MIDREX® HOT BRIQUETTED IRON --
A DIRECT REDUCED IRON PRODUCT FOR OXYGEN STEELMAKING

By

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INTRODUCTION

To date, the primary use of direct reduced iron (DRI) has been in the electric arc furnace. Relatively little DRI has been used for cooling applications in oxygen steelmaking since most DRI produced is in the form of pellets and lump. Because of their low density, DRI pellets and lump are not highly effective in penetrating the thick slag layer in oxygen steelmaking.

The MIDREX® Direct Reduction Process has provided steelmakers an energy-efficient, environmentally attractive and less capital intensive alternative to the blast furnace for 15 years. Now Midrex has added another dimension to its industry-leading process by incorporating a commercially proven hot briquetting technology into the basic MIDREX Direct Reduction Process. The product, known as MIDREX® Hot Briquetted Iron (HBI), is highly metallized and densified, making t an excellent cooling agent for oxygen steelmaking.

THE MIDREX® HOT BRIQUETTING PROCESS

Midrex and its three construction licensees used their combined technical expertise in designing an optimum hot discharge and hot briquetting system for the MIDREX Process. The final design required only minor process changes and incorporates commercially available hot briquetting equipment

As shown in Figure , the most significant process modification to the MIDREX Process s the elimination of the cooling gas circuit. One of the main features of the MIDREX Process is the high quality reducing gas produced in the MIDREX Reformer. With the high quality of the reducing gas, metallization is completed in the reduction zone of the shaft furnace. Thus, the cooling zone is used only for adjusting carbon content and cooling the product Therefore, by eliminating the cooling zone in the MIDREX Process, there is no loss of metallization control. Concerning carbon control, Midrex has developed a proprietary technique as part of the MIDREX® Hot Briquetting Process for maintaining up to 1.5% carbon content in the product

The MIDREX Hot Briquetting Process retains the reliable and low cost dynamic seal gas system used in all existing MIDREX Plants for containing reducing gases in the shaft furnace. However, the discharge seal gas circuit has been modified to accommodate the hot discharge of DRI. This seal gas system is a closed loop gas circuit which dedusts, compresses and reheats the gas. This feature allows optimum control of product temperature and atmosphere. After reduction in the standard MIDREX™ Shaft Furnace, the hot product is continuously discharged into a chamber where temperature and atmosphere are carefully controlled to insure high product quality and optimum briquetting temperatures. The hot product is then fed continuously to the hot briquetting machines. For a MIDREX™ Series 600 Plant, three hot briquetting machines are installed. The briquetting machine's capacity allows full production with only two machines on line, permitting the third machine to be maintained without affecting production rates. This design insures maximized overa plant availability. In fact, when the proven reliability of the basic MIDREX Process is combined with an installed spare philosophy hot briquetting system, no impact on overall plant reliability is expected. Maximum plant availability has been one of the many outstanding features of the basic MIDREX Direct Reduction Process The MIDREX Hot

Briquetting Process has been carefully designed to continue this tradition.

After the hot DRI product is briquetted, the briquette sheets are broken into single briquettes using a proprietary technique designed by Midrex. The briquettes, still hot, are cooled in a quench tank to prevent reoxidation. The quench time is controlled so that after removal from the quench tank, sufficient heat remains to completely drive off the water from the briquettes. At this point, the highly compacted direct reduced iron briquettes, also referred to as hot briquetted iron (HBI), are sent to product storage. Typical chemical and physica specifications for MIDREX HBI are given in Tables I and II, respectively.

PRESENT DAY COOLANT PRACTICES

Until recently, the BOF had changed little from its original concept of 20 years ago. Now, however, significant technological changes in gas blowing techniques have dramatically improved the operating flexibility and product quality of the oxygen furnace. In fact, even the name "BOF" is no longer appropriate for describing all of the newly developing processes. Rather, the term "oxygen steelmaking" is used to include all processes which use primarily gaseous oxygen to convert a charge of hot metal, scrap, fluxes and coolants into steel.

There is another facet of oxygen steelmaking which is beginning to receive increased attention from steelmakers -- cooling practices. Coolants are needed in oxygen steelmaking because heat is released during refining. In oxygen steelmaking, gaseous oxygen reacts with carbon silicon and manganese to form CO, SiO_2, and MnO. All of these reactions generate heat. Currently, oxygen steelmakers use a combination of scrap and iron ore, imestone, or direct reduced iron for cooling applications.

Coolants are required in oxygen steelmaking at various times during the heat and for various purposes. The largest coolant addition is the initial scrap charge added at the beginning of a new heat just prior to pouring of the hot metal. This coolant addition can be anywhere from 5% to 30% of the total charge. In order to receive the scrap and hot metal charge, the oxygen furnace must be tilted towards the charging aisle. After receiving the scrap and hot metal charge, the furnace is raised to the vertical psoition, the oxygen lance is lowered and the heat is ready to begin

When the furnace is vertical, all additional raw materials, fluxes and coolants can only be charged through the overhead material handling system, consisting of bins and charge chutes, as shown in Figure 2. Since scrap cannot easily be charged through the overhead material handling system, oxygen steelmakers have traditionally depended on iron ore pellets and imestone for cooling applications during and after the heat.

In discussing oxygen furnace cooling requirements, it is convenient to categorize coolant applications into four distinct requirements:

<u>Thermal Balancing</u> Coolants charged with the fluxes after ignition to thermally balance the charge

<u>Static Trim Cooling</u> Coolants charged after furnace turndown in a static controlled furnace

<u>Dynamic Trim Cooling</u> Coolants charged continuously during the final minutes of the blow in a dynamically controlled furnace

<u>Ladle Cooling</u> Coolants charged to the steel ladle to achieve optimum pouring temperature

Currently, many steelmakers use iron ore pellets in oxygen furnaces for coolant applications The ron ore is readily available, can be stored in the overhead flux bins and can be conveniently charged anytime during the heat. Steel bath cooling is achieved by melting and reducing the iron ore The reducing reaction consumes carbon and evolves gas in accordance with the following reactions:

$$Fe_2O_3 + 3C + heat \longrightarrow 3CO + 2Fe$$

Depending on the time of an addition and the steel chemistry, some recovery of iron into the steel bath is expected, ranging up to 75%

There are several disadvantages in using iron ore as a coolant. The evolved carbon monoxide often results in furnace slopping, which can translate into decreased steel yield. Also, although some recovery of iron units into the steel bath is effected, much of the iron is lost into the slag Finally, iron ore pellet additions often result in an erratic cooling effect, thus decreasing overall operating control of the oxygen furnace

When limestone is used as a furnace coolant, cooling is achieved primarily by melting and calcining the stone. If sufficient carbon is available when the limestone is charged, some decarburization may be effected by the evolved carbon dioxide. This reaction is also endothermic and will increase the overall cooling effect according to the following reactions:

$$CaCO_3 + heat \longrightarrow CaO + CO_2$$

$$CO_2 + C + heat \longrightarrow 2CO$$

Compared to iron ore pellets, limestone results in a consistent cooling effect. Also, imestone is very inexpensive. The main disadvantage with the use of limestone is the complete absence of iron units. For this reason, iron ore pellets are often preferred over limestone, despite the higher raw material cost

HBI is rapidly gaining acceptance as an excellent cooling agent, superior to iron ore pellets and imestone A number of major steelmakers, including

Bethlehem Steel, have already adopted this practice. Using MIDREX HBI, an oxygen steelmaker can improve the furnace operating control and lower liquid steel cost through an increase in yield. The overall benefits in using MIDREX HBI as a coolant in oxygen steelmaking are:

Improves liquid steel yield

Improves furnace operating control

Reduces slopping compared to iron ore use

Results in predictable cooling effect due to effective slag penetration and fast melting characteristics

Simplifies material handling requirements compared to DRI and iron ore pellets or lump ore.

USE OF HBI FOR THERMAL BALANCING

Thermal balancing is required because actual hot meta chemistry and temperature varies and often is not known at the time the scrap charge is prepared. Thus, the steelmaker will prepare a scrap charge which is slightly less than required, to insure sufficient heat is available. Once the actual hot metal analysis is received from the charging floor, a computerized charge calculation program will calculate the additional coolant required in order to thermally balance the heat. This thermal balancing coolant addition is added along with the flux additions after the oxygen blow has "ignited" the charge

The physical and chemical properties of MIDREX HBI make it an idea coolant for therma balancing. MIDREX HBI is easily discharged via the overhead bins and charge chutes. Because of HBI's high density, HBI will effectively penetrate the slag layer, thus resulting in a consistent and predictable cooling effect. Since MIDREX HBI is highly metallized, a high recovery of ron units into the steel bath is achieved, resulting in a significant increase in liquid steel yield These benefits enable a steelmaker to imorove his overall control of the process and to lower iquid steel cost through increased yield.

TRIM COOLING

Trim cooling is very similar to thermal balancing. However, whereas a thermal balancing coolant addition occurs near the beginning of the heat, a trim cooling addition is at the end of a heat.

Trim cooling is also somewhat different in a static controlled furnace compared to a dynamic controlled furnace. Static and dynamic control refer to the operating system used in making final temperature and carbon adjustments prior to tapping. A static controlled furnace is one where no temperature or carbon measurements are taken until after the oxygen blow is completed. In a dynamic controlled furnace, actual temperature and carbon are measured just prior to the end of the oxygen blow, usually by using a sub-lance, as shown in Figure 2.

In a static controlled furnace, once the pre-calculated oxygen blow is completed, the lance is raised and the furnace is turned down (tilted) in order to manually obtain a sample of the liquid steel. Often, the heat is too hot or too high in carbon or both. In these cases, a coolant and additional oxygen may be required. The furnace is returned to its vertical position and the required coolant is charged

In recent years, some oxygen steelmakers have installed dynamic control systems to improve turndown control. By enabling the steelmakers to determine actua temperature and carbon, adjustments can be made prior to the end of the oxygen blow. In dynamically controlled furnaces, most operators will charge the furnace "high-and hot," meaning enough hot metal is charged to insure that the carbon amount at turndown will be on the high side and the temperature hot Three minutes prior to the end of the blow, the sub-lance is lowered into the bath to determine the carbon content and temperature of the liquid steel Using this data, the computer automatically calculates the exact quantities of coolant and oxygen for decarburization) required to bring the heat in on target. The calculated addition of coolant is then automatically charged during the final minutes of the blow

All of the benefits described of using MIDREX HBI for thermal balancing also apply to static trim cooling and dynamic trim cooling. As oxygen steelmakers seek continued improvements in furnace operating control, steel quality, and yield, MIDREX HBI wil play an increasingly important role in oxygen steelmaking.

LADLE COOLING

Frequently, steelmakers with continuous casters or ladle metallurgy will tap the oxygen furnace on the hot side. This practice allows for precise control of the casting temperature, which is critical to the optimum operation of continuous casters. With ladle metallurgy, the extra heat is also needed to cover the heat lost during ladle treatments. Even with ingot casting, precise casting temperature is important, since high casting temperatures will reduce the life of ingot molds.

MIDREX HBI is an excellent ladle coolant. Since it has a very low tramp and impurity content, it will not contaminate the steel. With its high density and small size, it will provide controlled cooling of the ladle without stirring and without skull formation. In the future, MIDREX HBI wi undoubtedly be an important coolant for oxygen steelmakers. The combined consumption of HBI for thermal balancing, trim cooling and ladle cooling is expected to average around 2% of the charge of those steelmakers who adopt this improved practice

ECONOMICS

A simple evaluation of the savings and cost can demonstrate the economic desirability of using HBI in place of iron ore pellets and limestone. Basically, there are three major considerations in the economic evaluation:

Raw material costs iron ore pellets, limestone, and HBI)

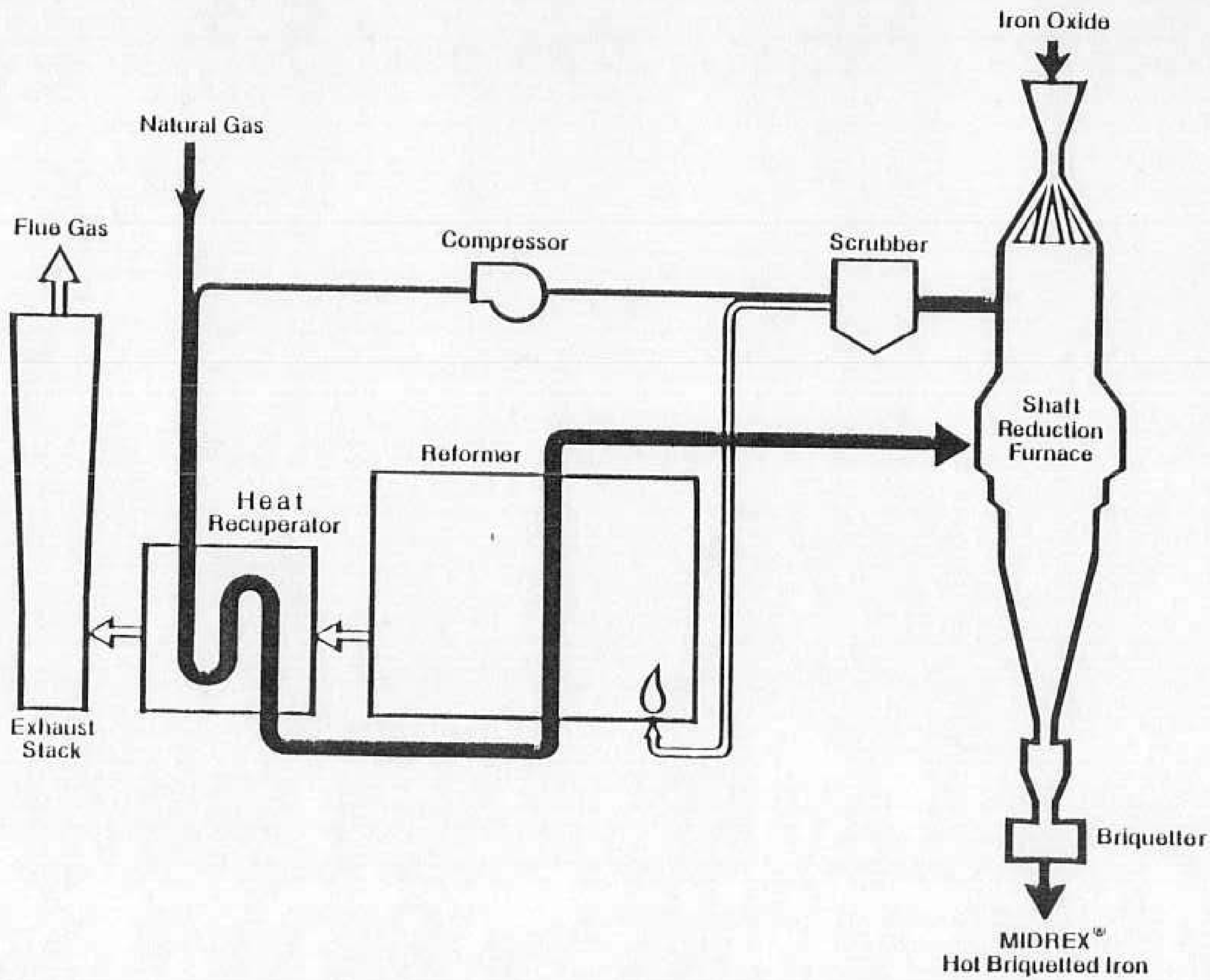
Yield increase

Liquid steel cost

Naturally, results of an economic evaluation will vary with each steel plant. Nevertheless, in order to demonstrate the potential economic incentive for replacing iron ore and limestone with HBI, a typical case is presented in Tables III and IV, respectively.

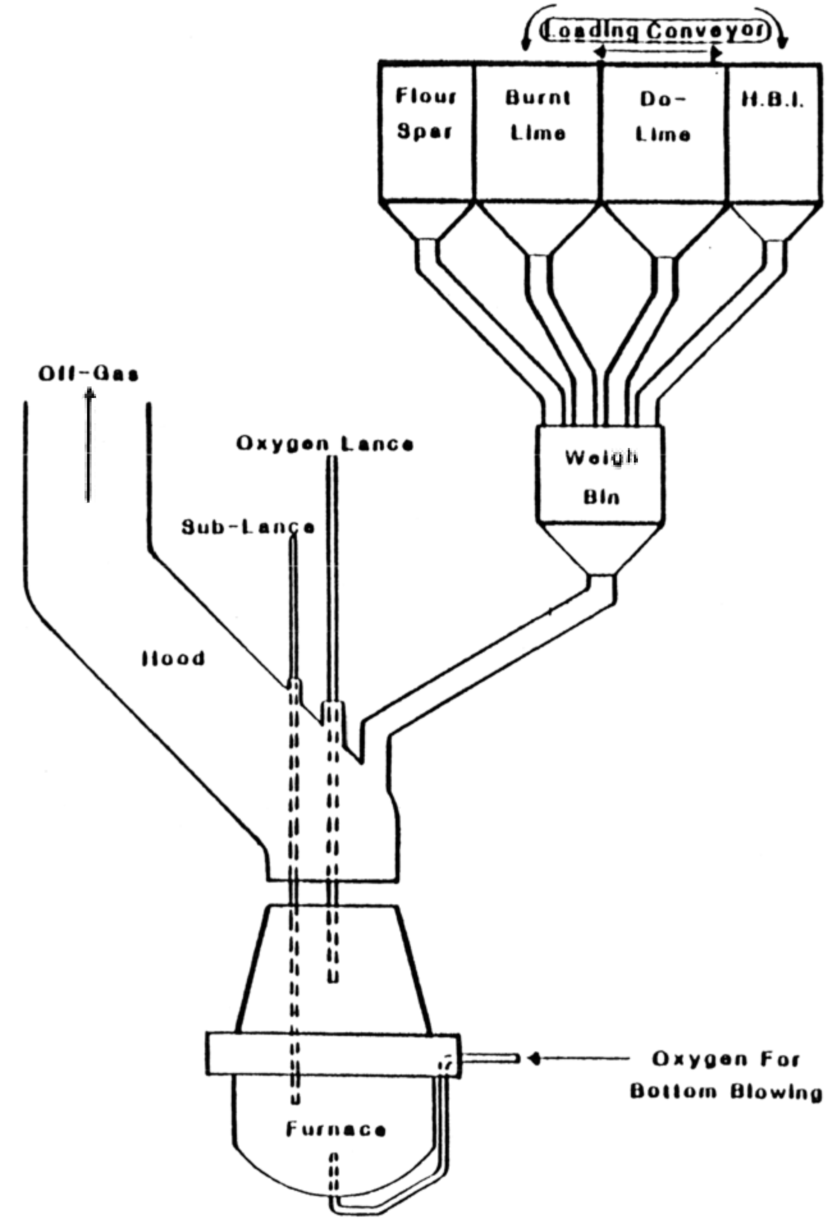
CONCLUSION

MIDREX HBI will play an important part in improving oxygen furnace turn-down control and in lowering overall steel costs. In the near future, MIDREX Plants will be producing this valuable product. Not only will MIDREX HBI open up a new market in oxygen steelmaking, it will also represent an improved product for the EAF and foundry industries.



MIDREX HOT BRIQUETTED
IRON FLOWSHEET

Fig 1



TYPICAL OXYGEN FURNACE SYSTEM

Fig 2

	Percent by Weight
Total Iron (Fe)	92 - 93%
Carbon (C)	1.5
Silica (SiO_2)	1.2 - 2.0
Alumina (Al_2O_3)	0.5 - 1.2
Lime (CaO)	0.3 - 1.7
Magnesia (MgO)	0.1 - 0.5
Manganese (Mn)	0.03
Phosphorus (P)	0.03
Sulfur (S)	0.01
Copper (Cu)	0.005
Pb, Sn, Mo, Zn, W, As, Sb, Co, Ni, Zr	0.05 Total
Metallization	92 - 95%

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TYPICAL CHEMICAL SPECIFICATION OF DRI

Table I

	Pellet/Lump	HBI
Bulk Density	1.6 – 1.9t/m^3	2.6 – 2.7t/m^3
Apparent Density	3.5t/m^3	5.0 – 5.5t/m^3
Nominal Size	4 – 20mm	30 x 50 x 100mm
Weight	– –	0.5 – 0.7 kg
Maximum Water Absorption	12 –15%	3%
Screen Analysis Below 4mm	5%	2%

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TYPICAL PHYSICAL SPECIFICATIONS OF DRI

Table II

Raw Material Value	
Iron Ore Pellets	$ 50/t
Limestone	$ 10/t
HBI	$150/t
Liquid Steel	$200/t
Iron Ore Replacement (per t L.S.)	
Benefits:	
Iron Ore Savings (10 kg)	$0.50
Yield Increase* (1.7%)	$3.40
Costs:	
HBI (20 kg)	(3.00)
Net Savings:	$0.90/t

* yield increase based on 85% iron recovery from HBI (by weight), 50% recovery from iron ore (by weight), and 0.5% yield increase due to lower slopping with HBI

MIDREX | IRON ORE REPLACEMENT ECONOMIC EVALUATION | Table III

Raw Material Value

Iron Ore Pellets	$ 50/t
Limestone	$ 10/t
HBI	$ 150/t
Liquid Steel	$ 200/t

Limestone Replacement (per t L.S.)

Benefits:	
Limestone Savings (8 kg)	$0.08
Yield Increase[1] (1.7%)	$3.40
Costs:	
HBI (20 kg)	(3.00)
Net Savings:	$0.48/t

[1] yield increase based on 85% iron recovery from HBI (by weight)

MIDREX | LIMESTONE REPLACEMENT ECONOMIC EVALUATION | Table IV