DIRECT FROM MIDREX

From The Hearth: RHF Technologies

SPECIAL REPORT WINTER 2007/2008

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Commentary

Successful, Commercially Proven RHF Technologies

Now is the right time to take a step back to "see the forest through the trees," in order to reintroduce Midrex's wholly successful, commercially proven RHF technologies. The first commercial FASTMET® plant has been in operation for seven years (since April 2000) at Nippon Steel's Hirohata Works in Japan, treating 190,000 tpa of BOF dust. With start-up proceeding smoothly and rapidly, the Performance Guarantee Test was achieved in July, 2000.

The second commercial FASTMET plant has been operating for six years at Kobe Steel's Kakogawa works in Japan, recycling 14,000 tpa of iron-bearing wastes. Since then, Nippon Steel has purchased another FASTMET plant, which has been operating for two years at 190,000 tpa.

It may be easy to sell a company a first FASTMET plant, but it speaks volumes about the superiority of our RHF technology when a second plant is ordered. FASTMET plants have excellent availability and their production exceeds design capacity.

The landscape of iron and steelmaking has been undergoing change as a result of strong demand and healthy prices. Capacities are being expanded and new projects are coming on-line and/or being announced every day.

Just a few years ago, some steel companies looked at iron ore mines as a liability. Now, they are such a strong asset that many companies are interested in developing iron and steelmaking directly from their precious reserves. We are seeing a trend where countries or regions within a country are interested in becoming steel production self-sufficient. They may not want to build a large integrated steel mill to produce five million tons per year, but instead are interested in producing a quantity along the lines of 500,000 tpa to meet their regional needs. In that case, ITmk3® or FASTMELT® are ideal to turn their ore reserves plus local coal into value-added iron as feed for a steel mill.

Our Success

Our success during the past decade has been contrasted, and perhaps even overshadowed, by several other examples of competing RHF technologies that have tried and failed to reach design capacity or become commercially successful.

Hiroshi Ishikawa
Executive Vice President

Our Technologies' Similarities

In addition to FASTMET (DRI), Kobe Steel and Midrex offer FASTMELT (pig iron) and ITmk3® (iron nugget) RHF technologies that have some similarities. In each case, iron-bearing materials are mixed with the proper amount of carbon, agglomerated and reduced at temperatures above 1300° C in a rotary hearth furnace. The carbon is typically coal, which acts as a fuel and reductant that removes the oxygen to produce iron. Coking coal, however, is not required. For each technology, some natural gas is normally needed as supplemental fuel. The iron oxide is typically either iron ore concentrate or waste iron oxides. If blast furnace dust is used, it typically has enough carbon for self-reduction, including the remainder of the waste oxide feeds from a mill. The agglomerates are made by briquetting or pelletizing. The capacity of the plant ranges from 14,000 to 500,000 tpa.

Our Technologies' Differences

We've stated the similarities, but what are the differences? Of course it depends on each situation and there are exceptions to the rules, but here are the basics. Simply stated, FASTMELT is just an extension of FASTMET that is followed by an electric ironmaking furnace (EIF®) to make pig iron (from the FASTMET DRI). ITmk3® is a revolutionary process where each pellet melts on the rotary hearth, allowing the iron to separate from the slag like oil from water, to produce iron nuggets. Steel Dynamics, Inc. has stated that:

*Melt tests using nuggets produced by a pilot plant have demonstrated that iron nuggets melt more efficiently in electric-arc furnaces than traditional pig iron (**Skillings**, 2007).*

(Commentary continued on next page)

Midrex Introduces Plant Sales Manager

Jayson Ripke
RHF Plant Sales Manager

S. Jayson Ripke has been announced as Plant Sales Manager for the FASTMET®, FASTMELT®, and ITmk3® Rotary Hearth Furnace (RHF) technologies.

As part of Midrex Technologies, Inc., Ripke has been promoting and negotiating new coal-based RHF Direct Reduction Plant sales worldwide throughout 2007. Prior to that, he was heavily involved in Midrex research and development center work dealing with RHF technologies.

Ripke completed BS and MS degrees in Metallurgical and Materials Engineering in 1997 and 1999 before earning his PhD in Chemical Engineering in 2002 from Michigan Technological University. He then embarked on a career in the iron ore industry.

After graduating, Ripke became a process control engineer with Northshore Mining Co. in Silver Bay, MN, owned by Cleveland-Cliffs Inc., after which he was named chief metallurgical engineer at CCI's Wabush Mines, in Labrador, Canada. During his tenure, he made significant advances in safety, cost-cutting and quality improvement.

Commentary

(Commentary continued from previous page)

So, You Can Ask, Which One Do I Apply?

FASTMET is used to recycle iron-bearing wastes at or near integrated or mini-steel mills into DRI as feed to an EAF, BOF or BF. FASTMET is excellent for:

- Turning waste into profit by recycling BF dust or sludge, BOF dust or mill scale from an integrated steel mill
- Producing zinc oxide and iron from electric arc furnace dust (EAFD) processed at a mini-mill
- Replacing multi-hearth furnaces
- Replacing rotary kilns

FASTMELT provides either a high-quality hot liquid iron as feed to an EAF or BOF, or merchant pig iron. FASTMELT is excellent for:

- The steel mill that is hot metal limited
- Replacement of a blast furnace (decommission the BF instead of refractory reline)
- An iron ore mining company that wants to produce iron and/or steel
- Countries that want to develop or increase their iron and steel production
- Those interested in becoming self sufficient steelmakers

ITmk3 provides a source of premium-quality merchant pig iron as iron nuggets that are easy to handle, ship and charge into an EAF or BOF. ITmk3 is excellent for:

- An iron ore mining company that wants to make high quality merchant iron nuggets at the mine site

Examples:

1. *Steel Dynamics, Inc. is participating with Midrex and our parent company, Kobe Steel, to construct and operate a $235-million ironmaking facility in Minnesota.*
2. *Cleveland-Cliffs, Inc. has formed an Alliance Agreement with Kobe Steel and plans to build an ITmk3 plant in Michigan or Minnesota.*

These technologies also have excellent potential for production of a value-added iron or steel product from available or imported iron ores with coal. Some locations of particular interest are in the United States, the Ukraine, Taiwan, China and India.

REFERENCES

Skilling's Mining Review, *April 2007, Vol. 96 No. 4, page 28.*

DIRECT FROM MIDREX is published by Midrex Technologies, Inc.
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A Layman's Guide to the Midrex and Kobe Steel Rotary Hearth Furnace Technologies

By James McClelland
Midrex Technologies, Inc.

Editor's note: This article is the first in a series on rotary hearth furnace (RHF) technologies available from Midrex and Kobe Steel. These articles will examine how the various RHF-based technologies fit each particular situation and application. This first article in the RHF series takes a quick look at the commercially-proven FASTMET® Process, the FASTMELT® Process and the breakthrough ITmk3® Process. In further issues, each technology will be featured individually in greater detail.

All rotary hearth furnace-based direct reduction technologies are not alike. This layman's guide is written to dispel misconceptions in the industry and to show how Midrex and Kobe Steel have evolved three primary technologies from the basic RHF concept to meet specific client needs.

Rotary hearth furnaces are not a new technology. For decades, they have been successfully used in a variety of industrial applications, including heat treating, calcification of petroleum coke, waste treatment and non-ferrous high-temperature metal recovery. Unfortunately, the problem with the use of RHF technology for the direct reduction of iron-bearing materials is not with the RHF itself, it's with the way it is being applied... the process technology.

The answer is process engineering. If the RHF is correctly integrated into the global process and direct reduction technology is applied correctly, the result is an energy-efficient, environmentally-friendly, economic system for producing quality alternative iron.

The coal-based direct reduction concept utilizing the RHF is a simple one; however, commercial implementation of the concept has not been easily achieved. Midrex and Kobe Steel have proven the concept with continuous commercial-scale operation of three RHF direct reduction plants utilizing FASTMET technology.

For those unfamiliar with the RHF concept, the rotary hearth furnace consists of a flat, refractory hearth rotating inside a stationary high temperature, circular tunnel kiln. The feed to the RHF consists of composite agglomerate made from a mixture of iron oxides and a carbon source such as coal, coke fines, charcoal or other carbon-bearing solid. The feed agglomerates are placed on the hearth evenly, one to two layers thick.

Burners located above the hearth provide heat required to raise the feed agglomerates to reduction temperature and start the process. The burners are fired with natural gas, fuel oil, waste oil or pulverized coal. Most of the heat required for maintaining the process is supplied by combustion of volatiles that are liberated from the heated reductant and combustion of carbon monoxide, which is produced by the reaction of carbon-reducing metallic oxides.

The agglomerates are fed and discharged continuously and stay on the hearth for only one revolution, typically six to 12 minutes, depending on the reactivity of the feed mixture and target product quality.

Table I shows the characteristics of each of the technologies.

	FASTMET®	**FASTMELT®**	**ITmk3®**
Iron Oxide Type	Iron ore concentrate or iron bearing wastes from integrated- or mini-mill; e.g. mill scale or BOF, BF or EAF dust		Iron ore concentrate
Internal Reductant	Pulverized coal (non-coking) or other solid carbon		
Fuel	Internal reductant plus natural gas		
Agglomerate Type	Briquettes or Pellets		Pellets
Plant Location	At or near integrated steel mill or mini-mill or stand alone for EAFD	At integrated steel mill to feed BOF or at mini-mill to feed EAF	Near iron ore concentrate source
Melter	No	Yes, includes electric ironmaking furnace (EIF®) specially designed to melt FASTMET DRI into FASTIRON	No, but iron nuggets each melt within the RHF allowing immiscible liquid iron and slag to separate
Product	Hot or cold DRI or HBI Zinc Oxide	Iron as liquid hot metal or solid pigs or granules	Iron nuggets
Byproduct	None	Slag	Slag recovered after magnetically recovering nuggets
Product Use	Iron source feed to BOF, EAF or BF	Hot liquid or hot or cold iron feed to EAF or BOF	Premium iron feed to EAF or BOF
Product Quality	82% Fe (contains gangue)	96 - 98% Fe (gangue removed as slag)	96 - 97% Fe (slag removed from iron nuggets after cooling with magnetic separation)
Capacity	150,000 to 1,000,000 tpa with excellent economies of scale at 500,000 tpa. A 1,000,000 tpa plant would consist of two 500,000 tpa modules. Specialty plants can be built between 20,000 and 150,000 tpa.		

Table I - Characteristics of FASTMET®, FASTMELT® and ITmk3® Technologies

MIDREX/KOBE STEEL TECHNOLOGIES

FASTMET

Process/Technology

FASTMET uses a rotary hearth furnace to convert steel mill wastes and iron oxide fines to highly metallized DRI. Carbon contained in the wastes or added as coal, charcoal or coke is used as the reductant. Combustion of volatiles from the reductant and carbon monoxide from the iron reduction supplies the primary energy to the RHF for the reduction reactions. The FASTMET Process is extremely energy efficient, unlike other new coal-based ironmaking processes that require offgas energy credits, as all fuel energy is consumed within the FASTMET rotary hearth furnace (100 percent post combustion). See Figure 1.

Purpose/Market

Many integrated steelmakers in North America, Europe and Asia, who have been stockpiling wastes on site for many years, are finding that option no longer available. Sending these wastes off-site for disposal can entail logistical difficulties and considerable cost. In many cases, there also is a need to recover wastes that are stored on site. Some integrated facilities have millions of tons of valuable minerals resources landfilled as waste. FASTMET provides an excellent means to deal with these materials by recycling them, thus greatly reducing the volume to be disposed of and producing a cost-effective iron product.

Mini-mills also face problems in disposing of electric arc furnace baghouse dust (EAFD), which is a listed hazardous waste in the USA and elsewhere around the world. FASTMET provides an economical means for processing this material. It produces a metallized iron product that can be recycled to the EAF and a saleable crude zinc oxide dust.

FASTMET is primarily a cost-effective iron oxide waste processing solution to convert steel mill wastes, such as blast furnace dusts and sludges, BOF dust and EAF baghouse dust, into useable mineral resources. This technology is especially desirable now because of such issues as disposal of iron-bearing waste, closure of on-site landfills, recovery of valuable iron units, controlling steelmaking raw material costs and conservation of capital.

FASTMELT

Process/Technology

FASTMELT also uses a rotary hearth furnace but adds an electric iron melting furnace to take the FASTMET Process one more step. In the FASTMELT Process, hot DRI produced via the FASTMET Process is fed to a specially-designed melter, the Electric Ironmaking Furnace (EIF®), for production of a high quality hot metal known as FASTIRON®. See Figure 2.

Purpose/Market

The FASTMELT Process is an attractive option for many applications. Highly metallized and high temperature FASTMET DRI is fed directly to a proprietary melter (EIF) to produce blast furnace-grade hot metal. By controlling the FASTMET DRI chemistry, FASTIRON can be tailored to precisely match the desired hot metal chemistry for further processing in a basic oxygen furnace (BOF) or electric arc furnace (EAF). Molten FASTIRON also can be cast into pigs or granulated for sale or later use.

Steelmakers face continuing problems and often high costs in operating, permitting and repairing blast furnaces, coke ovens and sinter plants. FASTMELT can enable integrated mills to

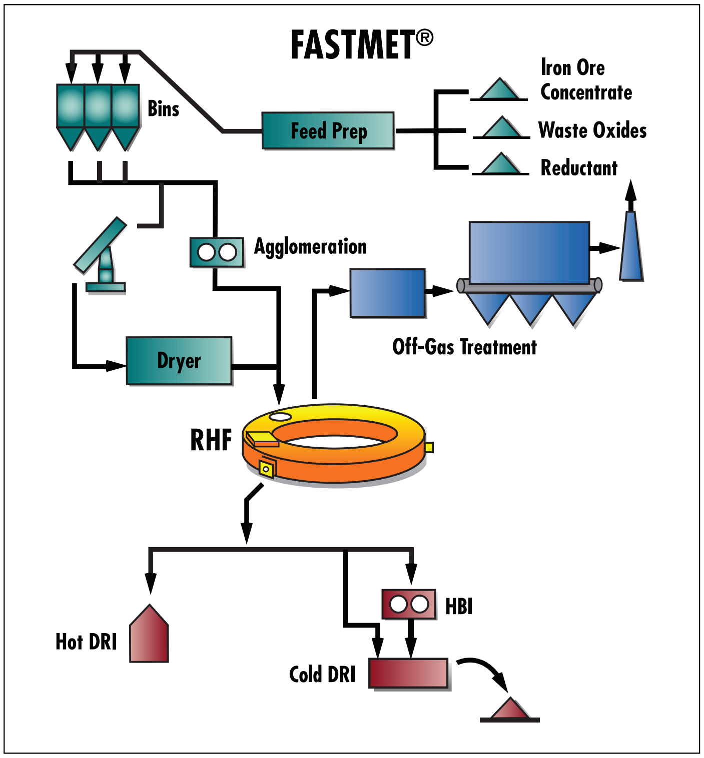

Figure 1

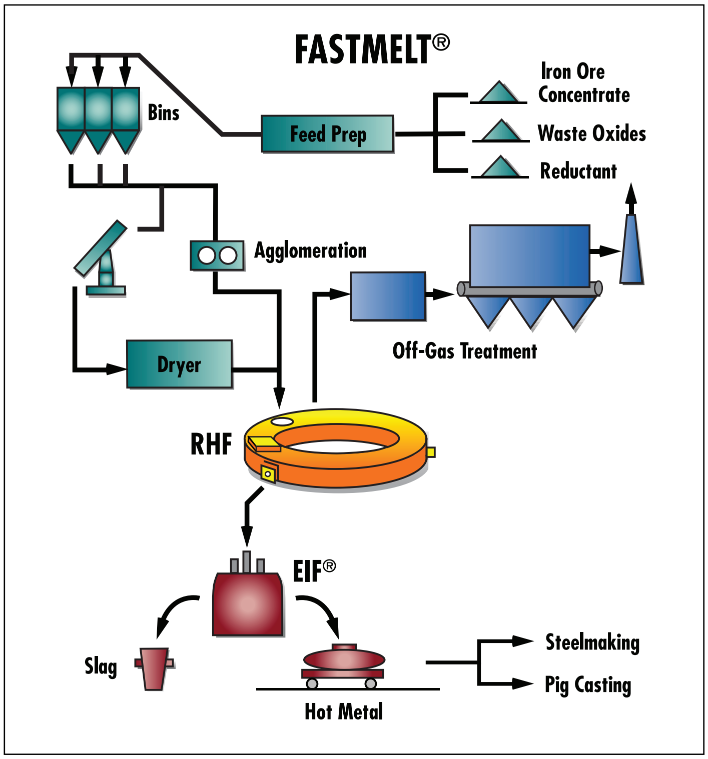

Figure 2

produce sufficient hot metal while shutting down some or all of these facilities. Because the RHF and EIF operating units are designed for high efficiency and minimal export heating value, the process operating costs do not require any offgas energy credits to be competitive, which also minimizes the overall capital expenditure.

FASTMELT can be used to economically convert low-grade iron ores and wastes into high-quality pig iron without extensive beneficiation or conventional pelletizing. The FASTMELT Process produces pig iron with the lowest energy consumption and least green house gases of any coal-based ironmaking process.

FASTMELT can replace or augment blast furnace ironmaking with lower operating cost and greater flexibility in feed selection. A FASTMELT merchant iron plant can convert poor quality iron ores and non-coking coals into quality pig iron products.

Kakogawa FASTMET® Plant

ITmk3

Process/Technology

ITmk3 represents the next generation of modern ironmaking technology, processing iron ore fines into almost pure pig iron nuggets in only ten minutes. The result is a conveniently-sized, slag-free material ideally suited for further processing by conventional technologies into high quality steel products and foundry iron castings. ITmk3 Process development has passed from the pilot stage into proven technology as shown by the demonstration plant at Cleveland-Cliffs' North Shore Mining Company located in Silver Bay, Minnesota, USA.

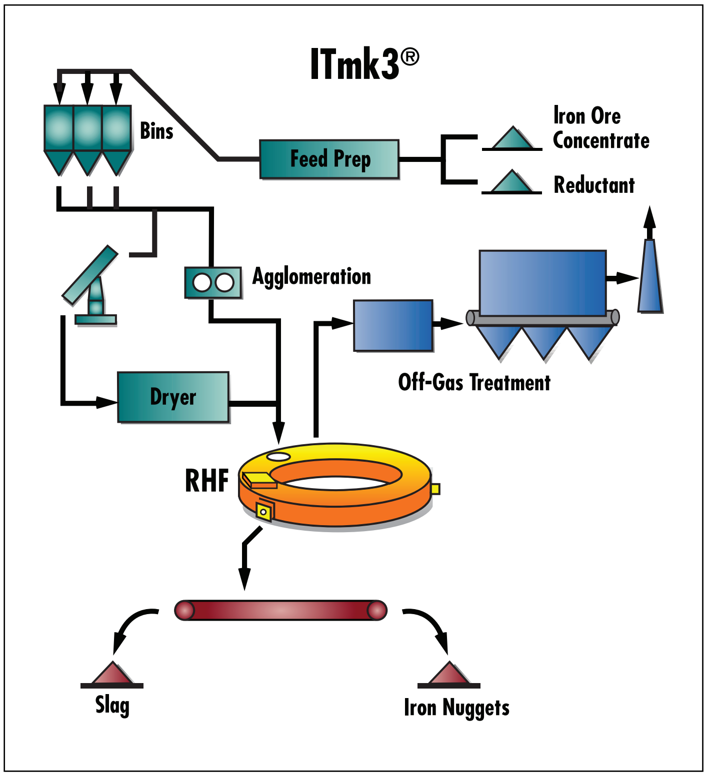

Figure 3

Purpose/Market

The ITmk3 Process is the ideal vehicle for iron ore mining companies to supply pig iron-grade nuggets directly to the EAF steelmaking industry. ITmk3 nuggets are a metallurgically-clean, dust-free source of alternative iron for high-quality EAF steelmaking. ITmk3 nuggets are not prone to reoxidation and do not require special handling during shipment. Because of their convenient form, they can be continuously fed for higher productivity and lower liquid steel cost. See Figure 3.

ITmk3® Nuggets

CONCLUSION

Subtle differences in detail separate these distinct rotary hearth furnace technologies available from Midrex and Kobe Steel. Knowledge of these details and how and when to apply them is the result of many years of ironmaking experience and process development. Proof of the benefit of this experience lies in the commercial success demonstrated by the FASTMET Plants at Hirohata and Kakogawa.

FASTMET®, FASTMELT®, and ITmk3®:
Development of New Coal-based Ironmaking Processes

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OVERVIEW

In recent years, world steel production has steadily increased. The current mainstream ironmaking technology is the blast furnace process that negatively impacts the environment. With global warming as a major consideration, concerns for decreasing the emission of carbon dioxide have increased accordingly.

With this as background, three new ironmaking processes, FASTMET, FASTMELT, and ITmk3, have been developed. These processes are based on the coupling reaction between the reduction of iron oxide and gasification of carbon, which can produce high quality iron units from iron ore fines and coal that exist in abundance all over the world. The energy consumption and environmental load of these processes are competitive compared with the large-capacity blast furnace process.

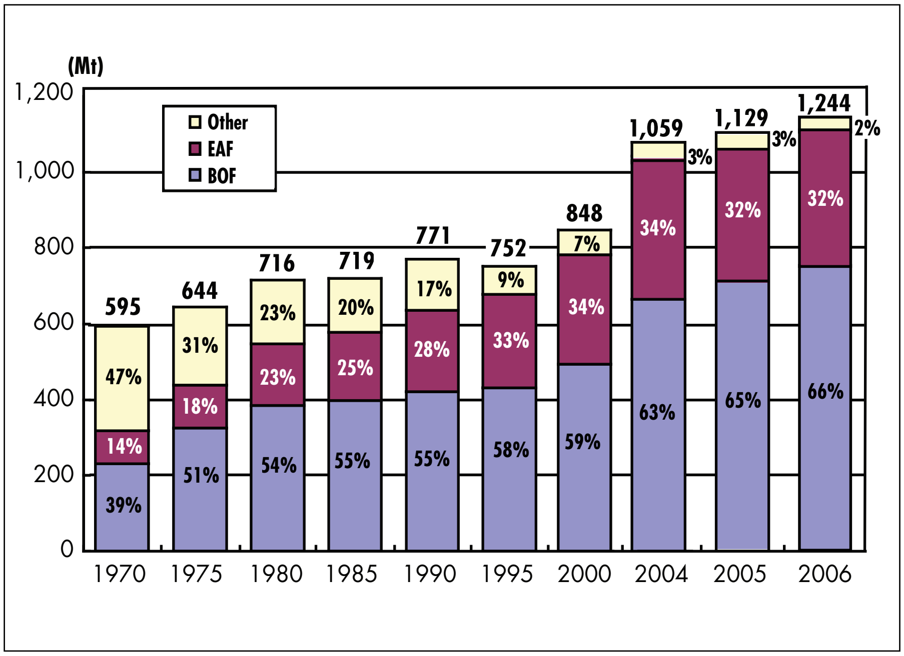

Figure 1 - Trend of world crude steel production

INTRODUCTION

World crude steel production has steadily increased, exceeding 1.2 billion tons in 2006, as shown in Figure 1.

The growth of steel production in Asian countries, including China, has been especially remarkable. One of the features in today's world steel industry is the increase in crude steel production from Electric Arc Furnace (EAF) steelmaking.

As steel production through the EAF route has grown over the years, the production volume of DRI has increased 70 times, from roughly 0.8 million tons in 1975 to approximately 60 million tons in 2006. (See Figure 2)

A major portion of the world's DRI and HBI is produced by gas-based processes, of which the MIDREX® DR Process had a 60%

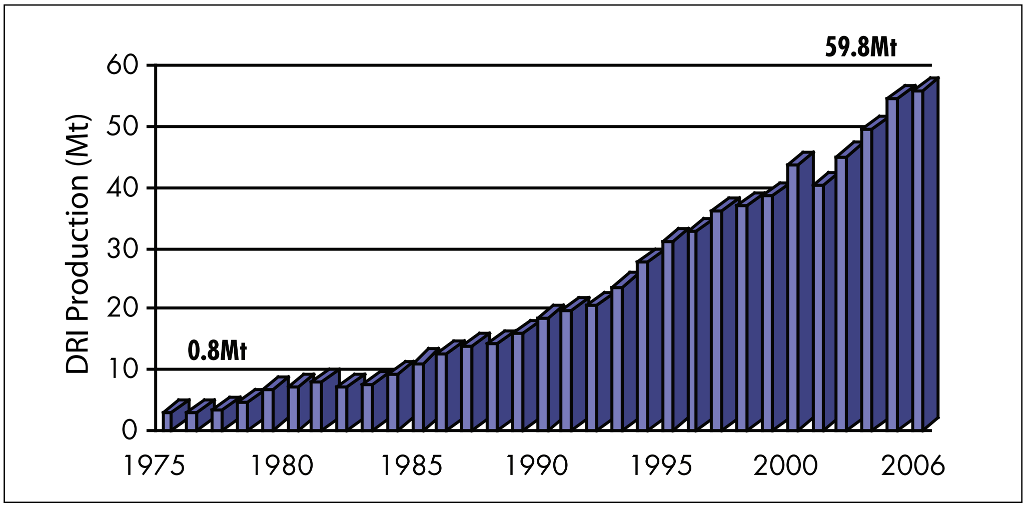

Figure 2 - World DRI production by year

share in 2006. (Figure 3)

Unfortunately, the locations of MIDREX Plants are limited to places where natural gas resources are abundant, since the plants use natural gas for iron reduction. In order to expand applications worldwide, it is necessary to develop reduced iron processes using coal, of which more abundant reserves are available in widespread geographic areas.

In response to this demand, three coal-based direct reduction ironmaking processes, FASTMET, FASTMELT, and ITmk3, have been developed. This paper explains why and how these coal-based DR processes will bring sustainable success to the steel industry.

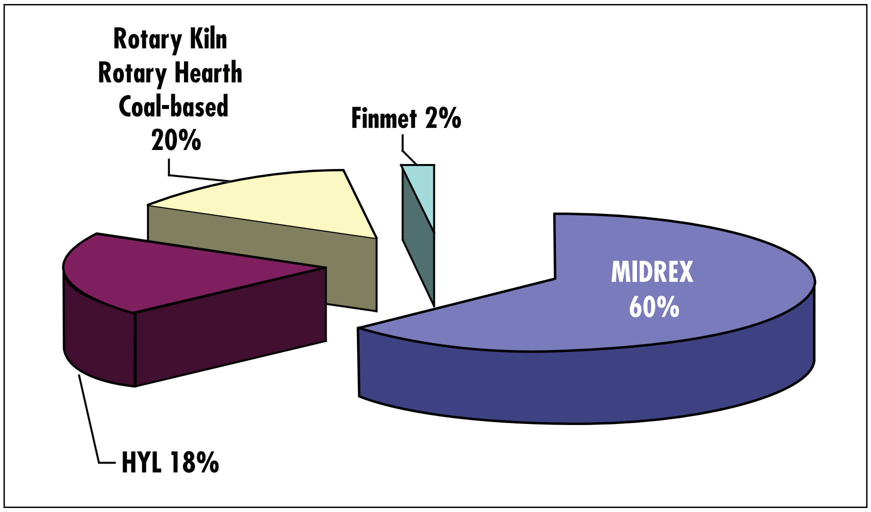

Figure 3 - World DRI production by process (2006)

COAL-BASED DIRECT REDUCTION PROCESSES

FASTMET Process

Figure 4 shows a schematic chart of reduction in a rotary hearth furnace (RHF). Iron ore and pulverized coal are mixed and agglomerated into pellets or briquettes. These agglomerates are fed into the RHF in one or two layers and heated rapidly to a maximum 1,350° C in the RHF by radiation heat. The oxides in the agglomerates are reduced to metallic iron by the composite carbon within the agglomerates. Recently, the reaction of composite pellets was investigated. The first reaction rate and relatively low starting temperature were reported due to the coupling reaction between reduction of iron oxide and gasification of carbon.

The DRI produced is continuously discharged from the RHF at a temperature of approximately 1,000° C and treated according to the customer's requirements.

Carbon monoxide generated from the agglomerates is used as a major fuel source in the RHF, and the fuel gas, which is equivalent to only 15% of the necessary energy, is added as a supplement. Thus, the FASTMET Process can attain a high-carbon utilization rate with reduced CO_2 emissions.

Kobe Steel and Midrex jointly began development of the FASTMET Process to establish this direct reduction technology. In 1995, the Kakogawa Demonstration Plant (KDP) with an annual capacity of approximately 20,000 tons was constructed to

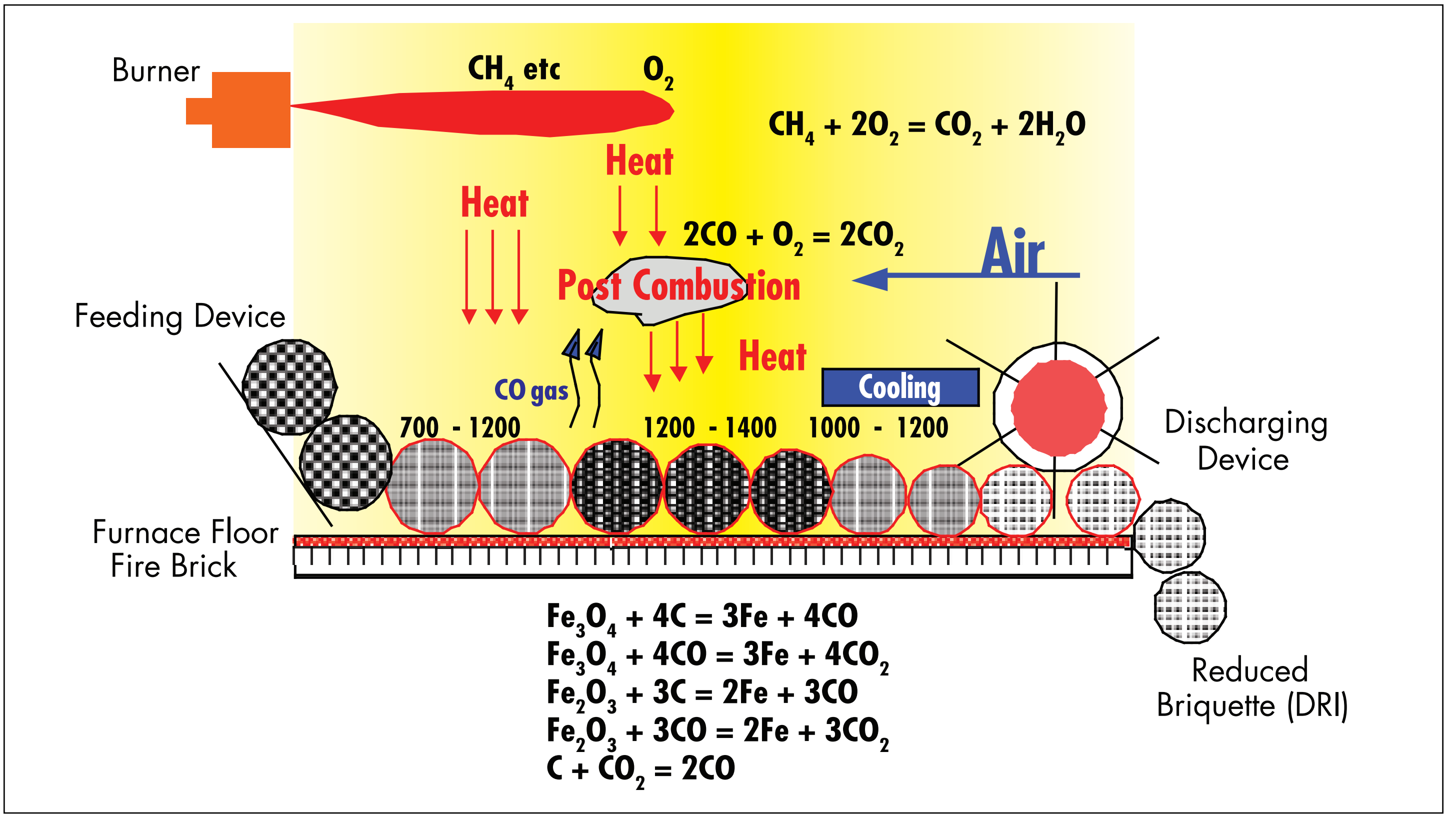

Figure 4 - Schematic drawing of reduction in RHF

demonstrate the process. Through this trial operation that continued until 1998, high metallic DRI and HBI were continuously produced at high productivity. The FASTMET Process proved to be a suitable process as a new ironmaking technology that utilizes coal as the reductant. The DRI or HBI produced can be charged into a melting furnace (EIF, EAF or SAF), BOF or Blast Furnace (BF). The benefits for BF include reducing the coke rate and increasing the hot metal production rate.

Plant Name	Capacity (t/y)	Operation Date
NIPPON STEEL Hirohata Works (No. 1)	190,000	April 2000
NIPPON STEEL Hirohata Works (No. 2)	190,000	February 2005
KOBE STEEL Kakogawa Works	16,000	April 2001

Table I - FASTMET® commercial plants

	Unit: Wt.%					
	Totol Fe	Metallic Fe	FeO	C	S	Zn
Dry Ball	58.70	17.10	36.60	11.90	0.17	0.75
DRI	82.20	74.20	7.40	3.30	0.23	0.05

Table II - Chemical composition of Dry Ball and DRI

The FASTMET Process reduces iron ore at high temperatures above 1,300° C, evaporates heavy metals, such as zinc and lead in steel mill waste material, and thus produces DRI without heavy metals. The processing of steel mill waste material is an urgent issue in steelmaking facilities. In the FASTMET Process, the elements evaporated from the RHF are oxidized in the exhaust gas and collected as valuable crude zinc oxide.

Table I shows the plants that are in commercial operation. Three FASTMET commercial plants are currently recycling steel mill waste material.

Table II shows the chemical compositions of the dry ball pellets and DRI.

FASTMELT Process

Ash and sulfur contained in coal tend to migrate into the reduced iron. The FASTMELT Process (Figure 5) was developed to resolve this issue of migration. The process melts reduced iron, hot-transferred from the FASTMET Process, and separates it into molten iron and slag. At the same time, the molten iron is de-sulfurized. The gas discharged from the DRI melter

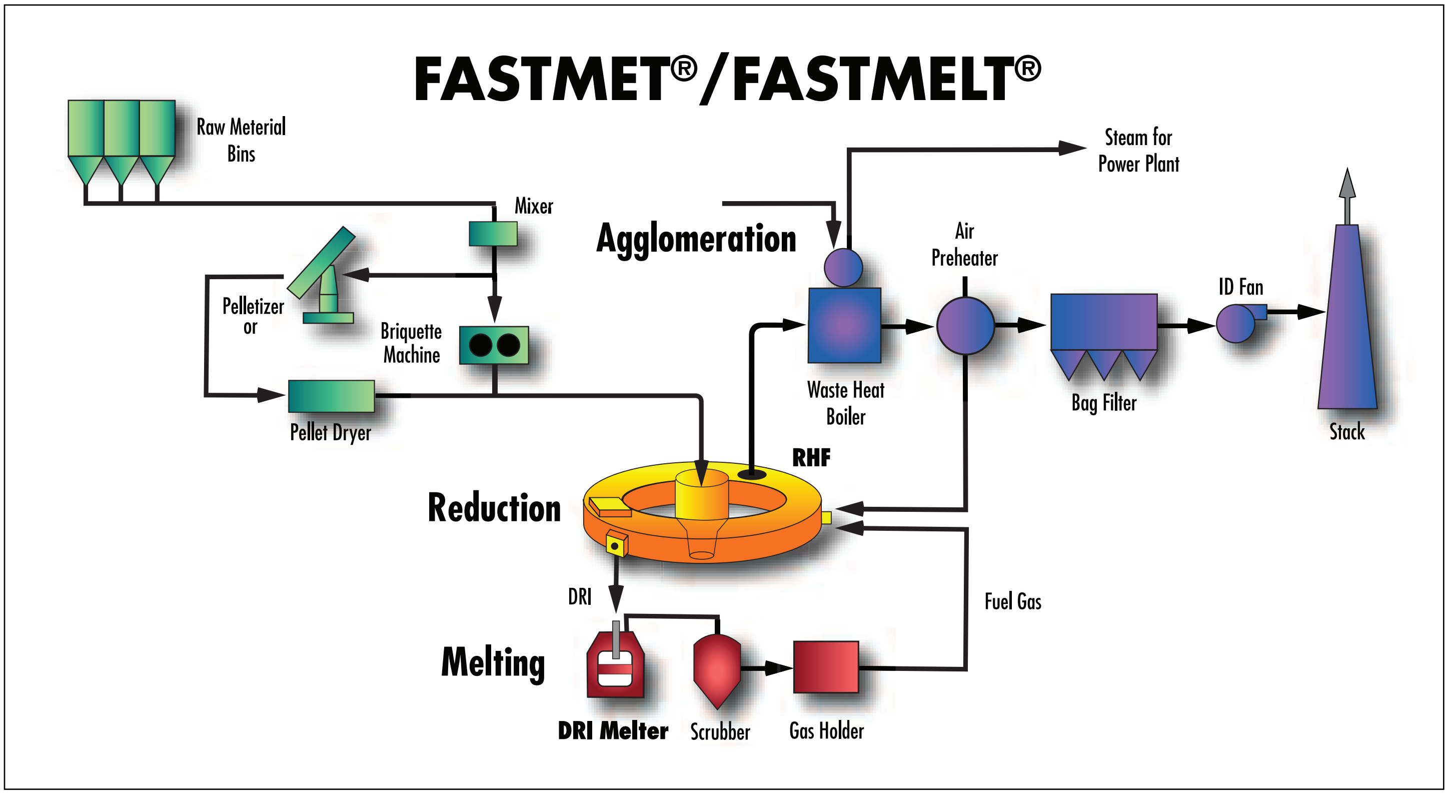

Figure 5 - FASTMELT® Process flow

consists mainly of CO and is used for the fuel gas in the RHF.

Either electricity or coal can be used as the energy source for melting. The choice of the energy source depends on conditions at the plant site. The use of coal as the energy source increases the amount of discharged gas and reduces the need for external fuel gas, such as natural gas.

The major design concept of FASTMELT is the achievement of high metallization DRI of over 90%. The DRI produced in the RHF is melted in the DRI melter to produce molten iron. It is important for the melting in the DRI melter to reduce the FeO contained in the DRI in order to prevent refractory damage in the DRI melter. Figure 6 shows the required energy for further reducing and melting in the DRI melter. High metallization of hot DRI reduces the thermal load in the DRI melter, as compared with that of cold ore; this protects the refractory.

The FASTMELT Process has been proven through melting campaigns at an EAF at Takasago Works, Kobe Steel, Ltd. in Japan, as well as in test operations of a small plant called a simulator at the Midrex Technical Center in the United States.

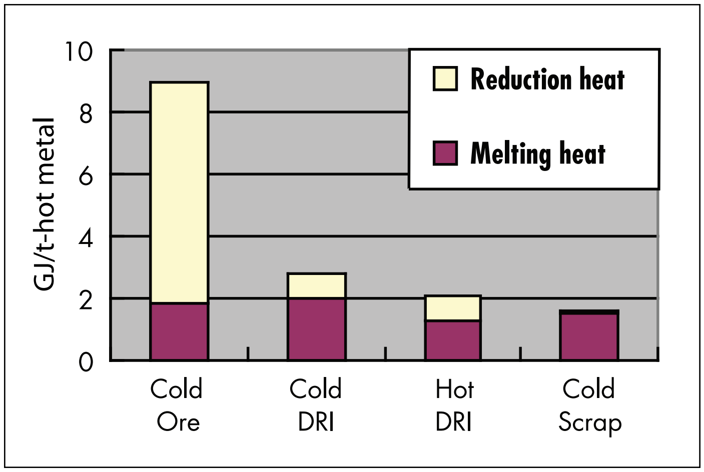

Figure 6 - Required energy for reducing and melting in the DRI melter

Temperature	Fe	C	Si	S	P
1,450 - 1,550° C	96 - 98%	2.0 - 4.0%	0.1 - 0.6%	<0.05%	<0.04%

Table III - Chemical analysis of FASTMELT® molten iron

Table III shows the typical chemical composition of FASTMELT hot metal. One standard FASTMELT commercial plant annually produces roughly 500,000 tons of molten iron.

ITmk3 Process

The ITmk3 Process, which also uses iron ore fines and pulverized coal, separates the iron nuggets and slag directly. We regard ITmk3 as a third generation ironmaking process; whereas, the current mainstream process of blast furnaces and converters is the first generation. The direct reduction processes, such as MIDREX®, are the second generation. The ITmk3 Process is based on a totally different concept from conventional processes.

The practical operation of the process proceeds as follows, and the process flow is shown in Figure 7.

1. Iron ore fines and pulverized coal are agglomerated into composite pellets.
2. Pellets are charged into an RHF, heated to 1,350-1,450° C, reduced, melted, and separated into iron and slag.
3. Molten iron is solidified into nuggets in the furnace, discharged after cooling, and separated from the slag.

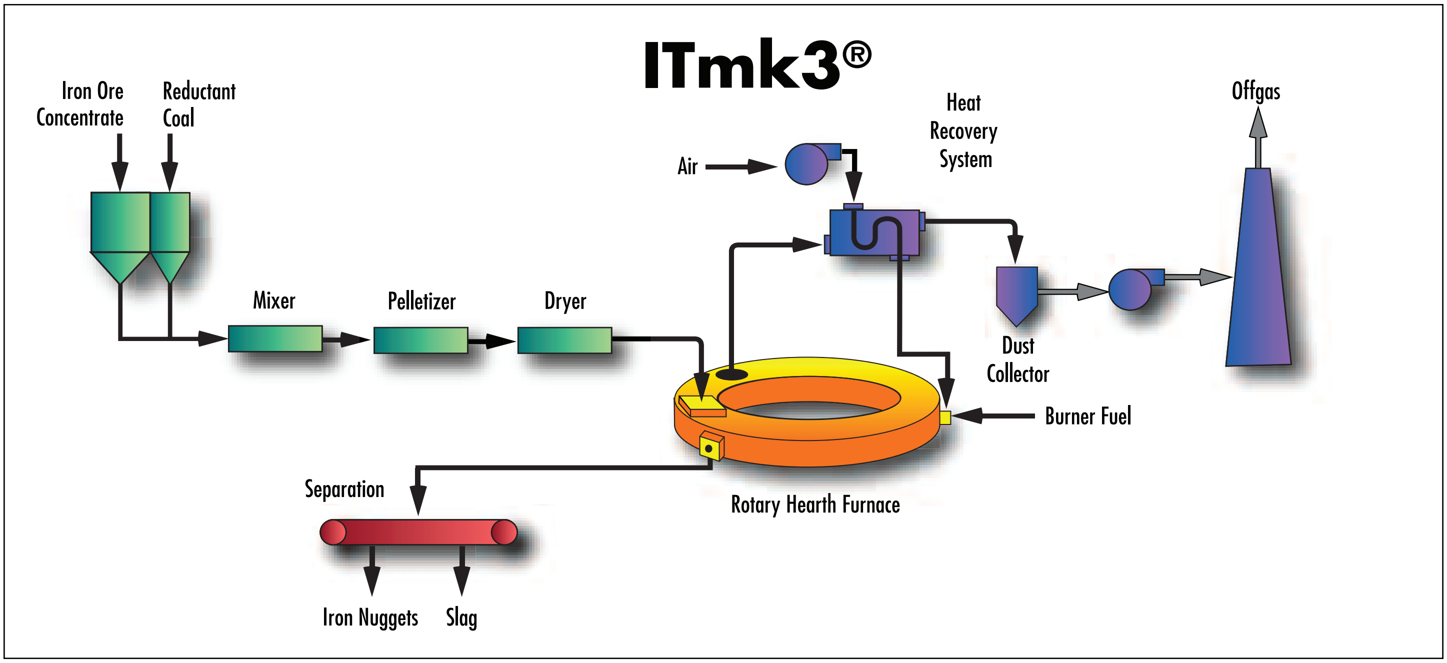

Figure 7 - ITmk3® Process flow

In the RHF, the following reactions take place when the carbon composite pellet is heated:

$$Fe_xO_y + yCO = xFe + yCO_2 \quad (1)$$

$$CO_2 + C = 2CO \quad (2)$$

$$C(s) = C(carburized) \quad (3)$$

$$Fe(s) = Fe(l) \quad (4)$$

The series of reactions are completed in approximately 10 minutes. Figure 8 shows both the outside and inside views of the agglomerate during reduction and melting in a laboratory furnace.

The ITmk3 Process enables the use of various raw materials, including non-coking coal and low-grade ore, without using expensive coke. The process is simple, as well as environmentally friendly. Table IV shows the iron ore grades and coal grades that can be used by ITmk3. A typical appearance of the iron nuggets and their composition quality is shown in Figure 9.

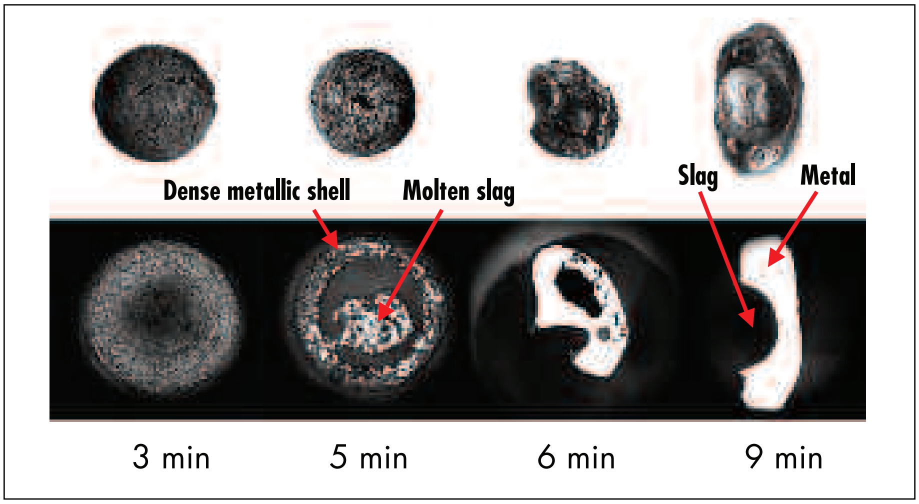

Figure 8 - Product figure and cross-sectional view of time sampled pellets

	Applicable	Preferable
Iron Ore (Wt.%)	TFe > 56% SiO_2 < 6%	TFe > 60% SiO_2 < 5%
Coal (Dry-base Wt.%)	FC > 50% VM < 45% Ash/FC < 25%	VM < 30% S/FC < 0.9%

Table IV - Required grade of iron ore and coal for ITmk3®

Item	Content (%)
Metallic Fe	96 – 97
C	2.5 – 3.0
P	0.01
S	0.05 – 0.07

Figure 9 - Photo and chemical analysis of iron nuggets

Figure 10 - ITmk3® Pilot Plant at Kakogawa Works

We started development of the ITmk3 Process in 1996, built a pilot plant at our Kakogawa Works (see Figure 10) to prove the process concept, constructed a demonstration plant with an annual capacity of 25,000 tons in the United States, and completed trials in 2004. Plans for commercial plants of 500,000 tons annual capacity are now under consideration.

Performance of New Ironmaking Technologies

Kobe Steel performed a study of processes to produce metallic iron from raw materials. The RHF Processes and the conventional Blast Furnace Process were evaluated to compare their energy consumptions and CO_2 emissions.

On the following page, Figure 11 shows the energy balance of the FASTMELT Process. The gas generated from the Electric Ironmaking Furnace® (EIF) is used as fuel for the RHF. The sensible heat from the RHF exhaust gas is recovered as steam and used for power generation.

Also on the following page, Figure 12 shows the energy balance of the ITmk3 Process, a process that can produce pure metallic iron with only an RHF. By-products are not generated by the RHF. The sensible heat from the RHF exhaust gas can be recovered, the same as in the FASTMELT Process.

The energy consumptions and CO_2 emissions in the FASTMELT and ITmk3 Processes are lower than in the blast furnace process, as

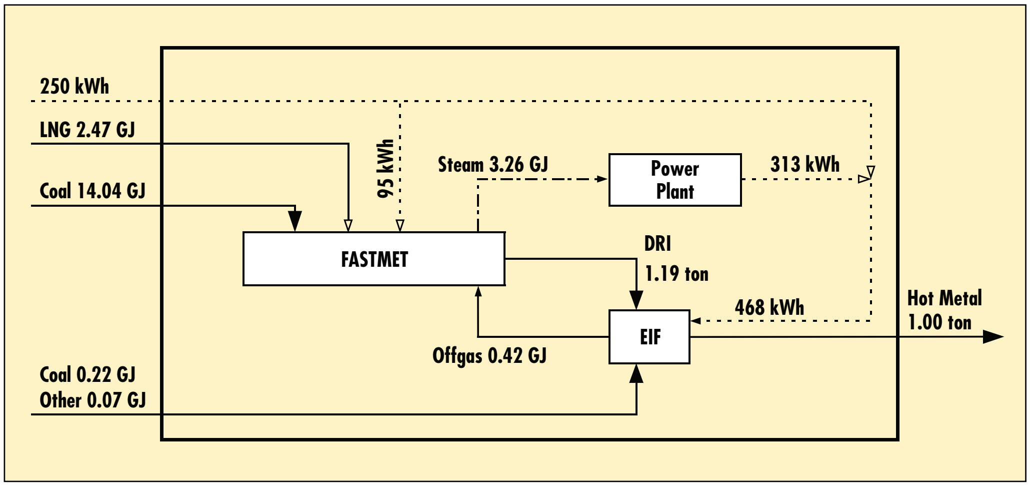

Figure 11 - Energy balance of FASTMELT® (500,000 t/y)

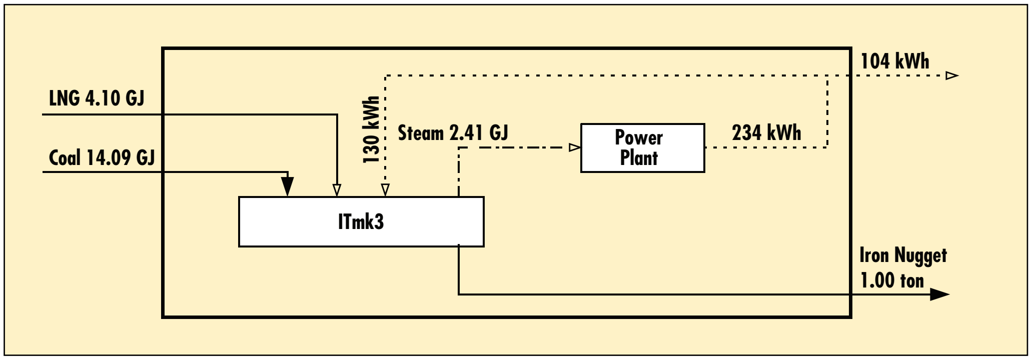

Figure 12 - Energy balance of ITmk3® (500,000 t/y)

shown in Figure 13 and Figure 14. This is due to the high efficiency of coal utilization in the two processes.

It should be noted that ITmk3 iron nuggets are not hot molten iron; they are cold solid iron. Additional energy is required to melt iron nuggets in a steel converter.

Therefore, FASTMELT, which can supply hot molten iron, is more suitable than ITmk3 in locations close to where the iron product is consumed.

In contrast, ITmk3 is advantageous if constructed at a mining site. Iron nuggets are easy to transport because they are pure metallic solid iron and difficult to re-oxidize. Transportation energy and CO_2 emissions can be reduced by transporting iron nuggets from the mining site to consuming locations, because the weight of the iron nuggets is one-half and the volume is one-tenth, compared with iron ore and coal.

CONCLUSION

The FASTMET, FASTMELT, and ITmk3 Processes suffer considerably less from raw material restrictions and are superior to the Blast Furnace in energy efficiency. With growing concerns about the conservation of resources and the environment, the processes are receiving more and more attention. We will continue to develop and supply coal-based direct reduction ironmaking processes and plants. In doing so, our goal is to contribute to growing the ironmaking industry, as well as improving the global environment.

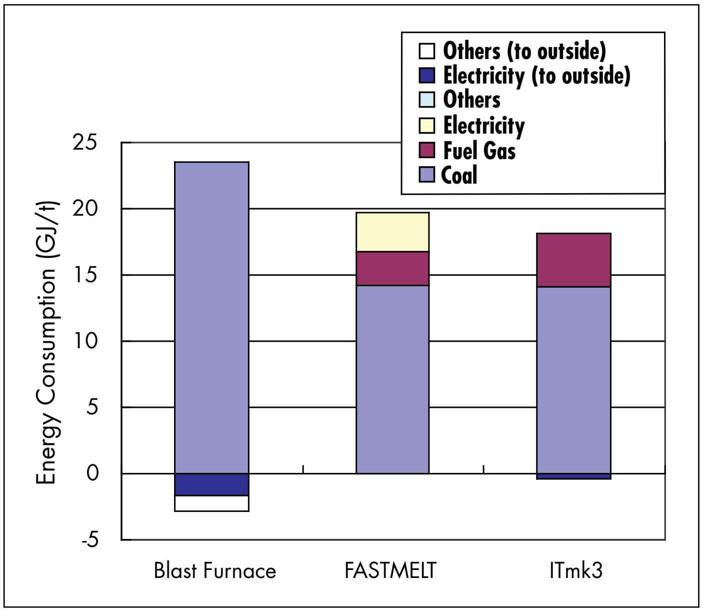

Figure 13 - Energy consumption of ironmaking processes

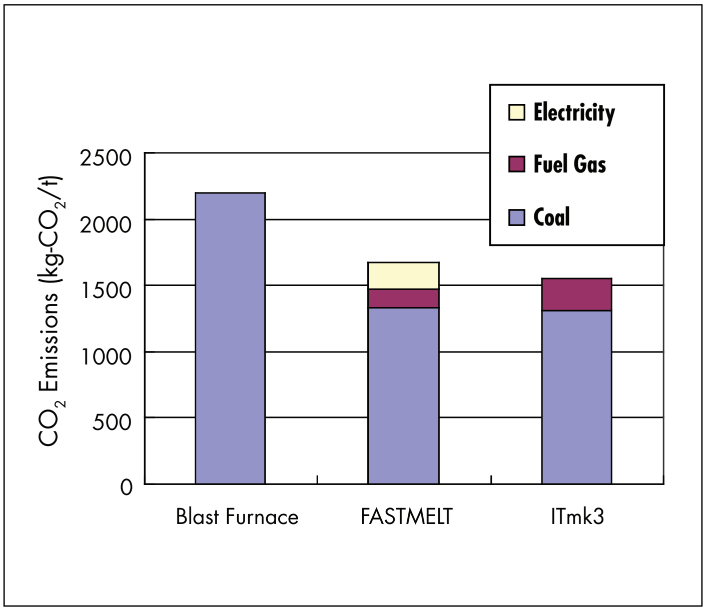

Figure 14 - CO_2 emissions of ironmaking processes

Midrex News & Views

ITmk3® Plant to Be Constructed in Minnesota

At the end of 2007, Kobe Steel, Ltd. reached agreement with Steel Dynamics, Inc. (SDI) for Kobe Steel and SDI to construct an ironmaking plant using Kobe Steel's ITmk3® Process at Hoyt Lakes, Minnesota (USA). Total investment is projected to reach $235 million (about 26 billion yen). Plans call for the new facility, which will have an annual production capacity of 500,000 metric tons per year, to start up in mid-2009.

Following the completion of trials demonstrating the viability of the process in July 2004, Kobe Steel and SDI began working on the next stage: planning construction of the first commercial-scale ITmk3 plant. The agreement to formally confirm the launch of the commercial plant project was signed November 20, 2007 at SDI's headquarters in Fort Wayne, Indiana.

This first ITmk3 commercial plant will be constructed and operated through a joint venture, Mesabi Nugget Delaware, LLC, which will produce and sell the iron nuggets. SDI will invest $85 million in the venture, holding an 81 percent equity share, while Kobe Steel will invest $20 million for a 19 percent share. SDI will manage construction of the facility and operate it.

Kobe Steel will provide the ITmk3 process license, engineering services, primary production equipment and technical support. Midrex will be the core plant and engineering supplier to both projects. Kobe Steel expects the commercial plant to provide essential operating data on plant and process effectiveness.

SDI anticipates that all of the nuggets produced by the ITmk3 plant will be consumed in its mini-mills. In a related initiative, SDI is acquiring an existing mine near the ITmk3 plant site on the Mesabi Iron Range and plans to construct a facility for concentrating iron ore. The processed iron ore will be used as a raw material feedstock for the nugget plant.

Kobe Steel emphasized the start of the first commercial ITmk3 plant project as a significant step forward in the next-generation ironmaking process that is increasingly recognized around the world. Kobe Steel is also working on other commercial ITmk3 projects, including one in Michigan that it is studying with Cleveland-Cliffs, Inc.

Kobe Steel Forms Alliance with Cleveland-Cliffs to Promote ITmk3® Ironmaking Technology

In 2007, Kobe Steel, Ltd. announced that it has formed an alliance with Cleveland-Cliffs, Inc. to market the ITmk3® ironmaking process.

The agreement, which has a 10-year term, enables the two companies to collaborate in commercializing the ITmk3 Process. Cleveland-Cliffs is granted a non-exclusive license to use the ITmk3 process and is able to freely promote ITmk3 projects mainly in the United States, Canada, Brazil and Australia. Kobe Steel will provide technical support for project promotion and development.

With the formation of the alliance, Cleveland-Cliffs and Kobe Steel also agreed to develop a commercial-scale ITmk3 plant, with an annual production capacity of 500,000 metric tons, on a joint venture basis as strategic partners at one of Cleveland-Cliffs United States mining properties. Cleveland-Cliffs and Kobe Steel will conduct feasibility studies and undertake the necessary environmental permitting for potential sites. The timing of this project, as well as the site location, will ultimately depend on permitting issues.

"Our alliance is aimed at expanding the use of the ITmk3 Process in major iron ore-producing countries worldwide," said Shohei Manabe, General Manager and head of Kobe Steel's Iron Unit Division. "ITmk3 offers an attractive alternative for mineral processing. For steelmakers planning to expand capacity and mining companies seeking to broaden their product range, the ITmk3 Process holds the promise of a cost-effective method of producing high-quality iron units for steelmaking," he said.

Commenting on the new alliance, Cliffs Chairman, President and Chief Executive Officer Joseph A. Carrabba stated, "We have been very interested in this technology since successfully testing the process in a pilot plant located at our Northshore facility. The alliance with Kobe moves us closer to realizing our mutual goal of commercializing and exploiting this innovative process."