

MXCōL[®]

Using Syngas to make DRI
in the MIDREX[®] Process

MIDREX

Designed for Today,
Engineered for Tomorrow[™]



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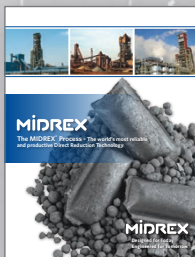
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ENVIRONMENTAL ASSURANCE

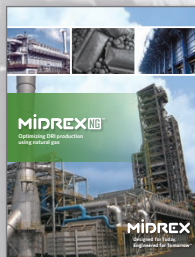
Midrex Technologies, Inc. along with its parent company Kobe Steel, Ltd., recognizes the importance of protecting the environment and conserving natural resources. Through the years we have been proactive in increasing efficiency, productivity, reliability and safety while reducing the environmental impact of our processes.

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

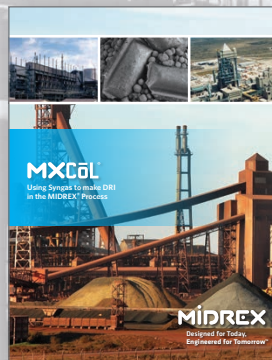
MIDREX® Plants meet applicable World Bank standards and more importantly, Midrex can and will provide DRI Plants designed to meet any local emissions or environmental standards regardless of location.



MIDREX® Process



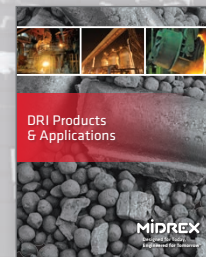
MIDREX NG™



MXCOL®



Building DRI Plants



DRI Products & Applications

DIRECT REDUCTION USING COAL

MXCOL® (PRONOUNCED “M-X-COAL”) IS THE NAME AND TRADEMARK FOR THE USE OF SYNGAS DERIVED FROM COAL IN THE COMMERCIALY PROVEN MIDREX® DIRECT REDUCTION PROCESS.

Syngas, or synthesis gas, is a gas mixture consisting of hydrogen, carbon monoxide and carbon dioxide resulting from the gasification of a carbon-containing fuel. Midrex commercially offers technology utilizing syngas derived from natural gas and coal sources. These technologies include: MXCOL®, COREX® / MXCOL® and the new MIDREX® Thermal Reactor System™ (TRS®).

MXCOL® can use reducing gas from several sources of syngas: commercial gasifiers using a variety of low cost fuels, export gas from the coal-based COREX® Hot Metal Process by Siemens VAI Metals Technologies GmbH, and the innovative MIDREX® Thermal Reactor System™ (TRS®).

The first commercial application of MIDREX® Technology using syngas from coal was commissioned in 1999 at ArcelorMittal Steel South Africa (formerly Saldanha Steel).

Here the export gas from a COREX® Plant is used in a MIDREX® Shaft Furnace to supply DRI to the meltshop in addition to the hot metal from the COREX® Plant.

Jindal Steel & Power Limited (JSPL) has built the first MIDREX® Direct Reduction Plant based on commercially available coal gasification technology in Angul, Odisha, India. The plant will use indigenous coal and iron ore to produce both hot and cold direct reduced iron (DRI) for use in an adjacent meltshop.

The Thermal Reactor System™ (TRS®) uses a new partial oxidation technology to convert hydrocarbon fuels into high quality, high temperature syngas suitable for DRI production. The TRS® will allow the production of DRI with a variety of fuels, including coke oven gas.



COKE OVEN GAS (COG)

COKE OVENS GENERATE AN OFFGAS CONTAINING HYDROGEN AND CARBON MONOXIDE. THIS GAS CAN BE USED FOR FEEDSTOCK FOR CHEMICAL PRODUCTION, HEATING APPLICATIONS AND ELECTRICITY GENERATION; HOWEVER, THE CHEMICAL ENERGY OF COG CAN MOST EFFICIENTLY BE USED BY STEEL-MAKERS TO CREATE ADDITIONAL IRON UNITS.

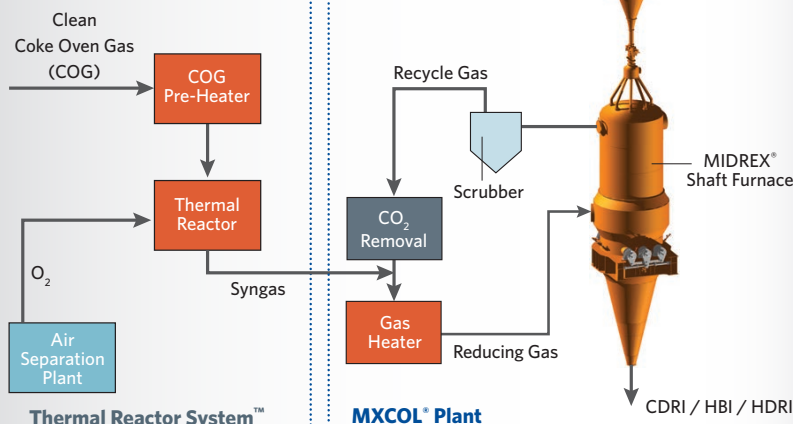
MIDREX® THERMAL REACTOR SYSTEM™ (TRS®)

Midrex and Praxair have partnered to develop the Thermal Reactor System™ (TRS®) technology that will reform COG for use in a MIDREX® Shaft Furnace. The TRS® reforms the cyclic and long chain hydrocarbons to make the resulting exhaust gas into a usable and efficient reducing gas.

Midrex has created two options for utilizing COG via the TRS® for DRI production. The first option uses and recycles COG for situations where the COG can be specifically allocated for DRI production. The second option - the "Once-Thru" flowsheet - allows clients to utilize some of the fuel value of their COG for other purposes while still enabling COG to be utilized for DRI production.

MXCOL® COG RECYCLE

MIDREX PRAXAIR



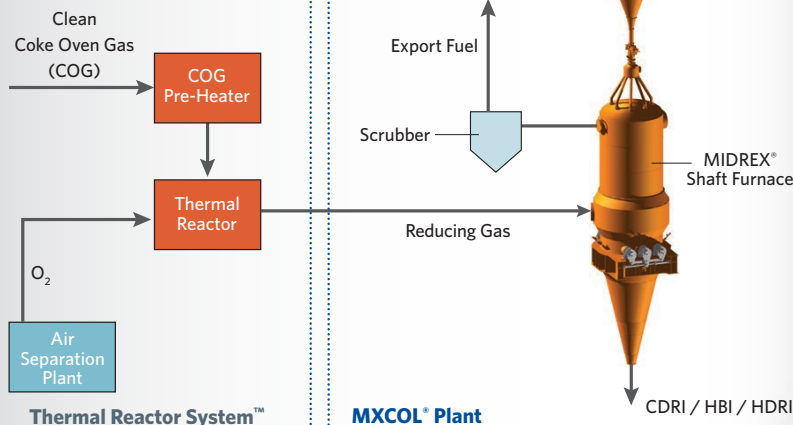
JSW DOLVI WORKS



JSW Steel Ltd. and Midrex are modifying the existing MIDREX® Direct Reduction Plant at JSW's steelworks in Dolvi, Maharashtra, India, to be the first to use coke oven gas (COG) as a supplement to natural gas for DRI production. This feature will provide the flexibility to operate the plant efficiently under a wide range of parameters.

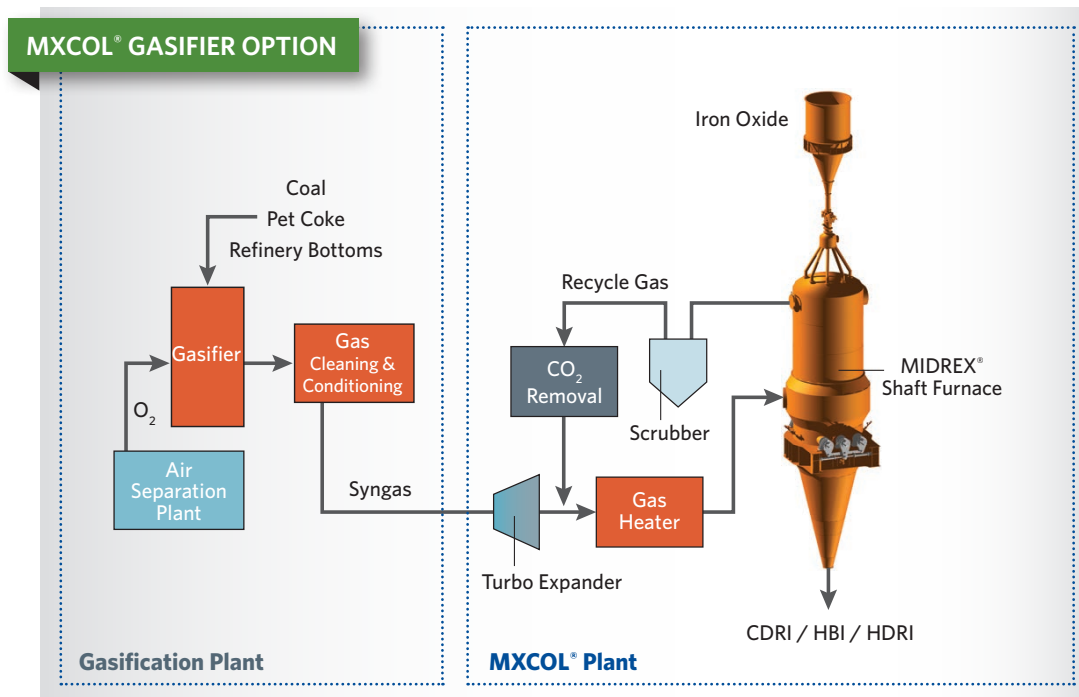
MXCOL® COG ONCE-THRU

MIDREX PRAXAIR



COMMERCIAL GASIFICATION

GASIFICATION REFERS TO THE REACTION OF COAL OR OTHER SOLID OR LIQUID CARBONACEOUS FEED-STOCK WITH OXYGEN TO PRODUCE A SYNTHESIS GAS (SYNGAS). THE ADVANTAGE OF GASIFICATION IS THAT USING THE SYNGAS IS POTENTIALLY MORE EFFICIENT THAN DIRECT COMBUSTION OF THE ORIGINAL FUEL. SYNGAS MAY BE USED TO GENERATE A HIGH QUALITY REDUCING GAS FOR PRODUCTION OF DRI.



MXCOL® GASIFIER SYNGAS SOLUTION

Commercially available gasification technology can be paired with a MIDREX® Shaft Furnace to produce any form of DRI (cold DRI, hot DRI, or HBI). The gasification syngas option includes gas-cleaning and conditioning systems, which prepare the syngas for reheating to the ideal temperature for use as reducing gas. The offgas from the reduction furnace is mixed with fresh syngas after scrubbing and CO₂ removal, reheated and recycled to the furnace.

A very high quality syngas can be produced by gasification technology regardless of the quality of the fuel. This allows for use of various bituminous and sub-bituminous coals, lignite, pet coke and petroleum refinery bottoms. In cases where natural gas availability is uncertain or when energy costs rise, the gasification syngas option can provide a beneficial alternative.

JINDAL STEEL & POWER LTD.



Gasification technology supplied by Lurgi GmbH is being used to generate syngas for the 1.8 million ton per year MIDREX® Direct Reduction Plant at Jindal Steel & Power Limited's steelworks. The gasifier will use indigenous coals and the MIDREX® Shaft Furnace will operate with local iron ore.

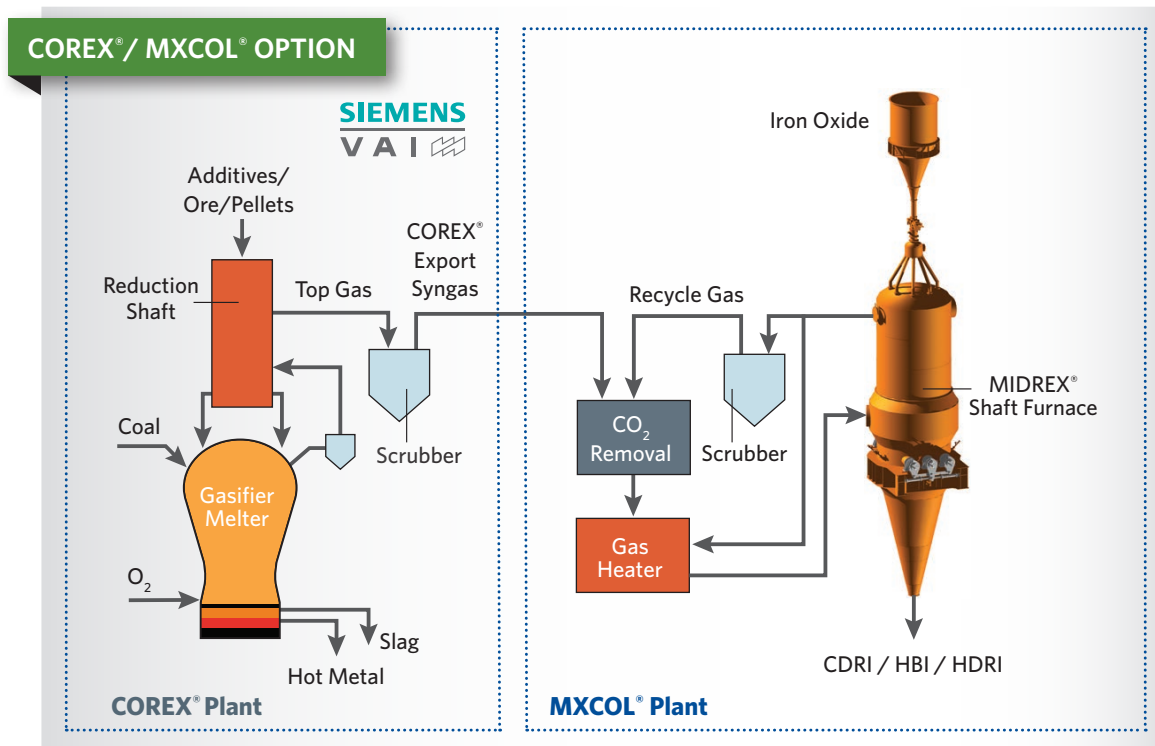
COREX® EXPORT GAS

THE APPLICATION OF EXPORT GAS FROM THE COREX® HOT METAL PROCESS AS REDUCING GAS FOR THE PRODUCTION OF DRI IN A MIDREX® SHAFT FURNACE HAS BEEN AN OPERATIONAL REALITY SINCE 1999.

COREX® OFFGAS

An MXCOL® Plant based on the use of COREX® export gas is capable of providing blast furnace-grade hot metal and high quality DRI. The COREX® Plant uses a melter/gasifier to simultaneously produce hot metal and export syngas. After scrubbing and CO₂ removal, the reductants-to-oxidants ratio of the COREX® export syngas is boosted to greater than 10. The prepared syngas is then heated to the target reduction temperature and introduced into the MIDREX® Shaft Furnace. The export gas from the MIDREX® Shaft Furnace is mixed with fresh COREX® export syngas after scrubbing and CO₂ removal, reheated and recycled to the furnace.

Benefits of the MXCOL® Flowsheet using COREX export gas over the coke oven-blast furnace route include lower environmental impact and improved economies of scale.



ARCELORMITTAL SOUTH AFRICA



In addition to the COREX® / MXCOL® Plant in Saldanha Bay South Africa, a second such plant has been constructed for JSW Steel, Ltd. in India.



ADVANCED TECHNOLOGY DEVELOPMENT

MIDREX HAS BEEN AT THE FOREFRONT OF DRI TECHNOLOGY DEVELOPMENT FOR MORE THAN 40 YEARS. MUCH OF THE COMPANY'S RESEARCH AND DEVELOPMENT HAS BEEN FOCUSED ON COMMERCIAL TECHNOLOGY SOLUTIONS TO PRODUCE DRI UTILIZING VARIOUS FUEL SOURCES INCLUDING NATURAL GAS, COAL, COG AND PROCESS SYNGAS.

Midrex has been steadfast in its mission to expand the direct reduction industry to embrace fuel sources other than natural gas. Since the commissioning in 1999 of the first **MIDREX® Shaft Furnace** to use a syngas derived from coal as reducing gas, Midrex is the only technology supplier to have commercial-scale DRI reduction furnaces in operation that use syngas derived from coal to make DRI.

Midrex has joined with leading companies in their fields including Siemens VAI Metals Technologies GmbH, Paul Wurth S.A., Lurgi GmbH, Synthesis Energy Systems, Inc. and Praxair, Inc. to identify and develop innovative solutions for generating and using syngas to use as reducing gas for direct reduction.

Midrex is involved in multiple projects based on syngas produced by a coal gasifier, a **COREX® Plant** or from the off gas of a coke oven to supplement natural gas. These include JSPL Angul I – the world's first DRI Plant paired with a coal gasifier located in Angul, Odisha, India. JSW Projects Ltd., a group company of JSW Steel Ltd., has built another **COREX®/MIDREX® Plant** featuring multiple discharge options. This new facility is at JSW Steel Ltd., located in Toranagallu, Karnataka, India. Lastly, JSW Dolvi is modifying their existing **MIDREX® Plant** to utilize coke oven gas (COG) to supplement its natural gas supply. The plant is located at the JSW-Dolvi Works (formerly JSW Ispat, Ltd.) Dolvi, Maharashtra, India.

In addition, a large-scale demonstration facility at the Midrex Technology Center has been operated for more than 1000 hours to prepare the **Thermal Reactor System™ (TRS®)** for commercialization by Midrex and Praxair.

The benefits of direct reduction, which were once available only to those with abundant sources of cheap natural gas, are now fueling a new paradigm in global steelmaking.

JSPL ANGUL



The world's first DRI Plant with coal gasifier at JSPL Angul I, India began operation in 2014.



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