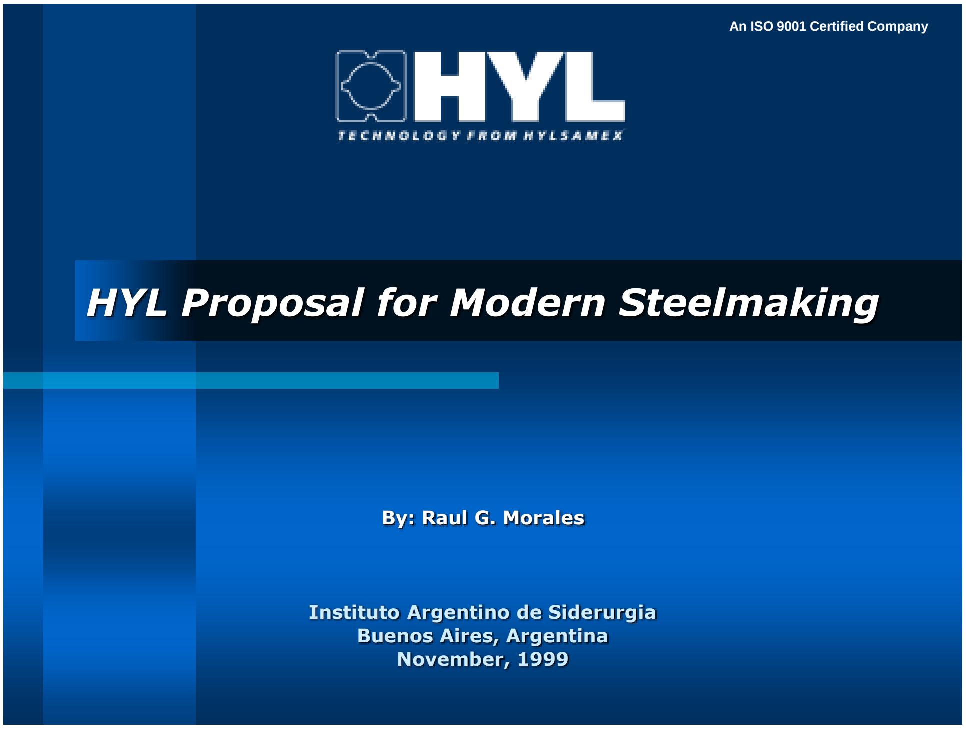
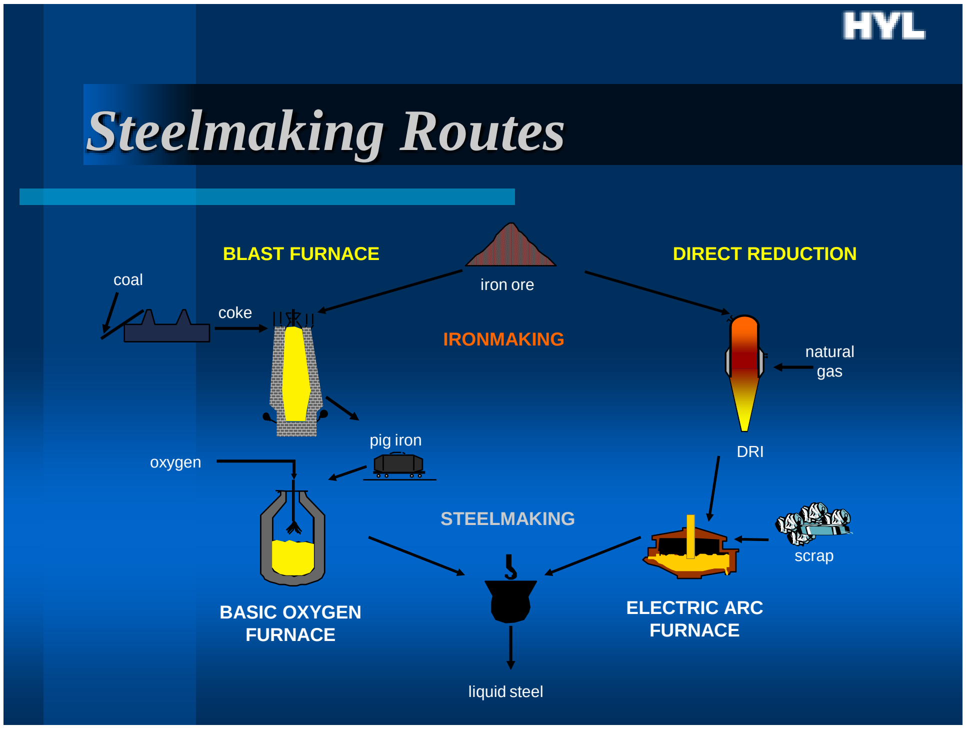


The Electric Arc Furnace (EAF) continues to claim an increasing share of the total world raw steel production. Economics and flexibility to produce different steel grades have had much to do with this development. The ability to produce quality steel products, efficiently and in quantities which permit economical and productive operations, is a key factor in the success of EAF mills. The ever increasing use of continuous casting techniques and the more recent trends to thin slab and near net shape casting have further helped EAF mills to enter into new, more demanding product segments.

Iron units required for producing modern steels must be free of the various tramp elements and impurities which are more and more present in steel scrap. Iron sources such as DRI, HBI and iron carbide are gaining acceptance and shall play a greater role in order to assure quality levels in the near future.

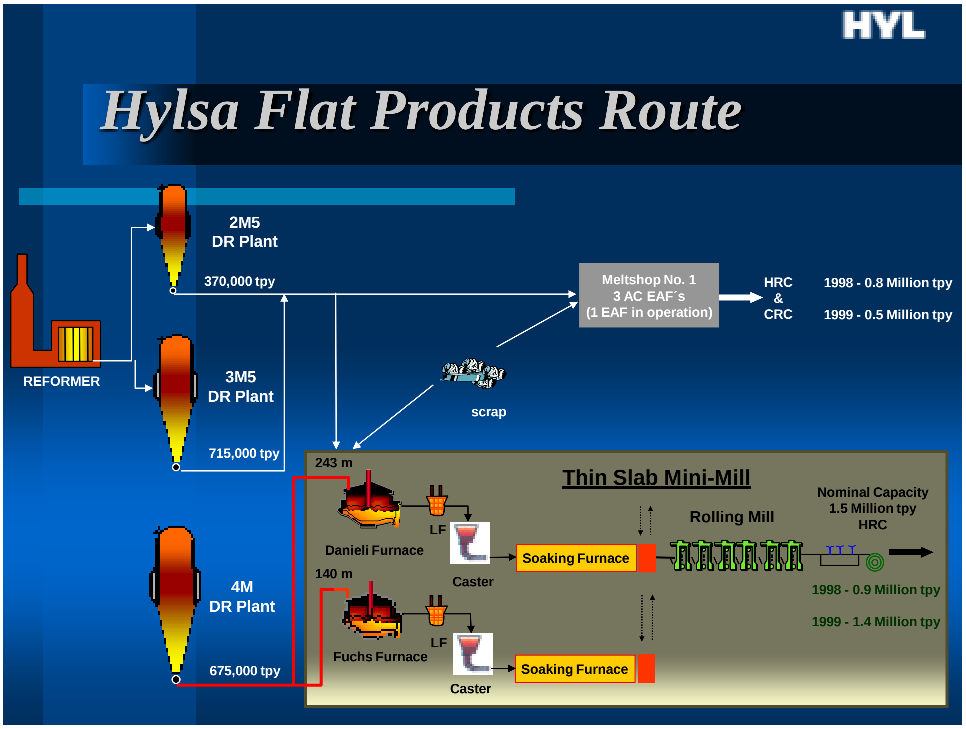
This document presents a summary of the latest developments of the HYL direct reduction technology: The self-reforming scheme and the HYTEMP system. The features of these systems allow the production and feeding to the EAF of high temperature-high carbon DRI. The benefits of these products in the EAF are also discussed.



There exist in the world two main routes for the production of liquid steel: On one side, the "Classical Route" based on blast furnace ironmaking and conversion of pig iron to steel. On the other side, the "Modern Route" for the production of steel in electric arc furnaces, using as raw material either scrap or Direct Reduced Iron (DRI).

Although the "Classical route" continues to produce the major percentage of steel in the world, the "Modern Route" is gaining participation in the market due to the following main advantages:

- Simplicity of the plant operation.
- Flexibility to operate at smaller capacities, down to 300,000 ton/year with an attractive production cost.
- Best environmental impact compared to coking plants and blast furnaces.
- New plants can be realized in phases, to optimize the financial structure of the project.
- Very attractive investment cost compared to the blast furnace-BOF route.

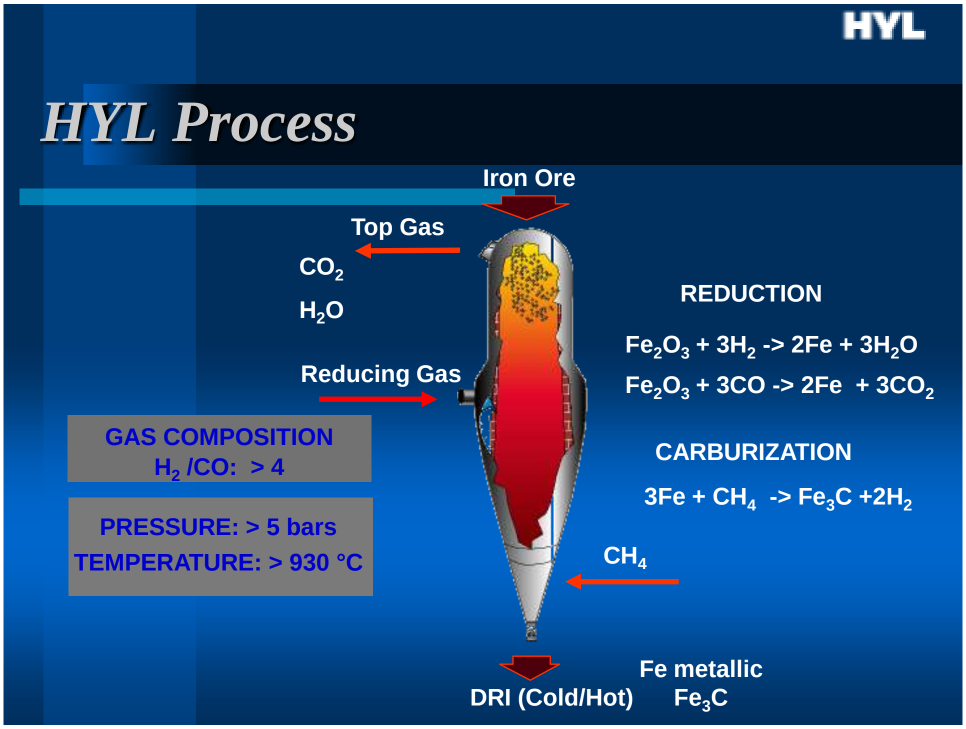


With the development of new technologies for thin slab casting and the use of efficient melting and highly productive electric arc furnaces (EAF's), a new era for the EAF based steelmaker has begun, particulary in the production of flat products, as indicated by the fast pace at which new capacity is added.

By considering these new technologies, together with the extensive use of DRI, the production of high quality products at low cost is now a reality.

At the Flat Product Division of Hylsa in Monterrey, Mexico, a new mini-mill was started up in February 1995, based on state of the art technology for direct reduction, melting, refining, casting and rolling. In a first stage, this plant produced 750,000 ton/year of finished product, which was increased to 1.5 Million ton/year in a second phase started in the third quarter of 1998.

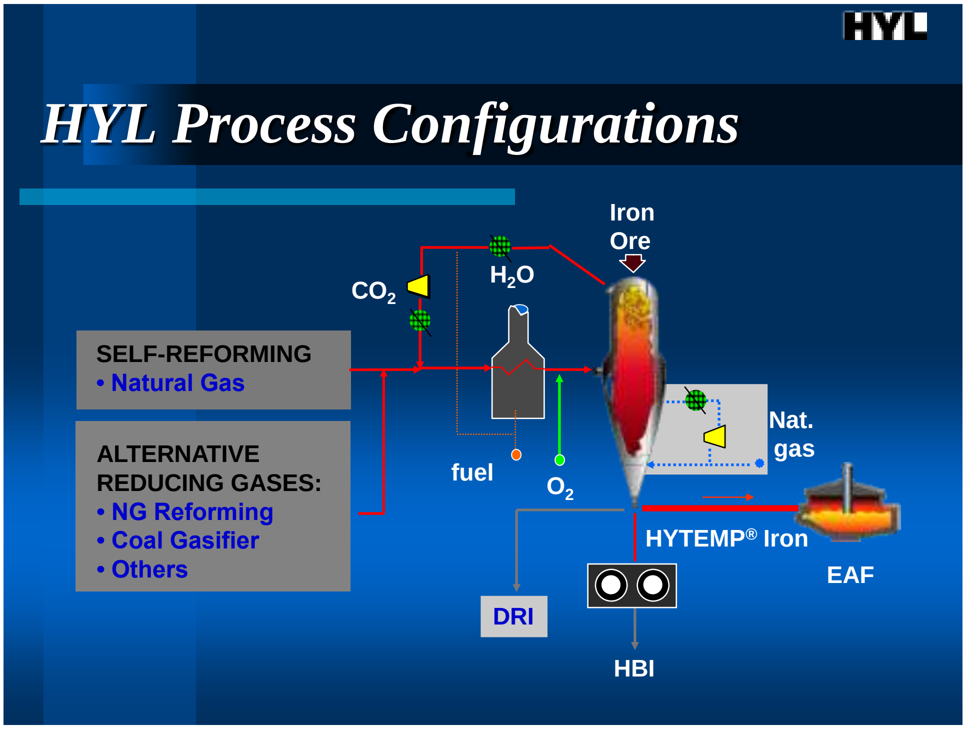
In Hylsa Monterrey, DRI is being supplied from the 2M5/3M5 and 4M plants, in thre amount of 1.8 Million ton/year. HYL DRI has been used in the Hylsa Monterrey facilities since 1957, and there is no other steel company in the world with more experience melting DRI than Hylsa.



The HYL process was designed for the direct reduction of iron ores, using reducing agents such as hydrogen (H_2) and carbon monoxide (CO).

The main characteristics of the HYL process are: Utilization of hydrogen rich reducing gases, high reduction temperature and elevated operating pressure.

Under these conditions, the DRI produced is characterized by high metallization levels, with an independent carbon control by means of the methane injection to the reactor. Due to these operating conditions, most of the carbon is deposited in the cementite form (FeC).



One of the main advantages of the HYL process is its configuration based on independent reducing gas generation and reduction sections. Under these conditions, the only requirement is an independent source to supply the H_2 and CO needed for reduction, with no changes involved in the process scheme.

The HYL technology offers the flexibility to produce three different product forms, depending on the specific requirements of each user:

DRI:

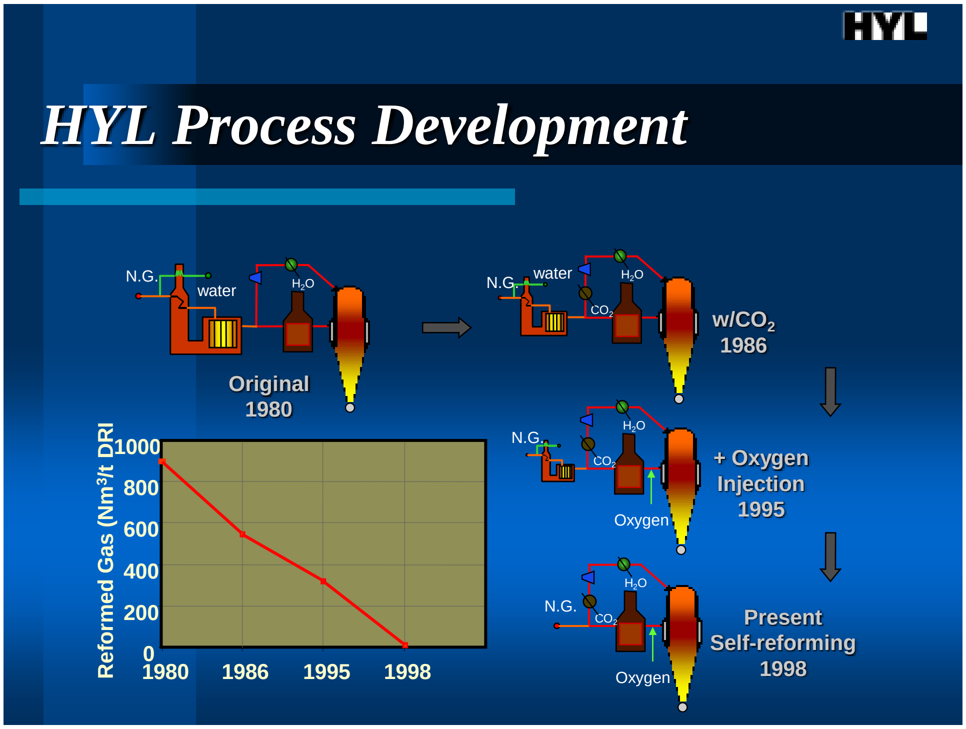
Cold DRI, which is normally used in adjacent meltshops close to the DR facilities. This product can be shipped and exported safely, provided that some precautions are taken to avoid reoxidation.

HBI:

Hot Briquetted Iron, produced from hot discharged DRI, which is more commonly used for overseas export. HBI can also be produced when low quality friable iron ores are to be processed, and these ores cannot be used for the production of cold DRI due to the high amount of fines in the product.

HYTEMP Iron:

Hot discharged DRI, which is pneumatically transported in a direct form to the electric arc furnace.

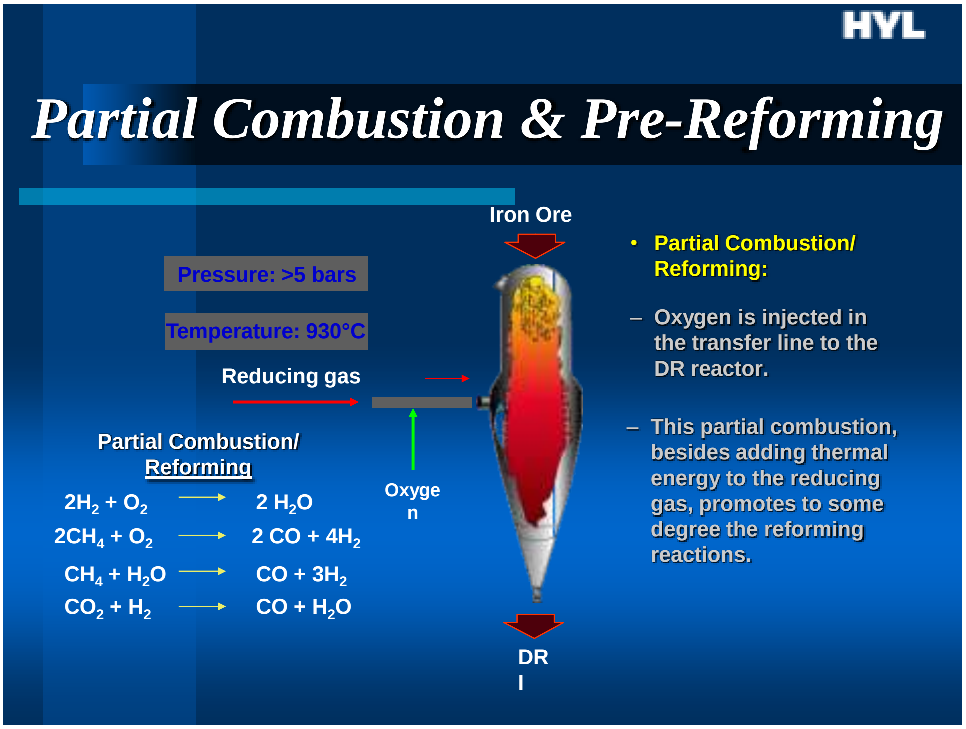


The first industrial plant operating with the HYL moving bed process started up in May, 1980, based on a process concept oriented to high plant productivity and superior DRI quality, low energy consumption, and a simpler operation. Through the years, several improvements have been incorporated in the moving bed process, thus optimizing the process efficiency and plant reliability.

In 1986 a CO_2 removal system was incorporated in the reducing gas circuit of HYL plants, allowing significant improvements in plant productivity and energy consumption. With this process scheme in industrial operation, the reformed gas consumption was decreased in about 50%, and the plant productivity was increased by a similar percentage.

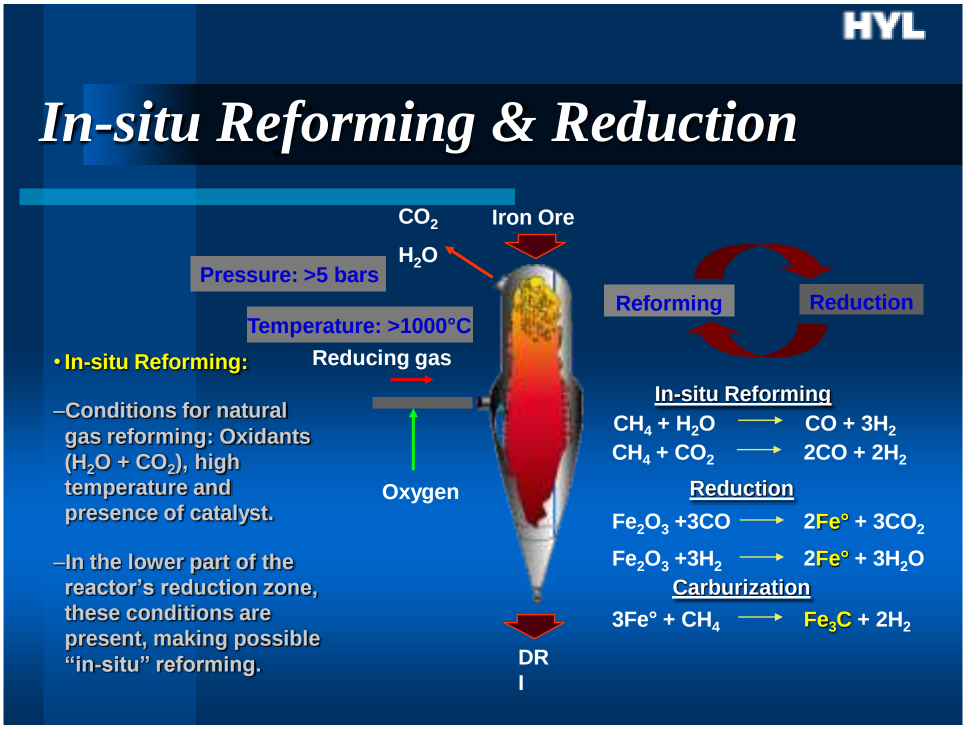
In 1995 the oxygen injection technique was applied in HYL plants, feeding oxygen at the transfer line between the reducing gas heater and the reactor inlet. The partial combustion scheme allowed an important increase in the reducing gas temperature, as well as in-situ reforming, decreasing the reformed gas consumption in about 25%, combined with a higher reactor productivity.

In 1998 the total natural gas feed and oxygen injection to the reduction reactor led to the "HYL Self-Reforming" scheme, where the reformed gas make-up to the reducing gas circuit is decreased to zero. This scheme is in successful industrial operation in the Hylsa 4M plant since April, 1998.



In general, partial combustion of natural gas with oxygen provides the additional energy, which is required for natural gas reforming in-situ, and for the carburization of the metallic iron, eliminating the need of a natural gas-steam reformer.

This partial combustion, besides adding the required energy to the reducing gas, promotes the reforming reaction to some degree, before the reactor inlet. The net balance of the partial combustion of natural gas provides an increase of reducing gases for reduction (as H_2 and CO) due to reforming reactions. The general path of the partial combustion and pre-reforming reactions is characterized by a dominant exothermic behavior.

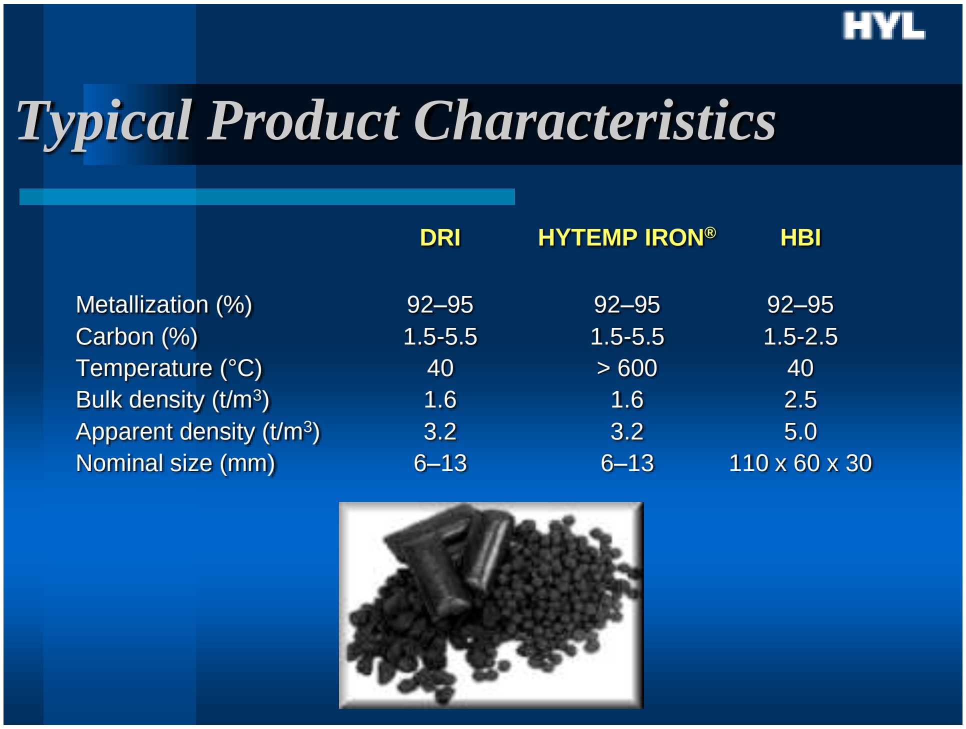


Reforming of natural gas requires: A certain level of oxidants (H_2O and CO_2), which have to be carefully controlled; a high temperature, as a result of partial combustion; and an active catalyst, which is provided by the metallic iron units from the iron ore already reduced.

The oxidants produced by the reduction reactions are partially consumed by the reforming reactions. In this manner, once in contact with the solid material inside the reactor, further methane reforming takes place in-situ due to the catalytic effect of metallic iron. Under these conditions, the methane is always in contact with new catalyst (metallic iron in DRI) since DRI is continuously removed from the reactor. Therefore, in-situ reducing gas generation and reduction take place in a highly efficient environment.

This reforming process is highly endothermic and it will continue up to the point where the temperature is still high enough. Once the temperature drops below a certain level, in-situ reforming will not occur and only iron ore reduction will proceed.

Most of the DRI carburization takes place by cracking of methane to produce iron carbide (Fe_3C).



The self-reforming scheme offers a great flexibility for a DRI production with high metallization and high carbon content.

Typical metallization figures are about 94%, whereas carbon content may vary between 1.5% and 5.5%.

Due to the high methane concentration of the reducing gas, this process scheme is much more efficient when DRI is produced with a high carbon content.

DRI produced by the self-reforming scheme presents a higher energy content compared to other direct reduction process. There is a higher carbon level for the same product metallization.

Under this situation, comparing the energy consumption figures for different direct reduction processes, the self-reforming configuration represents the most efficient method available for DRI production.

Typical Consumption Figures

SELF-REFORMING

	Cold DRI	Cold DRI	HBI	Hot DRI	Hot DRI
Metallization (%)	93	93	93	93	93
Carbon (%)	4.3	2.5	2.5	4.3	2.5
DRI Temperature (°C)	40	40	700	700	700
Iron ore (t/t)	1.36	1.39	1.41	1.36	1.39
Natural gas (Gcal/t)	2.24	2.18	2.22	2.33	2.23
Electricity (kWh/t)	65	65	80	65	65
Oxygen (Nm^3/t)	42	53	53	48	53
Water (m^3/t)	0.8	0.8	1.1	0.8	0.8
Nitrogen (m^3/t)	12	12	19	18	18
Labour (m-h/t)	0.11	0.11	0.13	0.12	0.12
Maintenance ($US/t)	3.30	3.30	3.30	3.65	3.65
Briquetting ($US/t)	-	-	3.00	-	-
HYTEMP System ($US/t)	-	-	-	incl.	Incl.
Administration ($US/t)	1.00	1.00	1.00	1.00	1.00

Notes: Same Fe total (68%) in the iron ore for all cases.
Including screening to -3.2 mm. Estimated for a plant capacity of 1.5 million tpy.

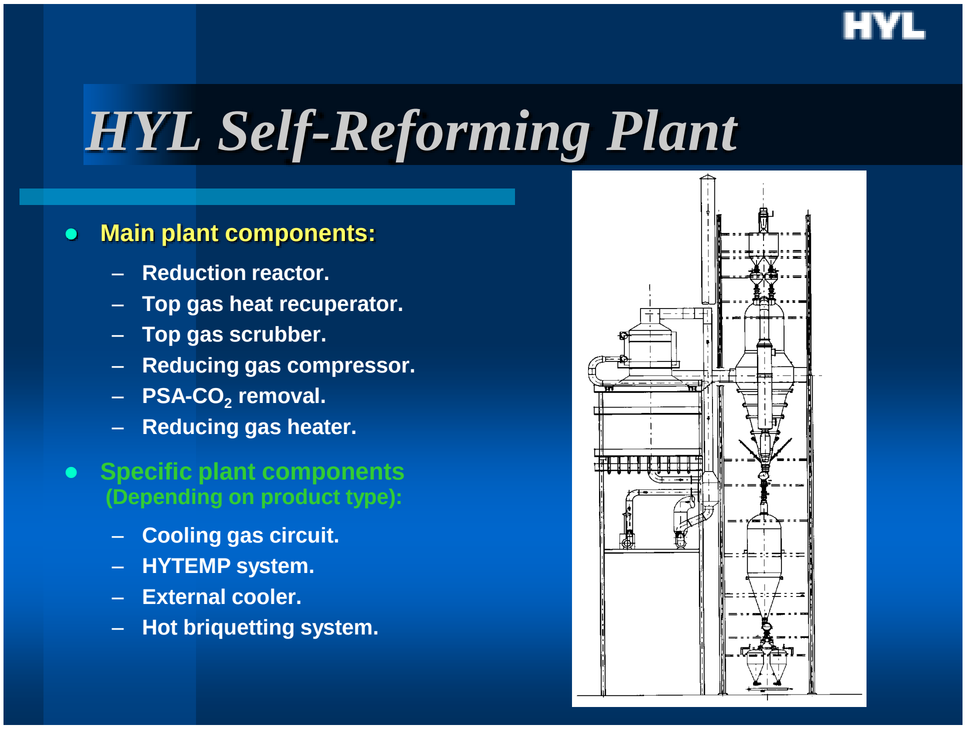
The above table indicates the expected consumption figures per ton of product, based on the self-reforming scheme, for the production of cold and hot DRI either in HBI form of directly transported to the meltshop (HYTEMP®).

The fourth and fifth columns are referred to the HYTEMP® scheme, including the corresponding figures for the operation and maintenance of the pneumatic transport system..

Typical DRI carbon levels are indicated for the same product metallization.

The iron ore consumption considers screening to -3.2 mm (about 2% dry basis).

The presented consumption figures may vary depending on the iron ore characteristics, the natural gas composition, as well as the particular plant configuration.



In the HYL self-reforming plant, the main components are the following: Reduction reactor, top gas heat recuperator, top gas quenching/scrubbing system, reducing gas recycle compressor, CO_2 removal system and reducing gas heater.

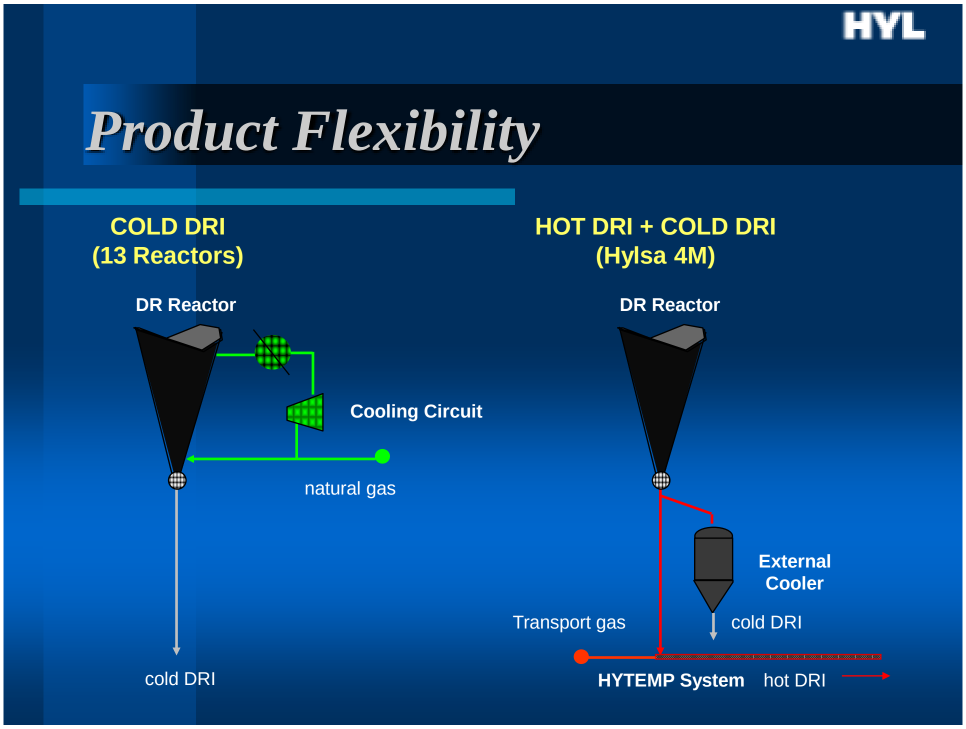
Depending on the specific product type, I.e. cold DRI, hot DRI or HBI, one or several of the following equipment components can be incorporated:

- Cooling gas circuit.

- HYTEMP system.

- External cooler.

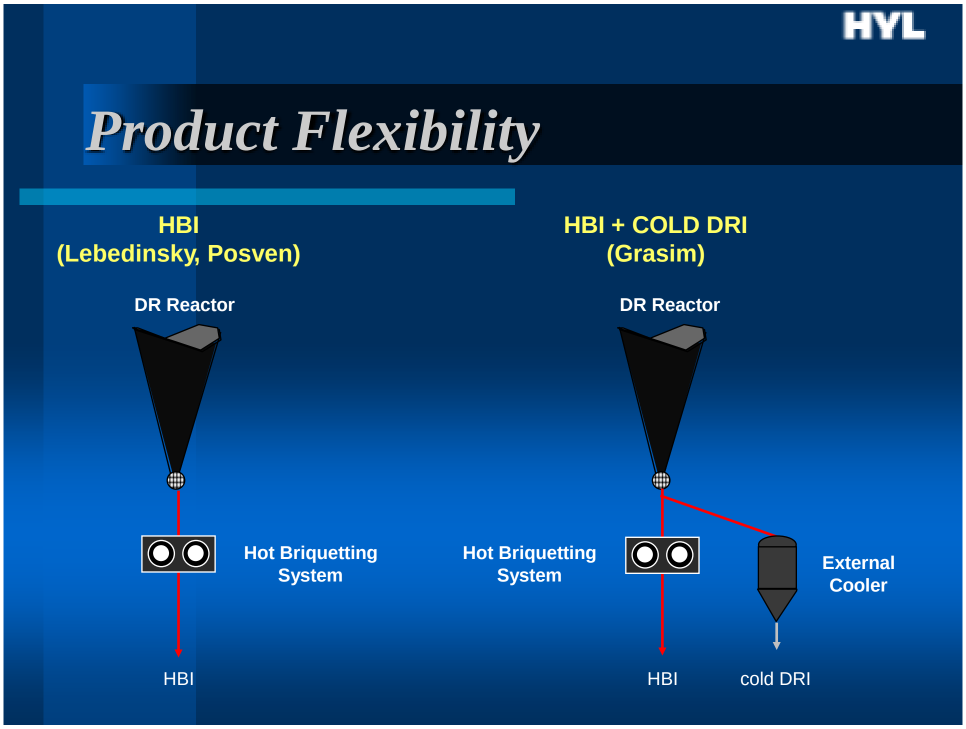
- Hot briquetting system.



The flexibility of the HYL direct reduction process, for the production of different product types and combinations of them, can be illustrated by the following examples of HYL plants in operation:

- Cold DRI. For the production of cold DRI only, a cooling gas circuit with natural gas is incorporated, discharging the product at less than 40 °C. Currently 13 HYL reactors operate under this scheme.

- Hot DRI + cold DRI. The Hylsa 4M plant started up in April, 1998, producing cold DRI in an external cooler. Since December, 1998, the plant produced both hot and cold DRI, and currently it is producing 100% hot DRI (700 °C) which is sent to the EAF via the HYTEMP system.



<u>Hot Briquetted Iron (HBI).</u> HBI is produced from hot discharged DRI (700 °C), and is more commonly used for overseas export. HBI can also be produced when low quality friable iron ores are to be processed, and these ores cannot be used for the production of cold DRI.

The briquetting machines consist of a set of roller presses, in which a pressing force is applied to the hot DRI to produce a briquette string. This briquette string is discharged vertically from the rollers and a chute deflects the material towards a briquette string breaker, where the briquette string is segregated to single briquettes mainly. The HYL Lebedinsky (Russia) and Posven (Venezuela) plants are designed to operate under this concept.

<u>HBI + cold DRI.</u> In some cases, it is convenient to produce a mix of HBI and cold DRI, to serve the export market and local market respectively. The Vikram Ispat (Grasim) plant in India is operating since June, 1998, under this concept. The average HBI/DRI ratio in 1999 has been about 3/1.

Reducing gases are generated by self-reforming in the reduction reactor, feeding natural gas as make-up to the reducing gas circuit and injecting oxygen at the inlet of the reactor. The partial oxidation and pre-reforming of natural gas with oxygen generates reducing gases (H_2 and CO) and increases the operating temperature up to 1020 °C, which are required for the iron ore reduction. Once in contact with the solid material inside the reactor, further cracking and reforming reactions are carried out due to the catalytic effect of metallic iron.

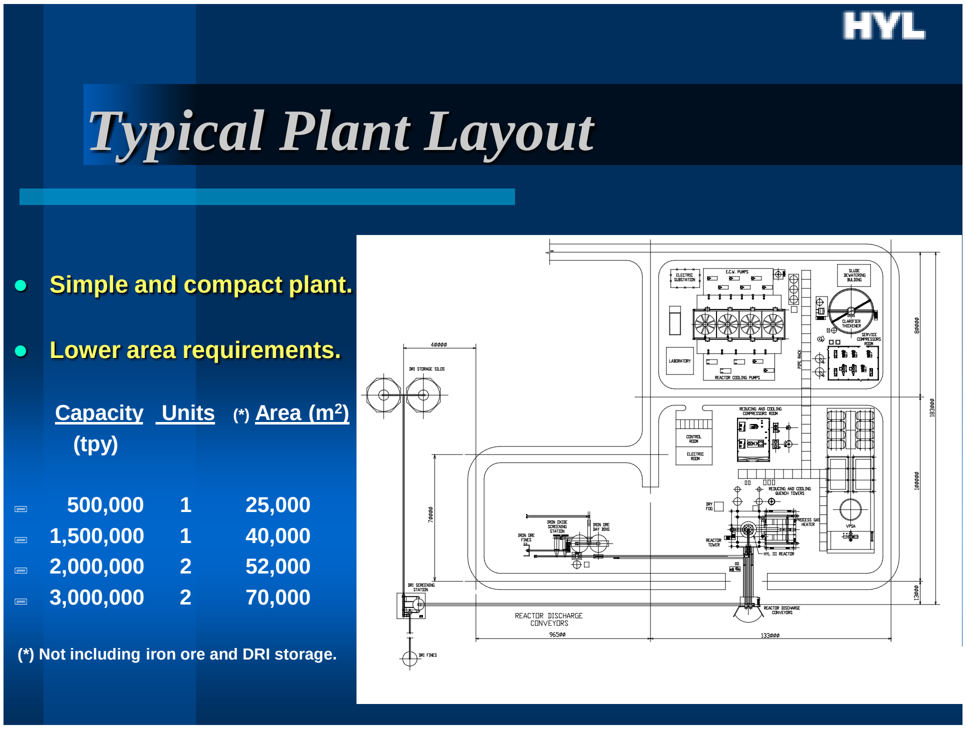
Since all reducing gases are generated in the reduction section, an optimum reduction efficiency is attained, and thus an external reducing gas generation (and associated services) are not required. Compared to a conventional DR plant including reformer, the total investment for an HYL self-reforming plant is typically 10%-15% lower.

A remarkable advantage of this process scheme is the wider flexibility for DRI carburization, which allows to attain carbon levels up to 4.5%, due to the improved carburization potential of the gases inside the reactor.

The overall energy efficiency of the self-reforming process is optimized, by the integration of partial combustion, pre-reforming and catalytic reforming inside the reactor, as well as by a minimum utilization of thermal equipment in the plant. Therefore, most of the energy supplied to the process is taken by the product, with minimum energy losses to the environment.

For the production of high quality DRI, I.e. 93% metallization, 4.5% carbon and discharged at 700 °C, the energy consumption is 2.20 to 2.35 Gcal/ton DRI as natural gas and 60 to 80 kWh/ton DRI as electricity.

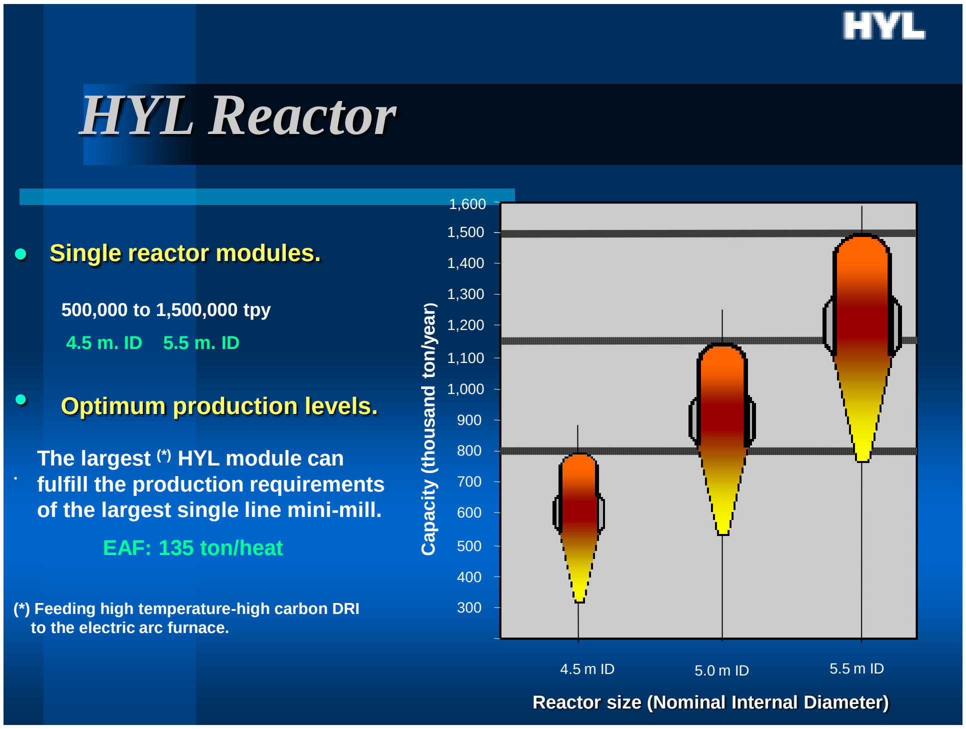
On the other hand, there is a natural synergy with the meltshop especially when high carbon DRI is melted. A common oxygen plant can be utilized for the DR plant and for the meltshop, thus decreasing the total investment cost of the steel complex.



HYL plants are simple in design and compact facilities, as can be observed in the typical layout for a plant design based on the self-reforming scheme.

A summary of the typical area requirements for different plant sizes is presented next. Iron ore and DRI storage areas are not included in these data, as they are normally defined in accordance with the specific needs of each project.

Plant Capacity (ton/year)	Reduction Units (#)	Area (m^2)
500,000	1	25,000
1,500,000	1	40,000
2,000,000	2	52,000
3,000,000	2	70,000



Based on single reduction units, HYL plants are designed for capacities ranging between 300,000 and 1,500,000 ton/year of DRI/HBI. There are three standard HYL reactor sizes (4.5 m ID, 5.0 m ID, and 5.5 m ID), which can be specified according to the required production capacity for each project.

Feeding high temperature-high carbon DRI to the EAF, a single reduction unit of 1,500,000 ton/year can fulfill the production requirements of the largest single line mini-mill, producing up to 1,335,000 ton/year of slabs.

Plants including multiple units can be designed for larger capacities. In this case, two, three, or more reactors can be grouped in one reduction tower, each reactor being fed by a reducing gas heater. General services such as material handling, water systems, and utilities, are designed to be common for the entire direct reduction plant.

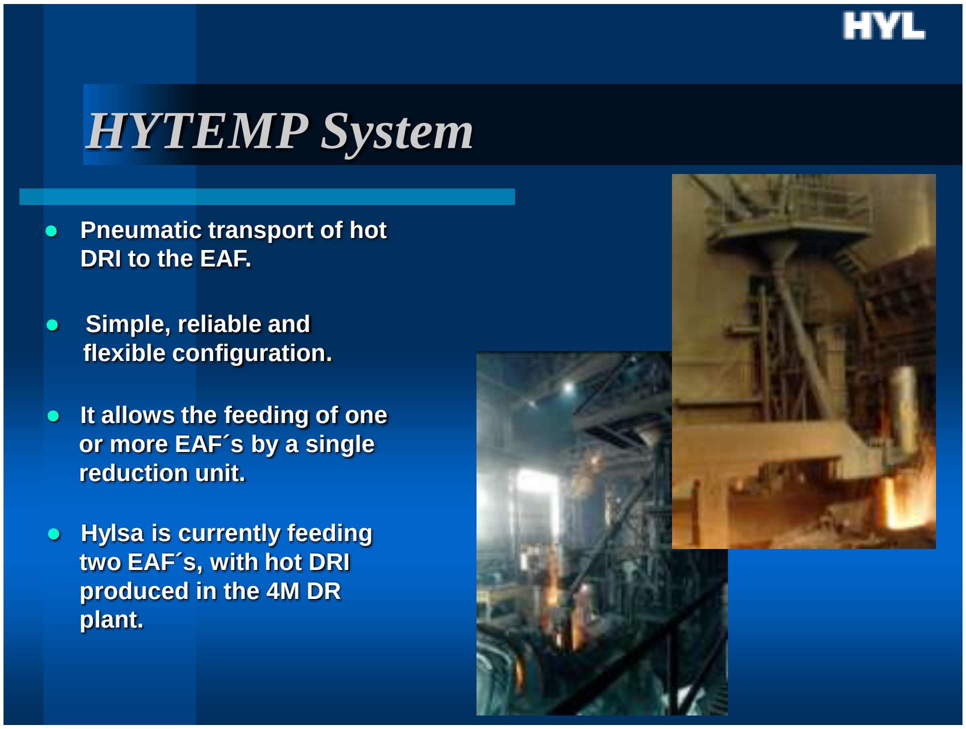
Personnel Requirements

Self-Reforming Single Module Plant

	Cold DRI	Hot DRI
Position	Total	Total
Administration	5	5
Operation	27	28
Maintenance	28	28
Water treatment and Quality control	12	12
Total	72	73

The manpower requirements for the operation and maintenance of HYL plants, based on the self-reforming scheme, is significantly lower than those required in other direct reduction plants.

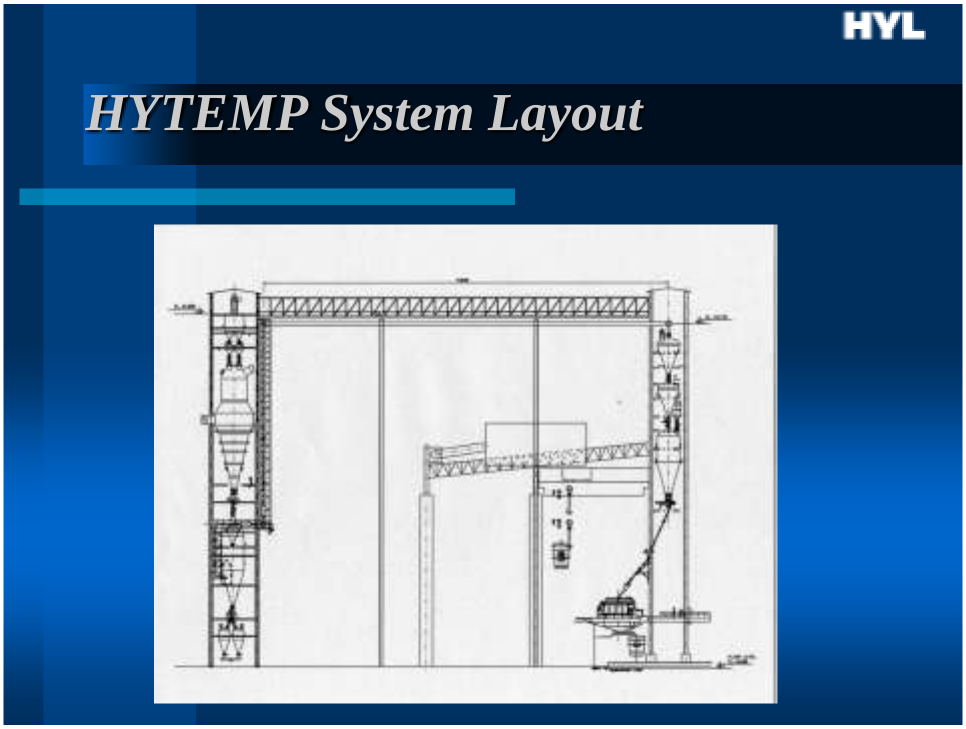
In the self-reforming case, there is no need of personnel for the operation and maintenance of a reformer, neither for auxiliary associated equipment such as natural gas desulphurizer, steam generation, reformed gas quenching, etc. The oxygen supply is normally provided from outside battery limits.



The typical configuration of a DR- EAF steel mill involved a reduction unit producing cold discharged DRI, which was sent to the EAF mill by means of belt conveyors. The DRI had typically a metallization level up to 95% and carbon levels in the range of 1.8% to 2.3%. Depending on the established practice, the DRI could be continuously charged or batch charged to the furnace.

The HYTEMP System, operating at industrial scale since December, 1998, at the Hylsa Monterrey plant, allows steelmakers to take advantage of the sensible energy in the hot DRI, to decrease the electrical energy requirements in the EAF and to increase productivity. Furthermore, by increasing the carbon content of the DRI (mainly as iron carbide) to levels up to 4.5%, the energy consumption and liquid steel cost decrease significantly and the EAF productivity increases. The HYTEMP System is an ecologically sound, highly efficient method for modernizing an existing EAF steel mill or for greenfield sites.

The system is highly versatile, since it allows the feeding of one or more EAF´s by a single reduction unit, as is actually the case in the Hylsa flat products plant.

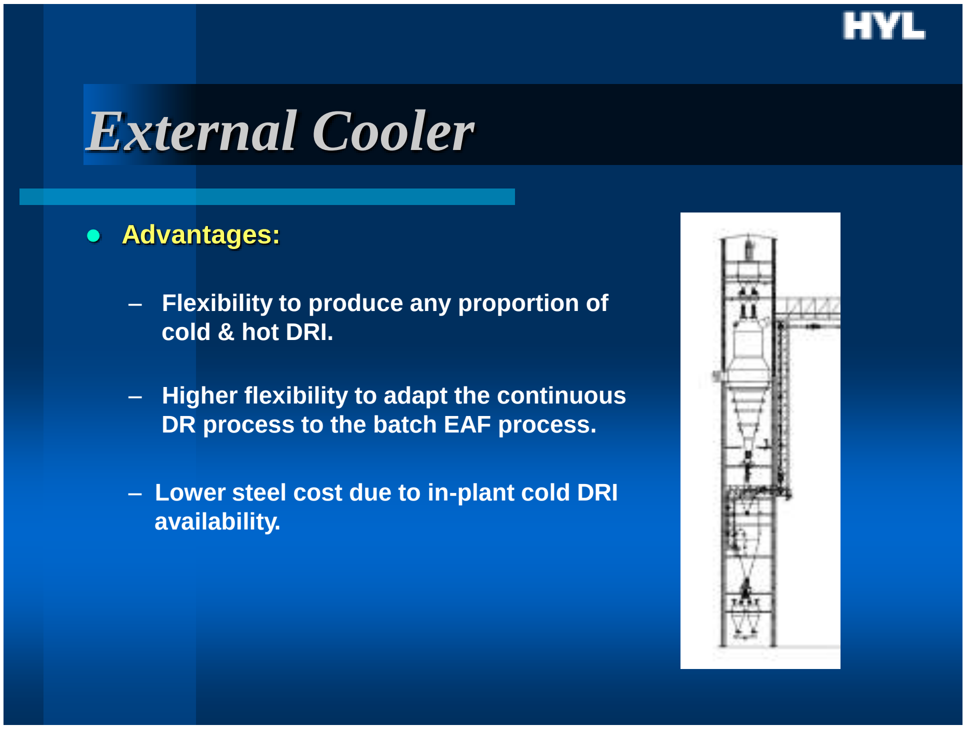


The HYTEMP system involves an HYL hot discharge direct reduction reactor, connected to an adjacent electric arc furnace mill by means of a pneumatic transport system.

As the DR plant designed for HYTEMP iron production is linked to steelmaking facilities, the reactor tower, pneumatic transport system and EAF feeding bins can be arranged in the most adequate layout to minimize distances and to match the continuous DRI output with the batch consumption of the meltshop.

Hot DRI is sent to the meltshop, where it is temporarily stored in insulated inertized storage bins, for feeding to the furnace by continuous injection mechanisms, which deposit the material directly in the metallic bath surface.

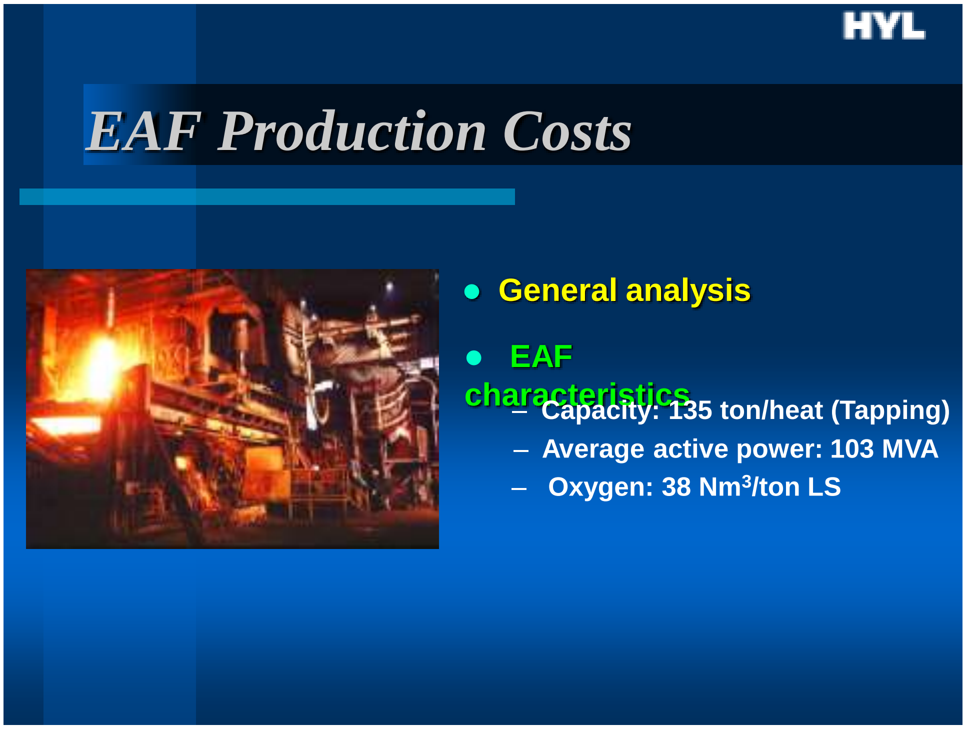
This process scheme offers the most adequate arrangement for integrated steelmaking facilities, due to the important benefits capitalized in the EAF.



Hot DRI is discharged by means of the reactor rotary valve, through the diverter valve, which delivers material either to the HYTEMP system or to an alternative external cooler (for cold DRI production). The pneumatic transport is normally carried out at the same rate as the reactor production rate.

According to the particular requirements of the steelmaking facilities, the external cooler can be used during long EAF downtime, for the production of cold DRI and inventory generation. This feature gives a high flexibility to adapt the continuous direct reduction process to the EAF batch process.

Due to the availability of in-plant DRI inventory, a higher annual liquid steel production and lower steel costs can be attained, specially in case of plants producing high quality steels. In case of a flat products facility, similar to the Hylsa plant, a saving of about 8% in the annual liquid steel production is estimated.



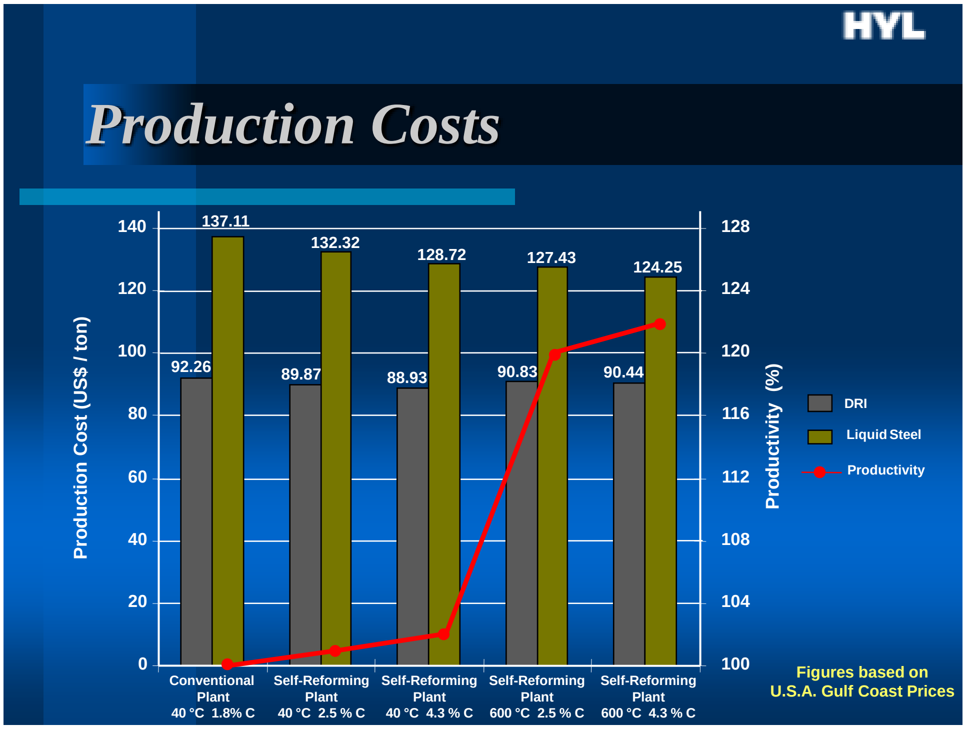
In order to evaluate the benefits of the use of high temperature-high carbon DRI on the production of liquid steel, an state of the art-EAF has been considered for all cases with the following characteristics:

- Capacity: 135 ton/heat (Tapping)

- Average active power: 103 MVA

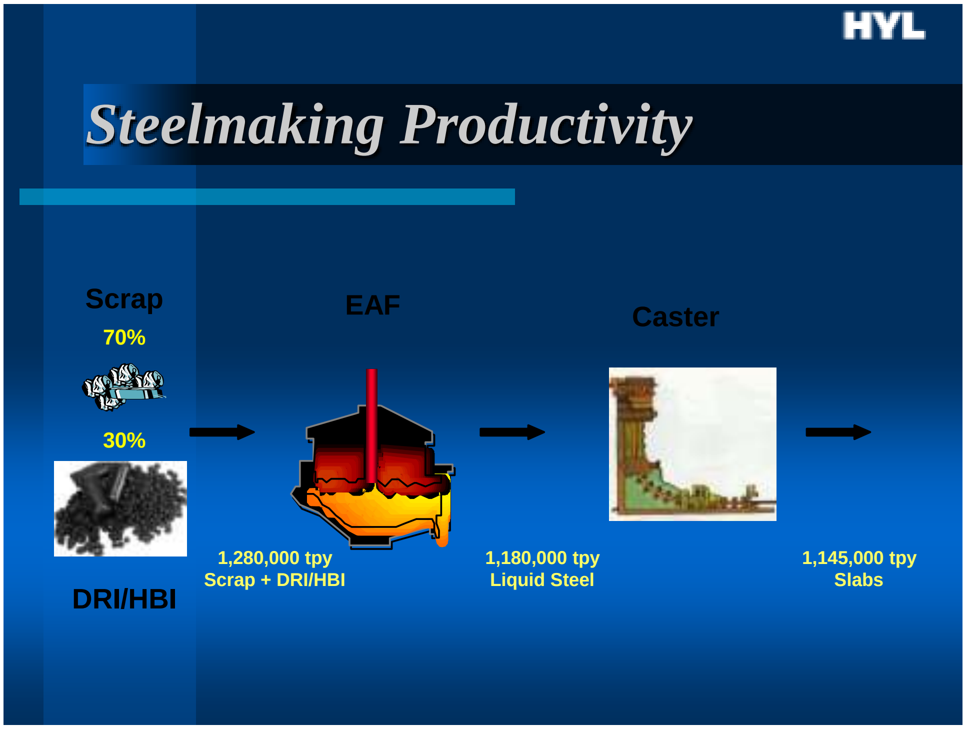
- Oxygen: 38 Nm^3/ton LS

The analysis has been made to determine the liquid steel production costs and productivity for five different types of DRI, and also to evaluate the maximum production of slabs, via the above mentioned EAF, with three different types of metallic charge to the furnace.

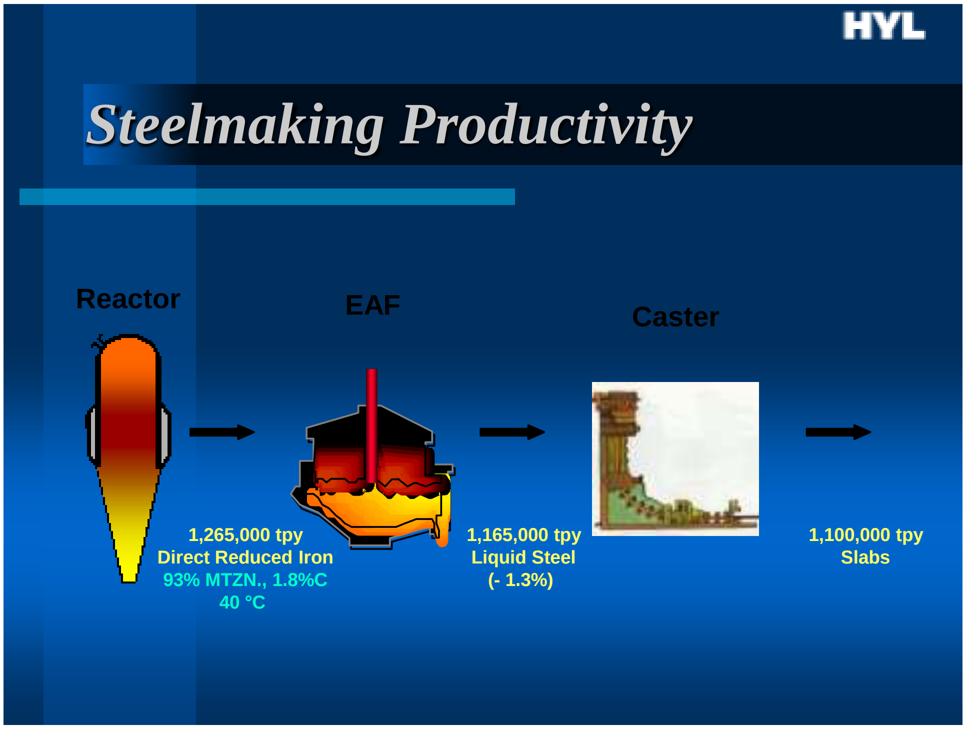


The effect of high carbon in the DRI leads to lower production costs and improved plant productivity, due to the main following reasons: The feeding of graphite or any external source of carbon units is avoided, and the conversion of Fe_3C into iron and carbon is an exothermic reaction which improves the thermal efficiency of the system, thus decreasing the total electricity consumption and the tap to tap time in the EAF. When carbon in the DRI is increased from 1.8% to 4.3%, the liquid steel production cost is decreased by more than 8 US$/ton and the furnace productivity can be increased by about 2%.

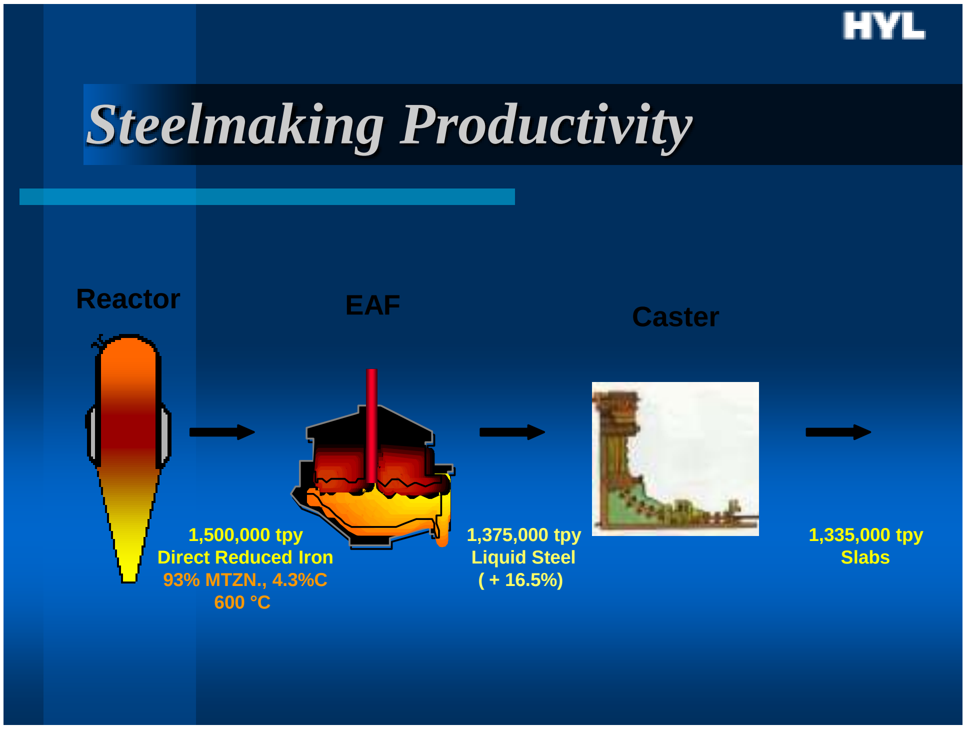
Regarding DRI temperature, the production costs are also decreased, but the main benefit is associated to a much higher furnace productivity. Due to the energy contribution of the DRI sensible energy, the electric power consumption and the tap to tap time in the EAF are significantly decreased. Comparing a DRI fed at 40°C and 1.8%C with a DRI fed at 600 °C and 4.3%C, the liquid steel production cost is decreased by about 13 US$/ton and the furnace productivity is increased by about 22%.



In a typical flat product mini-mill, using 70% scrap and 30% DRI/HBI, the maximum liquid steel production which can be attained in the reference EAF (135 ton of liquid steel per heat) is about 1,180,000 ton/year of liquid steel. The corresponding slab production is about 1,145,000 ton/year.

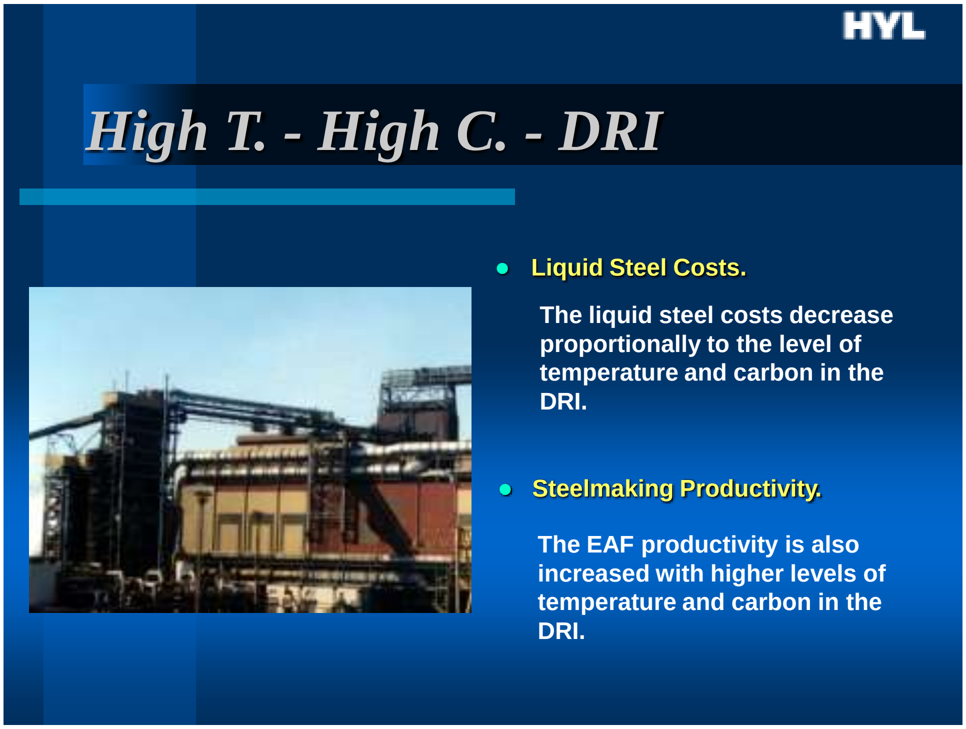


In case of a mini-mill feeding 100% cold DRI to the EAF, with 93% metallization and 1.8% carbon, the maximum liquid steel production for the reference EAF is about 1,165,000 ton/year of liquid steel. This means that the productivity of the EAF is very similar (1.3% lower) to that obtained in an operating practice feeding 70% scrap and 30% DRI/HBI. In this case, the slab production is about 1,100,000 ton/year.



However, when 100% high carbon-high temperature DRI is fed, with 93% metallization, 4.3% carbon and 600 °C, the furnace productivity is dramatically increased, reaching a liquid steel production of 1,375,000 ton/year in the reference EAF. Compared to the operating practice using 70% scrap and 30% DRI/HBI, the productivity is increased by 17%. In this case, the slab production is about 1,335,000 ton/year.

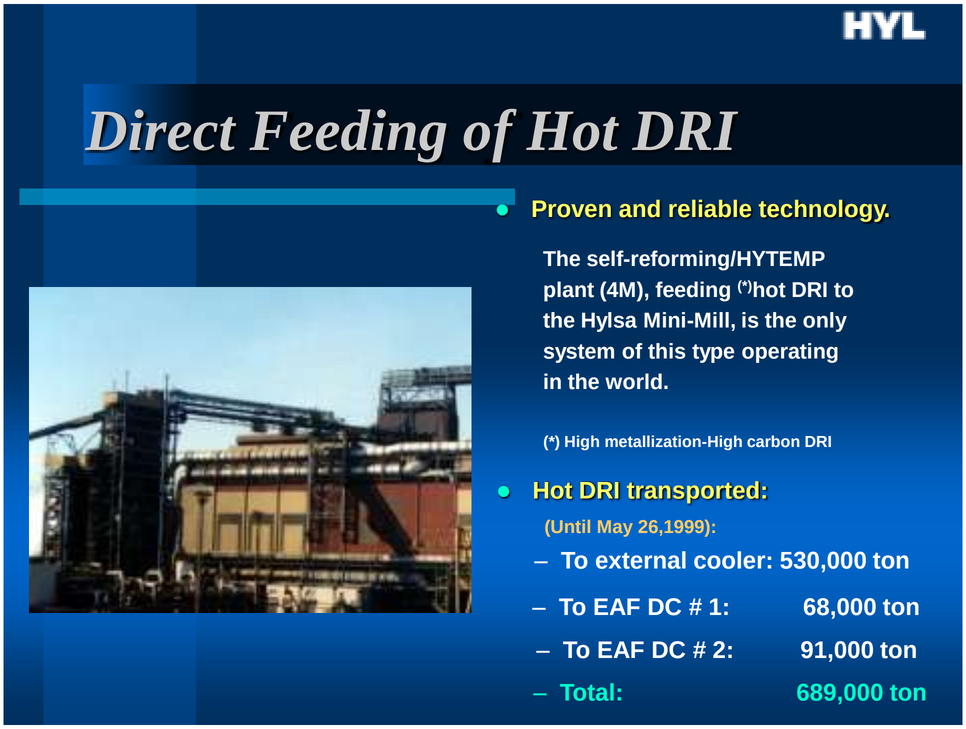
On the other hand, based on the largest casters available in the market, a single HYL reduction unit of 1,500,000 ton/year of DRI can fulfill the metallic charge requirements of a single line mini-mill, using high carbon-high temperature DRI. This scheme is the optimum solution in modern steelmaking, and is supported by the industrial experience of the Hylsa Monterrey plant.



According to the comparison of liquid steel production costs, as well as the productivity impact with different types of metallic charge, presented in this document, the following conclusions can be made:

- The liquid steel costs decrease proportionally to the level of temperature and carbon in the DRI.

- The EAF productivity is increased with higher levels of temperature and carbon in the DRI.



There is no doubt that the direct feeding of high carbon-high temperature DRI is a break-through in the steelmaking industry, and is also a revolutionary concept in the operating practices in flat products mini-mills.

Moreover, a very important fact is that HYL is providing a proven and reliable technology. The self-reforming/HYTEMP plant (4M), feeding high carbon-high temperature DRI to the Hylsa mini-mill, is the only system of this type operating successfully in the world.

Up to May 26, 1999, about 700,000 ton of hot DRI have been transported pneumatically to the following users:

- External cooler: 530,000 ton, since April, 1998.

- Fuchs EAF: 68,000 ton, since December, 1998.

- Danieli EAF: 91,000 ton, since April, 1999.

HYL

The Mini-Mill of the future is in operation now……




Hylsa Flat Products Division
Monterrey, Mexico