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The HYL Micro-Module

Economical solution for small-scale DRI production

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Over the years, gas-based direct reduction has evolved with larger and larger plant sizes driven by economies of scale. These DR plant units, typically averaging now from 1.0 to 1.6 million tpy capacity, are out of the scope of possibility for the typical small to medium scale steel producer. The HYL ZR Process however, provides new opportunities for reaching this market segment, since it does not require a natural gas reformer and is thus a much smaller plant overall. HYL Technologies, in cooperation with Electrotherm India Ltd. has developed a 200,000 tpy fully functional HYL ZR Process plant which is the most economical option on the market. The first plant of this type is being built for Al Nasser Industries in Abu Dhabi, UAE and will come online in 2007.

Keywords: Micro-Module, ZR Process, Self-Reforming, DRI, COG, Syngas, direct reduction

Historical development of gas-based DR plants

The world's first successful gas-based direct reduction plant was put into service in 1957 using the HYL Process, which at the time was a fixed-bed system rather than today's modern shaft furnace technology. The process by current standards would be considered inefficient, with low productivity and not very cost-effective in terms of its high natural gas consumption.

The Monterrey 1M plant was followed by numerous others, all using the HYL fixed-bed or batch process, and some of those plants are still in operation today. They are in fact very good at reducing fines for steelmaking since the batch process presents no difficulties in product flow for obvious reasons. In 1970 the Midrex shaft furnace process appeared on the market and in 1980, HYL started up its first shaft or continuous process as well.

Over the years, from 1957 to date, we can see how the size distribution of gas-based DR plants has changed (Figure 1).

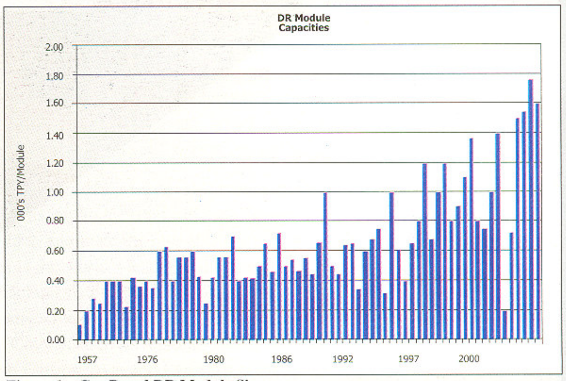

Figure 1 – Gas Based DR Module Sizes

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It is apparent that the module sizes of DR plants has continued to grow over the years, motivated by two principal factors – increasing plant capacity generally brings economy of scale and thus reduces investment on a cost per ton basis, and also the market for HBI which began to flourish in the 1990's and for which the typical size plant was generally 1.0 million tpy capacity or greater.

Steelmaking facilities and DRI/HBI requirements

While it is certainly true that the sizes and capacities of modern electric arc furnace steel mills have grown over the past few decades, the overall average capacity is still quite small when compared to integrated facilities.

Figure 2 shows the distribution of electric furnace steel mills worldwide as of 2004. Eliminating all those that have a capacity of less than 50,000 tpy, we are able to see that for 834 steel plants, 40% have capacities under 250,000 tpy, 23% range from 250,000 to 500,000 tpy and an additional 23% range from 500,000 to 1 million tpy capacity.

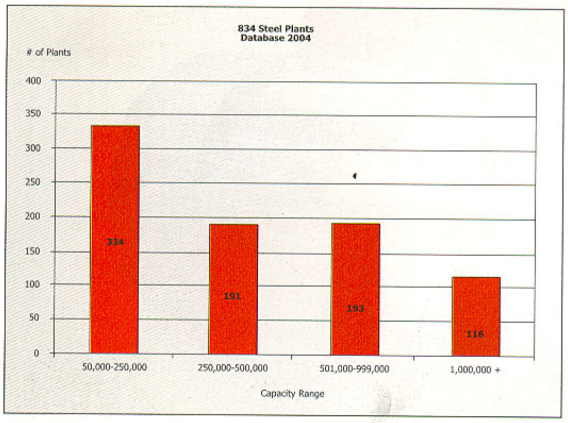

Figure 2 – Capacity Ranges of EAF Steel Mills Worldwide

If we take as an example a mill with a 500,000 tpy steel making capacity, and assume that for improving product quality it might require a charge mix of 80% scrap and 20% DRI/HBI, we are talking about 100,000 tpy of either of these virgin metallics. A mill of similar size which either faces a shortage or lack of steel scrap at acceptable prices, or which produces special qualities of steel that require reduced residuals content, could easily use 50% or more of DRI in the charge mix. This still demands only 250,000 tpy of DRI for those particular installations.

Captive vs merchant plant production

Based on the above calculations and the distribution of steel mill capacities, it is apparent that the majority of steel mills are not likely to consider installing a direct reduction plant onsite if the typical plant offering is in the range of 800,000 – 1 million tpy or greater. For a significant number of small mills, coal-based direct reduction has been implemented, principally in India, but these tend to be the very small capacity mills which have not been shown on the chart since their production capacities are even lower than 50,000 tpy of liquid steel.

A large scale merchant facility producing HBI for export can achieve the proper economics and supply material to mills such as these, however the market price fluctuates in large part based on the prevailing market for steel scrap. For the smaller producer, the consideration of whether or not to use HBI is based more on product quality requirements and not on any expected cost savings, although there is no capital cost required since the material is purchased on the open market.

On the other hand, the ideal situation for a steel mill, whether large or small, would be to have the onsite capability to produce DRI and feed it continuously to the melting furnaces. This is the best method for achieving the greatest cost benefit and productivity in the steel shop. If the material can be transported hot to the furnace, these benefits increase significantly by taking advantage of the hot DRI in the EAF. This can only be achieved if the investment for the DR plant is in proportion to the capacity of the mill to use the DRI produced and to amortize the plant cost as well, without having production costs exceed the market price for steel metallics.

A Technology solution

While the first DR plants at Hylsa and also those licensed to other companies by HYL were of smaller capacities (ranging from 100,000 – 350,000 tpy), the industry trend has been to increase capacity for better economies of scale. No serious consideration had been given to developing DR plants for smaller capacity requirements until HYL implemented a significant technology shift in 1998.

The HYL Process has always been characterized by its independent reforming and reduction sections (Figure 3), with no gas recycling to the reformer that would by necessity tie the two units together inseparably. In 1988 patents were obtained for a process modification in which the external natural gas-steam reformer was eliminated and gas reforming was carried out "in-situ" in the reduction reactor as well as the reduction and carburization reactions. Essentially, the HYL Process became the reduction circuit plus a pipe feeding reducing gases supplied externally.

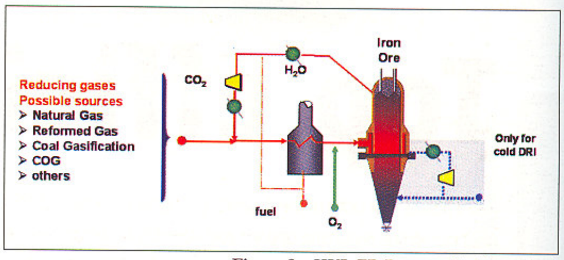

Figure 3 – HYL ZR Process Configurations

Ten years later, in 1998, the Hylsa 4M direct reduction plant in Monterrey, Mexico began operations using this new reformerless process scheme and it has been in successful operation ever since.

This new Self-Reforming or ZR Process scheme (for Zero Reformer) opened the way to two significant changes. The first was the ability to configure the HYL Process with other reducing gas sources such as coke oven gas, syngas from coal gasifiers, and essentially any reducing gas source that is capable of providing the required H2 and CO reductants to the reactor. This now permits the design of gas-based direct reduction units even in regions where natural gas is either unavailable or too expensive to be used for producing DRI.

The second change was that since without the external reformer the plant size was significantly reduced, it became possible to consider the development of a small-scale DR unit capable of serving the lower production range of the steel industry. HYL essentially was able to consider the early needs of the industry, back when Hylsa first developed the technology for its own onsite use within the company, and began to develop the concept of an HYL Micro-Module – a small, economic DRI facility capable of supplying the quality metallic needs of the small to medium steel producer.

Engineering the Micro-Module concept

HYL set out to develop a small DRI plant which would be cost effective and produce the required quality of metallics for the small to average sized steel mill. After careful consideration, the decision was made to develop the engineering for an HYL Micro-Module based on the following characteristics:

- Production capacity – 200,000 tpy
- Process design – HYL ZR (Reformerless) Technology
- High quality DRI – 93%+ Metallization, with Carbon in the range of 4%
- Low capital and operating costs

The smaller overall space and equipment requirement of the ZR Process plant presented important advantages in capital cost savings when designing the plant. Still other economies and efficiencies had to be obtained in order to reach the established goal of developing the Micro-Module at an investment cost per ton of annual capacity that would be similar to that of a much larger plant.

The engineering concept essentially went back to the (digital) drawing boards, reviewing every component and evaluating ways of simplifying or eliminating features while still keeping the process reliability and product quality. The pressurized operation of the HYL Process, for example, allows smaller piping and vessels which generally reduces the materials and equipment costs. The smaller diameter reactor (3.5 m) permitted a savings in overall structure for the reactor tower and related equipment and facilities.

An additional feature was in the implementation of modular design for certain plant sections and equipment, thus permitting a faster onsite assembly and erection which helps reduce the overall construction schedule and related costs. The battery limits HYL Micro-Module was also designed to make maximum use of existing plant facilities such as materials handling, water and oxygen in order to achieve even further economies.

The result was the HYL Micro-Module – a 200,000 tpy HYL ZR Process plant configuration which requires an area of only 60 x 90 m., and has an investment cost of around $175/ton capacity, similar to that of a much larger scale facility. The representative layouts are shown in Figures 4 and 5.

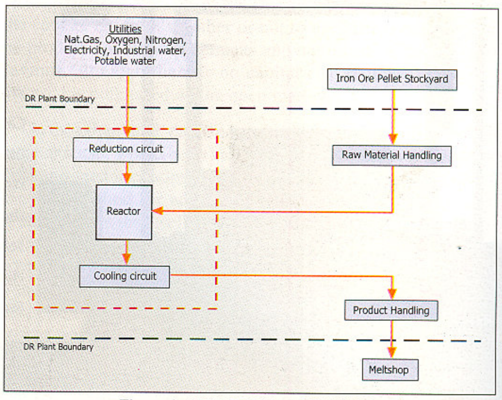

Figure 4 – HYL ZR Micro-Module Plant Battery Limits

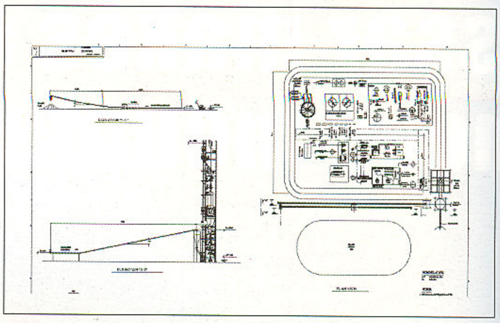

Figure 5 – HYL ZR Micro-Module Layout & Elevation

The importance of this development is that it brings onsite direct reduction capabilities to the small to medium scale steel mill at an economical cost. Previously the only other option available at smaller scales was coal-based direct reduction, however these plants tend to produce a DRI which is of lower metallization and higher residuals levels than that of gas-based DRI. Additionally, because of the independent nature of the HYL Process reduction circuit, the small footprint and economical investment is not possible from any other DR process since only the HYL Process scheme allows for the use of full "in-situ" reforming. Other processes claiming "in-situ" reforming refer only to some partial reforming within the reactor, however the external gas reformer and its associated cost and size are still an integral part of the plant.

Association with Electrotherm India Ltd.

At the time HYL was considering the concept of the Micro-Module, an association was entered into with Electrotherm India Ltd., based in Ahmedabad, India. Electrotherm India (ET) became the exclusive supplier of the HYL Micro-Module and worked jointly with HYL in development of the redesigned engineering for this unique plant concept.

ET is actively involved in the marketing and supply of the Micro-Module and as EPC contractor, completes projects on a turnkey basis including equipment manufacture and erection, as well as supplying technology packages.

ET also supplies electric arc and induction furnaces and other steel plant equipment like Metal Refining Konverters (MRK), DC Plasma Ladle Refining Furnaces, etc., and can design and install complete "mini" integrated plants based on DRI and electric furnaces (MF Induction Furnaces, Channel Induction Furnaces, Electric Arc Furnaces). Currently over 12 million tonnes of steel is produced annually on ET-supplied Induction Furnaces.

Immediate acceptance

The acceptance of the Micro-Module concept was immediate. Al Nasser Industrial Enterprise (ANIE) has signed a contract with HYL Technologies, S.A. de C.V. for a 200,000 metric tpy HYL Micro-Module to be installed at Mussafah, Abu Dhabi Industrial City. The plant uses the HYL ZR reformerless process, carrying out both gas reforming and ore reduction in the reduction shaft furnace. This will be the third HYL ZR Process plant to be installed; the Hylsa 4M plant has been in operation since 1998 and the Hylsa 3M5 plant was converted to the ZR configuration in 2001.

This first of its kind Micro-Module will be supplied by HYL Technologies on a turn key basis. The overall project calls for a DRI/EAF/ladle furnace/continuous casting mill and will boost ANIE's total steel production capacity to 600,000 tpy. The contract signed between HYL Technologies and Al Nasser calls for the new Micro-Module plant to begin operation in 2007. Basic engineering is completed and detail engineering is underway, as is site mobilization.

Additional alternatives

One of the main advantages of the HYL process is the configuration based on independent reducing gas generation and reduction sections and the selective elimination of both gaseous products from reduction: water (H_2O) and carbon dioxide (CO_2). Under these conditions the only requirement for the reduction process is a pipe supplying the required amount of hydrogen and carbon monoxide with no changes involved in the process scheme.

HYL modules can be adapted to any energy source and/or local conditions to obtain the most optimized scheme configuration in terms of both investment and operating costs. The HYL modules can incorporate the HYTEMP system, with flexibility to produce either 100% cold DRI or 100% hot DRI directly fed to the EAF.

For the HYL process there is a wide flexibility for using alternate sources of reducing gases, including conventional reformed gas, COG, syngas from coal gasification and others.

Syngas

For DRI production in locations lacking availability and/or low price of natural gas, HYL is offering an approach based on a coal or other carbonaceous fuel as source of reducing gas to a standard HYL ZR DR module. By using synthesis gas (syngas) from a gasifier as source of reducing agents, the amount, quality and conditions of the gases required for the reduction process are the most important parameters for definition of the most adequate gasifier-DR scheme. Characteristics of this syngas can be adjusted through gas conditioning to enhance H2 content.

The specific requirement of syngas per ton of DRI corresponds basically to the typical make-up of the conventional HYL gas scheme for natural gas-based process (about 685 Nm3/t DRI). By comparing the scheme based on syngas with the conventional ZR scheme the similarity of reducing gases entering the DR reactor is evident; hence there is no technological change for this application. Based on an analysis of treated syngas (typically from a Lurgi gasifier), the expected DRI characteristics from coal-syngas are 93% metallization and up to 2.5% carbon.

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 2.0 million tonnes/year of DRI in a single module. This approach is based on the incorporation of two proven technologies: the gasifier unit and the HYL DR plant. Expected plant performance figures, including an example of DRI operating cost estimate is presented in Table I, based on the same syngas analysis mentioned earlier.

DR Plant	Unit	Unit Cost	HYL DR Module based on Syngas 70% pellets, 30% lump ore	
Metallisation	%		= 93	
Carbon	%		2.5	
DRI Temperature at EAF	°C		600	
Concept		US$/unit	Specific Consumption	$US/t DRI
Pellets	t	100.0	0.97	96.60
Lump ore	t	80.0	0.41	33.12
Total Syngas	Nm3	0.033	625	20.38
Electricity	kWh	0.05	65	3.25
Oxygen	Nm3	0.05	5	0.25
Water	m3	0.02	1.0	0.02
Other consumables	$US			0.60
Variable Cost	**$US**			**154.22**
Maintenance	$US			3.01
Labour	m-h	3.0	0.17	0.51
G&A	$US			1.00
Fix Cost	**$US**			**4.52**
Total Operating Cost	**$US**			**158.74**

Table I - HYL DR plant with Coal Gasifier Expected Operating Performance and Operating Cost Estimate (Example)

COG

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, energy balances of integrated steel works show that most of the excess gaseous energies are mainly used for power generation or even flared. As only a minor part of the electrical power which could be generated from these gases can be used in the steelworks for its own requirements, most of the electrical power has to be exported.

An alternative use for the excess of COG is to produce DRI. The DRI produced can be used in several ways such as:

1. Substitute of scrap in the BOF
2. 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
3. It can be sold as scrap substitute to other company

The economics of using COG for DRI production, based on comparative cost study analysis, shows a benefit of more than double the annual cash flow when using COG for producing DRI instead of for generation of electric power. Of course, if the gas is being flared then the cost benefit is even more obvious. Table II shows the estimated DRI production cost based on COG, with the comparative analysis vs power generation illustrated in Figure 6.

COG Utilization - Economical Comparison					
DRI cost (w/o COG)	US$/tonne	142.00	Power gen. cost (w/o COG)	US$/kWh	0.01
DRI price	US$/tonne	250.00	Power Price	US$/kWh	0.05
DRI profit	US$/tonne	108.00	Power Profit	US$/kWh	0.04
DRI Plant production	tonne DRI/hr	65.0	Power generation	kWh/hr	65,000
DRI benefits	**MMUS$/year**	**56.2**	**Power benefits**	**US$/year**	**20.80**

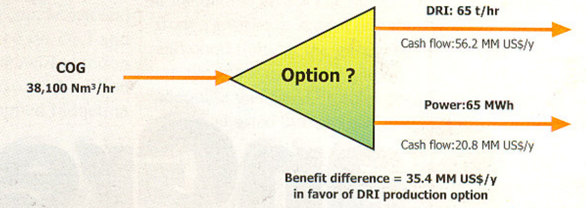

Figure 6 – Economical Comparison of COG Utilization

Summary

Based on an evaluation of the structure of the electric furnace steel industry worldwide, and the potential market for small onsite direct reduction plants, HYL developed the engineering for a compact, cost-effective direct reduction plant based on the ZR Process technology currently available. HYL Technologies, together with Electrotherm India Ltd., developed the Micro-Module concept and brought it to market, satisfying the demand for small production capacities of high quality DRI.

The independent reduction section of the HYL Process not only opened the way for the design of a small DR module, it also enabled the design of direct reduction plants based on syngas or COG in areas where natural gas is either too expensive or in short supply.

		Unit Cost	HYL MODULE 70% Pellets/30% Lump ore DRI: 94% Mtz, 4% C	
Concept	unit	US$	Consumption/t	$US/t
Pellets	t	100.0	0.97	96.60
Lump ore	t	80.0	0.41	33.12
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	3.00	0.17	0.51
G&A and others (financing)	$US			3.00
Total DRI Production Cost	**$US**			**141.42**

Table II - DRI production Cost based on COG

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