New Ironmaking Processes: Relevance to India

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Emerging Scenario in Iron Making

- More than 90% of world iron production is through Blast furnace technology route

- Driving forces: Alternative Ironmaking technologies
  - Costly and scarce coking coal: Need to look beyond coking coal
  - possibility to use iron ore fines directly
  - Land-constraint
  - Environmental considerations
    - eliminate pollution-intensive sintering and coke-making processes
  - Water scarcity
  - Large scale of economy
    - High capital cost
  - Scientific/ engineering knowledge to think/ design alternative processes

Possible Solutions: Alternatives for Ironmaking

1] Production of non-liquid Iron (DRI)

- Direct Reduced Iron (DRI) has emerged as an excellent substitute for scrap for electric furnaces.
- That's why, DRI production has zoomed throughout the world (`~63 mt in 2010)
- *SL/RN, MIDREX, ITmk3 etc.*

2] Alternative method for Liquid Iron (Hot Metal)

- Smelting Reduction (SR) processes:
- *COREX, FINEX, Hismelt etc*.
  - using non-coking coal
  - obviating the need for coke oven batteries and sinter plants
    - needing smaller land/ area
    - Iron ore fines can be used directly (except COREX)
    - Lesser pollution

DRI Production Technologies

- **DR processes have overcome many of theirs conceptual & engineering problems, and hence have been commercialized throughout the world in a big way.**

- ***Two major production technologies:***
  - **Coal Based Rotary Kiln process**
  - **~20% of world DRI production**
  - **SL / RN Process, Jindal Process, TDR etc.**

- **Gas Based Shaft Reduction processes**
  - **~80% of world DRI production**
  - **MIDREX (~60% among all DRI processes),**

DRI Technologies

- Both gas-based & coal-based DRI technology readily available
- Scale of operation
  - Gas based : 0.8 – 1.2 mtpa/module
  - Coal based : 0.03 – 0.15 mtpa/module
- Feed stock :
  - Gas based processes
    - Pellet (8-15mm): 33 – 100 %; Iron ore (6-30mm): 0 – 67%
    - Natural gas / Coal gas (not practiced yet)
  - Coal Based Processes (rotary kiln)
    - Iron Ore (10- 20 mm): 100%,
    - Non-coking Coal

•Any of these can be adopted based on techno-economics

•India : World Leader: ~ 20 mtpy: 1/3rd of world production

• India: Pollution specially rotary Kiln processes

New Scheme: Coal Gasification based DRI

Example: Angul Plant (6/12mt) of JSPL at Orissa

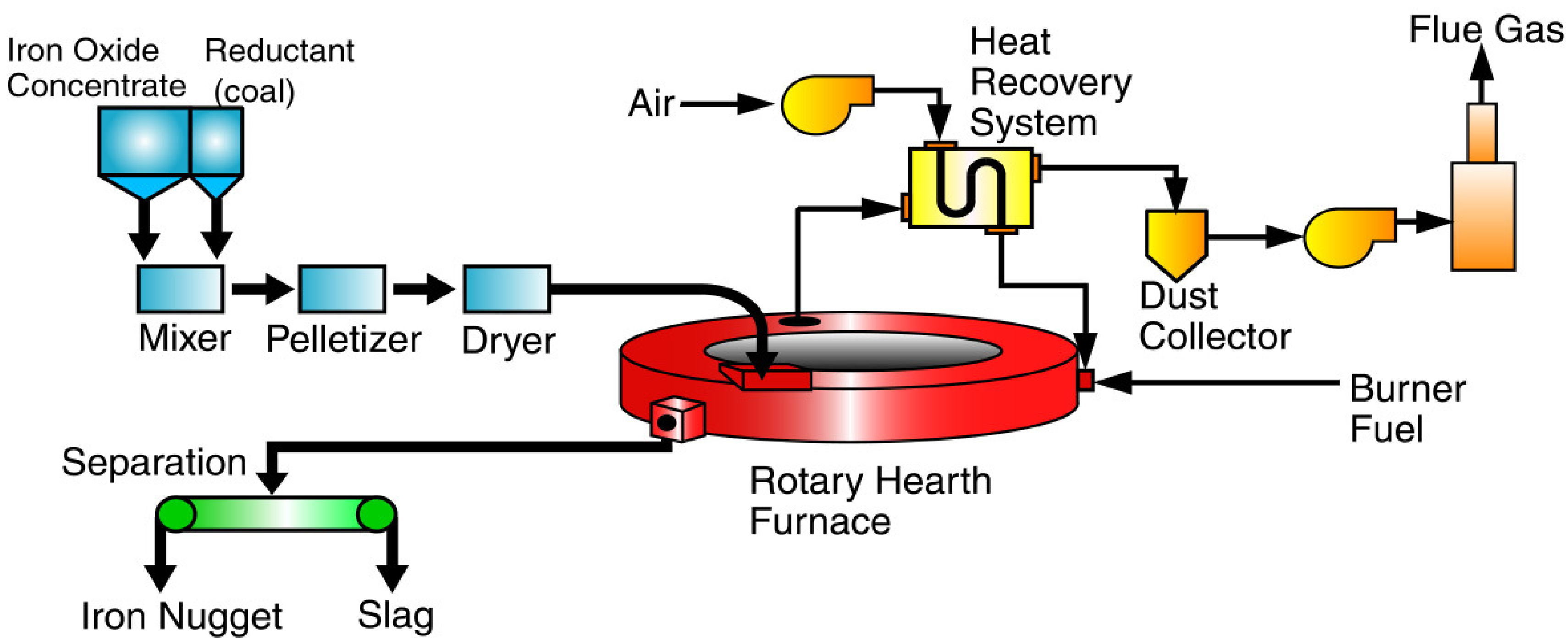
- **The DRI-BF-EAF route technology would be adopted for steel production.**
- **The DRI plant (2mt) has a unique feature of using Syn Gas from the coal gasification plant as reductant.**
- ***The DRI-Gasification route: first time in the world: using high ash coal.***
- **JSPL in agreement with Lurgi Sasol Technology Company, South Africa, for coal gasification technology.**

Blast Furnace and DRI can co-exist !

Cricket: Test, ODI and T-20

ITmk3 Process: Production of Iron nuggets

- Disadvantage in DRI: gangue remains within it
- Kobe Steel, Japan: ITmk3
- Ore + coal composite pellets: Reduction & melting at 1500C in RHF
- It produces almost low sulphur pure iron nuggets (& slag globules)
- 0.25 mtpy plant at Minnesota, USA



SMELTING REDUCTION PROCESSES
for
IRONMAKING

Advantage: Smelting Reduction Processes

- They produce hot metal; hence more relevant to BOF based Integrated Steel Plants
- Direct use of non-coking coal and Iron ore fines
- They need much less land as compared to conventional BF complex

Available Smelting Reduction (SR) Processes

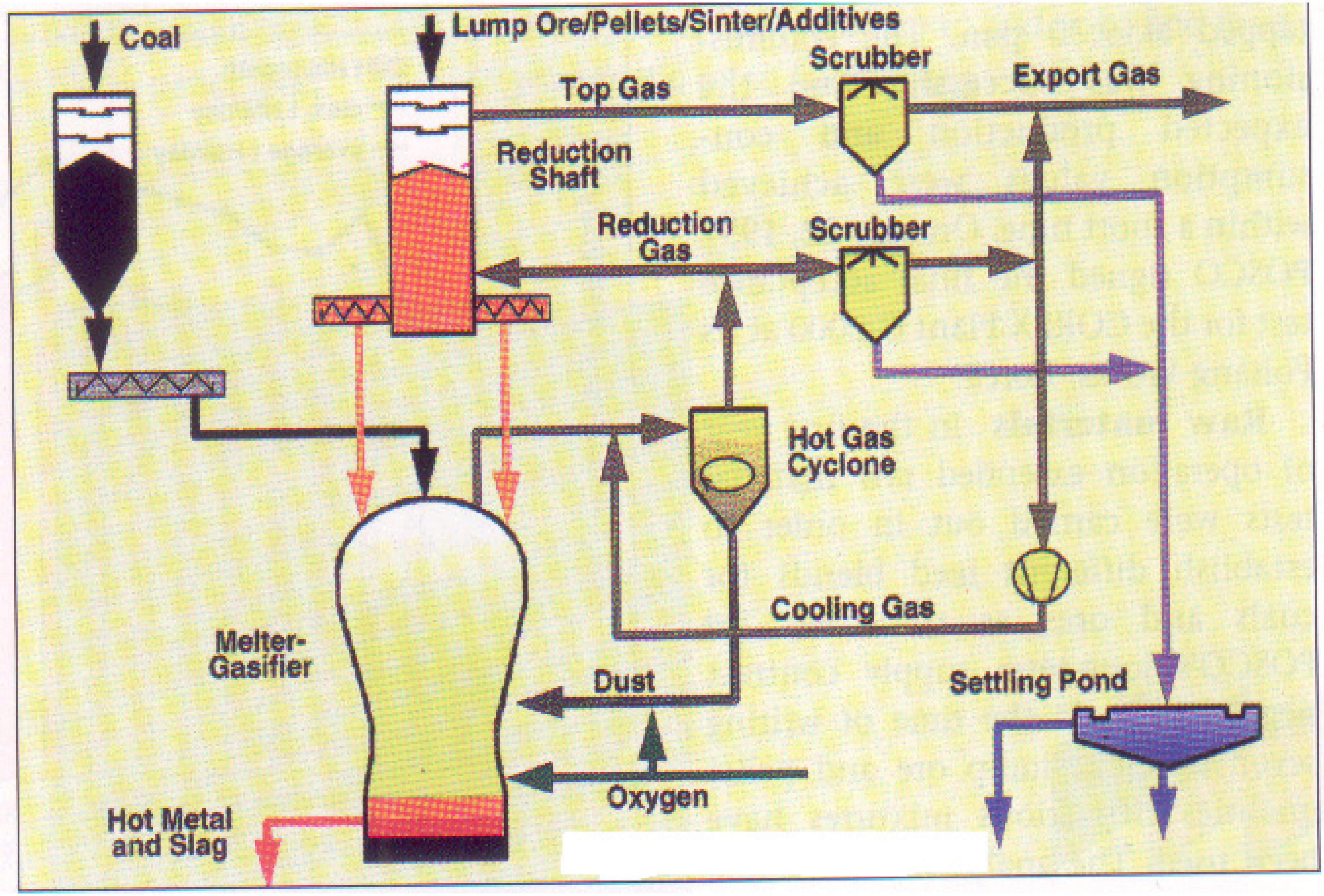
- 4 SR Technologies currently commercially exploited or ready for commercial exploitation

  - **COREX** (Two stage): Operating commercially
  - **FINEX** (Two stage): Operating commercially
  - **HISMELT** (Single stage): Not being Operating commercially at present
  - ROMELT (Single stage): Not being Operating commercially at present

- Single stage: Reduction & melting in the same vessel
- Two stage : Reduction in one vessel; melting in the 2nd vessel

COREX Process
for
Ironmaking

A schematic diagram of COREX process



COREX: Process Features

- Developed by Siemens VAI
- Commercially most successful amnongst SR Technologies
- Commercial units in operation
  - Korea: POSCO (COREX C-2000 – Capacity: 0.8 Mtpa)
  - India: JSW Steel, India (2 Units) (COREX C-2000)
  - South Africa: Mittal-SALDANHA, (COREX C-2000)
  - China: Baosteel, (COREX C-3000) – Capacity 1.5 mtpa

Experience of COREX at JSW

- Total fuel rate requirement = 950 kg/thm. Out of which ~200 kg coke is required.
- All the non-coking coal is imported. NCC of very high VM or very low FC cannot be used.
- ~ 100% pellets are charged.
- Oxygen requirement = 550 Nm3/thm (very high!)
- Corex HM ~ BF HM:
  - Typical HM Composition: C~ 4%, Si=0.5-0.9%, S=0.025-0.07%, P=0.13-0.19%, temp= 1480-1515C

COREX: Process Limitations

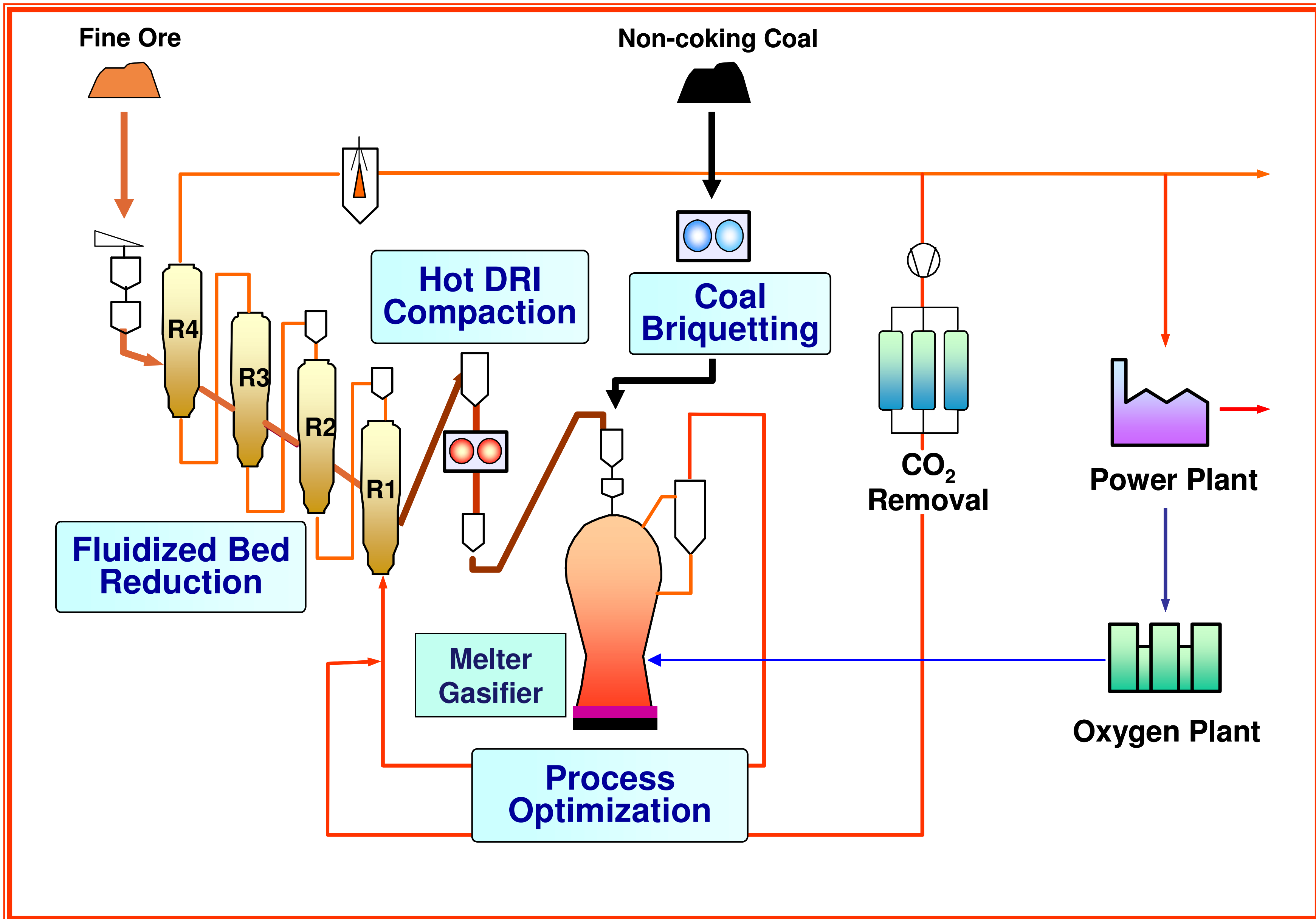
- Can't use ore fines directly

- Restriction on non-coking coal
  - VM of carbonaceous material to be maintained at ~25% (blending of coal and coke.

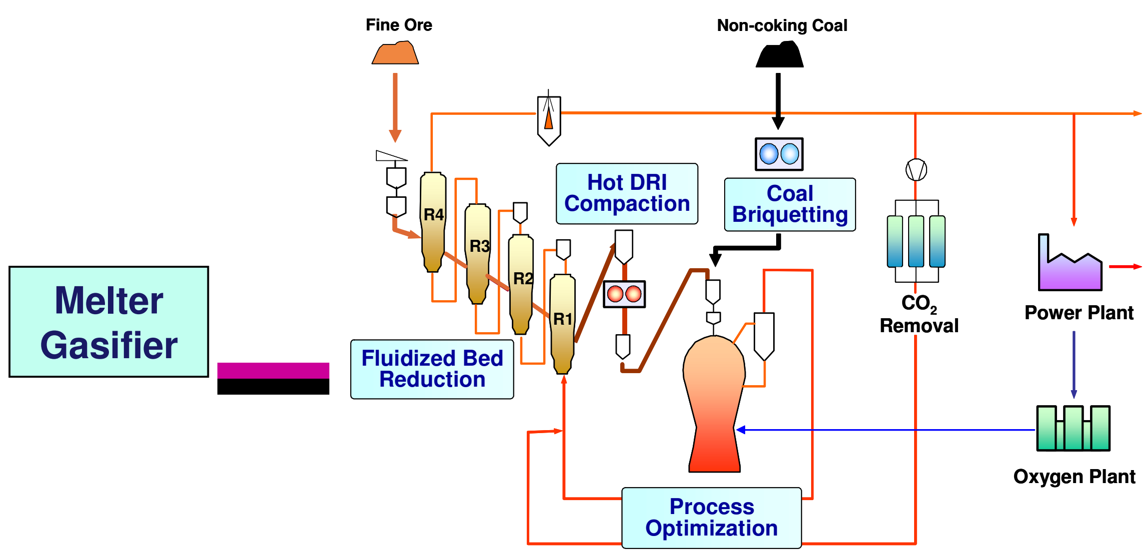
- Net export gas (1650 nm3/thm; CV:1800 Kcal/Nm^3) to be utilised very economically, the process becomes un-viable.
  - Hence, gas is used for production of DRI in MIDREX shaft (SALDANHA) and Power Generation (POSCO, JSW Steel and Bao Steel)

FINEX Process
for
Ironmaking

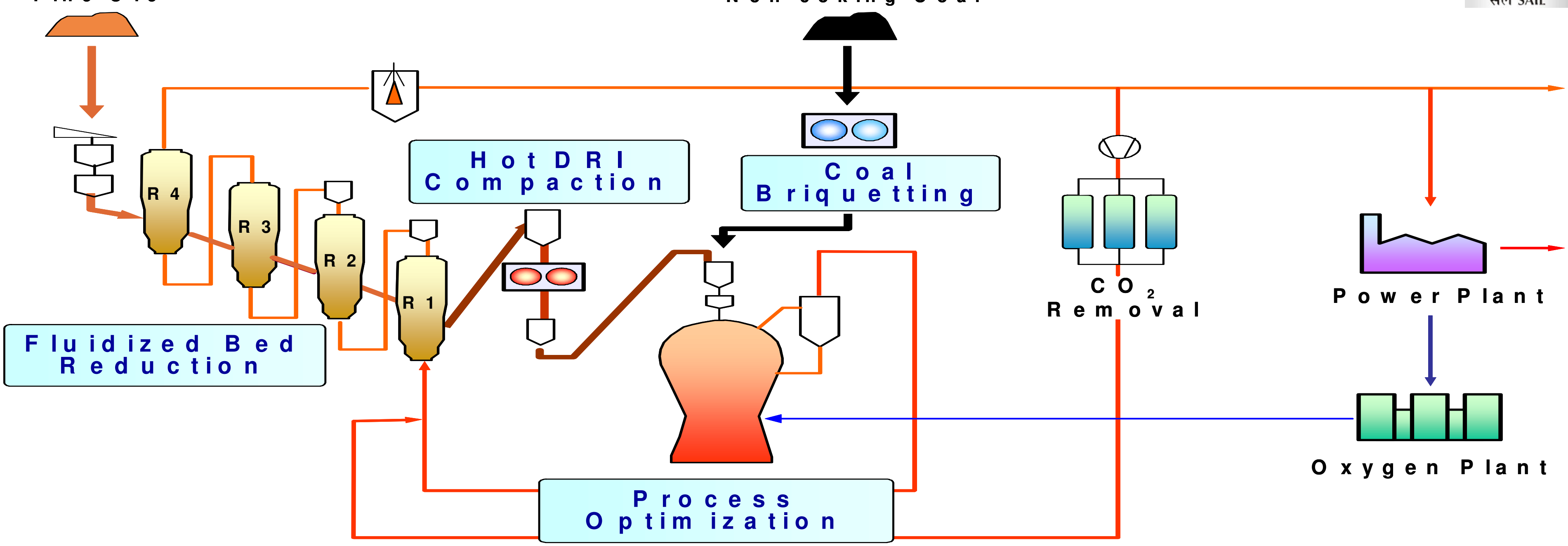
FINEX Process Flow Sheet: Jointly developed by VAI and research Institute of Industrial Science & Technology, Korea



FINEX Process Flow Sheet



FINEX: Process Features



- Off-shoot of COREX Process:to use iron ore fines (-8 mm) directly
- Direct use of non-coking coal (-6 mm)

➢ VM of carbonaceous material to be maintained at ~25% by proper blending of coal and use of coke

- Fine ore is pre-heated and reduced to DRI in a four stage fluidised bed system. R4 & R3 for preheating. In R2, fine ore is reduced to 30%. In R1, final reduction to 90%. Operational pressure: 4-5 bar.
- The DRI : melted in the COREX like melter- gasifier

FINEX: Process Features

- **FINEX HM ~ BF HM** [C= 4.5%, S = 0.03%, Si = 0.60% , Temp= 1520C
- **Export gas (CV~2000 Kcal/Nm^3) can be utilised for production of DRI or generation of power**
- **Coal consumption @ 720 kg/t HM achieved:**
  - **Pulverised coal injection @ 150 Kg./t HM.**

It is claimed by Finex Technology that Capital cost is lower by 20% and production cost is 15% lower as compared to BF process.

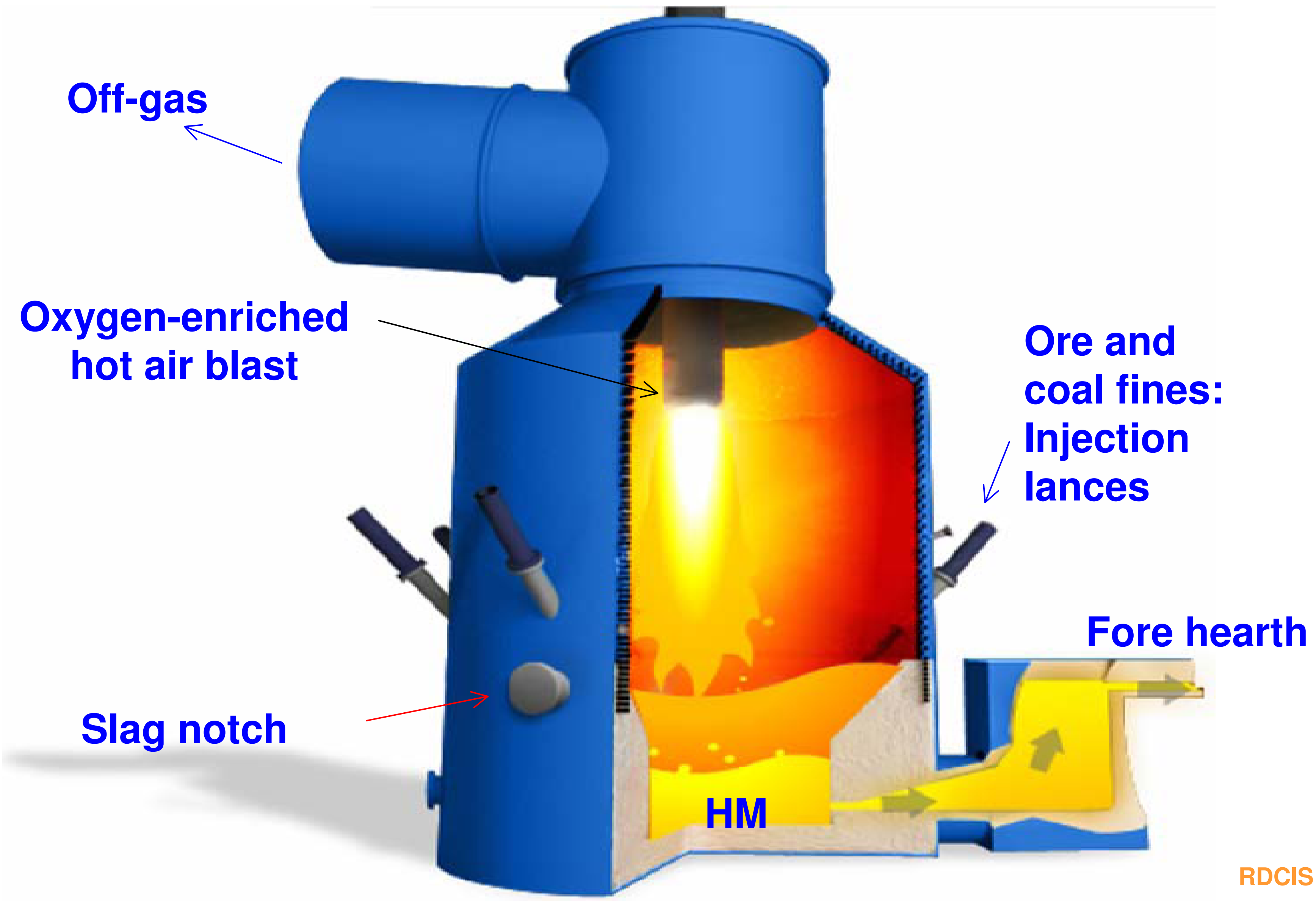
Limitations of FINEX Process

- Commercial unit of 1.5 Mtpa at Pohang, Korea – commissioned in 2007 and in operation since then.
- No other unit so far
- POSCO not interested in selling the technology

Recent GoI approval for POSCO plant in Orissa: FINEX being considered !

HISMELT Process
for
Ironmaking

Smelting Reduction Vessel of HIsmelt



HISMELT: Features

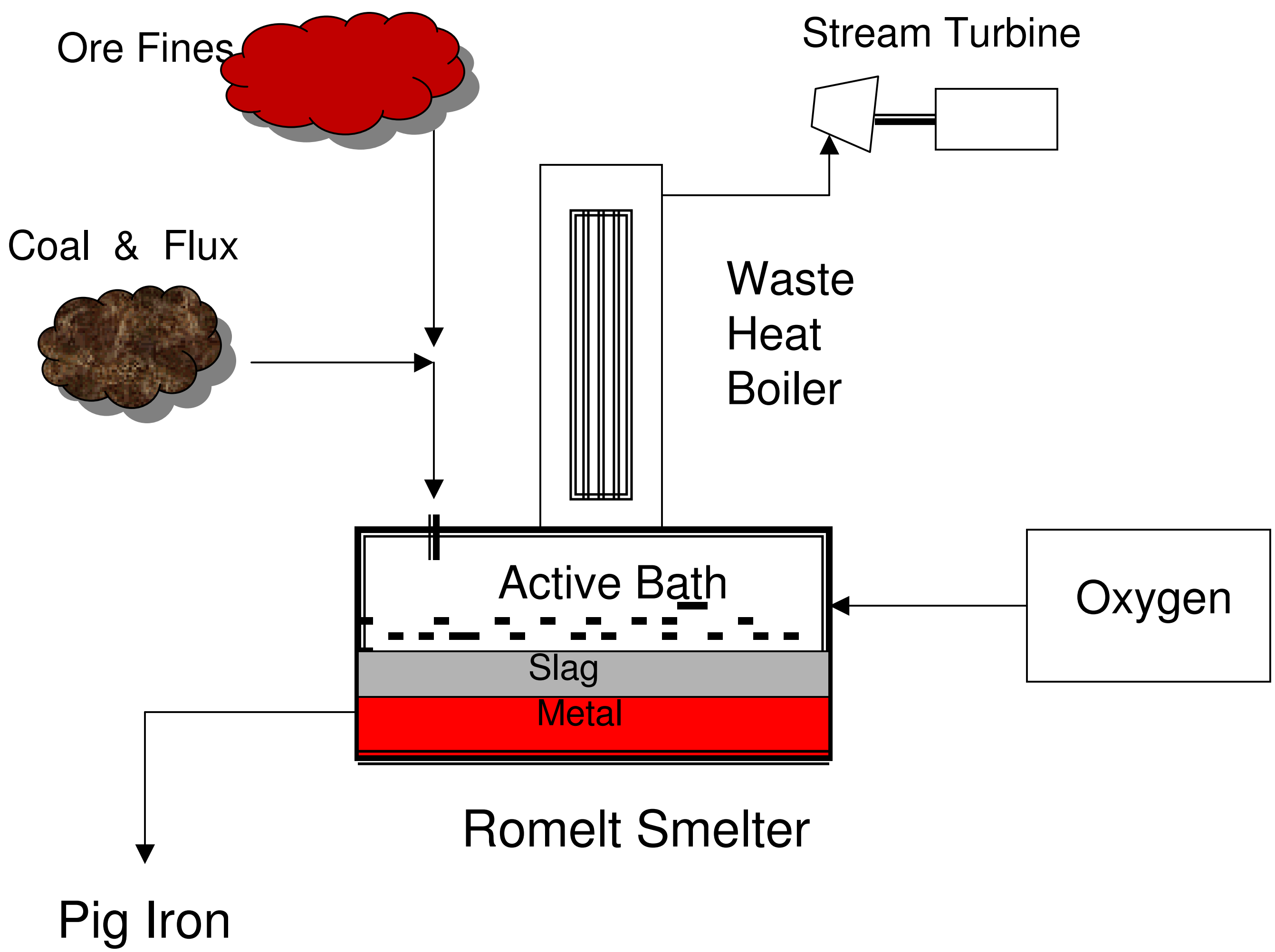
- Developed by Hismelt Corporation, Australia
- 1-Stage hot air based Smelting Reduction Process using metal bath as primary reaction medium which is unique:
- Bulk of smelting of ore takes place via dissolved carbon resulting in high reaction rate
- Direct utilisation of ore fines (-0.6 mm) and non-coking coal fines (-0.3 mm): feed martial is directly injected thru water cooled lances into metal bath.
- No oxygen requirement – only preheated air is used
- Variety of coals containing 10 to 38 %VM can be used, Low coal rate (600-620 kg/thm)
- HM: Low P (0.02-0.05% based on ore of 0.12% P) and very very low Si
- Off-gas not rich (CV ~700 Kcal/Nm^3) – no need to generate value from off gas

HISMELT: Present Status

- First industrial HIsmelt Plant (capacity 600,000 tpa) commenced operation in Kwinana, Australia in 2005.
- The plant is under maintenance as per their press-release.
- No other plant in the world
- Currently, there are two other licencees in China who have signed a HIsmelt Process Licence. Under the agreements, the groups can replicate the 800,000 tonne per year HIsmelt Plant.
- Process seems to be suitable under Indian conditions, specially for Flat product plant producing API X70/80 products needing low P steel.

ROMELT Process
for
Ironmaking

Schematic Flowsheet of Romelt Process



ROMELT: Process Features

- Developed by Moscow Institute of Steel and Alloys (MISA in mid 1980s)
- Process operates under a slight negative pressure (1-5 mm WC)
- Greater raw material flexibility
  - Accepts iron ore, slimes and other iron bearing materials in a wide range of sizes (0 – 20 mm) without any pre-treatment
  - Non-coking coals of size 0 – 20 mm with moisture content < 10% are acceptable. High VM non-coking coals can be used without any preparation

ROMELT: Process Features

Contd..

- Small scale production of 200,000 to 1,000,000 tpa HM
- Excellent quality of hot metal (C ~4%, Si ~0.6%, S ~0.040%, Temp. ~1400^0 C). Approx. 40% of input P goes to slag phase & 90% of input S goes to gas phase
- High coal (1.3 – 1.5 t / thm) and high oxygen (900-1100 – Nm^3/thm) consumption
- Fairly high degree of combustion. It produces rich off gas (CV ~1000 Kcal/Nm^3) – has to be utilised efficiently (e.g. power generation to meet the demand of oxygen plant) to make economic production of hot metal.
- No commercial plant anywhere in the world

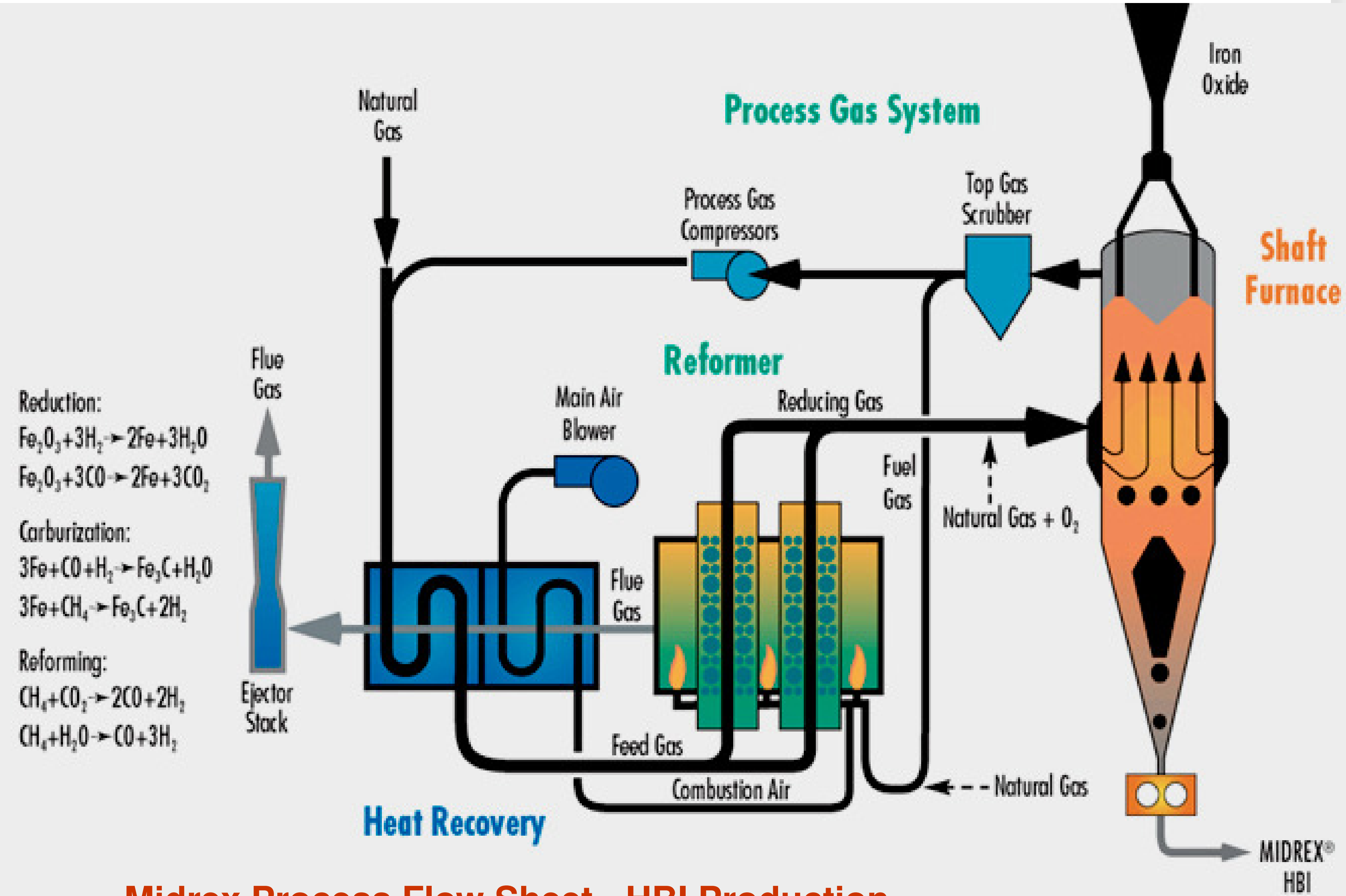
Comparison of Commercially exploited/ Potential SR Processes

	COREX	FINEX	HISMELT
Level of development	Fully Commercially	One 1.5 mtpy commercial plant in operation since 2007	One 0.8 mtpy plant was in operation in 2005, but not now
Ability to use ore fines	No	Yes	Yes
Reductant	Non-coking coal (VM ~ 25 %) (to be imported)	Non-coking coal (VM ~ 25%) (to be imported)	Non-coking coal fines (-0.3mm) (to be imported)
Oxygen (Nm^3 / thm) /	~ 550 (High !)	~ 550 (High !)	~ 300
HM Quality	Comparable with BF	Comparable with BF	Very low P & Si
Viability dependent on use of off-gases?	Yes	Yes	No
Ease of obtaining the technology	Commercially available	Uncertain	Available

Conclusions: Selection of SR Processes under Indian Conditions

- Out of 3 potential SR processes, only COREX is commercially exploited till date. FINEX is on the verge of commercialisation.
- COREX & FINEX processes: sensitive to quality of input material particularly w.r.t. VM and ash of coal. Type of coal required for these processes is scarcely available in India.
- Experience of COREX at JSW suggest that still ~ 15% coke is required in the process to control VM of the input reductant. Same may be the case for FINEX process.
- Use of pellet atleast partially is a must for COREX process. For FINEX & HISMELT process, iron ore fines can be directly used.
- For COREX & FINEX processes, large amount of oxygen is required.
- For COREX & FINEX processes, rich off gas generated in the process need to be used either for generation of power or for production of DRI.
- Hismelt is suitable for steel product with low P.

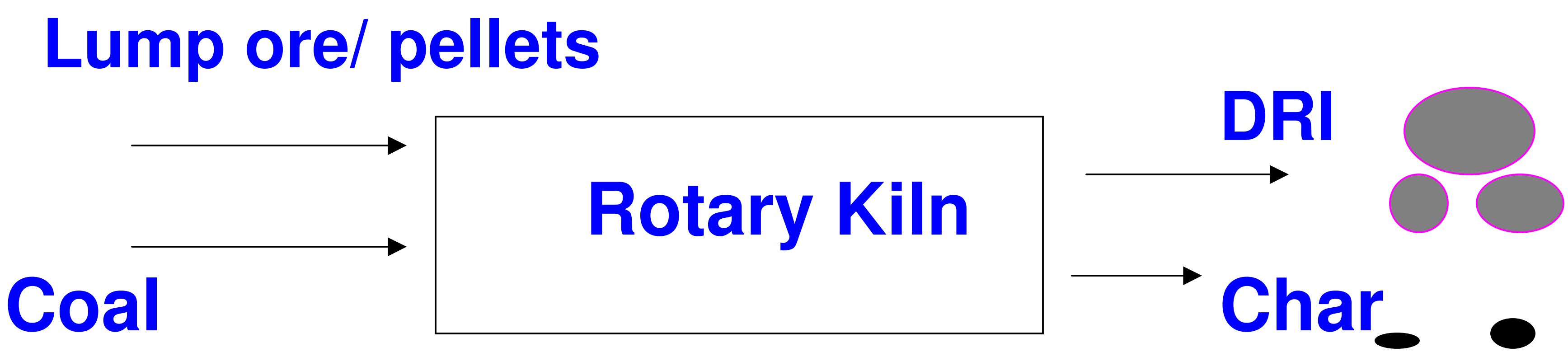
THANK YOU



Midrex Process Flow Sheet - HBI Production

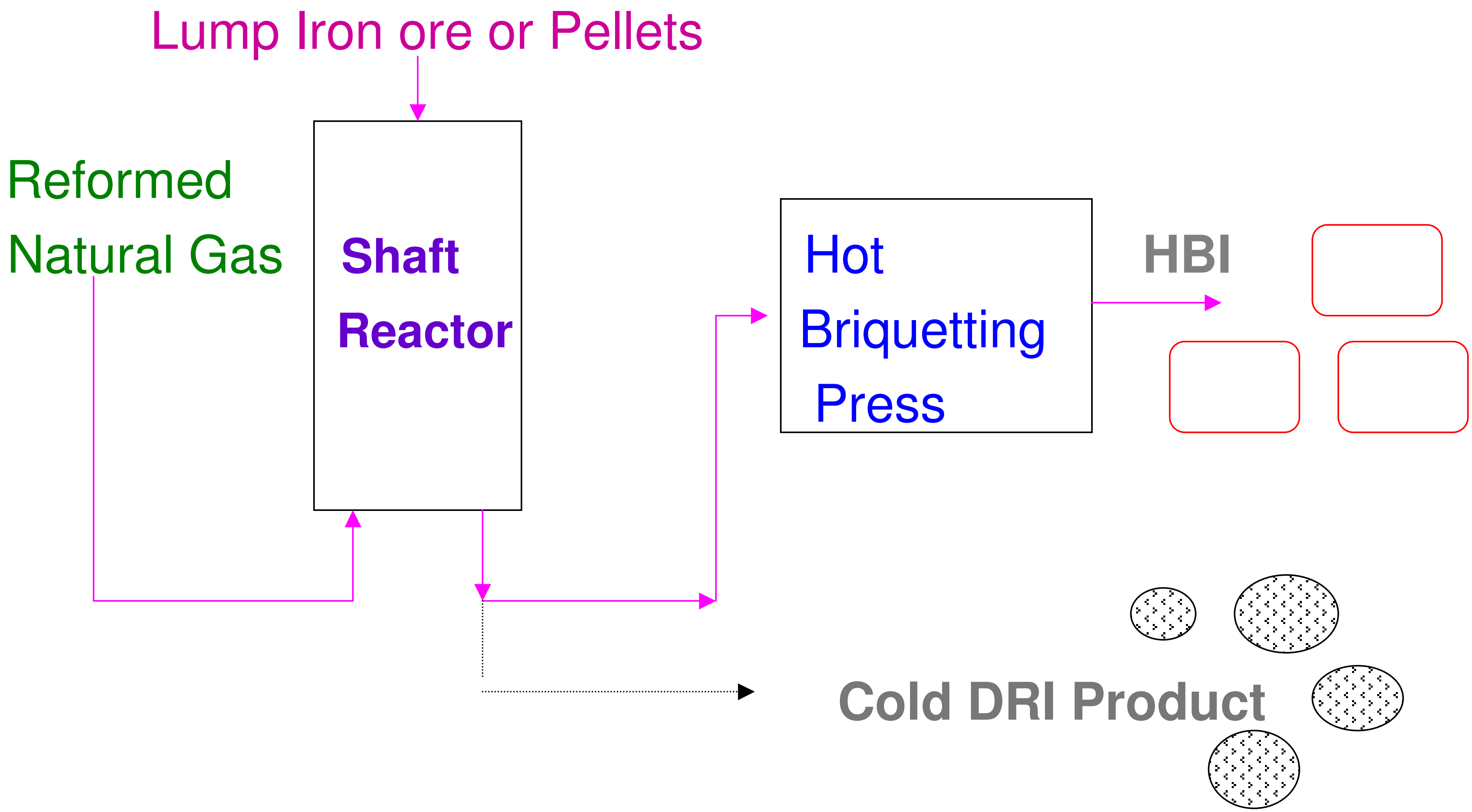
Production Technologies

- Coal Based Rotary Kiln process



Scheme for DRI Production in Rotary Kiln

Production Technologies
Gas based Process



Scheme for HBI Production in Shaft Reactor

Salient Features of Midrex Process

- Both pellets (8-15 mm) & sized lump ore (6-30 mm) (upto 50% can be charged).
- Reformed Natural Gas: CO=80%, H_2=20%
- Specially suitable for countries/ locations where natural gas is available in plenty and less expensive
- Indian Scenario:
  - Essar Steel, Hazira
  - Ispat Industries, Raigad

Coal gassification based DRI plant (JSPL plant at Angul, Odisha) may open a new trend in India/ world

ITmk3 technology has the better economics at small scale production compare to other competing processes

Relative cost to ITmk3 process	ITmk3	Midrex Coal Based (DRI)	Corex	Rotary kiln + melter	BF+CO+SP
Capital cost, 500,000 t/y	1	1.58	2.4	1.5	1.98
Operating cost, 500,000 t/y	1	1.11	1.53	1.2	1.27

Relative cost to ITmk3 process	HIsmelt	Romelt			
Capital cost, 500,000 t/y	1.16*	1.1			
Operating cost, 500,000 t/y	1.1	1.34			

RELATIVE ECONOMICS OF COMMERCIAL EXPLOITED SR PROCESSES vis-à-vis MINI BLAST FURNACE (MBF)

[A] Assessment of Raw Material & Energy

	COREX	FINEX	HISMELT	ROMELT	MBF
IRON BEARING MATERIALS					
• Sized Ore	Indigenous	-	-	-	Indigenous
• Pellets	Indigenous	-	-	-	-
• Fines	-	Indigenous	Indigenous	Indigenous	-
REDUCTANT					
• Non-coking coal	Imported	Imported	Imported	Blended*	-
• Coke	Imported	Imported	-	-	Imported

RELATIVE ECONOMICS OF COMMERCIAL EXPLOITED SR PROCESSES vis-à-vis MINI BLAST FURNACE (MBF)

Contd..

[B] Comparison of Specific Consumption Norms

	COREX	FINEX	HISMELT	ROMELT	MBF
A. Hot Metal Capacity ('000 tpa)	800	800	600	300	500
B. Raw Materials					
• Sized iron ore (t)	0.40	-	-	-	1.52
• Iron Pellet (t)	1.20	-	-	-	-
• Iron ore fines (t)	-	1.60	1.65	1.60	-
• Imported coke (t)	0.16	0.16	-	-	0.63
• Non-coking coal(1) (t)	0.90	0.90	-	1.27	-
• Non-coking coal(2) (t)	-	-	0.82	-	-
• Limestone (t)	0.16	0.16	-	-	0.09
• Dolomite (t)	0.09	0.09	-	-	0.11
• Calcined dolomite (t)	-	-	0.03	-	-
• Lime (t)	-	-	0.05	0.13	-
C. Energy inputs					
• Oxygen (Nm^3 / t)	570	570	253	1100	-
• Electric power (Kwh/t)	69	69	125	150	75
• Fuel gas (Nm^3 / t)	-	-	27	-	-

(1) Based on 50% Indigenous & 50% imported coal

(2) Based on imported coal with 10% VM & 10% ash

RELATIVE ECONOMICS OF COMMERCIAL EXPLOITED SR PROCESSES vis-à-vis MINI BLAST FURNACE (MBF) Contd..

[C] Relative Costs of Hot Metal

Process	Capital Cost	Production Cost (with power credit)
COREX		80
FINEX (1.5 mtpy)	80	85
HISMELT		
ROMELT		
Blast Furnace	100	100

RELATIVE ECONOMICS OF COMMERCIAL EXPLOITED SR PROCESSES vis-à-vis MINI BLAST FURNACE (MBF) Contd..

[D] Comparison of Power Generating Potential from Surplus Gas

Item	COREX	FINEX	HISMELT	ROMELT	MBF
Hot metal capacity, '000 tpa	800	800	600	300	500
Gas generation, Gcal/thm	3.7	3.7	1.03	2.4	1.6
CV of gas, Kcal/thm	2000	2000	Low	1000	800
Power plant capacity, MW	130	130	27	54	28
Energy credit (After internal consumption), kWh/thm	1161	1161	221	1210	359