DIRECT FROM MIDREX

2ND QUARTER 2020

INSIDE THIS ISSUE

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COMMENTARY

LEARNING FROM THE BUFFALO

Stephen Montague
President & CEO, Midrex Technologies, Inc.

First and foremost, with the COVID-19 pandemic all around the world, I hope this finds everyone safe and healthy. I bet you are tired of uncertainty, sick of staring at your computer for every meeting. Do you miss the in-person connection with friends, co-workers, and family? I certainly do!

Our world has changed and will continue changing as we emerge from the dark shadow of the COVID-19 pandemic. What we knew a few months ago as normal might seem appealing right now, but the status quo is overrated. Change happens when it becomes dissatisfying enough and unacceptable to stay where we are, so we try something new. Change produces innovation, and innovation drives progress.

We certainly did not choose this path for change, but how we respond is within our control. Now is not the time to wish everything would go back to the way it was. It's the time to recognize that we are being given the opportunity to create something better.

My Midrex teammates have heard the story about how buffalo and cattle react when a storm approaches. Cattle try to escape by turning away from the storm and heading in the opposite direction. But cows cannot outrun storms. Instead of running away, buffalo turn into the storm and meet it head-on. Both of them will have to endure the storm's fury, but the buffalo will spend less time in the storm, thereby reducing the pain and suffering.

At Midrex, we choose to address

OUR PURPOSE
To love and serve others.

OUR VISION & MISSION

To make Midrex the most valuable and reliable source of iron for the steel industry:

- Provide technologies and services that are innovative and sustainable
- Pursue excellence
- Exceed expectations

COMMENTARY

our challenges like the buffalo. We believe that moving forward toward a better future includes the following:

• CARING FOR PEOPLE

Our principles are the foundation and guide for our natural response. Our stated purpose is to love and serve others and is evident in our core values and purpose, vision & mission *(see inset on page 2)*. Our top priority is taking care of people: our families, our community, our customers, and our teammates.

• PLAYING OFFENSE NOT JUST DEFENSE

Consumer behavior is changing. How customers perceive value is continually evolving, especially with the advent of digitalization. These new realities create opportunities to build trust, loyalty, and market share.

• BEING NIMBLE

Recognize that no one has the answers, understand the general trends of change, and get moving. It is easy to become paralyzed by the lack of information needed to make accurate forecasts of the future. Better to be nimble and make frequent adjustments to direction than to put faith and time into pinpoint forecasting.

This issue of ***Direct From Midrex*** presents the third and final part of the series, "Maximizing Iron Unit Yield from Ore to Liquid Steel," with a discussion of melting practice. As is customary in the second quarter issue of DFM, you can read about the achievements of MIDREX Plants in the "2019 MIDREX Plants Operation Summary."

Getting the Most from Raw Materials Via the Direct Reduction/EAF Route

Maximizing Iron Unit Yield from Ore to Liquid Steel (Part 3)

This is Part 3 of a three-part series on getting the most from raw materials, which is focused on the four interrelated factors that influence iron unit yield via the DR/EAF route:

- *Ore selection (Part 1)*
- *DRI physical properties (Part 2)*
- *DRI handling and storage (Part 2)*
- ***Melting practice (Part 3)***

AUTHORS' NOTE: *We wish to clarify a comparison of the water absorption of CDRI and HBI, as included in TABLE I of Part 2 of this series of articles, which was published in* ***1Q2020 Direct From Midrex****. The comparison is of the two forms of DRI when they are saturated with water to show a "worst case" condition during handling, storing, and shipping. The comparison was made to show that denser, compacted HBI is less prone to water absorption than the porous pellet form of CDRI; therefore, less reactive and safer to ship. The condition shown in the comparison is not representative of the two forms of DRI under normal handling, storing, and shipping conditions. The percentages should be considered as maximum.*

INTRODUCTION

Melting yield – the amount of liquid steel that can be produced from one ton of ferrous charge material – is one of the key considerations of EAF steel producers. It usually follows that the higher the melting yield, the greater the value ascribed to the material. The yield of ferrous scrap can vary considerably depending on its grade and the contaminants it includes. For example, low density scrap tends to oxidize rapidly, which results in a low melting yield. Scrap containing glass, plastic, rubber, concrete, wood, dirt, oil, rust, and coatings will yield less when melted than clean, well-segregated scrap. Typical melting yield reported for various scrap grades are shown in TABLE I *(next page)*.

	MELTING YIELD (%)	
SCRAP GRADE	TYPICAL	RANGE
No.1 Bundles	94.0	92-96
No. 1 Busheling	93.0	92-94
Shredded	92.0	85-96
No. 1 Heavy Melting	91.0	90-92
No 1. Heavy Melting	87.5	86-89
No. 2 Bundles	83.5	79-87
Turnings	80.0	80-85
Home Scrap	93.0	93-94

TABLE I. *Typical melting yield of various scrap grades*

Like scrap, all DRI is not the same. The melting yield of DRI can vary depending on the iron ore chemistry, metallic iron content, carbon content, and melting practice. As we discussed in Part 1 of this series, the objective when selecting iron ores for direct reduction is to use those having high iron content, low gangue content (especially SiO_2 and Al_2O_3), and good reducibility characteristics. Metallic iron content of the DRI will depend on the degree of reduction achieved in the reduction process – the higher, the better. Carbon in the DRI should be sufficient to reduce any residual iron oxide and to carburize the bath and support oxygen injection.

Yield losses due to material handling and storage result from breakage, spillage, dusting, and rusting and are relatively straight-forward, as we discussed in Part 2. Low yield during melting is harder to understand, but it can be the largest single source of iron loss from ore to liquid metal in a DRI-based steelmaking operation.

PART 3 – MELTING PRACTICE

DRI is mainly used in EAF steelmaking. Scrap/DRI feeding ratios typically vary from 70/30 to 10/90, depending on the steel being produced, the melting practice, and the availability of scrap. In scrap-deficient regions, such as MENA, the feed can be as much as 90% DRI. CDRI and HBI are batch charged along with scrap in a clam shell-type bucket, and CDRI and HDRI are continuously fed during melting. DRI usually is charged in a way to assure it is positioned as close as possible to the center of the EAF to reduce the tendency to oxidize and cluster, which can result in high iron losses, delays in operation, and unexpected damage to refractory materials.

When continuously charging DRI, the feeding rate should be such that the steel bath is maintained at a constant temperature. If the feeding rate is too low, the bath temperature will increase and the melt will tend to “outrun” its schedule and/or have less iron units than required. If the feeding rate is too high, there is a risk of forming “icebergs”; the slag temperature is decreased, creating a thick crust, which the DRI, especially in pellet and lump form, cannot penetrate. [1]

There are four potential sources of iron unit loss during melting:

- exhaust of the EAF
- metallic iron lost in slag
- oxidation of iron to the slag (carbon deficiency)
- oxidation of iron to the slag (EAF operation)

Dust losses to the EAF exhaust system

Dust losses to the exhaust system are very dependent on furnace operation, location and control of the off-gas collection, method of adding DRI, and dust content of DRI material. This can exceed 2% of the charged material in some cases.

Metal droplet losses from the furnace during de-slagging

Metal losses during de-slagging are very dependent on the timing of DRI additions and the de-slagging operation, as well as the total volume of slag that is being generated. When very large slag volumes are generated, metal droplet retention time in the slag can be longer and the residence time of the slag in the furnace can be shorter, leading to significant losses.

Iron oxide loss to the slag when the DRI is carbon deficient

The third source of iron loss during melting of DRI/HBI is rarer than the first two. It can happen when the DRI has a low carbon content and low metallization (higher amounts of unreduced iron present as FeO in the DRI). Under this scenario, oxygen from lances will react with iron as carbon is depleted, causing the iron to oxidize. This occurs because there is not sufficient carbon to protect and reduce the FeO in the DRI. Typically, DRI producers of both captive and merchant material will have a product chemistry target that has a surplus of carbon relative to the retained iron oxide in the material.

Iron oxidation to the slag driven by furnace thermodynamics and kinetics

The fourth source of iron loss during melting of DRI/HBI in a steelmaking furnace is more difficult to understand. Acidic gangue (SiO_2 and Al_2O_3) from the iron ore pellets is not affected by the direct reduction process and enters the EAF in the DRI. To maintain slag basicity, basic slag conditioners (like CaO) are added to the vessel, resulting in larger slag volume. If the percentage of FeO in the slag is maintained constant, then more iron weight is lost to the slag.

Consider a simple case of melting 100 kg of DRI containing 3% SiO_2. This initially will produce 97 kg of liquid iron and 3 kg of SiO_2. To balance the V ratio* at 2.0 requires the addition of 6 kg of CaO and 2 kg of MgO to protect the refractories. The $CaO+MgO+SiO_2+Al_2O_3$ represents approximately 65% of total slag make up, thus the total slag weight is approximately 17 kg. With 30% FeO in slag, that represents 5 kg of FeO or 3.9 kg of Fe lost to slag (3.9% yield loss on iron units). The 30% FeO volume comes from the balance between carbon in the steel, dissolved oxygen in the steel, and FeO in the slag. This balance is driven by thermodynamics and the stirring conditions in the furnace (kinetics), as shown in ***Figure 1***, which was generated using actual plant data.

Higher slag volumes or higher FeO content of the slag will lead to higher iron in the slag. This is not unreduced oxide from the DRI product and is completely independent of metallization and DRI carbon content. This is the equilibrium (or disequilibrium) of the slag with the oxidation state of the liquid steel being produced. The EAF is a relatively poorly stirred vessel, as compared with a BOF or QBOP/OBM. Efforts to improve stirring in the EAF will improve the oxygen/carbon/FeO balance in the furnace and reduce the penalty for higher gangue DRI, as shown in ***Figure 2***.

Melting practice can help mitigate iron losses to the slag. Iron can be recovered by using injection carbon; however, this can be expensive and often yields inconsistent results. Another option is to melt in with low FeO (high carbon) and slag off prior to deep decarburization. This can be difficult to achieve in actual practice in a high productivity shop. Most often, melting, decarburization, and feeding of DRI occur simultaneously.

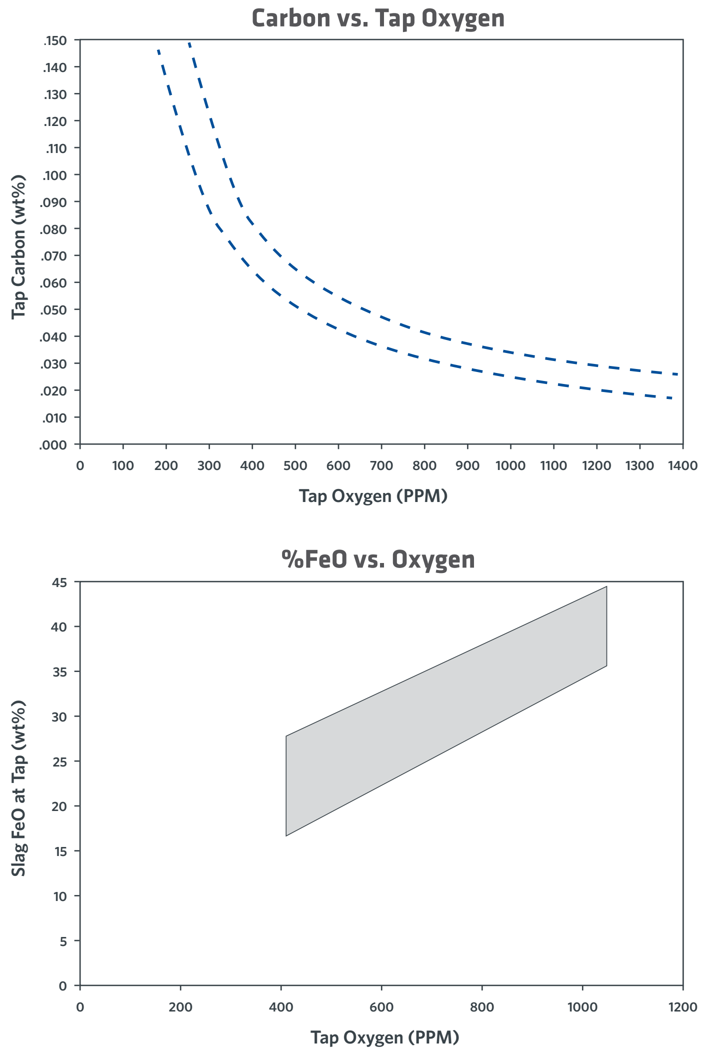


FIGURE 1. *Relationship between tap carbon, dissolved oxygen, and slag FeO.*

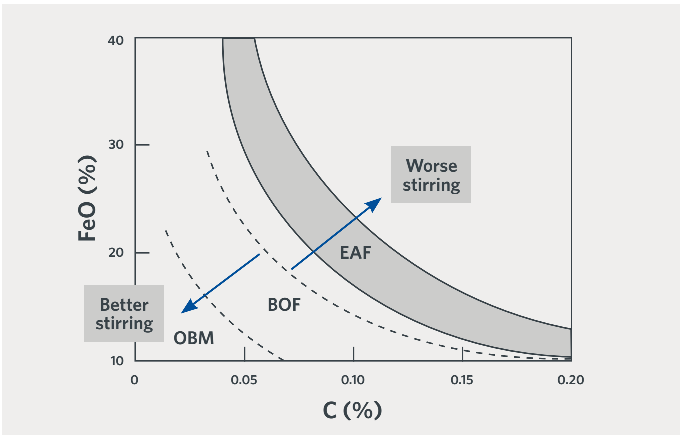


FIGURE 2. *Relationship between % FeO in the slag and % C in the steel at tap.* [1]

** V ratio is defined as % CaO / % SiO_2 in weight percentage – also called B ratio or B2 ratio.*

Careful slag chemistry control also can help minimize iron losses to the slag. Slag basicity has a strong impact on activity of FeO in the slag. By targeting the correct slag basicity, an equivalent oxygen activity in the slag can be achieved at lower concentration of FeO in the slag.

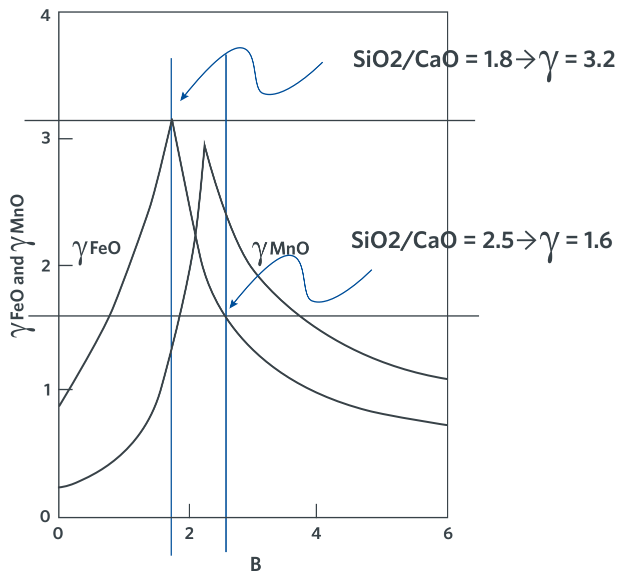


FIGURE 3. *Effect of slag basicity on the activity of FeO.* [2]

As ***Figure 3*** shows, pushing the V ratio from 2.5 down to 1.8, can double the 'potency' of the FeO in the slag. In theory, an 18% FeO slag at V = 1.8 has the same oxidizing potential as a 36% FeO at V = 2.5.

Production of phosphorus-restricted steel grades with higher phosphorus DRI can interfere with this effort. Under these circumstances, effective phosphorus control typically requires a higher slag V ratio and typically higher tap oxygen (and slag FeO). Higher V ratio leads to a higher slag volume and lower activity coefficient of FeO in the slag. Higher aim tap oxygen and lower activity coefficient of FeO leads to higher FeO concentrations in the slag and greater iron loss to the slag.

From the previous example, let's consider that the slag must be modified to perform de-phosphorization. Instead of V ratio = 2 and FeO = 30, consider V ratio = 2.8 and FeO = 35. The total slag weight is 3 kg SiO_2 (from DRI) + 8.4 kg CaO (for V ratio of 2.8) + 2 kg MgO (for refractory) / 0.6 (SiO_2+CaO+MgO represent ~60% of the slag make up) = 22.3 kg/DRI ton of total slag. With 35% FeO in the slag, this means 7.8 kg of FeO or 6.1 kg of Fe lost to the slag. (Note: In this example, a relatively small change to accommodate phosphorus removal increased iron loss from 3.9% to 6.1%.)

SERIES SUMMARY

Overall iron unit yield from ore to liquid metal can vary over a wide range via the direct reduction/EAF steelmaking route. Iron unit loss can add up to greater than 15% quite easily. The major root causes of these losses include:

- Iron ore physical properties, which affect breakage during handling of the oxide
- Handling losses if DRI / HBI breaks into chips and fines; although much less prominent in HBI. Handling losses can be controlled by careful design and selection of material handling equipment and recovery/recycling of dust and fines that are generated.
- Spillage
- Weathering during storage
- Losses resulting from melting in with a large slag volume. Losses to the slag during melting really start with the iron ore chemical properties.

Melting practice also plays a role and understanding the chemistry of slag generation in a steelmaking furnace is important. The large costs associated with iron unit loss are sometimes hidden, as they are distributed across several unit operations. These costs must be controlled in a competitive iron and steel market. Careful consideration at all steps highlighted in this series of articles can lead to significant improvement in yield, and thus a major reduction in operating cost. ■

Direct Reduction Terms of Interest to Steelmakers

Carbon Content (%): total carbon present in DRI as a percentage of total weight of DRI. Carbon in DRI can be both in free form and as cementite (Fe_3C).

Degree of Reduction (%): iron-bound oxygen removed during reduction.

Gangue Content (%): components of iron ores that are retained in DRI products (SiO_2, Al_2O_3, CaO, MgO, MnO, TiO_2, P, and S). Gangue content typically is 3-5%.

Gangue Basicity (%): weight ratio of basic (CaO + MgO) to acid (SiO_2 + Al_2O_3) gangue components.

Iron Yield (%): total iron present in DRI that can be converted to liquid steel by melting.

Liquid Steel/Metallic or Melting Yield (%): total DRI weight that is recovered as liquid steel by melting.

Metallic Iron Content (%): total DRI weight present as metallic iron, not including iron-bound oxygen.

Metallization (%): total iron in DRI present as metallic iron.

Phosphorus Content (%): amount of phosphorus present, expressed as percentage of total DRI weight. Phosphorus normally is present as P_2O_5.

Pre-reduced Iron: reduced iron material with metallization < 85% (not suitable for steelmaking).

Residual Elements: non-ferrous metals that are volatized or remain in the liquid steel bath during melting (Cu, Ni, Cr, Sn, Mo, Pb, and Zn). Total residual element content of DRI typically is < 0.02%.

Total Iron Content (%): metallic iron + oxygen-bound iron expressed as a percentage of total DRI weight.

Tramp Elements: residual elements + sulfur and phosphorus.

References

[1] Manfred Jellinghaus and Dr. Wolf-Dieter Ropke, "DRI and Scrap as Future Major Raw Materials for Steelmaking," Krupp Stahltechnik GmbH, 1987.

[2] R.J. Fruehan, ed., The Making Shaping and Treating of Steel, 11th Edition—Steelmaking and Refining Volume, Pittsburgh, PA: AISE, 1998.

This series is based on a paper titled, "Getting the Most from Raw Materials – Iron Unit Yield from Ore to Liquid Steel via the Direct Reduction/EAF Route" by Christopher Manning, PhD, Materials Processing Solutions, Inc. and Vincent Chevrier, PhD, Midrex Technologies, Inc. and articles previously published in ***Direct From Midrex*****.**

MIDREX® Direct Reduction Plants

2019 OPERATIONS SUMMARY

MIDREX® Plants produced 67.7 million tons of DRI in 2019, 5.1 percent more than the 64.4 million tons produced in 2018. The production for 2019 was calculated from the 39.2 million tons confirmed by MIDREX Plants located outside of Iran and the 28.5 million tons for Iran reported by the World Steel Association (WSA). Approximately 7.4 million tons of hot DRI (HDRI) were produced by MIDREX Plants, which were consumed in nearby steel shops and assisted them in reducing their energy consumption per ton of steel produced and increasing their productivity.

MIDREX Plants* have produced a cumulative total of more than 1.1 billion tons of all forms of DRI (CDRI, HDRI, and HBI) through the end of 2019.

MIDREX Technology continued to account for 80% of worldwide production of DRI by shaft furnaces. At least eight MIDREX Modules established new annual production records and at least seven established new monthly production records (no detailed production information has been received from Iran). Eight additional modules came within 10% of their record annual production and 13 operated in excess of 8,000 hours.

No new modules were started up in 2019; however, two are under construction: a 2.5 million t/y module designed to produce CDRI and HDRI, owned by Algerian Qatari Steel (AQS) in Bellara, Algeria, and a 1.6 million t/y HBI module belonging to Cleveland-Cliffs in Toledo, Ohio, USA.

** A MIDREX Plant can include one or more modules*

2019 PLANT HIGHLIGHTS

ACINDAR

In its 41st year of operation, ACINDAR's module exceeded rated capacity despite challenging local market conditions and the typical natural gas curtailment during the winter months. With over 31.5 million tons produced, ACINDAR has obtained the most production from a 5.5-meter MIDREX Shaft Furnace to date.

ANTARA STEEL MILLS

In its 35th anniversary year, the first MIDREX HBI Module operated at less than its annual rated capacity due to market conditions. Total iron of its HBI product was the highest of all MIDREX Plants, averaging 93.49% for the year. All production was shipped by water to third parties.

ARCELORMITTAL CANADA

Module 1 set a new annual production record, averaging over 80 t/h and more than 8,100 hours of operation in 2019, while setting three consecutive monthly production records in March, April, and May. Module 2 operated above rated capacity, after a record production year in 2018.

ARCELORMITTAL HAMBURG

In its 48th full year of operation, the oldest MIDREX Module in operation exceeded its annual rated capacity. Average product metallization was increased to 95.0%.

ARCELORMITTAL LÁZARO CARDENAS

AMLC produced 24% over its annual rated capacity of 1.2 million tons in its 22nd year of operation, falling just 20 hours short of reaching 8,000 hours of operation in the year. Its 6.5-meter reduction furnace has produced a total of 33.22 million tons of DRI, the most by a single module to date.

ARCELORMITTAL POINT LISAS

Twenty years after the start-up of Module 3, all three MIDREX Modules in Trinidad and Tobago remained shut down throughout the year.

ARCELORMITTAL SOUTH AFRICA (SALDANHA WORKS)

In its 20th year since starting operations, the COREX® export gas-based MxCol® Plant operated the whole year but was limited by the availability of gas from the COREX Plant and by market demand. The module surpassed the 10 million tons production milestone since initial start-up and averaged using 67.8% South African lump ore for the year.

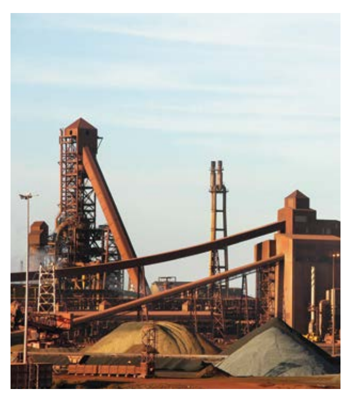
ACINDAR

Antara Steel Mills

ArcelorMittal Canada

ArcelorMittal Hamburg

ArcelorMittal Lazaro Cardenas



ArcelorMittal South Africa

COMSIGUA

COMSIGUA's production of HBI increased compared to 2018 but was restricted by the limited supply of locally produced pellets.

DELTA STEEL

The two modules in Nigeria did not operate in 2019.

DRIC

Both of DRIC's modules in Dammam, Saudi Arabia, set new annual production records for a second consecutive year in 2019, mainly through an increased number of operating hours (averaged 8,500 hours). The two-module plant set an annual production record of 1.09 million tons of DRI.

ESISCO

The MIDREX Module restarted operations in December 2019, after being shut down since January 2016 due to high natural gas prices in Egypt, as well as competition of foreign steel products.

ESSAR STEEL

In the 15th anniversary year since start-up of Module 4, Essar's six modules operated at less than maximum capacity; however, their DRI production totaled 4.84 million tons, which almost equaled their DRI production record of 4.86 million tons set in 2018. Modules 2-5 produced 2.5 million tons of HDRI (over 83% of their production), with the balance being HBI. Modules 5 and 6 operated using off-gas from Essar's COREX Plant for ~20% of their energy input.

EZDK

With increased natural gas availability in Egypt, EZDK's modules operated at about 82% of their rated capacity. Module 3 operated 8,300 hours in the year and was within 7% of its annual production record. Due to the current pellet shortage, EZDK continued to use ~25% lump ore in the oxide feed mix through the first half of the year.

FERROMINERA ORINOCO

Ferrominera Orinoco's HBI module in Puerto Ordaz, Venezuela, did not operate in 2019 due to limited availability of locally produced oxide pellets.

Comsigua

DRIC

Essar Steel

EZDK

HADEED

Hadeed exceeded rated capacity for the 35th consecutive year in Modules A and B and for the 27th consecutive year in Module C. Module C fell 400 tons short of producing one million tons of CDRI, operating 7,922 hours in the year. After 12.5 years of operation, Hadeed E almost reached a total of 21 million tons since start-up in July 2007 and came within 0.2% of breaking its monthly production record in May. Hadeed's four MIDREX Modules have produced over 93 million tons of DRI to date. Hadeed also owns an HYL module (Module D).


Hadeed Module E

JINDAL SHADEED

Following a shutdown for major maintenance and improvements in 2018, and with increased natural gas availability, Jindal Shadeed established a new annual production record (17% more than rated capacity). The HOTLINK® Plant operated 8,245 hours in 2019 at an average of 212 t/h and twice broke monthly production records. The module is designed to produce mainly HDRI, with HBI as a secondary product stream. A major portion (~89 %) of its annual production of over 1.74 million tons was consumed as HDRI in Jindal Shadeed's adjacent steel shop.


Jindal Shadeed

JSPL (ANGUL)

In its 5th anniversary year, Jindal Steel and Power Limited's (JSPL) MxCol Plant in Angul, Odisha State, India, restarted operations for approximately 1.5 months in early 2019 but remained shut down for the rest of the year. This is the first MxCol Plant using synthesis gas from coal gasifiers to produce both HDRI and CDRI for the adjacent steel shop.


JSPL (Angul)

JSW STEEL (DOLVI)

In its 25th anniversary year, JSW Steel's module operated very consistently for 8,174 hours. The system installed at the end of 2014 to reduce natural gas consumption by adding coke oven gas (COG) from JSW Steel's coke oven batteries to the reduction furnace operated throughout the year, providing over 14% of the plant's energy requirement. The module has averaged more than 8,030 hours per year of operation since its initial start-up in September 1994.


JSW Steel (Dolvi)

JSW STEEL (TORANAGALLU)

In its fifth anniversary year, JSW Steel's HDRI/CDRI module in Toranagallu, Karnataka State, India, using COREX export gas as energy input, produced 88% of its annual production record set in 2018. This is the second plant of its kind – the first one being ArcelorMittal's COREX/MIDREX Plant at Saldanha, South Africa.

LEBEDINSKY GOK

LGOK's MIDREX HBI Modules 2 and 3, located in Gubkin, Russia, and belonging to the Metalloinvest Group, set a new annual combined production record in 2019, averaging over 8,000 hours of operation. Module 3 set a new annual production record for the third consecutive year and Module 2 set a new monthly production record in May 2019. LGOK HBI-3 has produced over 5.4 million tons since its start-up in March 2017, and with over 23 million tons of combined production, the two modules surpassed the 20 million-ton milestone in 2019. LGOK HBI-1 is an HYL plant.

LION DRI

The Lion DRI module, located near Kuala Lumpur, Malaysia, remained shut down throughout 2019 due to insufficient market demand for locally produced steel products.

LISCO

Thirty years after start-up of Module 1, production by LISCO's three HBI modules in Misurata, Libya, was restricted to approximately 50% of rated capacity by ongoing civil unrest. The combined production of the three modules surpassed the 30 million tons milestone in 2019.

NU-IRON

In its 13th full year in operation, Nucor's module in Trinidad and Tobago produced over 1.7 million tons of CDRI, breaking its previous annual production record with over 8,000 hours of operation. Nu-Iron also broke its monthly production record in January, reaching an average production rate of 224 t/h. Average DRI metallization for the year was the highest of all MIDREX Plants at over 96.1%, with 2.66% carbon in the DRI.

JSW Steel (Toranagallu)

LISCO

LGOK HBI-2 and HBI-3

Nu-Iron Unlimited

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OEMK

OEMK's four modules had a combined record production year with over 3.2 million tons in 2019. The production of all four modules was within 1-5% of their individual record levels and all operated more than 8,400 hours in the year, averaging 8,434 hours. The total combined DRI output of OEMK surpassed the 70 million-ton milestone in 2019, and Module 1, the first to start-up in December 1983, surpassed the 20 million tons production milestone.

QATAR STEEL

In its 12th full year of operation, Qatar Steel's dual product (CDRI/HBI) Module 2 operated 10% over its rated annual capacity of 1.5 million t/y and set a new monthly production record in May, while averaging 233 t/h. Module 2 also set a record for 251 days of continuous operation. The entire production from Module 2 was CDRI, averaging 94.7% metallization and 2.54% carbon for the year. The production of Module 1 was less than 4% below its record annual production while operating over 8,292 hours during the year. Qatar Steel's Module 1 has produced over 27 million tons of DRI since its start-up in 1978, the most for a 5.0-meter shaft furnace.

SIDOR

Forty years after start-up, Sidor 2, which includes three modules, was idle due to a lack of oxide pellets. Single-module Sidor 1 also was inactive due to the allocation of the limited supply of oxide pellets in Venezuela to the HBI plants, which produce products for export.

SULB

Despite a scheduled major maintenance shutdown near year end, SULB's 1.5 million t/y combination module (simultaneous CDRI/HDRI production) in Bahrain achieved 91% of its production record set in 2018. SULB set a new monthly production record, averaging 215 t/h in March. Over 1.0 million tons of HDRI were sent directly to the steel mill and over 60% of the balance was exported by ship as CDRI.

OEMK

Qatar Steel Module 2

SULB

TENARISSIDERCA

TenarisSiderca operated below maximum capacity and was down for almost three months at midyear due to limited DRI demand by the steel shop and a natural gas curtailment during the winter months. The module's DRI metallization percentage was second highest of all MIDREX Plants at 95.40%.

TOSYALI ALGÉRIE

After starting operations in November 2018, Tosyali Holding's 2.5 million t/y combination module, located in Bethioua, near Oran, Algeria, continued ramping up operations and set new annual and monthly production records. While sporadically operating above its rated capacity of 312.5 t/h, the module's production was restricted by market conditions and internal strife in Algeria. This is the largest capacity MIDREX Module built to date.

TUWAIRQI STEEL MILLS

The 1.28 million t/y combination module of Tuwairqi Steel Mills, located near Karachi, Pakistan, did not operate in 2019 due to market conditions.

VENPRECAR

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

voestalpine TEXAS

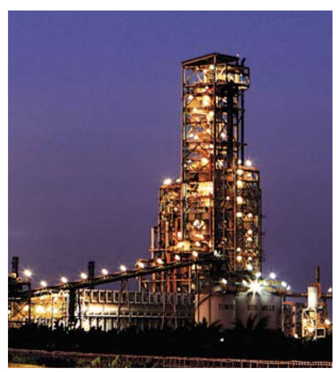
The voestalpine Texas 2.0 million t/y HBI module located near Corpus Christi, Texas, USA, continued to ramp up production, setting a new annual production record in 2019. voestalpine Texas is a 100% subsidiary of voestalpine AG in Austria.

EDITOR'S NOTE:

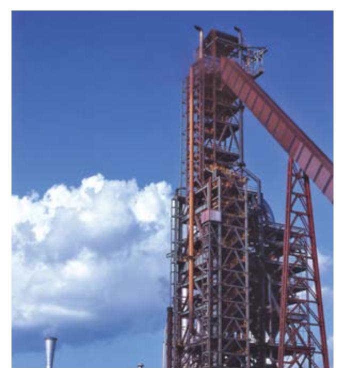
At the time of printing, no detailed information had been received from MIDREX Plants located in Iran.

TenarisSiderca

Tosyali Algérie



Tuwairqi Steel Mills



Venprecar

voestalpine Texas

MIDREX News & Views

Cleveland-Cliffs Targets 4th Quarter 2020 for Completion of HBI Plant

Cleveland-Cliffs, Inc. recently announced the restart of construction of its hot briquetted iron (HBI) plant in Toledo, OH. Construction was temporarily halted on March 20, 2020, due to COVID-19. Cliffs has begun to re-mobilize its workforce and expects to complete construction of the plant in the fourth quarter of this year. Throughout the construction shut-down, Midrex continued to support the project with a focus on select water and electrical systems.

Cliffs also announced that its Tilden mine in Michigan, which supplies the company's AK Steel facilities in Middletown, OH, and Dearborn, MI, will reopen ahead of schedule. The mine was idled in mid-April and was expected to resume operations in July.

Cliffs Chairman, President, and CEO Lourenco Goncalves said, "The demand for our steel, iron ore, and metallics products has recovered dramatically over the past month, and in light of this, we are restarting Toledo and Tilden sooner than we originally expected. We suspended these operations in a way that allowed us to restart as easily and efficiently as possible ..."

MIDREX News & Views

Dr. Vincent Chevrier Presents in AIST Ironmaking Webinar

Transition from Fossil to Hydrogen Economy
(for ore-based metallics)

Present: NG based DRI + EAF — MIDREX NG™

Near Future (Transition): NG/H_2 based DRI + EAF — MIDREX NG™ with Hydrogen Addition

Future: H_2 DRI + EAF — MIDREX H_2™

Feed Gas		Natural Gas	Natural Gas + Hydrogen (as % of energy coming from external H_2)			Hydrogen
			20%	50%	70%	
Reducing Gas	H_2	55%	62%	72%	77%	100%
	CO	35%	28%	18%	13%	0%
	Others	10% (mostly CO_2, H_2O, CH_4, N_2)				
	H_2/CO	1.6	2.2	4.0	5.9	n/a
Carbon in DRI		2.5% 4% w/ ACT	~ 1.5%	~ 1.0%	~ 0.5%	0%
CO_2 emissions (kg_{CO2} / t_{DRI}) *		500	400	250	150	From heater burners only

* only includes CO_2 emissions from flue gas (largest source)

Dr. Vincent Chevrier, Midrex Technologies General Manager – Business Development, participated in a panel of experts during an AIST webinar titled, "Ironmaking with Alternative Reductants." The webinar focused on the decarbonization of the steel industry worldwide and emerging technologies to support clean steelmaking solutions. Chevrier discussed MIDREX H_2 and the phased transition from fossil to hydrogen-based direct reduction in an EAF, which is outlined in the chart above. His presentation also covered process flexibility, bridge technology, and challenges to early adoption.

Midrex Donates 882 Pounds of Food to Charlotte-Area Food Bank

At Midrex, we see the importance of supporting our communities and giving back to assist those who need it. The Coronavirus (COVID-19) pandemic has upended our lives and created unprecedented challenges for people around the world. In the midst of a global crisis, the Midrex team has stepped up to help their community.

Midrex recently coordinated a food drive to support Second Harvest Food Bank of Metrolina, which provides a regional distribution warehouse and branches that supply food and grocery items to charitable agencies. During the food drive, Midrex teammates collected 882 pounds of food, in addition to making several monetary donations and donating volunteer hours. By Feeding America's measurement (1.2 pounds of food = 1 meal), Midrex provided 735 meals to people in need in the Charlotte Community.

MIDREX News & Views

Curtis Hughes, Midrex CIO, Finalist for Prestigious Industry Award

Curtis Hughes has been named a finalist in the corporate category for the 2020 CIO of the Year ORBIE® Award by CharlotteCIO, a peer leadership network and one of 17 chapters of the InspireCIO Leadership Network. The ORBIE award was founded in 1998 and signifies exceptional leadership, innovation, and vision and recognizes the characteristics and qualities that inspire others to achieve their potential. As Midrex Technologies CIO, Hughes is responsible for defining and executing the company's global technology strategy across more than 20 countries worldwide. Since joining Midrex in 2017, he has transformed the company's roadmap for technology solutions and IT management by implementing game-changing initiatives such as the cross-organizational implementation of Microsoft 365 and a new internal intranet, as a well as redefined IT security and data protection measures.

Lauren Lorraine: **Editor**
Vincent Chevrier, PhD: **Technical Advisor**

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All references to tons are metric unless otherwise stated.

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