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COMMENTARY

THE IMPORTANCE of INNOVATIONS and IMPROVEMENTS – HOT DISCHARGE FURNACE

By Stephen Montague, Midrex, Vice President - Sales & Marketing

When the HBI plant on Labuan Island, Malaysia, was completed and commissioned in 1984, there were 18 other direct reduction plants based on the MIDREX® Process operating in North and South America, Europe, the Middle East, and Africa. Their average rated capacity was almost three times greater than the production prototype modules started up in Portland, Oregon in 1969. Their furnaces were larger and taller, plant operation was much easier and they were more efficient.

These MIDREX® Plants were innovative in that they incorporated the DR industry’s first continuous discharge reduction furnace, but essentially they were based on incremental improvements to the MIDREX® Process derived from our continual research and development and the collective experiences of MIDREX® Process Licensees.

From the beginning, Midrex has emphasized technology sharing, practical innovations and improvements. The back-and-forth flow of information, data, and experiences between Midrex and its process licensees, construction partners and key suppliers continues to produce meaningful technological advances and options.

The MIDREX® Hot Discharge Reduction Furnace is an excellent example. It was a major technological innovation when it was introduced in the Labuan MIDREX® Plant (see feature article in this issue of DFM, Celebrating 30 Years of HBI Production – The Legacy of Sabah Gas Industries).

Through the collaborative efforts of Midrex, Voest-Alpine AG (now Siemens VAI) and Sabah Gas Industries SGI, the process licensee and plant operator, a modification was made to the furnace that greatly improved the flow of materials. This fundamental design concept for the MIDREX® Hot Discharge Furnace has gone on to be at the heart of some of the most significant MIDREX® Technology innovations to date including HOTLINK® for direct feeding of hot DRI (HDRI) from the reduction furnace to an nearby EAF, and ‘true’ combination plants that can produce hot and cold DRI simultaneously upon demand.
Plants from each of the five decades in which the MIDREX® Process has been available are in operation today. This is a testimony not only to the basic process design, but also to the effectiveness of how Midrex continuously improves its technology. The MIDREX® Process Licensing Program is a key element for continuous improvement through technology sharing. It keeps MIDREX® Technology in touch with the wants and needs of the market and provides a means to develop and perfect “the next great idea” while maintaining the vitality of existing ones.

Staying on the leading edge of technology requires a seamless blending of theoretical research and operational experience that never loses sight of the goal to provide customers the performance, flexibility and reliability they need to be successful.

Through information exchange with its process licensees and key suppliers, field experiences of its technical and commercial personnel and construction partners and research & development work at its technical center, Midrex continually increases the relevance and competitiveness of its products assuring that technology innovations and improvements remain focused on providing benefits for new and existing customers alike.
Editor’s Note: The following paper was adapted from a presentation given by Nu-Iron at the 2014 AIST Conference held in Indianapolis, Indiana. This paper describes the Nu-Iron experience in developing the safe transport of direct reduced iron (DRI). It is a detailed look at the precautions and measures that are necessary for safe transport of cold DRI (CDRI) and how Nu-Iron’s dedication and attention to proper procedures has allowed the company to transport millions of tons of products via safe ocean transport.

INTRODUCTION
The shipping of cold direct reduced iron (CDRI) is a complicated, detailed and potentially hazardous process. Nu-Iron has successfully tackled the challenges of storing and transporting CDRI over long distances following the extensive regulations laid out by the International Maritime Organization (IMO).

Nu-Iron is a MIDREX® CDRI facility with a nameplate capacity of 1.6 million metric tons (MT) per year located in Trinidad and Tobago and is a full subsidiary of Nucor Steel. Nucor is the most diversified steelmaker and the largest recycler of steel and steel products in the United States. The company also has facilities located in Canada and Italy.

Nu-Iron uses high quality DR grade pellets to produce what is referred to by the IMO as DRI (B), as defined on the right. Production began on December 31st, 2006, and the first cargo was shipped to Mobile, Alabama on January 21st, 2007. With no steelmaking capability at its site in Trinidad, Nu-Iron ships all DRI produced to four ports in the USA: Charleston, South Carolina; Mobile, Alabama; New Orleans, Louisiana and Morehead City, North Carolina. After discharge, the product is transported via barges to receiving mills based in: Berkeley County, South Carolina; Tuscaloosa, Alabama; Decatur, Alabama; Memphis, Tennessee; Hickman, Arkansas and Hertford County, North Carolina.

THE IMO’S CLASSIFICATIONS
The IMO carefully describes and categorizes different bulk materials for shipping, leaving as little room for misunderstanding as possible.

DRI (A) – Hot-molded Briquette Iron
DRI (B) – Cold Direct Reduced Iron, Cold-molded Briquette Iron
DRI (C) – By-product Fines

Nu-Iron has successfully shipped their DRI product without any major incidents over the past seven years. This has been
achieved by putting the right procedures in place for the storage, handling, passivation and loading of DRI, as well as using a shipping company (GBSMT) that has had experience in the carriage of DRI and whose vessels are configured in such a way that the cargo can remain safe during the vessel’s voyage. The integrity of the cargo is always maintained.

THE REGULATORY ENVIRONMENT IN 2007: THE BC CODE

When Nu-Iron started producing and shipping CDRI in 2007, the shipping of DRI was regulated by the 2004 International Maritime Organization Code of Safe Practice for Solid Bulk Cargoes, otherwise known as the BC Code. The BC Code made suggestions for the shipping of two forms of DRI: DRI (A) (generally known as HBI) and DRI (B) (generally known as CDRI). Nu-Iron’s product, of course, fell under the category of DRI (B). The main suggestions and definitions of the BC Code pertaining to Nu-Iron’s product were as follows:

- **Material description:**
  DRI (B) is a metallic material of a manufacturing process formed by the reduction of iron oxide at temperatures below the fusion point of iron.

- **Material Characteristics:**
  Lumps and pellets; average particle size, 6 mm to 25 mm; no more than 5% fines (particles smaller than 4 mm).

- **Hazard:**
  DRI may react with water and air to produce hydrogen and heat. The heat produced may cause ignition. Oxygen in an enclosed space may be depleted.

- **Hold Cleanliness:**
  All cargo spaces should be clean and dry. Bilges should be silt-proof and kept dry during the voyage. Wooden fixtures such as battens should be removed.

- **Weather Precautions:**
  Do not load cargo during precipitation. Keep the cargo dry and close hatches that are not being worked.

- **Loading:**
  DRI should not be loaded if the material temperature is in excess of 65° C (150° F).

**Precautions:**

A competent authority recognized by the national administration of the country of shipment should certify to the ship’s master that the DRI, at the time of loading, is suitable for shipment.

Prior to shipment, DRI should be aged for at least 72 hours, treated with an air passivation technique, or some other equivalent method that reduces the reactivity of the material to at least the same level of the aged product.

Hatches should be sealed. All ventilators and other openings should be closed to maintain an inert atmosphere.

Prior to loading, provision should be made to introduce an inert gas at tank top level in order to maintain the cargo spaces under an inert atmosphere containing less than 5% oxygen.

The hydrogen content of the atmosphere should be maintained at less than 1% by volume.

Suitable detectors for quantitative measurement of oxygen and hydrogen should be on board. The detectors should be suitable for use in an inert atmosphere.

Nu-Iron was also required to obtain a United States Coast Guard Special Permit I-07 for the shipping of DRI (B). This permit covered the special transportation requirements for the shipping of DRI (B) into the United States and for the movement of DRI (B) in unmanned barges within the United States.

DEVELOPMENT OF NU-IRON’S EARLY SHIPPING PROCEDURES

Prior to shipping its product, Nu-Iron developed procedures that surpassed the requirements of the concurrent BC Code, utilizing the input of relevant stakeholders. The prospective shipping company, the United States Coast Guard, various Protection & Indemnity Clubs (international maritime insurance providers) and cargo incident investigators all contributed to ensuring that personnel and cargo on board the vessels would remain safe during every voyage.
The procedures developed by Nu-Iron sought to manage the key areas impacting cargo transport. The main requirements were:

- **Vessel Suitability:**
  Once a vessel has been nominated by the ship owner, the ship owner is required to communicate to Nu-Iron prior to the vessel’s arrival that a pre-loading risk assessment has been performed by a representative of the ship owner, and this representative certifies that the vessel is suitable for the loading and carriage of DRI.

  On arrival at Nu-Iron, a surveyor performs ultrasonic testing to verify hatch and hold water tightness. Any abnormality is corrected and retested prior to berthing of the vessel.

- **Crew Readiness:**
  Prior to the berthing of a vessel, a vessel representative communicates to Nu-Iron that the vessel’s crew has reviewed all ship procedures related to the carriage of DRI.

- **Cargo Handling and Passivation:**
  Cargo is to be stored in enclosed silos. Once the silo is filled, the top slide gate is closed and seal gas (inert gas with between 0.7 and 3% oxygen by volume) is introduced at the top and bottom cone of the silo for a minimum of 72 hours. Once the passivation process is completed, the material is kept under a nitrogen blanket.

  If for any reason material has to be added to a partially filled silo with passivated material, the entire passivation process has to be repeated before that cargo can be loaded into a ship.

  Any un-passivated material that goes into the product warehouse must be aged in the warehouse for at least 120 hours before it can be loaded into a ship.

  All silos have analyzers that continuously monitor the oxygen and hydrogen atmospheres within the silo and three thermocouples that continuously monitor the temperature of the cargo.

- **Cargo Readiness:**
  Prior to vessel loading, Nu-Iron provides data to the competent authority and the ship’s master showing the quality (metallization and carbon); temperature; fines content; and start and end times for passivation of all cargo to be loaded.

- **Cargo Loading:**
  During loading, the temperature of the cargo is continuously monitored via a temperature monitoring device placed over the conveyor. If the temperature reaches 50°C, an alarm sounds in the control room informing the operator that some action needs to be taken. If the temperature reaches 58°C, the system will shut down to prevent the possibility of high temperature material going on to the vessel.

- **Vessel Inerting:**
  After loading, the cargo holds are sealed and nitrogen is injected into the hold until the oxygen content drops below 2%.

- **Cargo Monitoring:**
  During loading, sailing, and discharge, the cargo temperature and the vessel hold conditions (oxygen, carbon monoxide, and hydrogen content) are monitored three times a day (06:00, 12:00, and 18:00) and reported to the vessel and Nu-Iron. The gas monitors must be calibrated annually, and calibration records are shared with the ship owner representatives.

**THE NEW REGULATIONS: THE IMSBC CODE**

In 2008, the IMO published a new shipping code: the International Maritime Solid Bulk Cargo Code, or IMSBC Code. As opposed to the BC Code it replaced, which phrased its requirements as suggestions (“should”), the new IMSBC Code uses strictly requisite language (“shall”). It also provides significantly more detail concerning the shipping of many bulk cargoes, including DRI (B). This new code went into effect on January 1st, 2011. Many of the regulations are essentially the same. The main differences between the BC Code and the IMSBC Code for the shipping of DRI (B) are as follows: (next page)
Material Description:
The IMSBC Code gives a more detailed and descriptive definition for DRI: DRI (B) is a highly porous, black/grey metallic material formed by the reduction of iron oxide at temperatures below the fusion point of iron.

Material Characteristics:
The IMSBC Code uses larger particle size for fines and adds information on bulk density:
Lump and pellets: Average particle size 6.35 mm to 25 mm with no more than 5% fines (smaller than 6.35 mm) by weight.

Bulk density of DRI (B) is between 1750 and 2000 kg/m³.

Hazard:
These are more detailed as to the specifics of the potential hazards of DRI (B):
Increase in temperature of about 30°C due to self-heating may be expected after material-handling in bulk.

Hydrogen has the potential to form an explosive mixture when mixed with air in concentrations above 4% by volume.

Reactivity of the cargo depends on the origin of the ore, the process and temperature at which reduction is achieved, and the subsequent ageing procedures.

Loading:
The IMSBC Code provides checks that should be carried out on the system used to load the DRI on the vessel as well as vessel checks. It also describes the conditions that the cargo must conform to before, during, and after loading:

Prior to loading, the terminal shall ensure that the conveyor belts used for loading the cargo contain no accumulation of water or other substances.

Prior to loading, an ultrasonic test or another equivalent method with a suitable instrument shall be conducted to ensure weather tightness of the hatch covers and closing arrangements, and all readings shall confirm weather tightness.

Prior to loading, the shipper shall provide the ship’s master with a certificate issued by a competent authority recognized by the national administration of the port of loading, stating that the cargo, at the time of loading, is suitable for shipment and conforms to the requirements of the code. The certificate shall state the date of manufacture of each lot of cargo to be loaded in order to meet the requirements of ageing and temperature.

Prior to loading, the vessel should have provisions to provide an inert gas (preferably nitrogen) to purge air from the hold and airtight cargo spaces.

The cargo temperature and moisture for each lot of cargo shall be monitored during loading, recorded in a log, and copied for the ship’s master.

After loading, a certificate shall be issued by the competent authority confirming that throughout the whole consignment, fines are less than 5% by weight, the moisture has not exceeded 0.3% and the temperature does not exceed 65°C.

On completion of loading of a cargo space, it should be immediately closed, sealed, and inerted to less than 5% oxygen.

Precautions:
More detailed and specific about the rights of the vessel to confirm safety of the cargo and precautions to be taken by the vessel:
The carrier’s nominated technical persons or other representatives shall have reasonable access to stockpiles and loading installations for inspection.

Prior to shipment, the cargo shall be aged for at least 3 days or treated with an air-passivation technique that shall be approved by the competent authority which shall also provide a certificate to that effect.

Shippers shall provide comprehensive procedures to be followed in the event of an emergency. This advice may be an amplification of this Code but shall not be contrary thereto.
During any handling of the cargo, “NO SMOKING” signs shall be posted on decks and in areas adjacent to cargo spaces.

The ship shall be provided with the means to ensure that the cargo holds remains below 5% oxygen throughout the voyage.

The vessel shall be provided with the means for reliably measuring the temperature at several points within the stow and determining the concentration of hydrogen and oxygen within the cargo spaces.

The ship shall not sail until the ship’s master and the competent authority are satisfied that:
- All loaded cargo spaces are correctly sealed and inerted;
- The temperature of the cargo has stabilized and does not exceed 65°C;
- The concentration of hydrogen in the free spaces does not exceed 0.2% by volume.

**Carriage:**

More detailed and specific about the equipment to be used for monitoring cargo spaces and the frequency of the same:

Suitable detectors must be used for the quantitative measurement of hydrogen and oxygen during the voyage. The detectors shall be suitable for use in an oxygen-depleted atmosphere and of a type safe for use in an explosive atmosphere.

The temperature of the cargo and concentrations of hydrogen and oxygen in the cargo spaces carrying this cargo shall be measured at regular intervals during the voyage and the results recorded and kept on board for at least two years.

If the temperature in the cargo space exceeds 65°C or if the hydrogen concentration is higher than 1%, appropriate safety precautions shall be taken in accordance with the emergency procedures provided by the shipper. If in doubt, expert advice shall be sought.

**Discharge:**

Previously there were no discharge regulations: The hydrogen in the cargo space shall be monitored immediately before opening of the hatch covers. If the hydrogen concentration is greater than 1% by volume, all appropriate safety precautions must be taken before the hatch cover can be opened.

“AT ALL TIMES, NU-IRON’S OWN STANDARDS HAVE EXCEEDED THE REGULATIONS OF THE IMO.”

**MODIFICATION OF NU-IRON’S PROCEDURES**

On January 1st, 2011, with the changing of the shipping code, Nu-Iron had to make some minor updates to their procedures. Nu-Iron also chose to make some changes based on their experiences with shipping DRI over the years. The changes to Nu-Iron’s shipping procedures are as follows:

**Cargo Loading:**

During the loading of the vessel, Nu-Iron has samples taken from every lot of cargo being loaded. Each sample is tested for its moisture and screened to determine the fines content. The temperature of the material being loaded at the time the sample is taken is also recorded.

After loading is completed, the full lab analysis of temperature, moisture, and fines content is communicated to the competent authority, who issues a certificate confirming that the entire cargo loaded conforms to the IMSBC code.

**Vessel Inerting:**

After loading, the cargo holds are sealed and nitrogen is injected into the hold until the oxygen content drops below 3% oxygen.

At all times, Nu-Iron’s own standards have exceeded the regulations of the IMO. The development of thorough and stringent procedures has facilitated the safe shipping of over 9.0 million MT of CDRI over the last seven years. However, it wasn’t a journey without setbacks.
**CHALLENGES FACED BY NU-IRON**

The safe handling of DRI (B) involves unique hindrances, granted by the material’s tendency to react with moisture very readily. As a result, the IMSBC Code requires as little contact with water as possible, or else flammable and poison gases will be produced. Unfortunately, moisture is prevalent in Nu-Iron’s area. Cargo cannot be loaded during precipitation; the reduced iron must be aged for three days or passivated to an equivalent degree. The dry cargo is therefore very dusty and messy. If passivation procedures are breached, shipment is immediately delayed until aging is complete. Any setback means more money lost, both in lack of sales and production, as well as compensatory payments to the shippers.

Yet, Nu-Iron has confronted and minimized each of these barriers with great success and safety.

### Hydrogen & Carbon Monoxide Generation

In late 2007, Nu-Iron experienced instances of hydrogen generation. Small amounts of hydrogen (less than 20% LEL) and larger amounts of carbon monoxide (up to 800 ppm) were being detected in some of the vessel holds. Hydrogen generation typically occurs when DRI comes into contact with moisture. Carbon monoxide generation can come from either contact with moisture or interaction with air.

The generation of hydrogen and carbon monoxide meant that the DRI was being exposed to moisture somewhere within the storage, loading, or handling process. After extensive investigation, it was determined that hydrogen was only generated in vessel holds loaded with cargo that had been stored in Nu-Iron’s DRI warehouse.

Nu-Iron stores the majority of its DRI in enclosed silos (twelve silos with a total capacity of 72,000 MT) whereas the warehouse was used as back-up storage in the event of conveyor maintenance or DRI vessel scheduling delays. The warehouse only has a capacity of 6,000 MT.

At this time, Nu-Iron’s warehouse had an earthen floor.

They realized that during the rainy season in Trinidad (which is typically from June to November) moisture would seep up through the ground due to the water table being close to the surface, exposing the cargo to moisture.

Once this was determined, material storage in the warehouse ceased, and a concrete floor was laid in early 2008. Once this floor was laid, there were no more instances of cargo exposed to moisture and no more issues with hydrogen or carbon monoxide generation.

![Graph of CO Generation by Vessel Hold](image)

**Figure 1** Graph of Carbon Monoxide generation by vessel hold for July – December 2007 & 2008

*Figure 1* displays the prevalence and subsequent rectification of the problem. Between July and December 2007, approximately 80% of vessel holds loaded evolved less than 200 ppm carbon monoxide, while 20% evolved between 200 ppm and 800 ppm carbon monoxide. For the same period in 2008, approximately 95% of vessel holds loaded evolved less than 200 ppm carbon monoxide and 5% evolved between 200 ppm and 800 ppm carbon monoxide, a significant improvement.

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The improvement was even more significant for hydrogen levels. Between July and December 2007, approximately 88% of the vessel holds loaded evolved less than 10% LEL hydrogen, and 12% evolved between 10 and 20% LEL hydrogen. For the same period in 2008, 100% of the vessel holds loaded evolved 0% LEL.

Dust Mitigation
DRI is a cargo with a moisture content of less than 0.3% and can have up to 5% by weight of particles less than 6.35 mm in size. In sum, it is a very dry, dusty product.

Therefore during handling and loading of vessels, dust handling and the mitigation of its dispersion is a major concern. Ship owners were hesitant to transport DRI because of the additional cleaning and maintenance costs associated with handling a dry material that can contain up to 5% of fine particles.

To alleviate this problem, Nu-Iron worked with the vessel provider (GBSMT) to modify the vessel hatch covers that are used to load DRI, allowing Nu-Iron to load the vessel with the hatch covers closed. This alleviates the concern of airborne dust from loading activities and thus minimizes any additional maintenance and cleaning costs associated with handling the DRI.

Weather Delays
DRI must always remain dry, and thus, loading operations cannot be performed during precipitation. Nu-Iron is based in the Caribbean, where the rainy season lasts for about half of the year, June to November. During the rainy season, time was lost due to rain and “threat of rain”. Threat of rain” occurs when there is no rainfall, but loading stops because of the possibility of imminent rainfall.

Since loading through closed hatch covers began, time lost due to “threat of rain” was reduced by approximately 80%, reducing the time a vessel spends alongside and reducing the demurrage incurred.

Failure of the Seal Gas Compressor
In late 2007, Nu-Iron experienced the failure of their seal gas compressor, which provides the seal gas used to passivate the DRI in the silos. The repairs were expected to take several days, and there was sufficient material to load a vessel but no means to complete the passivation. This would have resulted in significant demurrage.

Nu-Iron put this problem to their teammates, and, “in true Nu-Iron style,” a teammate made the following suggestion: “Why not blend instrument air [which is very dry] with nitrogen in order to create a dry, inert gas?”

This was an excellent suggestion, as Nu-Iron was able to supply a dry inert gas with controlled oxygen content to the silos and thus continue the passivation process.

Given the success of this solution, Nu-Iron has installed an automated system whereby whenever there is no seal gas, they can blend instrument air with nitrogen to provide inert gas at a controlled oxygen content to continue the passivation process.

CONCLUSION
The shipping of cold direct-reduced iron (CDRI) is a complicated, detailed and potentially hazardous process if the proper procedures and precautions are not followed. CDRI may react with water and air to produce hydrogen and heat. The resulting heat produced may cause ignition leading to a risk of overheating, fire and explosion during transport. Due to the reactive nature of CDRI in bulk scenarios, special care is taken especially in wet environments such as Nu-Iron’s location in Trinidad and Tobago and for ocean transportation. Nu-Iron has followed and improved upon IMO procedures and practices to safely transport via ocean more than 9.0 million tons of CDRI since 2007. Their experience is a textbook case study for how to store and successfully ship CDRI.

FIGURE 2 Graph of Hydrogen generation by vessel hold for July – December 2007 & 2008

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The Legacy of Sabah Gas Industries

By Frank Griscom, Former HBI Association Executive Director and International Iron Metallics Association Secretary

Editor’s Note: This year marks the 30th anniversary of the start-up of the MIDREX® Hot Briquetted Iron (HBI) plant originally owned and operated by Sabah Gas Industries (SGI). The history of HBI production, its growing use and the first MIDREX® HBI plant built on Labuan Island off the coast of Sabah, Malaysia, are intimately connected. From its start-up in 1984, the plant, which today is owned and operated by Antara Steel Mills of The Lion Group, has been a catalyst for innovation and improvement. As the first MIDREX® Direct Reduction Plant designed for hot discharge/hot briquetting, the SGI plant was an “operational laboratory” where equipment was tested, personnel were trained and both were proven. To mark this milestone, Frank Griscom, who assisted SGI with its marketing program as Midrex Manager – Marketing Communications, looks back at the start-up of the plant and the how the impact of this first installation affected global DRI development and usage.

AT THE BEGINNING – A VISION FOR INDUSTRIAL DEVELOPMENT

The State Government of Sabah, one of the 13 federated states of Malaysia, located on the island of Borneo bordering on the South China Sea, established Sabah Gas Industries (SGI) in 1981 to manage the use of natural gas associated with the Erb West and Samarang offshore oil fields. SGI was part of the Malaysian economic program intended to create technical skills and manpower resources required for developing and sustaining industrialization in the country.

Dr. K.G. Sikchi, a highly respected chemical engineer in the field of fluid mechanics, was hired by the Sabah State Government to direct the development plan. Methanol and DRI were identified as products that could add value to the associated gas that otherwise would be flared. These products had potential markets not only in Peninsular Malaysia but also throughout South East Asia, the greater Pacific Rim and beyond.

Ultimately the decision was made by SGI to invest in a 660,000 metric tons/year methanol plant and a 600,000 metric tons/year direct reduced iron (DRI) plant, as well as a 47 MW
power plant to support the production facilities and supply local electricity needs.

The island of Labuan, located 100 kilometers southwest of Kota Kinabalu, the state capital of Sabah, was chosen as the project site due to its natural deep water port (17.5 meters draft) and proximity to the offshore oil and gas fields. The production facilities would be located in a 400-acre industrial estate on reclaimed land to optimize port operations.

Two offshore gas supply platforms would be constructed at the Erb West and Samarang oil fields and underwater pipelines of 85 and 35 miles, respectively, would be laid to an onshore gas gathering and control station on Labuan. The pipeline network would have a design capacity of 115 million cubic feet/day of natural gas, which would be available by 1984.

**DECISION FOR DIRECT REDUCTION**

In 1980, steel industries based on the electric arc furnace (EAF) were developing in ASEAN (Association of South East Asian Nations) and other countries in Asia and the Pacific Rim region. EAF steel mills could be sized to a specific market and were less capital-intensive than traditional integrated mills, but EAF-based mills melted scrap and the amount of scrap that could be generated in these emerging economies was extremely limited.

Direct reduced iron (DRI) was gaining attention as an effective alternative to scrap in the EAF. However, global production of DRI in 1980 was little more than seven million metric tons (tonnes), and almost all of that was being consumed by steel mills adjacent to the DR plants. In the same period, Asian countries were importing approximately eight million tonnes of scrap, primarily from the US.

A merchant DRI plant fit perfectly into the SGI development plan...a production facility that used natural gas to make a product that filled an existing need both in Malaysia and in the surrounding region. With gas expected be available to Labuan by 1984, it was essential to expedite development of the DRI project.

Gabe Carinci, President of AmeriFab, Inc, and former Midrex Manager – International Market Development, managed all phases of the SGI project for Midrex from its Kuala Lumpur liaison office and remembers the timing from first contact to contract signing.

“It was a done deal in 18 months,” Carinci recalls. “We had a client who knew what he wanted, a construction partner [Voest-Alpine AG (VA)] capable of providing what was needed,
and the determination to make it happen.”

The turnkey contract, valued at approximately $US 145 million, was awarded to VA on May 19, 1981, and a licensing agreement covering operation of the plant and sale/use of the product was concluded between Midrex Corporation and SGI on behalf of the State of Sabah. Site work began in November 1981, and the plant was scheduled for start up in early 1984.

**MAKING DRI SAFER TO SHIP**

In 1970, only 4,000 tonnes of DRI were shipped and all by land. As the attraction of using DRI in the EAF increased, so did the need to transport DRI for long distances over open water. The propensity of DRI to heat up and evolve hydrogen gas when exposed to water, especially saltwater, caused the Inter-Governmental Maritime Consultative Organization (IMCO, today known as IMO – International Maritime Organization) to develop a code for shipping DRI, which was adopted in October 1982.

The so-called IMCO BC (Bulk Cargoes) Code made the provision that ships’ holds containing DRI should be maintained under inert atmosphere conditions unless the DRI was manufactured or treated in a manner approved by the competent authority to provide protection against corrosion and oxidation by water and air* (see footnote on page 15).

SGI initiated a search for a method to make DRI safer to handle, ship, and store because its DRI plant would be located and the product primarily sold in a tropical region of the world where significant rainfall occurs 4-6 months of the year (average annual rainfall on Labuan is 4000 mm/160 inches). After comparative studies of several passivation techniques and hot briquetting by an outside consultant, SGI made a decision for hot briquetting. The plant supply contract was amended in August 1982, but plant start-up remained set for 1984.

The decision for hot briquetting was made for operational and marketing reasons, as well as to solve handling, shipping, and storing issues associated with conventional DRI. HBI production would improve in-plant losses and expand the potential market to include blast furnaces (BFs), basic oxygen furnaces (BOFs), and foundries (induction furnaces and cupolas).

Including hot briquetting in the SGI plant design involved installing a hot discharge reduction furnace, which would be elevated 18-20 meters to allow sufficient space to locate three briquetting machines and associated equipment underneath it. Hot DRI would be continuously discharged and fed by gravity into the briquetting machines where it would be compacted without a binder material. The compacted DRI then would be separated and cooled for temporary storage.

Mechanical construction of the SGI plant was completed in January 1984. Plant commissioning began in June 1984, and the plant produced highly metallized DRI during the first week of August 1984. A series of problems with the briquette separating equipment delayed steady production of HBI until December 1984, when the first shipment of 5,000 tonnes was made.

“As with any new process, there were many new designs and new equipment applications that required adjustments during commissioning,” said Jim McClelland, Director of Technology Development who was one of the numerous Midrex engineers who worked at the SGI Plant during start up, commissioning and early operations.

Ken Joyner, current Director of CIS for Midrex, was a Midrex equipment designer at the time. “We were constantly busy.” Joyner recalls. “We would make the modifications and detail drawings, get the parts fabricated either on-site or usually at the local ship refurbishing company, and then have to either supervise the installation or put the parts in ourselves.”

Optimization of the plant and the briquetting equipment was a collaborative effort of all parties involved in the project. It also marked the beginning of a long-term relationship between Maschinenfabrik Köppern GmbH & Co. KG (Köppern), Midrex, its construction partner (Siemens VAI), and the Labuan HBI plant, which continues today.

The design capacity of the Labuan HBI plant has been increased incrementally since 1984 ... from 600,000 tonnes/year to 660,000 tonnes/year to 715,000 tonnes/year. A plan is in place that would boost HBI output by 150,000 tonnes per year should market demand for HBI increase.
DEVELOPING THE MARKET FOR HBI

When the decision was made to produce HBI, few iron and steel-makers in the Asian region knew anything about the product. Although some potential customers already had experience using conventional DRI, many benefited from additional information regarding the particular traits of HBI, especially its melting characteristics and best practice for batch charging.

SGI began promoting the use of HBI early in 1984, while the plant was being completed. SAMA Industrial Products, a subsidiary of Sabah Marketing Corporation (SAMA), another company owned by the Sabah State Government, was created to market the HBI and methanol produced on Labuan. The trading arm of VA also was involved in marketing the SGI products. Midrex provided product training for the SGI/SAMA and VA Trading personnel and actively participated with them until the plant’s first year of production was sold out.

“I was on the road a lot with the SGI/SAMA marketing people introducing HBI to potential clients throughout ASEAN and the Pacific Rim,” Carinci remembers. “We were talking with anyone who melted scrap to make iron and steel products - from EAFs, BFs, and BOFs to open hearths, induction furnaces and cupolas. They were all very enthusiastic about a regional source of prime metallics.”

The strategy for marketing HBI was to identify potential customers in each of the market segments (EAF, BF, BOF, and foundries) and invite them to visit the plant on Labuan. During the plant visit, a trial shipment of HBI would be arranged. An SGI representative would accompany the shipment and be present during melting trials to advise and observe. Results of the melting trials would be published to attract other customers.

Between 1985 and 1987, SGI made shipments to 13 countries including China, India, Japan, Philippines and Turkey. By 1988, the SGI plant had shipped more than one million tonnes of HBI to EAF steelmakers and another 400,000 tons to BOF and open hearth furnace operators.

In October 1992, the SGI plant was acquired by The Lion Group, a diversified business group based in Peninsular Malaysia. The new owner viewed the plant as its protection from the uncertainty of scrap supplies and prices. The plant was renamed Amsteel Mills Sdn. Bhd. (Labuan) in 1995 in a corporate restructuring, and on September 1, 2005, the HBI business was again renamed Antara Steel Mills Sdn. Bhd. (Labuan).

The MIDREX® Shaft Furnace underwent an upgrade in October 2005, which increased its production volume by 13 percent – from 102 tonnes per hour to 115 tonnes per hour. A fourth briquetting machine was installed to increase machine availability and HBI output. Other improvements to the plant site included installation of a vacuum pressure swing absorption (VPSA) oxygen plant, a two-cell cooling tower, an oxide coating plant, and the provision for oxygen injection into the furnace bustle gas.

The Lion Group started up a 1.5 million tonnes per year hot discharge/hot transport direct reduction plant adjacent to its Megasteel melt shop in Banting, Malaysia, in May 2008. The commissioning of the new DRI plant has enabled Antara Steel Mills (Labuan) to return to its original role as a merchant source of high quality metallics for use in iron and steel production throughout the South East Asia, China, and the Pacific Rim.
**LEGACY OF SABAH GAS INDUSTRIES**

Producing value-added products from the natural gas associated with its offshore oil fields was only one of the goals set by Sabah State Government for SGI. Equally important was educating and training the state’s population in order to develop a sustainable industrial infrastructure.

SGI was a high profile project for Malaysia and Sabah, which attracted bright, young local professionals who quickly assimilated the technical and commercial training provided by Midrex and VA and assumed key roles. Many of these initial hires, including Anthony Pang, Henry Liew, and Dominic Lu have been instrumental in the plant’s 30-year history and continue today in management positions with current owner/operator, Antara Steel Mills, and the Lion Group.

During the optimization phase of the SGI plant, in-house modeling tests by SGI engineers led to installation of a device in the lower cone of the hot discharge reduction furnace that corrected a material flow issue. Today all MIDREX® Shaft Furnaces include this device in their design. SGI plant operators also demonstrated that the life of briquette machine segments could be as much as 100,000 tonnes, when initial estimates were for only 60,000 tonnes.

On the commercial side, SGI made a lasting impression. Alberto Hassan, who was instrumental in the emergence of Venezuela as a leading producer and exporter of HBI in the 1990s, and later founded the HBI Association, remembers the project.

“We were very impressed with how the Malaysians approached the market,” said Hassan. “They were well prepared, both technically and commercially, and showed a keen understanding of how to introduce a new product. The practice of offering trial shipments with on-site application assistance was highly successful for SGI and has been adopted by every merchant HBI plant since then.”

**CONCLUSION**

Although its name and ownership have changed, the direct reduction plant built on the island of Labuan for Sabah Gas Industries 30 years ago is today the longest operating HBI plant in the world.

The SGI plant was not the first to produce HBI, but it was the one that made it into a global industry. Its marketing message was that HBI makes DRI no longer just for EAFs and that it is easy and safe to handle, ship and store in any climate and weather.

Today the voestalpine Group is building an HBI plant outside of Galveston, Texas, primarily to supply its own blast furnaces in Europe, with some of the HBI to be available as merchant product. Russia’s Metalloinvest is expanding its HBI capacity with a second MIDREX® Plant in order to meet internal demand and that of BF operators and integrated and EAF steelmakers throughout Russia and the rest of Europe. None of this would have been possible if not for the original SGI MIDREX® HBI Plant and the effort and commitments of various individual companies and supporters.

Thus on the 30th anniversary of the start-up and operation of this first MIDREX® HBI Plant, we pay tribute to this landmark project and its many achievements. We recognize the vision of the Sabah State Government to diversify its economy and provide educational and career opportunities for its citizens. We also salute the spirit of innovation embodied in the design and optimization of the plant as well as the collaborative effort with the will to succeed that launched the most widely used HBI production technology in the world.

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**Footnote:**

*As a result of multiple incidents involving DRI cargoes that were deemed to have been “manufactured or treated in a manner approved by the competent authority to provide protection against corrosion and oxidation by water and air”, the subsequent International Solid Bulk Cargoes (IMSBC) Code issued by IMO stipulated that only HBI or “hot-moulded briquettes, DRI (A)”, as it is known in the Code, is not subject to inerting for ocean transport.
Designed for Today, Engineered for Tomorrow™

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Christopher M. Ravenscroft: Editor

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