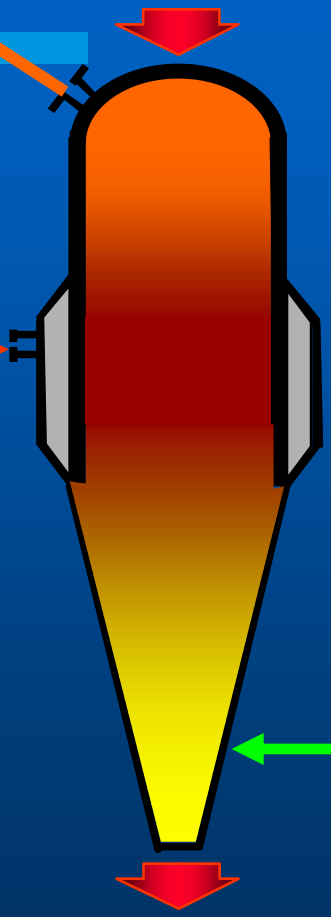
HYL Direct Reduction Process

Flexibility in Using Iron Ores for Direct Reduction

Raul G. Morales
Commercial Manager
HYL Technology Division

HYL DR Process



REDUCTION

$Fe_2O_3 + 3H_2 \longrightarrow 2Fe + 3H_2O$

$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

CARBURIZATION

$3Fe + CH_4 \longrightarrow Fe_3C + 2H_2$

$3Fe + 2CO \longrightarrow Fe_3C + CO_2$

GAS COMPOSITION

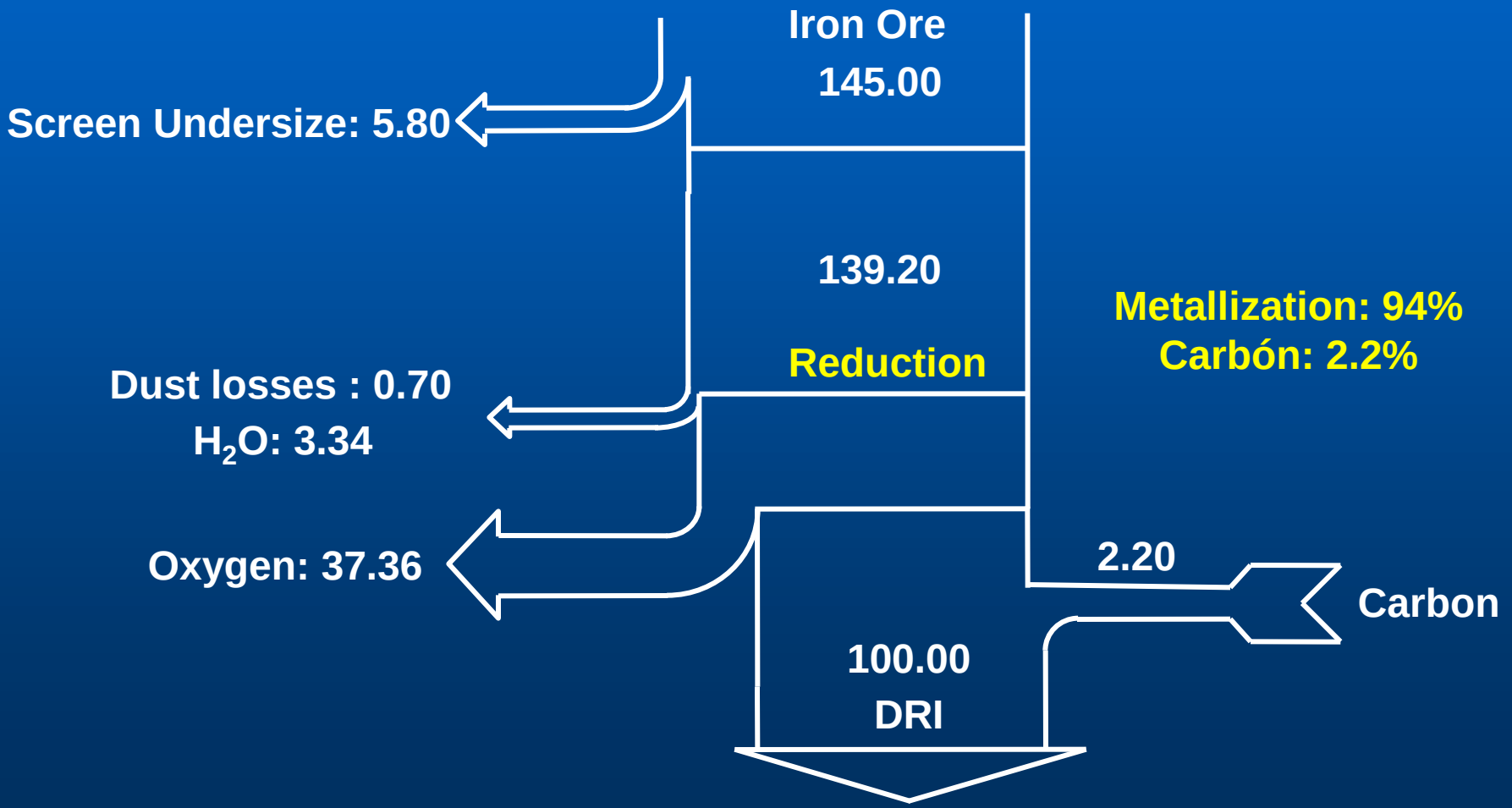
H_2 : 70-87%

CO: 5-16%

PRESSURE: > 5.5 kg/cm²

TEMPERATURE: > 920 °C

Typical Material Balance



DRI Production Cost

100% Pellets-International Price

Item	Unit (per ton DRI)	Consumption (per ton DRI)	Price (US$)/unit	Total Cost (US$)
Iron Ore Pellets	ton	1.42	42.00	59.64
Natural Gas	Gcal	2.40	8.75	21.00
Electricity	kWh	70.00	0.03	2.10
Water	m^3	1.50	0.20	0.30
Miscellaneous	US$		7.00	7.00
Direct production cost				90.04

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DRI Production Cost

70% Pellet/30% Lump Ore

Item	Unit (per ton DRI)	Consumption (per ton DRI)	Price (US$)/unit	Total Cost (US$)
Iron Ore Pellets	ton	1.02	42.00	42.84
Lump Ore	ton	0.43	37.00	15.91
Natural Gas	Gcal	2.40	8.75	21.00
Electricity	kWh	70.00	0.03	2.10
Water	m^3	1.50	0.20	0.30
Miscellaneous	US$		7.00	7.00
Direct production cost				89.15

DRI Production Cost

100% Pellets-Local Pelletizing

Item	Unit (per ton DRI)	Consumption (per ton DRI)	Price (US$)/unit	Total Cost (US$)
Iron Ore Pellets	ton	1.42	29.00	41.18
Natural Gas	Gcal	2.40	8.75	21.00
Electricity	kWh	70.00	0.03	2.10
Water	m^3	1.50	0.20	0.30
Miscellaneous	US$		7.00	7.00
Direct production cost				71.58

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HBI Production Cost

100% Cheap Lump Ore

Item	Unit (per ton HBI)	Consumption (per ton HBI)	Price (US$)/unit	Total Cost (US$)
Lump Ore	ton	1.50	18.00	27.00
Natural Gas	Gcal	2.50	8.75	21.88
Electricity	kWh	80.00	0.03	2.40
Water	m^3	1.60	0.20	0.32
Miscellaneous	US$		8.00	8.00
Briquetting	US$		3.50	3.50
Direct production cost				63.10

DR Grade-Iron Ores

Typical Range of Chemical Analysis

	(% weight)
Fe total	65.0 - 69.0
Gangue	1.40 - 7.00
Phosphorous	0.01 - 0.10
Sulphur	0.001 - 0.05
$SiO_2 + Al_2O_3$	1.1 0- 4.00
CaO + MgO	0.10-3.00
$Na_2O + K_2O$	0.05 - 0.20
CaO / SiO_2	0.02 - 1.50

Iron Ore Quality

	Pellet A	Pellet B	Lump A	Lump B
Fe Total	68.00	67.80	68.10	67.50
FeO	0.10	0.60	1.61	1.15
CaO	0.70	0.52	0.44	0.50
MgO	0.30	0.57	0.10	0.50
SiO_2	1.08	1.56	0.47	1.00
Al_2O_3	0.60	0.34	1.24	1.00
S	0.003	0.005	0.002	0.007
P	0.018	0.023	0.030	0.030
Others	0.09	0.12	0.03	0.09
L.O.I.	-----	-----	0.50	0.50
Gangue	2.79	3.14	2.81	3.63

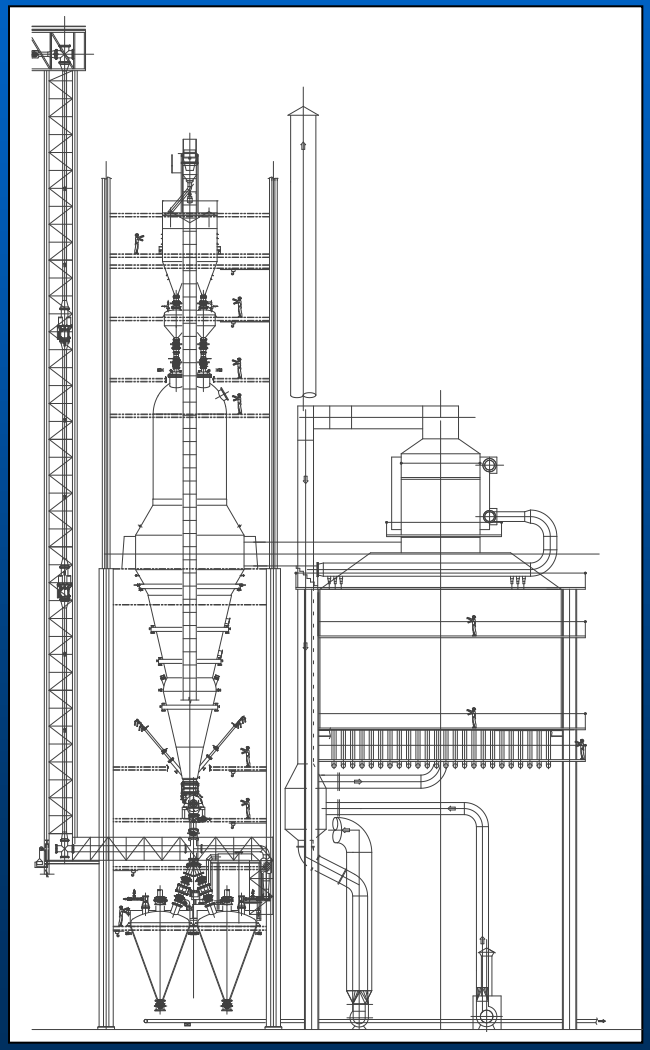
DRI/HBI Quality



Metallization (%)	**92.0-95.0**
Carbon (%)	**1.10-5.00**
Total Fe (%)	**84.0-95.5**
Metallic Fe (%)	**80.0-90.0**
Gangue (%)	**1.90-9.10**
P (%)	**0.013-0.14**
S (%)	**0.001-0.07**

Iron Ore Behavior in DR

- **Main Reduction Properties:**
  - Reducibility
  - Sticking Tendency
  - Low Temperature Disintegration



Iron Ore Evaluation



- Laboratory
- Pilot Plant
- Basket Tests
- Industrial Scale (Slices)
- Full Industrial Scale

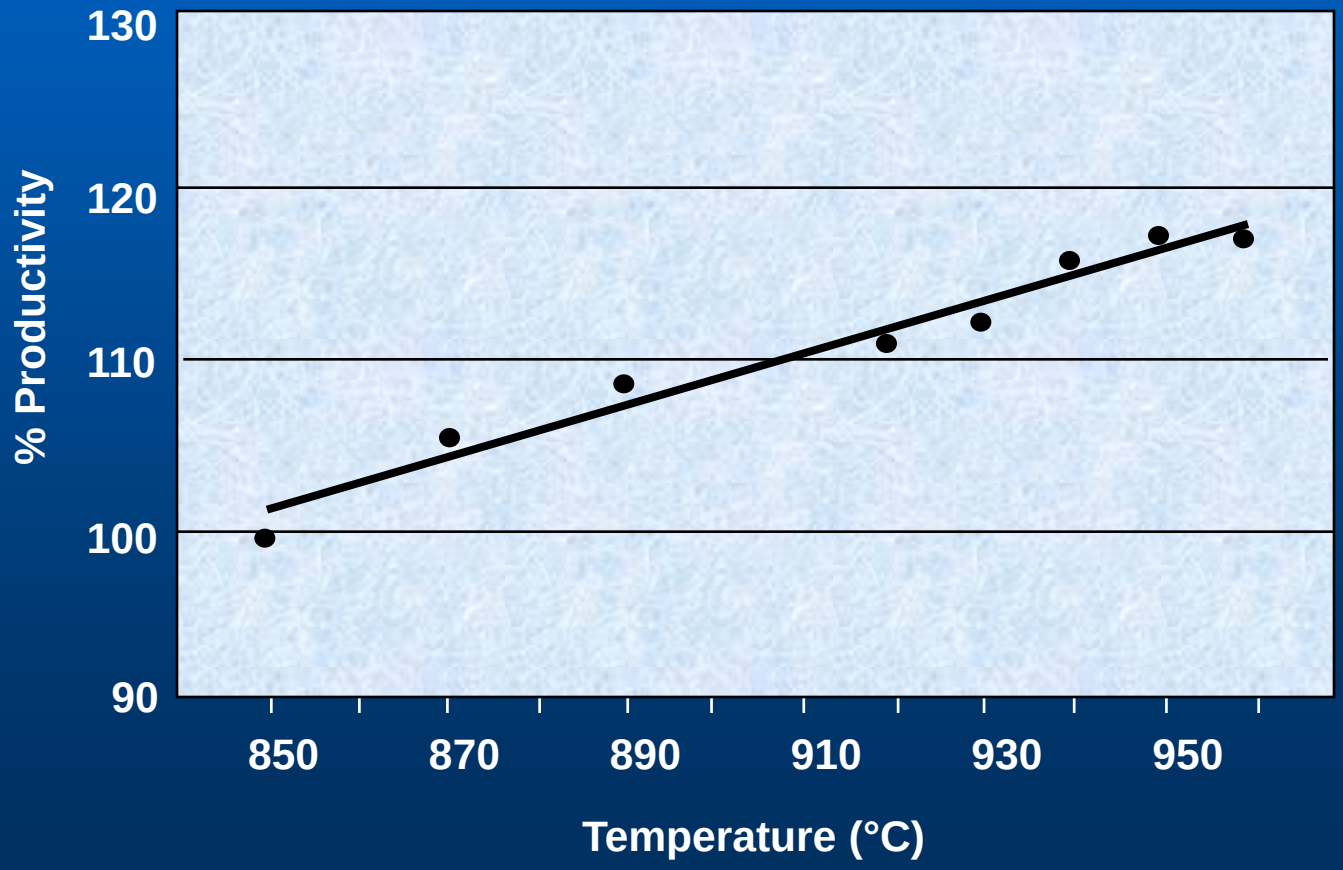
Process Parameters

Reduction Temperature:

- At higher temperature the plant productivity is increased, and the energy consumption is minimized.
- In any DR process, the highest operating temperature could be limited by the iron ore sticking tendency.
- HYL plants operate at reduction temperatures up to 980-1,020 °C.



Effect of Temperature



Process Parameters

Operating Pressure:

- The operation at high pressure allows the feeding of larger mass flowrates for the same volume flowrate.
- For a given reactor diameter, the reducing gas velocity is lower. Fluidization conditions are improved.
- Operation with friable ores can be carried out in better conditions.



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Process Parameters

Reducing Gas Composition:

- Reduction with H_2 leads to faster reaction kinetics, lower sticking tendency and lower material disintegration.
- Operation with H_2 rich-reducing gases gives more flexibility for different iron ore qualities.
- The H_2/CO ratio in the HYL process is up to 9.5/1.



Iron Ore Pellets Used in HYL Plants

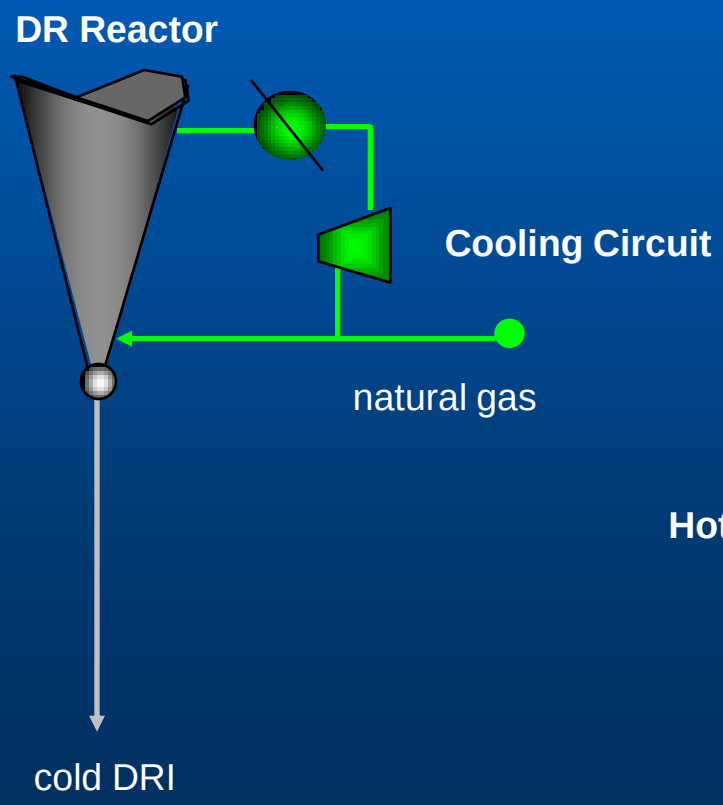
Pellet Source	2M5/3M5	IMEXSA	Grasim	PSSB	PTKS	Usiba	2P5	4M	Hadeed	LebGok
GIIC/Bahrain		●	●	●	●					
CVRD/Brazil		●	●		●	●			●	
Samarco /Brazil	●	●			●	●				
CMP /Chile		●		●	●					
Essar /India			●							
KIOCL /India			●		●					
Mandovi/India			●							
Alzada /Mexico	●						●	●		
IMEXSA /Mexico		●								
Peña Colorada /Mexico	●	●					●	●		
Sicartsa /Mexico		●								
Hierro Peru/Peru		●	●		●					
LebGok/Russia										●
LKAB /Sweden	●	●	●	●	●					
SIDOR /Venezuela	●	●								

Lump Ores Used in HYL Plants

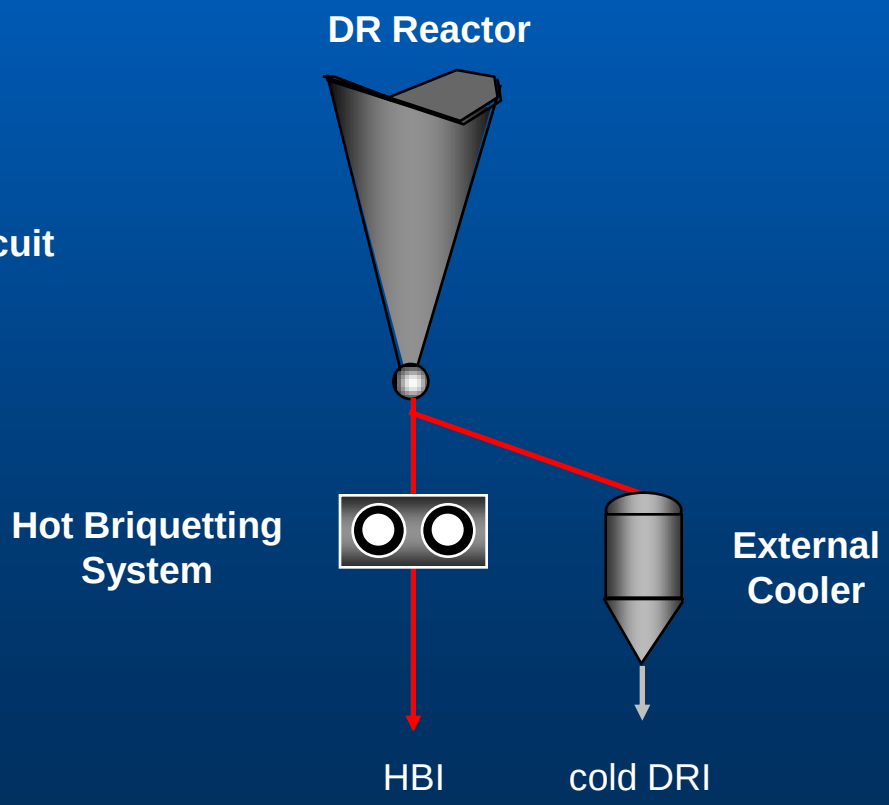
Lump Ore Source	2M5/3M5	IMEXSA	Grasim	PSSB	PTKS	Usiba	2P5	4M	Hadeed
Corrego /Brazil						◆			
Esperança /Brazil		◆							
Feijao / Brazil						◆			
Ferteco/ Brazil		◆	◆		◆	◆			
MBR/Brazil				◆		◆			◆
MBR-LORD /Brazil	◆					◆		◆	
MCR-Corumba /Brazil	◆							◆	
Mutuca /Brazil	◆	◆		◆		◆			
SARD-SAMITRI /Brazil			◆						
Bailadila /India			◆						
G.G. Brothers /India			◆						
Mineral Sales / India			◆						
NMDC /India			◆						
Private Parties /India			◆						
Belitung/Indonesia					◆				
Aquila /Mexico	◆						◆	◆	
Sishen /South Africa		◆	◆						
El Pao/Venezuela	◆								
Max. % of Lump Ore	100	30	50	30	15	75	20	70	30

Practical Cases

Usiba, Brazil--IMEXSA, Mexico (DRI)



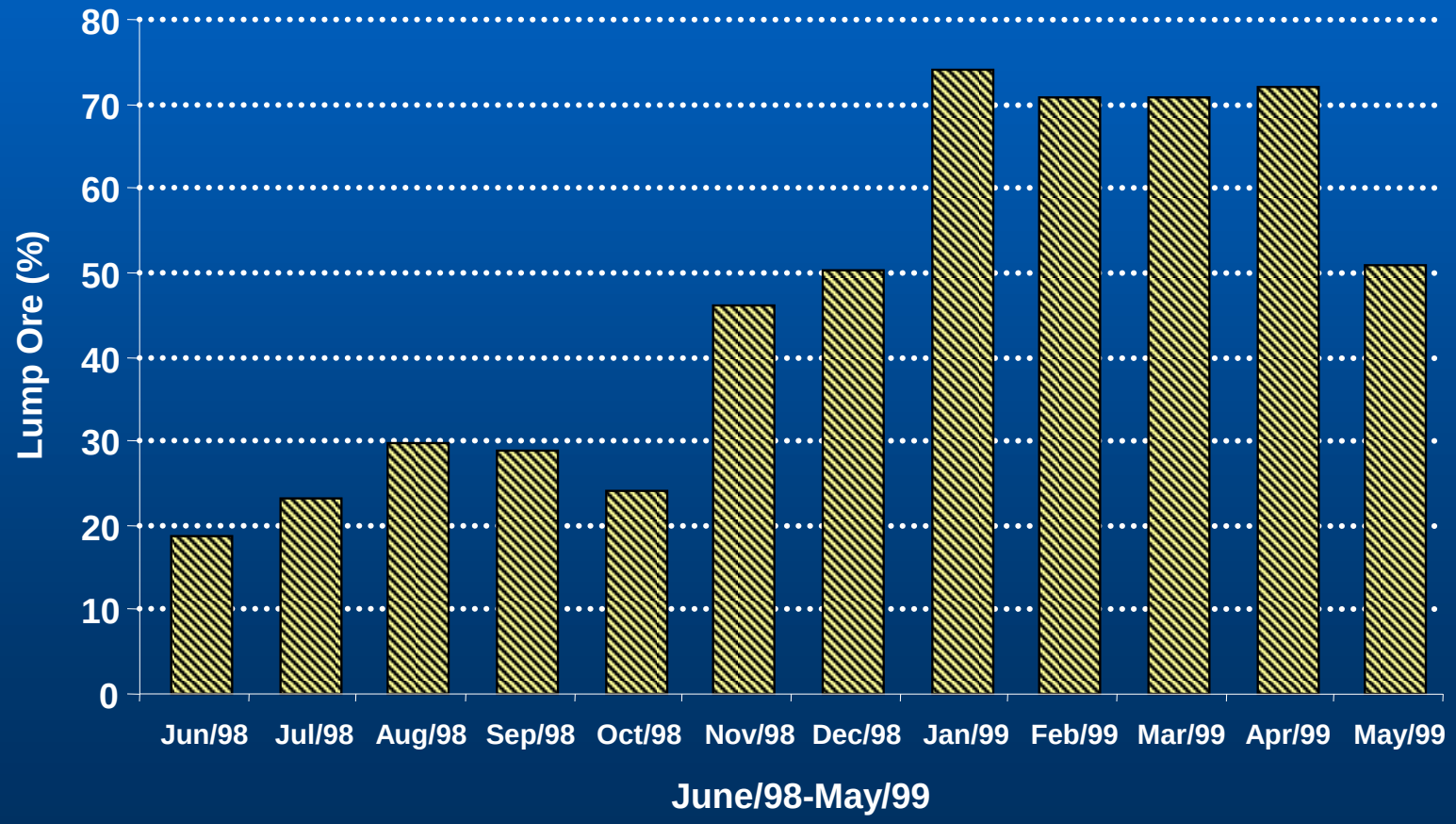
Grasim, India (HBI+DRI)



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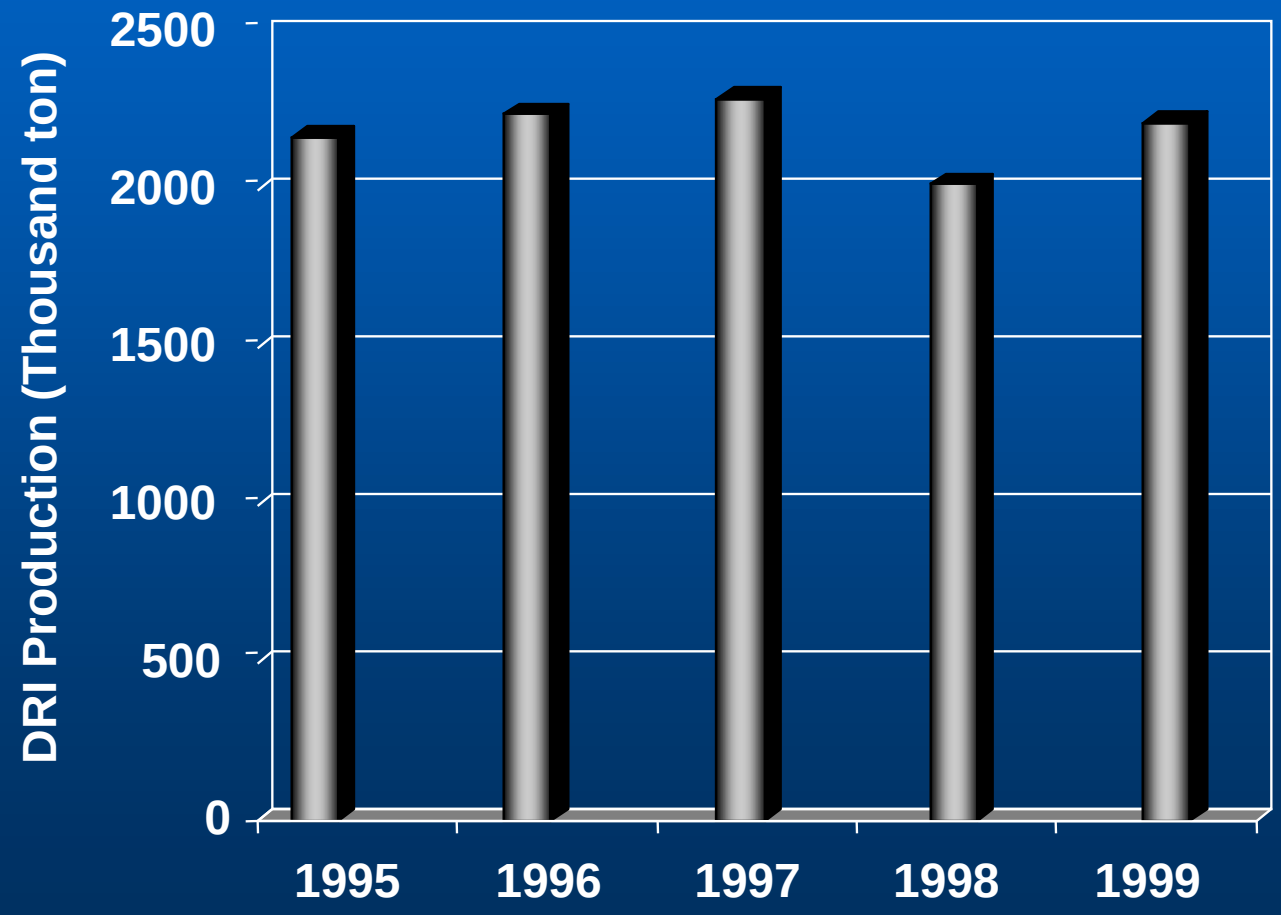
Usiba Plant

Lump Ore Utilization



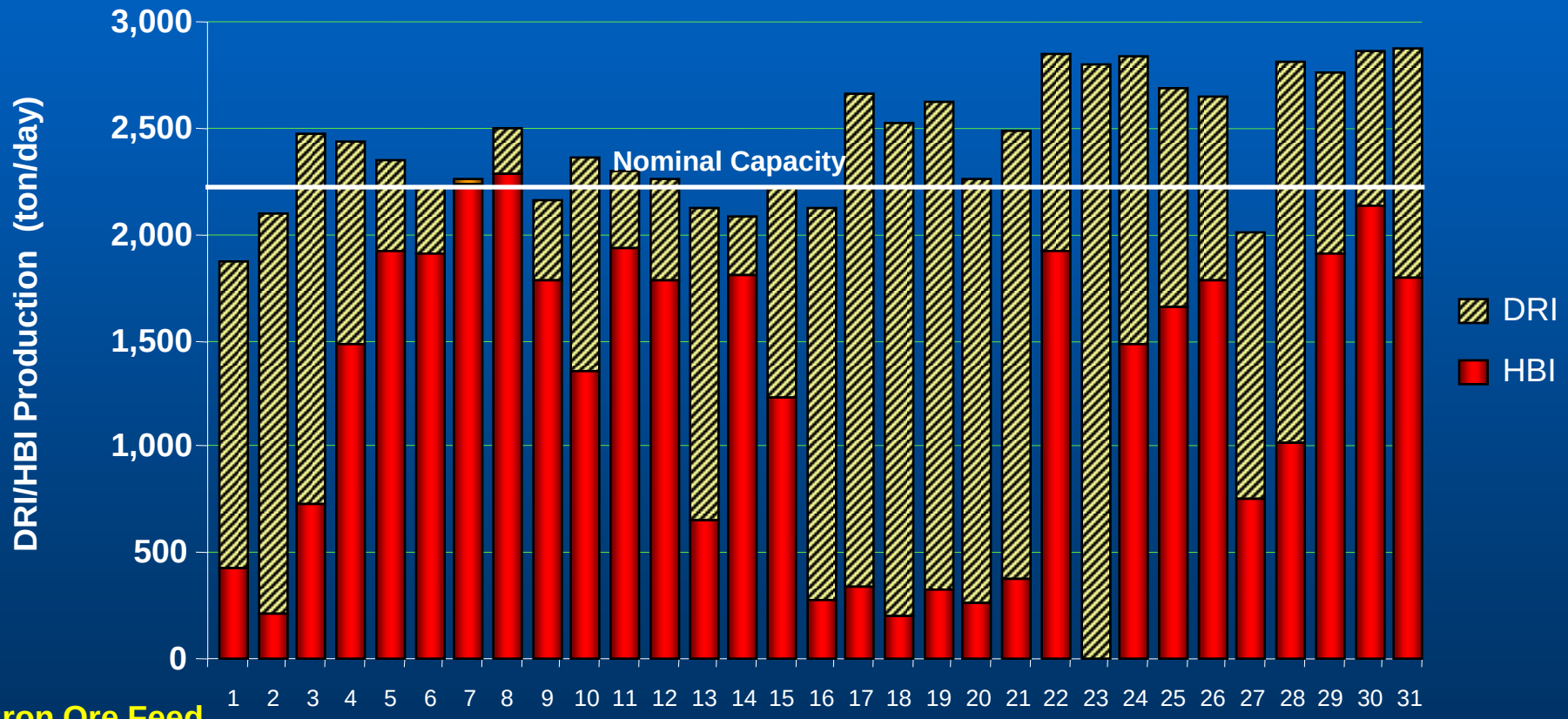
IMEXSA HYL Plant

Production Results



Grasim Plant

Production Results



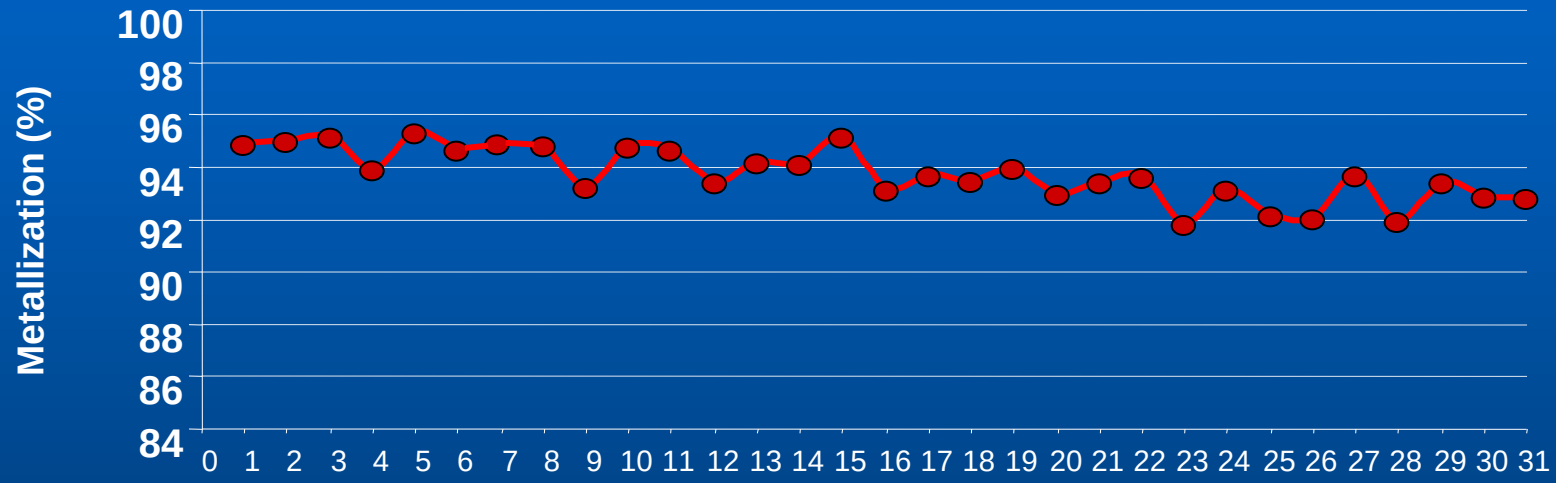
Iron Ore Feed

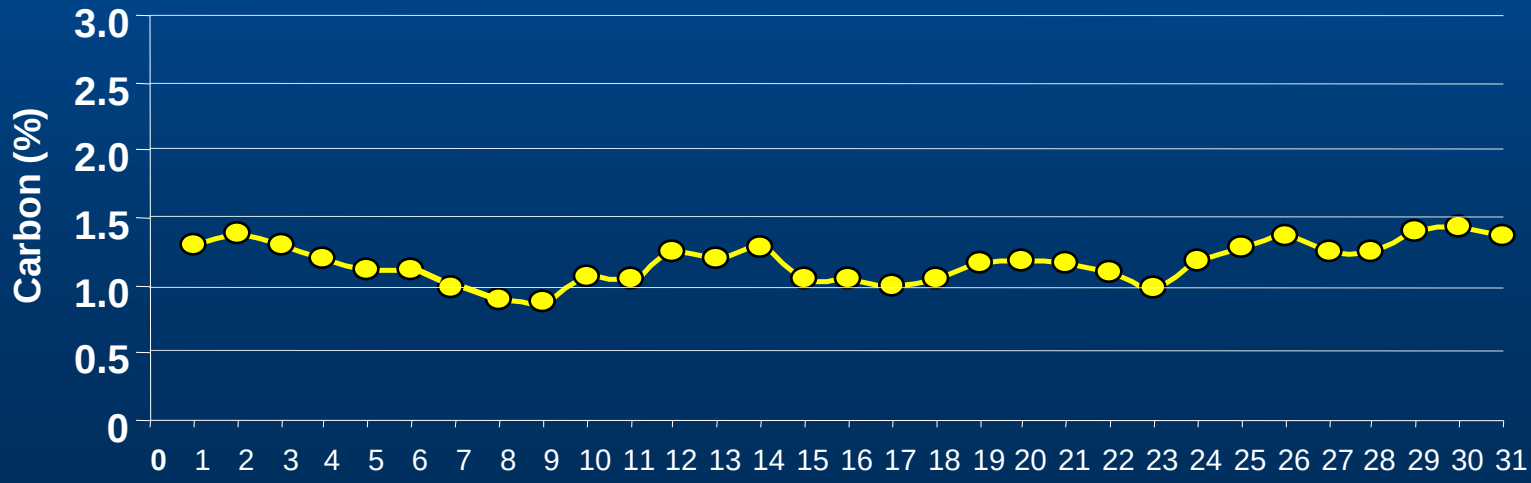
Pellets: 67%
Lump Ore: 33%

March 1999
Plant Productivity= 121%

Grasim Plant

Quality Results





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Conclusions



- The economic production of DRI/HBI is mostly influenced by the cost of iron ore.
- The flexibility of a DR process in the use of cheaper iron ores is a key factor.
- All the know how obtained through the HYL process evolution has given maturity and reliability to the plant design.