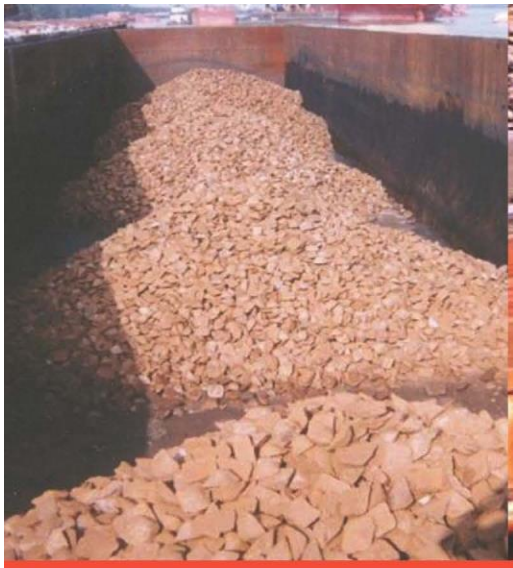

International Iron Metallics Association (IIMA)
presents

Pig Iron

A Guide for Transporting and Handling at Terminals

iima
INTERNATIONAL
IRON METALLICS ASSOCIATION
The Ore-Based Metallics Association

2011 International Iron Metallics Association (IIMA)

Printed and bound in the United Kingdom

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ACKNOWLEDGEMENT

The International Iron Metallics Association (IIMA) wishes to thank Dr. Oscar Dam, Chief Technical Advisor, and the Pig Iron Sub-Committee, chaired by Rodrigo Valladares, CEO of Viena Siderúrgica S/A, for preparing and editing the information presented in this guide.

FOREWORD

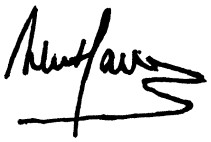
The International Iron Metallics Association was created to promote the use of ore-based metallics (pig iron, HBI, DRI, and iron nuggets) as value-adding raw materials for the iron and steel and ferrous casting industries.

Safe and efficient handling and shipping of merchant ore-based metallics are vital to the commercial trade and use of these materials.

Therefore, we are continuing the series of guides begun by IIMA co-founder, HBI Association (HBIA), with this guide which addresses the methods, techniques, and procedures for handling and transferring merchant pig iron at dry bulk terminals.

We trust you will find the information contained herein useful and insightful.

Respectfully,



Albert Hassan
President
International Iron Metallics Association (IIMA)

PREFACE

The transportation of merchant pig iron by sea and land is a very important link in the supply chain from the producer to the consumer. Therefore, the IIMA has published this guide for dry bulk terminal operators based on actual practical experiences of its members and the members of the Dry Bulk Terminals Group (DBTG).

The preparation of this guide has involved numerous technical discussions between major pig iron exporters, producers, and terminal and ship operators. As a result, this guide presents information about the physical and chemical properties of pig iron and how they affect safe transporting and handling during loading, unloading, and maritime carriage. Each group contributed its insights and experiences on the characteristics and behaviour of pig iron under various conditions and in different environments.

We hope this guide will help make the workplace safer for people involved in loading and unloading pig iron at terminals around the world and will serve as a useful reference for properly determining the risks and hazards associated with this bulk cargo.

Respectfully,

Dr. Oscar Dam and Rodrigo Valladares
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INTRODUCTION

This guide refers to the handling of merchant pig iron produced in blast furnaces, electric smelting furnaces, and iron making processes to produce so called “iron nuggets”.

The term “pig iron” can be traced back to the method of casting blast furnace iron into moulds arranged in sand beds such that they could be fed from a common runner. The group of moulds resembled a litter of suckling pigs; therefore, the ingots became known as “pigs” and the runner as the “sow”.

Merchant pig iron is cold iron either cast into ingots, granulated, or produced in the form of nuggets to be sold as ferrous feedstock for the steel and metal casting industries. Merchant pig iron is produced mainly by dedicated merchant plants, all of whose production is sold to external customers, but also by integrated steel mills with iron that is surplus to their internal requirements.

With its defined and closely controlled specification and the absence of metallic impurities, pig iron is a reliable and consistent charge material for both electric steelmaking and ferrous castings production. It also contains carbon and reduces the energy consumption of a melt.

Because pig iron is sold to external customers, the material is shipped in bulk and often by sea in ocean going vessels. Therefore, dry bulk terminals are a very important link in the supply chain and have an important impact on the commercial success of the global pig iron trade.

GLOSSARY (Alphabetical Order)

i. **Basic Pig Iron (SP)**
Grade mainly used in EAF steel making

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

iii. **Foundry Pig Iron (F)**
Grade mainly used in the manufacture of grey iron castings; also known as Hematite Pig Iron

iv. **Granulated Pig Iron**
Hot metal granulated by the use of either water or air sprays; sold as ferrous feedstock for the steel and metal casting industries; apparent density greater than 6.5-7.8 g/cm^3

v. **Hot Metal (Liquid Iron)**
Metallic iron product obtained upon reduction of iron ore, mainly in blast furnaces, containing about 93-94% iron (Fe) and other elements/impurities including carbon 4%, silicon ~1%, manganese +1%, and sulphur, phosphorus, etc.; primary input for production of steel in integrated steel plants (BF/BOF); also used in some electric arc furnaces (EAF)

vi. **IMSBC Code**
International Maritime Solid Bulk Cargoes Code, 2009 Edition, as published by the International Maritime Organization (IMO), which governs the carriage of solid bulk cargoes; supersedes the IMO Code of Safe Practice for Solid Bulk Cargoes (BC Code), 2004 Edition

vii. **Ingots**
Mass of solidified hot metal cast into a bar or other convenient shape for sale as ferrous feedstock for the steel and metal casting industries; weights typically range from 3 kg up to 45 kg.

viii. **Iron**
Base metal extracted mainly from iron ore but also from ilmenite (EAF smelting by-product); pure iron melting point 1530° C, density 7.86 g/cm^3.

ix. **Iron Making**
Process of reducing iron ore using a reducing agent such as coke, charcoal, etc. typically in a blast furnace or as by-product of ilmenite smelting in EAF

x. **Iron Nuggets**
Cold iron with a microstructure similar to white cast iron, produced by reduction of iron ores mixed with a carbon source in a rotary hearth furnace-based process;

contain 74-97% iron (Fe) with apparent density of 6.5-7.8 g/cm^{3}and; used as ferrous feedstock for the steel and metal casting industries

xi. Marpol Convention

Seeks to eliminate and reduce the amount of garbage being dumped into the sea from ships

xii. Nodular Pig Iron (SG)

Grade used in the manufacture of ductile, nodular or spheroidal graphite iron castings

xiii. Pig Iron Chips or Broken Pieces

Irregularly shapes created from breaking metal layers covering the spaces between the castings moulds during the casting process; chunks obtained by separation from the pig iron ingots by means of mechanical trommelling or by hand.

xiv. Scrap Pig Iron

Type of pig iron obtained by breaking up large pieces of solidified pig iron either by hand or by mechanical means; irregularly shaped but with chemical composition of pig iron grade as cast.

xv. Trommelling

Process of using a revolving cylindrical sieve to break off smaller pieces from the pig iron ingots to obtain a clean ingot product

Chapter 1 – Pig Iron Characteristics

1.1 Introduction

This chapter is devoted to merchant pig iron produced by reducing iron ores in blast furnaces, smelting ilmenite in electric furnaces, as well as by alternative iron making technologies such as Corex and ITmk3.

The following are the most common pig iron qualities by type:

The various grades of pig iron have specific chemical properties designed for their end use and should not be co-mingled in transport and handling processes (see Chapter 3).

Cast pig ingots come in a variety of shapes, as show in Figures 1-3.

Figure 1 – Small Pyramid Shape

Figure 2 – Large Pyramid Shape

Figure 3 – Large Stick or Loaf Shape

Today the most commonly used ingot mould sizes are from 7 x 10 x 15 cm to 8 x 15 x 20 cm in Brazil and 20 x 20 x 15 cm in Russia and Ukraine. However, sizes and dimensions can be customized to a customer's requirements.

1.2 Basic Pig Iron (SP):

The standard chemical composition of this grade is:

Carbon	3.5-4.5%
Silicon	<1.5%
Manganese	0.05-1.0%
Sulphur	<0.05%
Phosphorus	<0.12%

Also available in low manganese/low phosphorus forms (0.1% Mn, 0.1% P)

1.3 Foundry Pig Iron (F):

The standard chemical composition of this grade is:

Carbon	3.5-4.5%
Silicon	1.5-3.5%
Manganese	0.5-1.0%
Sulphur	<0.05%
Phosphorus	<0.12%

1.4 Nodular Pig Iron (SG):

The standard chemical composition of this grade is: 3.5-4.5% carbon, <0.05% manganese, <0.05% sulphur, 0.5-1.5 silicon, and <0.05% phosphorus.

Carbon	3.5-4.5%
Silicon	0.5-1.5%
Manganese	<0.05%
Sulphur	<0.05%
Phosphorus	<0.05%

Chapter 2 – Handling Equipment

2.1 Introduction

Merchant pig iron is handled, transported, and stored a number of times prior to being used in an iron casting or steel producing processes:

- within the production site from caster to temporary storage
- to trucks and rail cars for transfer to the bulk terminal
- within outbound bulk terminals for temporary storage
- to vessels for maritime carriage to inbound bulk terminals
- to barges, trucks, and rail cars for delivery to customers
- within stock yard of customer site

This chapter describes a variety of equipment that can be used for handling merchant pig iron. It also addresses the use of equipment for each form of pig iron; i.e. cast ingots, scrap pig iron, granulated pig iron and iron nuggets.

2.2 Cast Ingot Handling

At the production site, pig iron ingots can be loaded into trucks or rail cars by the use of traditional equipment, such as front end loaders, mobile cranes with grabs, and magnets (Figure 3).

Figure 3

2.3 Scrap Pig Iron

Larger pieces of scrap pig iron can be handled with equipment similar to that used for cast ingots. However, scrap handling grabs and magnets are most suitable, as shown in Figure 4.

Figure 4

2.4 Granulated Pig Iron and Iron Nuggets

Granulated pig iron and iron nuggets are easy to handle because of their size. These materials can be handled with front end loaders and magnets. Conveyor belts can be used for transferring them to and from temporary storage.

Chapter 3 – Merchant Pig Iron Loading/Unloading

3.1 Introduction

This chapter presents some considerations and guidelines for loading and unloading merchant pig iron.

3.2 General Considerations

- Check weather condition, although pig iron can be loaded during periods of rain and snow
- Sweep holds clean of previous cargo residue or other non-essential materials
- Clean out bilge wells and cover with burlap.
- Make sure stow is level and brows are in a straight line athwart ships
- Evenly spread the cargo across the tanktop to equalize the weight distribution and ensure it is not overstressed
- Trim in accordance with the relevant provisions required under sections 4 and 5 of the IMO IMSBC Code
- Check vessel stability and stresses

3.3 Merchant Pig Iron General Characteristics

- Weight: 3-10 kg (Brazil), 10-15 kg (Russia and Ukraine), …. kg (India) and …. Kg (Ilmenite smelted pig iron)
- Size Angle of repose: 49 degrees
- Stowage factor m^3/t: 0.28 - 0.30
- Bulk Density: 3.33-3.57 mt/m^3
- IMO Classification Appendix C, neither liable to liquefy nor to possess chemical hazard

3.4 Loading Cast Pig Iron Ingots

Consideration should be given in the loading operation to minimizing damage to the ship's holds from the impact of pig iron ingots and to reduce product breakage.

3.4.1 Soft Loading

Minimizing the height from which the material falls onto the hold bottom, commonly known as the tanktop, by using a "soft loading" practice is one solution.

Soft loading is so called because the cargo is placed in the hold by bucket conveyor and the vessel's crane. The series of photos below, (Figure 5), shows an

example of soft loading when the bucket is placed directly on the tanktop and inverted to discharge the ingots at the minimum possible height.

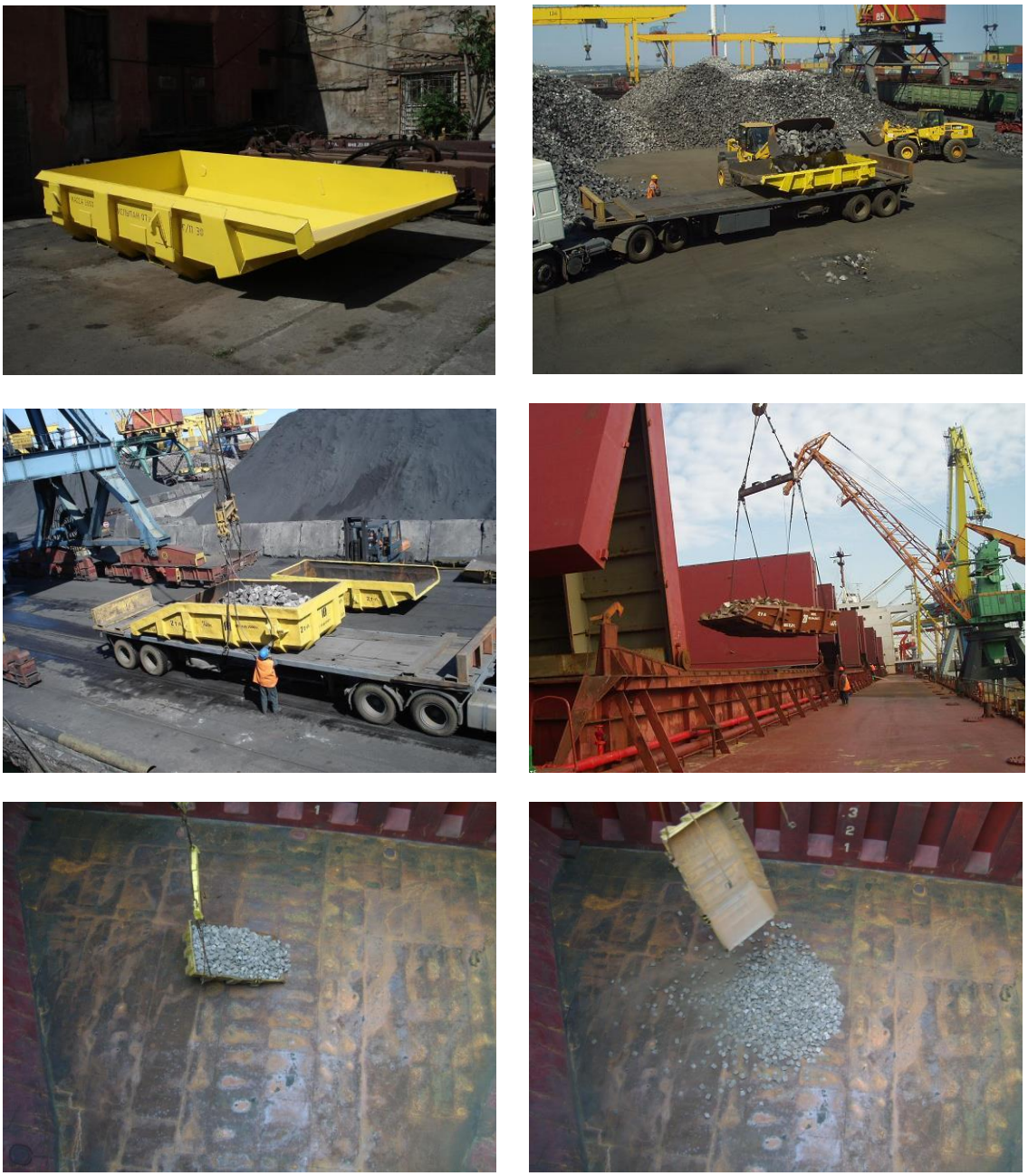

Figure 5

At Ponta da Madeira (PDM) Port, Vila do Conde Port and Itaqui Port in Brazil, the buckets used for soft loading pig iron have a capacity of 10-15 tonnes. In Russia and Ukraine these buckets can accommodate up to 30 tonnes.

The loading rate at Brazilian ports and the ports used by Russian and Ukrainian exporters can reach 14,000 tonnes/day and 15,000 tonnes/day when using three cranes.

When soft loading equipment is not available, the hold bottom can be covered with an absorbent material, such as wooden pallets, to lessen the impact of the

ingots. However, the broken wooden pallets tend to add unwanted debris to the pig iron cargo, which must be removed at some point.

The loading operation at PDM Port is done through conveyor belts and can receive Cape-size vessels of more than 150,000 dead weight tonnes (DWT). Due to the height from which the material falls onto the tanktop and in order to the impact of the ingots avoid damage to the ship's holds, Ponta da Madeira (PDM) Port in Brazil places ten (10) wooden pallets in the hold to absorb some of the impact (see Figure 6).

Figure 6.

For heavy and large-size materials, a Verstegen trimming grab-type device is an efficient solution. Trimming grabs also can used to handle DRI and HBI with very good results.

Crane-mounted industrial magnets also are effective devices for moving pig iron from a staging area and for loading it into the designated holds of a vessel.

3.4.2 Containers

Pig iron can be transported in containers rather than in bulk.

Containers are typically loaded using front end loaders, as shown in Figure 7.

Figure 7

The floor and sides of the containers can be lined with a suitable material for protection, as shown in Figure 8.

Figure 8

3.5 Loading Scrap Pig Iron

Scrap pig iron is usually loaded from tubs due to size and shape.

The loaded tubs are lowered by a crane into the hold and tipped to dump the contents. The first few tubs should be lowered onto the tank top to avoid damage.

3.6 Grade separation

When loading more than a single grade of pig iron, separation of grades is an important consideration. Never stow Foundry (F) grade and/or Basic Pig Iron (SP) grade with Nodular Pig Iron (SG) grade without good separation of the lots.

Methods of grade separation within a hold:

1. Paint marking on tanktop to identify different grades, providing free space between grades (Figure 9)
2. Stow different grades at opposite ends of the hold (Figure 10)
3. Separate grades with rope across hold covered by tarpaulin (Figure 11)

4. Use wood sheets, double-run chicken wire, or plastic sheets between the grades (Figure 12)

Figure 9

Figure 10

Figure 11

Figure 12

It is preferable to separate grades by a vertical face athwart ships rather than by horizontal separation. Mark each grade with white cloth labels bearing grade numbers printed in black and ensure that trucks servicing each hold are accurately marked. If more than one grade is loaded in a hold, cover each grade as it is completed to avoid mixing during subsequent loading.

Front end loaders or bulldozers can be used in the hold to separate the grades of pig iron (Figure 13).

Figure 12

3.7 'Tween Deck Vessels

Tubs or bolsters should be used for stowing pig iron in 'tween deck vessels to avoid undue stiffness. The amount will depend on a) the ship's stability requirements, b) the number of available bolsters or tubs, and c) and loading limitations.

Any bolsters or tubs stowed on steel decks require dunnage under them and suitable lashings.

A 'tween deck vessel hold and hatch cover are shown in Figure 14.

Figure 14

3.8 During Carriage

No special precautions are necessary during carriage. However, lashings should be checked routinely.

3.9 Discharge to Barges

The discharge of pig iron in North American ports such as New Orleans, LA, Mobile, AL, and Charleston, SC is typically carried out mid-stream, where high capacity floating cranes (as shown in Figure 15) are placed alongside the vessel.

Figure 15 - Vessels anchored mid-stream and secured to mid-stream buoys, floating cranes secured alongside the vessel

The pig iron is directly transferred from the vessel into inland river barges, see Figure 16. Inland river barges are then used to deliver the pig iron to the end user.

A typical barge can transport approximately 1,500 tonnes of pig iron (Figure 17).

Figure 16 - Direct transfer from vessel to river barge

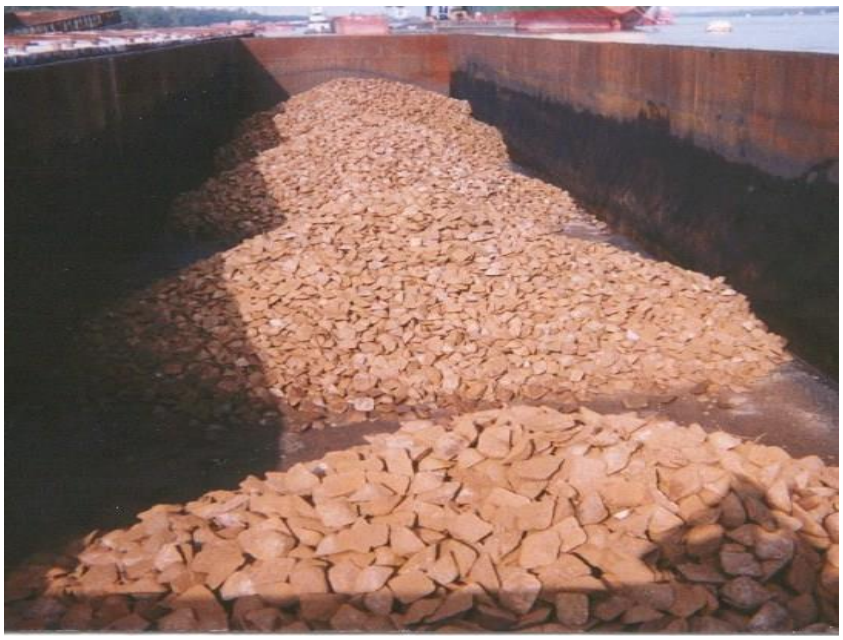

Figure 17 - River barge loaded with 1,500 Metric tons

The discharge of all forms of pig iron from bulk carrier-type vessels is normally done by use of clam shell bucket for small pig iron ingots and orange peel grab (grapple) for the larger stick or loaf shaped pig iron (see Figure 18).

Figure 18 - Clam shell grab for small pig iron (left) and orange peel grapple for large pig iron (right)

The size and shape of the pig iron determines whether a clam shell or grab or orange peel grapple is used for the discharge. The tradition clam shell grab is used for the small pyramid shaped pig iron and the orange peel grapple is used for the larger stick or loaf shaped pig iron as well as for beach iron and scrap steel.

While discharging pig iron from vessel cargo holds, care should be used in protecting the topside deck of the vessel. When the crane transfers the pig iron out of the ship and swings over into the barge or to dockside, pieces of pig iron may fall out of the clam shell bucket or orange peel grapple resulting in possible damage to the vessel.

Figure 19 shows wood pallets or plywood used to cover and protect on-deck piping and valves.

Figure 19 - Exposed above deck piping and valves (left) and plywood used to protect above deck piping and valves (right)

Adjacent pig iron grades in the same barge hold should be separated and covered to avoid co-mingling of different grades. Care is required when approaching separated grades to avoid clam shell buckets and orange peel grabs from tearing through the separation material.

3.10 Discharging to Trucks, Rail Cars, or Storage Pads

When discharging into trucks, rail cars, or to a storage pad, always check for residues of other cargoes to avoid contaminating the pig iron load with unwanted debris. When

discharging to storage pad or dockside it is important to ensure the dock or pad is strong enough to hold the weight of the pig iron.

Ensure that trucks, rail cars, and barges are clearly marked with the grade they are carrying and the hold they are working.

When grabs or magnets are used to load trucks, rail cars or barges, the material should be dropped the minimum distance possible or "soft loaded" in order to avoid damage, breakage and the generation of fines, as show in photos in Figure 20.

Barge "soft loading"

Truck "soft loading"

Rail Car "soft loading"

Figure 20

Due to the high bulk density of pig iron, care must be taken to avoid overloading trucks, rail cars, and barges. Pig iron should be even distributed in the carriage vehicle to prevent damage or accidents.

3.11 Clean Up

Prior to washing out the residues of a pig iron cargo, the bilge well of the cargo spaces should be cleaned.

3.12 Pig Iron Handling and Shipping Issues

In spite of most well planned procedures for handling pig iron, there are some handling issues that could arise.

3.12.1 Pig Iron Ingots

Dedicated Port Facilities:
The main risks associated with these ports are:

- Damage to the concrete surface of the jetty, especially when the pig iron is dumped from trucks or discharged to ship side by magnets and clam shell grabs (see Figure 21).

Figure 21

When unloading pig iron, to avoid damage it is recommended that the material should be loaded directly to trucks, rail cars or barges.

- Damage to the tanktop of the ship's holds.
- Corrosion of the floor in the ships holds resulting from the rusting of cast ingots that were loaded in rain or snow conditions. This is a rather common problem that has a relatively minor effect.
- Pig Iron delivery in containers (as shown in Figure 22) is a recent development, which could be subject to a different classification on the IMO's IMSBC Code.

Figure 22

Non-dedicated Port Facilities:
In ports that do not have dedicated facilities for handling pig iron, it is essential to take into account the following:

- The density difference with other bulk materials, which will affect the discharging rate and could damage the discharging equipment.
- The unloading of pig iron on the jetty, which could damage the concrete surface of the jetty when the material is handled with grabs, clam shells, and front end loaders.
- The unloading of scrap pig iron and cargoes containing large pieces or slabs of material, which could damage conveyor belts and transfer points.

3.12.2 Granulated Pig Iron and Iron Nuggets

Granulated pig iron and iron nuggets are physically different from the pig iron in ingot form. These products can be handled either in bulk (or in bags for smaller quantities). Due to their smaller size, conveyor belts can be used for transferring and handling these products at fast rates.

Although there is little experience with these products, a few potential issues have been identified:

- Possibility of liquefaction inside ships holds (see IMSBC Code, Section 7, and Paragraphs 7.1.2, 7.2.1): requires good trimming practice.
- Spillage of material in bulk from non-sealed compartments in trucks and rail cars.
- Formation of agglomerated lumps resulting from corrosion when shipped or stored in wet conditions (see Figure 23).

Figure 23

Chapter 4 Information at the Loading Port

4.1 Introduction

This chapter introduces guidelines intended to facilitate cooperation by shippers and the Masters of vessels carrying merchant pig iron. It has been developed to comply with the BLU Code, IMSBC Code and the Marpol Convention.

Although these are guidelines that are generally applicable to dry bulk terminals, some of the conditions and information could vary slightly from terminal to terminal.

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4.2 Protocol Guidelines

The representative of the Terminal Operator or other relevant person(s) should ensure, as applicable, that:

1. All ships nominated for loading are suitable in all respects for the purpose, and hold the appropriate certification, including a document of compliance for ships carrying solid dangerous goods in bulk, if required.
2. All relevant pre-information regarding the ship, the terminal, and the cargo to be loaded is exchanged between ship and terminal in sufficient time before the ship arrives.
3. The charterers/shippers provide the stevedores with the loading, stowing, and discharging requirements of the cargo.
4. Any representative appointed by the charterer/shipper receives full cooperation in ensuring these requirements are strictly followed.
5. The cargo information provided to the Master and to the stevedores involved in the loading operations is correct in all respects and in accordance with the latest version of the IMSBC Code where appropriate. Expert advice should be sought if there is any doubt about the cargo information provided.
6. The master has received:
    a. The relevant cargo declaration form from the shipper, in accordance with IMSBC Code requirements
    b. Material Safety Data Sheet and Emergency Response procedures for the product
    c. A certificate is issued if/as required by a competent person stating that the cargo meets the requirements of the IMSBC Code in relation to the carriage of pig iron as required for the specific quality:
        - Prior to loading to confirm that the cargo is suitable for Shipment
        - On completion of loading confirming all relevant details about the cargo loaded.
7. All relevant personnel are aware of the fact that the Master, at his sole discretion, has the right to reject any the cargo which does not conform to the IMSBC Code.
8. All relevant personnel involved in loading the cargo should be appropriately trained, commensurate with their responsibilities, and familiarized with any IMSBC Code recommendation for the specific cargo to be handled.
9. The surveyor representing the ship has safe and reasonable access to the stockpiles and loading installations for inspection prior to commencement of loading.
10. The conveyor belts and loading system is dry and safe for the cargo to be loaded.
11. Cargo is loaded carefully to:
    a. Minimize high impact drops on tanktops

b. Minimize dusting
c. Optimize Grade separation if required

12. Cargo is trimmed evenly in accordance with IMSBC Code guidelines to boundaries of cargo space.
13. Master receives full cooperation if cargo is loaded wet, where applicable, and with any reasonable requirements for loading to be delayed or off –spec cargo to be rejected or completely removed from the hold(s).
14. All hatches except the one being loaded are kept closed
15. All personnel involved in loading operations should wear appropriate PPE.
16. No entry to enclosed spaces – holds, hold accesses or mast houses on deck without a risk assessment being carried out and an Enclosed Entry Permit being put in place and /or all relevant spaces and holds confirmed by the master as safe for entry by shore personnel.
17. Terminal personnel and stevedores at discharge port are provided with training and familiarization in confined space entry procedures.

APPENDIX I – Further Reading

1. ”What is Pig Iron”, IIMA web site (www.metallics.org.uk)
2. “Pig Iron Nuggets: How Good Are They?”, B.A. Anameric and S. Komar Kawatra, Department of Chemical Engineering, Michigan Technological University
3. “Mesabi Nugget: World's First Commercial ITmk3® Plant”, Steven D. Rutherford, Mesabi Nugget LLC and John T. Kopfle, Midrex Technologies, Inc.
4. “Handling Pig Iron through Vyborg and Kaliningrad”, (need reference information)
5. “Ilmenite in Focus”, TZ Minerals International (need reference information)
6. “The Use of Alloyed Pig Iron in Stainless Steel Production”, Siemens VAI (need reference information)
7. “SSAB: Product information 2007”, pages 11-12.
8. “HBIA Terminals Guide for HBI (DRI A)”, IIMA web site (www.metallics.uk)
9. IMO BLU Code
10. IMO IMSBC Code
11. Marpol Convention