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Alternative Energy Sources, CO_2 Recovery Technology and Clean Environment Compliance – Integral Components of Energiron Technology

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The alliance between HYL Technologies, Techint/Tenova and Danieli brings a new brand - ENERGIRON - to the forefront of the direct reduction industry. Current environmental regulations not only in the EU but worldwide bring more stringent demands to the design of industrial plant operations of all types. ENERGIRON technology is characterized by its flexible process configuration which is able to satisfy and exceed these requirements. In regions where either the high cost or low availability of natural gas work against this traditional energy source, the process is easily configured to operate using coke oven gas, syngas from coal synthesizers and other hydrocarbon sources. More importantly, the air and water effluents of the process are not only low but easily controlled.

Incorporation of selective CO2 removal systems has been a key factor over the past decade in reducing significantly the emissions levels, providing an additional source of revenue for the plant operator via the captured CO2. The high pressure operation and closed system of an ENERGIRON plant combined with the HYTEMP Pneumatic Transport System reduces dust emissions to both air and settling tanks, making the process more economical and environmentally friendly. This paper will review the design configuration and economic impact of these green technologies.

Introduction

The modern direct reduction industry began with HYL more than fifty years ago. Since then, HYL has always been at the forefront with technological innovations, geared towards improving the bottom line for steelmakers. To the end of 2006, HYL plants have produced close to two hundred million tons of high quality DRI/HBI.

The ENERGIRON trademark is a concept derived from the unique quality of direct reduced iron produced by this technology, a combination of energy and iron for the steel shop that increases productivity and quality while reducing operating costs.

Process Flexibilty

General Process Scheme

In an ENERGIRON plant the reducing gas source can be either Natural gas, Coke Oven gas, Syngas, or in general any gas containing in significant amounts Hydrocarbons, or directly Hydrogen and/or Carbon Monoxide as indicated in Figure 1. In all cases the process configuration is always the HYL ZR configuration. This is possible only due to the selective removal of the Reduction "products" Water (H_2O) and Carbon Dioxide (CO_2).

When the source for reducing gas is Natural gas, the process configuration can include or not an external reformer. The scheme with external reformer consumes slightly more gas, but the power is minimized, while the Zero Reformer scheme minimizes the natural gas consumption but requires additional power (electricity + oxygen). Also, the product quality has to be considered: the scheme with external reformer produces DRI with up to 2.4% while the ZR scheme easily produces DRI with more than 4% carbon. The scheme is best selected based on a production cost analysis up to liquid steel, in order to consider all factors.

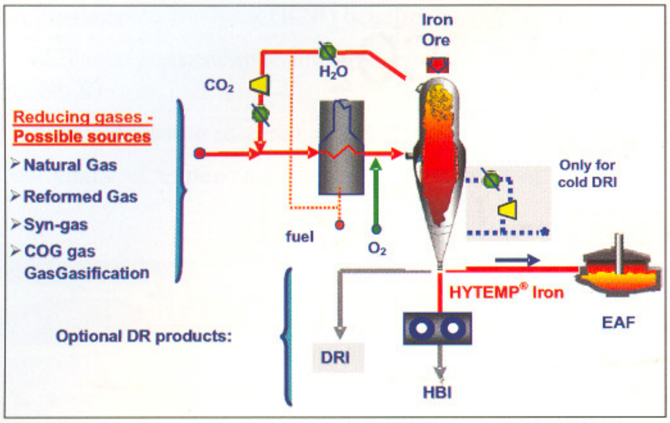

Figure 1: ENERGIRON Process Options

ZR Process Configuration

The ZR Process (Figure 2) is a major step in decreasing the size and improving the efficiency of direct reduction plants. Reducing gases are generated inside the reduction reactor simultaneously with the Reduction of the Iron ore.

Since all reducing gases are generated in the reduction section, optimum reduction efficiency is attained, and thus a reformer is not required. Compared to a conventional DR plant including reformer, in addition to lower operating/maintenance costs and higher DRI quality, the total investment for a ZR plant is lower.

A remarkable advantage of this process scheme is the wider flexibility to produce DRI carburization with carbon levels up to 5.5%, most in the form of Iron Carbide, this is so because the conditions under which Carburization takes place.

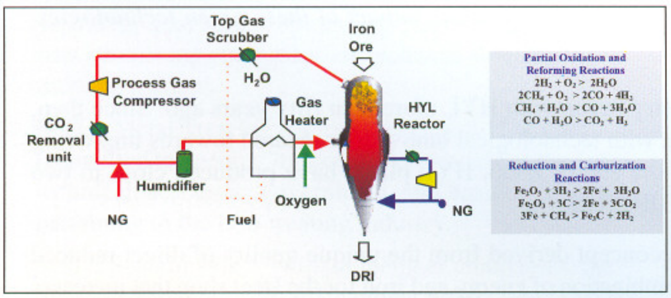

Figure 2: ZR Process Flow sheet

The impact of eliminating the external gas reformer on plant size is significant. For example, a plant of 1-million tpy capacity requires only 60% of the area needed by other process plants for the same capacity.

The Zero Reformer plant configuration has been successfully operating since 1998 in the 4M DR plant and since 2001 in the 3M5 plant, both at the Ternium Hylsa steel facility in Monterrey, Mexico.

ENERGIRON Plants – Flexibility for using alternative energy sources

Natural Gas

As was already mentioned, the basic reduction scheme (ZR) remains unchanged regardless of the source of reducing gases. For natural gas, the configuration can be based on either reformed gas or on the direct use of natural gas without a Reformer, the selected scheme, will depend on the local availability and/or cost of energy.

In this regard, an ENERGIRON plant can be designed to achieve the most optimized DRI production cost, depending on local conditions.

Coke Oven Gas

In any integrated facility producing steel via BF/BOF there is a natural unbalance in energy. The energy contained in the gases generated by the COG, BF, and the BOF is always higher than the energy required as fuel inside the facility, typically, the excess is used for power generation or in some cases just flared.

An alternative use for the excess of COG is to produce DRI. The DRI produced can be used in several ways such as; substitute of scrap in the BOF, metallic charge to the BF, to decrease the consumption of coke and/or powdered coal injection (PCI) or, to increase the production of hot metal, or for sale as a scrap substitute to other companies.

Typical production of COG is approximately 420 Nm•/t of coking coal.

Even though the chemical compositions of COG and natural gas are quite different COG can be used directly in the ZR process with the same basic configuration, actually, the gas composition entering the Reactor is very similar as indicated in Figure 3 for both cases ZR based on Natural gas or ZR based on COG.

Typical requirement of COG for DRI production, based on the HYL-ZR scheme is about 9.5 GJ/t DRI, for a DRI of 94% metallization and 4.0% carbon.

Item Vol. %	COG	Nat. gas	COG Based to Reduction	NG Based To Reduction
H_2	56.5		47.7	50.0
CO	7.5		8.5	15.0
$CH_4 + C_nH_m$	27.0	97.0	16.8	25.0
CO_2	2.5	2.5	1.5	3.0
H_2O			4.0	4.0
$(H2+CO)/(CO_2+H_2O)$			10.2	9.3
N_2	6.5	0.5	21.5	3.0

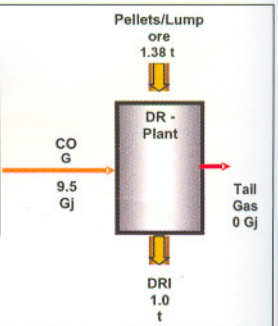

Figure 3: Comparative Gas Analysis: COG vs. HYL-ZR (Nat. gas-based) Scheme

Figure 4 presents a simplified overview of the global energy scheme and CO_2 emission for a typical integrated steelworks for production of slabs. Corresponding figures of this example are presented in Table 1.

For this application, spent gases from the integrated steel mill are sent to the DR plant and split as follows:

- An amount of 2.26 Gj of COG/t HM is used as process gas for DRI production.
- Required amount of BFG is used as fuel for reducing gas heating and steam generation, which is needed for CO_2 absorption in the DR plant.

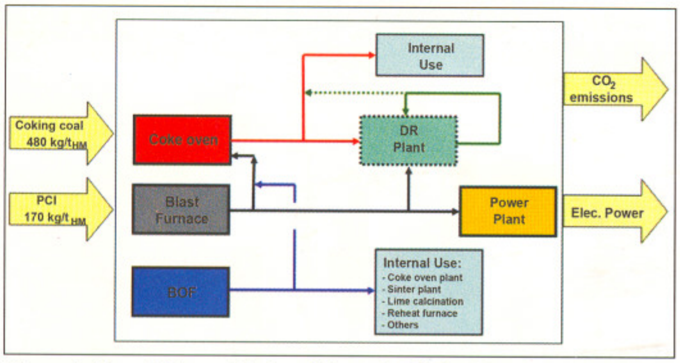

Figure 4: Overall Energy/Carbon Scheme for Typical Integrated Steelworks - Slab production

Table 1: Overall Energy/Carbon/DRI Balance for Typical Integrated Steelworks-Slab production

		Without DR-Plant	With DR-Plant
Power Generation	MW/tHM	375	142
Export Power	MW/tHM	194	0
Import Power	MW/tHM	0	21
Total CO_2 Emission	$KgCO_2/tHM$	1,780	1,780
Range of selective CO_2 removal	$KgCO_2/tHM$	0	30-150
DRI Production	KgDRI/tHM	0	227
Note :			
Maximum potential DRI Production from a balance/ optimised-integrated Steel Plant (using COG & BOFG for DRI)	KgDRI/tHM		380

As commented before, the COG can be used either to generate power or to produce DRI. In order to determine which alternative is more profitable, an economical analysis must be made.

A simpler and direct answer to the above question can be obtained if for comparison purposes we use a flow of COG of 38,000 Nm3/hr, with this flow you can produce either 65 MW or 65 tonnes of DRI/hour (equivalent to 500,000 t DRI/year). In both cases no capital cost is considered, the cost for the COG is null and only running cost is considered.

Table 2: DRI production Cost-based on COG

		Unit Cost	HYL MINI -MODULE 70% Pellets.30% Lump Ore DRI: 94% Mtz, 4%C	
Concept	unit	US$	Consump/t	$US/t
Pellets	t	90.0	0.97	86.94
Lumo Ore	t	70.0	0.41	28.98
Coke Oven Gas	GJ	-	10	-
Electricity	kWh	0.05	80	4.00
Oxygen	Nm3	0.05	11	0.55
Water	m3	0.02	1.3	0.03
Other consumables	$US			0.60
Maintenance	$US			3.01
Personnel	m-h	5.00	0.17	0.85
G&A	$US			1.00
Total DRI Production Cost	$US			125.96

The DRI running cost estimate is presented in Table 2 above, while for the power generation a running cost of 0.01 US $/KWH was considered. To calculate the cash flow both the DRI and the power are sold externally at market prices of 0.05 US$/kWh and 220 US$/ton of DRI.

The results of the economical analysis for the use of COG to produce Power or DRI are presented in Figure 5 below.

COG Utilization - Economical Comparison					
DRI cost (w/o COG)	US$/tonne	125.00	Power gen. cost (w/o COG)	US$/kWh	0.01
DRI price	US$/tonne	220.00	Power price	US$/kWh	0.05
DRI profit	US$/tonne	95.00	Power profit	US$/kWh	0.04
DRI plant production	tonneDRI/hr	65.0	Power generation	kWh/hr	65,000
DRI benefits	MMUS$/year	49.4	Power Benefits	US$/year	20.80

Figure 5: Comparative analysis of DRI production vs. Power with COG

Syngas from Coal Gasification

As presented in Figure 6 below, the syngas from the gasifier can be fed directly to the standard HYL ZR DR plant.

Specific requirements of syngas per tonne of DRI are only about 700 Nm3/t DRI. Or about 9.5 GJ.

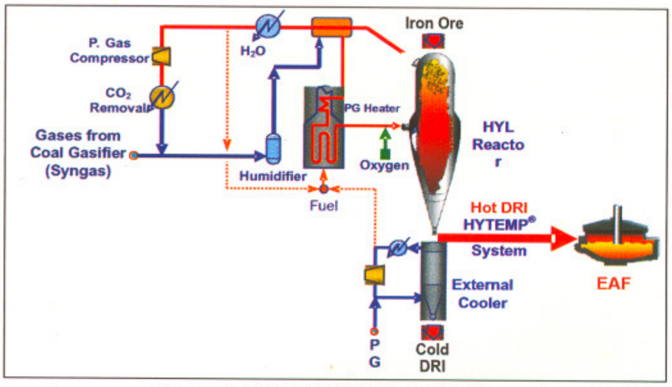

Figure 6: HYL-ZR DR Plant with Syngas from Gasifier

As can be seen in Table 3, the reducing gas composition entering the Reactor, it can be seen that the gas composition is very similar, either when natural gas or when Syngas is used as make up for the reduction circuit.

Item Vol.%	Syngas Make-up	NG Make-up	Syngas to Reactor	ZR to Reactor
H_2	55		54	55
CO	25		20	14
$CH_4+C_nH_m$	16	97	18	22
CO_2	2	2	2	3
H_2O	0		4	5
$(H_2+CO)/(O_2+H_2O)$			13	9
N_2	1	1	4	2

As compared to other existing and emerging coal-based DR technologies, this scheme offers the possibility to install a DR plant of any size up to 1.6 million tonnes/year of DRI in a single module. This approach is based on the incorporation of proven technologies: Gasifier unit and HYL ZR plant.

High Carbide Iron.

A unique benefit of the ZR Process is the DRI which it produces. This product, which we call High Carbide Iron or HCI, typically has a metallization of 95% and a carbon content of around 4% in the form of Iron Carbide. Figure 7 present actual information on the DRI produced industrially by a ZR plant.

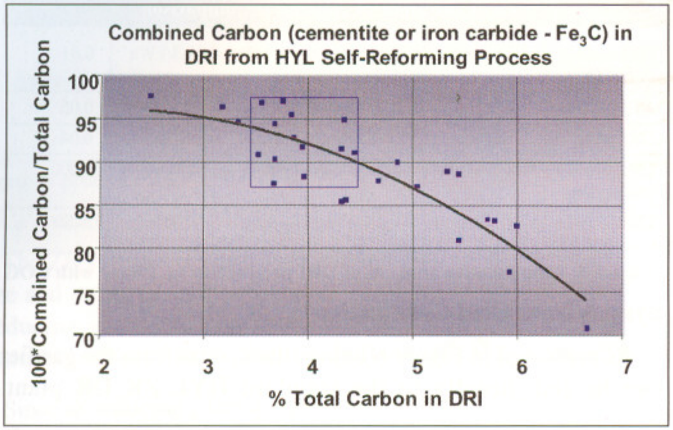

Figure 7: High Carbide Iron (HCI)

DRI produced with the ZR scheme is characterized by its high stability, much higher than the conventional DRI produced in other DR process. The reason for this high stability, is the high cementite or Fe3C content, which inhibits the re-oxidation of metallic iron in contact with air. For a carbon content of 4% approximately 95% is present as Fe3C. In general every 1% of combined carbon corresponds to 13.5% of Fe3C. Therefore a DRI with 4% Carbon contains more than 50% of Fe3C.

The HYL® HYTEMP System.

A technology which, on its own provides significant benefits for steelmakers is the HYL HYTEMP pneumatic transport system for sending hot DRI from the reduction reactor to the EAF shop. A simplified process scheme of the HYTEMP system is presented in Figure 8. The HYTEMP System involves a hot discharge direct reduction reactor connected to a nearby electric furnace by means of a pneumatic transport system. In this manner, the energy value of the hot DRI is capitalized in the EAF. The system also includes the means to continuously feed the Hot DRI to the EAF in a controlled and safe manner.

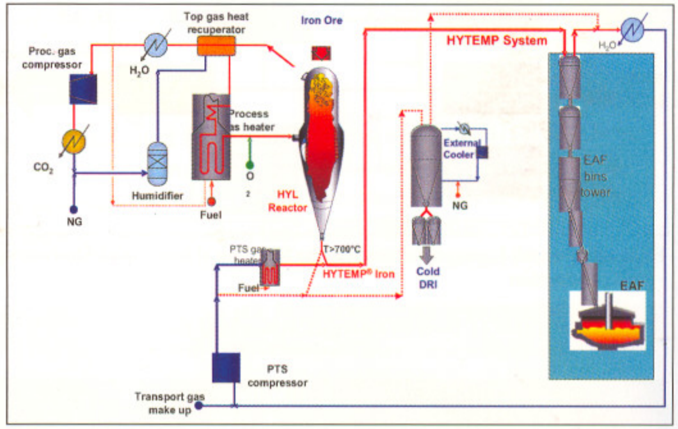

Figure 8: HYL® HYTEMP System

Conclusions

- The HYL ZR technology, can use any kind of gas such as COG, Syngas, Corex off gas, Natural gas, etc maintaining always the same process configuration.
- The HYL ZR technology can produce a High Carbide Iron containing more than 50% of Fe3C
- The technological risk involved in the use of other gas different from Natural gas for DRI production is minimized with the ZR process scheme.
- The use of COG to produce DRI in an integrated facility can help the optimization of production cost and reduce the CO2 emissions.
- The use of High Carbon DRI in the EAF reduce the power consumption and increases the productivity
- The use of Hot DRI in the EAF reduce the power consumption and increases the productivity
- The use of the HYTEMP system reduces the dust emissions in a DR-metlshop installation.
- The use of the HYL ZR process reduces the emissions of NOx to the atmosphere.