Iron Making and Steel Making
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Module – 11
Lecture – 58
Smelting Reduction (SR) Processes
(continued)

In this lecture, we will discuss on the Single stage Smelting Reduction Processes, namely Romelt, HIsmelt and most recent two stage HISARNA process.

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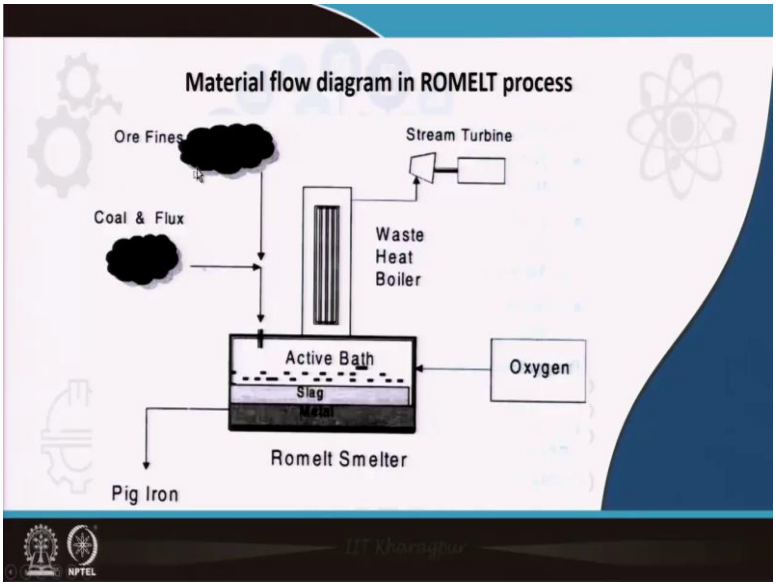

Figure 58.1 shows the flow sheet of ROMELT process.

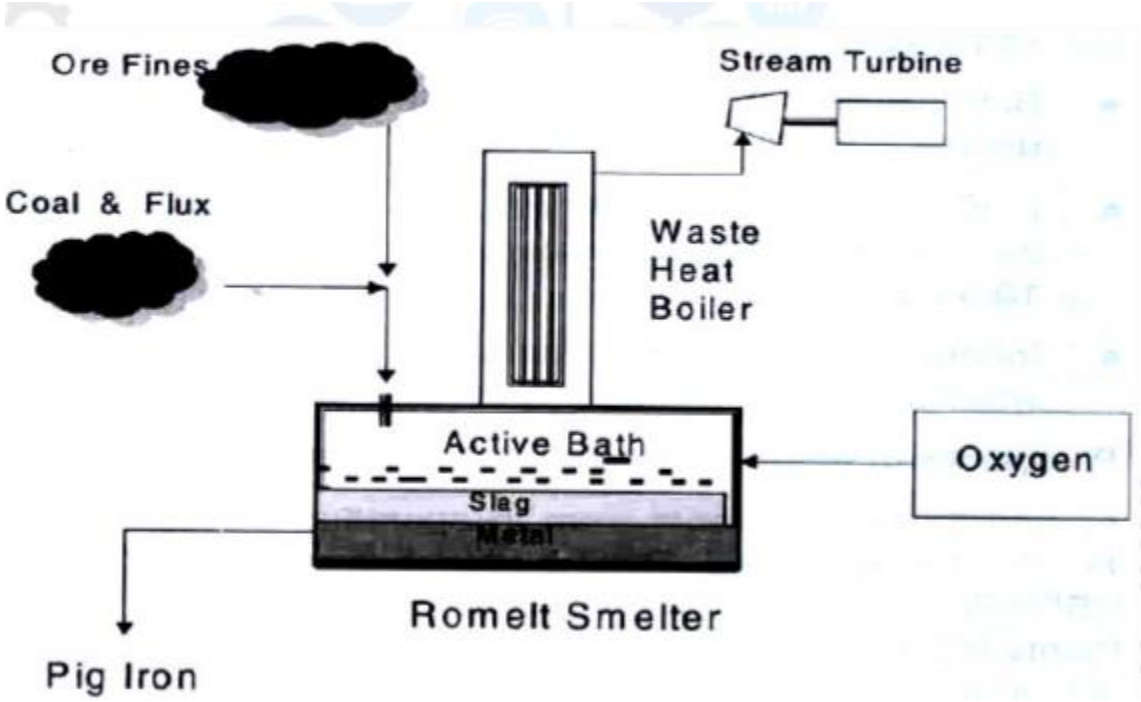

Figure 58.1: Flow sheet of Romelt Process [2]

It is seen that iron ore, coal, flux and oxygen is charged in the single reactor. Two distinct zones of slag baths are formed- top and active slag bath and a lower quiescent slag bath. Pure oxygen is injected above the top slag layer for post combustion of CO and generate heat to melt iron burden. Oxygen enriched air along with fuel are also bubbled through the lower slag bath for coal combustion, heat generation, gasification and reduction. Gas bubbling also stirs the upper slag layer to highly agitated states enhancing efficacy of heat transfer and reduction. Metal is collected at the hearth at the bottom of the furnace.

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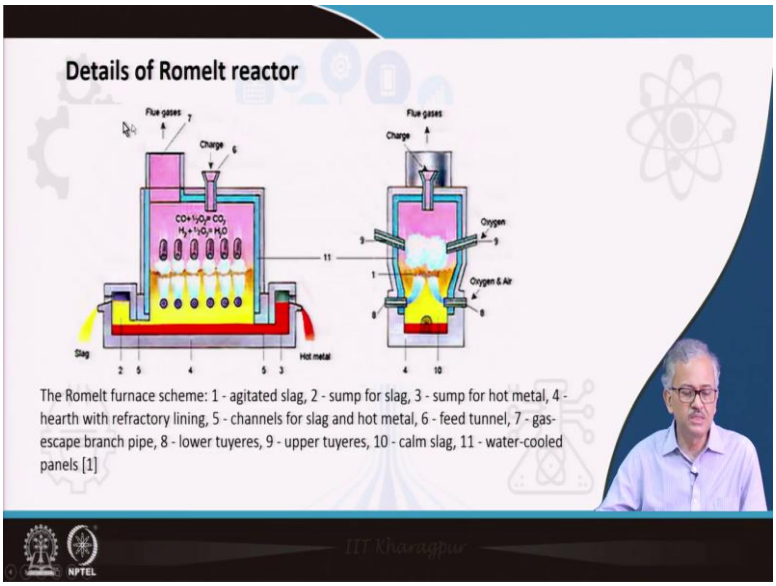

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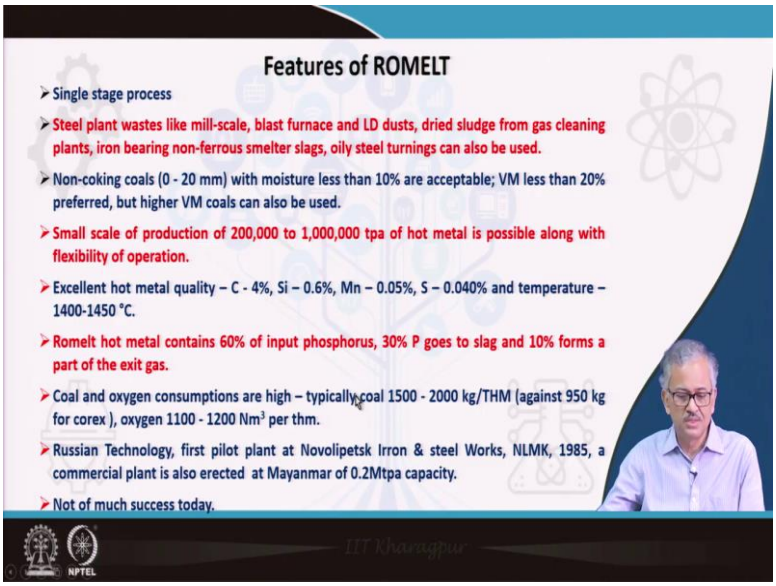

Some features of Romelt process is noted below:

(i) It is a single stage process.

(ii) Very flexible about raw material: iron bearing steel plant waste like mill scale, blast furnace dust, and LD dust, EAF dust, dry sludge from the gas cleaning plants, iron bearing non-ferrous smelter slag, oily steel turnings could be melted in this furnace.

(iii) Non-coking moisture free dry coal usually up to 20 mm size is favored for enhanced flow-ability and combustibility. Moderately high volatile coal is also good as it it increases the combustibility of the coal.

(iv) Small scale production in the capacity range 2,00,000 to 1,000,000 tpa hot metal is suitable small scale production.

(v) Excellent metal quality. Sulphur, zinc joins the gas phase and phosphorus, silicon mostly joins the slag phase. So, hot metal contains very low impurity. Since basic slag forms early and basicity could be maintained high in fluid slag at high temperature, acidic oxides are safely retained in the slag phase. Due to post combustion the active slag are also exposed to oxidizing atmosphere favoring stable FeO in the top slag and portioning of impurities in slag.

(vi) Coal consumption rate is quite high, around 1500 kg/ton of hot metal, compared to the blast furnace, maximum 500 kg/ton and in the Corex process, maximum 1000 kg/ton. So, that is the major bottleneck and the export gas is very rich in calorific value. Therefore, power generation from off gas is essential to make the process economic.

(vii) It is Russian technology and the first pilot plant was put up at Novolipetsk Iron and steel works in NLMK in Russia in 1985, a commercial plant is also erected at Mayanmar 0.2 million ton capacity to treat the very low grade iron ore.

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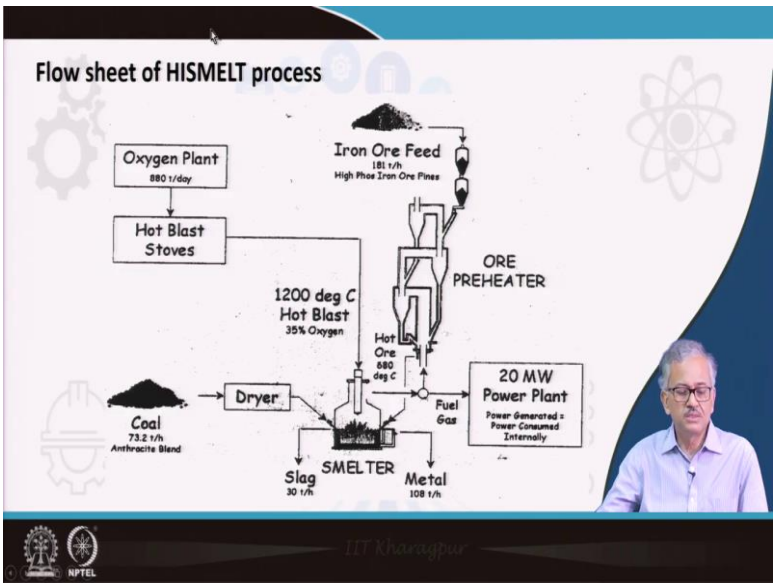

Now, I am coming to another single stage process that is called the HISMELT process. The flow chart of HIsmelt process is given in the Figure 58.2.

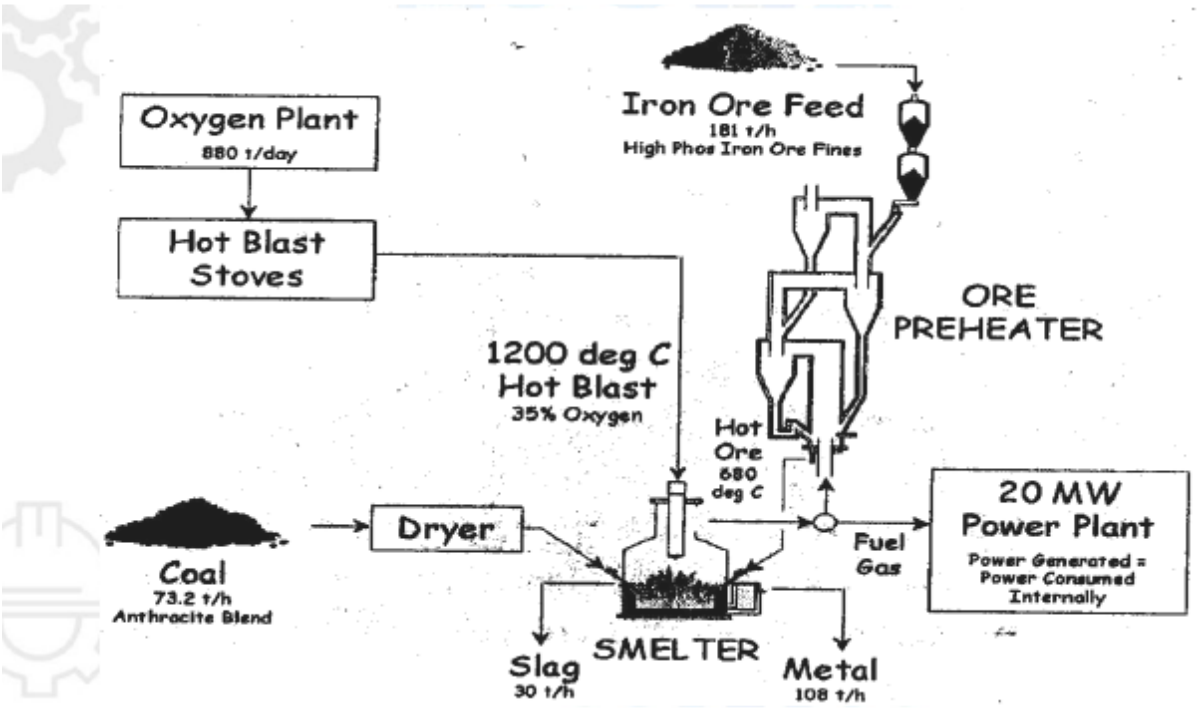

Figure 58.2: Flow sheet of a 0.8mtpa HISMELT commercial plant [2]

In HISMLET process, dried iron ore fines and coal fines are directly injected into the liquid bath. Iron ore fines are heated to 680^{o}C before injection. Oxygen enriched preheated air blast (35% oxygen) is injected by a top lance into the liquid bath.

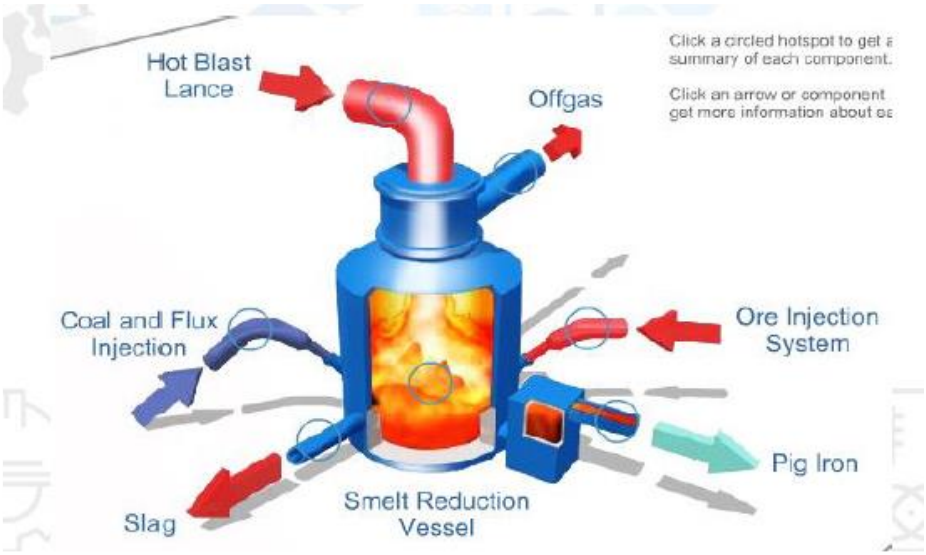

Figure 58.3: In 3D view of HIsmelt process [1].

The products of the furnace are hot metal and slag. The off gas is used to generate power. To produce hot metal 108tons per hour, slag produced is 30ton and power generation is 20 MW. Ore required is 181 ton, coal 73 ton. The 3 dimensional view of HIsmelt process is shown in Figure 58.3.

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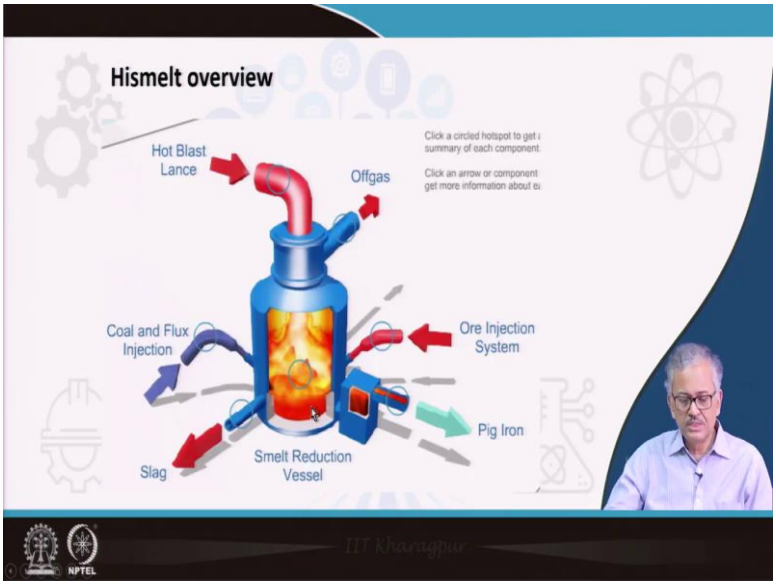

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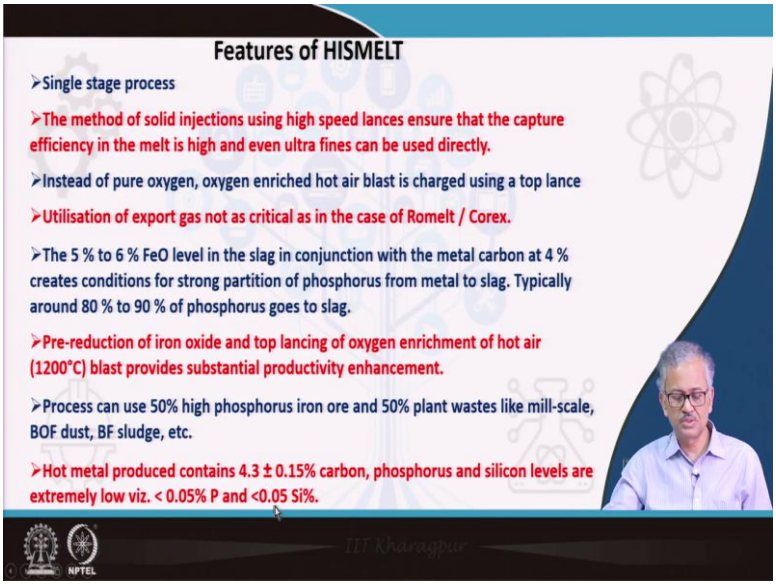

Some special features of the HISMELT process:

(i) It is a single stage SR process

(ii) Solids like iron ore and coal fines are injected using high speed side lance, which ensures the dissolution and melting efficiency of solid fines in the melt. Otherwise process fines are briquetted and charged into MG.

(iii) HIsmelt is the only unique process where oxygen enriched preheated air blast is charged in place of pure oxygen at room temperature, which is followed in all other SR processes. Secondly, unlike in any SR process, the air blast is injected through a top lance just like in LD furnace. Preheated air blast carries lots of sensible heat that reduces coal rate significantly. Utilization of the export gas is not as critical as in other SR processes like Romelt and the Corex process because the coal rate is much less here. Consequently, off gas generated becomes less rich and a small power plant would justify the gas utilization

(iv) The 5 to 6 wt% of FeO level in the slag along with 4% carbon in the hot metal, and highly basic slag produces the suitable condition for phosphorus partitioning into the slag. Typically 80 to 90% phosphorus goes to slag.

(v) Process can handle 50% high phosphorus ore and 50% iron bearing solid waste from the plant.

(vi) Hot metal contains 4% carbon and silicon and phosphorus to a very low value<0.05%.

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Finally, the most promising SR process is the HISARNA process. It is basically ISARNA (meaning Iron) plus HIsmelt. It has some features of the HISMELT. Basically the smelting reduction vessel it has similar to the HISMELT process and at the top of the furnace there exists a top cyclone where the iron ore feed is melted.

It is developed by Tata Steel Europe and Rio Tinto. The schematics of the reactor is shown in Figure 58.4.

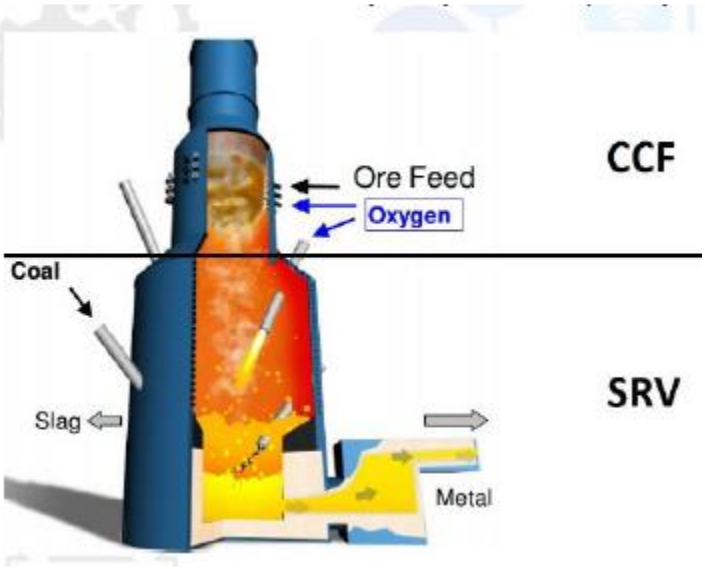

Figure 58.4: The schematics of HISARNA Process[1]

(i) It has two parts in the same reactor. The bottom part is called the Smelting Reduction Vessel (SRV). The top part is called the Cyclone Converter Furnace (CCF). The SRV has several features of HISMELT process, while CCF has features of ISARNA cyclone technology. Like in HIsmelt coal fines is directly injected in the SRV. However, pure oxygen is lanced through side lance in the SRV to burn and gasify coal for liquid state reduction of iron ore, which is subsequently collected in the hearth and tapped from iron notch. After impurity partitioning into slag, it is also collected from slag notch. The CO generated in the SRV is completely burned in the upper part of SRV to generate heat to melt the feed iron ore in the cyclone and liquid iron flow to SRV through the wall. The iron ore particles remain near the wall and melted. Alkali, zinc, lead, tin, Sulphur all vaporize and and reoxidise to fine solid oxides in presence of CO_2 and get entrained in the core of the cyclone. The off gas is almost pure CO_2, along with solid dross of tin and zinc, lead and alkali metal. After separating the fine solids, CO_2 could be sequestrated.

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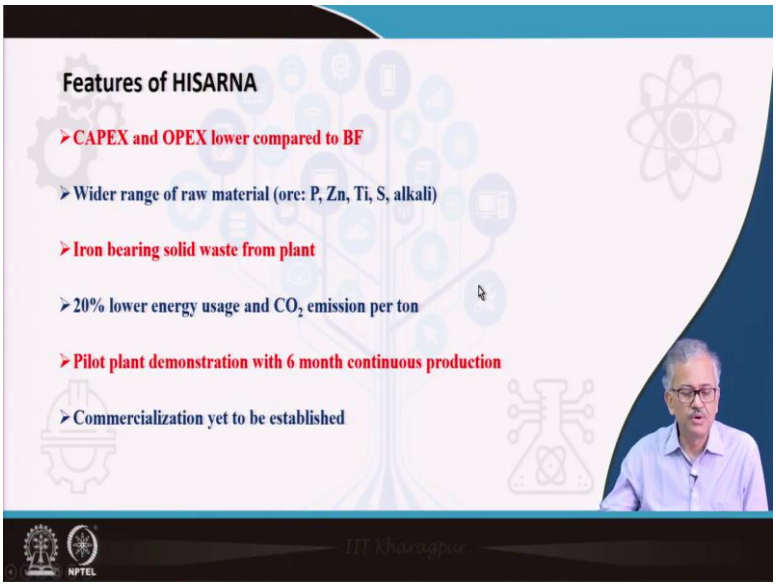

Features of HISARNA Process:

(ii) The capital expenditure as well as operating expenditure are low compared to BF process.

(iii) Flexibility in raw material usage. Zinc, lead, tin containing iron bearing solid wastes, high alkali, phosphorous, tin, sulfur bearing iron ores could be used. Alkali, zinc, lead, tin, Sulphur all vaporize and re-oxidize to fine solid oxides in presence of CO_2 and get entrained in the core of the cyclone.

(iv) After separating the fine oxides, the gas is pure CO_2 which could be sequestrated.

(v) 20% lower energy usage and CO_2 emission per ton of iron produced.

(vi) A continuous 6 months trial has been made. But commercialization is yet to be done.

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So, these are the references:

1) https://www.totalmateria.com/page.aspx?ID=CheckArticle&site=kts&NM=516
2) Amit Chatterjee: Smelting Reduction Process, PHI, New Delhi, 2012
3) Ghosh & Chatterjee: Ironmaking & Steelmaking: Theory & Practice, PHI, New Delhi, 2008

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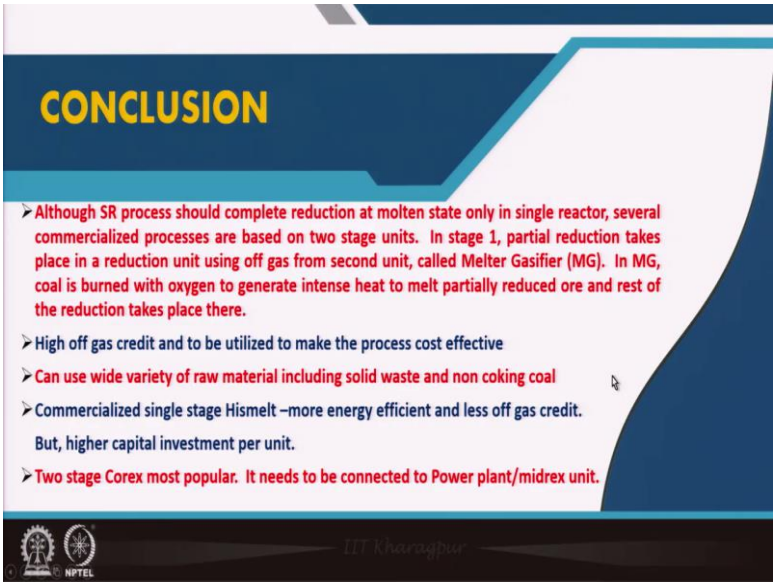

Conclusion:

(i) Although SR processes are supposed to complete reduction at molten state only in single reactor, several commercialized SR processes are based on two stage units. In stage 1, partial reduction takes place in a reduction unit using off gas from second unit, called Melter Gasifier (MG). In MG, coal is burned with oxygen to generate intense heat to melt partially reduced iron ore and rest of the reduction takes place there. However, these two reactors are operated independently connected by solid and gaseous streams that makes the operation easier.

(ii) All SR processes has high off gas credit and to be utilized for power generation or DRI production to make the process cost effective

(iii) All SR processes, especially Romelt, HIsmelt, Hisarna, are flexible with respect to acceptance of raw material. They can accept wide variety of raw materials including iron bearing solid waste from plant like BF sludge, BOF dust, EAF dust, high alkali, phosphorus, tin, lead, zinc bearing iron ores. All types of non-coking coal could be accepted in certain proportion.

(iv) Commercialized single stage Hismelt –more energy efficient and less off gas credit. But, it has higher capital investment per unit.

(v) Two stage Corex most popular. It needs to be connected to Power plant/midrex unit.

(vi) HISARNA is the most promising low carbon and cost effective technology that can convert iron bearing solid waste and off grade ore to hot metal using non coking coal. But Its commercialization is awaiting.