DIRECT FROM MIDREX

4TH QUARTER 2006

CONTENTS

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Commentary

Show Me the Numbers

Henry P. Gaines, Jr., PE
Plant Sales Director

Midrex has enjoyed a strong run beginning in late 2004. Since then, we have signed contracts for six new MIDREX® Direct Reduction Plants, two relocations, and one expansion. This represents 11.3 million tons of new capacity. What has caused this surge in activity? The economics of shaft furnace gas-based direct reduction in locations with low cost natural gas. Since nearly all the world's steel capacity is now privately owned, profitability is the key consideration. Steel company managements are focused on maximizing profits while ensuring the long-term success of the enterprise. In areas such as the Middle East, Latin America, and Russia, the attractive economics of the direct reduction/electric arc furnace route to steelmaking are compelling. These locations have low cost natural gas ($1-2/MMBtu), either domestic high quality iron ore or good access to seaborne trade of pellets, and low cost electricity ($0.01-0.03/kWh). In addition, with the exception of Russia, there is relatively little domestic scrap generation and thus they are reliant on the world spot market for scrap. Given these factors, the well-proven gas-based DR/EAF route is quite attractive. Even with the higher iron oxide prices of the last two years, the DRI and steel production costs allow them to compete well in world markets.

As an example, an analysis of DRI production economics in the low gas cost areas shows a conversion cost from iron oxide to DRI of only about $20/t. The conversion cost from DRI/scrap to liquid steel is about $30/t. These result in a cash cost for liquid steel on the order of $160-230/t, which is lower than the cost from blast furnace/BOF complexes in most areas. The use of hot charged DRI contributes to these economics, providing a savings in operating costs plus a substantial increase in melt shop productivity.

With the increasing internationalization and consolidation of the steel industry, steelmaking is growing in countries with abundant raw materials and energy and a need for steel to feed their growing economies. It is incumbent on steel company management to produce iron and steel in areas with economic and strategic advantages. Natural gas-based direct reduction will continue to expand in those regions.

The decision to construct a new ironmaking and steelmaking complex is not an easy one and requires intensive analysis, foresight, and an assessment of reward versus risk. It is a long-term investment and the key consideration is profitability throughout the cycles of the steel industry. The levels of steel and metallics prices at the time the decision is made, whatever they may be, should not outweigh the longer-term considerations!

While direct reduction represents less than 10 percent of world ironmaking capacity at present, it continues to grow because of its outstanding economics in many areas. We believe its importance will increase as progressive steelmakers realize the potential profitability of a DR/EAF facility. We are pleased to be able to participate in this growing market.

Editor's Note:

Today, nearly 14 million tons of DRI is shipped annually. Approximately half is in the form of pellets/lump and half is HBI. In this issue, we are carrying two articles on DRI and HBI shipping, handling, and use.

The first article, by Köppern and Midrex, discusses the advantages of HBI. The second article, contributed by LISCO, describes their procedures for shipping DRI. We hope these articles provide useful information for evaluating the attributes of various DRI forms.

HBI: Thirty Years Old and Still Growing

Hot briquetting of direct reduced iron (DRI) has been practiced on an industrial scale for 30 years and is now the preferred method of preparing DRI for storage and transport.

Beginning with the start-up of the FIOR de Venezuela plant in late 1976 in Puerto Ordaz, Venezuela, hot briquetting has been proven technically and commercially over the years. *(See Note #1 on page 6)* The FIOR plant operated three briquetting machines supplied by Maschinenfabrik Köppern GmbH & Co. KG and was capable of producing about 400,000 metric tons per year (t/y). It and the second hot briquetted iron (HBI) plant (Thyssen Purofer plant in Ahwaz, Iran), which are no longer in operation *(see Note #2 on page 6)*, introduced a product form that is now produced by 14 other direct reduction plants worldwide. In 2005, these plants produced well over 10 million metric tons (Mt) of HBI. An additional four MIDREX® Direct Reduction Plants representing 5.94 million tons per year total capacity are under construction. These plants will produce HBI as all or a portion of their output. By the beginning of 2007, Köppern will have supplied more than 100 presses for HBI worldwide.

This article will review the 30-year history of hot briquetting - why it is done and what are the relevant issues today.

Why Hot Briquetting?

As the DRI industry experienced its early growth in the 1970s, numerous steel works around the world were curious about its uses and how they might apply it in their own practices. Shipments of DRI went to many locales, and quite a number of papers were published describing the use of this "new" form of iron. *(See Note #3 on page 6)* But one aspect of DRI's nature quickly became evident: under specific circumstances, it was possible for the heat of oxidation from wet, rusting DRI to accumulate, and if these circumstances were prolonged, the temperature of the iron could continue to rise to the point of combustion. In some cases, the DRI softened and agglomerated into a cluster.

During the first few years of use, DRI was so popular that Midrex reported that merchant shipment accounted for approximately 10 percent of the total output of MIDREX Plants, although none of the plants had been built for merchant supply. However, there were some incidents in which cargoes of DRI overheated while involved in deep water transport. In some cases, it is possible for hydrogen to be produced in the ship holds, creating a flammable gas mixture. Because of these incidents, by 1982 shipments of DRI had declined significantly. Cargo insurance rates for ocean transport rose to the point that the cost of insurance essentially was prohibitive to shipment.

Midrex investigated a number of potential techniques for passivating DRI to make it safer to ship, including one that is being marketed by others today. All of these investigations led to dead ends except one promising method where DRI is briquetted at a temperature of 650-700° C to make a product known as hot briquetted iron (HBI). The briquettes are pillow-shaped, with typical dimensions 30 mm X 50 mm X 100 mm. Briquetting closes up the pores of the DRI and greatly reduces the surface area available for reoxidation. It increases the density of the product by a factor of two.

Early tests by Midrex of HBI product showed that it was approximately 100 times more resistant to oxidation (dry conditions tests) than DRI passivated by the means routinely practiced at that time. In addition, Midrex found that the heat created by oxidation was more easily conducted through the briquettes; therefore, the heat would not collect within the bulk stack of iron. The result of these two mechanisms – far lower oxidation rates and much better conduction of heat out of the stack of iron - prevents the overheating and combustion of the reduced iron product. Figure 1 shows the typical reactivity of various forms of dry DRI. Note that the y-axis is logarithmic, emphasizing the extremely low reactivity of HBI.

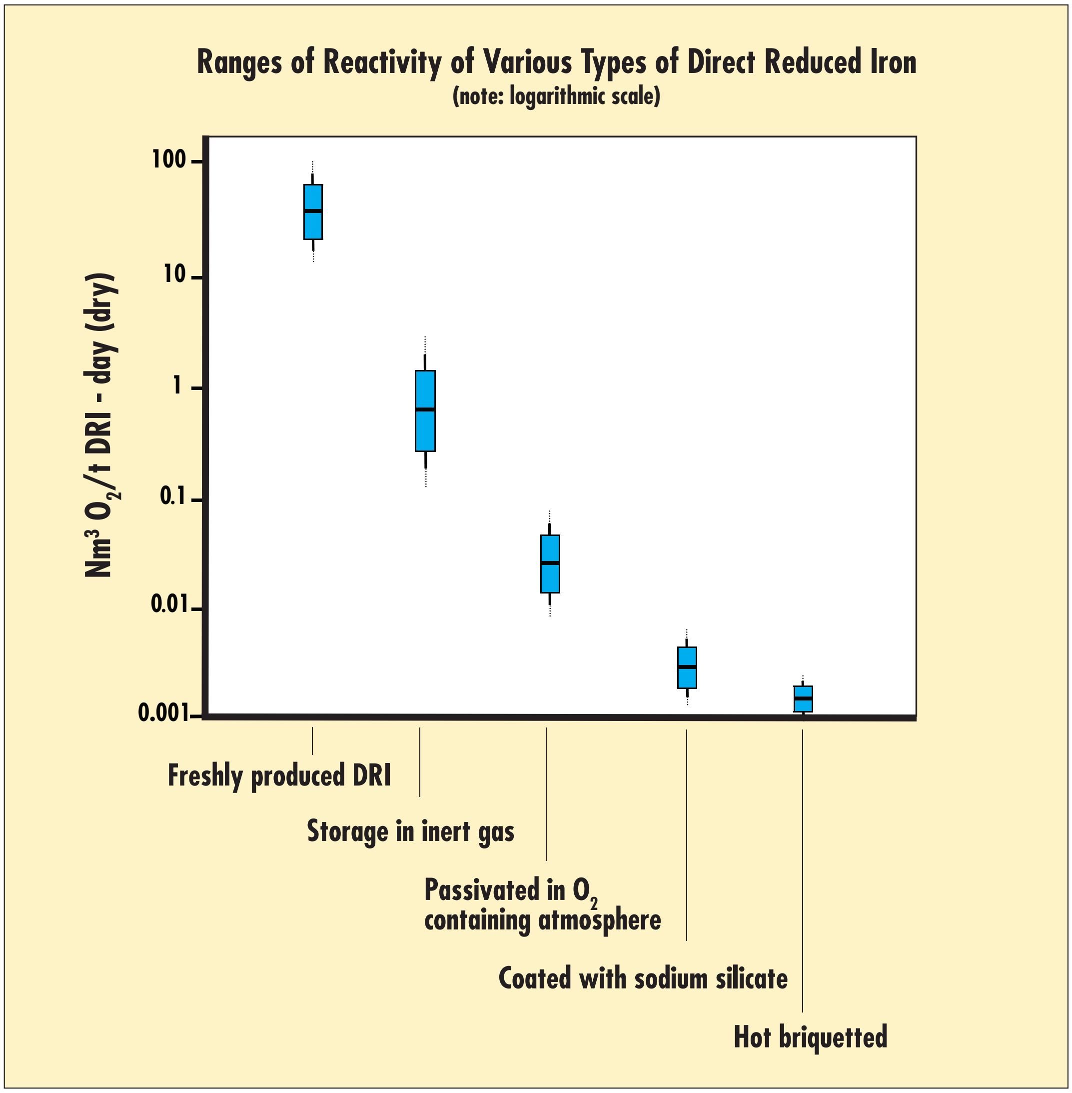


Figure 1 - Ranges of reactivity of various DRI/HBIs

Today, nearly 14 million tons of DRI is shipped annually

Also in the early 1980s, Midrex was in the preliminary design phase of the Sabah Gas Industries (SGI) direct reduced iron plant in Malaysia (now know as Antara Steel). Because SGI was to be a dedicated merchant facility, it was decided that HBI technology, based on machines designed and supplied by Köppern, should be included in the plant. After start-up, SGI shipped 100 percent of its output without any incident.

The HBI concept proved to be remarkably successful, as evidenced by the large number of plants built since SGI and as noted in the second paragraph of this article. The growth of HBI allowed direct reduced iron to be shipped anywhere in the world with much less strenuous precautions required to ensure product and vessel safety. With this improvement, the percentage of MIDREX® Iron shipped relative to the amount produced rose to twice its former level, representing approximately 20 percent of total production by MIDREX Plants.

IMO Guidelines, Passivation and Insurance

In 1982, an international effort by the iron and steel industry, shippers, insurance companies, and the International Maritime Organization (IMO) resulted in a set of guidelines for safe shipping and handling of DRI and of the newer product, HBI. These were incorporated into the Code of Safe Practice for Solid Bulk Cargoes, commonly known as the BC Code. This code is issued by the IMO with the following advice, "The BC Code is recommended to Governments for adoption for use as the basis for national regulations ..." As such, it has become the foundation for the laws relevant to transporting bulk cargoes, which are written by most sovereign nations.

Due to the much lower reactivity and higher thermal conductivity of HBI, the code is considerably less restrictive for transporting HBI. One of the more stringent requirements placed on DRI (but not needed for HBI) is a requirement for, "Maintenance throughout the voyage of cargo spaces under an inert atmosphere containing less than 5% oxygen; or that the DRI has been manufactured or treated with an oxidation- and corrosion-inhibiting process which has been proved, to the satisfaction of the competent authority, to provide effective protection against dangerous reaction with seawater or air under shipping conditions." *(See Notes #4 and #5 on page 6)*

Perhaps equally important is that the insurance companies do not recognize any practice for passivating DRI as being effective. Specifically, the Protection and Indemnity (P&I) Clubs, which provide insurance underwriting for oceangoing cargoes, have reinforced their stated positions that DRI must be inerted. Quoting from a circular recently released (August 2006) by Skuld, one of the P&I clubs, "The Association therefore continues to believe that the only proven method of carrying the low density product DRI (B) (that is, un-briquetted DRI) safely is by maintaining the cargo holds in an inert atmosphere ..."

Benefits of HBI - The Rest of the Story

As more and more MIDREX HBI plants have begun operation since 1984, the wealth of true operating knowledge and experience has validated HBI as the best technical and most economical solution for merchant DRI. This is evidenced by the recent wave of new plants and the acceptance of HBI as an alternate iron commodity to the steelmaking industry.

An innovative technology born from the need to safely transport DRI now provides HBI plants and steelmakers alike many other benefits including:

- High density HBI generally produces less fines than pellet or lump DRI and thus the yield to finished steel can be higher.
- An HBI plant has the ability to recycle fines to the briquette machines, thereby increasing productivity and adding value to the typically low value or zero value fines at DRI plants.
- HBI can be stored outside without special precautions so the end user (the steel mill) does not require special storage/inerting facilities.
- HBI can be moved using typical scrap handling equipment and easily batch charged to the EAF.
- HBI can be continually charged to the EAF with specially designed systems.

World DRI Shipments (Mt)

Year	DRI	HBI	Year	DRI	HBI	Year	DRI	HBI
1970	0.004	–	'84	0.83	0.39	'98	4.24	3.00
'71	0.04	–	'85	0.71	0.61	'99	4.01	4.41
'72	0.08	–	'86	0.89	0.73	'00	4.54	5.02
'73	0.13	–	'87	0.85	0.77	'01	2.83	6.58
'74	0.26	–	'88	1.48	0.83	'02	4.85	6.45
'75	0.34	–	'89	1.27	0.94	'03	4.63	7.63
'76	0.37	–	'90	1.46	1.71	'04	4.26	6.82
'77	0.32	–	'91	1.29	2.67	'05	6.76	7.12
'78	0.28	0.11	'92	1.45	2.71			
'79	0.66	0.12	'93	1.45	3.56			
'80	0.81	0.25	'94	2.44	3.93			
'81	0.83	0.25	'95	3.69	3.98			
'82	0.80	0.18	'96	3.58	3.20			
'83	0.59	0.36	'97	3.99	3.51			

Source: Midrex Technologies, Inc.

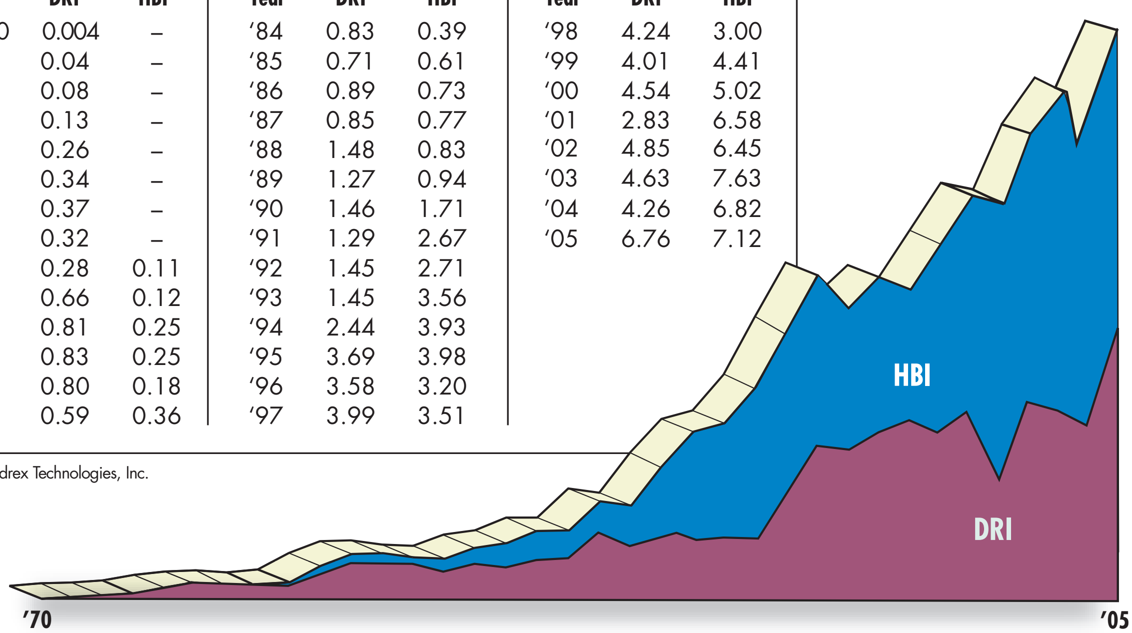


Figure 2 - HBI and DRI shipped year-by-year

Success of HBI

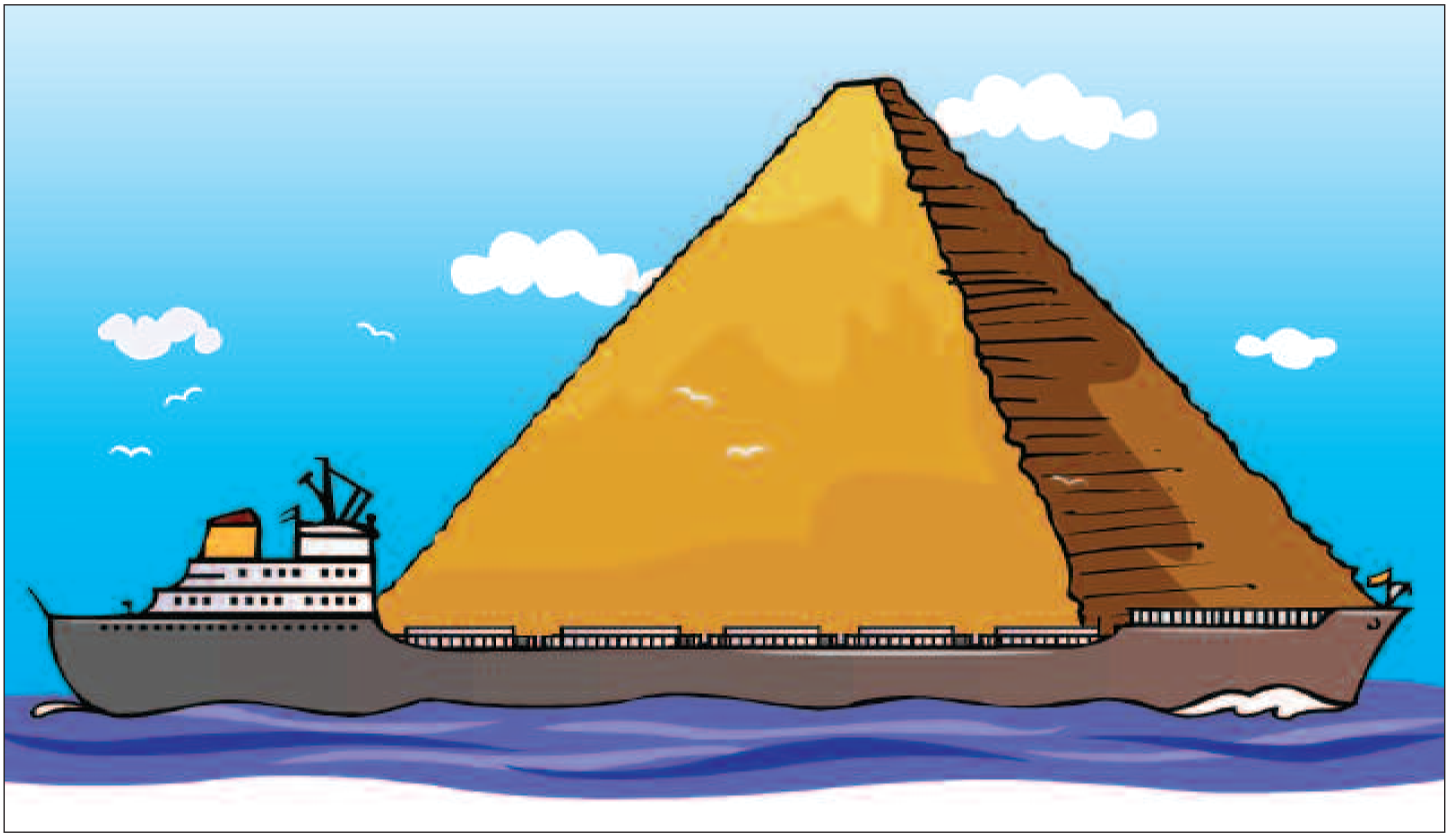
Over the past 30 years, massive quantities of HBI have been shipped to almost all corners of the globe, as shown in Figure 2 on the previous page. To date, shipments of HBI are believed to total more than 400 billion tons-kilometers. That is enough to ship the Great Pyramid at Giza around the world and then more than halfway around again!

Based on the success of HBI technology to date, more HBI plants are being built. A number of the direct reduction plants currently under construction include HBI capability, even though the plants are intended to make DRI for melting by an adjacent EAF. The ability to produce HBI will allow those facilities the flexibility to ship HBI during periods when the output of the direct reduction plant exceeds the needs of the meltshop, and to store the HBI easily and without the need for silos or other buildings when the steel works is down for maintenance..

The HBI industry continues to grow steadily. By 2010, it is expected that HBI shipments will exceed 10 million t/y. Hot briquetting has proven itself to be a crucial advancement, greatly facilitating the use of merchant DRI.

For more information, see the Hot Briquetted Iron Association Website: www.hbia.org

Acknowledgement
Midrex appreciates the contributions of Norbert Klinker and Wolfgang Schuetze of Köppern to this article.



Shipments of HBI since 1976 are equivalent in ton-kilometers to shipping the Great Pyramid at Giza around the world one and one-half times!

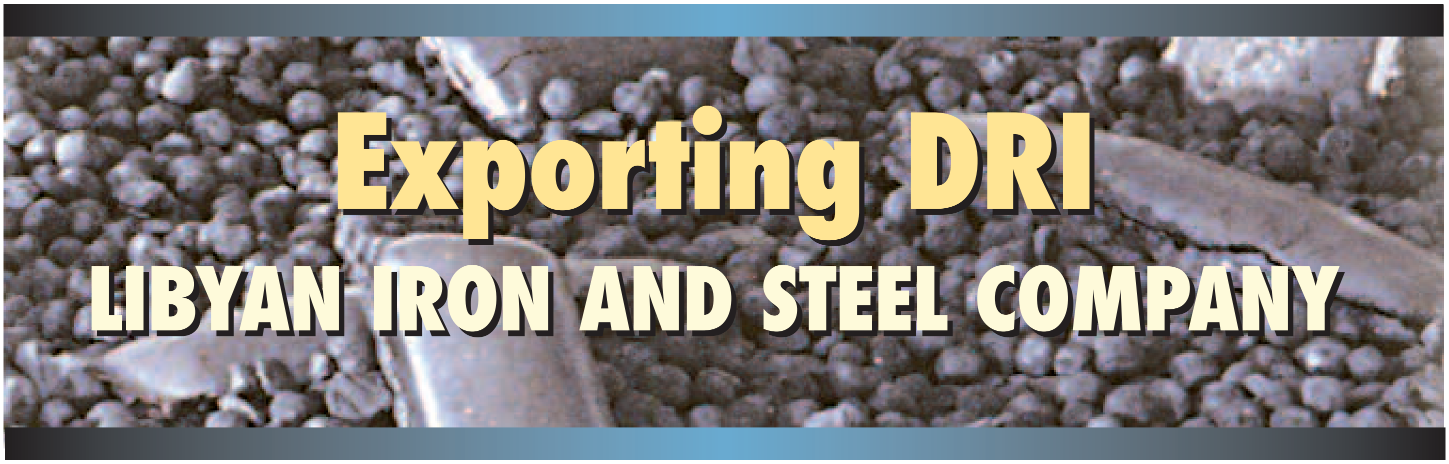
Note #1. There was an earlier attempt to produce HBI, the High Iron Briquette project, sponsored by US Steel in Venezuela, but it was not successful.

Note #2. Siderurgica Venezolano, the owners of the FIOR de Venezuela plant, are currently working to restart the plant.

Note #3. Midrex has some of these papers on file in its library. If you are interested, please contact info@midrex.com.

Note #4. The BC Code may be purchased from the IMO at ..... https://www2.imo.org/b2c_imo/b2c/init.do. The sections about DRI and HBI are on pages 107-111.

Note #5. The "competent authority" is defined by the BC Code as, "A competent person recognized by the national Administration of the country of shipment." This person is also charged to "certify to the ship's master that the DRI, at the time of loading, is suitable for shipment."



Exporting DRI

LIBYAN IRON AND STEEL COMPANY

By Ali M. Shtewi
Operations Manager, DRI and Material Handling
Libyan Iron and Steel Company (LISCO)
Misurata, Libya

Our steel complex at Misurata, Libya consists of two MIDREX® DRI Series 500-Modules and one MIDREX HBI Series 500-Module. Our first DRI module was commissioned in 1989, the second in 1990, and our HBI unit was commissioned in 1997. The production of DRI is primarily intended for in-house consumption in two steel meltshops, SMS-1 and SMS-2, with total annual liquid steel production of 1.3 million metric tons (Mt). HBI production is mainly for export. To date LISCO has produced over 14 Mt of DRI.

We decided to export our surplus DRI to prospective buyers. Our first DRI consignment of 25,000 t was shipped to India in April 2006. The voyage took 14 days. As per IMO Guide Lines, we took extra precautions in the production of DRI, regarding its passivation, storage, loading, and shipment as detailed below.

LISCO

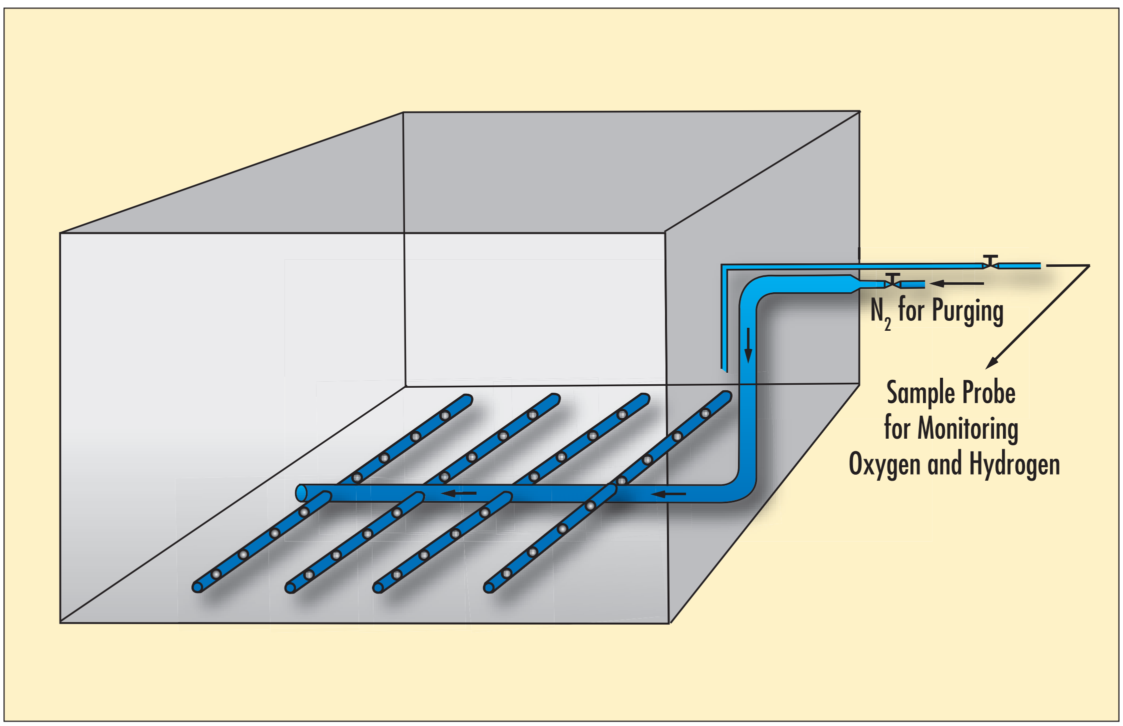


Figure 1 - Cargo hold nitrogen purging system

Production Precautions

We used 100 percent feed mix of CVRD, LKAB, and Samarco pellets – a mix we have consistently used over the years. We started lime coating of pellets at 1 kg/t oxide feed and operated the reduction furnace at a maximum bustle temperature of 900° C. This was achieved without oxygen injection because currently LISCO does not have surplus oxygen. The produced DRI has more than 93 percent metallization and 1.6 percent carbon with a maximum temperature of 40° C at furnace discharge. The full batch of DRI for export was discharged via a remet hopper, as the product screens downstream of product bins were being used to feed DRI to the steel meltshops.

Natural Passivation by Air

The DRI discharged through the remet hopper was stored in small heaps of approximately 50 t on a dry concrete surface. The temperature of each small heap was monitored. After about three to four days of air passivation, the smaller heaps were accumulated into larger heaps of about 1,000 t, with a maximum pile height of three meters. Pile temperatures were recorded by inserting thermocouple probes with temperature gauges. The readings were recorded daily with a maximum temperature reading of 55° C. About 12,000 t of air-passivated DRI was stored inside the product warehouse before loading for shipment. Storage inside the product warehouse was arranged in piles of about 2,000 t within each section. Again, the pile temperatures were measured by inserting thermocouples in each pile. The product warehouse was naturally ventilated, and the DRI stored outside was protected against rain with tarpaulins.

DRI Loading

DRI was shipped in a vessel with five cargo holds, each roughly 19 m x 14.4 m x 15.6 m. Before loading the DRI, all cargo holds were inspected to make sure they were clean and dry. At the bottom of each hold, a perforated pipe was installed for purging the hold with nitrogen after loading of the DRI was completed.

LISCO has its own captive port with specialized facilities, such as a telescopic ship-loading conveyor for loading HBI into ships. The conveying system extends from the HBI plant to the port, about 1,500 meters away.

The loading of DRI was done through the existing conveyor. Because of the specialized facilities, about 8,000 to 9,000 t could be loaded per day by deploying three pay loaders to feed the conveyor. No feeding was done during rain.

The cargo loading sequence was decided by the Shipmaster. Feeding in each hold was about 3,000 Mt. A network of portable thermocouples (immersion probe J-type of 316 stainless steel) was placed over the heap in four different locations to measure the temperature of the cargo during voyage. The remaining DRI cargo was fed into individual holds after installation of thermocouples with extended wiring. No thermocouple was placed on the floor or on top of the cargo. DRI volume in each hold was maintained at less than 50 percent of the hold volume.

When the total DRI cargo had filled four holds and HBI cargo was fed into a fifth, the hatch covers on all cargo holds were closed. Nitrogen purging devices were installed in all four DRI cargo holds. A common sampling probe to measure oxygen and hydrogen concentration during purging, as well as during the voyage, was also installed in each hold.

The hold hatches were then properly sealed; sealant was applied to all leaking points when nitrogen purging began. Purging of the DRI cargo holds was done by supplying compressed nitrogen gas in tankers at 15 bar pressure. Two tankers were deployed for transporting the gaseous nitrogen. Each hold required about 10,000 Nm^3 of nitrogen for purging to less than five percent of oxygen in the hold. Monitoring cargo temperature started eight hours after filling was completed.

While loading and unloading DRI, ship instruments such as radar and telecommunication systems were protected against dust.

Measurements While Sailing

As determined from the readings of variable oxygen concentration in the cargo space, there was a gradual increase in oxygen concentration during the voyage even though the hatches were closed and sealed. All ventilators and other hold openings were also closed before disconnecting nitrogen purging. Hydrogen concentration was not detectable throughout the journey. There was marginal change in cargo temperatures during the voyage. The oxygen and hydrogen concentrations were measured with a hand-held portable monitor by drawing samples from the sample probe of the cargo space. Temperatures were measured with a portable digital thermometer.

Safety Precautions for DRI Cargo

Before sailing, a final set of reading of temperature, oxygen and flammable gas concentrations (hydrogen) were taken. Acceptable criteria were:

Temperature	< 65° C
Oxygen	5.5% (max.) in all holds
Flammable gas	Nil

During the voyage, temperature and oxygen measurements were taken in all holds containing DRI at least three times a day, weather and sea conditions permitting. All readings were reported to the Master and the shipper daily.

In case of heavy weather, the frequency of readings must be increased temporarily. Also, all weather-tight doors must be properly closed and secured after readings are taken.

Atmosphere in the holds will warm up during the day and cool down during the night, and air may be drawn into the hold while taking readings at night and early morning. Therefore, a good seal around the probe is essential to prevent loss of inert atmosphere and inaccurate readings.

The inert gas in the holds may leak into the crane-houses in which the sampling points are located, thereby rendering the atmosphere dangerous. Therefore, the oxygen level in the crane-houses was confirmed before entering them.

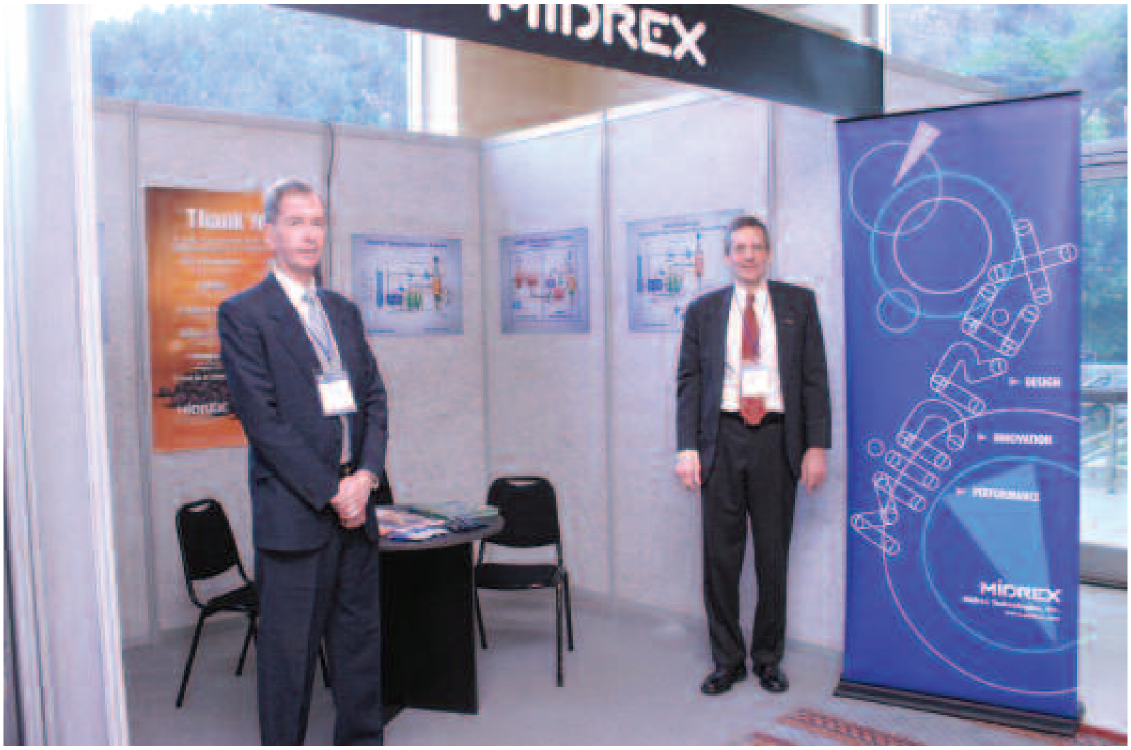
Successful DRI Shipping Experience

A number of factors contributed to the success of our first shipment of DRI. Our plant produced DRI with excellent chemical characteristics and physical attributes, which we carefully passivated and properly stored prior to shipping. As the DRI was loaded, we made certain it was dry and the ship's holds were properly closed, sealed, and purged. During the trip, we routinely checked the oxygen and hydrogen levels in the holds and closely monitored the temperature of the DRI.

At journey's end, we delivered our customer a high quality DRI product and demonstrated that DRI can be safely shipped when proper procedures are put into place and closely followed.

Midrex News & Views

ILAFA 2006



Midrex exhibit at the 47th Latin American Steel Congress, sponsored by ILAFA, in Santiago, Chile. Shown are Antonio Elliot, Manager - Technical Services, and John Kopfle, Director - Corporate Development

Christopher M. Ravenscroft: Editor

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