MIDREX

DIRECT FROM MIDREX

2ND QUARTER 2025

MIDREX® DIRECT REDUCTION PLANTS
2024 OPERATIONS SUMMARY

STRUCTURE & PROPERTIES OF HYDROGEN-BASED DRI

NEWS & VIEWS
Jindal Steel Sohar – Driving Oman's Economic Diversification

NEWS & VIEWS
New Leadership – Inside Midrex Global Solutions

NEWS & VIEWS
MIDREX® Plant with 2nd Quarter Anniversary

Pictured: Jindal Steel Sohar DR Plant

COMMENTARY

INVESTING IN A PARTNERSHIP, NOT JUST A PLANT

By John Linklater
General Manager - Midrex Global Solutions Middle East & North Africa

INTRODUCTION

There is a saying that "two heads are better than one." Multiply that many times over and you see why Midrex decided to take a different approach to technology transfer from the outset. Conventional thinking at the time was for companies to own, manage, and operate plants based on their technology. This approach tended to protect and preserve the technology but did little to achieve industrial self-reliance of the host nations. Moreover, it limited further development of the technology beyond the capability of the developer and the plants it controlled.

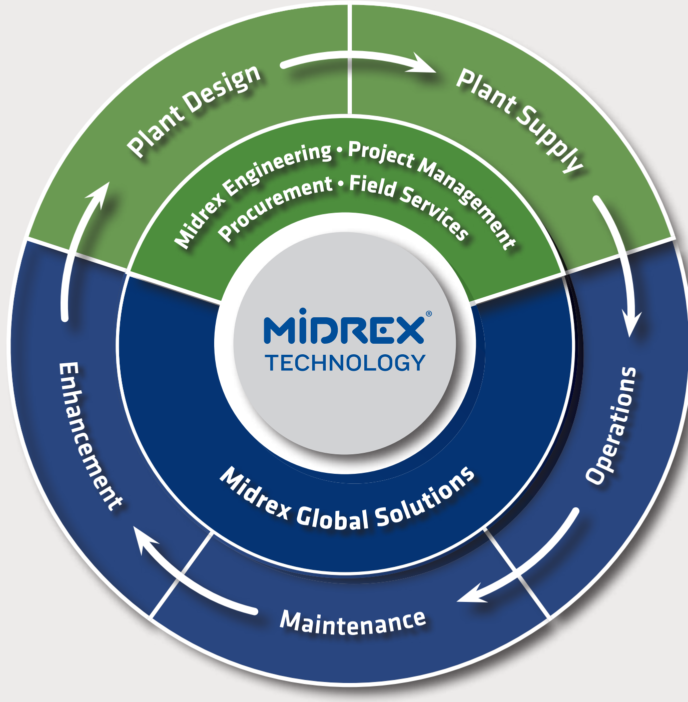

FIGURE 1. *Life cycle of a plant*

Midrex recognized the importance of creating a collaborative partnership with the growing number of process licensees that have been operating MIDREX® Plants worldwide since the 1970s. This bi-directional exchange of knowledge, expertise, and experience benefits both Midrex and our current and future licensees and shows that the plant sale is only the beginning of a partnership that lasts for the life of the plant and makes everyone a winner.

LIFE CYCLE OF A MIDREX PLANT

The typical life cycle is shown in ***Figure 1***, and consists of:

- Plant design
- Plant supply
- Plant operations
- Plant maintenance
- Plant enhancement

Throughout its life, the plant and its equipment are continually assessed and improved, as needed.

During each phase, there are specific roles for Midrex and our licensees. However, it is the interaction between the parties that yields mutual benefits and maximizes the operating life of the plant.

PLANT DESIGN AND PROCUREMENT

From day one, the client and Midrex become a team. There will always be a scope split, necessitating collaboration from the start. Midrex and its construction partners are often responsible for the core plant, with the client responsible for the balance of the plant, such as material handling. This requires an information exchange on many fronts, such as the layout and clear battery limits. Often an existing licensee will share previous plant issues and propose solutions to us, such as conveyor angles and speeds. Sometimes a client will request to fabricate vessels, and we will

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"From day one, the client and Midrex become a team. There will always be a scope split, necessitating collaboration from the start."

share and exchange design information with them. However, regardless of scope split, Midrex is responsible for the plant passing the performance test and will be actively involved with the entire plant.

CONSTRUCTION & COMMISSIONING

Typically, the client will have a third-party construction company or companies responsible for erecting the plant. Midrex will provide construction advisors to help ensure the plant is constructed according to design. Our advisors are effectively involved in protecting both the client's investment and the Midrex guarantee of plant performance.

Before moving into commissioning, Midrex is actively involved in client training to prepare its team to properly operate and maintain the plant during the performance tests and for the commercial life of the plant.

OPERATION & MAINTENANCE

Once the performance tests have been completed and all Midrex personnel have left the site, the client determines the level of Midrex involvement. This is the longest phase of a plant's life, when the value proposition of the Midrex/Client partnership is most evident: a successfully operating plant results in profits for the client and a stronger Midrex.

This is when our collaboration with the operating plants becomes customized to their individual needs. It is also an area where we now offer advanced services, such as:

- Remote Professional Services (RPS) for real-time operational collaboration
- Water Treatment Services (WTS) for chemical supply and technician assistance
- Turnkey solutions that expand the supply of equipment to include not just advisory services but installation and start-up with operational guarantees

PLANT AND EQUIPMENT ASSESMENTS AND UPGRADES

A MIDREX Plant is always evolving, driven by:

- Feedback from other plants
- Advancements in technology
- A need for increased production or cost reduction

When a piece of equipment nears the end of its operational life, the question becomes, "Do we replace like-for-like or look for an upgrade?" An example is reformer tubes. If a plant has 10-inch tubes, can it go to 10.5 or 11-inch tubes and will this result in more DRI production? Are there bottlenecks that could prevent this? If so, what are they? This

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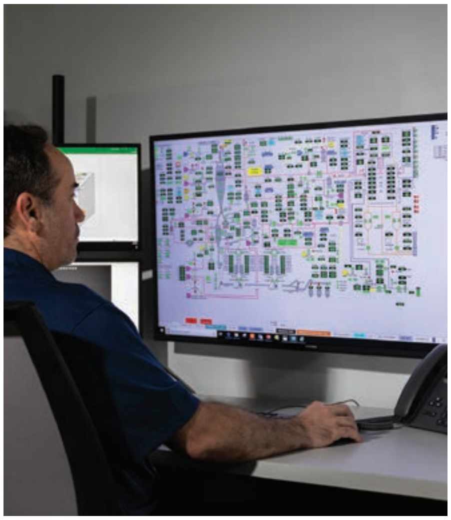
is where Midrex and the client can explore together the options and make an informed decision.

Client requests also drive equipment changes. Recently, a client requested the oxygen injection skid be designed to allow its use from start-up. This has resulted in reduced carbon build-up in the oxygen injection area of the duct, as well as operational savings. This improvement is now available to the entire family of MIDREX Plants.

FOCUS ON WHAT YOU DO BEST

What does a Midrex Process Licensee do best and what does Midrex do best? And more importantly, how can we benefit each other?

Plants know how to make DRI and keep their plants operating, while Midrex, as the process developer, has proprietary software and design knowledge and focuses on optimizing and debottlenecking process systems, improving equipment designs and specialized support areas, such as water, turnkey installation, etc. When their expertise is combined, there are decades of proven results to show for it.



The successes achieved can be attributed to both teams working together with a common goal in mind, "finding the solution and not the blame," an attitude that drives sustainable success. When we join forces and share our expertise, we both win.

SUCCESSES

Here are but a few of the many success stories:

- Nu-Iron and the Midrex RPS team collaborated to increase hourly production by approximately 30 tons.
- Antara HBI operations team working with the Midrex water treatment team have run a three-year campaign without any down days for cleaning and packing, unheard of previously.
- Jindal Shadeed Sohar Hadeed and DRIC had their furnaces relined by Midrex and have had no hot spots or refractory issues during operation.

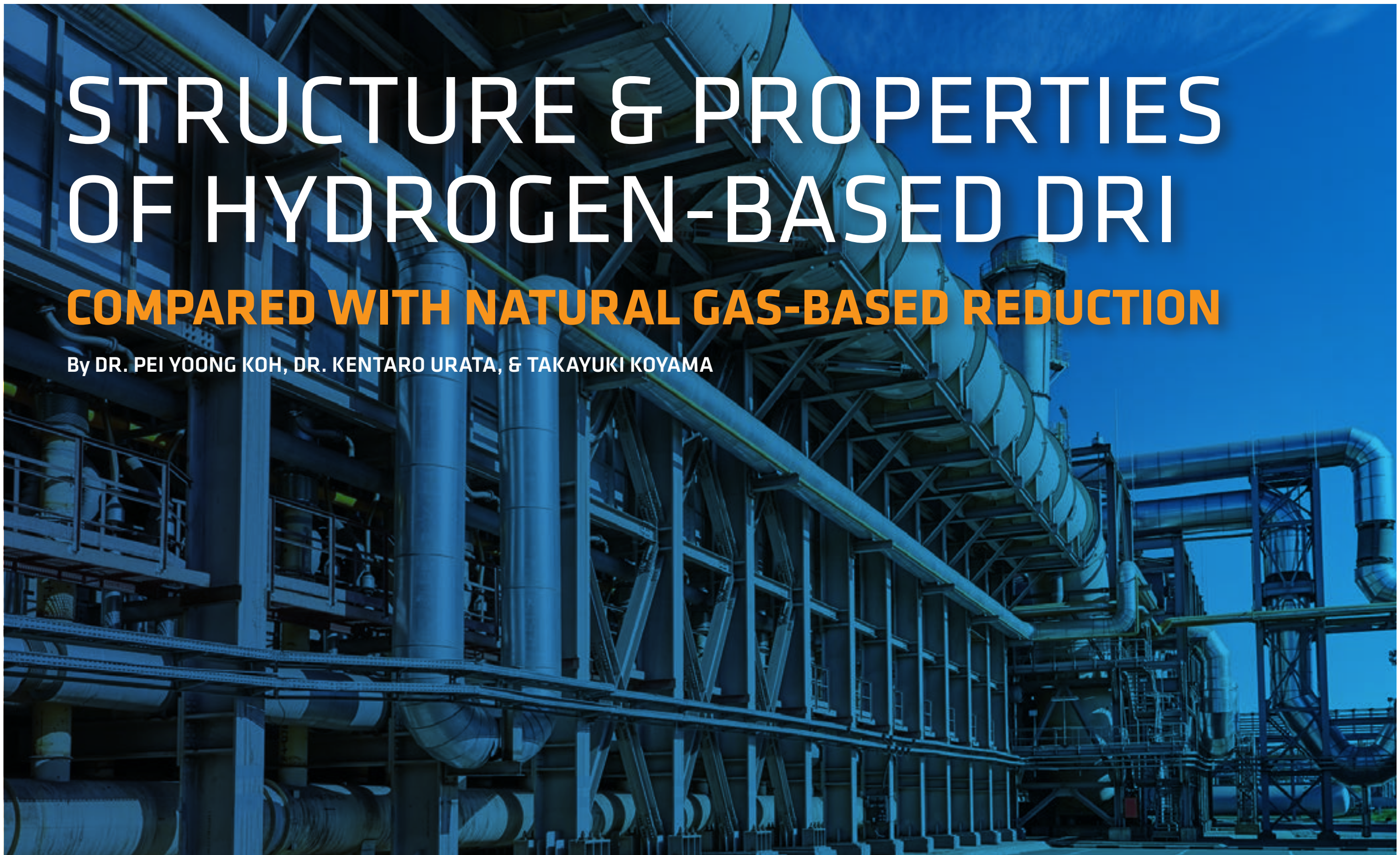
→

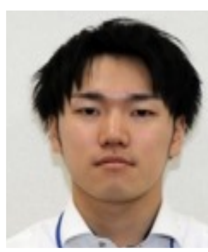
This issue of *Direct From Midrex* features articles about test work at the Midrex Research & Technology Development Center comparing the structure and physical characteristics of DRI produced with natural gas and with hydrogen and a summary of the operation of MIDREX Plants in 2024. News & Views celebrates the record-setting achievements of Jindal Steel Sohar, the long DR industry career of David Durnovich and recognizes the appointment of John Linklater and Matt Rea to head Midrex Global Solutions, and the 35th anniversary of the start-up of LISCO Module 2.

STRUCTURE & PROPERTIES OF HYDROGEN-BASED DRI

COMPARED WITH NATURAL GAS-BASED REDUCTION

By DR. PEI YOONG KOH, DR. KENTARO URATA, & TAKAYUKI KOYAMA





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INTRODUCTION

The mechanical properties of direct reduced iron (DRI), such as swelling behavior and strength are influenced by reducing gas composition. Zhao et al. reported that the higher carbon monoxide (CO) concentration is in reducing gases, the more serious the swelling that occurs[1]. Mizutani et al. examined the relationship of the reduction disintegration tendency and the reduction mode and concluded that the topochemical reduction in hydrogen (H_2) and CO mixture resulted in worse disintegration behavior than the homogeneous reduction under pure H_2 atmosphere[2]. These studies indicate that there is less possibility of swelling and disintegration when DRI is produced under H_2.

The use of pure hydrogen (H_2) as direct reduction reducing gas gives rise to the question whether the as-produced cold DRI (CDRI) will reach the same targeted parameters, such as product strength, when compared to CDRI produced from reformed natural gas (NG).

Investigations were conducted at the Midrex Research & Development Technology Center to examine and compare the effects of gas composition on the apparent density, porosity, reduction swelling, cold crush strength, and fines generation of carburized and non-carburized CDRI when using either H_2 or reformed NG as the reducing gas. We determined that the structure and physical properties of CDRI are influenced by the reducing gas composition and subsequently may affect plant operation or cause materials loss during processing and transportation.

TESTING & CALCULATING METHODOLOGY

Five direct reduction grade-pellets, with total Fe ranging between 67.6% and 68.3%, were selected and subjected to two modified ISO 11258 reducibility tests. Two types of reducing gas were employed for the reducibility tests (labeled Standard NG and Standard H_2). The gas compositions of the Standard NG and Standard H_2 reducing gases are shown in ***Table 1***.

The pellets reduced under Standard NG reducing gas were further carburized to achieve around 2% carbon level to mimic industrial DRI. After the pellets completed the reduction process under Standard NG conditions, the NG-reduced DRI was immediately subjected to 30 minutes of cooling under nitrogen (N_2) flow to a temperature of 700°C, followed by carburization under a continuous flow of a mixture of H_2 and CH_4 (methane) gas, maintained at 700°C during the carburization process.

The physical properties of the H2-DRI and the carburized NG-DRI, such as apparent density, porosity, volume expansion, cold crushing strength, and tumble strength were measured using methods developed in-house. The reduction degree of the pellets at any given time was determined by weight loss of the samples during reduction based on reduction degree at a set time, weight change in load cell at a set time during the reduction test, and total weight change of sample after the completion of the reduction test.

The reduction degree of the DRI was determined by measuring the concentration of total Fe (%T.Fe), metallic Fe (%M.Fe), and FeO (%FeO) via chemical analysis.

	Temp °C	Gas Composition				
		% H_2	% CO	% CO_2	% N_2	%CH_4
STD. NG	800	45	30	15	10	0
STD. H_2		80	0	0	20	0

TABLE I. *Gas Composition Standard NG and Standard H_2 reducing gas*

The carburizing percentage of NG-DRI was determined by weight gain of the samples during carburization. The volume expansion ratio of DRI was determined with a series of equations that considered volume of sample, sample weight after reduction and carburization, weight of oxygen combined with iron as Fe_2O_3 and Fe_3O_4 in oxide pellet, weight of oxygen removed by reduction, sample weight after reduction, apparent density of sample, and oxygen concentration of the oxide pellet.

RESULTS

Chemical analysis and reduction curves of oxide pellets and DRI

	Pellet A	Pellet B	Pellet C	Pellet D	Pellet E
T.Fe of Oxide	68.29	68.13	67.81	67.68	67.57
T.Fe of DRI (Std H2 red.)	95.15	95.91	91.41	94.14	94.44
T.Fe of DRI (Std NG red. + carb.)	92.97	93.11	91.99	92.51	92.63
M.Fe (Std H2 red.)	93.84	95.06	89.33	92.75	92.99
M.Fe (Std NG red. + carb.)	91.31	91.10	90.10	89.95	90.75
%Metallization (Std H2 red.)	98.62	99.11	97.72	98.52	98.46
% Metallization (Std NG red. + carb.)	98.22	97.84	97.95	97.23	97.97
%RD (Std H2 red.)	98.92	99.29	98.02	98.91	98.77
%RD (Std NG red. + carb.)	98.53	98.23	98.03	97.80	97.97
%C (Std H2 red.)	0.03	0.04	0.06	0.02	0.03
%C (Std NG red. + carb.)	2.40	2.67	2.67	1.85	1.86

TABLE II. *Typical DR-grade oxide pellets characteristics*

Table II shows the chemical analysis of the five selected pellets in their initial oxide state after Standard H_2 reduction and after Standard NG reduction followed by carburization, respectively.

The reduction curves of the five oxide pellets that were reduced under Standard H_2 and Standard NG reduction conditions are shown in ***Figure 1A*** and ***Figure 1B.***

The reduction curves indicate that under the same reduction temperature (800°C), the reduction rate (i.e., for achieving a given reduction degree) was the fastest for the pellets reduced under the Standard H_2 reduction condition. We also observed that there was not much difference in the reduction behavior of the different oxide pellets when they were reduced under the Standard H_2 condition. On the other hand, the reduction rate varied among the different oxide pellets when they were subjected to Standard NG reduction condition. The reason for the different reduction behaviors between the oxide pellets and reduction conditions is not clear, as there are many factors that can affect the reduction curve of oxide pellet including pellet size distribution, iron oxide grain size distribution, size of pores, pores complexity inside the pellet, slag phase, bonding strength of oxide grains, and pelletizing temperature.

Apparent density and porosity comparison

Figure 2 and ***Figure 3 (following page)*** show the average apparent density and porosity of oxide pellets, H2-DRI, and carburized NG-DRI. There is no noticeable difference between the H2-DRI and NG-DRI.

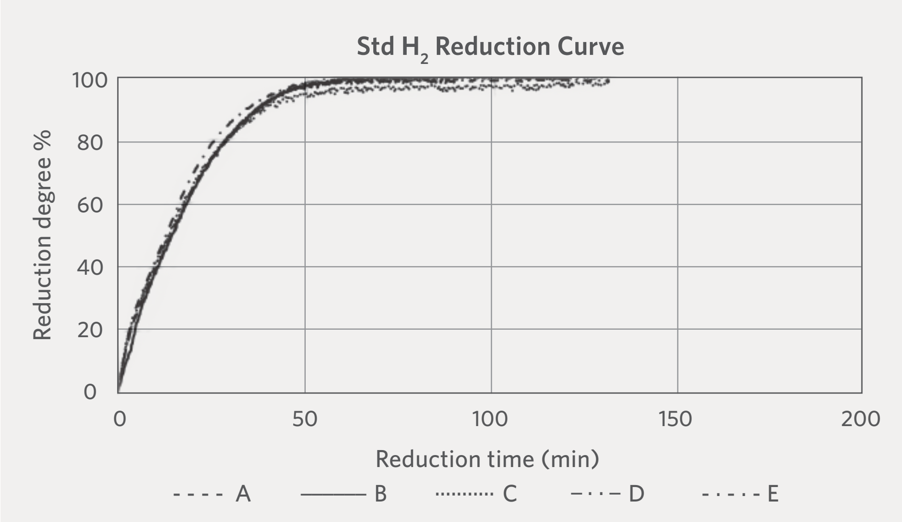

FIGURE 1A. *Reduction curves under Standard H_2 conditions at 800°C*

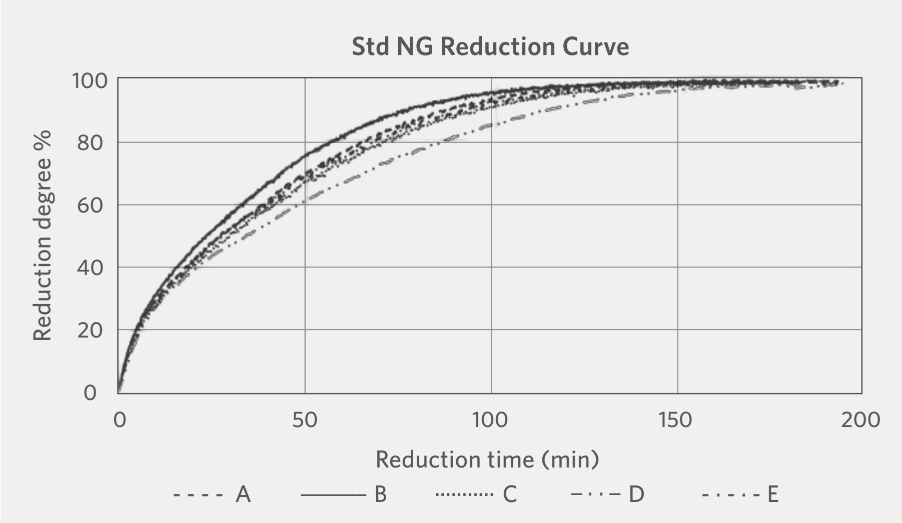

FIGURE 1B. *Reduction curves under Standard NG condition at 800°C*

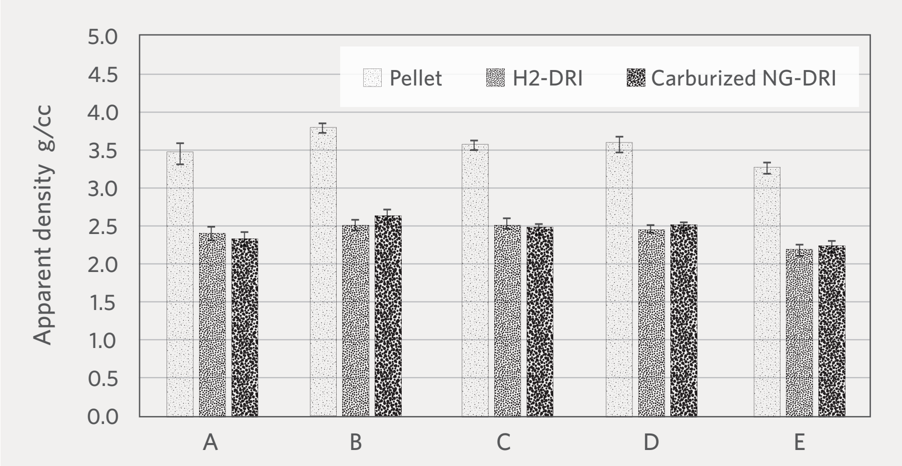

FIGURE 2. *Apparent density of oxide pellet, H2-DRI, and carburized NG-DRI*

Figure 4 shows the relationship between the porosity of oxide pellets and DRI. As can be seen in *Figure 4*, the porosity of DRI trends with the porosity of the respective oxide pellets and this suggests that the porosity change during the reduction process, or the final porosity of the reduced pellets, is mainly governed by the pre-reduced oxide pellets.

Volume expansion comparison

Figure 5 shows the volume expansion comparison between H2-DRI and carburized NG-DRI of each pellet brand. For all oxide pellet brands, hydrogen reduction produced comparable or smaller volume expansion than reformed natural gas reduction.

Cold Crushing Strength (CCS comparison)

Figure 6 (following page) shows the average CCS (kgf/ piece) of H2-DRI and NG-DRI. For all pellet brands, H2-DRI has slightly higher CCS than NG-DRI. Based on this result, we can expect CDRI produced from H_2 reduction to have less cracks or breakage during handling or transportation compared to NG-CDRI.

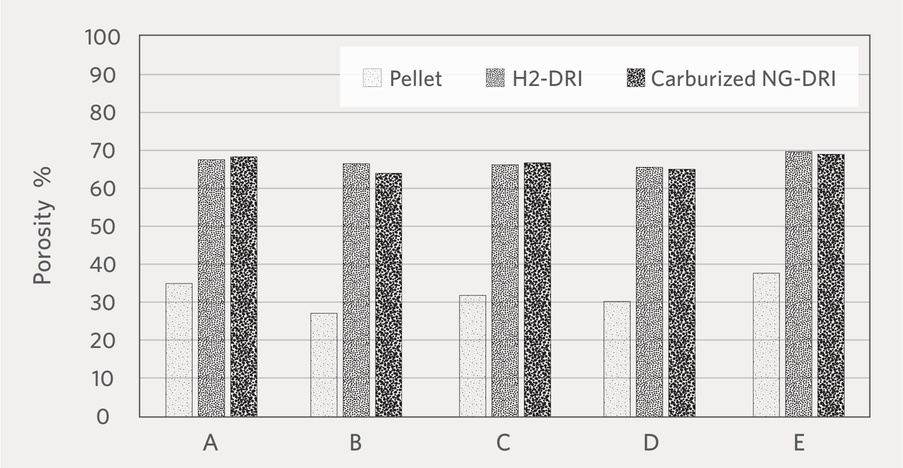

FIGURE 3. *Porosity of oxide pellet, H2-DRI and carburized NG-DRI*

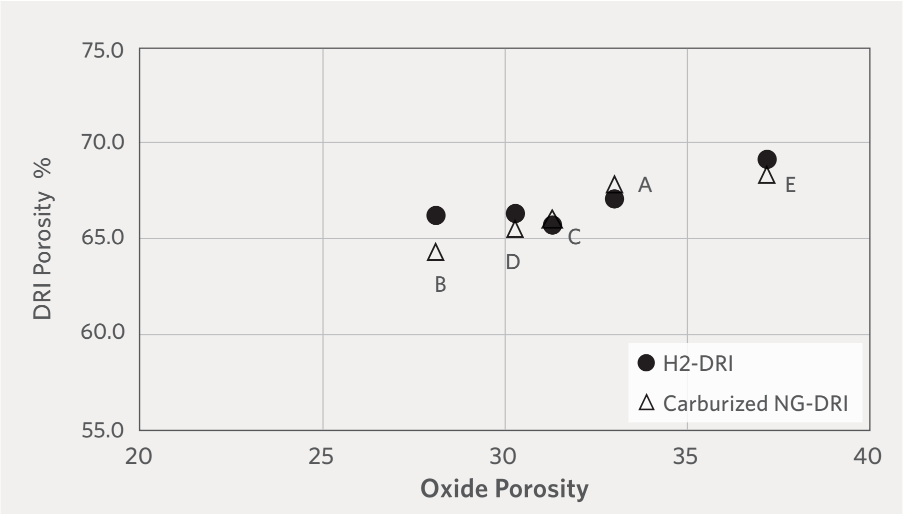

FIGURE 4. *Comparison between porosity of oxide pellet, H2-DRI and carburized NG-DRI*

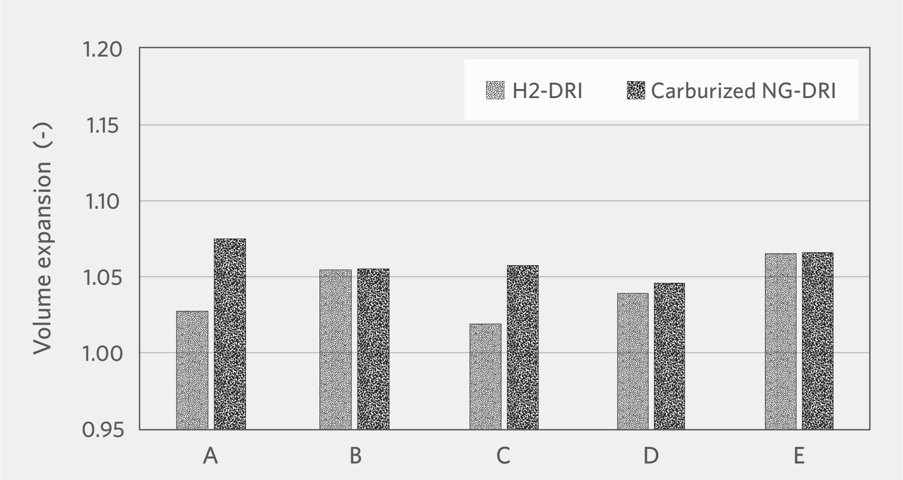

FIGURE 5. *Volume expansion comparison between H2-DRI and carburized NG-DRI*

Tumble Strength (CCS comparison)

Figure 7A and *Figure 7B* show the average weight ratio of fines at -3.35 mm and -1.0 mm generated H2-DRI and NG-DRI, respectively. For all the pellet brands, H2-DRI generated less fines compared to carburized NG-DRI. Based on this result, we can expect that cold H2-DRI would generate less fines during handling than NG-DRI. One possible reason for the higher fines generation by carburized NG-DRI could be that the Fe_3C (iron carbide) phase has less resistance to abrasion than metallic iron.

DISCUSSION

Effect of reduction gas composition on physical properties

To better understand the effect of H_2 reduction on the physical properties of DRI, the CCS and weight ratio of fines results were compared with respect to DRI porosity. *Figure 8A* and *Figure 8B (following page)* show the relationship between porosity and CCS of H2-DRI and carburized NG-DRI, respectively. The result shows that for a given porosity, the CCS of H2-DRI is stronger than carburized NG-DRI and the compression strength decreases with increasing porosity.

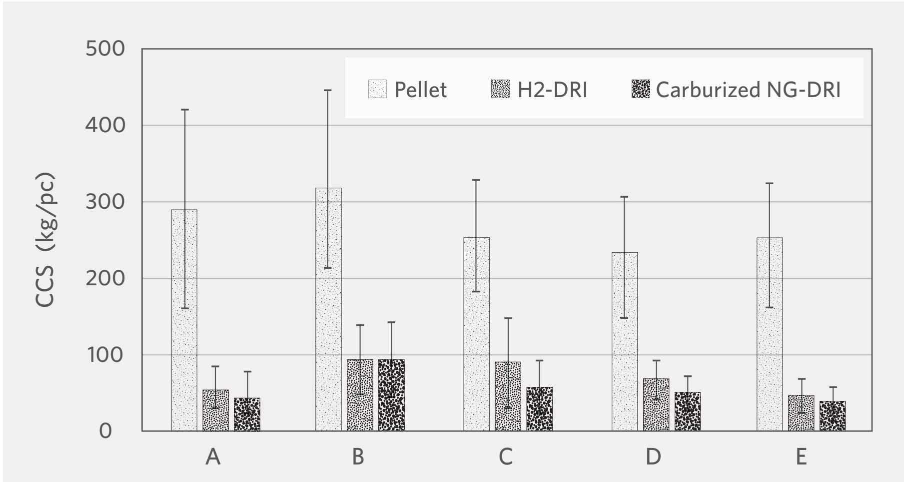

FIGURE 6. *CCS comparison between oxide pellet, H2-DRI and carburized NG-DRI*

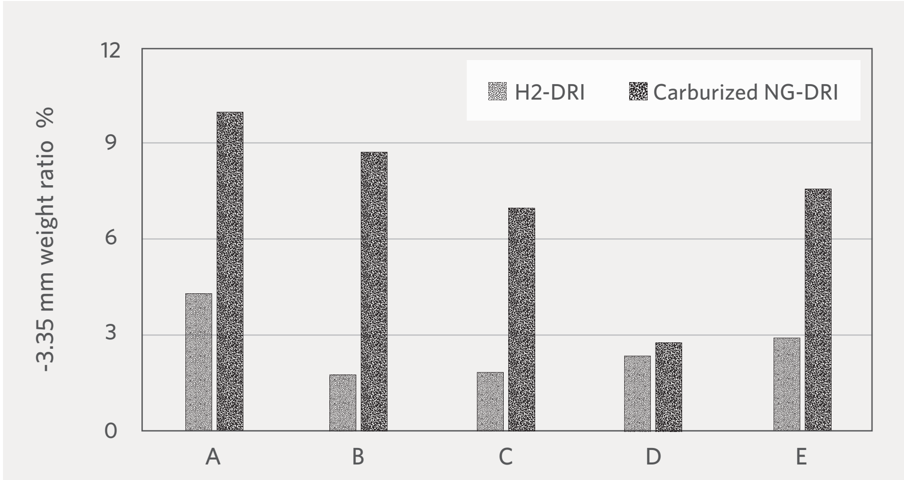

FIGURE 7A. *Weight ratio of -3.35 mm fines generated by H2-DRI and carburized NG-DRI*

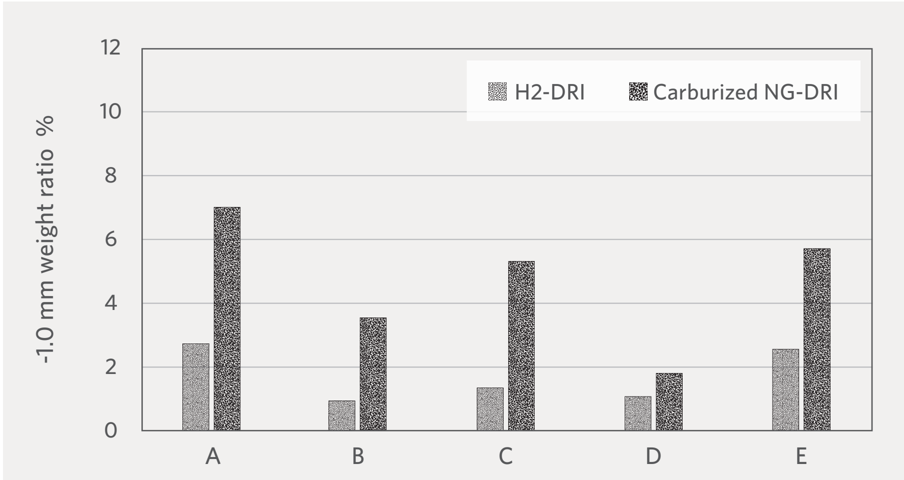

FIGURE 7B. *Weight ratio of -1.0 mm fines generated by H2-DRI and carburized NG-DRI*

Furthermore, ***Figure 9*** shows the relationship between porosity and fines generation of H2-DRI and carburized NG-DRI. Both conditions have exhibited linear relationship of fines generation over DRI porosity. However, H_2 reduction produced lower amount of fines generation than carburized NG-DRI.

Thus, we can conclude that hydrogen reduction allows higher strength and lower fines generation for CDRI than NG reduction with carburization. Among the different DR-grade pellet brands, oxide pellet porosity is key for determining CDRI physical properties.

CONCLUSIONS

A detailed study and comparison of physical properties of H2-DRI and carburized NG-DRI produced from five DR-grade oxide pellets was conducted. There was no apparent difference in apparent density, porosity, and CCS between H2-DRI and carburized NG-DRI. Fines generation by H_2 reduction is comparable or lower than that by NG reduction. Specifically, H_2 reduction had lower<1mm fines generation than NG reduction. CCS and fines generation correlated with DRI porosity. The descending order of pellet brands for DRI porosity is similar with that for oxide pellet porosity. Thus, oxide porosity is a key factor determining the physical properties of CDRI.

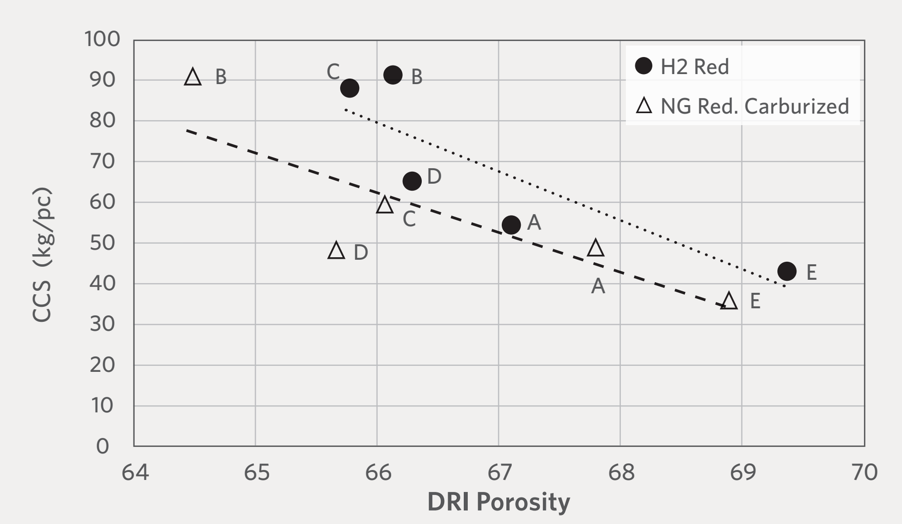

FIGURE 8A. *Relationship between porosity and CCS of H2-DRI and carburized NG-DRI*

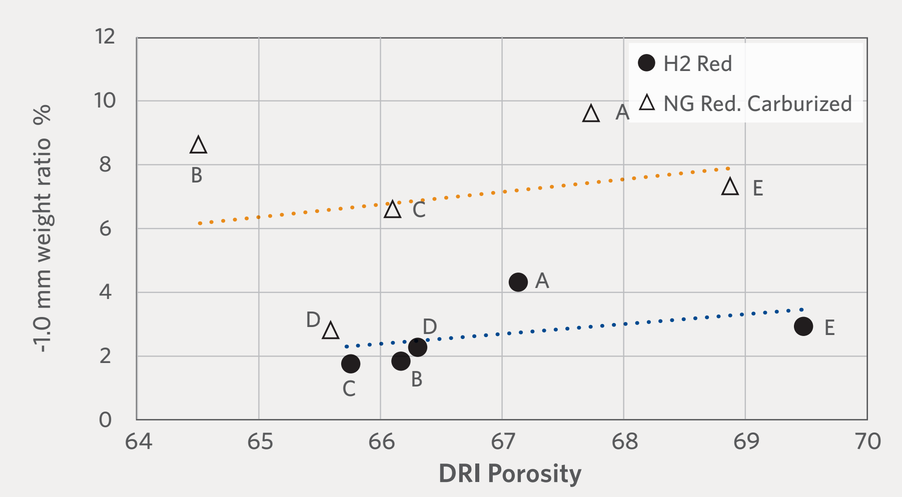

FIGURE 8B. *Relationship between fines generated and CCS of H2-DRI and carburized NG-DRI*

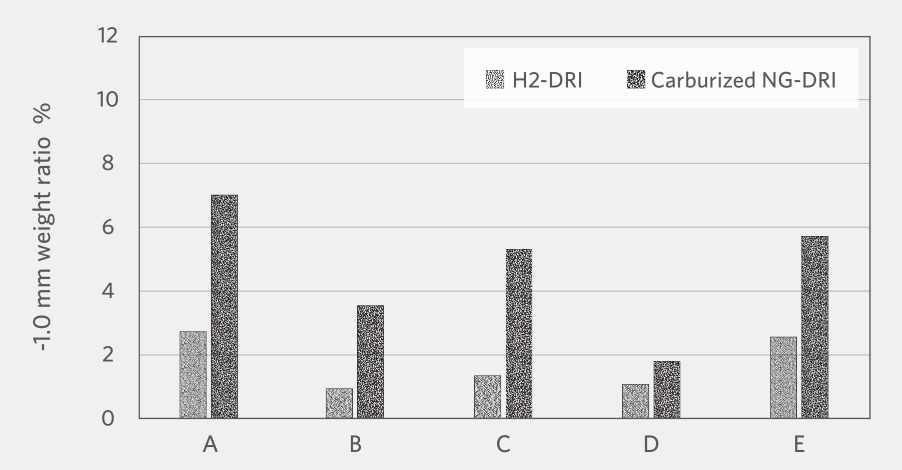

FIGURE 9. *Weight ratio of -1 mm fines generated by H2-DRI and carburized NG-DRI*

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1. Zhao, Z., Tang, J., Chu, M., Wang X., Zheng, A., Wang, X., Li, Y., Direct reduction swelling behavior of pellets in hydrogen-based shaft furnaces under typical atmospheres, International Journal of Minerals, Metallurgy and Materials, Vol. 29, 2022, pp. 1891-1900.

2. Mizutani, M., Nishimura, T., Orimoto, T., Higuchi, K., Nomura, S., Saito, K., Kasai, E., Influence of Reducing Gas Composition on Disintegration Behavior of Iron Ore Agglomerates, ISIJ International, Vol.57, 2017, pp. 1499-1508.

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This article was developed from the paper titled, "Comparison of the Morphology and Physical Properties of CDRI Following Hydrogen and Natural Gas-Based Reduction and Carburization," presented at *AISTech*, May 5-8, 2025, in Nashville, TN, USA, by Dr. Pei Yoong Koh of Midrex Technologies, Inc. and Dr. Kentaro Urata and Takayuki Koyama of Kobe Steel Limited.

MIDREX® Direct Reduction Plants

2024 OPERATIONS SUMMARY

Pictured: Algerian Qatari Steel (AQS)

MIDREX® Plants produced 76.284 million metric tons (Mt) of direct reduced iron (DRI) in 2024, which is 0.37% more than the 76.002 Mt produced in 2023. The total production for 2024 was calculated from the 37.943 Mt confirmed by plants located outside of Iran, Venezuela, and Russia plus the estimated 38.336 Mt for plants in Iran, Venezuela, and Russia based on data reported by the World Steel Association (WSA). Eleven Mt of the total DRI produced in 2024 by MIDREX Plants was hot DRI (HDRI), which were consumed in nearby steel shops to assist in reducing energy consumption per ton of steel produced and to increase steelmaking productivity.

MIDREX Plants have produced a cumulative total of more than 1.475 billion tons of all forms of DRI (cold DRI, CDRI; hot DRI, HDRI; and hot briquetted iron, HBI) through the end of 2024.

At least six MIDREX Modules* established new annual production records and at least four established new monthly production records. Thirteen additional modules came within 10% of their record annual production and 14 operated more than 8,000 hours.

The Venezuelan plants (COMSIGUA, Ferrominera Orinoco, Sidor, and Venprecar) operated during 2024 at reduced capacities, but most of their production details were not available. No detailed production information was received from the plants in Iran and Russia. The following plants did not operate in 2024 due to commercial or market conditions: ArcelorMittal South Africa, Delta Steel in Nigeria, ESISCO in Egypt, Lion DRI in Malaysia, NSCL National Steel Complex Ltd (formerly Tuwairqi Steel Mills) in Pakistan, and TT Iron Steel Company Ltd. (formerly AM Point Lisas) in Trinidad and Tobago.

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

2024 PLANT HIGHLIGHTS

ALGERIAN QATARI STEEL (AQS)

In its third full year of operation, AQS has produced over 6.3 million tons since its initial start-up in March 2021, and continued ramping up production to meet its steel shop's requirements. AQS set new annual production, productivity, natural gas, and electricity consumption records, and broke monthly production records twice in 2024. HDRI production was 65% of total production.

ANTARA STEEL MILLS

In its 40th anniversary year, the first MIDREX HBI Module set a new annual metallization record in 2024. Total iron in its HBI was the highest of all MIDREX Plants, averaging 92.3% for the year. All production was shipped by water to third parties.

ARCELORMITTAL ACINDAR

AM ACINDAR module operated the whole year below maximum capacity due to local market conditions in Argentina. AM ACINDAR has achieved the most production from a 5.5-meter MIDREX Shaft Furnace to date, with over 34.8 Mt of CDRI produced.

ARCELORMITTAL CANADA

Both modules operated above rated capacity and combined have produced over 45 Mt to date. Their combined production fell 5.6% short of equaling their all-time production record established in 2018. Module 2 set new annual natural gas and electricity consumption records and operated above 8,200 hours. The average total iron percentage for the year was the second highest of all MIDREX Plants at 92.07%.

ARCELORMITTAL HAMBURG

The longest-serving MIDREX Module (initial start-up in 1971) operated at reduced capacity, running only during the last five months of the year due to market conditions.

ARCELORMITTAL LÁZARO CARDENAS

AMLC's 6.5-meter reduction furnace has produced a total of 40.2 Mt of CDRI, the most by a single module to date. The plant operated above rated capacity and used almost exclusively oxide pellets made in its adjacent pellet plant during 2024.

Algerian Qatari Steel (AQS)

Antara Steel Mills

ArcelorMittal Acindar

ArcelorMittal Canada

ArcelorMittal Lazaro Cardenas

ArcelorMittal Hamburg

ARCELORMITTAL SOUTH AFRICA (SALDANHA WORKS)

This COREX® export gas-based MxCol® Plant was idled in January 2020, and has remained shut down throughout 2024.

ARCELORMITTAL TEXAS HBI

The ArcelorMittal Texas 2.0 Mt/y HBI module located near Corpus Christi, Texas, USA, established a new annual natural gas consumption record in 2024. In July 2022, ArcelorMittal completed the acquisition of an 80% stake in the HBI plant from voestalpine AG (Austria).

ARCELORMITTAL/NIPPON STEEL INDIA

All six modules combined have produced over 96.5 Mt of HDRI, HBI, and CDRI since start-up of the first two modules in 1990. In 2024, they were only 0.7% short of equaling their multi-module production record established in 2021. AM/NS India's Modules I, IV, V, and VI operated above rated capacity. Module I surpassed the 15 Mt mark and Module V surpassed the 20 Mt milestone. In the 20th anniversary year from its initial start-up, Module IV established new annual production, productivity, and operational time records and Modules V and VI established new annual operational time records in 2024. Modules IV, V, and VI operated an average of 8,162 hours in the year. More than 96% of the output from the four HDRI/HBI modules was in the form of HDRI. Modules I and VI produced CDRI exclusively. Modules V and VI operated using top gas fuel-to-VPSA for CO_2 removal, and COREX gas was used to fuel the reformer burners. COREX gas represented 20-21% of the energy input.

CLEVELAND-CLIFFS

In its fourth full year of operation, Cliffs has produced over 6.5 Mt since its initial start-up in December 2020. Cliffs operated over its annual rated capacity and produced just 4.1% less than its annual production record set in 2022. Cliffs set a new annual electricity consumption record in 2024. The 1.6 Mt/y plant located in Toledo, Ohio, USA, produces HBI, mainly for consumption by internal Cleveland-Cliffs steel companies in the region.

DELTA STEEL

The two modules in Nigeria did not operate in 2024.

ArcelorMittal Texas HBI

ArcelorMittal/Nippon Steel India

Cleveland-Cliffs

DRIC

Both of DRIC's modules in Dammam, Saudi Arabia, operated above rated capacity and combined have produced over 15 Mt to date. Total production in 2024 fell only 3.1% short of the record established in 2023. Module 1 set a new annual production and operational time records in 2024. The operational time was the second highest of all MIDREX Plants. Module 2 set a new annual productivity record in 2024.

ESISCO

After shutting down in early March 2020, Beshay Steel's MIDREX Plant remained shut down throughout 2024.

EZDK

Production was above rated capacity by all three modules, which combined have produced over 77.2 Mt to date. The average operational time for the three modules was 8,192 hours in 2024, and the average for the last two years was 8,209 hours. Modules 1 set a new annual electricity consumption record in 2024.

HADEED

The four MIDREX Modules at Hadeed in Saudi Arabia, surpassed the 113.7 Mt production milestone in 2024, and were within 6.4% of their multi-module annual production record set in 2013. Module C was shut down for major maintenance in May. Module E was within 2.9% of its annual production record. With over 29.4 Mt produced to date, Module E has attained the most production from a 7.0-meter MIDREX Shaft Furnace. Hadeed also owns an HYL plant (Module D).

JINDAL STEEL SOHAR (FORMERLY JINDAL SHADEED)

Jindal Steel Sohar established new annual production, productivity, natural gas consumption, and operational time records in 2024, and broke its monthly production record in March. Its annual operational time of 8,726 hours was the highest of all MIDREX Plants. Thanks to additional bin capacity, 95% of the HOTLINK® Plant's production in 2024 was consumed as HDRI in the steel shop, which is physically attached to the DR Plant. The single module plant, located in Sohar, Oman, is designed to produce mostly HDRI, with HBI as a secondary product stream.

DRIC

EZDK

Hadeed Modules

Jindal Steel Sohar

JSPL (ANGUL)

In its 10th anniversary year, the first MxCol® Plant using synthesis gas from coal gasifiers to produce both HDRI and CDRI for the adjacent steel shop produced just 0.5% shy of its 2021 production record and set new annual metallization, electricity consumption, and operational time records in 2024. HDRI production was 61% of total production. The MIDREX Plant continued to use supplemental coke oven gas (COG) throughout the year.

JSW STEEL (DOLVI)

In its 30th anniversary year, JSW Steel's CDRI module has produced over 35.8 Mt to date. Approximately 8% of the plant's energy input was COG injected into the shaft furnace to reduce NG consumption. JSW Steel (Dolvi) has averaged 8,040 hours of operation per year since its initial start-up in 1994, and 8,143 hours per year in the last nine years.

JSW STEEL (TORANAGALLU)

In its 10th anniversary year, JSW Steel's HDRI/CDRI module in Toranagallu, Karnataka State, India, using COREX export gas as energy input, operated on-average over 8,076 hours per year in the last four years, although limited by the availability of COREX export gas. Fifty six percent of production went to the steel shop as HDRI, with the balance being CDRI. This is the second plant of its kind, the first being ArcelorMittal's COREX/MIDREX plant at Saldanha, South Africa, which is presently shut down.

LION DRI

The Lion DRI module, located near Kuala Lumpur, Malaysia, remained shut down throughout 2024 due to competition from foreign steel products.

LISCO

In the 35th anniversary year since initial start-up of Module 1, the three MIDREX Modules of LISCO in Misurata, Libya, surpassed the combined production total of 36.7 Mt production and set new annual production records in 2024. Module 3, producing HBI mainly for export, surpassed the 10 Mt milestone and set new annual production, electricity consumption, and operational time records, as well as a new monthly production record in December. Module 2 produced CDRI to feed the LISCO steel shop and set a new operational time record in 2024.

JSPL (Angul)

JSW Steel (Dolvi)

JSW Steel (Toranagallu)

LISCO

NSCL (FORMERLY TUWAIRQI STEEL MILLS, LTD)

The 1.28 Mt/y combination plant, located near Karachi, Pakistan, did not operate in 2024. Ciena Group acquired the plant in April 2022, renaming it National Steel Complex Limited (NSCL).

NU-IRON

Nucor's module in Trinidad and Tobago reported production of 1.52 Mt of CDRI in 2024, surpassing the 25 Mt milestone since initial start-up. Average DRI metallization and carbon for the year was the highest of all MIDREX Plants at over 96.2% and 2.73%, respectively.

QATAR STEEL

Module 1 remained shut down for more than half of the year due to limited market demand. Module 2 operated an average of 8,112 hours for the last three years and produced over its annual rated capacity, supplying the adjacent steel mill in addition to producing CDRI and HBI for export in 2024. Qatar Steel's Module 1 has produced over 28.7 Mt of DRI since its initial start-up in 1978, the most for a 5.0-meter shaft furnace, and the average carbon percentage in 2024 was the second highest of all MIDREX Plants at 2.62%.

SIDOR

Only Sidor's Module 2B has been reported to have produced DRI in 2023. The other three modules remained shut down.

SULB

SULB's 1.5 Mt/y combination plant (simultaneous HDRI/CDRI production) in Bahrain, surpassed the 15 Mt milestone and operated an average of 8,243 hours in the last two years. Of the total production in 2024, 83% was consumed by the adjacent steel shop as HDRI and 17% was produced as CDRI to use in the steel shop, with the balance exported by sea.

TENARISSIDERCA

TenarisSiderca's CDRI module in Argentina operated the entire year to satisfy the DRI demand from its steel shop, with the customary shutdown in the cold month of July due to natural gas price. The module's average DRI metallization percentage for the year was the second highest of all MIDREX Plants at 95.6%.

Nu-Iron Unlimited

Qatar Steel Module 2

SULB

TenarisSiderca

TOSYALI ALGERIE

Tosyali's 2.5 Mt/year HDRI/CDRI, Module DRI-I), located in Bethioua, near Oran, Algeria, has achieved the most production from a 7.5-meter MIDREX Shaft Furnace to date. Over 73% of production went to the adjacent steel shop as HDRI. Tosyali Module DRI-II, began production in December 2024. Together with Algerian Qatari Steel (AQS), these are the largest capacity MIDREX Module built to date.

TT IRON STEEL COMPANY LTD. (FORMERLY ARCELORMITTAL POINT LISAS)

TT Iron Steel Company Limited ("TT Iron") signed a sales and purchase agreement with the liquidator of ArcelorMittal Point Lisas Ltd. to acquire the iron and steel plant in the Point Lisas Industrial Estate in June 2023. All three MIDREX Modules remained shut down throughout 2024.

VENPRECAR

VENPRECAR operated at minimum capacity as best possible due to a lack of raw materials and NG shutoffs.

Tosyali Module I and II

TT Iron Steel Company Ltd.

Midrex News & Views

The full news articles are available on **www.midrex.com**

JINDAL STEEL SOHAR – Driving Oman's Economic Diversification

IN 2017, **JINDAL STEEL SOHAR** BECAME THE THIRD FASTEST MIDREX PLANT TO SURPASS **10 MILLION TONS** OF PRODUCTION AND REACHED THE **20 MT** PRODUCTION MILESTONE IN 2023.

Oman has embraced steel production as the bridge to industrialization and diversification of its economy, and the Jindal Group is its partner in progress.

Strategically located in the industrial port of Sohar, Sultanate of Oman, Jindal Steel Sohar (formerly Jindal Shadeed Iron and Steel) is the largest privately-owned integrated steel producer in the Gulf Co-operation Council (GCC) region. Its range of steel products are sold worldwide under the brand name Jindal Panther, and Jindal Steel Sohar (JSS) can export hot briquetted iron (HBI) when the steel shop does not need hot DRI (HDRI).

Aside from the range and quality of its products and strategic location, the commitment of JSS to the growth of the national economy, protection of the environment, and the needs of the local communities are what set it apart. In 2023, the Jindal Group acquired Sohar Steel after it had been shut down for several years, restoring jobs and adding to Oman's steel exports. JSS is recognized as a pioneer in sustainability within the global steel industry by Det Norske Veritas (DNV) and Sustainalytics, and the company conducts continuing education programs and on-the-job training to further develop the skills of its employees while providing for the health and wellbeing of them and their families.

A History of Record-Setting Achievements

JSS has been setting records since it was established in 2010, when the Jindal Group acquired Shadeed Iron & Steel Company (aka Hamil Steel, subsidiary of Al-Gaith Holdings UAE) in July. The fledgling company commissioned its first production unit - a 1.5 million metric tons (tonnes) per year (Mt/y) MIDREX® Direct Reduction Plant - within four months and shipped its first HBI in December. This first-of-its-kind HOTLINK® Plant is designed for charging HDRI by gravity flow at 600-650° C to the adjacent electric arc furnace (EAF) melt shop and is equipped with briquetting machines to produce HBI as a secondary income source.

In 2017, JSS became the third fastest MIDREX Plant to surpass 10 million tons of production and reached the 20 Mt production milestone in 2023. Along the way, Midrex has assisted JSS in boost-

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JINDAL STEEL SOHAR COMPLEX **MILESTONES**

- **2010 JULY** – Jindal Group acquires Shadeed Iron & Steel Company; Jindal Shadeed Iron and Steel established
- **DEC** – 1.5 M t/y MIDREX HOTLINK Plant starts production; first HBI shipped
- **2011 DEC** – 4th briquetting machine added
- **2014 APR** – 2.0 M t/y EAF melt shop commissioned
- **2016 APR** – 1.4 M t/y rolling mill commissioned
- **2017** – 10 Mt cumulative DRI production
- **2018 SEP** – HOTLINK Plant upgraded to 1.8 M t/y
- **DEC** – 2nd caster commissioned, increasing steel capacity to 2.4 M t/y
- **2021 OCT** – 300 M t/y lime & dolomite plant commissioned
- **2023 AUG** – HOTLINK Plant upgraded to 1.92 M t/y – First phase
- 20 Mt cumulative DRI production; Jindal Group acquires Sohar Steel
- **2024** – 8,725+ operating hours (of 8,784 hours available); 1.95 Mt produced
- **2025 APR** – Jindal Shadeed Iron and Steel is rebranded to Jindal Steel Sohar

ing the plant's annual rated capacity from 1.5 Mt initially to 1.8 Mt in 2018, and completed the first phase in 2023 to achieve in a middle term capacity of 1.92 Mt. A further upgrade that will boost productivity rate to 240 t/h is planned and underway. However, by achieving extremely high plant availability, production rate, and operating hours, JSS was able to produce 1.952 Mt (primarily HDRI) in 2024.

Overall, 2024 was a banner year for JSS's HOTLINK Plant, setting numerous production records: annual (1.951+ Mt), monthly (169,646 t in March), and daily and hourly (5,610 t and 233.75 t, respectively, on 16 March), as well as operating hours (8,725+ of 8,784 available), a worldwide record for MIDREX Plants).

Jindal Steel Sohar HOTLINK Shaft Furnace (Height: 148 m)

JINDAL STEEL SOHAR
HDRI & HBI CHARACTERISTICS

CHEMICAL PROPERTIES (HDRI & HBI)

Fe Total:	87.9 %
Fe Metallic:	81.8 %
Metallization:	93%
Carbon:	1.9 %

PHYSICAL PROPERTIES (HBI)

Typical size:	110x50x30 mm
Bulk Density:	2.4-2.7 mt/m3
Apparent Density:	4.7 gm/cc min
Under-size (below 6.3 mm):	5% max
Typical weight per briquette:	0.63 kg

Midrex News & Views

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John Linklater and Matt Rea to Lead Midrex Global Solutions

David Durnovich Completes 40+ Year DR Industry Career

John Linklater and Matt Rea will head Midrex Global Solutions upon the recent retirement of Global Solutions Director David Durnovich. Midrex Global Solutions steps in after plant commissioning to offer continued support and services that help plants run efficiently and reliably. From the Midrex headquarters in Charlotte to the regional office in Dubai, they provide tailored technical support to optimize plant performance; spare parts, equipment upgrades, and field services; innovative engineering solutions to meet unique operational needs; and a direct, ongoing partnership with customers to help them achieve long-term success.

John Linklater
General Manager -
Midrex Global Solutions
Middle East & North Africa

John Linklater has over 30+ years of experience in operating and maintaining direct reduction and steel plants. He joined Midrex in 2007 as Lead Mechanical Engineer and has served as Chief of Mechanical Engineering and Services Program Manager - Global Solutions. Prior to joining Midrex, Linklater was a mechanical engineer for the Hadeed direct reduction plants in Al-Jubail, Saudi Arabia. He is registered in the United Kingdom as an Incorporated Engineer with a Graduateship from City and Guilds London.

Matt Rea
General Manager -
Midrex Global Solutions
Europe & Americas

Matt Rea brings a wealth of experience in direct reduction plant operations and management, as well as iron ore preparation. Rea joined Cleveland-Cliffs in 2008, at the Tilden Iron Ore Mine in Michigan and served in roles of increasing responsibility before being appointed General Manager – Toledo Direct Reduction Plant in January 2021.

Rea joined Midrex in 2024, after serving as Senior Division Manager Primary at Indiana Harbor, where he was responsible for blast furnace operations and two steel shops.

He has a degree in Chemical Engineering from James Cook University and a Graduate Diploma in Business Management from Monash University.

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David Durnovich began his direct reduction industry career more than 40 years ago in the Midrex Operations Department. In addition to playing a key management role in the start-up and operational success of the first MIDREX HBI Plant on Labuan Island, Sabah, Malaysia, in 1984, he served as Production General Manager of Operaciones al Sur del Orinoco (OPCO) in Venezuela, Chief Operations Officer of American Iron Reduction (AIR) in USA, Vice President Operations of ArcelorMittal Point Lisas in Trinidad and Tobago, and Vice President Operations of Lion Group in Malaysia. Prior to being appointed Director of Global Solutions in 2019, Durnovich was General Manager - Operations & Maintenance at Midrex.

MIDREX® Plant with 2nd Quarter Anniversary

We are proud to celebrate this notable milestone with our customer – **35 years** since initial start-up of **Libyan Iron and Steel Company (LISCO) Module 2** in Misurata, Libya.

LISCO Modules 1-3, *from front to rear*

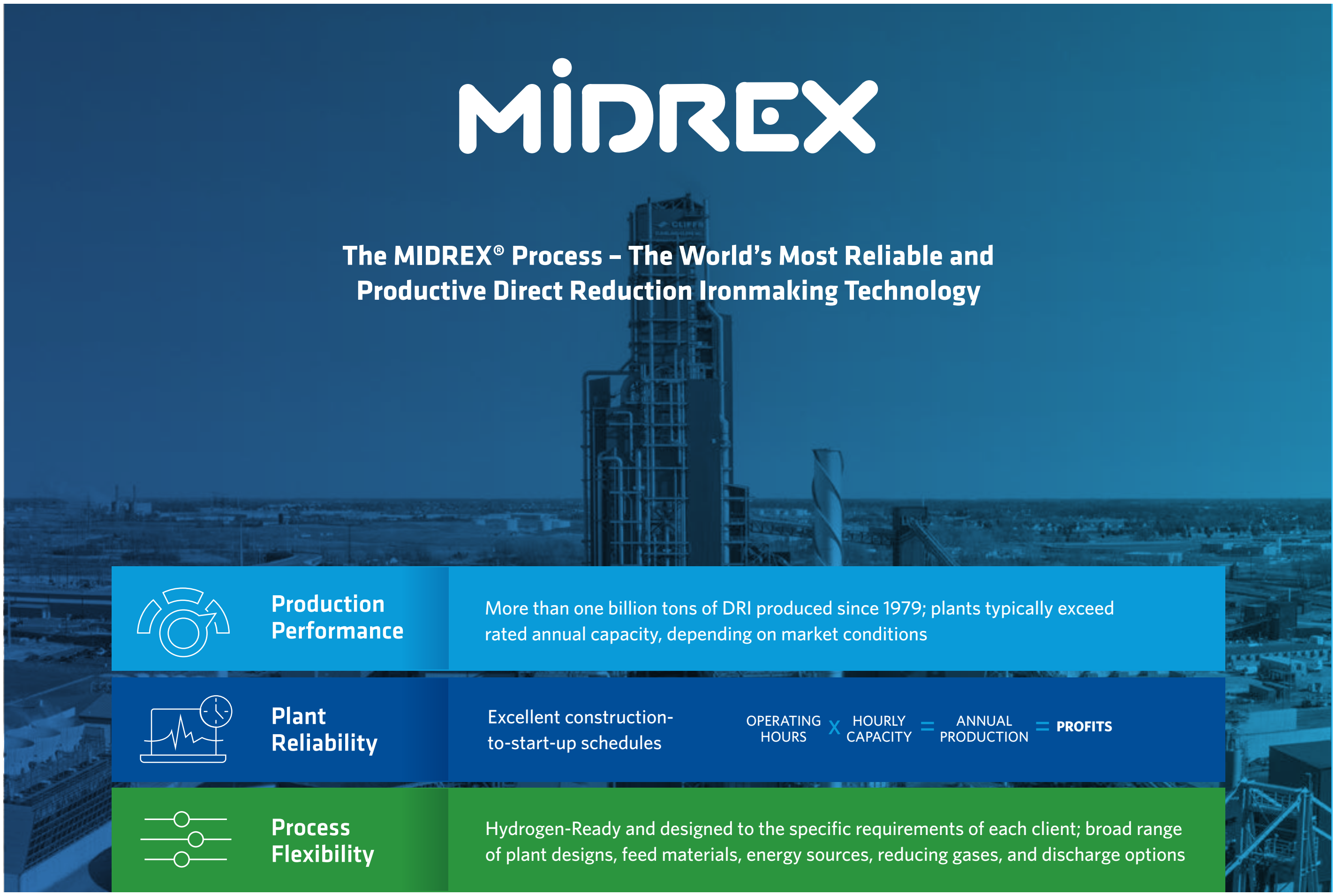
Libyan Iron and Steel Company (LISCO) Module 2

Location: Misurata, Libya
DR Plant: MIDREX

- **Start-up:** March 1990
- **Product:** CDRI
- **Rated Capacity:** 0.55 M t/y

Module 2 supplied CDRI to the LISCO steel mill in 2024, setting a monthly operational time record in December. The three MIDREX Modules (two CDRI, one HBI) have combined to produce 36.7 Mt, with Module 2 accounting for more than 13.3 of the total.

Read more about Libya Iron and Steel Company (LISCO) at: https://libyansteel.com



Lauren Lorraine: **Editor**

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