Flexibility of Direct Reduction Technology
The MIDREX® Way

PRESENTED BY
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STEEL SUCCESS STRATEGIES
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www.midrex.com
Innovation takes many forms, but true innovation leads to remarkable results...
True Innovation Must Stand the Test of Time

- Of the 67 MIDREX Plants built and started-up since 1969, only 3 have been dismantled and taken completely out of service
- 33 MIDREX Plants have been operating more than 20 years
- These are the measuring sticks for evaluating the results of our innovation
How do industrial plants remain competitive over time?

- Before making a technology selection consider the economics of longevity (i.e. performance history, annual availability, market flexibility, potential for technology improvement, etc).
- Begin with a solid foundation – for DR Plants that means the MIDREX® Process.
- Total dedication to continuous technology development.

Many of the oldest MIDREX Plants are producing annually at 2x original capacity as a result of ongoing technology development.
Midrex Technical Center

XRF/XRD

ICP-OES

Briquette Test Facility

RHF Simulator with melter
MIDREX® Process Flexibility

New Technologies
- MXCol®
- Thermal Reactor System
- SynRG™
- SuperMEGAMOD®
Midrex has broad design experience and plants currently operating with:
- CO\(_2\) Removal + Heater (using COREX offgas)
- MIDREX Reformer
- Steam Reformer

Experience producing DRI/HBI with reducing gas H\(_2\)/CO ratio ranging from 0.3 to 3.9

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Midrex Plant Reference</th>
<th>Reducing Gas Train</th>
<th>Reducing Gas H(_2)/CO</th>
<th>Start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corex offgas</td>
<td>Arcelor Mittal South Africa</td>
<td>CO(_2) Removal + Heater</td>
<td>0.3 to 0.4</td>
<td>1999</td>
</tr>
<tr>
<td>Corex offgas</td>
<td>JSW Projects Limited</td>
<td>CO(_2) Removal + Heater</td>
<td>0.5 to 0.6</td>
<td>construction</td>
</tr>
<tr>
<td>Coal Gasifier</td>
<td>JSPL Angul I</td>
<td>CO(_2) Removal + Heater</td>
<td>2.0</td>
<td>construction</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Numerous - 60 modules in operation</td>
<td>Midrex Reformer</td>
<td>1.5 to 1.7</td>
<td>since 1969</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>FMO (formerly OPCO)</td>
<td>Steam Reformer + Midrex Reformer</td>
<td>3.2 to 3.9</td>
<td>1990</td>
</tr>
</tbody>
</table>
COREX®/MIDREX® Plant
ArcelorMittal South Africa

- Midrex has the ONLY commercial scale shaft furnace technology that is using syngas derived from coal to produce DRI
- This plant has been successfully operating since 1999
- H₂/CO ratio ~0.4 which is the lowest of all DR Plants
- Consistently uses 70% lump ore (Sishen) in the feed mix
A breakthrough in Coal-Based Direct Reduction

What is MXCOL®? (pronounced “M X coal”)

- The name and trademark for the commercially proven MIDREX® Shaft Furnace technology that uses syngas derived from coal
- A technology that opens the door for Direct Reduction in markets (like China and India) where coal is abundant but natural gas is unavailable or very expensive

MXCOL® can receive syngas from many sources:

- **Gasifiers**: using high or low quality coals or other alternative fuels
- **Thermal Reactor System**: new technology using an innovative partial oxidation system
JSPL Angul I
World’s First DR Plant + Coal Gasifier

- Capacity: 1.8 Mt/y
- Energy Source: Coal (with 40% ash)
- Location: Angul, India
- Status: Under Construction
- Key Advantages: Uses indigenous iron ore and coal; no coke required
Midrex and Praxair have formed a strategic alliance to demonstrate and provide Thermal Reactor Systems and Facilities. This new Thermal Reactor System uses innovative partial oxidation technology to convert hydrocarbons (like COG) into high quality, high temperature syngas for Direct Reduction.
Integrated Mills can benefit from Direct Reduction technology by using:
- HBI to increase hot metal production in the BF
- DRI/HBI/HDRI as an alternative to scrap in the BOF

The MXCOL® plant can be fueled using COG from the integrated mill.

COG typically has high quantities of H2 and CH4—chemical energy that is great for making DRI (more valuable than electrical power generation).

The new Thermal Reactor System from Midrex and Praxair enables this COG to be converted into a high temperature syngas suitable for DR.
Using COG for Direct Reduction

Rough Conversions

1 ton Coke → 3 ton LS
1 ton Coke → 500 Nm³ COG
500 Nm³ COG → 1 ton DRI → 0.88 t LS (using DR grade pellets)

Key Points

- Using COG to produce DRI would increase liquid steel production by ~30%
- Product from the MIDREX DR Plant can be used in the BF, BOF, or an EAF
- This allows tremendous flexibility to adapt to numerous market conditions
The use of HBI in Blast Furnaces is not new
AK Steel began using HBI in their Middletown blast furnace in 1989
Blast furnaces in Canada, Western Europe and Japan have also begun using HBI
HBI is typically less than 30% of the charge
HBI is often used when additional hot metal is required
For each ten percent (10%) of the iron charged into the blast furnace as metallic iron:
- Productivity is increased by 8%
- Fuel rate is decreased by 7%
HBI also lowers the CO2 emissions per ton of hot metal produced
MIDREX® SynRG™ Reformer
The Next Generation

- Pronounced “synergy”
- The next generation MIDREX® Reformer with even better efficiency:
  - High Capacity: wider design
  - Larger Tubes: 10” to 11”
  - Higher Temperature Tubes: up to 1180°C
  - Higher Activity Catalyst
  - Lower NOx Burners: 80% less NOx
- This new Midrex Reformer can produce the same amount of syngas with about 80% of the original size
For new plants with capacities over 2,000,000 tons per year
Maximizes economy of scale
This new innovation has been in development for several years and represents extremely low risk due to reasonable scale-up factor and careful planning
A SuperMEGAMOD® with an annual production rate of 2,500,000 tons per year represents a 1.28 scale-up factor from the highest capacity MIDREX plant
World Record Annual Production: Hadeed Module E produced nearly 2,000,000 tons in 2011 from a single shaft furnace

Long term capacity is best evaluated by looking at annual production (not by using best month x 12) because plant availability must be taken into consideration

### Best Annual Capacity
Natural Gas Based – Shaft Furnace Technologies

<table>
<thead>
<tr>
<th>Technology Provider (discharge)</th>
<th>Plant</th>
<th>Location</th>
<th>Best Year</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIDREX (hot discharge)</td>
<td>Hadeed Module E</td>
<td>Saudi Arabia</td>
<td>2011</td>
<td>1,943,127</td>
</tr>
<tr>
<td>MIDREX (cold discharge)</td>
<td>ArcelorMittal Lazaro Cardenas</td>
<td>Mexico</td>
<td>2004</td>
<td>1,758,207</td>
</tr>
</tbody>
</table>
Plant Specifics
• Start-up: July 2007
• Rated Capacity: 1.76 Mt/y
• Products: CDRI/HDRI using hot ~100m long transport conveyor to EAF

Operations Summary
• 2011 production 1,943,127 tons
• Monthly record 179,870 t (2.15 Mtpy annualized)
• Typical operation:
  • 243 tph
  • 94.5 Met / 2.4% C

Primary HDRI Benefits in Meltshop compared to 100% CDRI
• HDRI Energy Savings: 110 kW/t
• Productivity Increase: 15-20%
**Key Points**

- MIDREX Plants located next to a steel mill (EAF) should charge HDRI to take advantage of sensible heat (500-650°C).
- Midrex offers three methods for hot charging.
- A second product stream from the DR Plant, either cold DRI or HBI, is required to maximize production in the event the steel mill cannot accept the HDRI.
MIDREX
Hot Charging Methods

HOTLINK®
(distances <40m)

Hot Transport Conveyor
(distances <200m)

Hot Transport Vessels
(distances >100m)

ESISCO (Egypt)
Others not shown:
Jindal Shadeed (Oman)

Hadeed Mod E (Saudi Arabia)
Others not shown:
JSPL Angul I (India)
SULB (Bahrain)
JSW (India)

Lion (Malaysia)
Others not shown:
Essar I-V (India)
Oxide consumption is critical to the OPEX of any DR Plant

In general, oxide consumption:
- decreases as metallization decreases, and
- decreases as carbon increases

There are a lot of comparative theories and misinformation about oxide consumption

The best way to compare oxide consumption is to evaluate data from a plant having both major DR technologies:
- Same owner/operator
- Same metallization/carbon targets
- Same boundary conditions

Midrex evaluated oxide consumption data from such a plant for a consecutive period of 18 months:
- Midrex Average: 1.426
- Competitor Average: 1.462
2012-2013 will be the busiest period for plant start-ups in the history of Midrex Technology Inc.
<table>
<thead>
<tr>
<th><strong>Furnace Type</strong></th>
<th>MIDREX MEGAMOD® (7.15 m I.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reformer</strong></td>
<td>19 Bays</td>
</tr>
<tr>
<td><strong>Products</strong></td>
<td>Hot DRI (0-100%) and/or</td>
</tr>
<tr>
<td></td>
<td>cold DRI (0-100%)</td>
</tr>
<tr>
<td><strong>Hot DRI Transport</strong></td>
<td>HOTLINK 2G</td>
</tr>
<tr>
<td><strong>Start-Up</strong></td>
<td>2012</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>1.76 million tpy Hot DRI &amp; CDRI</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Sadat City, Egypt</td>
</tr>
<tr>
<td>Furnace Type</td>
<td>MIDREX MEGAMOD® (6.65 m I.D.)</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Reformer</td>
<td>16 Bays</td>
</tr>
<tr>
<td>Products:</td>
<td>Cold DRI</td>
</tr>
<tr>
<td></td>
<td>(hot DRI future)</td>
</tr>
<tr>
<td>Hot DRI Transport</td>
<td>Future</td>
</tr>
<tr>
<td>Start-Up</td>
<td>2012</td>
</tr>
<tr>
<td>Capacity:</td>
<td>1.28 million tpy cold</td>
</tr>
<tr>
<td>Location:</td>
<td>Karachi, Pakistan</td>
</tr>
</tbody>
</table>
Furnace Type: MIDREX Hot Discharge (7.15 m I.D.)

Reducing gas: Coal Gasification

Gasifier: Lurgi

Products: Hot DRI (0-100%) and/or Cold DRI (0-100%)

Hot DRI Transport: Mechanical Conveyor

Start-Up: 2012

Capacity: 1.80 million tpy HDRI

Location: Angul, Odisha, India
Furnace Type: MIDREX Hot Discharge (7.15 m I.D.)

Reformer: 19 Bays

Products: Hot DRI (0-100%) and/or Cold DRI (0-100%)

Hot DRI Transport: Mechanical Conveyor

Start-Up: 2012

Capacity: 1.50 million tpy HDRI

Location: Bahrain
**Furnace Type:** MIDREX Hot Discharge (7.15 m I.D.)

**Reducing gas:** COREX export gas

**Products:** Hot DRI (0-100%) and/or Cold DRI (0-100%)

**Hot DRI Transport:** Mechanical Conveyor

**Start-Up:** 2013

**Capacity:** 1.20 million tpy HDRI/CDRI

**Location:** Toranagallu, Karnataka State, India
What’s Next for Midrex?

- 2012-2013 will be the busiest for plant start-ups in Midrex’s history
- Midrex Technologies has 9,340,000 tons of annual production to commission/start-up most of which will occur in 12-18 months
- That represents nearly 13% of the world’s DRI produced in 2011
- Demonstrate the new Thermal Reactor System with Praxair
- Continue innovating!

### New MIDREX Plants Since 2006 Operating or Under Engineering/Construction

<table>
<thead>
<tr>
<th>MIDREX® Plant</th>
<th>Location</th>
<th>Capacity (Mt/y)</th>
<th>Products</th>
<th>Start-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nu-Iron</td>
<td>Trinidad</td>
<td>1.60</td>
<td>DRI</td>
<td>2006</td>
</tr>
<tr>
<td>Al-Tuwairqi</td>
<td>Saudi Arabia</td>
<td>1.00</td>
<td>DRI</td>
<td>2007</td>
</tr>
<tr>
<td>Essar Module V</td>
<td>India</td>
<td>1.50</td>
<td>HDRI/HBI</td>
<td>2007</td>
</tr>
<tr>
<td>Hadeed Mod E</td>
<td>Saudi Arabia</td>
<td>1.76</td>
<td>HDRI/DRI</td>
<td>2007</td>
</tr>
<tr>
<td>Qatar Steel Module 2</td>
<td>Qatar</td>
<td>1.50</td>
<td>DRI/HBI</td>
<td>2007</td>
</tr>
<tr>
<td>LGOK Module 2</td>
<td>Russia</td>
<td>1.40</td>
<td>HBI</td>
<td>2007</td>
</tr>
<tr>
<td>Lion Group</td>
<td>Malaysia</td>
<td>1.54</td>
<td>HDRI/HBI</td>
<td>2008</td>
</tr>
<tr>
<td>Jindal Shadeed</td>
<td>Oman</td>
<td>1.50</td>
<td>HDRI/HBI</td>
<td>2011</td>
</tr>
<tr>
<td>Essar Module VI</td>
<td>India</td>
<td>1.50</td>
<td>HDRI/HBI</td>
<td>2011</td>
</tr>
<tr>
<td>ESISCO</td>
<td>Egypt</td>
<td>1.76</td>
<td>HDRI/DRI</td>
<td>construction</td>
</tr>
<tr>
<td>Tuwairqi Steel Mills</td>
<td>Pakistan</td>
<td>1.28</td>
<td>HDRI/DRI</td>
<td>construction</td>
</tr>
<tr>
<td>Jindal Steel &amp; Power</td>
<td>India</td>
<td>1.80</td>
<td>HDRI/DRI</td>
<td>construction</td>
</tr>
<tr>
<td>SULB</td>
<td>Bahrain</td>
<td>1.50</td>
<td>HDRI/DRI</td>
<td>construction</td>
</tr>
<tr>
<td>JSW Projects Ltd.</td>
<td>India</td>
<td>1.20</td>
<td>HDRI/DRI</td>
<td>construction</td>
</tr>
<tr>
<td>to be announced</td>
<td></td>
<td>1.80</td>
<td></td>
<td>Pre-contract</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>22.64</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Thank You