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COMMENTARY

AN INNOVATIVE IDEA – INNOVATION THAT WORKS!

By Christopher Ravenscroft

Innovation is, and can be, truly amazing. Innovation has given the world everything from smart phones to “sliced” bread. It has made fortunes overnight and left others out in the cold who failed to recognize the ability to harness it. Innovation has arguably made our lives easier, more productive and dare I say, more fulfilling.

However, it should be noted that not every idea is innovative and that sometimes innovative ideas, especially if not properly thought out, are often less than spectacular.

Let’s take aviation for instance...

Today, the world is a much smaller place thanks in part to modern aviation. Over the centuries there were progressive leaps and bounds of technology, building on solid foundations to bring us where we are today.

From the Wright brothers’ glider to Howard Hughes’s many commercial advances (such as hydraulics that are common place to modern jumbo jets), there were many significant leaps and bounds.

With that said, it does bother me when people talk about aviation innovators and cite Leonardo Da Vinci and his famous design for a helicopter... or as it was otherwise known: the “Aerial Screw.”

To see a model or the original sketches is impressive, but alas it never flew in his lifetime (or in ours). There were several issues including ratio of weight to lift, efficiency of power supply needed (man-power wasn’t to be), no directional control and worst yet, no comfy seating – or any seating for that matter! He had great presentation, but he left a lot of practical issues flying in the wind (bad pun intended).

Now I would graciously accept a painting or sculpture painted by “the great” Leonardo Da Vinci, but take a trip on his helicopter (sorry Aerial Screw)... not a chance.
COMMENTARY

So how does this even relate to our industry?

It may be a bit of a stretch, but Midrex believes there is a major difference between technically complicated and “technically advanced.” An inventive sounding idea such as Da Vinci’s Aerial Screw is not always a practical idea. The same parallel can be drawn to DRI technology, as history has often shown.

Technology should have the flexibility to fit your needs, the reliability to assure consistently high plant availability and the performance to deliver the product quality expected by steelmakers. A pretty picture and paint job, illustrating a novel idea might seem nice and appealing, but something that works for you (not against) is really what any customer truly needs.

This “Midrex” name is synonymous with direct reduction technology, as the MIDREX® Direct Reduction Process has become the world’s most successful direct reduction technology in terms of both total annual tonnage and the total number of successfully and reliably operating plants. Production numbers on their own mean little, but the results and operational flexibility they have afforded their owners mean everything.

“An inventive sounding idea such as Da Vinci’s Aerial Screw is not always a practical idea.”

Since pioneering the MIDREX® Shaft Furnace technology in the 1960s, the company has continued to develop innovative technology solutions that apply to both new and existing plants.

In this issue we look at the MIDREX® Combination Plant configuration. This is a prime example of innovation that benefits the user (see page 4). A MIDREX® Combination Plant allows the plant operator to manage changing operating and market conditions easily, quickly and with total confidence.

A final thought, there is no expiration date for a MIDREX® Plant. Midrex has never let the technology sit idle, nor do we ever plan to stop searching for improvements and furthering innovation. Our innovation and technology improvements are designed to make the MIDREX® Process continuously better so that our Process Licensees can have better operational flexibility and add greater value to their overall operations.

*Author’s note: To anyone searching for additional subtext in this article, I assure you that the Leonardo Da Vinci reference was purely coincidental. Promise."
Opportunity is often the mother of invention. The decision in the early 1980s to amend the Sabah Gas Industries (SGI) plant supply contract to produce hot briquetted iron (HBI) is a good example.

Leading up to the SGI project (Editor’s note: plant now owned and operated by Antara Steel Mills, a Lion Group company), Midrex had the idea of designing a reduction furnace to discharge hot DRI (HDRI). Several development programs were conducted in parallel by Midrex and its licensees. The result was a marriage of the proven MIDREX® Shaft Furnace design with technical innovations that allowed for uniform discharge of HDRI and assured consistent gas and product flow characteristics.

The MIDREX® Hot Discharge Furnace has proven to be a keystone technological development. This innovative design has since gone on to be at the heart of a direct reduction plant that gives operators the ability to respond quickly and effectively to changing market conditions - the MIDREX® Combination Plant.

WHAT IS A MIDREX® COMBINATION PLANT?
As the name implies, a MIDREX® Combination Plant is capable of simultaneously discharging hot DRI (HDRI) and cold DRI (CDRI). HDRI then can be transported in insulated vessels or enclosed conveyors to a nearby electric arc furnace (EAF), discharged directly into a close-coupled EAF, or compacted into HBI and sold as a merchant product. CDRI can be reclaimed from storage silos or covered piles and either batch charged or continuously charged along with scrap into a nearby EAF.

As part of an integrated DR/EAF steel mill, the MIDREX® Combination Plant can continue to produce and discharge DRI during periods when the EAF is down for maintenance or in response to changing market conditions. Conversely, the EAF can utilize stored CDRI or HBI to maintain production while the MIDREX® Plant is undergoing routine maintenance.

A merchant HBI plant equipped with an external product cooler can continue to produce CDRI when the plant’s briquetting machines are shut down for maintenance. A typical DRI plant that makes CDRI or HDRI is rated at 8000 hours per year and an HBI Plant is rated at 7800 hour of year because of additional preventive maintenance required. A combo plant allows a traditional HBI plant to produce additional product during this maintenance downtime.

Simply stated, a Combination Plant is a MIDREX® Direct Reduction Plant, either natural-gas based (MIDREX® NG configuration) or coal-based (MXCOL® configuration), equipped with a hot discharge furnace and an external product cooler. HDRI is discharged into either the product cooler, which is designed similar to the cooling zone in a CDRI furnace, or into a bottom seal leg/product discharge chamber (PDC) system. The most important innovations embodied in a MIDREX® Combination Plant are the way in which the furnace is barometrically sealed while discharging HDRI and how uniform material flow is maintained. Two proprietary equipment designs play key roles: the bottom seal leg and the PDC, which have been integral components of the MIDREX® Hot Discharge Furnace since its introduction in the HBI plant for SGI.
KEYS TO HOW A MIDREX® COMBINATION PLANT WORKS

The MIDREX® Reduction Furnace operates at a relatively low pressure (≤ 1 barg), which simplifies the design of the charging and discharging systems. Two dynamic seals accomplish the same task that would require as many as 50 mechanical valves and five lock hoppers if the furnace were designed to operate at a pressure of 5-6 barg. This takes on added importance when designing a hot discharge furnace to simultaneously discharge HDRI and CDRI on a continuous basis.

The lower pressure operation of the MIDREX® Reduction Furnace combined with the bottom seal leg/PDC system make it possible for a MIDREX® Combination Plant to achieve true simultaneous discharge of CDRI and HDRI while maintaining consistent chemistry throughout the material bed and uniform material flow in the furnace.

Bottom Seal Leg

The lower cone of the reduction furnace feeds into a bottom seal leg, which functions as a dynamic seal for the furnace discharge just as the upper seal leg does for furnace charging. The dynamic seal concept allows the down-flowing material to provide the majority of the seal while using seal gas to fill in any voids between the materials and establish an inert purge.

The function of the bottom seal leg is to contain the pressurized process gases within the reduction furnace and thus maintain the integrity of the closed loop of process gases at the lower end of the furnace. By sealing the reduction furnace, process gases are prevented from escaping from the furnace while air or oxygen is prevented from entering the furnace, thus preventing oxidation of the metallized material.

Because of the lower pressure drop associated with this restriction and the dynamic seal concept, the quantity of seal gas required is relatively small, while the movement of the metallized material is maintained as a smooth continuum, unobstructed by mechanical closures or sealing mechanisms. The bottom seal leg terminates at the wiper bar inside the Product Discharge Chamber (PDC).

Product Discharge Chamber (PDC)

The PDC includes all equipment from the point where product is discharged from the bottom seal leg to the point where metallized product is delivered to briquetting machines or to a hot transport vessel, hot transport conveyor, or in the case of HOTLINK®, directly into an EAF. This portion of the discharge system is responsible for discharging product from the furnace, screening and sizing the product, and feeding it to the designated destination. (Note: The product cooler has its own cold seal leg into which it discharges. There is no seal leg between the furnace discharge and the product cooler.)

The PDC consists of a wiper bar, screen sizers, and tramp doors. The wiper bar is a variable speed, positive displacement feeder that moves the metallized product into the screen sizers. Any material exceeding 50mm X 50mm is directed by the screen sizers to each side of the PDC, where it is discharged through tramp doors into containers.
The PDC is designed to:

1) Discharge HDRI from the reduction furnace at a consistent rate
2) Maintain constant feed to briquetting machines or to an EAF meltshop
3) Screen out any large pieces that could damage down steam equipment or cause the screw feeder to jam
4) Break up any soft material clusters
5) Capture and remove tramp material from the furnace discharge
6) Provide an outlet for seal gas from the bottom seal leg
7) Provide product surge into feed leg(s) when the feed leg(s) slide gate is opened

COLD, HOT OR SOME OF BOTH

The operator of a Combination Plant has available a variety of product options: CDRI, HDRI, HBI, or simultaneous production of CDRI/HDRI, CDRI/HBI, or HDRI/HBI.

Cold DRI (CDRI)

Traditionally, DRI is cooled to about 50° C prior to discharge. CDRI is used primarily in a nearby melt shop and has excellent flow characteristics for continuous charging to the EAF.

CDRI is carburized and cooled in the product cooler by counter-flowing cooling gas. A centrally located cooling injection device serves two important purposes: 1) it distributes cooling gas uniformly throughout the burden, and 2) it prevents the material in the center of the cooler from descending at a faster rate than material along the periphery of the cooler. This is extremely important for producing CDRI at a uniform temperature and with consistent chemistry.

Hot DRI (HDRI)

During the reduction of iron oxide, the furnace burden reaches temperatures of 800-900° C. HDRI can be transported to a nearby EAF at a temperature of greater than 600° C in order to take advantage of the sensible heat. Electricity consumption can be reduced by about 20 kWh/t liquid steel for each 100° C increase in DRI charging temperature. Therefore, energy savings alone can be 120 kWh/t or more when charging HDRI.

Charging DRI at 600° C reduces tap-to-tap time, allowing a productivity increase of up to 20 percent versus charging DRI at ambient temperature. Use of HDRI can increase liquid steel production by 20 percent, resulting in $10/t savings in operating cost.

Figure 1 shows relative steel mill profitability versus profit margin per ton of steel, for a range of margins. Over this range, the increased profit by the use of HDRI is $43-70 million per year.

Midrex offers three methods for transporting HDRI: hot transport vessels (HTV), hot transport conveyor (HTC) and HOTLINK®. Insulated HTVs are appropriate when the distance...
between the DRI plant and the melt shop is greater than 200 meters, while specially designed HTCs are effective for distances up to 200 meters and can be used to service multiple EAFs, if needed. HOTLINK® is designed to feed a close-coupled EAF by gravity flow; therefore, the distance is typically 40 meters or less.

With multiple options for transporting HDRI, there is no limitation on the location of a MIDREX® Hot Discharge Plant within the overall layout of the steel mill.

**Hot Briquetted Iron (HBI)**

HBI is made by compressing HDRI into pillow-shaped briquettes having a typical size of 30 x 50 x 110 mm and a density ≥ 5 gm/cc. No binder is needed to make HBI.

HBI is the preferred DRI product for the merchant metals market because it is much denser than CDRI. This enables HBI to be stored and transported without special precautions and provides operational benefits in the EAF. Its enhanced physical characteristics make HBI highly effective when used in the blast furnace (BF) to increase productivity and in the basic oxygen furnace (BOF) either in the primary charge or as a trim coolant.

**COMBINATION PLANTS IN ACTION**

The combination plant design is the result of continually evolving MIDREX® Direct Reduction Technology. It gives plant owners the confidence that their investment is secure by providing plant operators the ability to respond quickly and easily to various operational and market changes.

For example, Midrex started up a 1.5 Mt/y MIDREX® Combination Plant in 2007, for Qatar Steel Company. Qatar Steel II, as the plant is known, primarily feeds CDRI to a new EAF meltshop. The MIDREX® Plant is designed for simultaneous discharge of CDRI and HDRI, which is compacted to make HBI. In 2013, Qatar Steel II produced more than 1.6 Mt of CDRI and HBI and almost 1.8 Mt in 2014. The flexibility to quickly and efficiently change between CDRI and HBI allowed Qatar Steel to respond to changes in the market for its primary product, billets, by selling HBI to other steel mills in the Middle East and North Africa (MENA) region.

### TABLE I  Plants Equipped with Hot Discharge MIDREX® Reduction Furnaces

<table>
<thead>
<tr>
<th>Plant</th>
<th>Location</th>
<th>Design Capacity (Mt/y)</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antara Steel Mills</td>
<td>Labuan, FT, Malaysia</td>
<td>0.65</td>
<td>HBI</td>
</tr>
<tr>
<td>Essar Steel I &amp; II</td>
<td>Hazira, India</td>
<td>0.88</td>
<td>HBI/HDRI</td>
</tr>
<tr>
<td>FMO</td>
<td>Puerto Ordaz, Venezuela</td>
<td>1.00</td>
<td>HBI</td>
</tr>
<tr>
<td>VENPRECAR</td>
<td>Matanzas, Venezuela</td>
<td>0.82</td>
<td>HBI</td>
</tr>
<tr>
<td>Essar Steel III</td>
<td>Hazira, India</td>
<td>0.44</td>
<td>HBI/HDRI</td>
</tr>
<tr>
<td>LISCO 3</td>
<td>Misurata, Libya</td>
<td>0.65</td>
<td>HBI</td>
</tr>
<tr>
<td>COMSIGUA</td>
<td>Matanzas, Venezuela</td>
<td>1.00</td>
<td>HBI</td>
</tr>
<tr>
<td>Essar Steel IV</td>
<td>Hazira, India</td>
<td>1.00</td>
<td>HBI/HDRI</td>
</tr>
<tr>
<td>Essar Steel V</td>
<td>Hazira, India</td>
<td>1.50</td>
<td>HBI/HDRI</td>
</tr>
<tr>
<td>Hadeed E</td>
<td>Al-Jubail, Saudi Arabia</td>
<td>1.76</td>
<td>HDRI/CDRI</td>
</tr>
<tr>
<td>LGOK II</td>
<td>Gubkin, Russia</td>
<td>1.40</td>
<td>HBI</td>
</tr>
<tr>
<td>Qatar Steel II</td>
<td>Mesaieed, Qatar</td>
<td>1.50</td>
<td>CDRI/HBI</td>
</tr>
<tr>
<td>Lion DRI</td>
<td>Banting, Malaysia</td>
<td>1.54</td>
<td>HDRI/HBI</td>
</tr>
<tr>
<td>Jindal Shaded</td>
<td>Sohar, Oman</td>
<td>1.50</td>
<td>HDRI/HBI</td>
</tr>
<tr>
<td>Tuwairqi Steel Mills</td>
<td>Karachi, Pakistan</td>
<td>1.28</td>
<td>HDRI/CDRI</td>
</tr>
<tr>
<td>JSW Projects Ltd.</td>
<td>Toranagallu, India</td>
<td>1.20</td>
<td>HDRI/CDRI</td>
</tr>
<tr>
<td>Jindal Steel &amp; Power</td>
<td>Angul, India</td>
<td>1.80</td>
<td>HDRI/CDRI</td>
</tr>
<tr>
<td>ESISCO</td>
<td>Sadat City, Egypt</td>
<td>1.76</td>
<td>HDRI/CDRI</td>
</tr>
<tr>
<td>SULB</td>
<td>Hidd, Bahrain</td>
<td>1.50</td>
<td>HDRI/CDRI</td>
</tr>
<tr>
<td>LGOK III</td>
<td>Gubkin, Russia</td>
<td>1.80</td>
<td>HBI*</td>
</tr>
<tr>
<td>voestalpine Texas</td>
<td>Corpus Christi, Texas, USA</td>
<td>2.0</td>
<td>HBI*</td>
</tr>
</tbody>
</table>

* Under construction
Midrex designed a 1.5 Mt/year HOTLINK® Plant (1.1 Mt HDRI, 0.4 Mt HBI) for Shadeed Iron & Steel LLC, located in Sohar, Oman, as part of an integrated DR/EAF steel mill. Four months prior to start-up of the MIDREX® Plant in 2010, Jindal Steel and Power Limited (JSPL) acquired the plant and renamed it Jindal Shaded. The change of ownership delayed completion of the steel mill. However, because the MIDREX® Plant was capable of producing HBI as well as HDRI, Jindal Shaded has been operated as a merchant HBI facility since start-up. In 2014, the plant produced almost 1.5 Mt of HBI and operated at 98.5 percent availability.

Midrex and its Construction Licensees have supplied 13 combination plants since 1990: six producing HDRI/CDRI, five producing HDRI/HBI, and one each producing HDRI/CDRI and CDRI/HBI. This represents more than 17.5 million metric tons (Mt) of installed capacity.

These plants were designed for dual product discharge. However, existing MIDREX® HBI Plants equipped with a hot discharge reduction furnace can be retrofitted for dual discharge if a steel melt shop is added at a later date (See Table I on page 7).

**MAKING INNOVATION COUNT**

Technology is defined as the practical application of knowledge, which makes an innovative technology a new, advanced application of knowledge in a practical way. The MIDREX® Combination Plant is the embodiment of the cascading effect of innovative technology, from originally adapting an iron oxide pelletizing furnace for continuous production of DRI to modifying the resulting reduction furnace for discharging HDRI to adding the flexibility of simultaneous dual discharge of CDRI and HDRI.

The MIDREX® Combination Plant gives owners options. When part of a steel mill complex or when located in the vicinity of a steel mill, HDRI can be transported by insulated conveyor or containers and charged hot into one or several EAFs. If equipped with briquetting machines, the same plant can produce HBI to sell as an additional commercial product. An external product cooler allows for the production of CDRI when the steel mill does not require HDRI or when the hot briquetting machines are undergoing maintenance.

With change being the only sure thing in the global steel market, it makes sense to prepare for it. The MIDREX® Combination Plant not only provides owners a quick and effective response to sudden changes in market conditions but also gives them the opportunity to take advantage of those changes.
Plants based on MIDREX® Direct Reduction Technology accounted for 47.12 million tons of DRI products in 2014, which once again led all technologies with 63.2 percent of the market total. The production for 2014 is estimated from the 32.57 million tons confirmed by MIDREX® Plants located outside of Iran and the 14.55 million tons from within Iran, as reported by the World Steel Association. All Iranian production was by plants using MIDREX® Technology as licensed by Kobe Steel, Ltd.

MIDREX® Plants continued to account for approximately 80 percent of worldwide production of natural gas-based direct reduced iron (DRI) in shaft furnaces. Despite growing exports of steel from China, which caused steel production in many locations worldwide to slow, at least 11 MIDREX® Plants established new annual production records and at least nine plants established new monthly production records. Nine MIDREX® Modules came within 10 percent of their record annual production values and at least 12 modules operated in excess of 8000 hours. MIDREX® Plants have produced a total of more than 820 million tons of DRI/HBI through the end of 2014.

Two new MIDREX® Modules were started up: one, the first cold/hot DRI MXCOL® DR Plant using synthesis gas from a coal gasifier, belonging to Jindal Steel and Power Ltd. (JSPL) in Angul, India, and the second, a cold/hot DRI plant using COREX® export gas belonging to JSW Steel in Toranagallu, India.
2014 PLANT HIGHLIGHTS

ACINDAR
ACINDAR’s MIDREX® Plant broke its annual production record in 2014 for the second year running, exceeding 1.04 million tons despite typical winter natural gas curtailments. The plant averaged more than 132 tons per hour for the year. In 36 years of operation, ACINDAR’s MIDREX® Plant has produced 277 million tons, the most by a single MIDREX® Module to date.

ANTARA STEEL MILLS
In its 30th anniversary year, the first MIDREX® Plant designed to make HBI produced under annual rated capacity due to market constraints.

ARCELORMITTAL HAMBURG
AM Hamburg’s MIDREX® Plant, the oldest in operation having been commissioned in 1971 (44 years), comfortably exceeded annual rated capacity in 2014. The plant operated at 75 t/h while producing 15 percent over the DRI tonnage budgeted for the year.

ARCELORMITTAL LAZARO CARDENAS
AMLC operated 34 percent over its rated capacity of 1.2 million tons and within 10 percent of its record annual capacity, using iron ore pellets made exclusively with Mexican iron ores. In early 2014, AMLC surpassed the 25 million ton production milestone, achieved in 16.5 years since start-up up in August 1997.

ARCELORMITTAL MONTREAL
Module II set a new annual production record in 2014 for the second consecutive year, after restarting production in 2011. The plant produced more than 977,000 tons with over 8100 hours of operation in the year. Module I’s production for the year was within 5 percent of its record annual production. It restarted operations in June 2013 at full capacity due to competitively priced natural gas and oxide pellets sourced locally. The cumulative production from both modules exceeded the 30 million ton mark by the end of 2014.

ARCELORMITTAL POINT LISAS
All three of AMPL’s MIDREX® Modules operated in 2014, producing more than 1.7 million tons of DRI for the adjacent steel shop and for overseas export. The modules surpassed the 40 million ton production milestone in early 2014. Module 3’s DRI metallization exceeded 95.9 percent on average for the year and carbon averaged 2.67 percent.

ARCELORMITTAL SOUTH AFRICA (SALDANHA WORKS)
Operation of the COREX® export gas-based MXCOL® Plant was limited by the availability of gas from the COREX® Plant. Fifteen years after its initial start-up, the plant established a new record for annual operating hours using on average more than 67 percent South African lump ore for the year.
COMSIGUA
COMSIGUA operated at reduced capacity from June through November due to the limited supply of locally produced pellets. COMSIGUA accounted for a majority of the 365,000 tons of HBI produced by MIDREX® Plants in Venezuela in 2014.

DELTA STEEL
The two Delta Steel MIDREX® Modules did not operate in 2014.

DRIC
DRIC’s two MIDREX® Modules in Dammam, Saudi Arabia, continued to ramp up production to satisfy the demand of their neighboring Al-Tuwairqi steel shops. Both modules set new annual production records and new monthly production records, and both operated more than 8000 hours in the year, averaging 8196 hours per year between the two of them. Module 1 set a new annual production record for the fifth consecutive year.

ESSAR STEEL
The two largest of Essar Steel’s six MIDREX® Modules operated at reduced production rates due to the shortage of iron ore and very high natural gas prices in India. The four smaller modules remained shut down for the whole year.

EZDK
Limited by natural gas availability in Egypt, all three of EZDK’s MIDREX® Modules produced just less than 2.0 million tons in 2014. EZDK’s three modules were down most of August and all of September due to a total NG curtailment during this period before restarting again in October.

FERROMINERA ORINOCO
Ferrominera Orinoco’s MIDREX® HBI Plant in Puerto Ordaz, did not operate in 2014 due to limited oxide pellet availability in Venezuela.

HADEED
Hadeed exceeded rated capacity for the 30th consecutive year in Modules A and B and for the 22nd consecutive year in Module C. A year after establishing a new DR plant one-year production world record of 2,000,458 tons of HDRI/CDRI with 8,453 operating hours, Hadeed’s Module E exceeded rated capacity in 2014. Modules A and B averaged 8561 hours of operation in the year, while Module C set a new monthly production record, averaging 140 t/h. Hadeed’s four MIDREX® Modules have produced more than 74 million tons of DRI to date.
JINDAL SHADEED

Jindal Shadeed's production in 2014 was just 1.4 percent lower than its record set in 2013. The MIDREX® Plant is designed to produce mainly HDRI with HBI as a secondary product stream. It operated an exceptional 8629 hours in 2014 and set a new monthly production record in January, averaging 194 tons/hour. Jindal Shadeed started off the year producing mainly HBI while shipping some HDRI via hot transport vessels to a nearby steel shop. Around mid-year, Jindal Shadeed's own steel shop started taking HDRI. The plant's DRI production was limited toward year end by the availability of natural gas.

JSPL (ANGUL)

Jindal Steel and Power Ltd. (JSPL) completed commissioning in July 2014 of the first MXCOL® DR Plant using synthesis gas from coal gasifiers. The plant, located in Angul, India, produces HDRI and CDRI for the adjacent steel shop. Production was ramped up as the coal gasifier units were being commissioned and brought on line.

JSW STEEL (DOLVI)

JSW Steel comfortably exceeded rated capacity in 2014 and was within 10 percent of its annual production record even though production was restricted due to the increased price of natural gas. A new system was installed to add coke oven gas (COG) coming from JSW Steel's coke oven batteries on site to the MIDREX® Shaft Furnace to reduce natural gas consumption. This system was started up towards year end. Excluding the first partial year of production in 1994, JSW Steel's plant in Dolvi has averaged 8040 hours of operation per year in its 20 years of operation. The plant was shut down in July for major maintenance after 21 months from its previous major shutdown.

JSW STEEL (TORANAGALLU)

JSW Steel's new cold/hot DRI plant using COREX® export gas in Toranagallu, India, finalized commissioning and was started up in August 2014. The plant is designed to produce 1.2 million tons per year of HDRI and CDRI. This is the second plant of its kind; the first one being the COREX®/MIDREX® Plant at Saldanha, South Africa.

LEBEDINSKY GOK

LGOK's MIDREX® HBI Module achieved its rated capacity of 1.4 million tons in 2014, after a record breaking annual production of 1,537,000 tons in 2013.
**LION DRI**
The production of the Lion DRI plant located near Kuala Lumpur, Malaysia, continued to be limited by steel shop demand. Production in 2014 consisted of 82 percent HDRI and 18 percent HBI.

**LISCO**
After restarting in 2012, the three MIDREX Modules in Misurata, Libya, continued to increase production but were restricted by natural gas supply. Modules 1 and 2 each have produced 10 million tons since their start-up in 1989 and 1990, respectively, despite lengthy shutdowns due to market and political conditions.

**NU-IRON**
In 2014, Nucor’s MIDREX Plant in Trinidad and Tobago established a new annual production record and exceeded the 10 million ton milestone. Average DRI metallization for the year was the highest of all MIDREX Plants at 96.15 percent, with 2.79 percent carbon in the DRI produced.

**OEMK**
OEMK produced more than 2.8 million tons in 2014. Modules 1 and 3 set new annual production records while the annual production of Module 2 was only 1.8 percent less than its record production of 2013. Module 3 also broke its previous monthly production record twice in 2014. The operating hours for all four of OEMK’s modules averaged an exceptional 8440 hours in the year.

**QATAR STEEL**
In its seventh full year of operation, Qatar Steel’s dual products (CDRI and HBI) Module II set a new annual production record for the fourth consecutive year, 6.9 percent above its previous record. This MIDREX Module operated 19 percent over its rated annual capacity, averaging 223 t/h. In March, Module II set a new monthly production record while reaching 230 t/h. Almost the entire production from Module II was CDRI, with metallization averaging 94.6 percent for the year. The production of Module I was only 2.6 percent below its record annual production, and the module operated 8323 hours in the year.
SIDOR
Production from Sidor’s four MIDREX® Modules was limited to 1.3 million tons in 2014 due to a lack of oxide pellets. Module 2C remained shut down the whole year.

SULB
SULB’s 1.5 million ton/year combo MIDREX® Plant (simultaneous CDRI and HDRI production) in Bahrain operated 8247 hours in its first full year of operation, establishing new annual and monthly production records. It operated using 100 percent GIIC pellets from the neighboring pellet plants.

TenarisSiderca
TenarisSiderca operated below maximum capacity throughout 2014 due to limited DRI demand by the steel shop and natural gas curtailments during the winter months. CDRI metallization averaged 95.7 percent for the year.

TUWAIRQI STEEL MILLS
The Tuwairqi Steel Mills 1.28 million ton/year combo MIDREX® Plant (simultaneous CDRI and HDRI production) located near Karachi, Pakistan, did not operate in 2014 due to market conditions.

VENPRECAR
VENPRECAR’s HBI production was severely restricted by the limited availability of iron ore pellets in Venezuela.

EDITOR’S NOTE:
No DRI production data was received from the following plants located in Iran: South Kaveh Steel, Mobarakeh Steel, Khouzestan Steel, Khorasan Steel, IMPADCO, IGISCO, and Hormozgan Steel.
LENDING A HELPING HAND:

Midrex Global Solutions
By Henry Gaines, PE, Director – Marketing

Editor’s note:
In the previous issue of Direct From Midrex, we saw how Midrex designs and engineers the best performing direct reduction plants in the world (“Technical Excellence with a Human Touch: Engineering, the Midrex Way” in 1Q 2015 DFM). In this issue we will look at how Midrex seamlessly transitions from plant supply to aftermarket services and support in order to assist customers in maintaining and operating their MIDREX® Plants.

One of the most important responsibilities of the project manager as a MIDREX® Plant nears start-up is to establish the link between plant management and staff and the Midrex team that is dedicated to helping them succeed in operating and maintaining the plant. Midrex Technical Services within Engineering liaises with the plants to manage technology transfer under the provisions of the MIDREX® Process License Program. As part of the Sales & Marketing Group, Midrex Global Solutions provides the engineering, procurement and field services that support good maintenance and operating practices.

What is Midrex Global Solutions?
The clientele of Midrex Global Solutions is exclusively operators of MIDREX® Plants, which by no means is limiting. With plants located throughout the world, Midrex Global Solutions can be called on for a debottlenecking study in India, a capacity expansion project in South America or the procurement of essential parts and equipment in the Middle East.

Midrex Global Solutions is the latest in a natural progression of customer service functions that has evolved as the family of MIDREX® Plants expanded globally. For the first 20 years, Midrex primarily provided technical advice and managed the transfer of technology. In 1990, Professional Services International (PSI) was established as a subsidiary of Midrex in order to provide procurement and logistics services to Kobe Steel (parent company of Midrex) for non-Midrex projects, as well as to support MIDREX® Process Licensees. The decision was made in 2004 to integrate PSI into Midrex. As a result, Midrex Solutions was formed and soon thereafter renamed Midrex Global Solutions.

Within a MIDREX® Plant, Midrex Global Solutions is capable of servicing a wide range of production and maintenance operations. These activities include designing engineered solutions, managing maintenance, repair and operation (MRO) programs, sourcing and procuring spare parts and materials, and providing field services. Let’s take a closer look at each of these areas (See page 16).
ENGINEERED SOLUTIONS
Midrex Global Solutions can manage and implement capital projects requiring up to 10,000 man-hours of engineering with its own resources. These projects typically involve working with a Process Licensee to identify ways in which plant productivity and/or operating costs can be optimized. The scope of these projects can involve engineering services, equipment designs and supply, and on-site troubleshooting.

In the case of a project that is larger in scope, Midrex Global Solutions can call on the full engineering, procurement and logistics resources of Midrex.

SPARE PARTS AND MATERIALS PROCUREMENT
Midrex maintains relationships with a large number of equipment suppliers worldwide who are certified to supply spare parts and materials specifically designed and manufactured for use in MIDREX® Plants. This enables Midrex Global Solutions to provide essential spares and materials in the most cost-effective, timely manner. In addition, Midrex Global Solutions makes certain that shipments are expertly packed and shipped by the most expedient method. All spare parts and materials orders include technical support and the assurance that customers receive the latest technological improvements.

MRO SERVICES
Many items used within a MIDREX® Plant are not manufactured or stocked locally. Midrex Global Solutions has the expertise and experience to support maintenance, repair and operation (MRO) activities. MRO services can include locating, bidding and buying all items that must be procured offshore at highly competitive prices. This service frees up plant personnel to focus on other essential operational and administrative tasks with full confidence that the items will be available when needed.

FIELD SERVICES
The 45 years in which MIDREX® Plants have been in operation around the world have produced technical personnel highly proficient in all aspects of operating and maintaining these plants, from start-up and commissioning through plant expansions and improvements. Midrex Global Solutions can draw from this impressive reservoir of talent when a new or existing MIDREX® Process Licensee has a temporary requirement for skilled and experienced personnel.
DEDICATED TO EXCELLENCE

The MIDREX® Process Licensing Program has been instrumental in forging a record of exemplary performance and reliability by MIDREX® Plants. This innovative approach involves the sharing of technology, know-how and field experience by Midrex and the operators of MIDREX® Plants. Midrex Global Solutions is uniquely qualified to offer engineered solutions parts, equipment, and materials guaranteed to be designed and manufactured to Midrex specifications.

Frequent contact and communication are important for any aftermarket services organization. Midrex Global Solutions uses its own staff, as well as Midrex Technical Services, Engineering, and Plant Sales personnel to make on-site visits to foster key relationships within the plants. With these visits and the annual MIDREX® Plant Operations Seminar, Midrex Global Solutions is able to determine how and when its services are required and to propose informed solutions.

The management of Midrex Global Solutions exemplifies the group’s dedication to providing excellent service and support to MIDREX® Plants.

THE MIDREX GLOBAL SOLUTIONS TEAM

Chris Clancy was general manager of a metals processing facility prior to joining Midrex, so he knows the value of suppliers who can be trusted to deliver on-time at a competitive price with the knowledge, expertise and backing of the original equipment designer. He has more than 20 years of experience matching processing plant needs with solutions from the vantage point of a supplier and a customer.

Clancy recognizes that the most significant role for Midrex Global Solutions is to partner with the engineering staffs of MIDREX® Process Licensees to optimize their plants’ performance. His team is drawn from the various engineering disciplines and support functions within Midrex so they appreciate the importance of engineering to original design specifications and demanding high manufacturing standards of suppliers.

“Being a part of Midrex is no assurance that we will be the choice of MIDREX® Process Licensees for aftermarket services. We have to earn their confidence and trust through performance,” Clancy said. “We work with the engineering personnel of MIDREX® Plants to find the best solutions for their specific needs and then deliver the most cost-effective equipment, parts, materials and field services on time, every time.”

John McFadden is one of the most recognized faces at Midrex by the Process Licensees. He has spent much of his 27-year Midrex career in the field, turning design concepts into operational systems and processes. However, he is most highly regarded and perhaps best known for his unique ability to work and communicate effectively with customers’ personnel.

McFadden’s educational background in design and mechanical engineering technologies combined with extensive field experience constructing, starting up, and optimizing MIDREX® Plants have prepared him well for his Midrex Global Solutions duties. He can evaluate the operation of a plant to identify and diagnose issues and develop solutions. His customers know that he will stay involved in their projects throughout engineering, procurement and construction.

(cont’d. on next page)
(John McFadden cont’d.)

"Repeat customers make up more than half of MIDREX® Plant sales. In order to have repeat customers, they must be satisfied with their first plant," McFadden said. "Midrex Global Solutions makes certain that customers have access to the latest process and equipment improvements and the support and service to take full advantage of them."

Marlene Rivinus has been matching customer’s materials and equipment needs with shipping and logistics solutions for more than 25 years. Often she is the first contact for a MIDREX® Process Licensee, and typically she is the one who follows an order from the initial inquiry stage to delivery at the site.

Joining Midrex from Maersk Line, where she was customer service manager, Rivinus was responsible for coordinating the flow of spare parts, consumable materials, and replacement equipment from global vendors to plant sites around the world. She became senior sales agent in Midrex Global Solutions in 2010, and was promoted to proposal manager in 2014.

"We are our customers’ representative when we are dealing with equipment manufacturers and vendors. That means we must be fully knowledgeable of what they need, how they will use it and when it needs to be there," Rivinus said. "It’s a very satisfying feeling to know that we helped our customers receive timely delivery and a good price."

VALUE-ADDED SOLUTIONS

Midrex is in its fifth decade of developing and implementing value-added solutions. Its heritage is one of innovation and opportunity. Midrex Global Solutions embodies this spirit and gives it form and presence with MIDREX® Process Licensees.

How well a plant is maintained and serviced is instrumental in determining its performance, reliability, and longevity. The larger the capital investment, the more important the selection of an aftermarket services provider becomes.

Midrex Global Solutions, as its name represents, goes beyond supplying spare parts and materials. It takes a broad, in-depth approach to the needs of its customers, developing comprehensive solutions based on the knowledge, expertise and experience of Midrex and its family of Process Licensees.

Midrex Global Solutions – lending a helping hand to keep MIDREX® Plants operating at peak performance in all parts of the world in all types of weather.
MIDREX News & Views

SUSTAINING DRI PRODUCTION BY REDUCING RELIANCE ON NATURAL GAS:

JSW Steel successfully uses coke oven gas at JSW Dolvi

JSW Steel, India’s largest producer of direct reduced iron (DRI) since 2003 and largest private steel company, has replaced a portion of the natural gas used in the operation of its MIDREX Direct Reduction Plant with coke oven gas (COG) as the first phase of an integration plan intended to bolster the sustainability of DRI production. Based on the operating results, JSW Steel could decide to allocate additional COG for DRI production at a later date. This is the first time that COG has been used commercially in a MIDREX Shaft Furnace to supplement natural gas usage.

“High natural gas pricing within India has presented challenges to making DRI with natural gas alone,” said Alok Chandra, Chief Operations Officer of the JSW Dolvi Plant. “Therefore, JSW Dolvi has embarked on a way to reduce natural gas consumption with no impact on production rates, and still deliver quality DRI to our steel shop by utilizing COG from onsite coke oven batteries.”

Midrex Technologies, Inc. was contracted by JSW Steel in late 2013 to modify the 1.0 million ton per year MIDREX Plant at JSW’s Dolvi Works to utilize COG as a reductant source. Working closely with JSW, Midrex completed the project on schedule within 16 months.

“We are excited to announce that approximately 20,000 m³ of coke oven gas is being used in the JSW Dolvi MIDREX DRI Plant on an hourly basis,” Anil Mhatre, JSW Head of Operations (SIP), stated. “This is allowing our DRI plant to offset natural gas equal to half of COG consumption and produce DRI at a steady rate with the same product quality.”

Strategically located near the coast in the state of Maharashtra, India, the JSW Dolvi Works MIDREX Plant began operation in 1994 producing cold DRI for use on site utilizing 100% natural gas. With the continuing escalation of natural gas pricing, combined with infrequent availability of consistent gas supply in India, JSW Steel has looked to Midrex for use of coke oven gas to create better sustainability for the plant and overall site.

“We are proud to say we accomplished what JSW and Midrex set out to do,” Midrex Project Manager Laszlo Tibold said. “By using COG as a supplement to natural gas, the JSW Dolvi plant is able to operate with a greater efficiency under a wide range of operating parameters, offering maximum flexibility to JSW.”
**MIDREX News & Views**

**Tosyali Holding to Build World’s Largest DRI Combo Plant**

Project Awarded to Midrex and Paul Wurth for 2.5 MTPY HDRI/CDRI Plant in Algeria

Tosyali Holding has awarded Midrex and its partner Paul Wurth, the project to build the world's largest multiple product direct reduced iron plant for Tosyali Algeria located in Bethioua (Oran), Algeria.

The MIDREX NG™ Direct Reduction Plant will be designed to produce 2.5 million tons of DRI and have the capability to vary its production to produce hot direct reduced iron (HDRI) and/or cold direct reduced iron (CDRI) simultaneously without stoppage of production. This new DRI plant will be the largest single DRI plant to produce multiple DRI products in combination. HDRI will be fed via an Aumund hot transport conveyor to a new EAF meltshop located adjacent to the MIDREX® DRI Plant allowing for greater EAF productivity and energy savings; CDRI also can be produced for onsite use.

The new Tosyali Algeria MIDREX® DRI Combo Plant will provide the Tosyali Algeria steelmaking facility with greater production flexibility to produce high quality, low impurity steels as well as decrease their demand for imported scrap.

The history of Tosyali Holding goes back to 1952. Iskenderun's first holding, Tosyali Holding, began a rapid period of growth in the 1980s. Tosyali Holding has 16 facilities throughout Turkey with six in the Osmaniye Organized Industry Zone (OIZ), one in Istanbul, one in Izmir, seven in the Iskenderun OIZ and one in the investment stage. Also the company has two facilities in the North African country of Algeria and one in Europe's Montenegro. Tosyali Holding has a total of 18 facilities on three continents in six different regions along with 12 affiliates. Under the Tosyali Holding umbrella there are the three production companies: Tosçelik Profil ve Sac Endüstrisi A.Ş., Tosyali Demir Çelik Sanayi A.Ş. and Tosçelik Granül San. A.Ş., which are all leaders in their own sectors, and Tosyali Dış Ticaret A.Ş., which conducts the foreign trade operations. For more information please visit: [en.tosyaliholding.com.tr](http://en.tosyaliholding.com.tr/).

**PHOTO: SIGNING FOR CEREMONY IN ISTANBUL TURKEY, JUNE 2015**

*Pictured Front Row (left to right):*

James D. McClaskey - President & CEO Midrex Technologies, Inc.; Fuat Tosyali, President Tosyali Holding; Thomas Hansmann - Chief Technology Officer Paul Wurth Italia S.p.A.

*Pictured Back Row (left to right):*

Mehmet Gezgin - Project and Investment Manager Tosyali Holding; KC Woody, Director Plant Sales – Midrex; Don Lyles Manager - Contracts and Licensing Midrex; Stephen Montague - Vice President Sales & Marketing Midrex; Alp Topcuoglu - Member of the Board, Tosyali Algeria; Suhat Korkmaz - CEO Tosyali Holdings; Todd Ames - MENA Plant Sales Midrex; Alberto Totaro - Manager Contracts and Legal Affairs; Roberto Cirelli - VP Contracts, Legal Affairs, and Risk Management Paul Wurth Italia S.p.A.; Alberto de Ferrari - Project Director Paul Wurth Italia S.p.A.; Mohammad Siddiqui - Head of DR Plant Tosyali Algeria.
2014 World DRI Production tops 74.5 Million tons

New technology and expansion continues despite difficult conditions

The world’s direct reduction industry produced 74.55 million tons of DRI Products in 2014 according to data compiled by Midrex and audited by World Steel Dynamics. Production fell slightly from 2013 due to natural gas shortages and curtailments in India, operational disruptions in other DRI producing regions, as well general downturns in steel market conditions. DRI growth was evident in a number of nations including the USA and Bahrain. Plants based on MIDREX® Direct Reduction Technology accounted for 47.12 million tons, which once again led all technologies with 63.2 percent of the market total.

Output in 2014 was more than 70 percent greater than in 2000. Factors mentioned previously that have limited growth for the last decade persist but have been somewhat offset by demand for DRI products in “non-traditional” applications (i.e., blast furnaces and basic oxygen furnaces) and by the introduction of new reductant sources (i.e., gasified coal and coke oven gas).

In Bahrain, production increased rapidly as the SULB plant, which had been commissioned the prior year, was ramped up toward full capacity. Nearby, the Gulf nations of Saudi Arabia and Qatar also saw significantly greater DRI production due to strong internal demand by their national economies. In the USA, the DRI plant owned by Nucor Steel began production, which marked the first time in five years that DRI was made in the US.

New national records for DRI output were established in six nations; Russia, Canada and four countries in the Gulf region, Bahrain, Iran, Qatar and Saudi Arabia. The concentration of growth in the Gulf area is a result of the many plants which have been started-up in the past few years. Although, it did not set a new record, it bears note that the South African DRI industry accomplished an increase of 10 percent over the previous year while national steel production dropped by more than eight percent.

For more complete information on the 2014 DRI production, please visit www.midrex.com to download the 2014 World Direct Reduction Statistics.
Mr. Hiroya Kawasaki, President of Kobe Steel, Ltd., recently visited the Midrex Technologies, Inc. corporate headquarters in Charlotte, NC, USA, and newly expanded and upgraded Midrex Research & Development Technology Center in nearby Pineville, North Carolina, USA.

The Kobe Steel Group offers many “Only One” products—original, high-end technologies and products. Many of these command the top share of their respective global markets, such as the MIDREX® Direct Reduction Process. Kobe Steel is committed to quality manufacturing across a broad range of fields and to supplying outstanding products and technologies that contribute to the advancement of industry and the promotion of a prosperous society.
MIDREX News & Views

Here and back again... A Midrex Tale.

Midrex exhibited at this year’s METEC conference June 15-19 2015 in Dusseldorf showcasing its latest technologies and DRI projects.

Pictured is Midrex’s 1st booth in June 16-22, 1979 along with its latest showing in 2015.