High Carbide Iron – Economical Solution for Russian Merchant DRI Supply

Metal Bulletin

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First: About Our New Name, Logo and Trademark…

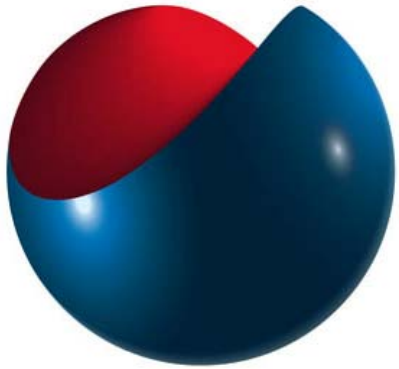
- HYL Technologies became part of Techint Technologies in 2005.
- Techint Technologies is now called Tenova

The ENERGIRON Alliance

- HYL Technologies, now known as Tenova HYL, has joined with Danieli to create the new Key Player in the DR plant market.
- ENERGIRON is the innovative HYL direct reduction technology, jointly developed by Techint/Tenova and Danieli.
- This strategic alliance allows the companies to join their own know-how and technology for the design and construction of Gas Based DR Plants worldwide, under the new ENERGIRON trademark.

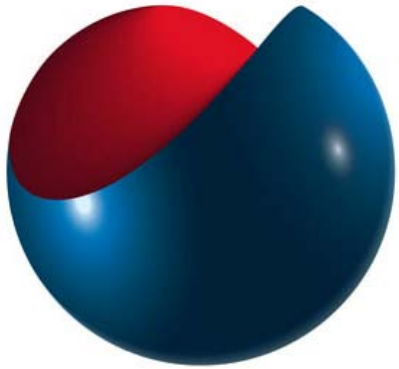
The ENERGIRON Alliance

- Together, HYL and Danieli can offer any project approach; from any size DR plant to a complete integrated minimill facility; from technology packages to EPC turn-key projects.
- The new trademark highlights the high energy content of the final product from the offered technologies, which are also able to process multiple typologies of iron ore, including high sulfur ores and employ reducing gases as different as natural gas, syngas and coke oven gas.



INDUSTRY OVERVIEW
2006 – A Year of Growth

- Steel production
  - Worldwide – 1,217,400 tons
  - CIS – 119,455 tons (9.81% of world output)
- EAF steel route
  - Worldwide – 33.2%
  - CIS – 14.6%
- DRI production
  - Worldwide – 59.8 Million tons
  - CIS – 3.28 Million tons (5% of world output)
- Merchant DRI/HBI
  - CIS – 100%



Perspective for Future Growth

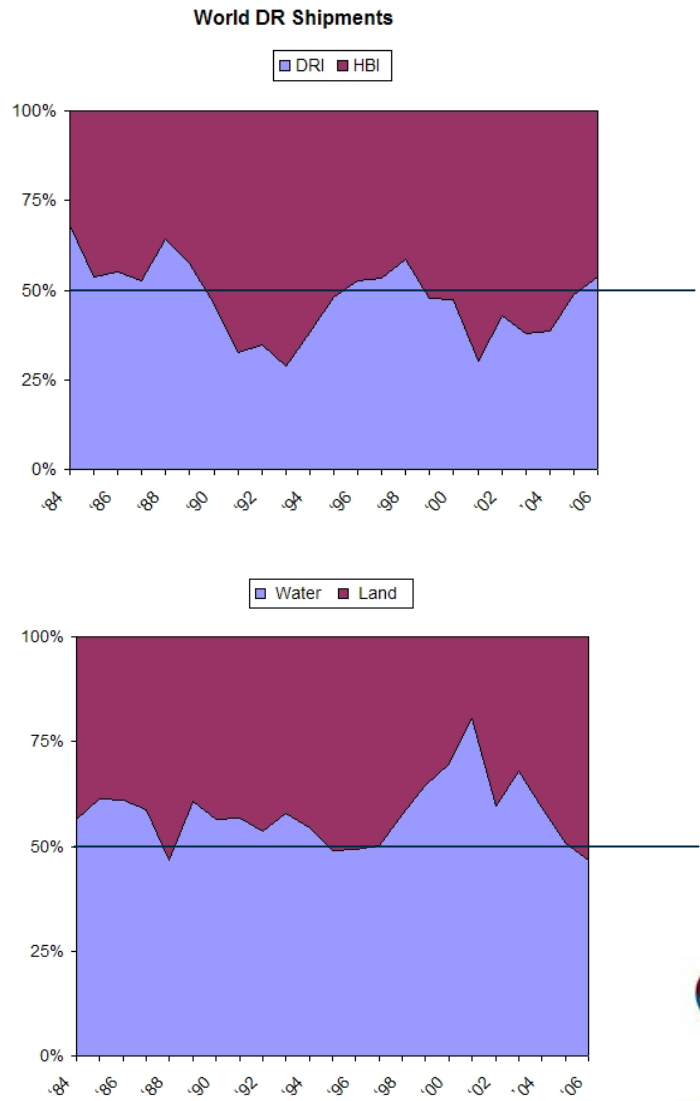
- Modernization will increase Russia's EAF share from 14.6% to reach world average of 33%+
- While the trend in recent years for DRI is for onsite production and hot charging to the electric furnace shop, there is a continuing market for merchant product.
- DRI production as merchant product can see significant growth
    - Minesite production is practical and cost-effective
    - Potential market (domestic alone) is very large

DRI vs. HBI

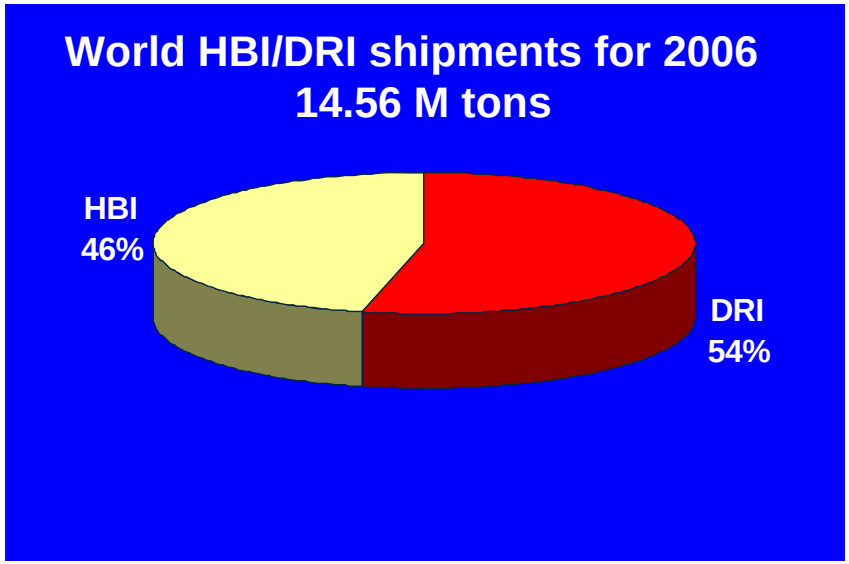
- Two different forms of the same product:
  - DRI is the traditional form, in either pellet or lump ore form
  - HBI is compressed DRI
- Two different uses (theoretically) :
  - DRI is for onsite production and use in EAF meltshops
  - HBI is for commercial shipment to customers worldwide, usually by sea
- HBI is the form adopted for merchant sale of reduced iron, since it is deemed safer for shipping and handling

The Reality: World DR Shipments

- Shipments of product historically includes both DRI and HBI
  - Shipments tend to average 50% for either product form
  - Shipments by land or sea are also usually 50% for each
- If DRI can safely be shipped, then the cost of producing HBI has to be justified.
- Cost of producing HBI is $6-15 per ton higher than for DRI.



Market Scenario



- Based on experience from HYL and other producers, DRI shipments are mainly characterized by the following target markets:
- For internal use in mills with own DR plants.
- For regional export - land transport.
- Particular shipments from own plants with own harbors to other own plants with own harbors.
- As merchant product from some plants.

Merchant Product

- To define the most suitable product for export, we need to take into consideration:
  - Production and investment cost
  - Stability of the product
  - Yield due to fines generation and losses during handling and transport
  - Suitability for safe transport
  - Use and benefits in meltshops
  - Merchant market trend

Energiron Technology

- Energiron technology is uniquely flexible in terms of energy requirements. The plant can either carry out reforming of natural gas within the reduction shaft furnace, or the reformed gas can be supplied externally.
- The main difference between both schemes regarding product characteristics is the carbon content in DRI:
  - ✓ Carbon content when using external reformer:
    - 0.8 – 2.5% (more suitable for HBI, yet not best for EAF)
  - ✓ Carbon content when reforming in the shaft furnace:
    - 2.5 – 5% of which > 90% in form of cementite or Fe_3C- iron carbide (ideal for the EAF). No other technology can offer “high” carbon above 2%.

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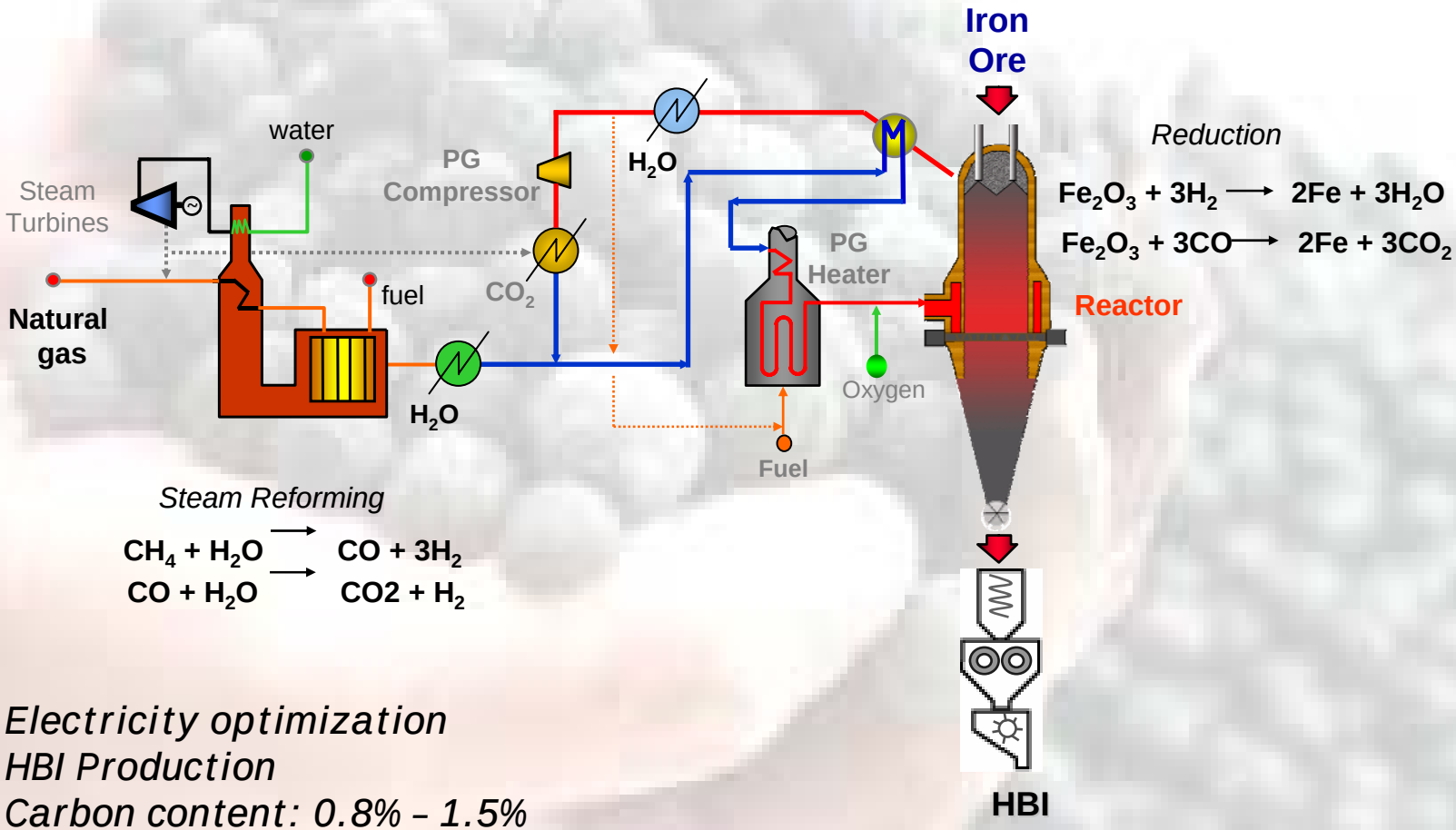
Technical Overview
Plant configuration: Scheme with Reformer for HBI



- *Electricity optimization*
- *HBI Production*
- *Carbon content: 0.8% – 1.5%*

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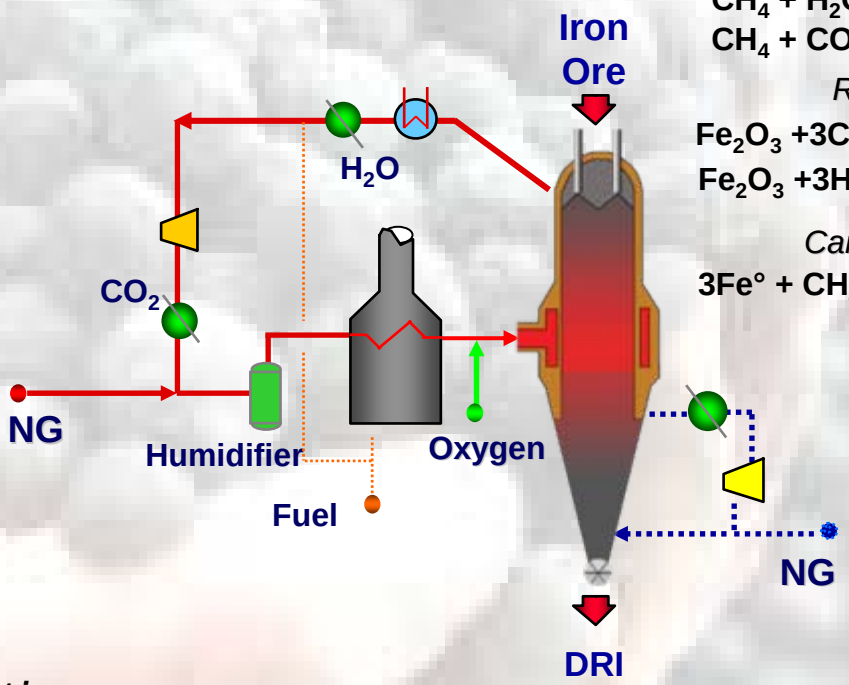
Technical Overview
Plant configuration: Scheme w/o Reformer for DRI

- **The scheme w/o reformer is characterized by the following features:**
  - ✓ Partial combustion of the reducing gas.
  - ✓ "In-situ" reforming of CH_4 in the lower part of the reduction zone.
  - ✓ Adjustable composition of the reducing gas to control DRI metallization and carbon.



In-situ Reforming

$CH_4 + H_2O \rightarrow CO + 3H_2$

$CH_4 + CO_2 \rightarrow 2CO + 2H_2$

Reduction

$Fe_2O_3 + 3CO \rightarrow 2Fe° + 3CO_2$

$Fe_2O_3 + 3H_2 \rightarrow 2Fe° + 3H_2O$

Carburization

$3Fe° + CH_4 \rightarrow Fe_3C + 2H_2$

- *NG optimization*
- *High-Carbon DRI Production*
- *Carbon content: 2% – 4.5%*

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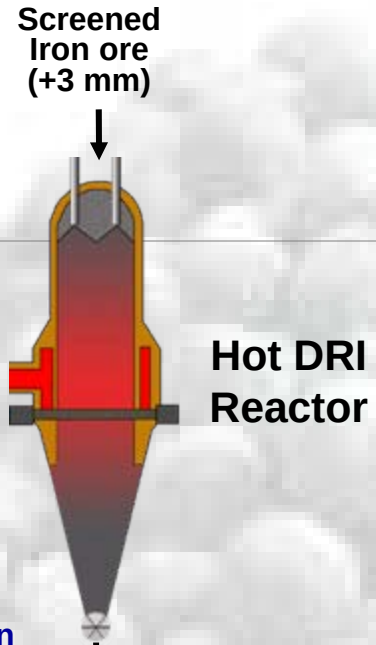
HBI Plant Yields



From pellet plant: 267 t/h
Screened Pellets: 258 t/h

Consumption per
Saleable HBI
including chips: 1.44 t/t

Note: As per IMO regulations: DRI/HBI product: +4 mm

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High-C DRI Plant Yields

Screened Iron ore (+3 mm)

From pellet plant: 270 t/h
Screened Pellets: 261 t/h

Consumption per Saleable DRI: 1.45 t/t DRI

Cold DRI Reactor

DRI
94% Mtz
4% Carbon

196 t/h

Note: As per IMO regulations: DRI/HBI product: +4 mm

About 1% of the 7 m t/a pelletizing capacity

Fines -4mm
5%

10 t/h

To Pelletizing

DRI Product
+4 mm

For Shipment

186 t/h

Losses during transport:
~ 2%

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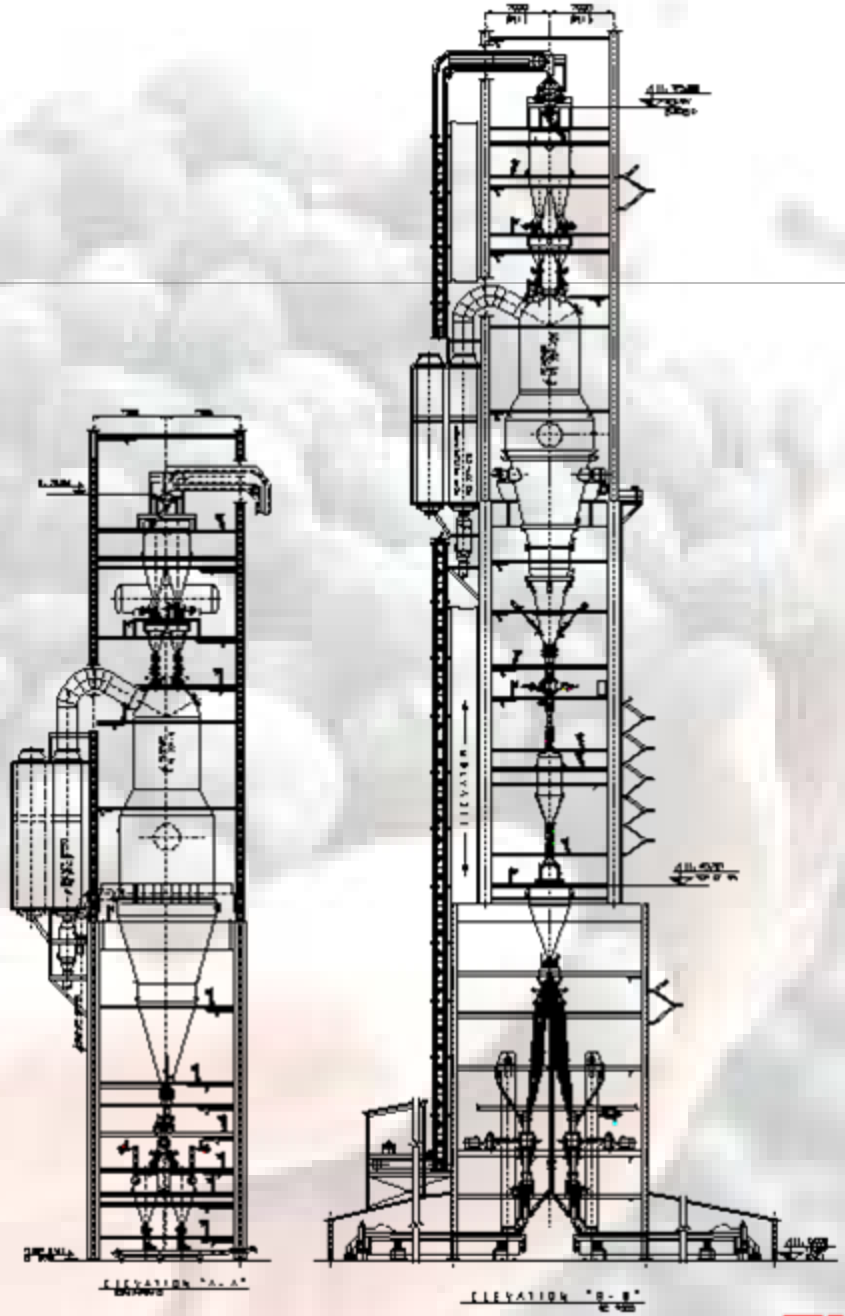
High-C DRI vs. HBI

Reactor Tower

Cap: 1.6 m tpa

DRI tower: 80 m
HBI tower: 125 m



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High-C DRI vs. HBI Production Costs

High-Carbon DRI vs. HBI Production Cost Analysis						
			ENERGIRON-ZR High-Carbon DRI		**Conventional HBI Plant**	
Metallization **Carbon**	**%** **%**		**94%** **4.0%**		**93%** **1.5%** based on published data	
Total DRI/Saleable	ratio		1.054		1.016	
	Unit	Price US$/unit	Consump. Unit/t Saleable DRI	Cost US$/t Saleable DRI	Consump. Unit/t Saleable HBI	Cost US$/t Saleable HBI
DR Plant						
Iron ore pellets	t	80.00	1.45	116.00	1.47	117.87
Lump ore	t	0.00	0.00	0.00	0.00	0.00
Natural gas	Gcal	3.00	2.44	7.33	2.40	7.19
Electricity	kWh	0.035	121	4.24	117	4.09
Oxygen	kWh	0.042	included	0.00	12.2	0.51
Water	m^3	1.60	1.21	1.94	1.55	2.48
Other consumables	US$			1.14		1.70
Maintenance	US$			3.3		7.1
Labour	m-h	8.00	0.12	0.95	0.15	1.20
Capital cost difference	US$					4.20
Total Saleable DRI/HBI cost FOB	**US$/t**			**134.87**		**146.36**
Transport-Insurance cost diff.	US$/t			3.00		
Including transport losses CIF	**US$/t**		*2% losses*	**140.63**	*0.5% losses*	**147.09**

Note: All Consumption figures are affected by the ratio of Total DRI/Saleable Product

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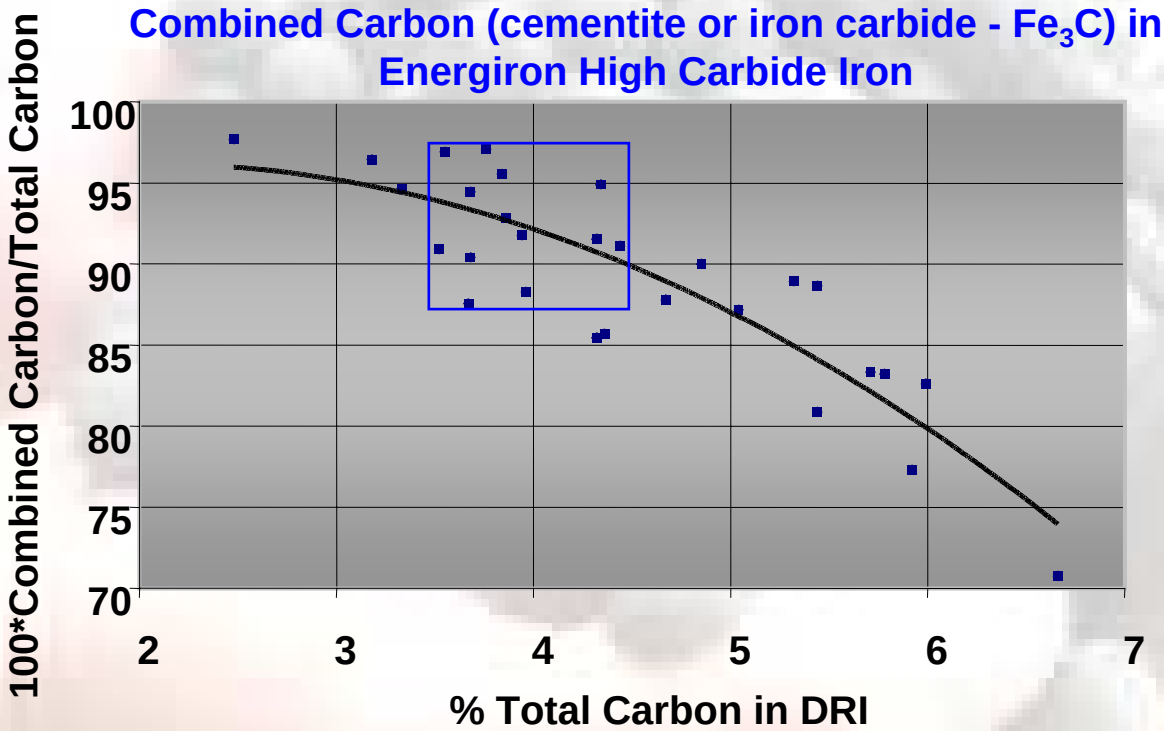
High-Carbon DRI



DRI Analysis – 4M Plant:

Metallisation	94%
Carbon	4%
Fe°	83.0%
Fe Total	88.3%
Fe_3C	55.1%
Gangue	6.2%

- ✓ A DRI with 4% Carbon contains more than 50% of Fe_3C.
- ✓ The high percentage of Fe_3C in the DRI of the 4M plant makes the product very stable.
- ✓ Most of the Carbon in the DRI is present as Fe_3C, for a Carbon content of 4% approx. 95% of it is present as Fe_3C.
- ✓ Every 1% of combined Carbon corresponds to 13.5% of Fe_3C.

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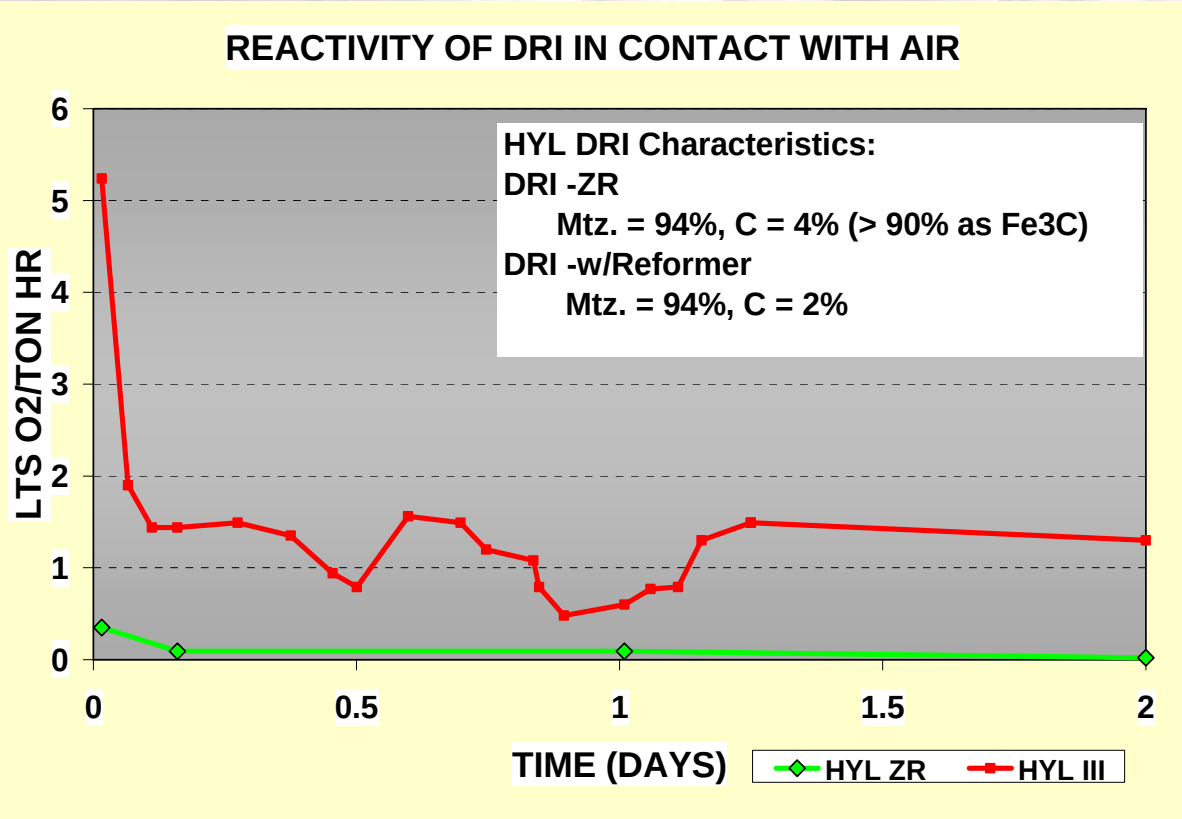
Effect of High Carbon

- High carbon content in DRI, especially in chemically combined form (iron carbide) has significant advantages:
  - ✓ For steelmaking, it provides a source of chemical energy, reducing steelmaking costs and improving furnace yields
  - ✓ It increases product quality
  - ✓ It is more stable than conventional DRI, making it easier to store and transport

High Carbide Iron vs. conventional DRI

- In general, High Carbide Iron is more stable than conventional DRI. This has been proven through specific tests.



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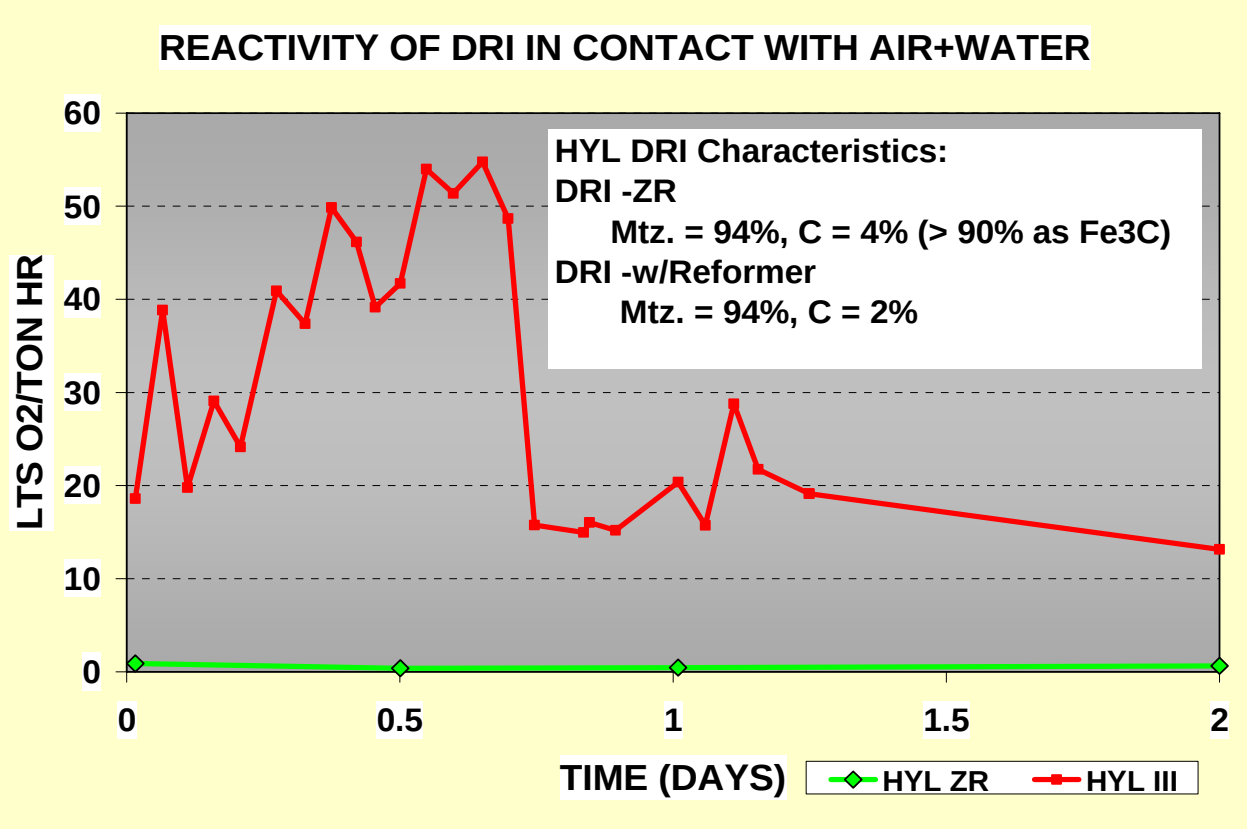
High Carbide Iron vs. conventional DRI

- DRI samples from Ternium Hylsa 3M5 plant before and after conversion to ZR Scheme for high carbon DRI. Note samples before were 2% - what others consider to be “high carbon”.



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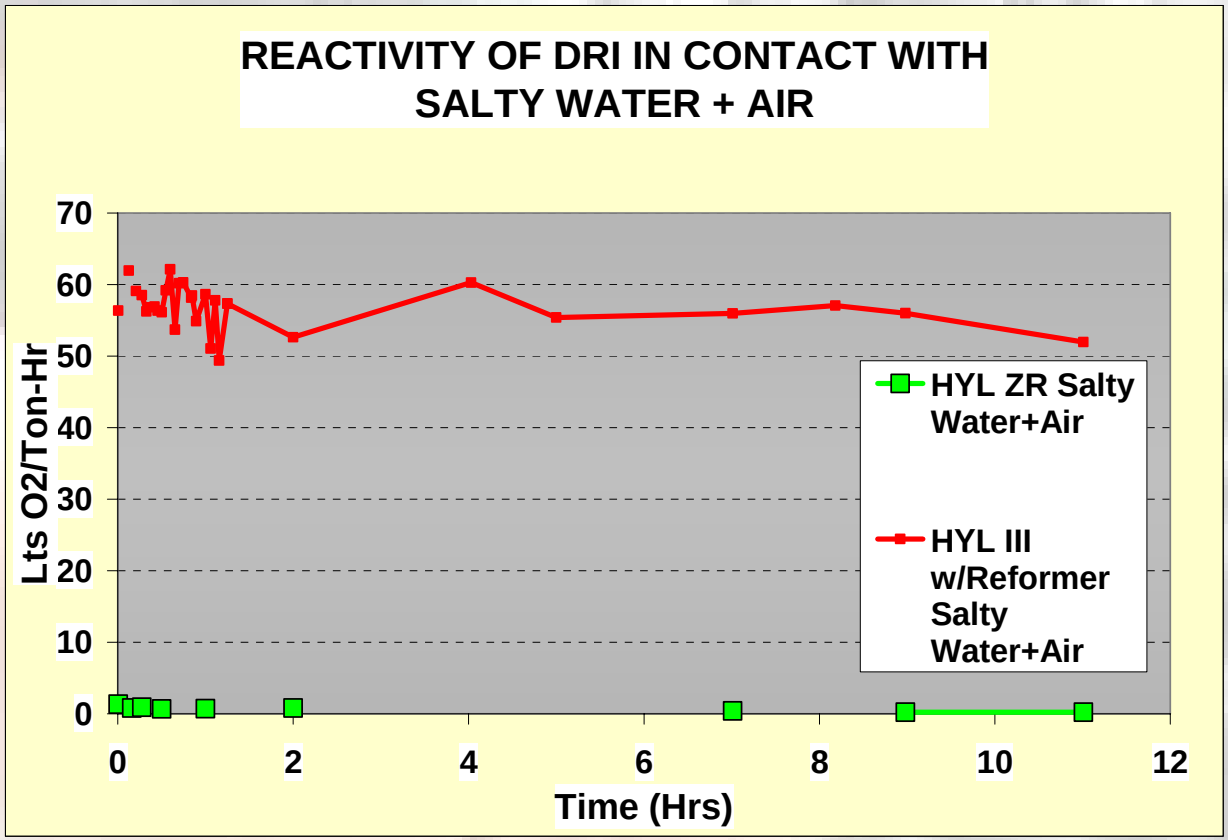
High Carbide Iron vs. conventional DRI

- These test results with salty water are of relevance due to the low risks for High Carbide DRI overseas transportation.



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Stability from High Carbon

- This means that High Carbide Iron is not only a more desirable product for steelmaking than conventional DRI, but it is safer to transport as a merchant product.
- The density of HBI briquettes, defined as 5.2 grams/cm3 is a limiting factor in the carbon content of HBI. The lubricating effect of carbon impedes the formation of briquettes for carbon levels near or above 2%.

High-C DRI vs. HBI: Comparative Analysis

Item	High-Carbon DRI	HBI
Product stability	The High-carbon DRI produced by ZR plants is significantly more stable than conventional DRI. The stability of High-Carbon DRI is due to the high Fe_3C content (about 55%).	The high stability of HBI is due to the low exposed surface.
Degradation during handling **Yield**	Mechanical behaviour for both, High-C DRI and conventional DRI is similar. More fines generation and losses during handling as compared to HBI. Due to higher C in the DRI, total Fe is about 90%.	HBI is the DRI product with the highest strength. Minimum losses during handling. Total Fe in HBI is about 92% For this analysis, chips of -9+4mm have been considered as product at the same value, even though its price may be lower.
Special adaptations at consumer's storage/handling	DRI can be charged in any existing EAF by batch charging or continuous feeding. In case of batch charging, DRI is charged together with scrap, reducing the no. of back charges.	HBI can be used in mills in a similar way as scrap. It requires additional EAF opening for sequential charges.

DRI vs. HBI: Comparative Analysis

Item	High-Carbon DRI	HBI
DR/Plant Investment Factor	Simpler plant configuration Lower investment	More complex plant Additional reformer and briquetting system About 15 - 20% more
Production cost	Lower than HBI. Additional savings per tonne of liquid steel for the steelmaker	About US$ 10/t more
Maritime transport conditions Insurance cost	Special provisions for maritime transport as per current IMO guidelines Insurance cost about US$3/t higher than HBI.	More relaxed IMO restrictions Lower insurance cost
Inland transport	Railroad and truck shipment, without major problems	No problems for RR and truck transport

DRI vs. HBI: Comparative Analysis

Item	High-Carbon DRI	HBI
Product value: Melting in EAF	High-C DRI provides additional energy to the EAF due to high Fe_3C content thus requiring less power for melting as compared to HBI (about 100 kWh/t) and time. Lower or no coal injection. Easy generation of foamy slag resulting in lower electrodes and refractories consumption. Total benefits in EAF costs (for 100% charge) are about US$3/t liq. steel as compared to HBI. DRI charge can be up to 100% in the EAF.	HBI requires more power and time during melting in EAF as compared to High-C DRI. External coal injection (with lower yield) if oxygen is used. There may be limits for high percentages of HBI in the EAF charge; typically it is about 30%.
Transport losses loading/unloading	About 1-2% depending on pellets characteristics.	Negligible (about 0.5%).
Total iron ore consumption for merchant plants	For DRI of 94% Mtz and 4% carbon: 1.45 t/t	For HBI of 94% Mtz and 1.5% carbon: 1.44 t/t (including chips of -9+ 4 mm)

Overall Comparison

- The size of an HBI plant is significantly larger when compared to an Energiron ZR plant for high carbide iron production.
  - ✓ Both reactor tower and overall plant area are larger for HBI plants
  - ✓ Capital expense is thus higher
- Production costs per ton of product are also higher for producing HBI.
- Due to the high stability of the High-C DRI, there are minor differences as compared to HBI regarding stability, handling and transport. The only factor for which the first was relatively lower is the additional insurance cost due to current IMO regulations for transporting DRI and HBI overseas.
- The lower capex and operating costs as well as higher product quality make high carbide iron the better choice.

Final Remarks

- Based on available and proven Energiron technology and current industrial experience, Danieli and HYL are in a unique position to offer:
  - Merchant plants based on ZR scheme for high-Carbon DRI.
  - Merchant plants, based on reformer scheme designed for HBI production applications.
- Based on the comparative analysis included in this presentation, Danieli and HYL strongly recommend:

  ✓ High-Carbon DRI
- In this regard, the high-Carbon DRI is a product of relevant importance to be considered as merchant commodity due to its high stability. It is expected that transport insurance cost will be decreased once IMO defines a new category for this product.

thank you

tenova
HYL