DIRECT FROM MIDREX

4th Quarter 1999

IN THIS ISSUE

DIRECT FROM MIDREX

4th Quarter 1999

Table of Contents

Editorial Staff

Derek M. Sheedy
Editor

John T. Kopfle
Research/Statistics

Adgroup International, Inc.
Graphic Design/Production

AN ISO 9001 CERTIFIED COMPANY

DIRECT FROM MIDREX is published quarterly by Midrex Direct Reduction Corporation, 201 South College Street, Suite 2100, Charlotte, North Carolina 28244 U.S.A., Phone: (704)373-1600 Fax:(704)373-1611, Web Site: http://www.midrex.com under agreement with Midrex International B.V. The publication is distributed worldwide free-of-charge to persons interested in the direct reduced iron (DRI) market and its growing impact on the iron and steel industry.

All tons referred to are metric tons (t) or million metric tons (Mt)

Commentary

Around the World in 30 Years

Winston L. Tennies
President

As 1999 draws to a close, I would like to recognize a noteworthy milestone. This year marks the 30th anniversary of the start-up of the first MIDREX® Direct Reduction Plant at Oregon Steel Mills, the beginning of the commercial success of the MIDREX® Direct Reduction Process. There are a few of us left at Midrex who participated in that start-up, including me, and it is rewarding to look back upon the ensuing 30 years and know that we played some part in that effort. Bruce Kelley, our Vice President of Engineering and Technology, and Dave Meissner, Manager of R & D, are veterans as well. Chuck Sanzenbacher, another pioneer, passed away recently, as noted in the 3rd Quarter issue of *Direct From Midrex*.

Many of the innovations and solutions we developed in the early days of the MIDREX Process are still used in MIDREX Plants today. During the three decades since start-up at Portland, the MIDREX Process has become the world's most successful direct reduction technology, accounting for more than 60 percent of world DRI production each year since 1987. To date, a total of 53 MIDREX Modules have been built on five continents, in 18 countries, representing over 30 Mt of capacity.

It is interesting to reflect upon the direct reduction industry. In the early 1980s, there was a flurry of interest in direct reduction, and many processes were proposed and developed. Of 16 processes we tracked then, only four have enjoyed commercial success. This shakeout is typical in an industry with many more aspirants than ultimate contenders. This process ensures that only those processes and equipment with the best technological features and economics win out, which benefits us all. The crucible of competition ensures survival of the fittest.

We are now going through a similar shakeout situation due to the strong steel market and high scrap prices from 1993 until 1998. By my count, there are about two dozen direct reduction processes that are being offered commercially. Undoubtedly, most of these will not be ultimately successful.

We continue to enhance the state-of-the-art for MIDREX™ Technology with innovations such as HOTLINK™ (see article on page 3), our system for transferring hot DRI directly to an EAF. Other developments to be featured in future issues of *Direct From Midrex* include high carbon DRI (up to 3.5 percent), and OXY+™, our system for producing additional reformed gas using partial oxidation of natural gas. We also are pleased that the first commercial FASTMET® Plant is now under construction in Japan, with start-up scheduled for April 2000 (see News & Views). We are staking our future upon continued innovation for the MIDREX Process and the successful commercialization of FASTMET and FASTMELT®.

It has been a fascinating journey with the MIDREX Process since 1969. Thirty years from now, it will be very interesting to look back at the DR industry and see what evolution has occurred.

MISSION STATEMENT

Midrex Direct Reduction Corporation will lead in the ironmaking technology industry by supplying superior quality services that provide good value for our clients. We will meet or exceed performance expectations, execute projects on time, enhance existing product lines, and develop or acquire new technologies. Our employees are the key to our success, and we are committed to encouraging them to grow professionally and personally.

HOTLINK™

HOT CHARGING DRI FOR LOWER COST AND HIGHER PRODUCTIVITY

By Stephen C. Montague
MIDREX Direct Reduction Corporation

Dr. W. Dieter Häusler
SMS Demag AG - Metallurgy

INTRODUCTION

There have been many modifications in Electric Arc Furnace (EAF) design, driven by strong pressure within the industry to reduce costs. Now, steel producers are looking at upstream process designs that can further improve efficiency. Hot charging is one such improvement that can reduce operating cost and increase EAF productivity. Various scrap-preheating technologies are now available, however, preheating of direct reduced iron (DRI) cannot be accomplished applying conventional off-gas preheating systems.

A variety of systems have been designed to convey hot DRI (HDRI) from a Direct Reduction (DR) furnace to an EAF. These systems include mechanical conveyors (apron type or drag chain), transport vessels (by rail or truck) and pneumatics. These systems, although functional, have inherent maintenance and reliability problems and typically require significant capital investment.

Midrex Direct Reduction Corporation has designed a system to transport HDRI to an EAF or similar melter using *gravity*. This system, called HOTLINK™, is primarily intended for greenfield sites and takes advantage of lower power and electrode consumption as well as higher EAF productivity which can be realized by hot charging.

ADVANTAGES OF HOT CHARGING

The concept of hot charging is not new. In fact, several MIDREX facilities have successfully charged HDRI into an EAF and realized significant savings. Hot charging is an effective means of lowering the cost per metric ton (tonne) of liquid steel because of the reduction in power and electrode consumption (Figures 1 and 2). As a rule of thumb, power consumption can be reduced about 20 kWh/tonne of liquid steel for each 100°C increase in the composite charge temperature. Electrode consumption is also reduced due to its linear relationship with power consumption (about 0.004 kg/kWh). The composite charge may consist of a mixture of HDRI, cold DRI or cold scrap.

In addition to the power and electrode savings, hot charging will increase EAF productivity for a meltshop designed to charge cold DRI. For a greenfield site, significant capital cost savings can be realized by downsizing the EAF electrical system in order to take advantage of this increase in productivity.

WHAT IS HOTLINK?

There are several methods of transporting HDRI from a Direct Reduction (DR) furnace to an EAF. HDRI can be conveyed pneumatically, carried by hot transport vehicles, transported by a variety of mechanical conveyors, or simply charged by gravity via a direct connection from a DR furnace to an EAF. Of all these options, gravity is the simplest, most reliable, least maintenance-intensive and is the basis for the HOTLINK system.

HOTLINK is suitable for greenfield facilities planning to use high percentages of DRI to make liquid steel or hot metal. It is the most efficient way to charge HDRI to an EAF or similar melting furnace because

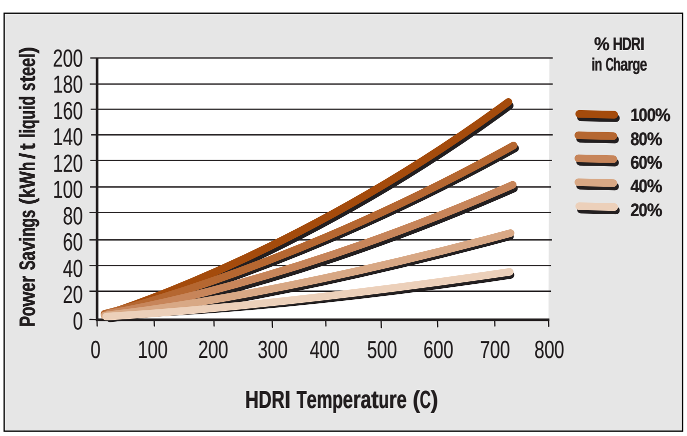


Figure 1 Estimated EAF power savings (kWh/ton)

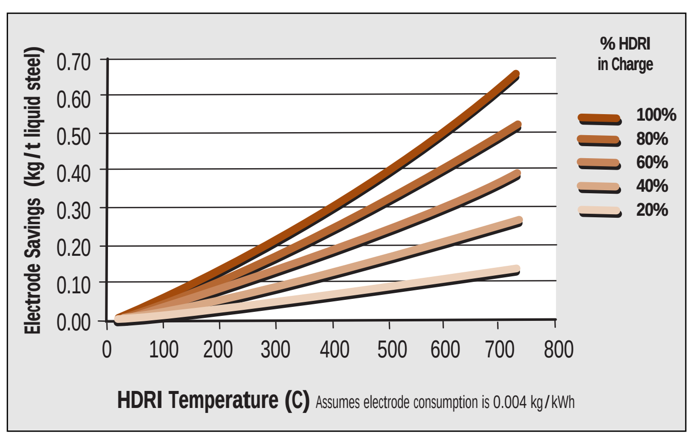


Figure 2 Estimated EAF electrode savings (kg/ton)

there will be:

- minimal temperature loss since the distance conveyed is short
- minimal HDRI degradation since material velocities are low
- no re-oxidation of material since the system is sealed
- low maintenance and high reliability since the system uses gravity for transport and is based on existing technology.

The incorporation of MIDREX™ Technology into the integrated steel mill is a natural fit. The MIDREX MEGAMOD™, first introduced in 1994, has consistently proven to achieve capacities of 1,000,000 tons/year to nearly 1,600,000 tons/year from a single DR furnace. A single MEGAMOD is the perfect match to "HOTLINK" with a single EAF to produce liquid steel or hot metal.

MIDREX has worked closely with SMS Demag to develop several system layouts to connect the DR furnace with the EAF. A variety of arrangements are possible and should be evaluated on a project-by-project basis.

HOTLINK DESIGN FEATURES

It is critical that the transport method from the DR furnace to the EAF be capable of delivering HDRI without adversely affecting product quality while providing maximum operational flexibility. Additionally, the transport system must be reliable, maintenance-friendly and easy to operate. The HOTLINK system is designed for these key requirements. Figure 3 shows a schematic representation of the material handling system for a typical HOTLINK arrangement.

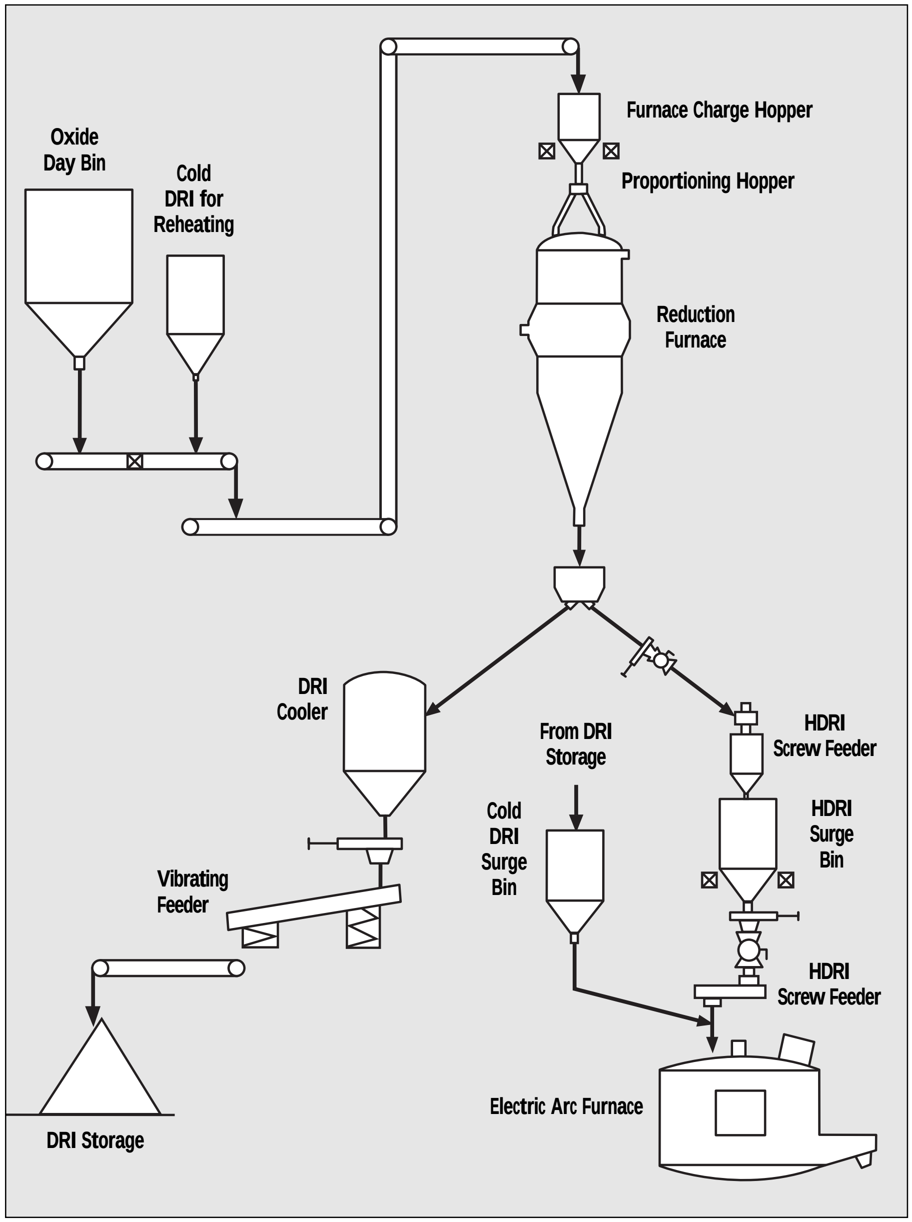


Figure 3 A schematic representation of the material handling system for a typical HOTLINK™ arrangement

Maintaining Product Quality

MIDREX can design a DR facility to produce up to 1,600,000 tons/year of hot and/or cold DRI. The plant is capable of providing DRI or HDRI up to 95 percent metallization with carbon from 0.5 to 3.5 percent.

HDRI Temperature

HDRI will be delivered to the inlet of the EAF at more than 700°C. Since the DR furnace is located close to the EAF and because the HDRI is transported by gravity, there will be minimal temperature loss of the HDRI from the discharge of the furnace to the inlet of the EAF (<20°C).

Making HDRI is not new to MIDREX. For more than 15 years, our HBI plants have been routinely briquetting HDRI at 700°C. These same plants have never attempted to maximize HDRI temperature because higher temperatures could damage the briquetting equipment. With DR furnace bed temperatures approaching 900°C in many plants, HDRI temperatures to the EAF would be maximized and could exceed 700°C.

Product Degradation

Gravity transport allows equipment to be sized for low material velocities. This is important because material velocity directly affects product degradation, not to mention the wear rate of the equipment. Low material velocities minimize unnecessary fines generation and promote longer equipment life. There will be minimal degradation of HDRI during transport from the DR furnace to the EAF.

Re-oxidation

From the discharge of the DR furnace to the inlet of the EAF, the HDRI is maintained in an inert atmosphere. The design philosophy is similar to the design of the briquetter feed legs of an HBI plant where inert gas, from the products of combustion in the reformer, provide the seal. There will be no re-oxidation or loss in metallization of the HDRI during transport to the EAF.

Operational Flexibility

Midrex recognizes the difficulty of matching a continuous process (the DR plant) with a batch process (the EAF). An HDRI surge bin, located between the DR furnace and the EAF, acts as a buffer to account for the difference in instantaneous throughputs of the two plants. Typically, there is also a significant difference in the availability of the DR plant (8,000 hours/year) and the EAF (7,200 hours/year) due to operational and maintenance schedules. A DRI cooler, also gravity fed, is incorporated into the design to provide maximum availability of both the DR furnace and the EAF. This allows the DR plant to maintain production (making cold DRI) when the EAF is down. Conversely, the EAF can also maintain production using cold DRI from storage when the DR plant is down.

Simultaneous Production of DRI and HDRI

Both DRI and HDRI can be produced simultaneously. In fact, any combination of cold DRI or HDRI can be discharged on demand (i.e., from virtually 100 percent cold DRI to 100 percent HDRI). The plant can *instantaneously* switch from producing DRI to HDRI, or vice versa, without stopping production.

Product Size Variation

HOTLINK can operate with large variations in product size and is designed to convey all product less than 200 mm diameter to the EAF.

Provisions for Cold DRI Usage

The material handling system has several provisions for cold DRI usage. These options are very important to insure that EAF availability and productivity are maximized. The integrated plant has the ability to do any one or all of the following:

- Charge cold DRI directly to the EAF
- Mix cold DRI with HDRI during charging the EAF
- Send cold DRI back to the DR furnace to be reheated
- Produce cold DRI for sale

If the DR plant is shut down while the meltshop is in operation, then cold DRI can be charged directly to the EAF through the cold DRI surge bin. If the plant would like to reduce cold DRI storage while the DR plant is on-line, then cold DRI from the surge bin can be blended with HDRI and charged to the EAF. This option will lower the composite charge temperature, thus reducing the savings in power and electrode consumption. Alternatively, a significant amount of cold DRI (up to 10% of furnace discharge) can be added back into the DR furnace for re-heating to avoid lowering the charge temperature. Since the cold DRI is already reduced, it will not consume much reductant. This effectively means the discharge rate of the DR furnace can be increased by almost the same amount of cold DRI that is being reheated. Certainly more energy is required to heat the additional throughput, but nearly the same quantity of oxide can be reduced.

Equipment Description

The HOTLINK concept is based on simple philosophy and solid principles. Utilizing gravity for transport reduces material handling requirements to the simplest possible form. Like gravity, the design of all ancillary equipment must be simple and reliable. Almost all equipment is currently being used at existing MIDREX™ Plants, which provides a low-risk, reliable and low-maintenance solution for hot charging.

DR Furnace

The DR furnace design is similar to that used at existing HBI Plants. The DR furnace has been raised about 15 m relative to a typical HBI MEGAMOD™. The discharge of the DR furnace is designed so that mass flow can be maintained in the reduction zone whether discharging hot, cold or both. A “pant leg”, located at the discharge of the DR furnace, directs product to the EAF and to the DRI cooler.

DRI Cooler

The DRI cooler is similar in design to the cooling zone of cold discharge furnaces. The cooler is designed to operate over a wide range of DRI flow rates, from minimal discharge up to the maximum output of the DR furnace. There is a dynamic seal leg located at the discharge of the cooler, and below that, a vibrating feeder controls the DRI discharge rate.

HDRI Surge Bin

Between the DR furnace and the EAF, a surge bin is used to stage the HDRI for EAF charging cycles. The HDRI surge bin is sized to accommodate marrying the continuous DR process with the batch EAF process. Dynamic seal legs are used to separate the surge bin from the DR furnace and seal the top of the DR furnace and the bottom of the DRI cooler. This seal leg allows material to pass while preventing the escape of combustible gases from the DR furnace into the bin.

The HDRI surge bin has more than enough capacity to completely charge one EAF furnace heat. A vertical screwfeeder, similar to the briquetter feed screw at HBI plants, is used to control the rate at which material is fed to the bin. A horizontal screwfeeder, remotely controlled from the EAF pulpit, discharges material from the bin to the EAF. Isolation valves are located at the inlet and outlet of the HDRI surge bin so that periodic maintenance can be conducted safely.

Cold DRI Surge Bin

Located within the DR furnace structure, the cold DRI surge bin gives the ability to feed cold DRI to the EAF when required. Sized to supply more than one EAF furnace heat, this bin can feed cold DRI directly to the EAF, even if the DR plant were shut down. If the DR plant is on-line, the cold DRI surge bin can still be used to blend cold DRI with HDRI before entering the EAF. This option can be particularly important to limit the size of DRI storage. The discharge rate of the cold DRI surge bin is controlled from the EAF pulpit.

MELTSHOP DESIGN FEATURES

Demag has developed a variety of meltshop arrangements to accommodate the HOTLINK system. At the steelmakers’ discretion, the Demag EBT furnace can be oriented so either the slag door, transformer or fourth hole are facing the DR furnace. Given this flexibility, the appropriate arrangement can be selected on a project-by-project basis.

Figure 4 shows a basic HOTLINK arrangement connecting to a Demag EBT furnace with the transformer positioned underneath the DR furnace structure. The tap hole and slag door are opposite one another and are located perpendicular to the flow of HDRI. The pulpit, attached to the other bay wall, is positioned opposite the furnace to facilitate visual control of the

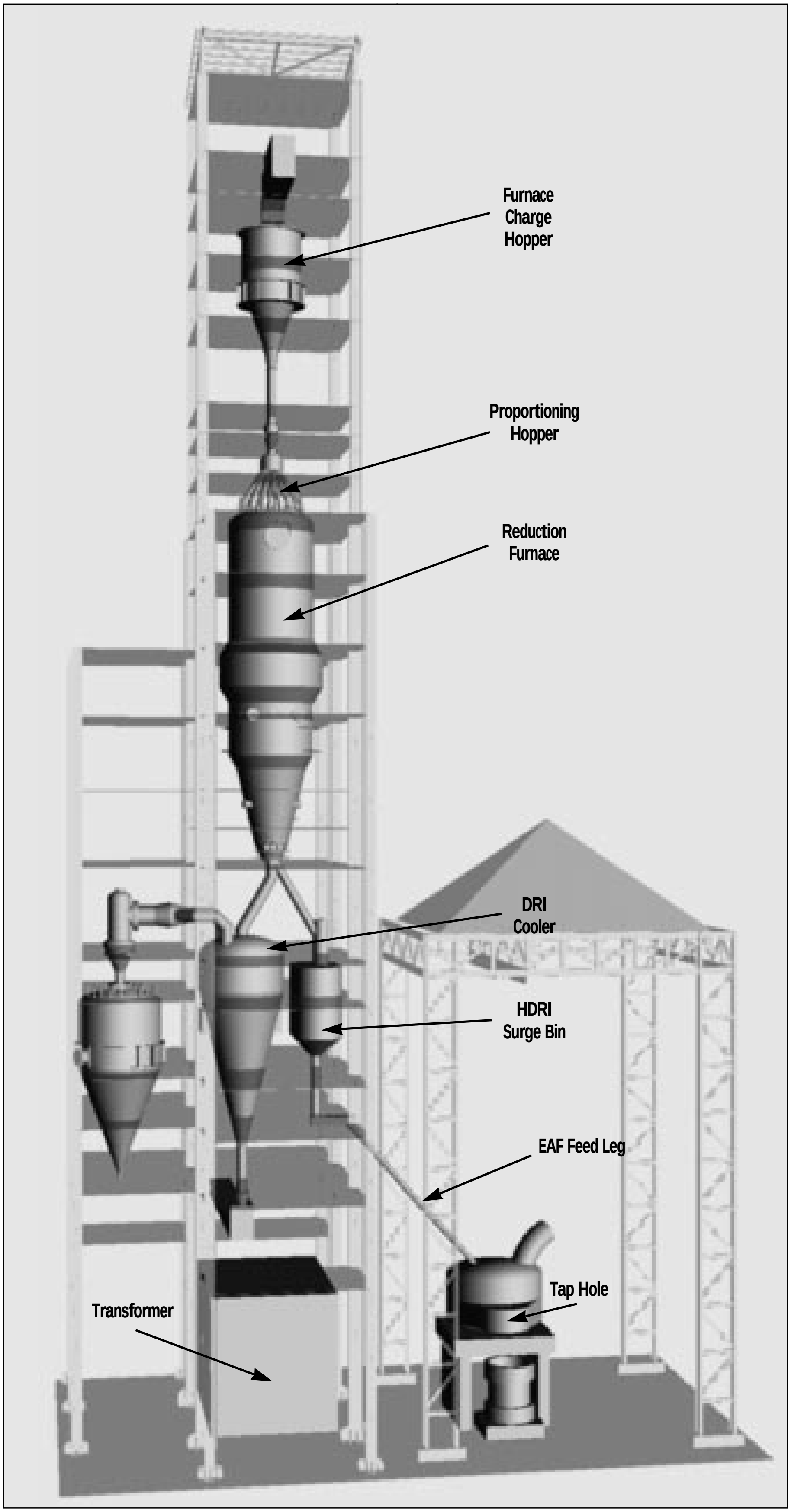


Figure 4 Typical HOTLINK arrangement with transformer located underneath the DR furnace

operation. The alloy storage bins are incorporated in the meltshop bay columns next to the DR plant.

The horizontal screwfeeder below the HDRI surge bin is remotely controlled from the EAF pulpit. The flow of cold DRI is also controlled from the EAF pulpit, using a separate feeder. From the HDRI and the cold DRI surge bins, material flows through a feed leg to the EAF. A small amount of inert gas is used to continually purge the feed leg to prevent product reoxidation. The feed leg extends through the EAF roof near the furnace center. This feed leg is fabricated of high-quality steel and is water-cooled. After being hydraulically lifted, the feed leg can be swung out of the feeding position when tilting the furnace for tapping.

There will be minimal degradation of the HDRI because of the relatively low material velocity and the short distance material is conveyed. Nevertheless, the HDRI will contain some small quantity of fines generated during the reduction process (depending largely on the quality and type of oxide feed). For this reason, the EAF feed leg has been designed to ensure conveyance of product fines into the liquid bath. This will increase HDRI yield and prevent problems in the off-gas system.

COST COMPARISON

To establish a base case for cost comparison, consider a stand-alone cold discharge MEGAMOD located adjacent to a meltshop with one EAF, ladle furnace and slab caster. In the base case, all EAF charge materials would be at ambient conditions (25° C).

The HOTLINK system would be designed to produce any combination of DRI from 100 percent hot to 100 percent cold. The meltshop would be designed to handle composite charges containing blends of HDRI, cold DRI and additional scrap (or return scrap) if required. The ladle furnace and slab caster would be the same as the base case. Following are the relative capital and operating cost comparisons.

Capital Cost

In the DR plant, extra equipment and additional structures are required for HOTLINK. Obviously, these items represent an increase in capital cost relative to a cold discharge facility. In the meltshop, however, capital cost is actually reduced.

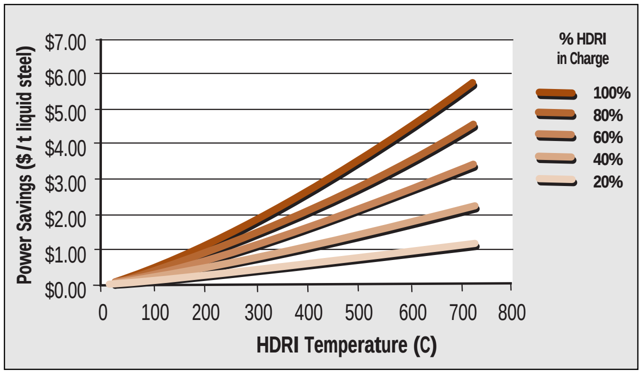


Figure 5 Estimated power savings ($/ton of liquid steel) based on electricity cost of $0.035/kWh

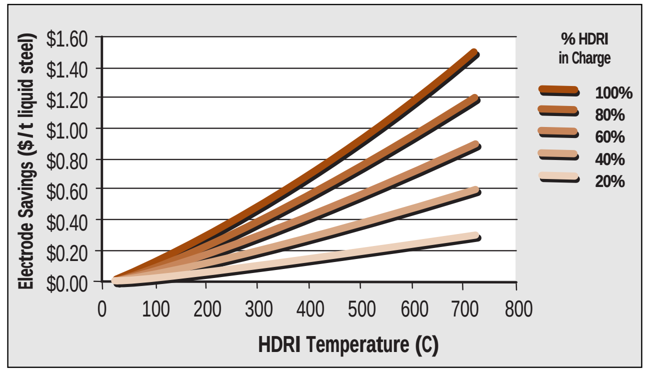


Figure 6 Estimated electrode savings ($/ton of liquid steel) based on 0.004 kg/kWh and $2.30/kg

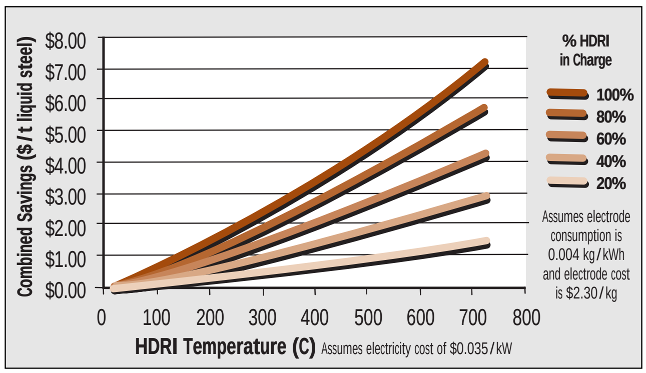


Figure 7 Combined power and electrode savings ($/ton of liquid steel)

The capital cost savings in the meltshop can be summarized as follows:

- The cold DRI feeding system within the meltshop is no longer required.
- The width of the melting bay can be decreased by about 15 percent.
- About 10,000 m^2 savings in site area due to the DR plant/meltshop proximity.

The capital cost savings in the meltshop will somewhat offset the additional capital required in the DR plant. Considering the plus and minus in the DR plant and the meltshop, the overall capital cost would increase by approximately 3 percent.

Operating Cost

In the DR plant, the operating cost is very close to that of the cold discharge plant in the base case. The specific consumption of oxide, power, and water will be essentially the same. The specific consumption of natural gas is expected to increase about 0.1 Gcal/ton of DRI relative to the base case. In the United States, this increase in natural gas consumption would cost around $1/ton of DRI (assuming natural gas cost of $9.92/Gcal [$2.50/mm BTU]).

In the meltshop, significant reduction in operating cost savings can be realized by using high quantities of HDRI. The operating cost savings generated by HOTLINK is primarily a function of electricity cost and the temperature of the materials being charged. Figure 5 shows the estimated power savings per tonne of liquid steel for an electricity cost of $0.035/kWh. Similarly, Figure 6 shows the estimated electrode savings per tonne of liquid steel assuming electrode consumption is 0.004 kg/kWh and the electrode cost is $2.30/kg. Figure 7 illustrates the combined savings from the previous two figures.

From Figure 7, charging 100 percent HDRI at 700°C would save nearly $7.00 per ton of liquid steel from power and electrode consumption alone. The power savings is proportional to electricity cost, therefore, if the cost of electricity were doubled ($0.07/kWh) then the power savings would double. This will have a dramatic impact on the above example increasing the savings from around $7.00 per ton of liquid steel to nearly $12.50 per ton of liquid steel.

Taking the energy savings for melting 100 percent HDRI at 700°C (Figure 7) and the additional cost for natural gas in the DR plant ($1/ton of DRI) into account, the estimated operating cost savings for the production of slabs would be about $6 per ton of slab. This would represent a decrease in operating cost of approximately 3 percent to 4 percent relative to the base case. For a plant producing 1.2 million tons of slabs per year, this would represent an annual saving of $7.2 million.

CONCLUSIONS

Hot charging is a viable means to reduce the operating cost of producing liquid steel or hot metal. Intended primarily for greenfield facilities, HOTLINK is the most efficient way to charge HDRI to an EAF or similar melter because gravity is used for transport. The concept is based on simple design philosophy and proven equipment, which provides low risk and high reliability.

HOTLINK is capable of producing any combination of HDRI and DRI (from 100 percent hot to 100 percent cold). The system is designed so that:

- HDRI is conveyed to the EAF at more than 700°C with minimal temperature loss during transport
- There will be no re-oxidation or loss of metallization
- DRI degradation during transport is prevented
- Operational flexibility is maximized

The capital cost of an integrated HOTLINK facility making slabs is about 3 percent higher than that of an equivalent facility equipped to charge cold DRI. The operating cost savings generated by charging 100 percent HDRI at 700°C would be between 3 percent to 4 percent based on electricity cost of $0.035/kWh. For a mill producing 1.2 million tons per year of slabs, this would represent a saving of $7.2 million per year resulting in a payback of less than two years.

The preceding paper was originally presented at the Iron & Steel Society's 57th Electric Furnace Conference held in Pittsburgh, PA, Nov. 14-16, 1999.

FINES TO SLABS IN WESTERN AUSTRALIA

A Case Study of the Integrated Mini-mill

By Robert M. Klawonn
Director – Sales
Midrex Direct Reduction Corporation

David C. Meissner
Manager – Research & Development
Midrex Direct Reduction Corporation

Paul D. Pupazzoni
Midrex Australia
Australian Commercial Management
Perth, WA, Australia

Introduction

Western Australia is very well known for its large iron ore reserves, supplying more than 143 Mt of iron ore products to East Asia and Europe in 1998.

Western Australia, with its strong political and economic ties to Southeast Asian countries such as Taiwan, China, Japan, Korea, Malaysia, etc., is well-positioned to become a long-term, high-quality supplier of steel products to this growing region. Furthermore, the WA government has long supported the concept of value-added iron ore sales, and is ready to act.

The final piece of the puzzle has now fallen into place, as energy prices in WA have reached levels competitive with other industrialized countries. In fact, WA has two key ingredients necessary to make it a very cost-competitive supplier of steel to the Asian markets: abundant iron ore and natural gas.

While pellet plants have long been built in multi-million ton sizes, only recently have iron ore direct reduction plants reached a similar scale. Only the MIDREX® Direct Reduction Process has been proven to achieve capacities of 1.6 million tons per year (Mt/y) or more in a single module, pushing capital cost well below US$140 per annual ton. These economies of scale are detailed in the following case study of a mini-integrated slab-making facility built in WA using iron ore fines as the feed material. The location is Oakajee, WA, and it is adjacent to the industrial estate and port facility being proposed by the WA government.

The concept has been promoted by several parties, including Kingstream Steel, Austeel and more recently by the Oakajee Steel project being developed by North West Shelf Gas, and the iron ore owner Mt. Gibson Iron NL.

Plant Concept

The process plant concept is as follows. Direct reduction grade fine iron ore concentrate (pellet feed) is delivered to the plant by way of slurry pipeline or dedicated rail system. The concentrate is delivered to the pellet plant ready for mixing, balling and induration. The iron ore pellets are fed to the MIDREX MEGAMOD™ Shaft Furnace, and reduced using natural gas to produce DRI. The DR plant concept also includes the state-of-the-art HOTLINK™ hot DRI delivery system, in which hot DRI is fed directly to the EAF at 700°C. Liquid steel is processed by the ladle furnaces and delivered to the twin-strand conventional thickness slab caster. Slabs will be delivered on board ocean-going vessels for transport (FOB). Thus, using fine iron ore concentrate as the input and slabs as the product, we have the following plant configuration:

1) Pellet Plant (3.9 Mt/y)
2) MIDREX DRI Plant with HOTLINK (2.8 Mt/y)
3) Slab-making Facility (2.4 Mt/y)
4) Interplant Services (as required)

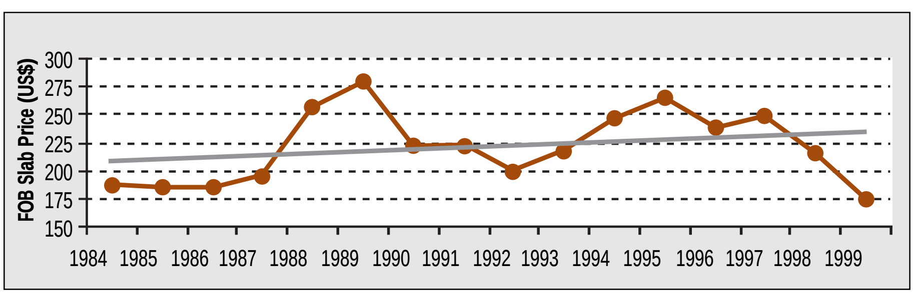


Figure 1 Historical slab prices (actual US$-FOB)

Capital Cost and Financing

An approximate capital cost breakdown is shown below. It is envisaged that the plant will be funded with a 70:30 ratio of debt to equity. Debt is financed at 8 percent interest, and the exchange rate is assumed steady at 0.65 US$/A$ for the life of the project. All interest during construction is included in the pre-operational costs below. A detailed but basic financial model was generated using these assumptions, as well as the following considerations for selling price and operating costs.

Pellet Plant	US$ 210 Million
MIDREX Plant w/HOTLINK	$ 410 Million
Meltshop & CCM	$ 330 Million
Interplant	$ 90 Million
Total EPC Cost	**US$ 1,040 Million**
Pre-Operational Costs	$ 160 Million
Total Project Cost	**US$ 1,200 Million**

Slab Selling Price

In 1998, approximately 24 million tons of slabs were exported throughout the world.

It is unfortunate that the most recent trough of steel prices was experienced at the same time as the Asian crisis, causing prices to fall much further than any historical lows (see Figure 1).

FOB prices for merchant slabs are expected to average US$225 per ton (A$346 per ton) over the next 11 years.

Operating Cost Detail

Before we can establish operating costs for the mini-integrated steel mill facility, we must first establish the input costs which can be assumed for a Western Australian plant. The unit costs assumed for this plant are outlined in Table I.

Pellet Plant Operating Costs

We have assumed a pelletizing plant capable of producing approximately 3.90 Mt/y of iron oxide pellets of approximately 67.5 percent Fe. The iron ore concentrate is high-quality magnetite (Fe_3O_4) with an iron content of approximately 70 percent Fe. The pellet plant converts the iron ore concentrate into hematite pellets (Fe_2O_3) for approximately A$10 (US$6.50) per ton, plus the cost of concentrate. Recycled dust, fines and sludges from the DR plant are used to minimize waste.

DR Plant Operating Costs

We have assumed a MIDREX™ Direct Reduction Plant capable of producing 2.80 Mt/y of DRI with 93 percent metallization and 1.5 percent carbon produced from two MIDREX MEGAMODS at 1.40 Mt/y each. The DR plant converts the oxide pellets into hot DRI which is then transferred to the EAF via the HOTLINK system.

	(A $)	Unit	(US$)
Natural Gas	2.00	GJ	1.30
Concentrate	34.00	MT	22.10
Electricity	0.040	kWh	0.026
Water	0.50	m3	0.33
Labor	34.00	mh	22.10
Oxygen	0.06	Nm3	0.04
Argon	0.75	Nm3	0.49
Carbon	0.27	kg	0.18
Internal Scrap	30.00	MT	19.50
Lime	0.09	kg	0.06
Electrodes	5.00	kg	3.25
EAF Refractory	1.20	kg	0.78
CCM Refractory	4.50	kg	2.93
Port Handling Fee	8.00	MT Slabs	5.20

Table I Input costs

DRI Capacity: 2.80 MTPY
Exchange Rate: 0.65US$ / A$

ITEM	Consumption (per ton DRI)	Unit Cost (A$)	Cost (A$ / ton DRI)
Oxide Pellets	1.40 MT	42.97	60.15
Electricity	110.00 kWh	0.04	4.40
Natural Gas (HHV)	10.50 GJ	2.00	21.00
Make-Up Water	0.30 m3	0.50	0.15
Labor	0.11 MH	34.00	3.74
Maint. / Consum.	6.00 A$		6.00
		Cumulative cost per ton DRI:	**A$ 95.44**
			US$ 62.04
		Cost for this step:	**A$ 35.29**
			US$ 22.94

Table II DR plant operating costs

HOTLINK delivers DRI by gravity directly into the adjacent EAF without temperature loss, metallization loss or degradation. Hot DRI from HOTLINK is delivered to the EAF at over 700°C.

The processing cost per ton of DRI is approximately A$35 (US$23), plus the cost of pellets. Using a ratio of 90 percent hot DRI and 10 percent cold DRI results in a significant power and electrode savings at the EAF. In addition, the waste materials (sludges, fines, dust) are recycled back to the pellet plant to minimize the iron ore consumption per ton of DRI. The cost detail for the direct reduction step is shown in Table II.

EAF Plant Operating Costs

We have assumed a meltshop with two EAFs capable of producing 2.48 Mt/y of liquid steel. Each EAF receives a combination of hot and cold DRI. The plant is set up so that each EAF is linked to one MIDREX MEGAMOD. However, the cold DRI is produced and stored in a common area, so it can be delivered to either EAF for maximum flexibility. The processing cost per ton of liquid steel is approximately A$52 (US$34), plus the cost of DRI. Internal scrap is recycled at a cost of A$30 per ton. During normal operation, hot DRI is delivered as required by gravity to the EAF via HOTLINK at over 700°C, and on average should constitute 90 percent of the DRI feed to the EAF resulting in a significant power and electrode savings.

Ladle Furnace Operating Costs

We have assumed a meltshop with two ladle furnaces capable of processing 2.48 Mt/y of liquid steel. The processing cost per ton of liquid steel in the LF is approximately A$14 (US$9), plus the cost of liquid steel from the EAF.

Continuous Caster Operating Costs

We have assumed a traditional thick slab caster capable of producing 2.40 Mt/y of slabs. The processing cost per ton of slabs is approximately A$23 (US$15) plus the cost of liquid steel from the LF.

With total operating costs for the plant at US$132 per ton of slabs, this project is one of the most competitive slab producers in the world!

Other Costs

In addition to the operating costs within each process plant shown above, we must also add the cost of administrative fees for company management, sales, etc., as well as slab handling and port handling fees. An allowance has been made for these two items.

Operating Cost Summary

Table III on the following page shows the operating costs broken down by process. Concentrate costs are the single largest expense at US$35 per ton of slabs (25.2%), followed by the EAF costs and DR plant costs.

Financial Results

Using the above financial inputs, and slab selling price of US$225 per ton as the base case for the model, we calculate an IRR for the equity investor of 18.9 percent after tax, after 20 years of operation and using a 70:30 debt-to-equity ratio. Assuming the project was completely funded by equity, the total

Exchange Rate:	0.65 US$/A$				
	Annual Cost (x 000's)		Specific Cost per ton slabs		
PLANT	A$	US$	A$	US$	%
Concentrate	129,282	84,033	53.87	35.01	25.2%
Pellet Plant	39,141	25,442	16.31	10.60	7.6%
DR Plant	98,812	64,228	41.17	26.76	19.2%
EAF	129,605	84,243	54.00	35.10	25.2%
LF	35,266	22,923	14.69	9.55	6.9%
CCM	54,897	35,683	22.87	14.87	10.7%
Sub-Total	A$ 487,002	US$ 316,551	A$ 202.92	US$ 131.90	94.8%
Gen'l & Admin.	7,800	5,070	A$ 3.25	2.11	1.5%
Port Fees	19,200	12,480	A$ 8.00	5.20	3.7%
Total Costs	A$ 514,002	US$ 334,101	A$ 214.17	US$ 139.21	100.0%

Table III Operating cost summary breakdown by process

Basis	
Slab Selling Price (FOB)	US$ 225/ton
Operating Cost (FOB)	US$ 135/ton
Capital Cost	US$ 1,040 Million
Pre-Contract Cost	US$ 160 Million
Total Project Cost	US$ 1,200 Million
Construction Period	30 months
Loan Payback Period	12 years
Loan Interest Rate	8% p.a.
Loan Grace Period	None
Debt : Equity Ratio	70 : 30
IRR Equity Investor, after tax:	
After 10 yrs. Operation	13.4%
After 15 yrs. Operation	17.4%
After 20 yrs. Operation	18.9%
Equity Investor Payback Period: 4.8 years operation	
IRR Overall Project, after tax:	
After 10 yrs. Operation	7.3%
After 15 yrs. Operation	10.8%
After 20 yrs. Operation	12.2%
Overall Project Payback Period: 6.5 years operation	

Table IV Financial results

project IRR is 12.2% after tax. The equity investor achieves payback of its investment after only 4.8 years of operation, and payback of the entire investment of US$1.20 billion occurs after 6.5 years of operation. The summary is shown in Table IV.

One of the biggest concerns of companies contemplating an investment of this magnitude is capital cost overruns. The BHP HBI plant at Port Hedland, and its abnormally large price tag, has made many investors wary of Western Australian construction conditions. While the specific construction costs are definitively higher than many other regions of the world, the capital cost specified in this study is also higher than would be expected elsewhere. In fact, these figures compare favorably with those recently proposed for the Kingstream project in Western Australia, which was bid on a fully competitive basis for a turnkey project.

Conclusions

A greenfield steelmaking plant is not only viable in Western Australia, it is very profitable for the equity investor. The combination of huge quantities of iron ore, low-cost energy, and politically stable government should be very attractive to foreign investors as well as domestic mining companies looking toward value-added projects.

It is unfortunate that recent steel prices have dipped well below all expectations, due largely to the Asian financial crisis, and its coinciding with a steel industry downturn. Recovery is already occurring, and by the time this project starts up, prices should have already peaked.

What is most promising for WA is that this plant has one of the lowest operating costs in the world for slabmaking, and should be profitable even in the worst market downturns. The MIDREX™ Direct Reduction Technology is well suited to the use of fine iron ore as the combination of pellet plant and MIDREX Plant result in a very cost-competitive plant, both from a capital cost and operating cost basis. The economies of scale provided by two MIDREX MEGAMODS, and their very good match with pellet plant, EAF, LF and CCM capacities, provide the owner with proven processes with little risk.

The after-tax IRR of 18.9 percent should prove very attractive to the steel industry investor, as should the project IRR of 12.2 percent.

Midrex News & Views

EMCI Enters Agreement with Flohe GmbH & Co.

On October 25, 1999, EMC International, Inc. of Pittsburgh, Pennsylvania, announced that they have entered an exclusive License Agreement with Flohe GmbH & Co. of Castrop-Rauxel, Germany, for the sale and manufacture of Current Conducting Electrode Arms. EMCI has become the exclusive representative of Flohe in the North American Free Trade Zone (United States, Mexico, and Canada).

The agreement covers Flohe-designed equipment, including:

- Copper Clad Steel and Aluminum Arm Body Designs
- Low Loss Electrode Column Heads
- Integral Electrode Holders
- DC EAF Current Conductive Furnace Bottom Assemblies

Flohe GmbH & Co. has over 60 years of high current engineering experience and has developed the premier state-of-the-art technology.

Two MIDREX Plants Reach One Million Ton Milestone

In September, the COMSIGUA HBI Plant in Matanzas, Venezuela, produced its one millionth ton of HBI, reaching its full rated capacity within the first year of operations.

On November 7, 1999, Mobile DRI, in Mobile, Alabama, USA, produced its one millionth ton of DRI. The two MIDREX Modules began operations in late 1997 and early 1998.

Midrex Appoints New Sales Manager and Manager of Technical Services

Midrex is pleased to announce the promotion of Rob Cheeley to the position of Sales Manager. Rob has been with Midrex for over six years, the past three and a half with the Sales Department. During this time Rob has increasingly demonstrated the skills necessary to carry out the duties and responsibilities required of Sales Manager. His technical knowledge of the MIDREX Process will continue to serve him well in his new position.

Rob Cheeley
Sales Manager

Rob has a BS in Chemical Engineering from Texas A & M, an MBA from the University of Houston and is a registered Professional Engineer in the state of North Carolina.

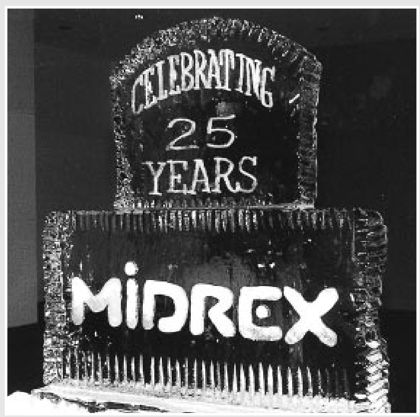
Antonio Elliot has been named as the new Manager – Technical Services. Tony has over 15 years of technical experience in the operation, start-up, engineering, and construction of MIDREX™ Direct Reduction Plants. Prior to joining Midrex, Tony held various technical positions at SIDERCA in Argentina, SIDOR in Venezuela, and with Hatch Associates Ltd. in Toronto, Canada. In his new position, Tony will serve as the primary liaison between Midrex and its licensees.

Antonio Elliot
Manager-
Technical Services

Midrex Celebrates 25th Anniversary

Midrex employees past and present gathered at the Charlotte Convention Center for dinner and dancing to celebrate the 25th Anniversary of the formation of Midrex Corporation and 30 years of the MIDREX Process. Over 170 people attended the event including employees from Midrex's sister company, Professional Services International, Inc., and representatives from Midrex's parent company, Kobe Steel, Ltd.

Special guests at the celebration included Evelyn Sanzenbacher and Jon Molnar, wife and grandson of the late Chuck Sanzenbacher, and Eileen and Matthew Ahrendt, wife and son of the late Bill Ahrendt. Each of the special guests received prints of the "Pioneers of the MIDREX Process" plaque which hangs in the lobby of Midrex Headquarters (see *Direct From Midrex* 3rd Quarter 1999, p.3). Prints of the plaque were also given to the other 'Pioneers' in attendance, including Winston Tennies, Bruce Kelley, David Meissner, and Robert Escott. In a letter addressed to the employees of Midrex, Donald Beggs, Jr., son of the Father of the MIDREX Process, Donald Beggs, Sr., thanked the company for honoring his father and the process to which he dedicated the better part of his life.



Ice sculpture commemorates Midrex's 25th Anniversary

Mr. M. Muramoto, General Manager of International Operations for Kobe Steel, read remarks on behalf of Kobe Steel executives, congratulating Midrex on the success it has enjoyed over the past 25 years and wished Midrex greater success in the future.

Kobe Steel Signs Contract With Nippon Steel for First FASTMET Plant

Kobe Steel, Ltd. has announced that the world's first commercial-scale iron-bearing waste recycling plant using the FASTMET® Process will begin operation in the second quarter of 2000 at Nippon Steel Corporation's Hirohata Works in Himeji, Hyogo Prefecture, Japan.

Kobe Steel is responsible for designing, fabricating and constructing the waste treatment plant, which will have a nominal capacity to process 190,000 metric tons per year of iron-bearing waste. The 140,000 metric tons of DRI produced by the facility will be charged hot to the BOF at the Hirohata Works.

In this application of the FASTMET Process, steel mill waste in the form of iron oxide dust from steelmaking operations and mill scale is collected and formed into pellets. The pellets are fed to a rotary hearth furnace, which reduces the pellets using coal as the reducing agent. The high-purity reduced iron is then recycled for use in steelmaking. The new plant will enable Nippon Steel to produce direct reduced iron (DRI) with a metallization of over 90 percent. Recycling the dust is an efficient use of steel by-products and enables Nippon Steel to greatly reduce iron-bearing wastes.

The FASTMET Process offers an attractive alternative technology to produce DRI, a premium quality raw material or supplement in EAF steelmaking, blast furnace steelmaking and foundry operations.

DIRECT FROM MIDREX

published by

Midrex Direct Reduction Corporation
201 South College Street, Suite 2100
Charlotte, NC 28244
USA

U.S. POSTAGE
PAID
BULK RATE
PERMIT NO. 1793
CHARLOTTE, N.C.

ADDRESS CORRECTION REQUESTED