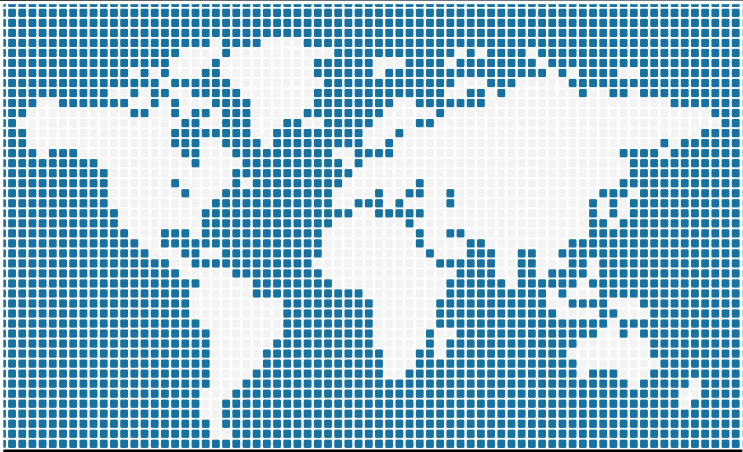
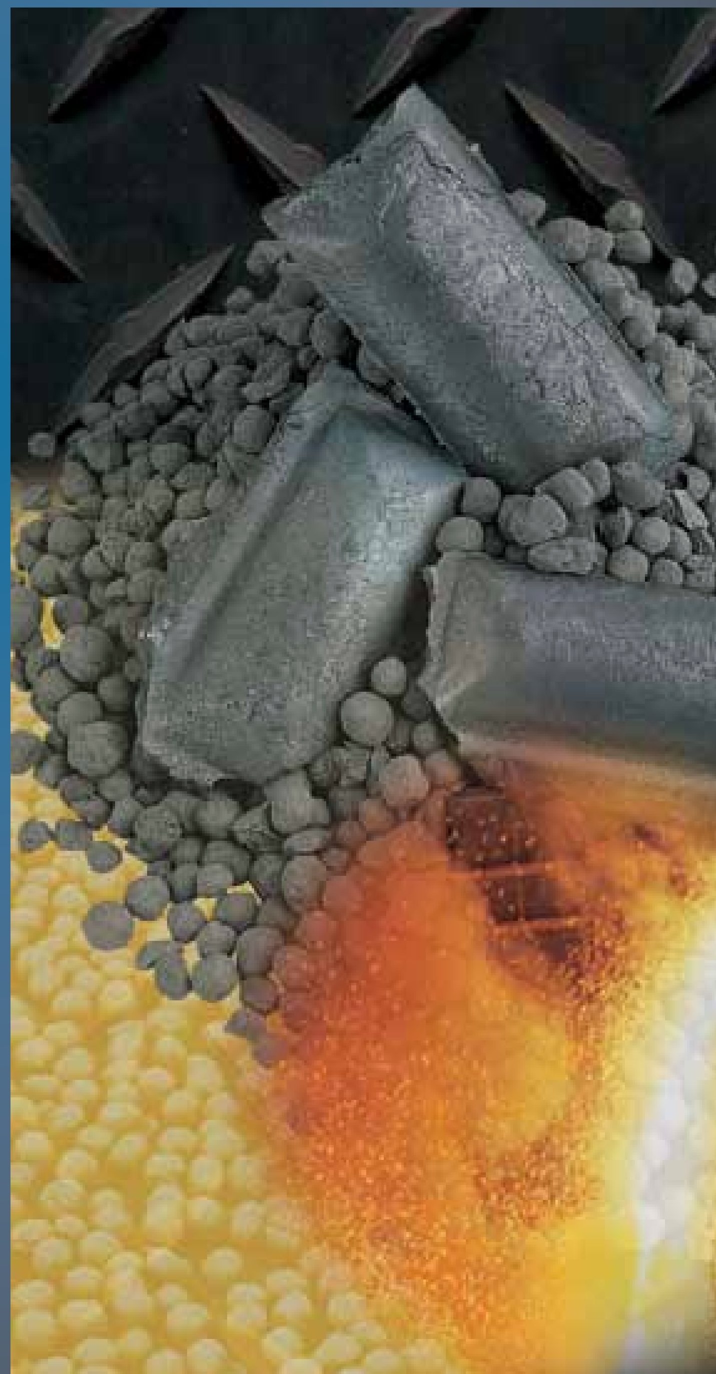


DIRECT FROM MIDREX

1ST QUARTER 2011



CONTENTS

www.midrex.com

COMMENTARY

5 Questions with... Dan Sanford

Vice-President of Operations, Daniel J. Sanford, recently took time out from his work and travels to talk about Midrex, the technological advancements in the MIDREX® Direct Reduction Process and new ironmaking technologies. Sanford, as many of Midrex's executives, has spent decades working on MIDREX® Projects and alongside our Licensees throughout the world.

Tell us about your career and how you started with Midrex?

My career at Midrex can be broken up in to two periods spanning more than 23 years in total. The first period at the company started in 1984. Previously I had worked in plant maintenance as a mechanical engineer in both the petrochemical and fabrication industries. I moved to Charlotte, NC in the 1980's (location of Midrex's company headquarters) and realized that Midrex was a unique opportunity. I began as a mechanical engineer and started working on what was to be the first MIDREX MEGAMOD®, OPCO (FMO Planta de Briquetas). The MEGAMOD® was a milestone for the MIDREX® Technology and the DR Industry. It was a scale-up of the MIDREX technology for the furnace and other process equipment resulting in an annual DR capacity of 1 Mtpy and I was proud to be part of it. I left at the end of the 1980's and returned to the company in 1993 continuing where I left off, working with the MIDREX MEGAMODs, but this time in India.

This second time around I served as lead mechanical engineer for the NDIL (Ispat Industries) project in Mumbai. As we implemented MEGAMOD technology in additional plants such as IMEXSA (ArcelorMittal Lazero Cardenas) and CIL (ArcelorMittal Point Lisas), we continued our technology development and began developing the SUPER MEGAMOD® and hot charging technologies. Shortly after NDIL, I became the Director of Engineering, where I was in charge of supervising engineering as well as the development and implementation of this next generation of MIDREX® technology.

In 2001, I was promoted to Vice President of Operations, which inlcudes procurement and project management, not just engineering, and within a few years, we began the most ambitious period of MIDREX Plant construction in company history. Our projects included Qatar Steel 2 CDRI/HBI, LGOK HBI 2, LION HDRI/HBI and HADEED HDRI/CDRI Mod E among others. The projects featured various various technological improvements ranging from new higher capacity briquetters to hot transport systems for charging hot DRI into an EAF. All in all, it's been a very eventful 23 years and looks to be just as exciting in the next few years as we begin implementing coal fueled MIDREX® MXCOL® plants for India and other regions.

Dan Sanford
MIdrex Vice President of Operations

From the early 90's: At Sakara pyramids in Egypt during visit to ANSDK (now EZDK)

What makes Midrex Project Engineering unique?

We are basically unique for what we do, but more so for how we go about doing it.

We are a technology company, the leading technology supplier for the global DR industry, but we are also a reasonably small company. Usually most similar-type and size companies primarily license technology. Midrex is different. We have a "hands on" approach to the technology and heavy involvement with each project, because we want to be in charge and have responsibility

COMMENTARY

Continued from page 2

over the technology rather than simply licensing it to others. I'm proud to say that we provide a true value for our clients by working with engineering, procurement and construction (EPC) companies such as Siemens VAI, Kobe Steel and Samsung. to all types of projects, from technology package to full lump sum turnkey.

Shanghai Expo 2010

We're unique because of our involvement in every Midrex DR project. Being in charge of the technology has allowed us to learn and continuously improve the process technology and equipment. We have been able to improve upon prior equipment designs to increase throughput and improve reliability. We have steadily improved the MIDREX® Technology, not only in terms of equipment design, but also process flexibility, product quality and general operation.

For example, older plants have benefitted from new equipment designs in the reformer and heat recovery systems, advances in shaft furnace mass flow and process optimization for high temperature and high carbon operation. Our participation in the operation of various plants has provided us the know-how to design and supply proven and flexibile technology with high annual availability. Our plants are known for often well exceeding their annual capacity but they can also run efficiently at 50-60% of that capacity for economical operation in down steel cycles.

Learning and sharing from each experience and client means advancement and improved quality for all. We share our insight with our clients through our Technical Services Group, which visits the plants, issues regular Technical Service Bulletins and hosts an annual Operations Seminar to discuss operational improvements and experiences. It's this constant influx of new information and the application of it, that makes our core technology truly cutting edge.

Is there such a thing as a standard MIDREX® Plant?

A great thing about the MIDREX Process is that we have standardized the technology, but each plant is unique and designed specifically for each client's precise requirements.

It is easy to say you have the most technologically advanced process, but what does that actually mean? Through four decades of technology development, successful implementation and project execution, we have created a reliable process with more options and flexibility for the client than any other competing technology.

The 1980's saw the birth and implementation of the MEGAMOD and successful hot briquetting of DRI. The seamless improvements of the technology, coupled with our continuing R&D programs, led to new technologies in the 1990's. The one million ton per year MIDREX MEGAMOD paved the way for even larger plants as we

In sub-zero weather while inspecting a jobsite with Samsung in 2010.

COMMENTARY

Continued from page 3
began developing the SUPER MEGAMOD technology that pushed annual production past the 2 Mtpy mark. The hot discharge feature of the successful HBI plants led to hot transport systems for more efficient steelmaking. Our process has steadily been updated and improved but most importantly continues to provide reliable solutions for steelmaking for a multitude of scenarios.

Over the years the MIDREX Process has grown with the industry to meet the need for product options and process flexibility. Our technology can handle a wide variety product feeds and ores. It can run on a various energy sources from natural gas to coal through coal gasification using COREX® gas or other coal-based off gases. In addition we offer product flexibility ranging from cold DRI, HBI, HDRI and any combination of the three. We can control the product temperature, chemistry as well as the plant emissions to further reduce NOx or virtually eliminate CO_2 via capture.

The differences in plant features are numerous, but at the core of every plant is the same process technology package and equipment; the balance of plant is specially designed and tweaked for each client to provide them with the best solution for their needs.

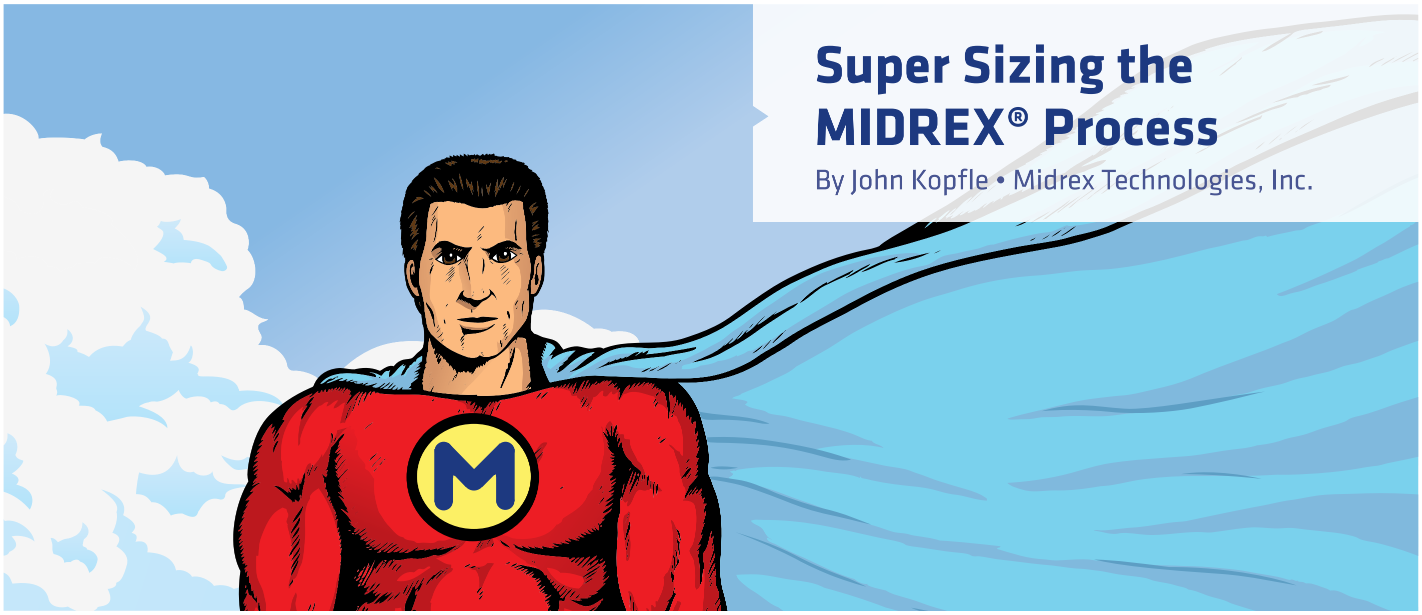
How has Project Engineering/ execution evolved over the past 30 years?

Advancements in communications have probably been the biggest evolution to project engineering and execution. The early projects relied on telexes and post and sometimes communication could take weeks. Even back in the late 1990's it was difficult to get landline or mobile communications in many areas, but now we have very fluid forms of telecommunications that help us be more efficient and productive. As I've said, the process itself has evolved, but so has the company. Manual drawing has gave way to CAD software which led to complete 3D modeling of plants and projects. We can call up any number of equipment designs and revisions in digital format. Today it is much easier to reuse and share information Because of these design advances and better communication channels, we have been able to work with Jacobs Engineering in India for detailed engineering to further increase execution efficiency. In essence, time differences that in the past would hinder progress now help as we have almost seamless 24 hour operation. When one region is finished with work, another can pick it up. Naturally this global approach also helps us to better integrate with our EPC partners Siemens, KSL and Samsung.

At the Mesabi Nugget ITmk3 Plant in Minnesota, 2009.

Any favorite projects or experiences?

Over the years, there have been many, and I've mentioned a few already such as working on NDIL and the Hadeed hot transport system as well as successfully integrating Jacobs Engineering into our core engineering capabilities. But so far I've talked about the MIDREX Process; however, in the last decade we have also worked on bringing a new technology to the market – ITmk3®. This has been a big achievement for everyone involved. We've taken the technology from concept to reality, from Pilot Demonstration Plant to full scale commercial operation. ITmk3 is a different type of ironmaking process with a different niche; however, the project benefitted from the lessons learned through years of project execution and development that Midrex had to offer. I look forward to the next commercial plants and to the continuing improvements.



Super Sizing the MIDREX® Process

By John Kopfle • Midrex Technologies, Inc.

INTRODUCTION

Other than the blast furnace, the MIDREX® Direct Reduction Process has proven to be the world's most successful ironmaking technology. MIDREX® Plants now produce over 40 million tons of iron per year and modules are being designed with a rated capacity of 2.5 million tons per year (Mtpy). This is 17 times the capacity of the first MIDREX Plant. Midrex and its partners have built (or are constructing) 74 MIDREX® Modules (shaft furnaces plus reformers and associated systems) in 22 countries since 1969.

GENESIS OF THE MIDREX PROCESS

The Surface Combustion Company (SCC) in Toledo, Ohio, USA was Midrex's predecessor. SCC was formed in the 1920s to apply combustion processes and heat transfer principles to industrial needs and it became one of the world's largest suppliers of industrial furnace equipment. SCC designed and sold vertical shaft furnaces for minerals processing, particularly iron ore hardening, or induration. During the late 1940s to the 1970s, SCC sold about 34 shaft furnaces for indurating iron oxide pellets. In 1936, SCC started making hydrogen from natural gas (reforming) in the laboratory for use in heat treating. The development of shaft furnace technology for processing minerals and a process for natural gas reforming was crucial for the later success of the MIDREX Process. In 1959, Midland-Ross Corporation acquired SCC and continued to operate the company as a separate division.

In 1966, Midland-Ross discussed the idea of developing a DR process for producing highly metallized iron pellets for EAF use. Donald Beggs, Manager of the Surface Combustion Division's (SCD) Research Group, conceived the idea of employing natural gas reforming to produce high quality gas which would be used to reduce iron oxide pellets in a shaft furnace. Beggs proposed that a pilot plant be built in Toledo, incorporating a 0.46 m inside diameter shaft furnace with a capacity of 180-225 kg per hour. SCD's mineral processing lab is shown in Figure 1. The plant was built in 1967 and operated successfully for one month. The product was shipped to Oregon Steel Mills in Portland, Oregon, and the steel mill established a new production record with the DRI.

FIGURE 1 *SCD Minerals Processing Lab*

Oregon Steel then contracted with Midland-Ross for a full-scale prototype plant in Portland. It consisted of two modules, each with a 3.7 m (12 foot) diameter furnace, and a capacity of 200,000 tons per year (the capacity was later downrated to 150,000 tpy).

There were a number of problems encountered in the Portland plant, but the work done to solve them paved the way for the success of the MIDREX Process. These issues included carbon formation, DRI degradation and clustering. For a complete history of Midrex and the MIDREX Process, see the series "A Better Mousetrap" in the 1st through 4th quarter 2004 issues of *Direct from Midrex*.

CONTINUING EVOLUTION

The second generation plant designs incorporated improvements from the experience in Portland, including a higher reducing gas temperature, larger reformer tube diameter, and more tubes. The furnace internal diameter (ID) was 4.88 m. The reformer had a modular design, with 250 mm diameter reformer tubes filled with catalyst, arranged in rows. There were four rows and 8 "bays," each bay consisting of 20 tubes, for a total of 160 tubes. Four of these plants were built, with two starting up in 1971: ArcelorMittal Georgetown in Georgetown, SC, USA and ArcelorMittal Hamburg in Hamburg, Germany *(see Figure 2)*. Both these plants were rated at 400,000 tpy and took several years to reach capacity. In 1975 and 1976, the plants increased the number of reformer tubes to 200.

FIGURE 2 *Georgetown (top) and Hamburg (bottom) MIDREX® Plants*

TABLE I *MIDREX Plant Capacity Evolution*

Name	Capacity (Mtpy)	Shaft Furnace ID (m)	Reformer Tubes	Modules Installed	First Module	Start-up Date
Protoype	0.15	3.7	120*	2	Oregon Steel	1969
2nd generation	0.40	4.88	160-200	4	ArcelorMittal Georgetown	1971
Series 400	0.35-0.44	5.00-5.21	220-336	21	Ternium SIDOR I	1977
Series 600	0.51-1.00	5.50-5.65	320-468	28	ArcelorMittal Canada 2	1977
MEGAMOD	0.80-1.99**	6.5-7.15	450-576***	19	Ispat Industries	1994
SUPER MEGAMOD	2.00 and up	7.5 and larger	640 and up	-		

Notes: *200 mm ID tubes; other plants use 250 mm tubes **0.80 Mtpy capacity is due to volume of COREX offgas available
***For natural gas plants – ArcelorMittal South Africa uses only COREX offgas

Table I shows the evolution of MIDREX Plants.

The Georgetown Plant's highest yearly production was 579,000 tons in 2000. It operated until 2003, producing over 10 million tons of DRI over the years. It has now been dismantled. ArcelorMittal Hamburg is still operating and its record production was 607,000 tons in 2004. Cumulative production to date is over 13 million tons. The third and fourth plants, ArcelorMittal Canada 1 and TenarisSiderca, are also still operating.

The next step in the evolution of the process was to increase the furnace ID to a nominal 5 m and increase the number of reformer tubes. The first plant built with this design was Ternium SIDOR I in Venezuela, in 1977 and a total of 21 modules have been built with this general configuration. It was called a MIDREX® Series 400 Module because of its nominal rating of 400,000 tpy. These plants have furnace IDs ranging from 5.0 to 5.21 m and include from 220-336 reformer tubes. Although the furnace IDs are just slightly larger than the previous designs, the production history of these plants has been remarkable. The highest production of this group has been 1.04 Mt at Ternium SIDOR I in 2005, which is nearly three times its rated capacity of 0.35 Mtpy. Several other modules have produced 800,000-900,000 tons.

Plant execution for the MIDREX Process has always relied on construction licensees, who are assigned projects geographically or on a project-by-project basis. One design feature that varied between modules was reformer tube diameter, which at times varied between licensees. From Georgetown on, Midrex has always used a 250 mm ID for the plants it has designed. The plants built by licensees Korf Engineering, Lurgi Metalgesellshaft, and Siemens VAI Metals Technologies generally used a 200 mm ID tube. This difference affected the plant ratings and output.

Quickly after the building of the first few 5 m ID Shaft Furnace plants, Midrex went to the next level, a 5.5 m ID shaft. This module was formerly known as the Series 600 Module because the nominal capacity was 600,000 tpy. There have been 28 of these modules built, with the first being ArcelorMittal Canada 2, which started up in 1977. The highest output for any plant in the group was 1.05 Mt at EZDK II *(see Figure 3)* in 2006. These MIDREX Shaft Furnaces range from 5.5-5.65 m in diameter, with 320-468 reformer tubes.

THE MIDREX® MEGAMOD

As the Shaft Furnace ID and number of Reformer tubes increased, Midrex engineeers wondered how large could MIDREX Plants be built. What limitations and challenges would there be in reaching and exceeding one million tons per year? By the mid-1980s, Midrex began the process of designing such a plant, named the "MEGAMOD." There were no insurmountable hurdles and the first MEGAMOD, Ispat Industries, incorporated a 6.5 m ID Shaft Furnace and a Reformer with 450 tubes. It started up in September 1994 and was an immediate success. Production for 1995 was 1.1 Mt and to date it has produced over 17 Mt. There are now 15 plants operating or under construction with a Shaft Furnace of 6.5-6.65 m ID.

FIGURE 3 *EZDK Plant*

Interestingly, four of the MEGAMODs use syngas sources other than a MIDREX Reformer, demonstrating the tremendous flexibility of the MIDREX Process:

1. FMO Plant (Venezuela) - started up in 1990, was converted from an old fluidized bed direct reduction plant. The fluidized beds were replaced with a 6.5 m ID MIDREX Shaft Furnace, but the original steam reformers were retained. Because of that, the plant rating at start-up was only 800,000 tpy. In 1996, a supplemental MIDREX Reformer was added and the plant capacity was increased to 1 Mtpy.

2. ArcelorMittal South Africa – world's first COREX®/ MIDREX® Plant. It has a 6.5 m ID Furnace, but is rated at 803,000 tpy because of the amount of COREX offgas available.

3. Essar Steel Modules V and VI (India) – these plants have full size MIDREX Reformers and will also use some offgas from the COREX Plants being installed, as reformer burner fuel.

The highest production from any of the MEGAMODs has been 1.76 Mt at ArcelorMittal Lazaro Cardenas in 2004.

Several of the MEGAMODs have rated capacities of 1.4 Mtpy and higher. These plants incorporate centrifugal process gas compressors, rather than the traditional rotary lobe machines. The use of centrifugals allows for fewer units, providing lower capital and operating costs.

The next step was to build a plant of capacity approaching two million tons per year. The first contract signed was for Hadeed, in Saudi Arabia, which was already operating three MIDREX Plants. This design incorporated a 7.15 m ID Furnace, and a 570 tube Reformer. Current designs have 30 tubes per bay; thus, the Hadeed Plant has 19 bays. The design also incorporates a hot transport conveyor for feeding hot DRI to the meltshop. The rated capacity is 1.76 Mtpy of DRI and the plant started up in 2007. Several more plants are under construction with 7.15 m ID Furnaces for other clients. Figure 5 shows a representation of the evolution of the Shaft Furnace.

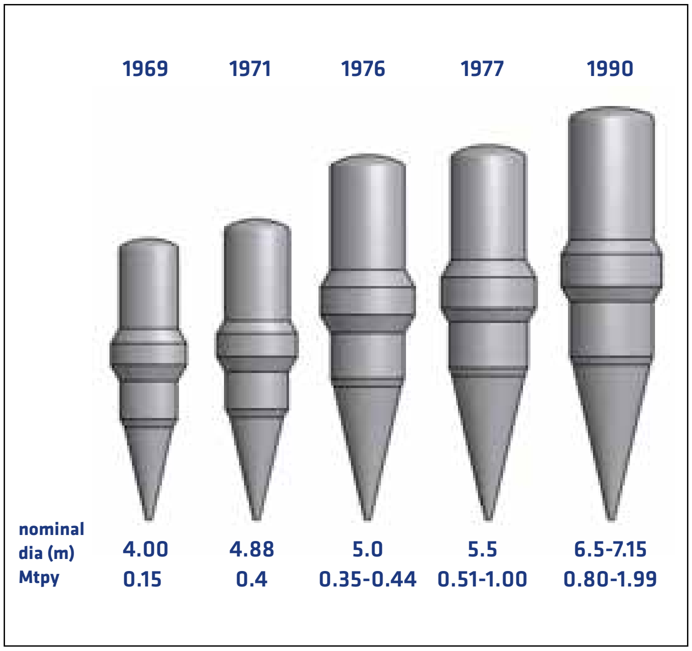


FIGURE 5 *MIDREX Furnace Sizes (to scale) and Capacities*

FIGURE 4 *Hadeed MIDREX Plant*

A SUPER IDEA

Given the economic benefits of larger production units *(see section "NOT JUST BIGGER TO BE BIGGER" on right)*, Midrex began to think about even larger modules, prompted by interest from clients. The MIDREX® SUPER MEGAMOD has been talked about for some time, but has now become a reality. Midrex classifies the modules by capacity, with the MEGAMOD ranging from 1.00-1.99 Mtpy and the SUPER MEGAMOD 2.00 Mtpy and higher.

The first SUPER MEGAMOD design incorporates a 7.65 m ID Shaft Furnace along with a reformer with 640 tubes. This reformer will be the first eight row version, which was necessary to ensure good gas distribution. This design incorporates a CO_2 removal system, which reduces the number of reformer tubes required. This plant is rated at 2.5 Mtpy. Midrex does not see any serious obstacles to designing and building a plant to produce three million tons per year. This is truly a remarkable achievement: a capacity increase of 20-fold from the first Modules at Portland.

NOT JUST BIGGER TO BE BIGGER

What is the advantage of building these larger capacity plants? One major trend in the steel industry over the last 40 years has been the growth of the EAF based mini-mill. Originally, mini-mills were built in rural areas, to collect scrap from the region, say a 300 km radius, and make ordinary long products for that area. The mills typically had capacities of 200,000-300,000 tpy. As EAF technology improved, capacities increased, as did the electrical grids to support them. Beginning in the 1990s, EAFs were built to produce up to one million tons per year, they were forced to reach farther and farther to collect scrap, and they began selling their products further afield. Developing countries without iron ore and coking coal, but with a growing demand for steel, found the mini-mill the ideal way to produce steel for the domestic market. Today, EAFs often have annual capacities of 0.5

-1.5 Mtpy, requiring a large amount of feed materials.

Regions that have abundant natural gas resources, such as the Middle East/North Africa, South America and Russia, saw that using that gas to produce DRI that would be fed to an EAF was a very good strategic move. These mills were built around the world beginning in the 1970s - and the MIDREX Plants were designed to produced 0.4-1.0 Mtpy. With the success of the MIDREX Process and the building of larger plants, steel executives realized the economic benefits.

The MIDREX Shaft Furnace and Reformer are well suited to capacity increases because they can be expanded without major design modifications. Also, the larger plants perform as well or better than the smaller ones.

Today, Midrex designs shaft furnaces for a specific production rate of 12 tons per day per cubic meter of reduction volume (t/d-m^3). This figure has been achieved and exceeded largely through the use of higher operating temperatures, which increases reaction kinetics, and internal devices, which facilitate good gas-solids contact. Some MIDREX Plants have achieved sustained productivities of 16 t/d-m^3, the highest in the direct reduction industry. MIDREX Plants routinely exceed rated capacity, and in recent years the overall capacity utilization has been 100-130 percent.

Since the capacity of the Shaft Furnace increases with the square of the diameter, a doubling of capacity requires an increase of only 40 percent in diameter. Also, as with many process facilities, the plant cost does not increase proportionally with capacity, instead following the "seven-tenths" rule: cost = capacity to the 0.7 power. Thus, doubling a MIDREX Plant's capacity increases the cost by just 62 percent. Because the capital charge is a significant part of the total production cost, larger plants can result in substantial savings over time, assuming the steel mill can use the extra DRI.

CONCLUSIONS

Since 1969, Midrex and its partners have built (or are constructing) 74 MIDREX® Modules (shaft furnaces plus reformers and associated systems) in 22 countries. The successful operation of MIDREX Plants has resulted in a market share for MIDREX® Technology of 60 percent or more nearly every year since 1987. This success is based on the firm foundation of the work done by Donald Beggs and his colleagues, who conceived the idea of pairing a stoichiometric CO_2 reformer with a shaft furnace to reduce iron oxide. A major factor in the success of the process has been the ability to scale up the MIDREX Shaft Furnace and MIDREX Reformer. The largest Shaft Furnace designed to date has an internal diameter of 7.65 m and the largest reformer employs 640 tubes, plus a CO_2 removal system. The rated capacity of this plant is 2.5 Mtpy, 17 times larger than the first MIDREX Modules, and even larger sizes are feasible. The economic benefits of the larger modules are significant, as reflected in the number of sales in the last eight years. Midrex will continue to innovate, developing technologies demanded by the steel industry.

MXCŌL®

What you NEED to know about MXCOL®: A MIDREX® Plant fueled by Coal Gasification

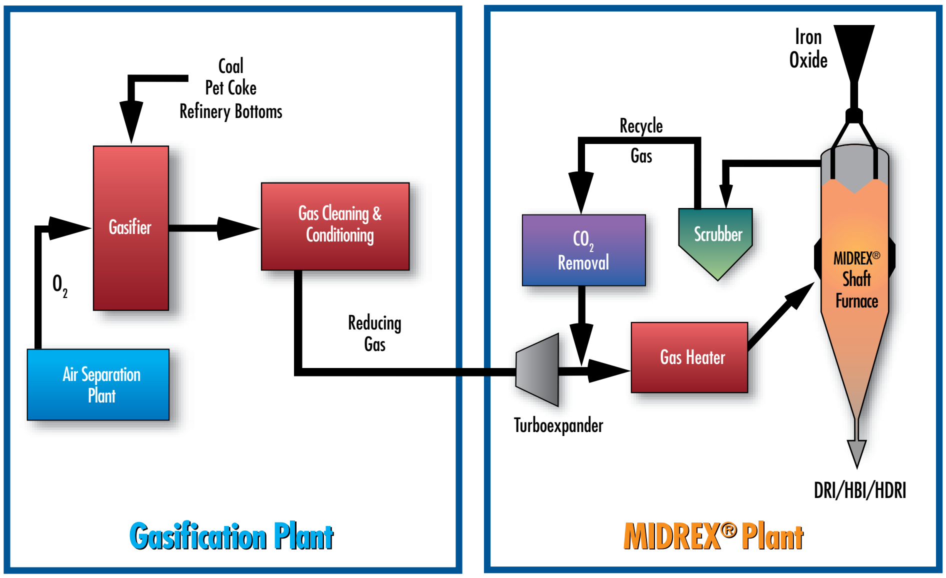
Question: What is MXCOL®?
Answer: Simply, it is the future of coal-based DRI production.

MXCOL® (pronounced "M X coal") is the name and trademark for the commercially proven MIDREX® Shaft Furnace technology using synthetic gas (syngas) from a coal source (gasification). There are many options for producing the required syngas including coal gasifiers.

MXCOL® is the future of coal-based direct reduced iron (DRI) production because it allows all of the benefits, quality and reliability of the MIDREX® Process, but using coal as the primary energy source rather than natural gas. With larger shaft furnace sizes, MXCOL® allows for greater competiveness for steelmakers by providing further fuel options for the MIDREX Process. As energy costs rise, gasification also enables the use of lower quality coals or waste products to produce energy.

Question: Does MXCOL® use the same MIDREX Shaft Furnace?
Answer: Yes, it has the same features as the world's most productive direct reduction technology.

The shaft furnace used for MXCOL® is nearly identical to the one used in natural gas-based MIDREX® Plants, which have produced over 640 million tons of DRI since 1969. The main difference between the traditional MIDREX® Flowsheet and MXCOL® is that MXCOL® uses a coal-based syngas source rather than a natural gas reformer. Options include: Coal Gasifier Syngas, Coke Oven Gas and BOF Gas. The coal gasifier option is the most flexible and can use a wide range of low cost fuels, such as bituminous and sub-bituminous coal, lignite, pet coke and petroleum refinery bottoms to generate the synthesis gas.



MXCOL® Flow Sheet

Question: **Can MXCOL® replace a Blast Furnace?**
Answer: Yes, and it has environmental benefits too.

Since MIDREX® Shaft furnaces can be designed to produce in excess of two million tons per year, this technology is ideal to replace some blast furnaces. In addition, the environmental benefits of an MXCOL® Plant versus a blast furnace include reduced air emissions (significantly lower SOx, NOx, particulates) and no need for coke ovens or sinter plants.

Question: **Where is MXCOL® applicable?**
Answer: In regions where there are limited quantities of inexpensive natural gas and a need for high quality metallics.

The MXCOL® Direct Reduction Plant is an economical and environmentally sound solution for the iron and steel industry in areas of the world where natural gas as a fuel is not a viable option. It has great potential for regions such as India, China and the CIS that need higher grade metallics and have access to low cost coal. MXCOL® allows steelmakers in those areas to better to utilize domestic coal for the production of DRI, versus the traditional rotary kilns and blast furnaces. It also avoids the need for expensive coking coal or coke.

Question: **Is using coal gas to fuel a MIDREX® Shaft Furnace commercially proven?**
Answer: Yes, Arcelor Mittal South Africa has been using Coal Gas from its COREX® Plant for more than a decade.

The concept of MXCOL® has been in place for years, but the rationale behind branding MXCOL® now is to show the steel industry that there is a better alternative to other coal-based technologies. The world's first application of coal gasification to produce DRI in a MIDREX® Plant started up in 1999 at ArcelorMittal Steel South Africa (formerly Saldanha Steel) and the facility has produced over six million tons of high quality DRI. More recently Jindal Steel & Power Limited (JSPL) contracted last year to build a 1.8 million ton per year MXCOL® Plant in Angul, Orissa, India. The new MIDREX® Module will pair commercially available gasification technology from Lurgi GmbH of Germany, together with a 7.15 meter MIDREX® Shaft Furnace to produce DRI for use in meltshop applications.

ArcelorMittal Steel South Africa

This is the first time a Lurgi gasifier will be paired will a MIDREX® Furnace; the new installation will use indigenous coal and iron ore.

Question: **Can MXCOL® hot discharge DRI to a melt-shop or produce HBI?**
Answer: Yes, all the product flexibility and options of a traditional MIDREX® Plant are applicable to MXCOL®.

An MXCOL® Plant can be designed to produce combinations of cold DRI, hot DRI and HBI, just as a conventional MIDREX® Plant. This provides great flexibility to the owner in using or selling the products. Midrex provides three methods of producing and transporting hot DRI: HOTLINK®, hot transport conveyor and hot transport vessels. These provide a simple, reliable and economical means for retaining the sensible heat contained in HDRI. All three methods can be applied to either a natural gas MIDREX® Plant or an MXCOL® facility.

MXCOL®: A breakthrough in coal-based direct reduction

By Gary Metius and John Kopfle
Midrex Technologies, Inc.

INTRODUCTION

Since 2000, world steel production has increased at a compound annual growth rate of over 5 percent, as shown in Figure 1. This has been driven by growth in the developing world, especially China, which now accounts for 46 percent of global steel output. Steel demand depends on economic expansion and growth in China, India, Southeast Asia, Latin America, and the Middle East/North Africa has propelled the steel industry to new heights. With the continued growth of the emerging markets, many experts forecast that world steel output will reach two billion tons by 2020.

FUTURE STEELMAKING GROWTH

To achieve the steel production growth that is forecast, what are the options? Certainly, the blast furnace/BOF route, which now accounts for 70 percent of world steel production, will continue to be the predominant method. However, there are a number of issues. First, the blast furnace requires coke, and coking coal is not available in many countries. The need to import coal or coke puts those areas at an economic disadvantage, since coking coal prices have increased greatly in recent years. In addition, there may be environmental issues with the BF/BOF route and the capital costs can be high.

The electric arc furnace (EAF) steelmaking route is an excellent steelmaking choice for developing countries. However, those countries do not produce a lot of scrap and some source of iron must be added. Direct reduction using natural gas-fired shaft furnaces (such as the MIDREX® Process) or coal-fired rotary kilns is a good option for supplying the necessary iron

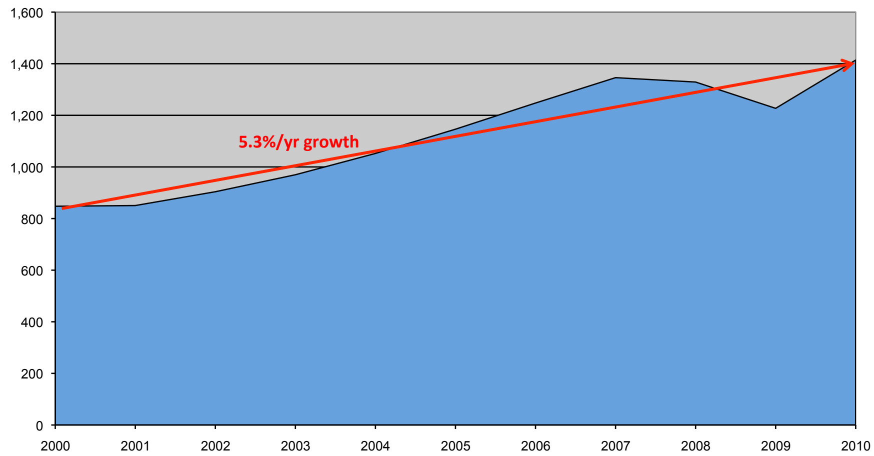


FIGURE 1 *World Steel Production (million tons)* Source: WorldSteel

units. World DRI production increased to 69 million tons (Mt) in 2010 and may rise to 120 Mt by 2020.

There is a need for another direct reduction alternative because not all regions have abundant, inexpensive natural gas, and there are issues with rotary kiln production. Many rotary kilns have been installed in India and other countries, but there is a limit to the growth of this technology because they cannot be built larger than about 200,000 tpy. Also, there are product quality issues because of the use of lump ore and coal with high levels of ash and sulfur.

MXCOL®: USE OF SYNGAS FROM COAL IN A MIDREX® PLANT

An alternative option generating significant interest in India and elsewhere is MXCOL, which is the use of synthetic gas (syngas) made from coal in combination with a MIDREX® Direct Reduction Plant. Syngas options include a coal gasifier, coke oven gas or BOF gas. The big advantage of coal gasification is that lower grade, inexpensive domestic coals can be used to produce a high quality reducing gas for the MIDREX Shaft Furnace.

Coal Gasification

There are three general types of coal gasifiers: fixed bed, entrained flow and fluidized bed. All three technologies are based on partial oxidation (gasification) of a carbonaceous (carbon containing) feed material.

The general partial oxidation reaction is:

$$2\ CH_n + O_2 \text{ -------> } 2\ CO + n\ H_2$$

In addition to the desired CO and H_2, the syngas exiting a gasifier also contains CO_2, H_2O, CH_4, H_2S, NH_3 and particulates. If a fixed bed gasification technology is utilized, the syngas will also contain aromatic organic compounds.

While each of the gasifier types can make an acceptable reducing gas for a MIDREX DR Plant, the fixed bed and fluidized bed technologies will be the preferred choices for many locations because they can accommodate the high ash domestic coals. Countries of interest include India, China and the CIS. The leading fixed bed process is the Lurgi Gasification process; it is well-proven, with over 102 gasifiers in commercial operation worldwide, the earliest of these built in 1955. Figure 2 shows Lurgi gasifiers at the Sasol Plant in Secunda, South Africa. There are a number of fluidized bed processes, including the KBR Transport Gasifier, known as TRIG™, and the U-Gas Process, which is licensed by Synthesis Energy Systems. These processes are in the early stages of commercialization, but show good promise.

FIGURE 2 *Lurgi Gasifiers in Secunda, South Africa*

THE COAL GASIFICATION PROCESS

Figure 3 shows a simplified MXCOL process flowsheet. In the gasification processes, coal is gasified at elevated pressures by reacting with high pressure steam and high purity oxygen to produce a syngas suitable for the production of fuels and chemicals, power generation or the reduction of iron ore. The fixed bed and fluidized bed gasifiers operate at a temperature below the ash melting point so the coal ash is discharged from the gasifier as a solid. Because of this low operating temperature, these technologies require significantly lower quantities of oxygen than the entrained flow gasification processes which melt the ash.

The syngas exiting the gasifier is hot, dirty, and contains a significant amount of non reducing gas components. Downstream of the gasifier, the syngas is cleaned and conditioned to remove most of the undesired components and produce saleable commodities such as sulfur and petrochemical plant feedstocks.

MIDREX® DIRECT REDUCTION PLANT

The cleaned, high pressure syngas (reducing gas) exiting the gasification plant contains approximately 85 percent H_2+CO, 2.5 percent CO_2, and 10-12 percent CH_4. Table I shows the syngas quality required for MXCOL.

TABLE I *MXCOL Syngas Quality*

Syngas Characteristic	MIDREX Requirement
CO_2 content	2.0-3.0%
Gas Quality*	≥ 10
Gas Requirement	~ 2.2 net Gcal / t DRI
Pressure	> 3 barg
H_2/CO ratio	1 - 2.0
Sulfur content	< 5 ppmv
Particulates content	< 10 mg / Nm_3
N_2 + Ar content	< 0.5 %

** Gas Quality is defined as (% H_2 + % CO) / (% H_2O + % CO_2)*

GASIFICATION PLANT / MIDREX® PLANT FLOWSHEET

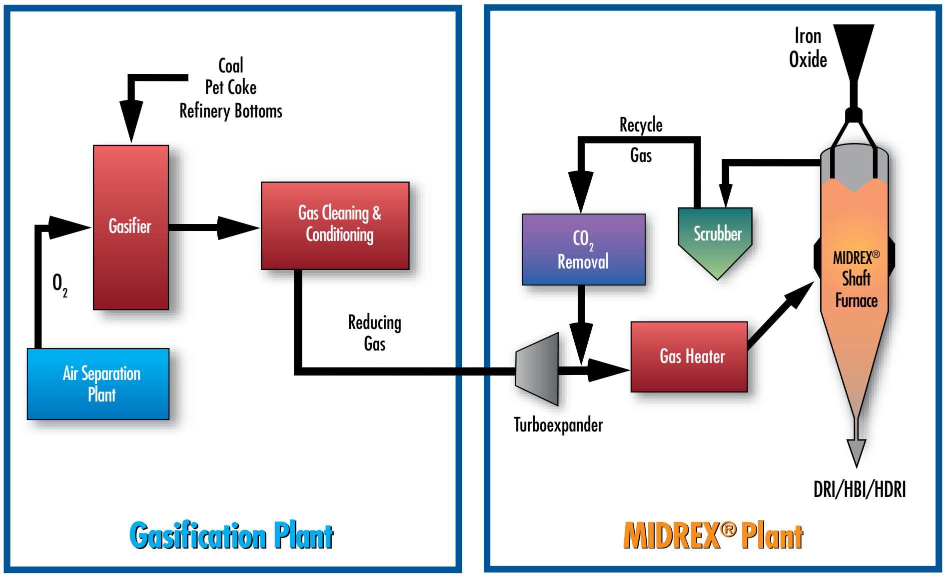


FIGURE 3 *MXCOL Flowsheet*

In the MIDREX Plant, the cold syngas is depressurized to about 3 barg in a turboexpander, which generates electricity. The low pressure syngas is mixed with recycled gas to produce the required reducing gas. The mixed gas is then heated to over 900° C and enters the MIDREX® Shaft Furnace, where it reacts with the iron oxide to produce DRI.

The reduction reactions are shown below:

$$Fe2O_3 + 3H_2 \text{ -------> } 2Fe + 3H_2O$$

$$Fe2O_3 + 3CO \text{ -------> } 2Fe + 3CO_2$$

The spent reducing gas (top gas) exiting the shaft furnace is scrubbed and cooled, then passed through a CO_2 removal system. This reduces the CO_2 content to 2-3 percent or less, which ensures that the mixed reducing gas (syngas from the gasification plant and recycled top gas from the MIDREX Plant) has an acceptably high reductants (H_2+CO) to oxidants (H_2O+CO_2) ratio for efficient iron oxide reduction. The CO_2 removal system will also remove the sulfur gases contained in the recycled top gas. The recycling of the top gas makes MXCOL a very efficient process.

The CO_2 recovered from the gasifer gas cleaning and conditioning plant and the CO_2 removal system in the MIDREX Plant are high purity. These streams could be sequestered or sold for enhanced oil recovery or use in a petrochemical or other operation. Emissions from MXCOL are shown in Table II.

TABLE II *MXCOL Emissions*

	PM10 mg/Nm³	SO_2 mg/Nm³	NOx mg/Nm³	CO_2 kg/t DRI
Reheater	<20	<15	<200	218.9
CO_2 acid gas stacks				
DR plant	<20	trace	<320	306.1
Coal Gas Island	<20	trace	<320	374.8
Aux. Boiler	<20	150	<700	265.9
		(90% FGD)	(0.5 lb/10^6 Btu's)	

MIDREX PLANT OPTIONS

A major advantage of MXCOL is that it uses the well proven MIDREX Shaft Furnace and ancillary systems. Since 1969, there have been 74 MIDREX Modules built or under construction, with a total rated capacity of 56 Mt. The largest of these plants has a capacity of 1.8 Mtpy.

TABLE III *Lurgi Gasification Plant + MIDREX Plant Combination Predicted Major Operating Consumptions for Indian Conditions*

Basis: MIDREX MEGAMOD® with capacity of 1,800,000 tpy of hot DRI [1]
Lurgi Gasifier using typical high ash Indian coal

Input	Units	Quantity per t hot DRI [2,3]
Iron Ore	t	1.42
Coal (as mined)[4]	t	0.75
Coal (ash free)[4]	t	0.41
Oxygen	Nm³	150
Electricity	kW-h	150
O & M costs	USD	27

1. The hot DRI product characteristics are: 93% metallization, 1.8% carbon, and 700° C discharge temperature
2. Quantities are for the combined Lurgi Gasification Plant and MIDREX DR Plant
3. The consumption values will vary depending on the actual coal quality and the project requirements
4. Value assumes typical high ash Indian coal

There are many options available for MXCOL Plants, including DRI capacity, product form and hot transport method. Plants can be designed for capacities of 2 Mtpy and higher. Product forms include cold DRI, hot briquetted iron (HBI) and hot DRI (HDRI). Combinations of product forms can supplied, providing the plant operator great flexibility in using and selling the product. There are three options for transporting the DRI to the meltshop and charging it to the EAF: hot transport containers, a hot transport conveyor and HOTLINK®. Since 2003, over 22 Mt of MIDREX HDRI has been charged to EAFs worldwide.

JINDAL STEEL & POWER MXCOL PLANT

Jindal Steel & Power Ltd. (JSPL) is building one of India's leading corporations, with a major presence in iron and steelmaking. JSPL is building a 12.5 Mtpy integrated steel complex in Angul, Odisha State with an expected investment of $10 billion. As part of this project, JSPL contracted with Midrex Technologies for a 1.8 Mtpy MXCOL Plant, the world's first coal gasifier based unit. Details are shown in Figure 4.

FIGURE 4 *JSPL MXCOL Plant Details*

Midrex is in discussions with several other potential clients about MXCOL Projects.

OTHER SYNGAS SOURCES

In addition to a coal gasifier, other applications of coal-based syngas are possible. Midrex is working on flowsheets to use BOF offgas and coke oven gas as reducing gas in a MIDREX Plant. It would also be possible to supplement coal syngas with gas made from biofuels or wastes, creating an even "greener" technology.

CONCLUSIONS

MXCOL is an excellent option for producing high quality DRI using syngas made from coal. It provides a good solution for areas of the world without abundant and inexpensive coking coal or natural gas.

Advantages of MXCOL include:

• Can use any coal gasification technology, including the well-proven Lurgi Gasifier or emerging fluidized bed processes such as KBR TRIG and U-Gas
• The fixed bed or fluidized bed gasifiers can readily use the low rank, high ash domestic coals in India and China
• Potential to use coal syngases from other sources such as coke oven gas or BOF gas
• Uses the well-proven MIDREX Direct Reduction Process. This technology can readily use domestic iron oxides as feed material.
• Produces DRI with quality comparable to natural gas-based MIDREX Plants
• The DRI can be hot charged into a nearby electric arc furnace (EAF) to significantly reduce the EAF electricity requirement and significantly increase the EAF productivity.
• The MXCOL Plant can be paired with an EAF-based mini-mill to produce high quality long or flat steel products
• No coke, coke ovens or sinter plant required.
• Lower specific capital cost than an integrated steel works
• Lower air emissions than an integrated steel works
• Ability to capture high purity CO_2 for sequestering or injecting into oil and gas fields
• DRI capacities of over 2 Mtpy in a single module

MIDREX News & Views

Jindal Shadeed begins production in Oman in record time

Startup less than four months after acquisition and four months ahead of schedule

Jindal Steel and Power Limited (JSPL) announced that its Jindal Shadeed plant in Oman has started trial production four months ahead of schedule with the production of Hot Briquetted Iron (HBI) on 5th December 2010.

This is a source of much pride for everyone associated with the project, especially those in Oman who were able to accomplish the feat substantially before the target date of 31st March, 2011, according to JSPL. The feat was achieved by the well coordinated and collective efforts of Jindal Shadeed, its contractors and sub-contractors along with the strong support of the local community and the Omani government.

Jindal Shadeed features a 1.5 Mtpy MIDREX® HOTLINK® hot discharge plant with HBI capabilities located at the Sohar Industrial Port area of Sohar, Oman. This facility will help support the strong demand for steel in the Middle East and North African countries. JSPL anticipates the supply shortfall to be more than 12 million tonnes.

Shadeed's acquisition is significant for JSPL as the facility is engineered by Kobe Steel (Japan) and Midrex (USA). This is also the same technology JSPL will be using in its Odisha facility, and the additional experience will help bring this new facility on stream in a timely manner.

JSPL, through its 100% subsidiary Jindal Steel & Power (Mauritius) Ltd., Mauritius (JSPLM) acquired Shadeed Iron & Steel Co. LLC (Shadeed), a company incorporated under the laws of the Sultanate of Oman. The Shadeed acquisition is a major step in the international strategic expansion for JSPL, which includes several coal and iron ore mines located in Africa, Indonesia, Australia and Bolivia.

OEMK Mod 1 is back on line, new and improved!

The original Module 1 OEMK MIDREX® Plant has been in operation since 1983 with very few modifications other than normal maintenance.

As with all operations there is room for improvement, especially on an almost 30 year old facility, and in February 2008, Midrex received a contract for upgrading the plant. Initial shipments of equipment started in the fall of 2008. However, due to the international economic situation that happened in the latter part of 2008, most of the equipment to be supplied was either delayed or was stored, thus delaying construction. As markets recovered, the decision was made in the first quarter of 2009 by Metalloinvest, OEMK's parent company, to install the equipment and the restart was scheduled for August of 2010.

The original design of the OEMK Plant was a Midrex 400 Series that operated at about 55 tons per hour (approximately 440,000 tpy). The new contracted design changes would increase

the new nameplate capacity to 95 tons per hour (approximately 760,000 tpy.)

Plant updating included replacing the 8" reformer tubes with 10" tubes, replacing all the piping under the reformer, installing new reformer burners, replacing reformer roof and floor refractory, installing new furnace cooling zone off-takes and Christmas tree, replacing the refractory in the furnace with thin wall lining, installing new process gas compressors, installing a new heat recovery system, adding oxygen injection, modifing the top gas scrubber, installing a new hot fan, main air blower and dilution air blower, replacing much of the existing ductwork, and upgrade of several other areas to debottleneck the plant. Midrex did all the process, electrical, equipment, and piping engineering, and purchased and supplied the bulk of the new process equipment. OEMK did the detailed structural engineering, supplied support equipment, did extensive water system modifications, and was responsible for overall schedule and construction activities.

As much preliminary work was done as possible prior to shutting down the plant. OEMK worked using a detailed construction schedule that broke down the plant activities into individual tasks that had to be completed by daily shift. This detailed schedule allowed them to maintain strict control of project construction and to control costs.

The plant shut down on August 3, 2010 and on September 19, 2010 refractory dry out was completed, and the plant was put back into operation. This was a remarkable effort by an OEMK and Midrex team for a DRI plant to make such major modifications while only being shut down for approximately 6 weeks.

Within two weeks of completion of refractory dryout the plant passed the performance test parameters for the expansion project. Within three weeks the plant was operating at 105 tph and is now currently operating at 110 tph while still producing 94%+ metalized product containing more than 2.5% carbon. This project is clearly a tribute to the OEMK and Midrex teams in showing how teamwork can make a project successful.

Christopher M. Ravenscroft: Editor

DIRECT FROM MIDREX is published quarterly by Midrex Technologies, Inc.,
2725 Water Ridge Parkway, Suite 100, Charlotte, North Carolina 28217 U.S.A.,
Phone: (704)373-1600 Fax: (704)373-1611,
Web Site: www.midrex.com under agreement with Midrex Technologies, Inc.

The publication is distributed worldwide by email to persons interested in the direct reduced iron (DRI) market and its growing impact on the iron and steel industry.

To subscribe please register at www.midrex.com to receive our email service.

CONTACTING MIDREX

General E-mail:
info@midrex.com

Phone: (704) 373-1600
2725 Water Ridge Parkway
Charlotte, NC 28217 USA

General Press/Media Inquiries
Christopher M. Ravenscroft
cravenscroft@midrex.com
Phone: (704) 378-3380