HOTLINK™

HOT CHARGING DRI FOR LOWER COST AND HIGHER PRODUCTIVITY

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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

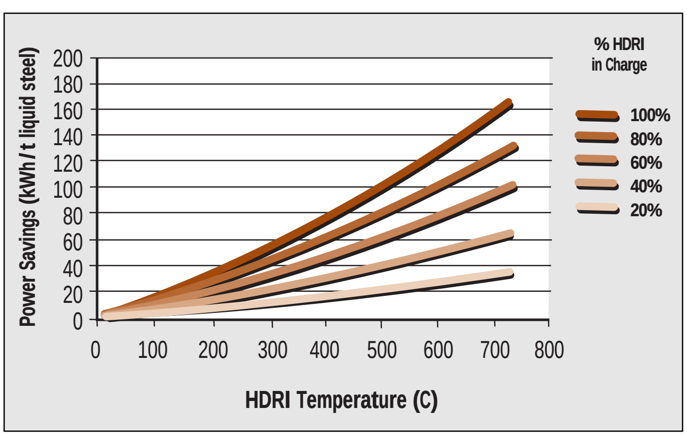

Figure 1 Estimated EAF power savings (kWh/ton)

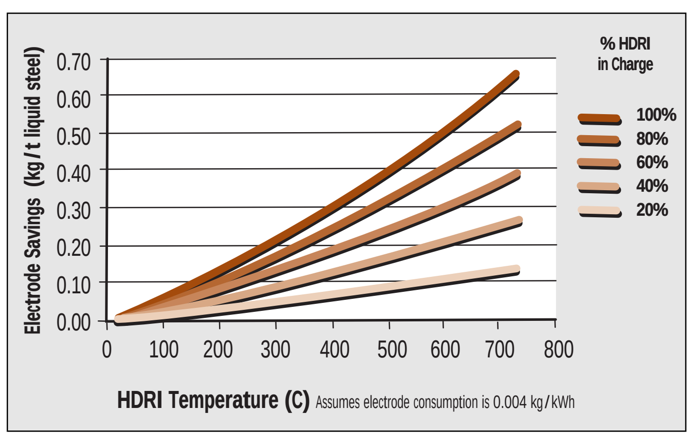

Figure 2 Estimated EAF electrode savings (kg/ton)

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.

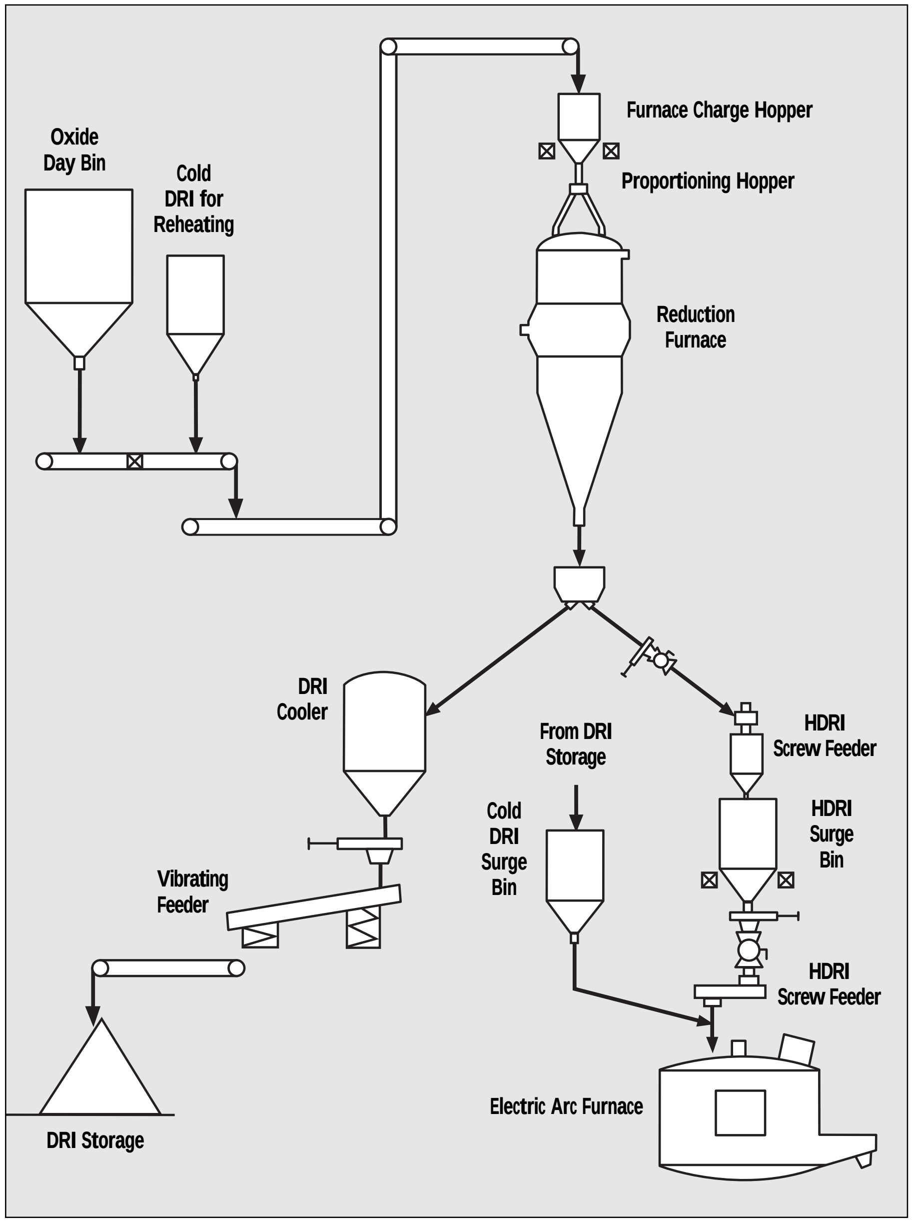

Figure 3 A schematic representation of the material handling system for a typical HOTLINK™ arrangement

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

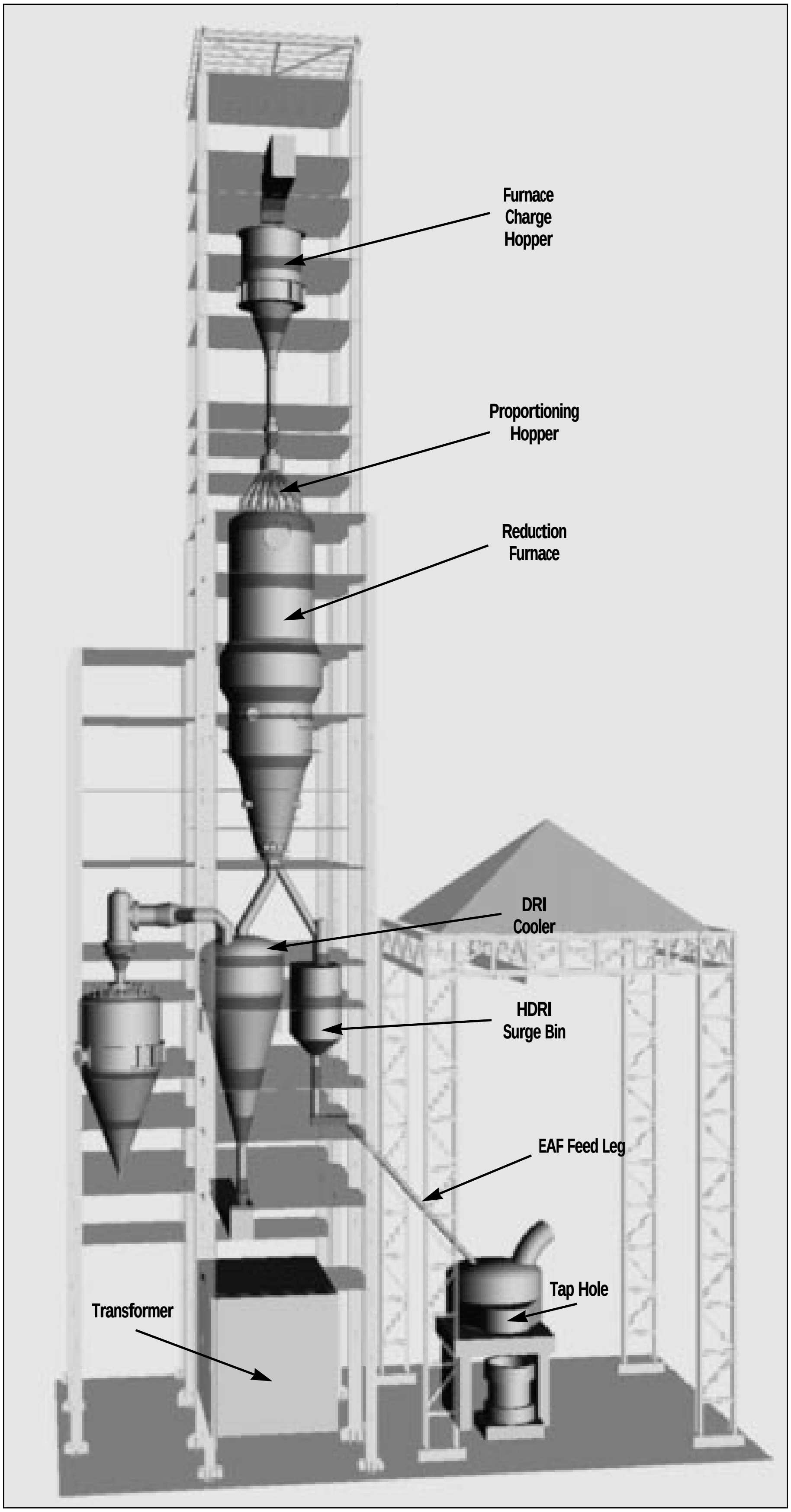

Figure 4 Typical HOTLINK arrangement with transformer located underneath the DR furnace

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.

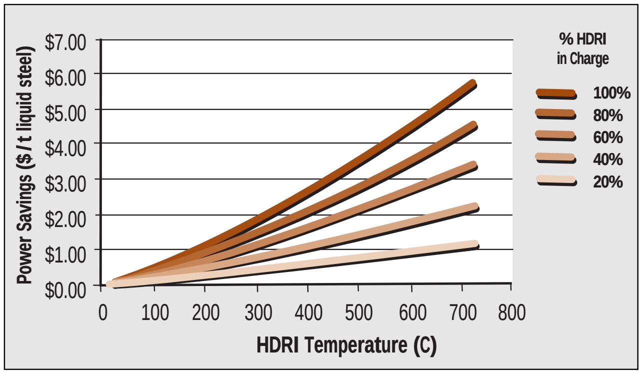

Figure 5 Estimated power savings ($/ton of liquid steel) based on electricity cost of $0.035/kWh

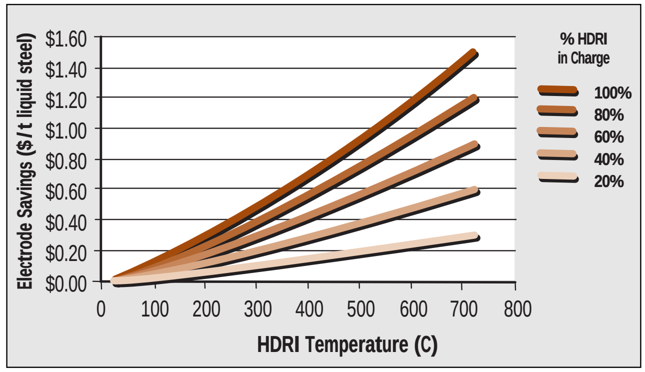

Figure 6 Estimated electrode savings ($/ton of liquid steel) based on 0.004 kg/kWh and $2.30/kg

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.

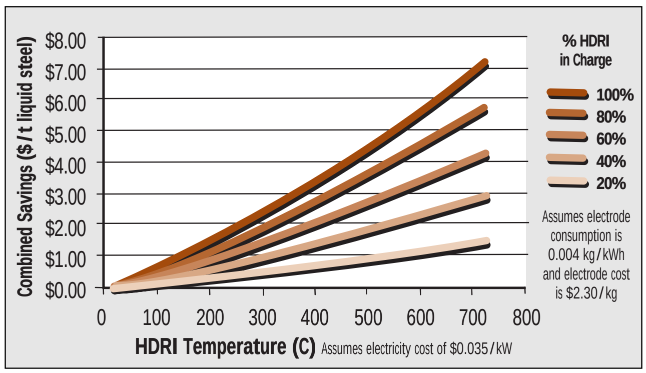

Figure 7 Combined power and electrode savings ($/ton of liquid steel)

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.

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