MIDREX ACT™
Achieving Higher Carbon in MIDREX® DRI Products
ENVIRONMENTAL ASSURANCE
Midrex Technologies, Inc. along with its parent company Kobe Steel, Ltd., recognizes the importance of protecting the environment and conserving natural resources. Through the years we have been proactive in increasing efficiency, productivity, reliability and safety while reducing the environmental impact of our processes.

MIDREX® Plants are designed to minimize water, noise and air pollution.

MIDREX® Plants meet applicable World Bank standards and more importantly, Midrex can and will provide DRI Plants designed to meet any local emissions or environmental standards regardless of location.
To meet the market interest in DRI products with a wider range of carbon content (from 0.5% and 4.5%), Midrex has introduced the new ACT™ (Adjustable Carbon Technology). This technology is now commercially available and can be added to new plants or retrofitted to existing MIDREX® Shaft Furnaces to increase carbon without lowering temperature.

Flexible Carbon
Electric arc furnace (EAF) steelmaking and direct reduced iron (DRI) have been closely associated for half a century. DRI products are used primarily in EAFs as supplementary iron units for the production of various steel products. Depending on the available metallic charge (scrap, hot metal, pig iron, etc.) and the steel product and grade being manufactured, carbon in the DRI can have a beneficial effect on EAF operation; however, the desired percentage of carbon will vary for each melt-shop.

The new ACT™ gives MIDREX® Plants even greater control over the range of carbon, allowing higher carbon content in the DRI without sacrificing temperature.
Carbon the MIDREX® Way

Challenged to develop technology which could adjust carbon content of DRI products while maintaining the product discharge temperature, the Midrex Research and Technology Development group developed the ACT™ concept. In the MIDREX® Shaft Furnace, carbon is added to DRI in three places (see Figure 1):

- **The reduction zone** – In the MIDREX® Process, the main purpose of the reduction zone is to metallize the iron to the desired product metallization using reductants CO and H₂ produced by the MIDREX® Reformer; some carbon is added in the reduction zone derived from CH₄ and CO. Carbon from CH₄ is endothermic (i.e., consumes heat), while carbon from CO is exothermic (i.e., liberates heat).

- **The transition zone** – A controlled flow of transition zone natural gas is added, which is the main method of adding and controlling the amount of carbon in MIDREX® DRI Products. The natural gas feedstock to MIDREX® Plants contains hydrocarbons, mostly methane, and using methane as an example, the carbon comes by:

\[
\begin{align*}
3\text{Fe} + \text{CH}_4 &\rightarrow \text{Fe}_3\text{C} + 2\text{H}_2 \quad \text{(endothermic)} \\
\text{CH}_4 &\rightarrow \text{C} + 2\text{H}_2 \quad \text{(endothermic)}
\end{align*}
\]

These carbon-forming reactions are endothermic and cool the DRI, it makes it desirable for plants producing CDRI but not necessarily so for plants producing HDRI or HBI.

- **The cooling zone** – MIDREX® Plants that have a cold discharge furnace use cooling gas to cool the DRI. The cooling gas contains hydrocarbons and carbon is added in a similar manner as in the transition zone.
WITH AN ACT™ BOOST

With the MIDREX ACT™, carbon monoxide (CO), made in the MIDREX® Refomer, is added to the transition zone in the form of a CO-rich gas stream. The CO contacts the DRI bed and the resulting exothermic reactions provide extra energy:

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\begin{align*}
3\text{Fe} + \text{CO} + \text{H}_2 & \rightarrow \text{Fe}_3\text{C} + \text{H}_2\text{O} & \text{(exothermic)} \\
3\text{Fe} + 2\text{CO} & \rightarrow \text{Fe}_3\text{C} + \text{CO}_2 & \text{(exothermic)} \\
\text{CO} + \text{H}_2 & \rightarrow \text{C} + \text{H}_2\text{O} & \text{(exothermic)} \\
2\text{CO} & \rightarrow \text{C} + \text{CO}_2 & \text{(exothermic)}
\end{align*}
\]

Transition zone natural gas is added along with the CO-rich stream, using the CO-generated energy to provide the energy to produce additional carbon without sacrificing temperature:

\[
\begin{align*}
3\text{Fe} + \text{CH}_4 & \rightarrow \text{Fe}_3\text{C} + 2\text{H}_2 & \text{(endothermic)} \\
\text{CH}_4 & \rightarrow \text{C} + 2\text{H}_2 & \text{(endothermic)}
\end{align*}
\]

By adjusting the amount of CO in the transition zone, the plant operator can adjust the amount of energy added to the HDRI. Adjusting the natural gas addition will control the carbon content of the DRI. Using these simple principles, this technology allows for independent control of the temperature increase and amount of carbon added.

WHAT CARBON IS RIGHT FOR YOU?

Based on the individual needs of their steelmaking operation or the merchant metallic markets they serve, MIDREX® Plants have different operational requirements and goals. The MIDREX ACT™ will enable MIDREX® Plants to produce cold DRI (CDRI), hot briquetted iron (HBI) or hot DRI (HDRI) with higher carbon content while maintaining a consistent discharge temperature. 85-90% of the carbon created by the MIDREX ACT™ will be in the form of iron carbide (Fe₃C).

The MIDREX ACT™ increases product flexibility of existing or new MIDREX® Plants by providing an independent means to increase the carbon level of the DRI products or to increase the discharge temperature at a given carbon level. For applications where higher carbon is desired, the amount of carbon added is controllable and the DRI discharge temperature is maintained.

WITH THE MIDREX ACT™, A MIDREX® PLANT WILL HAVE THE ABILITY TO:

- Produce CDRI with higher carbon content.
- Produce HDRI with either higher carbon or at higher temperature or both.
- Produce HBI with higher carbon content without detrimental loss of temperature at the briquetting machine or increasing briquetting temperature at a given carbon content.
- Merchant plants (CDRI and HBI) can tailor their product chemistry and produce a value-added product to the specifications of their end users.
- Flexibility to chose to operate with the MIDREX ACT™ when higher carbon levels are desired or to operate without the MIDREX ACT™ when lower carbon levels are desired.

The MIDREX ACT™ is designed for retrofitting into existing plants, as well as installing in new plants. The equipment used in the technology is well proven, and the design is of the same robust nature as all MIDREX® Technology solutions.
ACT™ DESIGN FEATURES


REFORMED GAS COOLER
All new MIDREX® Plants (and most existing ones) have a reformed gas cooler, which is used to control bustle gas temperature during plant start-up and occasionally during normal operation. There, a relatively small stream (typically about 10% of the reformed gas flow) of cooled reformed gas diverted to the MIDREX ACT™.

MIST ELIMINATOR
The cooled reformed gas is then sent to a mist eliminator, which is similar in design to ones already used in MIDREX® Plants, to remove excessive water and protect subsequent equipment.

FIGURE 2. Simplified ACT™ Flowsheet
**GAS COMPRESSOR**
The gas is then compressed to approximately 14 barg. This pressure is needed for the downstream membrane unit.

**GAS COOLER**
The gas from the compressor is hotter than needed for the downstream membrane unit, so it is cooled by a syngas aftercooler and the mist is removed by a mist eliminator, similar to equipment already used by Midrex.

**MEMBRANE SEPARATOR UNIT**
The gas, having been suitably compressed and cooled, enters the membrane unit. This technology, which is used in gas separation industries, employs a pressure difference to selectively allow some of the gas components in the feed stream to permeate across a membrane, separating the feed into two product streams. In this case, a CO-rich stream and a H₂-rich stream are produced. The CO-rich stream is sent to the transition zone, where the exothermic reactions generate heat (and some carbon deposition) and the endothermic reactions deposit carbon. The H₂ rich stream (i.e., the low-pressure stream from the membrane unit) is recycled to the discharge of the process gas compressors. The gas entering the membranes is cleaned and suitably conditioned within the membrane system, the features of which have been tailored for the MIDREX® Process.

**CONTROLS AND LOGIC**
The amount of carbon added to the MIDREX® DRI Products is adjusted by the flowrate of gas to the membrane unit (affecting mostly temperature) and the flowrate of transition zone natural gas (affecting mostly carburization), which provides operators an independent control loop for carbon and temperature.

The necessary engineering was performed for piping, controls, instrumentation, gas composition measurements, isolation and control logic for normal operation, start-up, shutdown and isolation of the MIDREX ACT™.

**UTILITIES**
The MIDREX ACT™ has the following utilities requirements:

- **Electricity** – Electrical consumption for the MIDREX Plant will increase approximately 20 kWh/ton of DRI due mainly to the compressor and the electric heater in the membrane unit.
- **Cooling water** – Machinery cooling water is needed for compressor cooling and the syngas aftercooler.
- **Nitrogen** – A small amount of nitrogen is needed intermittently for system purging.
- **Instrument Air** – A small amount of instrument air is needed for control valves.

**MIDREX ACT™ BENEFITS**

- Can be used in every type of MIDREX® Plant (CDRI, HDRI, HBI or a combination)
- Allows amount of carbon in DRI to be adjusted up or down
- Carbon can be added without cooling the DRI
- 85-90% of the carbon in the DRI products will be in the form of iron carbide (Fe₃C)
- Can be retrofitted into existing MIDREX® Plants, as well as included in new MIDREX® Plants
- Can be turned on and off to suit the desired carbon level without disrupting plant operation (i.e., MIDREX® Process can operate with or without it)