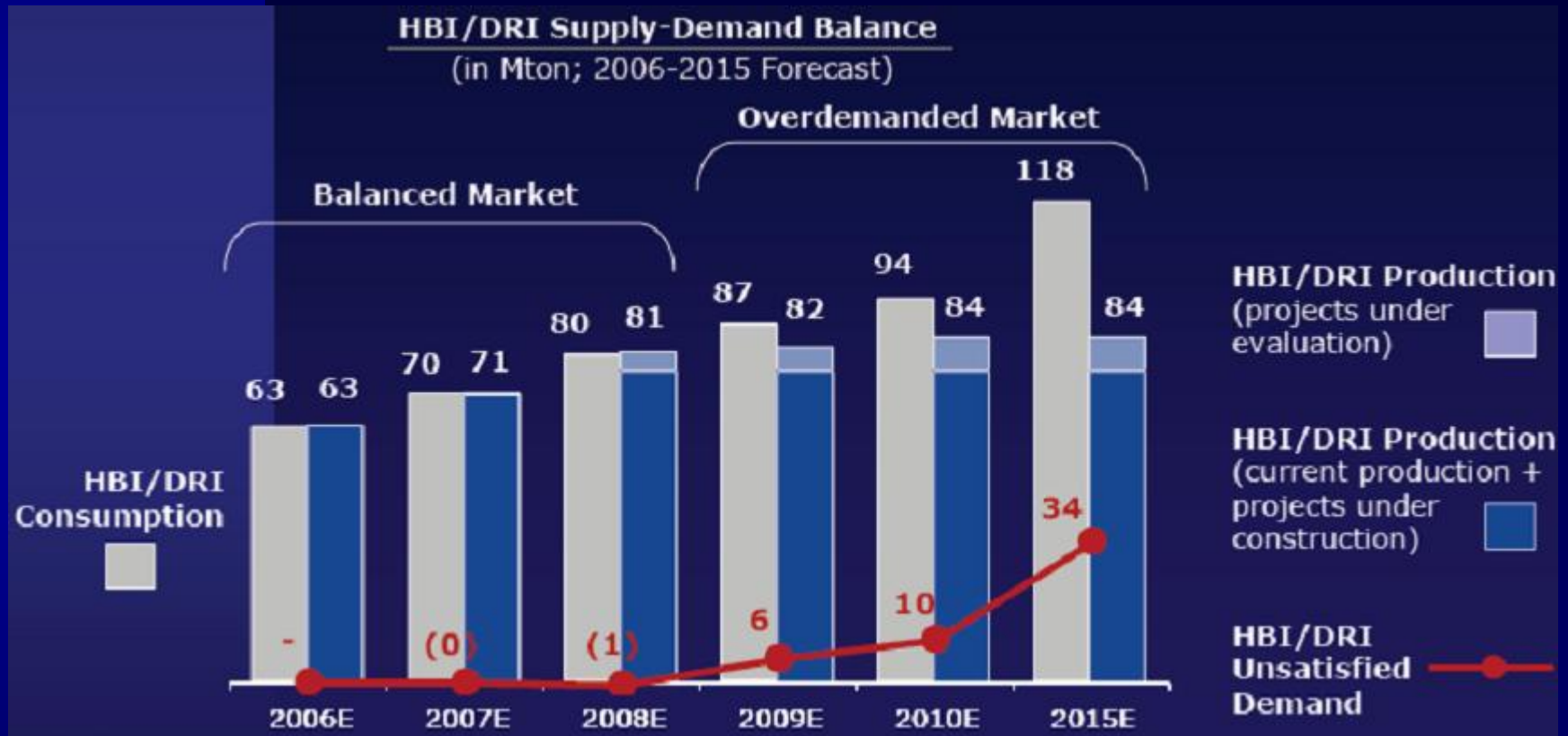
Source: Exiros estimations based on information from CRU, Midrex, Tex Report, HBIA, IVS and Trade Statistics. Venezuela is the main producer of merchant HBI

➤ **Venezuela HBI reaches competitively all the demands markets**



Source: Exiros estimations based on information from CRU, Midrex, Tex Report, HBIA, IVS and Trade Statistics. Venezuela is the main producer of merchant HBI

- **Announced and proposed investments in DRI/HBI will cover the short term demand, but new projects will need to come online to satisfy the long term demand.**



Source: CRU Group.

- It is possible to foresee, according to the DRI increasing capacity worldwide, that DRI Fines products and their mixtures will be:
 - ✓ Available in the range of 570,000 MT
 - ✓ Of the interest of the iron and steel making market due to its quality, price and environmental benefit from the recycling point of view (source: HBIA, www.hbia.org).

Independent Laboratories Results (UN Test Method No. 4 & 5)

- Oxygen depletion in enclosed spaces.
- Hydrogen generation - explosive mixture in concentration over 4% by volume.
- Self-heating.
- Dust generation.

DR Products Characterization

Results of independent laboratory (MVTL & Stressau USA) analysis on samples of DRI (B) and DRI Fines (*UN Test Method N° 4 & 5*).

- Spontaneous Ignition of Gas: Not Applicable.
- Not considered to be Division 4.2 Self-Heating Substance.
- Not considered to be Division 4.3 Dangerous When Wet.
- Non-combustible or has a low fire risk.

- Similar UN testing on samples of DRI (B) & DRI Fines.
- Longer period of time.
- Simulated ship holds.
- After 16 hours of testing hydrogen gas generation was registered.
- The first 16 hours, water vapor is generated.
- Results in following graphs.

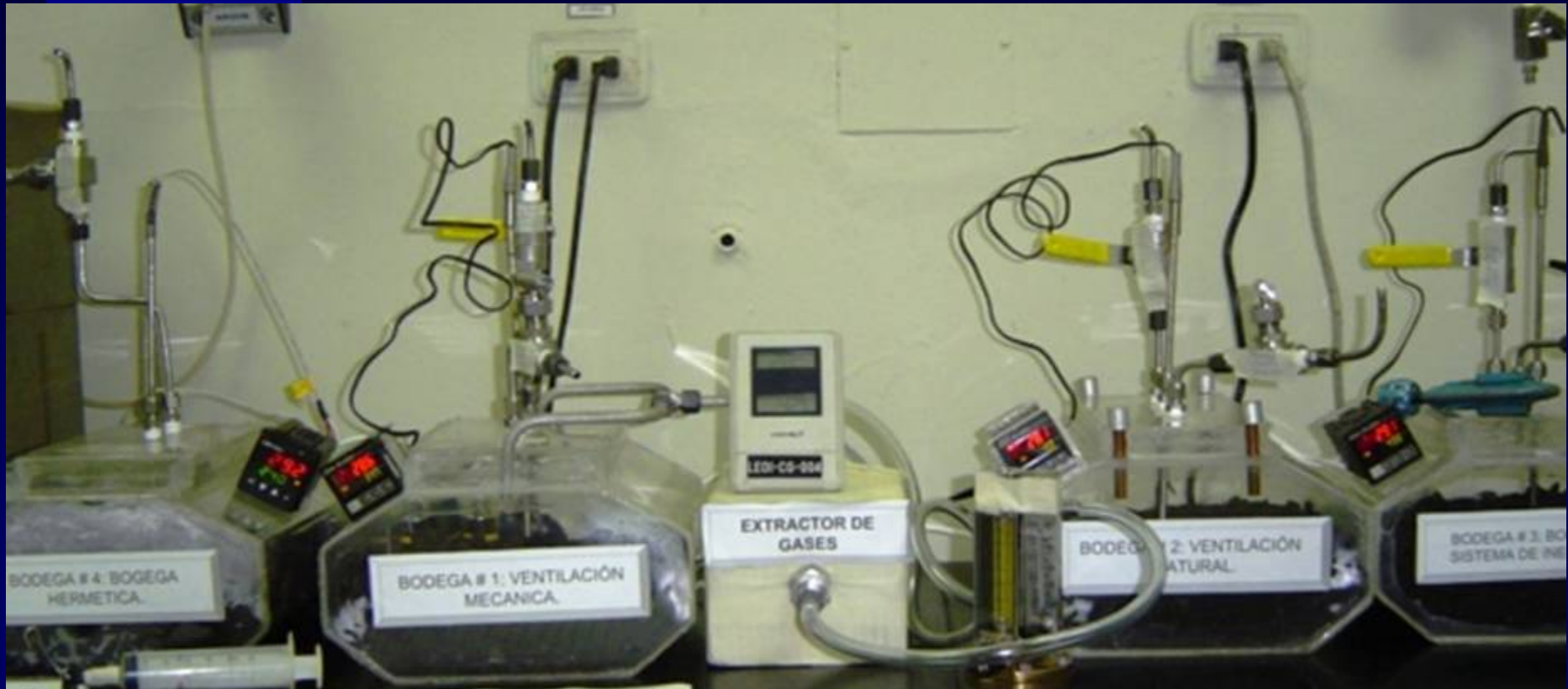
Simulated cargo holds



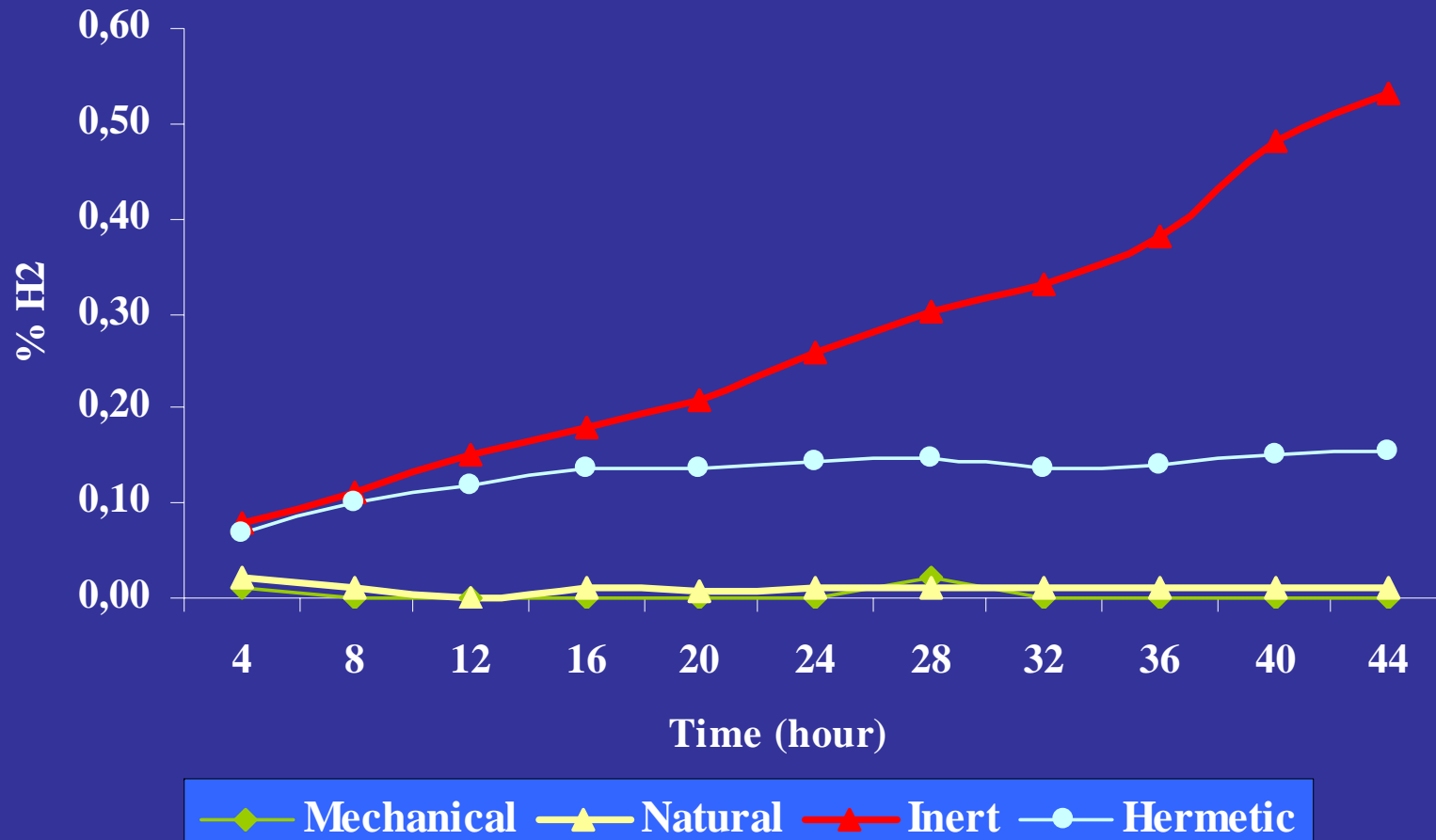
Simulated cargo holds



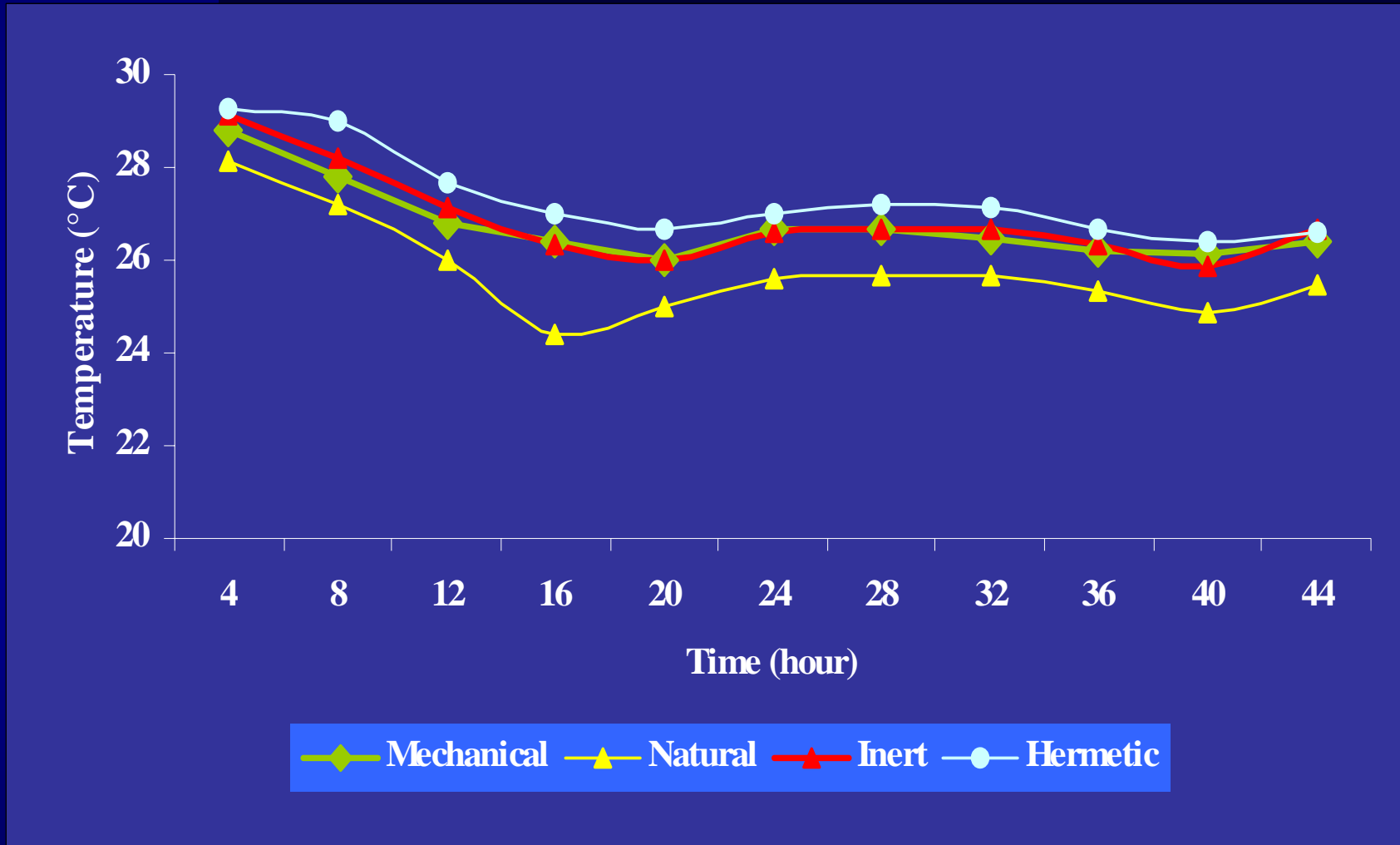
Simulated cargo holds.



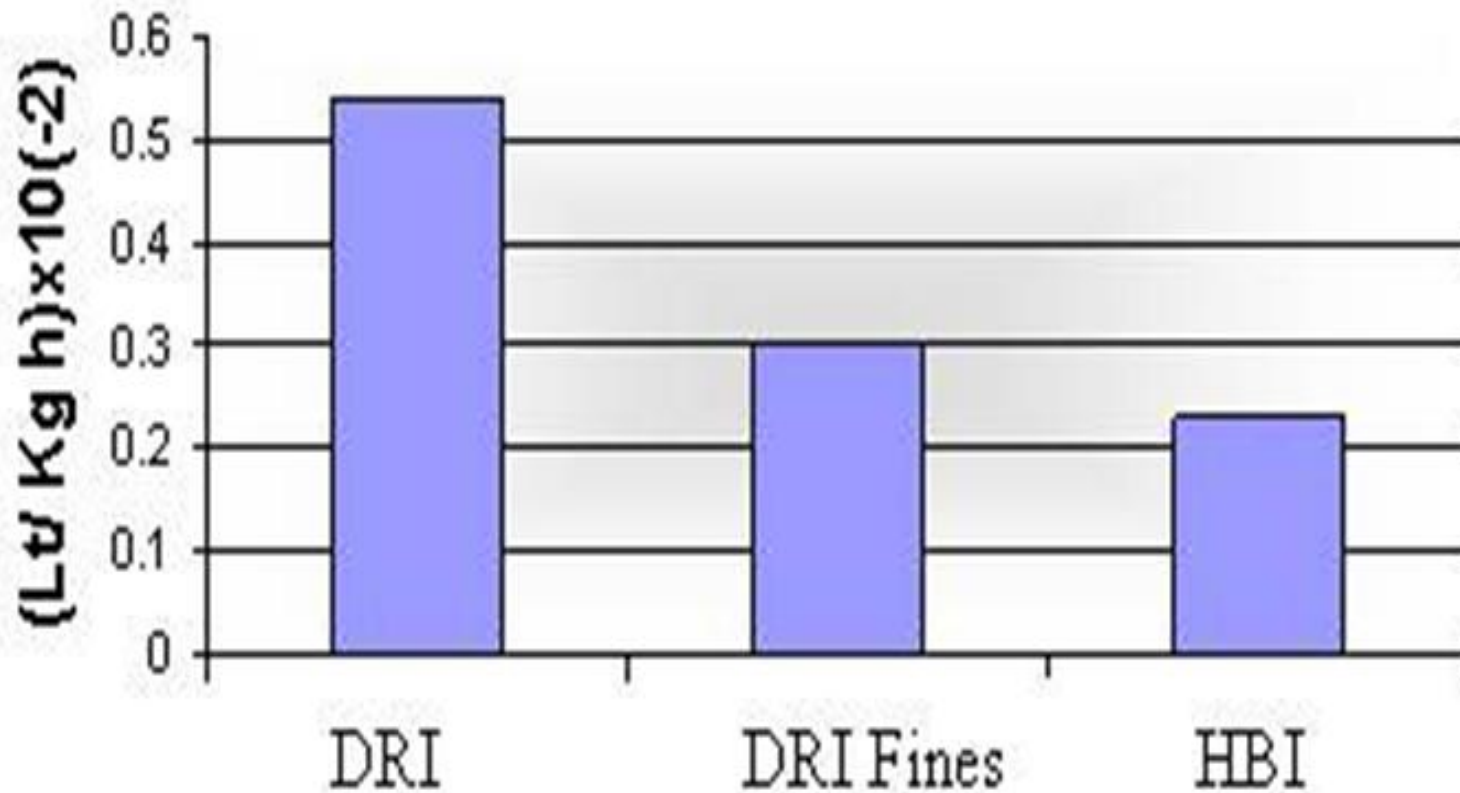
Hydrogen Generation DRI Fines sample



Temperature profile on a DRI Fines sample



Reactivity of Different DR Products



- Ventilation or
- Inerting (N₂) of the cargo during the transport

The answer is as follows:

HYDROGEN EVOLUTION FROM DIRECT- REDUCED-IRON PRODUCTS REACTING WITH WATER

**(after W.P. Gallagher U.S. Steel Corporation
Research, ISS Transactions, Volume one, 1982,
pp 69-73).**

“ The results ... show that for DRI briquettes exposed to air, the rate of hydrogen evolution drops rapidly with time. “

“ In contrast, the samples in a nitrogen atmosphere evolve hydrogen initially at an average daily rate approximately 140 times higher than that of identical samples in air, and this rate does not drop rapidly with time.”

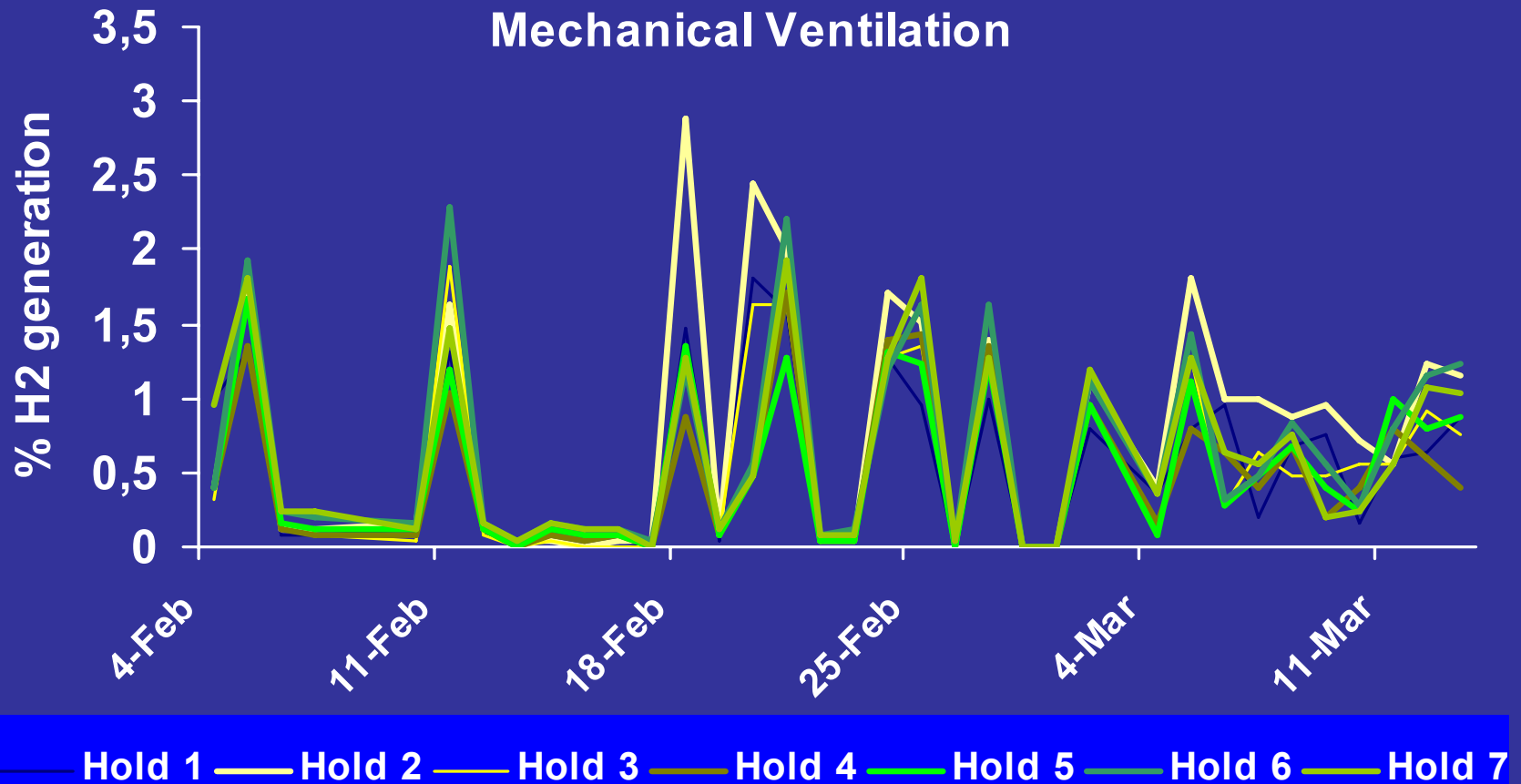
DRI (A) Briquettes, hot-moulded

- **As per BC Code: MHB.**
- **Surface ventilation required.**
- **Safe.**
- **No special precautions.**
- **Non-combustible or has a low fire risk.**
- **Golden rule: Do not allow HBI get in contact with seawater.**

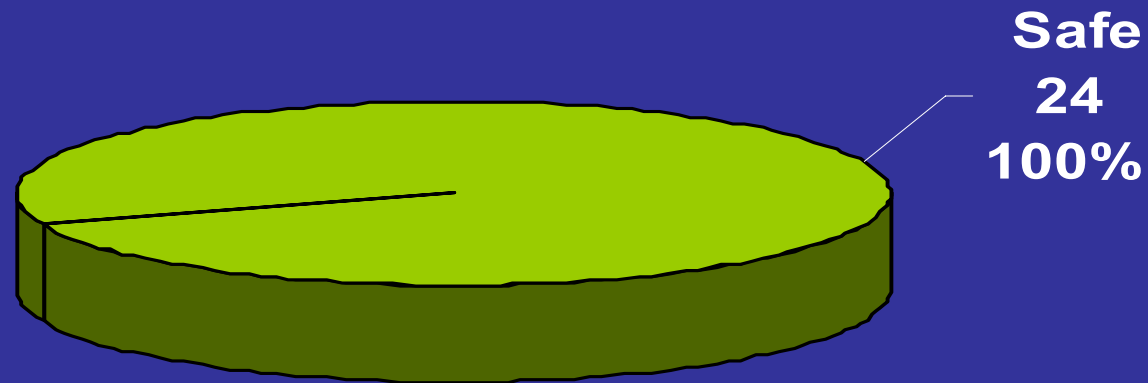
- **As per BC Code: MHB.**
- **Inerting or passivation required.**
- **Golden rule: Do not allow DRI (B) get in contact with water.**

- **MHB**
- **Mechanical surface ventilation required.**
- **Two changes of air per hour.**
- **Duration: from continuous to 1 hr. every 4 hrs.**
- **Ventilation operating under all weather condition.**
- **No ingress of water in holds.**
- **Non-combustible or has a low fire risk.**
- **Fan drives – explosion proof.**
- **Golden rule: Do not allow DRI Fines get in contact with seawater.**
- **To be discussed at IMO-DSC 12.**

DRI Fines shipment to China - H2 generation (%)
Jan. 2007

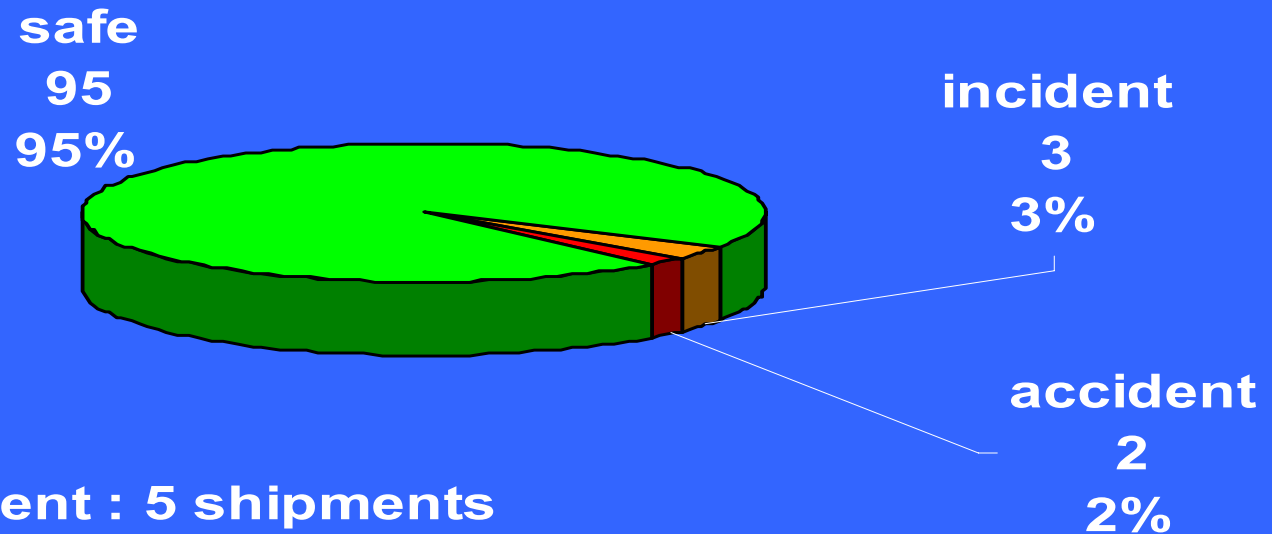


Total DRI Fines Carriage by Sea Mechanical Ventilation Safety Index 1980 - Feb. 2007 (# shipments: 24)



- Accident / incident : 0 shipments
- Self-heating / Auto-ignition: 0 shipments

Venezuelan DRI Fines Carriage by Sea Safety Index 1980-Feb. 2007 (# shipments:100)



- Accident/incident : 5 shipments
- Self-heating / Auto-ignition: 0 shipments

BLU CODE REMARKS

Section 2

(2.1.2) Terminals should determine the suitability of a ship for compatibility with both loading and unloading terminal infrastructure as appropriate.

(2.1.3) It is important that the terminal operators keep its relevant costumers Informed of current terminal standards, imitations and operating and terms of any change to relevant navigational conditions, water depths, loading and unloading equipment and rates.

Other relevant sections:

2.2.4.- Hatches and hatches operation systems and safety devices should be in good functional order, and used only for their intended purpose.

2.3.2.- Terminal equipment certification and maintenance.

2.3.3.- Training personnel.

3.1.2.- Loading and unloading plans.

4.1.1.- Cargo and safety issues for loading and unloading.

- The information is provided considering that:
 - Increment the safety of life at sea.
 - Known of past experiences on ship's accidents carrying DRI Fines and the attempt to avoid future ones.
 - Being aware of the characteristics of the Direct Reduced Iron and the hazards involved.
 - Having knowledge of past studies on DRI/HBI from the industry.
 - It is desirable to increment the safety on the carriage of DRI Fines.

- Handy size. Single deck self trimming bulk carrier; HO/HA McGregor hydraulic folding type
- Handy max, +100 A1 Bulk carrier strengthened for heavy cargoes; HO/HA McGregor hydraulic folding type.
- Mechanical Ventilation available on the hatches.

Arrangement of the ventilation system I



- Mushroom electric ventilators located on deck between hatchcovers.

- Natural vents located on top of the hatchcovers.



Type of fan drive (level of explosion proof):

1. certified marine explosion-proof in compliance with requirements of Classification Societies of ships,
2. of axial flow
3. reversible
4. with non-sparking blades
5. variable speed
6. with the following possible driving mechanisms:
 - i. air driven,
 - ii. water driven, or
 - iii. electrically driven

- **Cargo temperature not to exceed 65°C**
- **Moisture of DRI Fines to be less than 12%**
- **Holds to be clean and dry free of residues from previous cargoes**
- **Weather deck closures should be thoroughly inspected and tested to ensure water tight integrity**
- **Strainer plates on bilge wells to be sift-proof**
- **Electrical cables and fittings on deck should be in good conditions**
- **Radar, RDF scanner and other delicate equipment should be protected against dust and fines.**

Advisable Actions during loading

- **No smoking or hot work to be carried out**
- **No loading to be done during precipitation**
- **Stow cargo as even as possible**
- **No smoking, no hot work on deck**
- **After completion of loading close and seal all hatchcovers**

➤ Ventilation Procedure:

✓ Performance (number of air changes per hour):

- Two changes of air per hour based on an empty compartment as minimum capacity of fans per hold. Cap. 235 m³ / min.
- Four changes of air per hour based on an empty compartment as preferred capacity of fans per hold.
- If the capacity of fans is lower, the duration of ventilation should be extended accordingly.

- **Ventilation Procedure:**
 - ✓ **Duration of ventilation: (based on above capacity of fans)**
 - One hour every two hours or continuous ventilation for the first 72 hours after loading and closing hatches.
 - Afterwards, one hour every four hours.
 - **Restrictions:**
 - » From 0 to 72 hours after loading and closing hatches, the maximum time permitted without any ventilation is four (4) hours.
 - » After 72 hours, the maximum time permitted without ventilation is 12 hours.

➤ Monitoring

✓ Hydrogen gas:

- Level to be maintained at less than 1% (50% LEL)

✓ Oxygen

✓ Temperature of cargo:

- Should be kept below 65°C

Advisable Actions Before Unloading a Vessel

- Check for H₂ concentration before opening cargo holds.
- Verify cargo temperature inside cargo holds.
- Measure O₂ before entering any cargo spaces.
- If possible ensure grounding of holds.
- Radar, RDF scanner and other delicate equipment should be protected against dust and fines.
- Unloading under all weather conditions is acceptable.

Advisable Actions Before Unloading a Vessel

- If H₂ concentrations in cargo holds approach 4% ... **Ventilate – Re-check – Proceed opening holds.**
- If entering holds ... **ensure O₂ is over 21%.**
- If temperature readings are normal (<65°C)... **proceed to unload cargo in normal yard area.**
- If the temperature of the cargo exceeds 120°C ... **proceed to unload the cooler cargo in specially designated area.**



**The following suggested emergency procedures
are based on the best Venezuelan experience
with this product**

ADDITIONAL PRECAUTIONS IF CONCENTRATION OF HYDROGEN OVER 1% (25% LEL):

- Operate the mechanical ventilation system continuously.
- Monitor hydrogen gas concentration in the holds continuously until level drops to less than 1%.
- If below 1%, ventilate 1 hr every 4 hrs.
- If above 1%, keep the mechanical ventilation operating.
- Avoid any possible ignition source on the vicinity.
- Inform the shipper immediately.

Procedures If DRI Fines Temperatures Rise above 65°C:

- **Monitor temperature and hydrogen generation**
- **Operate the mechanical ventilation system**
- **If there was ingress of sea water, the effect will only be noticed after 16-24 hrs.**
- **The temperature would increase and then should stabilize**
- **DO NOT AT ANY TIME USE WATER DIRECTLY ON DRI FINES TO COOL THEM OR IN ANY SPACE CONTAINING DRI FINES DO NOT AT ANY TIME USE WATER DIRECTLY ON DRI FINES TO COOL THEM OR IN ANY SPACE CONTAINING DRI FINES**
- **If temperatures of the cargo rise over 120 °C, preparation to jettison or discharge the cargo at the nearest safe and suitable port should be conducted.**
- **Inform the shipper immediately.**

WARNING

- **DO NOT USE EITHER FRESH WATER OR SEAWATER TO COOL DOWN HOT MATERIAL** 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. The surface mechanical ventilation system should be operating continuously to lower the concentration of hydrogen gas inside the cargo hold.**
 - iii) Be prepared to jettison cargo if very high temperatures arrangements to get to the nearest safe and suitable port for discharging the hot cargo.**

Consider the solutions with the following priorities as follows:

- **unload the troubled cargo at nearest port**
- **jettison of cargo**
- **flood the hold with water**

Temperature Greater than 80 °C and less or equal to 150 °C.

The following actions shall be carried out:

- First unload the holds with temperature Greater than 80 °C and less or equal to 150 °C:**
 - ✓ take temperatures readings and register the same every two (2) hours.**
 - ✓ first unload the holds with temperature between 80°C and 100°C.**
 - ✓ then continue unloading the holds with temperatures between 100 and 150°C.**

Greater (>) than 150 °C.

The following actions should be taken:

- **Keep monitoring temperature.**
- **In case of DRI (B), position the material with the temperatures greater than 150°C at the end of the reception zone and spread out.**
- **When the temperature slows down to an interval of (80°C ≤ to 150°C) proceed to dispose the material to a safe zone.**

- **DRI (B) should not get in contact with water.**
- **DRI (A) should not get in contact with seawater**
- **DRI Fines should not get in contact with seawater**
- **DRI products are neither class 4.2 nor 4.3.**
- **Can be safely handled if hazards are known.**
- **Check for O₂, H₂ and T before discharging.**
- **Monitor the cargo during the voyage.**
- **Holds must be clean, dry, and free from combustible materials.**

- **Shipowners are invited to:**
 - **Take note of the information provided; and**
 - **Taking into consideration the conclusions to develop an appropriate circular in this regard.**

- **Briquettes Reception and Unloading Procedure, code POP-02-001 (Procedimiento de Recepción y Descarga de Briquetas, código: POP-02-001).**
- **Contingency Notification in the Industrial Area of Palúa, code PPC-02-017 .**
- **COVENIN Norm 2237:1989. Clothing, equipment and personal protection devices. Selection According to Occupational Risk.**
- **Risks Control System Manual, code: GG-MSCR-01-01.**
- **Venezuelan Norm COVENIN 3.395:1999. Iron Minerals and Iron and Steel Industry Products. Briquettes.**
- **Pan-American Norm COPANT C 105:043 1992. Iron and Steel Industry. Iron Mineral Pre-reduced Briquettes.**
- **Safe Practice for Bulk Loading Solids (BC Code), Edition 1998.**



**Thank you
for your attention**

Contacts:

www.hbia.org

odam46@cantv.net

agonzalez@comsigua.com.ve

ggeneral@copal.com.ve

igibellini@comsigua.com.ve