Iron Making and Steel Making
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Module – 11
Lecture – 57
Smelting Reduction (SR) Processes

In lecture 57 and 58, I will cover the Smelting Reduction Processes. In this lecture, we will cover features of SR process and will discuss COREX, FINEX, two stage SR processes. All single stage processes like ROMELT, HIsmelt and HISARNA will be discussed in the next lecture.

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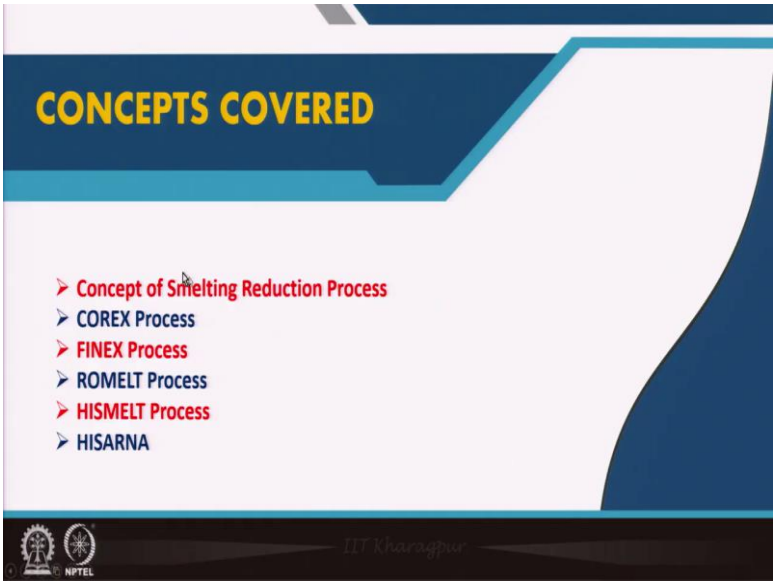

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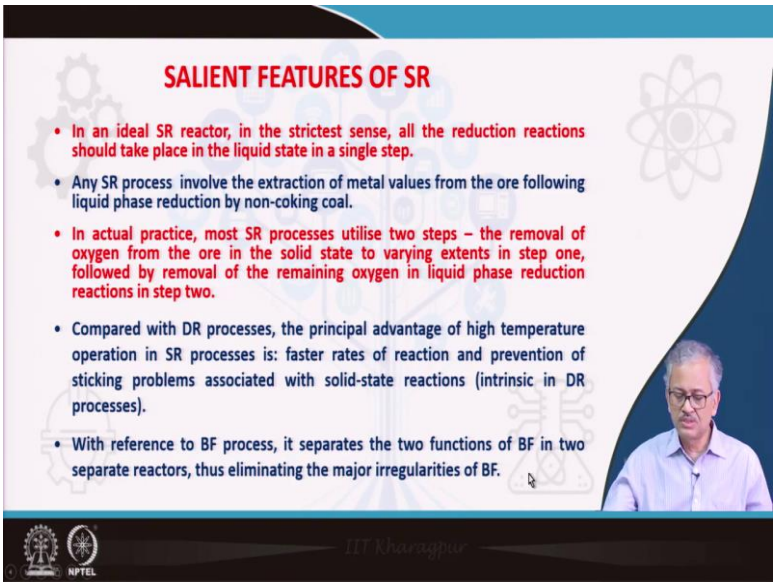

I have already given a brief introduction of smelting reduction process. Now, we will discuss the salient features of the SR processes.

As I have already mentioned that the blast furnace is the most efficient reactor both in terms of chemical and thermal efficiency. But, blast furnace is also a very complex reactor in terms of internal structure. There exists a dry zone in the upper part of the furnace and a liquid zone in the lower part of the furnace separated by a complicated cohesive zone all existing in the single reactor. Heat and mass exchange takes place through counter current gas, solid and liquid flow; gas moves up and solid, liquid moves down. For efficient heat and mass exchange maintenance of good permeability, which evolves dynamically, is a must. Therefore, sometimes it is not possible to operate the blast furnace without any irregularities (channelling, flooding) taking place, unless quality burden is used. Quality burden means coke in place of coal, sinter, pellets in place of lump ore. Such burden preparation requires ancillaries like coke oven, sinter machine, grate-kiln for pelletization; all these processes involve cost and most importantly pollutes atmosphere. Besides, some raw materials like coking coal is scarce and costly. Besides, fines and iron bearing solid waste from plant could not be input into blast furnace. Pollution and no waste utilization, makes blast furnace not sustainable in near future. Therefore, people are looking for coke free, environment friendly and sustainable processes and SR emerges as one of the promising alternative routes of ironmaking. The idea in SR process was to melt everything in a reactor followed by liquid state reduction such that all problems of blast furnace could be overcome and any kind of raw materials could be utilized.

So, SR process devised a new concept and reactor where liquid iron could be made directly from non coking coal. Some of the features of SR process are:

- In an ideal SR reactor, in the strictest sense, all the reduction reactions should take place in the liquid state in a single step.
- Any SR process involve the extraction of metal values from the ore following liquid phase reduction by non-coking coal.
- In actual practice, most SR processes utilise two steps – the removal of oxygen from the ore in the solid state to varying extents in step one, followed by removal of the remaining oxygen in liquid phase reduction in step two. In fact the idea is borrowed from blast furnace, but here the reduction and smelting are separated in two independent reactors that gives full independent control into reduction and smelting processes and thereby reducing the complexities of blast furnace.
- Compared with DR processes, the principal advantage of high temperature SR processes are: faster rates of reaction and prevention of sticking problems associated with solid-state reactions (intrinsic in DR processes), and also SR produces liquid iron directly.
- In SR process coal is burned with oxygen to generate intense heat for melting partially reduced ore, followed by its complete reduction in liquid state. Coal rate is quiet high in these reactor and therefore off gas credit is also high. Unless off gas is used for power generation, or DRI production, the process becomes uneconomic.

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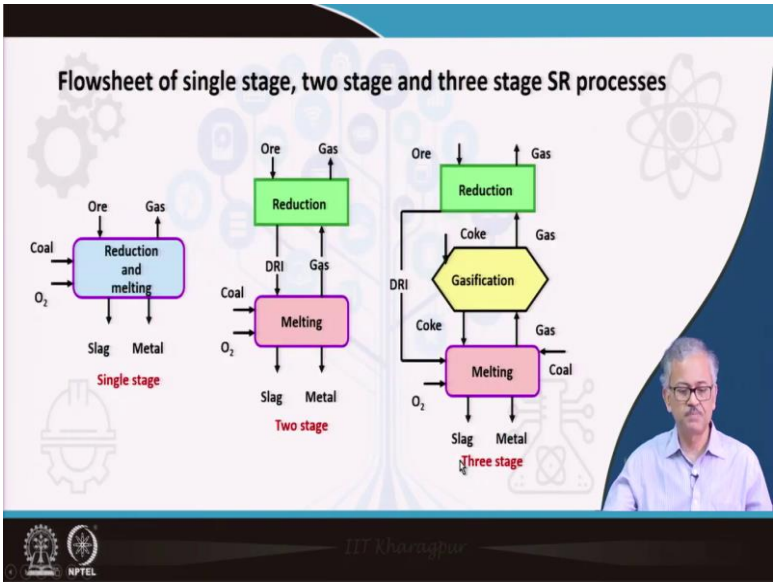

SR process started with single stage reduction smelting, followed by two stage SR (most popular) and three stage SR is also conceptualized, although no such process has so far demonstrated. The different stages of SR process is schematically shown in the Figure 57.1.

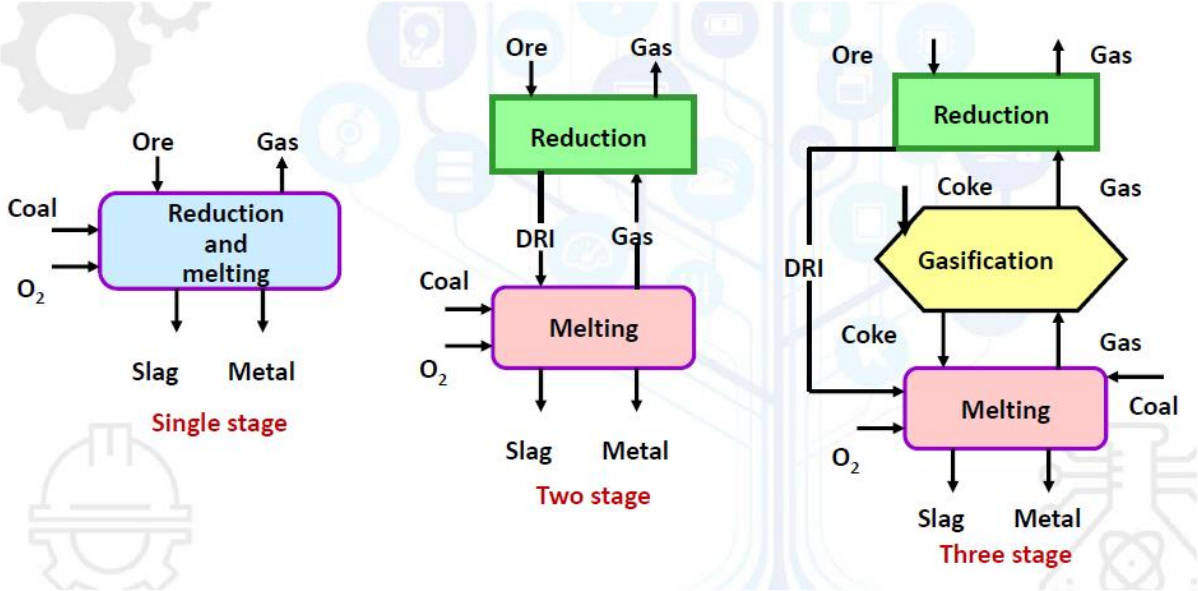

Figure 57.1: Schematics of three stages of SR Processes [2]

It is seen in single stage reactor inputs are coal, oxygen, ore and outputs are hot metal, slag, and gas. Pure oxygen gassifies coal as well as oxidise carbon to generate heat for the process. The quality of hot metal produced by SR process is similar to that of blast furnace and may be even better.

In two stage reactor, there are two independent reactors: Reduction Reactor (RR) and the Melter-Gassifier (MG) unit. These reactors are physically separated and they are connected by solid and gaseous streams. From RR partially reduced iron ore is fed into MG and the off gas from MG is used as reducing gas in RR after cleaning. As usual coal and oxygen is added to MG; while ore is added to RR and final off gas from RR after cleaning should be used for power generation or DRI production. The liquid products namely hot metal and slag are generated from MG unit.

In three stage reactor another reactor is added to gassify the coal seperately. So here you have reduction unit, melting unit and a gassifying unit. Basically the functions of MG i.e., melting and gassifying are separated. So total carbon is partitioned between gasifier and melter. In fact carbon in gasifier is used in the form of coke to enhance gassifying kinetics. While coal is used for melting purpose. No such commercial reactor exists in three stage but it is a

potential technology where carbon efficiency could be improved compared to two stage reactor.

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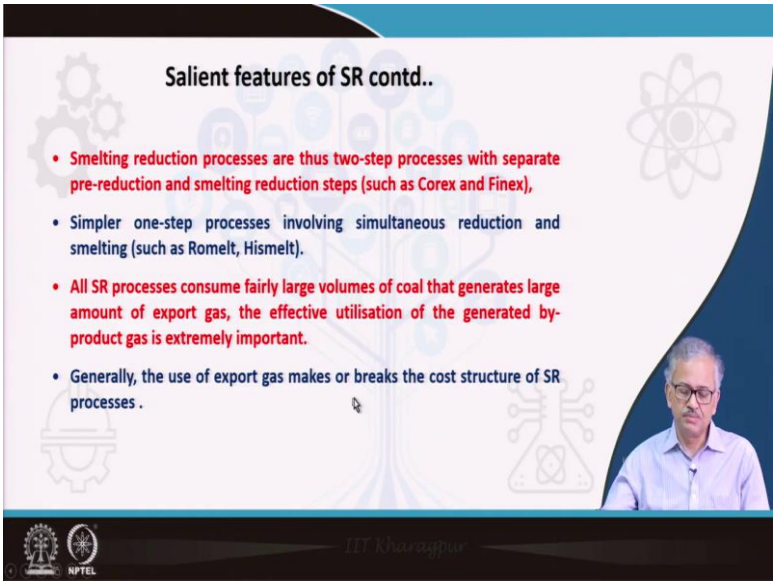

COREX and FINEX, HISARNA are examples of two stage commercialized SR processes; while ROMELT, HISMELT are single stage SR processes. All SR process are characterized by coal consumption and consequently high off gas credit. Generally use of export gas makes or breaks the cost structure of SR process.

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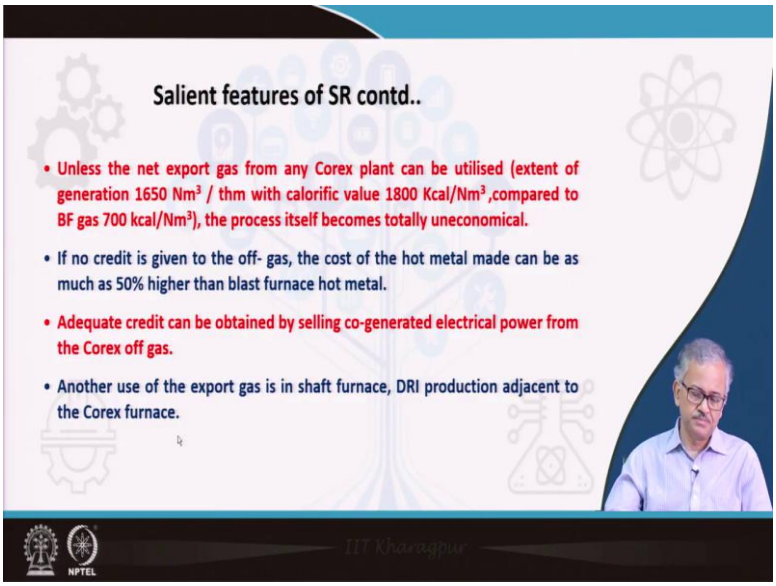

For example, COREX plant produces 1650 Nm^3 off gas (similar to BF gas but it contains only CO and CO2, unlike in BF gas which contain 60% is N_2) with calorific value 1800kcal/Nm^3 (compared to 900 kcal/Nm^3 of BF gas). So, the off gas is very rich and has to be utilized. So, you can see if no credit is given to the off gas, then the product of SR process can be 50 percent costlier than that of blast furnace hot metal. You off gas can be processed to generate power which can sustain SR process as well as can be sold outside, which can make the process cost effective.

The export gas can also be used in shaft furnace for DRI production. Dolvi plant of JSW has a Corex plant of 2000 tonnes per day and the gas are used to generate the DRI in a midrex furnace. The flow sheet of a Corex process is given in Figure 57.2.

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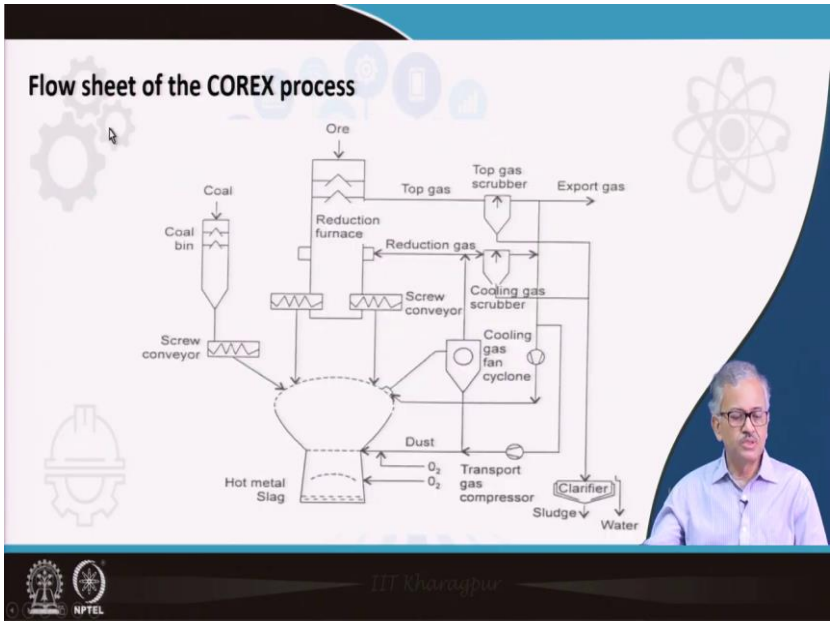

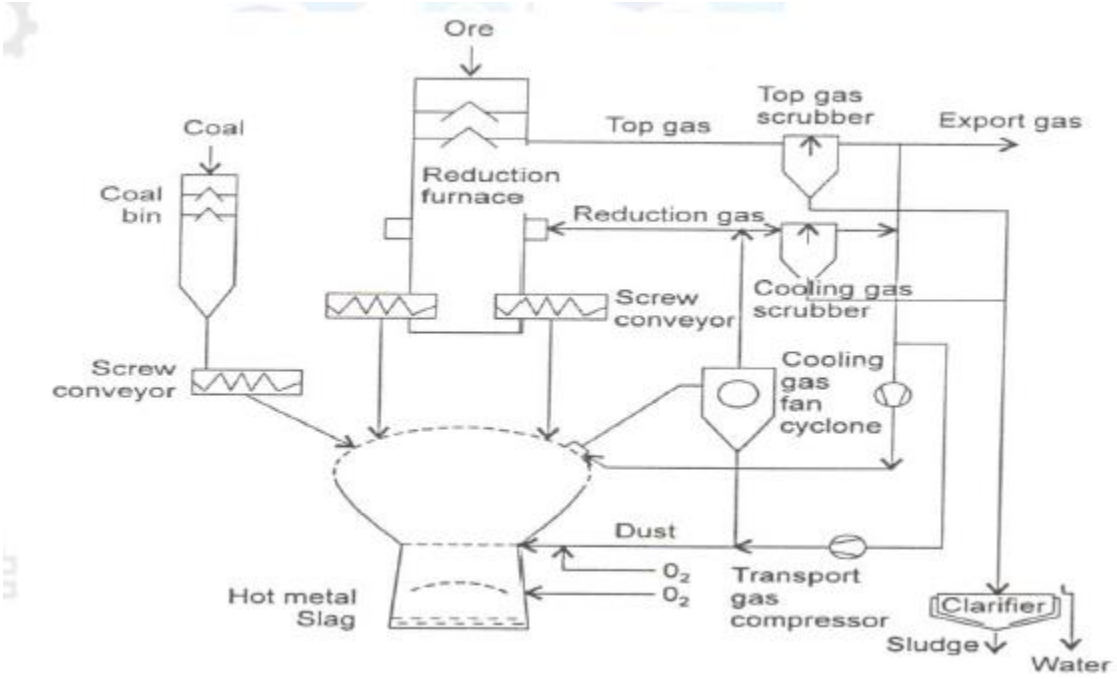

Figure 57.2: Flowsheet of COREX Process [3]

The concept of two stage reactor I have already discussed. Please note that efforts have been made to recycle the solid and gaseous stream to the maximum extent. The off gas from MG is passed through cyclone to separate the coal char dust, which is recycled back to MG along with oxygen for burning. The cleaned off gas enters the reduction unit. The final off gas from reduction unit after scrubbing the dust is partially recycled back to mix with MG off gas, undergo cyclone for fine dust separation and enters the reduction unit. The majority of the off gas from reduction unit is exported for power generation. Oxygen enters at two locations at the bottom of the hearth and at the top of the hearth. Oxygen above the hearth participate in the post combustion of CO and burning of dust char particles.

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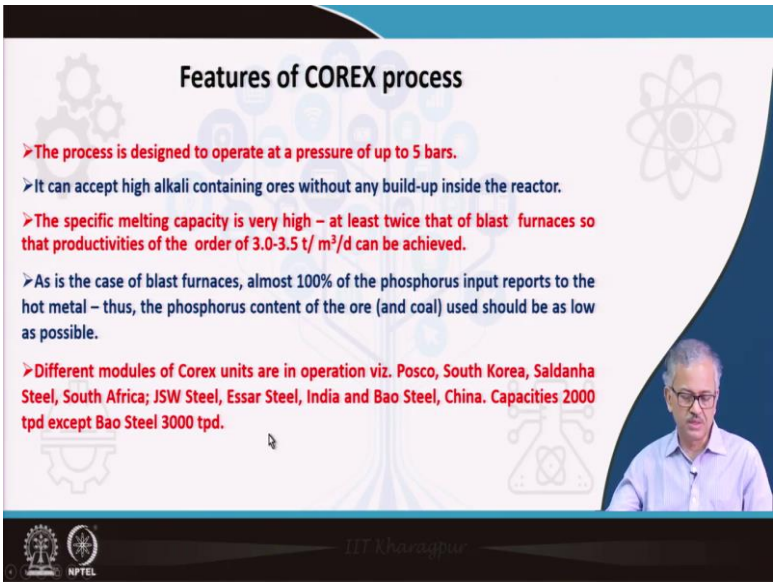

Oxygen at the bottom of the hearth burns coal to generate heat. The reduction units operates at a high pressure (5 atm), which minimise the shaft volume and accommodates lump ore charging. High pressure also allows for ore containing alkali metal, which are likely to swell. The specific productivity of COREX (3-3.5 t/m^3/day) is much higher than that of blast furnace. Like BF, 100% ore phosphorus reports to hot metal. COREX plants exists in POSCO, Sout Korea, Saldhana Steel, South Arfica, JSW/Essar Steel, India, Bao Steel, China, Usual capacities 2000 tpd except Bao steel 3000tpd.

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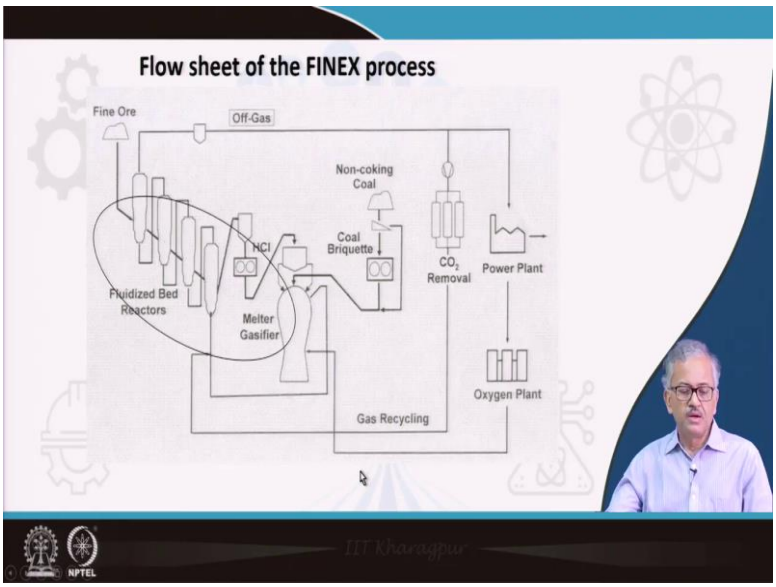

The other commercialized two stage SR process is FINEX process. The flow sheet of FINEX process is given in the Figure 57.3.

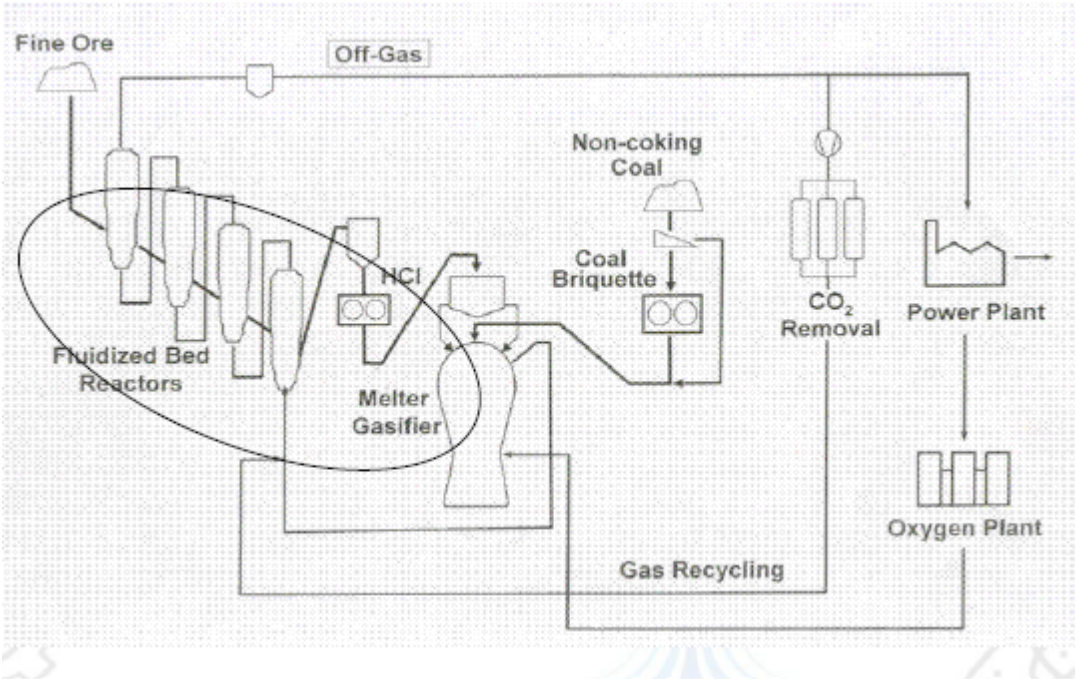

Figure 57.3: Flow sheet of FINEX process [2]

In FINEX, the reduction unit consists of series of four fluidized bed reactors connected in series, where iron ore fines directly put up for reduction. The off gas is partially recycled back to reduction unit after scrubbing CO2. Majority of the off gas is exported to power generation and oxygen production. Oxygen is subsequently goes to the MG unit. The reduced iron fines is hot compacted to briquette before it is charged to MG. HCI represents Hot Compacted iron. Non-coking coal is dried and briquetted before it is dumped into MG. Fines are briquetted to enhance the melting and dissolution efficiency in hot metal.

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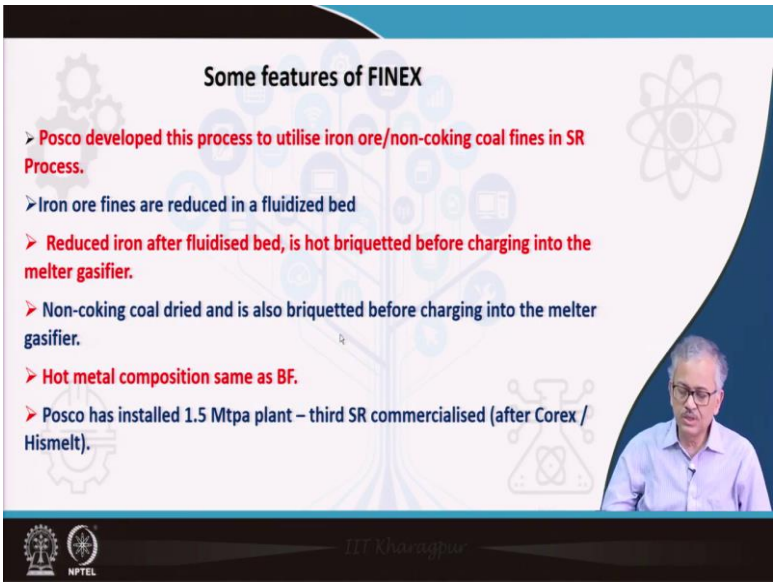

To reiterate the unique features of FINEX may be stated as: (i) Posco has developed this process to utilize their iron and coke coal fines directly (without green pelletization) in SR process. The cost of pelletization could be avoided. (ii) Second thing is that both iron ore fines and coal fines are compacted to briquettes ai hot condition before being charged in MG. (iii) Hot metal composition is same that of hot metal from BF. (iv) Posco has installed 1.5Mtpa plant, which is the 3rd commercialized SR unit in Posco after Corex/HIsmelt. So, in the Corex, Posco use their lump ore, pellets, in Hismelt they use iron bearing solid waste from the plant and in Finex they can utilize their iron ore fines/coal fines.

I have just talked about two stage processes like Corex and Finex, I will talk in the next lecture about the single state processes like Romelt and then Hismelt process. And also I will discuss about a new process that is coming up that is called the Hisarna process which is also a two-stage process.