DIRECT FROM MIDREX

1ST QUARTER 2004

CONTENTS

30 YEARS

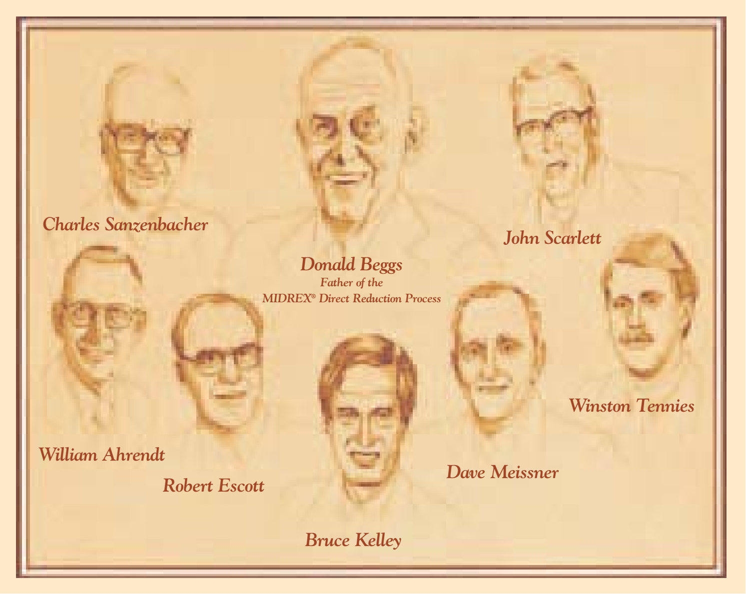
www.midrex.com

Commentary

A Storied History, An Exciting Future

John T. Kopfle
Director - New Business Development

This year, Midrex is marking the 30th anniversary of the founding of the company as Midrex Corporation. It is a fascinating story and as with most companies, there were many twists and turns along the road to success. We're running a four-part series on the history of the company with the first installment beginning on page 3. One theme that stands out is the dedication of Midrex's employees and our licensees over the years. Through steel industry downturns, difficult operating conditions, and technical issues, the Midrex family has met the challenge. The genius of the MIDREX® Process is its simplicity. Don Beggs' concept of combining stoichiometric natural gas reforming with shaft furnace direct reduction of iron ore was a breakthrough that has stood the test of time. In addition, the process has been significantly improved over the last 30 years, and our largest plants now produce 10 times the annual volume of the prototype modules at Oregon Steel Mills. These incredible productivity gains are due to scale-up of the process equipment, continual refinement of the process, and new technologies such as double bustle, in-situ reforming, oxide coating, thin wall refractory, and oxygen injection.



Pioneers of the MIDREX® Direct Reduction Process

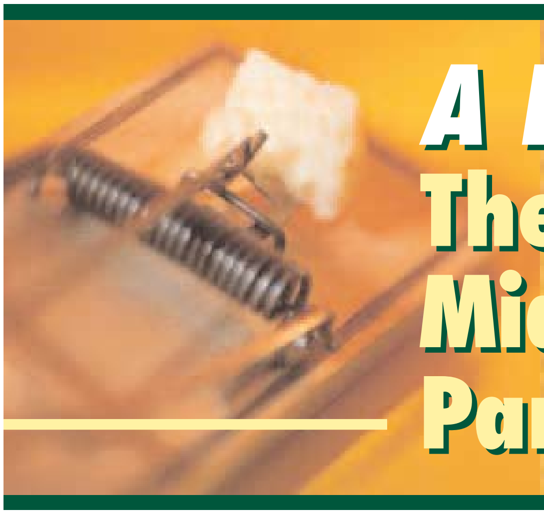
Since 1969, MIDREX® Direct Reduction Plants have produced over 375 million tons of DRI and they routinely exceed design capacity. Each year since 1987, MIDREX Plants have produced over 60 percent of the world's DRI.

However, we're not resting on our laurels. We continue to enhance the technology with developments such as oxygen use, continuous hot charging (HOTLINK®), and enhanced control (SIMPAX®). These developments have positioned the technology to take advantage of the upcoming wave of interest in new DR facilities. The past six months have seen an explosion of metallics prices and the most interest we've seen in new facilities since the mid-1990s. HBI prices have reached an all-time high, driven by Chinese steel and metallics demand, insufficient metallics supplies, and other factors. As noted in News & Views, Midrex has begun engineering for a new MIDREX Plant including HOTLINK in the UAE, and we signed a contract with OEMK for expansion of one of its MIDREX® Modules. We hope to sign more contracts soon.

We continue to make progress with our coal-based direct reduction technologies, including FASTMET®, FASTMELT®, and ITmk3®. Mesabi Nugget, the ITmk3 pilot/demonstration plant in Minnesota, is performing well and a commercial plant is in the planning stages.

In addition to our direct reduction efforts, we are continuing to evaluate and develop new business opportunities outside the steel industry. Our focus is on technologies that fit our expertise in high temperature processing of solids and gases and result in engineering, procurement, and construction management (EPCM) opportunities. The industry areas we are investigating include non-ferrous minerals processing and energy and environmental technologies. Look for announcements on these new ventures in upcoming issues of *Direct from Midrex*. For more details on our new business development efforts, check our website, under "Products & Technology Development," and select the PowerPoint presentation.

As you will read in the first installment of "A Better Mousetrap," Midrex has a storied history and there are many lessons to be learned. We are proud to build on our past successes and we look forward to an exciting future.



A Better Mousetrap: The History of Midrex Technologies Part 1

By *John T. Kopfle*
Director - New Business Development

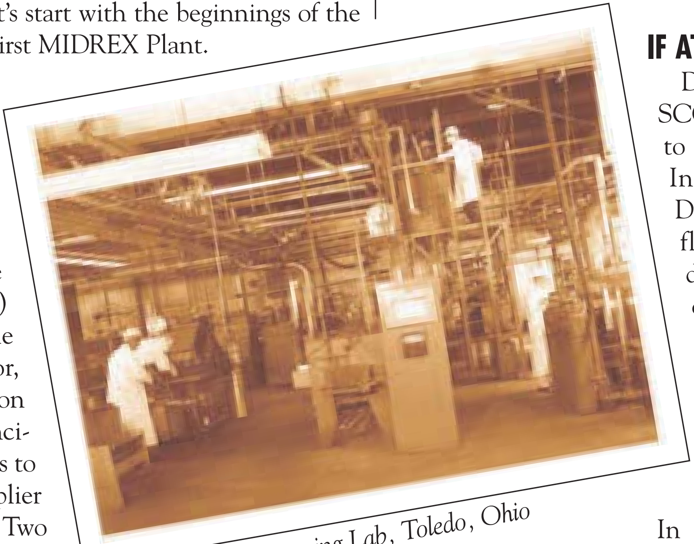
Introduction

The MIDREX® Direct Reduction Process has become the world's most successful direct reduction technology. Each year since 1987, over 60 percent of the world's direct reduced iron has been produced in MIDREX® Direct Reduction Plants. Since 1969, 53 MIDREX® Modules have been installed in 18 countries. As with most industrial technologies, the history of the MIDREX Process has been a combination of vision, entrepreneurship, hard work, mistakes, and luck.

As we celebrate the 30th anniversary of the founding of Midrex Corporation this year, *Direct from Midrex* will retrace the fascinating history of the company and the process. Each issue will cover a portion of the three decades. Let's start with the beginnings of the process and the building of the first MIDREX Plant.

IN THE BEGINNING...

The genesis of the MIDREX Process was technology and market opportunity. The story begins in the 1920s with the founding of the Surface Combustion Company (SCC) in Toledo, Ohio, USA. The company, Midrex's predecessor, was formed to apply combustion processes and heat transfer principles to industrial needs. SCC was to become the world's largest supplier of industrial furnace equipment. Two technological developments proved to be of particular significance in the evolution of the MIDREX Process. First was the design of shaft furnaces for minerals processing, particularly iron ore hardening, or induration. Second was the technical expertise SCC acquired in the combustion and reforming of hydrocarbon gases.



SCC Minerals Processing Lab, Toledo, Ohio

In 1936, SCC started making hydrogen from natural gas in the laboratory. Two years later, a gentleman named Julius Madaras of Detroit approached SCC with an idea for a process to directly reduce iron ore using hydrogen. The process required 0.65 Nm^3 of hydrogen per kilogram of DRI. The economic incentive for the process was the availability of fine hematite ore from iron sands and natural gas in Texas; oilmen and ranchers were among the potential investors. The developers believed this process could compete with blast furnace-produced steel.

After performing successful bench-scale tests, a corporation was formed to develop the technology. A 1.2 m diameter, 1.8 m tall reactor was built and installed at Hooker Chemical Company in Niagara Falls, New York, then moved to Longview, Texas. After some testwork, World War II intervened, and the effort was terminated.

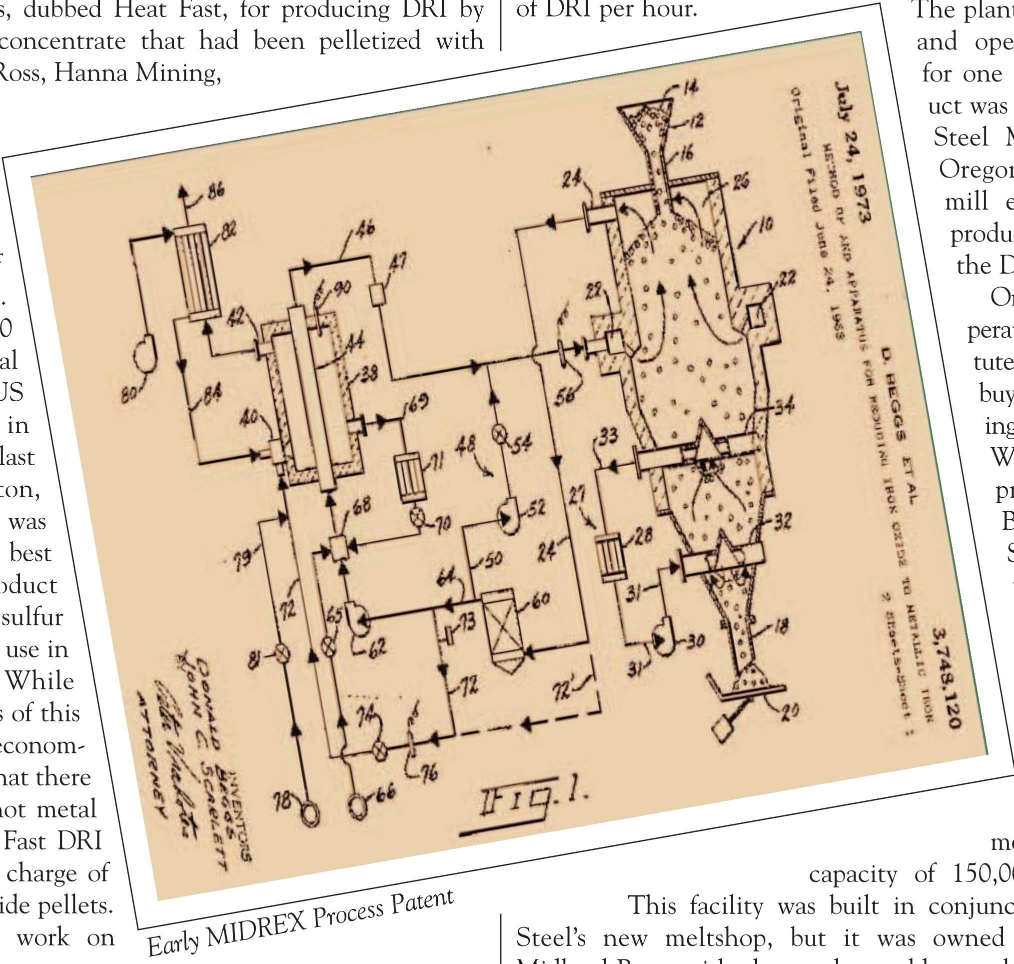
IF AT FIRST YOU DON'T SUCCEED...

During the war, some researchers at SCC began thinking about other ways to reduce iron ore. The director of the Institute of Gas Technology, one Dr. Sullivan, had experience with fluidized beds, which were being developed to crack oil for production of high octane gasoline. A laboratory-scale reactor was built, but the test runs were not successful in completely reducing the iron ore. Due to several personnel changes, no one championed the fluidized bed project and it was terminated.

In 1946, there were two momentous developments. First, SCC developed a shaft furnace for indurating iron oxide pellets. Project sponsors were Pickands-Mather, Interlake Iron, Bethlehem Steel, and Youngstown Sheet and Tube Company. Second, Raymond Patterson approached SCC with a process for reducing mill scale with granulated charcoal. The mill scale was mixed with charcoal, placed in a paper tube, then inserted into an alloy tube. Reducing gas was introduced to the tube and after several hours, the paper tube was removed and the product was crushed and magnetically separated. Then, the magnetic fraction was reduced again with gas, producing a 97 percent iron powder.

SCC formed a subsidiary, Superior Metals Corporation, to produce the powder commercially. A plant was set up in Toledo and began operations in early 1947; the product was sold for 12 cents per pound. About six months later, orders began to drop, and it was found that Hoeganes, a Swedish company, was selling a similar product for eight to ten cents per pound. Superior Metals decided to abandon the technology and the company was dissolved in 1951. Interestingly, Hoeganes still operates plants today in Sweden and the US.

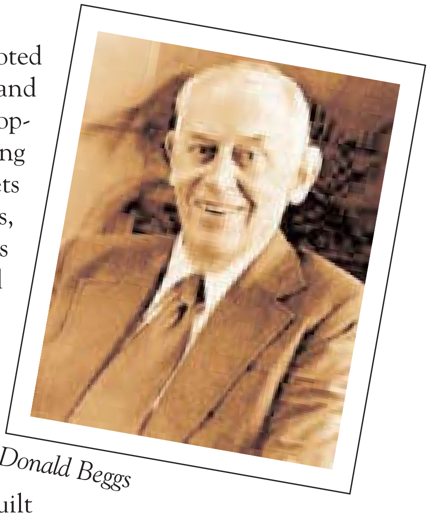
During the late 1940s and 1950s, SCC sold 41 shaft furnaces for indurating iron oxide pellets. In 1959, Midland-Ross Corporation acquired SCC and continued to operate the company as a separate division. In 1963, the Surface Combustion Division (SCD) developed a process, dubbed Heat Fast, for producing DRI by reducing iron ore concentrate that had been pelletized with fine coal. Midland-Ross, Hanna Mining, and National Steel built a $2 million demonstration plant in Cooley, Minnesota, and a sizable quantity of DRI was produced. Approximately 9,000 tons of the material was tested by the US Bureau of Mines in an experimental blast furnace in Bruceton, Pennsylvania. This was believed to be the best use for the product because its high sulfur content would limit use in electric furnaces. While the technical results of this trial were good, an economic analysis showed that there was no benefit in hot metal cost by using Heat Fast DRI versus the standard charge of 100 percent iron oxide pellets. The SCD stopped work on the process.



Early MIDREX Process Patent

At about the same time, the Steel Company of Canada and Lurgi Corporation of Germany produced DRI in a rotary kiln using coal as the reductant. These low-sulfur pellets proved an excellent feed material for Stelco's Edmonton, Alberta EAF plant. This technology was the forerunner of the SL/RN Process.

BEGGS PICKS A WINNER



Donald Beggs

In 1966, Midland-Ross noted the results in Canada and discussed the idea of developing a DR process for producing highly metallized iron pellets for EAF use. Donald Beggs, Manager of the SCD's 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 of180-225 kg of DRI per hour.

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.

Oregon Steel was desperate for a scrap substitute because Japanese buyers were purchasing scrap on the US West Coast and the price skyrocketed. By mid-year, Oregon Steel 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 150,000 tons per year. This facility was built in conjunction with Oregon Steel's new meltshop, but it was owned and operated by Midland-Ross, with the product sold on a long-term contract. Midland-Ross decided to retain ownership of the facilities rather than sell equipment and engineering services. Operations began on May 17, 1969.

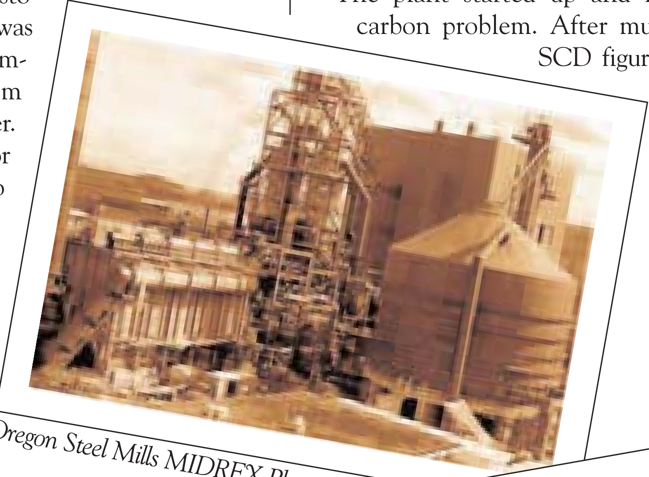
There were a number of problems that were resolved in the laboratory and during start-up of the plant, and the solutions were crucial to the ultimate success of the process. These included:

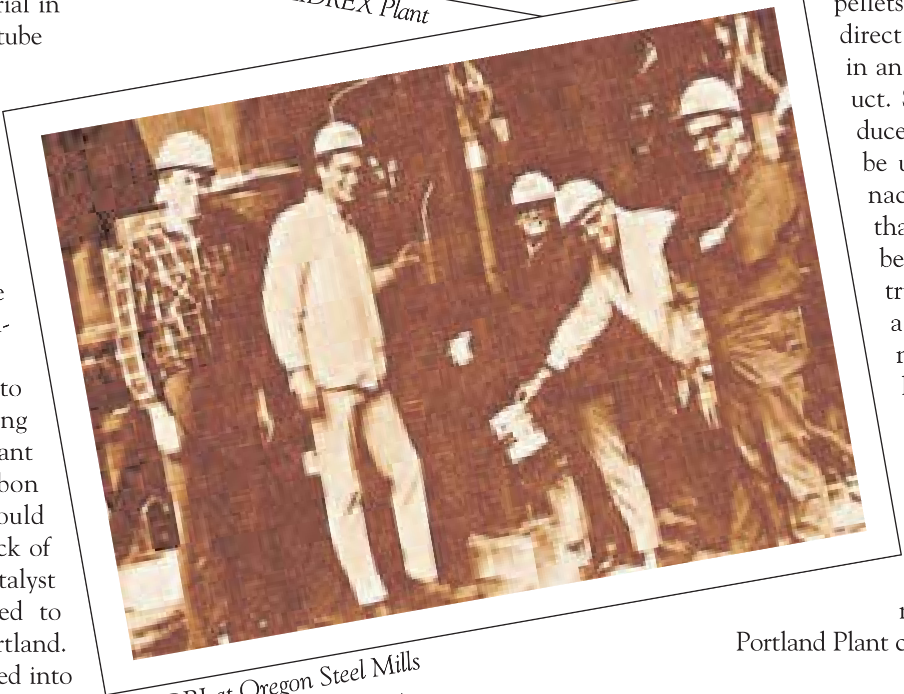
Carbon Formation

The conventional wisdom in 1968 was that reforming of natural gas was not possible without a large excess of CO_2 and H_2O, and that stoichiometric reforming would cause catalyst degradation. However, the SCD had been performing stoichiometric reforming for 20 years and was confident it would be successful on a commercial basis. The company built a 0.2 m by 7.3 m reformer at its research center. One key to the success of this endeavor was the use of a strong catalyst able to withstand the formation of Boudouard carbon and also endure the crushing action which occurs when the tube cycles between operating and idle conditions.

Boudouard carbon is formed via the Boudouard reaction, shown in Table I. The concept for preventing it was to place an inert material in the bottom of the catalyst tube (where the gas enters), then active catalyst above. This would enable the gas to be heated above the dangerous temperature range before reforming began. Unfortunately, all attempts at using this approach in the pilot plant failed, and considerable carbon was formed.

The decision was made to provide an extremely strong catalyst for the Portland Plant so that if Boudouard carbon formed, the catalyst would remain intact. Due to the lack of facilities for producing the catalyst in Toledo, the SCD decided to coat the catalyst in-situ at Portland. The carrier material was loaded into the tubes and a solution of catalyst material was pumped into them. Then the solution was drained out. To provide inert material at the bottom of the tube, water was pumped into the bottom of the tube to remove the catalyst, and then drained.


Oregon Steel Mills MIDREX Plant


First DRI at Oregon Steel Mills

Boudouard Reaction

$$2CO = CO_2 + C$$

Stoichiometric Reforming Reactions

$$CH_4 + H_2O = CO + 3H_2$$

$$CH_4 + CO_2 = 2CO + 2H_2$$

Table I Reforming Reactions

The plant started up and never experienced a Boudouard carbon problem. After much discussion and research, the SCD figured out the reason for the carbon formation problems in the Toledo laboratory and the lack of them in Portland. The concept developed at Portland is now standard practice in MIDREX Plants.

DRI Degradation

Another conventional wisdom in 1968 was that swelling and weakening of low gangue iron oxide pellets would occur during direct reduction, resulting in an unacceptable product. Since the DRI produced at Portland would be used in electric furnaces, it was crucial that low gangue feed be used. While it was true that when using a typical blast furnace reducing gas high in CO, product degradation did occur, the SCD had confirmed in laboratory tests that with a higher H_2 content, this was not a problem. The Portland Plant confirmed this result.

Clustering

During initial operations, clustering of DRI in the shaft furnace was a continuing problem. SCD surmised that methanation might be the cause by raising the bed temperature to the fusion point of iron. Methanation occurs when the reforming reactions shown in Table I reverse. This result was confirmed when methane was injected into the shaft furnace, suppressing the methanation reaction. Thus was born methane enrichment of the bustle gas, standard practice at all MIDREX Plants today.

In the next issue of DFM, we'll continue our story of the evolution of Midrex. Included will be the purchase of Midrex by Willie Korf and the ensuing growth of the company in the 1970s.

MIDREX® Direct Reduction Plants
2003 Operations Summary

Thanks to the significantly improved market conditions, MIDREX® Plants produced 31.9 million tons in 2003, more than a six percent increase over the previous year, establishing a new all-time high production record. All the MIDREX Plants in the U.S. ended the year shut down due to high natural gas prices, with the latest casualty being Georgetown Steel, which declared bankruptcy and closed in the second half of 2003. While no new MIDREX Plants came on line, many plants established new production records, thanks to the greatly increased demand for metallics. Ispat Sidbec (in Canada) plans for its Module II to go from half capacity to full capacity in early 2004. Some plants even faced a scarcity of raw materials due to the extremely high demand from China and South Korea. MIDREX Plants accounted for 64.6 percent of the 49.45 million tons of DRI produced worldwide in 2003.

ACINDAR

During their 25th anniversary year, ACINDAR operated above rated capacity for the twelfth consecutive year, producing almost 950,000 tons, even though the plant was shut down to reline the Shaft Furnace. Plant productivity was limited by the reduced availability of pellets.

ANSDK

Amsteel Mills

Amsteel operated at high capacity throughout the year almost breaking its annual production record, and again established a new monthly production record in March. Most of its HBI was produced using little or no lump ore in the feed mix. The reported electricity consumption was 109 kWh/t.

ANSDK

For the third straight year, ANSDK's Modules II and III broke annual and monthly production records. The three modules combined produced 2.87 million tons in 2003.

Caribbean Ispat Ltd

Module II broke its previous monthly production record. Oxygen use commenced in Module II in 2003.

COMSIGUA

Despite being shut down almost the entire month of January due to the curtailed local natural gas supply, COMSIGUA fell short of breaking its annual production record by only one percent. A new monthly production record, averaging 171 t/h, was set in October.

COMSIGUA

Essar

Hadeed

Essar Steel

All three of Essar's modules established new annual production records and between the three, they averaged more than 8100 hours of operation in the year. Modules I and III also established new monthly production records. A significant portion of the DRI produced is charged hot to Essar Steel's EAFs.

Georgetown Steel

After restarting in October 2001, GSC's MIDREX Plant reached the 10,000,000 tons production mark in 2003, before the company closed and filed for bankruptcy.

Hadeed

Hadeed exceeded rated capacity for the 19th consecutive year in Modules A and B, and for the 11th consecutive year in Module C. Hadeed achieved very high availability in 2002, averaging over 8400 hours of operation in the year.

IMEXSA

IMEXSA had a very good production year despite a two-week strike, falling just 1.9 percent short of its annual production record. IMEXSA will be reaching the 10 million ton mark in 2004, within seven years after startup.

Ispat HSW

Ispat HSW broke its annual and monthly production records for a second consecutive year in 2003 through a combination of increased productivity from the use of oxygen injection and increased plant availability. IHSW should be reaching the 10 million ton mark in late 2004.

Ispat Industries, Ltd

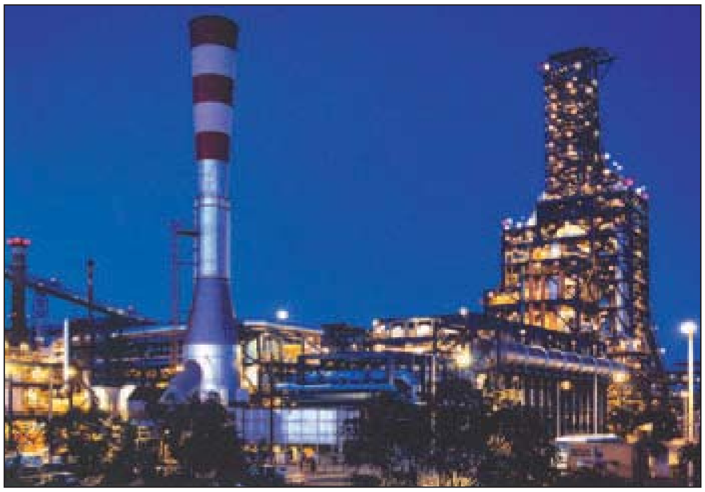
IIL of India experienced limited production due to restricted availability of natural gas. Lump ore usage averaged 55 percent for the year.

Ispat Sidbec

Module I remained shut down the whole year. Module II operated at reduced capacity (operating with only one of its two MIDREX® Reformers) but due to the improved demand, it is scheduled to ramp up to 100 percent production in early 2004.

Mobarakeh Steel

On their 10th anniversary year, Modules A and C set new annual records, reaching 780,000 tons per year production levels, and almost reaching 8300 operating hours in the year. The five modules produced 3.46 million tons this past year, exceeding their previous year production through increased plant availability



IMEXSA

Mobarakeh Steel

and productivity. Three modules (A, B and C) broke their previous monthly production records.

OEMK

On the 20th anniversary year of their first module, OEMK's Modules I and II missed matching their previous year's records by less than 1000 tons, and established new monthly production records in Modules I and III. With a production of 1.9 million tons for the year, the four modules handily exceeded rated capacity.

OPCO

Production was restrained by limited natural gas availability, but passed the 10 million ton mark in 2003.

QASCO

In their 25th year of operation, QASCO broke their previous annual production record for the third consecutive year by 3.2 percent, mainly through increased productivity with very good plant availability (8383 hours in the year). QASCO started using oxygen injection in July and with it, they also set a new monthly production record.

Saldanha Steel

Saldanha set a new annual production record, mainly through increased availability, as well as a new monthly production record, and averaged 60 percent Sishen lump usage for the year.

OEMK

QASCO

Saldanha Steel

SIDERCA

SIDERCA

SIDERCA exceeded its previous annual production record set in 1997 by 19 percent, through very high operating availability (8346 hours) and increased hourly productivity, being able to use its full plant capacity thanks to the improved market conditions.

SIDOR

Module I broke its monthly record twice in 2003, passed the 10 million ton production mark and almost broke its annual record. Module IIA set a new annual production record based on an hourly availability of 8205 hours and also passed the 10 million ton mark in its 25th year of operation. Module IIC was revamped and its capacity increased during the year to set a new monthly production record. Production from all four modules again exceeded 3.0 million tons in 2003, even though they were affected by natural gas shortages due to political turmoil in Venezuela.

VENPRECAR

VENPRECAR's annual production was also affected by the natural gas curtailment at the beginning of the year, but they were able to set a new monthly production record in May when natural gas became available again.

OEMK Contracts Midrex for Plant Expansion

First Contract for OXY+® Partial Oxidation Technology

Midrex Technologies, Inc. has announced a new contract with OEMK (Starry Oskol, Russia) for engineering and equipment supply that will increase the capacity of OEMK's MIDREX® Direct Reduction Module IV by 20 tons/hr, nearly 30%.

Oskol Electrometallurgical Kombinat (OEMK) is one of the most modern steelworks in Russia producing high-quality rolled steel products. The steelworks currently has four MIDREX Direct Reduction Modules, the first of which began operation in 1983. OEMK's four MIDREX modules produced more than 1.9 million metric tonnes of DRI in 2003. This new project marks the establishment of Midrex's first OXY+® Partial Oxidation System.

The MIDREX OXY+ System produces a high temperature gas consisting primarily of H_2 and CO to significantly increase productivity. The OXY+ gases will be used in a proprietary combination with the MIDREX Center Injection system for localized application of the fresh hot reducing gases where they will have the greatest effect on productivity.

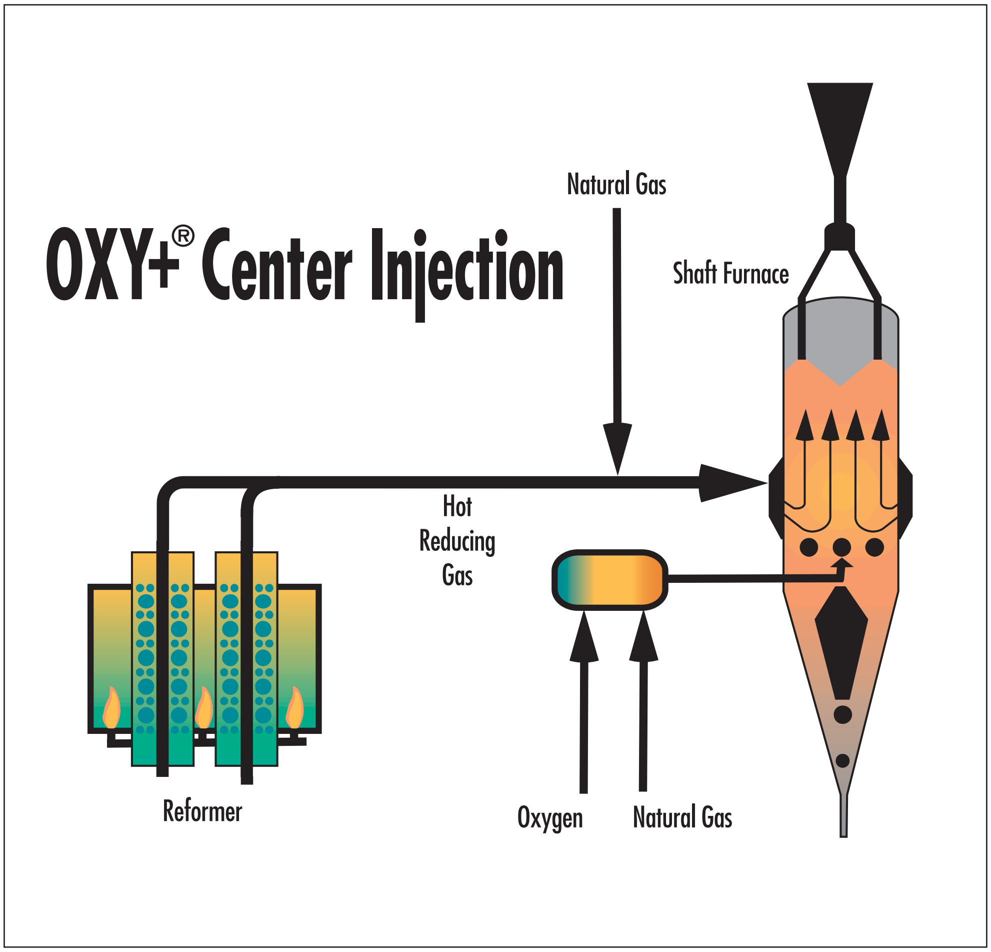
Also included in the contract are numerous process improvements to Module IV's flue gas system, reformer, main air system, top gas scrubber, process gas compressors, transition zone natural gas system, as well as other new systems such as furnace hydraulics, dust collection and oxygen injection.

OEMK intends to install a dedicated air separation unit to supply oxygen for consumption by Module IV. Once proven, OEMK intends to retrofit each of the other three MIDREX Modules to incorporate these same improvements.

OXY+ Partial Oxidation Technology

The use of oxygen is a very cost effective means to significantly increase productivity at existing MIDREX® Plants. OXY+ employs a partial oxidation system to provide unmatched operating flexibility for the following direct reduction plant benefits:

- Increase furnace temperatures for increased efficiency/production
- Increase gas utilization in the furnace
- Produce hot H_2 and CO for increased production
- Mitigate the need for excessive bustle gas temperatures



OXY+ Flowchart

Midrex Strengthens Its Sales Force with Gaines

Henry Gaines

Midrex welcomes Henry Gaines to its Commercial Department as Plant Sales Manager.

Henry previously worked five years in the early 1980s with the engineering department. For the past 13 years, he has been working in sales for Controls Southeast in Charlotte, NC and in Houston, TX.

Midrex News & Views

2004 MIDREX Operations Seminar in Ixtapa

The small coastal Mexican town of Ixtapa-Zihuatanejo was host to more than 40 MIDREX Plant operators and personnel for the 2004 MIDREX Operations Seminar held March 14-18, 2004.

More than 45 Process Licensees and invited guests from around the world came to take part in the five day seminar that examined technical issues and discussed technological innovations related to the MIDREX® Direct Reduction Process. This year's topics included reducing scale formation in the furnace, optimization of oxygen injection, oxygen usage, major shutdown planning and execution, as well as new commercial technologies such as HOTLINK®.

The seminar featured four days of programs geared to aid MIDREX Plant operators from around the world, including a tour of the MIDREX MEGAMOD® at IMEXSA.

MISSION STATEMENT

Midrex Technologies, Inc. will be a leader in design and integration of solids and gas processes. We will meet or exceed performance expectations, execute projects on time, enhance existing product lines, and provide value-added design, procurement, logistics and field services to our clients. We will develop new business opportunities that will challenge our employees and maintain the economic vitality of our company. Our employees are the key to our success, and we are committed to encouraging them to grow professionally and personally.

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: http://www.midrex.com under agreement with Midrex International B.V.

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