Iron Making and Steel Making
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Module - 11
Lecture - 55
Gas Based DR Processes

In this lecture I will cover the Gas Phase Direct Reduction Processes partially.

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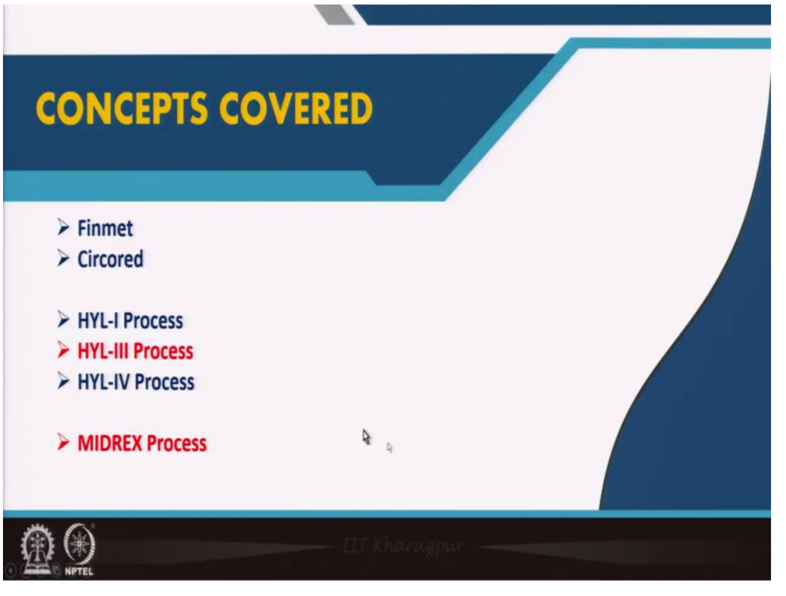

Topics covered in this lectures are Finmet, Circored, HYL-I and HYL-III processes. Other gas based process like HYL-IV and MIDREX will be discussed in lecture 56.

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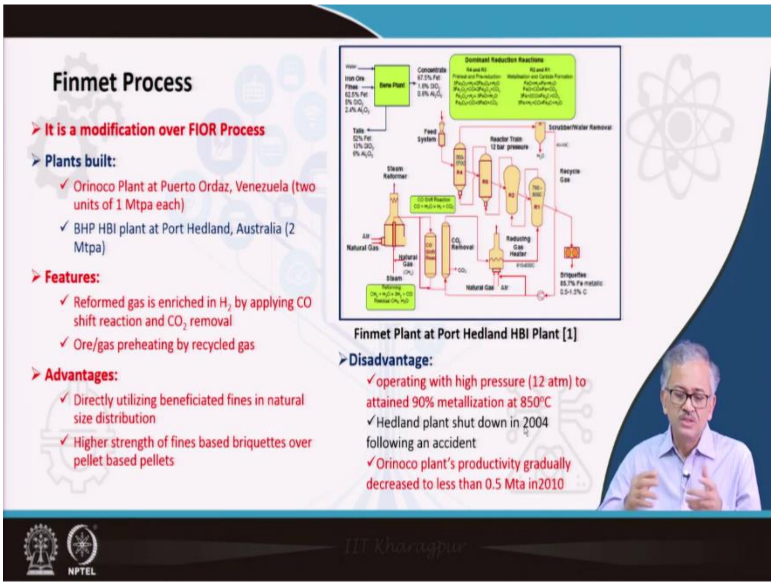

Finmet process: It is a fluidized bed process and is a modification over the FIOR process. The Finmet plants was built in Orinoco plant at Puerto Ordaz in Venezuela. Venezuela is a gas rich country and obviously they should venture in the gas based process like Finmet. And they had y 2 units of 1 million tonne per annum each. And then another plant with capacity of 2 million tonne per annum was established in Australia at BHP HBI plant at Port of Hedland. However, the plant was closed later.

Figure 25.1 shows the schematics of Finmet process. Reformed natural gas enriched in hydrogen is used in the four fluidized reactors. Natural gas is used both as fuel for heating as well as reforming gas. Steam is used for reforming natural gas and subsequently water gas shift reaction is applied to convert CO to hydrogen to make the reformed gas enriched in hydrogen. Hydrogen being a better reductant reduction in fluidized bed could be carried out at comparatively lower temperature. And that is beneficial, because the fine solid particles shows agglomeration/sticking tendency at operating temperature in the fluidized bed.

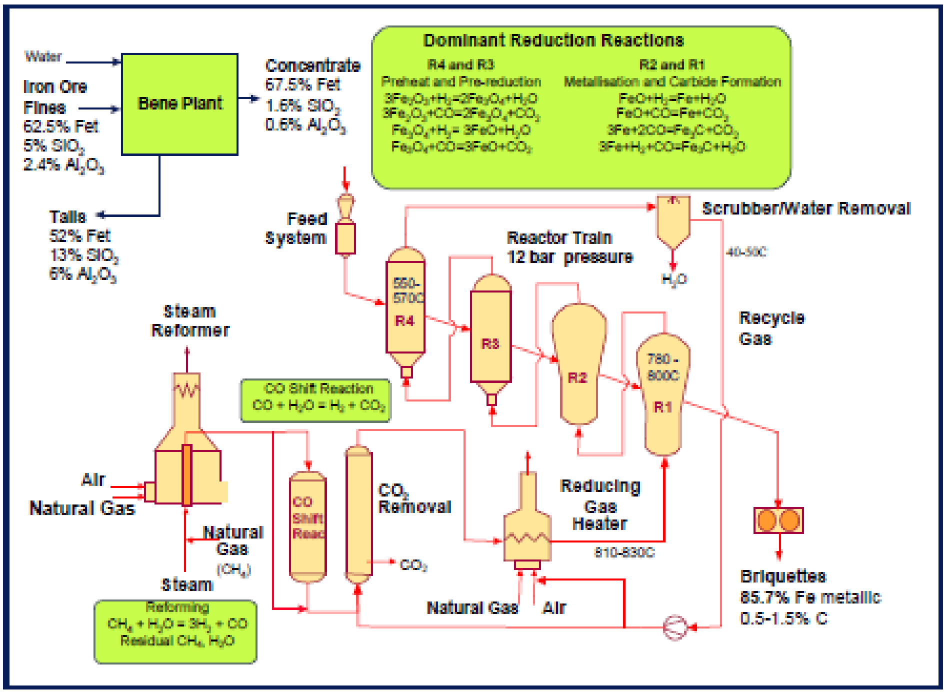

Figure 55.1: Schematics of Finmet process

. Off gas, after cleaning is used as fuel; it is also partially used in the input gas stream after scrubbing CO_2. The reformed gas enters the fluidized bed reactors via a gas heater, where it is preheated to around 810 to 830°C.

Inlet gas moves from reactor 1 to reactor 2 to reactor 3 to reactor 4 and finally escape to off gas. The first reactor is the final reduction unit where fresh reducing gas enters at higher temperature. The temperature and reduction potential of the gas decreases as it moves through the upstream reactors which acts as pre reduction, preheating units. Sponge is taken out from reactor 1 and sent to HBI plant for briquetting. The product has 86% metallic iron with 0.5 to 1% carbon. It is to be noted that all fluidized reactors works at very high pressure of 12 bar pressure, which makes the running the process difficult.

Iron ore is beneficiated and dried by recycled off gas and then fed to reactor 4, which subsequently move to reactor 1 via reactor 3 and reactor 2. Major modification of Finmet process is the utilization of off-gas for preheating input streams and more importantly addition of the unit for water gas shift reaction to enrich the reform gas with hydrogen and reduce the furnace temperature.

The major disadvantage of this process is the maintenance of high pressure in all the fluidized beds. Hedland plant shut down in 2004 following an accident; and Venezuelan plant is also running at reduced capacity.

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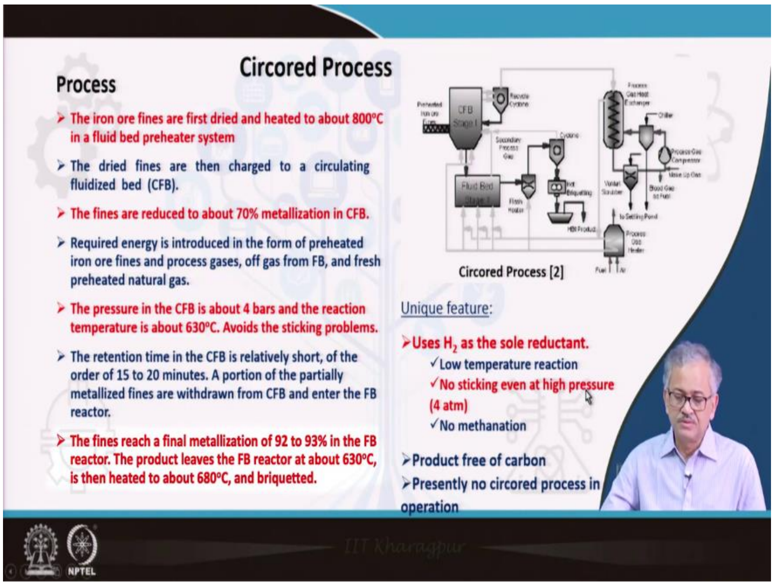

Circored Process: The schematics of circored process is given in Figure 55.2. The iron ore fines are first dried and heated to about 800 ^{o}C in a fluid bed preheater system. The dried fines are then charged to a circulating fluidized bed (CFB). The fines are reduced to about 70% metallization in CFB. Required energy is introduced in the form of preheated iron ore fines and process gases, off gas from FB, and fresh preheated natural gas. The pressure in the CFB is about 4 bars and the reaction temperature is about 630 ^{o}C. Avoids the sticking problems. The retention time in the CFB is relatively short, of the order of 15 to 20 minutes. A portion of the partially metallized fines are withdrawn from CFB and enter the FB reactor. The fines reach a final metallization of 92 to 93% in the FB reactor. The product leaves the FB reactor at about 630ºC, is then heated to about 680ºC, and briquetted.

The process uses the hydrogen as the sole reductant. So temperature of reaction is comparatively low that avoids sticking problems. In absence of CO there is no methanation and no carbon in the product. No Circored process is in operation today.

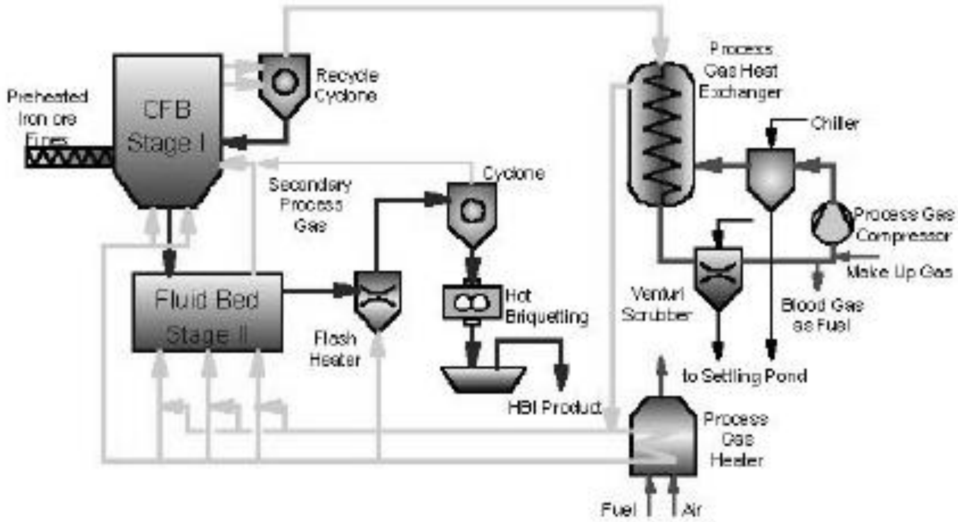

Figure 55.2 Schematics of circored process.

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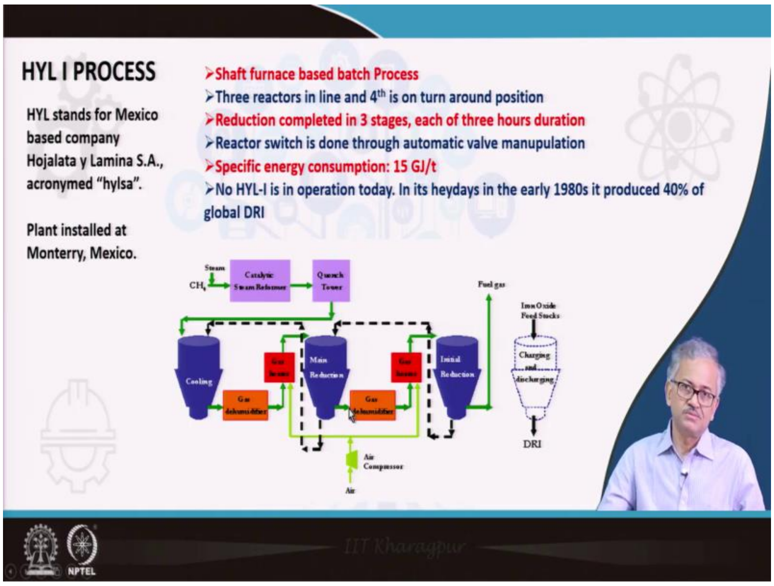

HYL process: HYL is derived from Hojalata y Lamina S A, a company based in Mexico who developed this process. The first plant was installed at Monterry Mexico. HYL process has been improved over the time and four generations of HYL process have evolved.

The most primitive HYL-I process was based on four batch reactors; three of them put in tandem and the one reactor remains always on the turnaround position, either charging, discharging. A schematics of HYL-I process is shown in Figure 55.3.

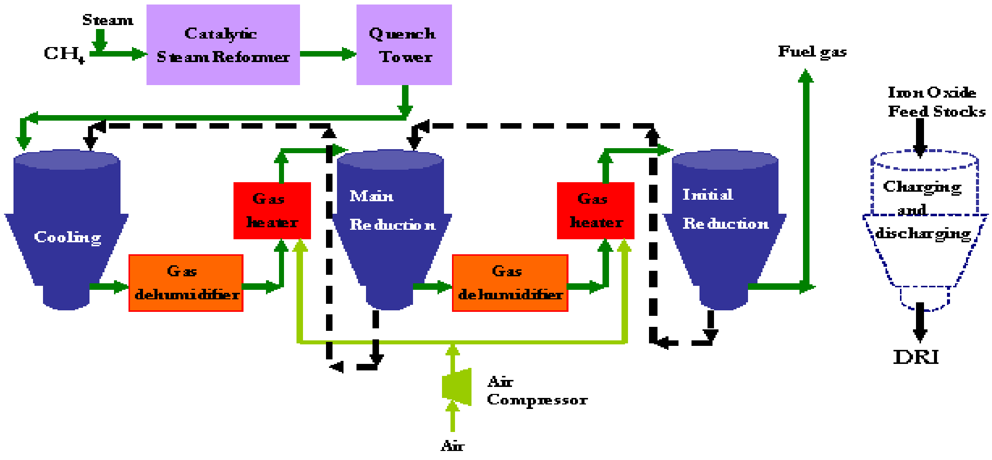

Figure 55.3: Schematics of HYL-I process

The three batch reactors in tandem pass through three successive stages like initial reduction, main reduction and cooling. Reactor switch is done through automatic valve manipulation; in other words the reactor does not change their position, or it is neither undergo charging and discharging and only the gas switching to the reactor is done. The fresh reformed gas first pass through the cooling reactor (reactor-3) where the gas get preheated and the solid DRI cools down. The gas is subsequently dehumidified and heated and passed on to the main reduction reactor (reactor-2). The off gas from main reactor is subsequently dehumidified, heated and passed to reactor-1 for preheating and pre reduction of the fresh solid charge. The reactor-3 after cooling operation is shifted to charging/discharging section for discharging of DRI followed by fresh charging. After charging, this reactor is put on initial preheating and pre reduction (reactor-1).

The process uses steam reforming of natural gas in presence of nickel catalyst. Specific energy consumption: 15 GJ/t. No HYL-I is in operation today. In its heydays in the early 1980s it produced 40% of global DRI

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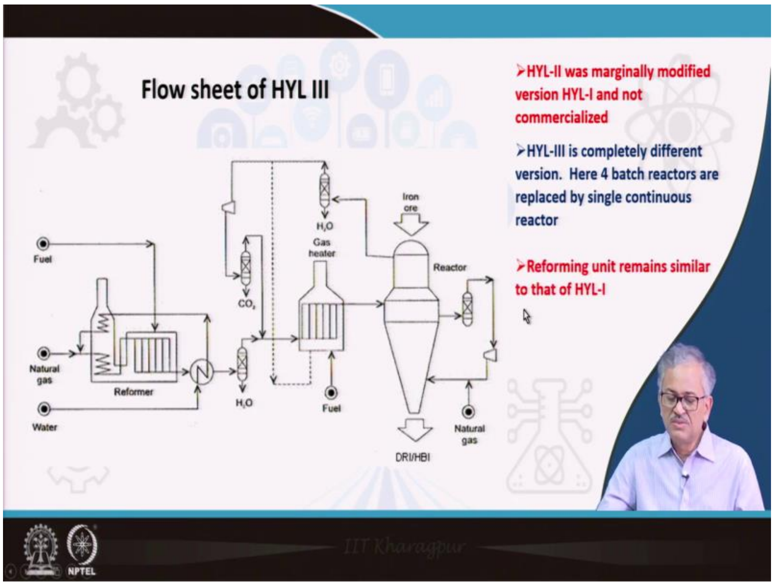

HYL-II was marginally modified version HYL-I but not commercialized. The third generation HYL-III is completely different version. Here 4 batch reactors are replaced by single continuous reactor. Gas reforming unit remains similar to that of HYL-I. The schematics of HYL-III process is given in Figure 55.4.

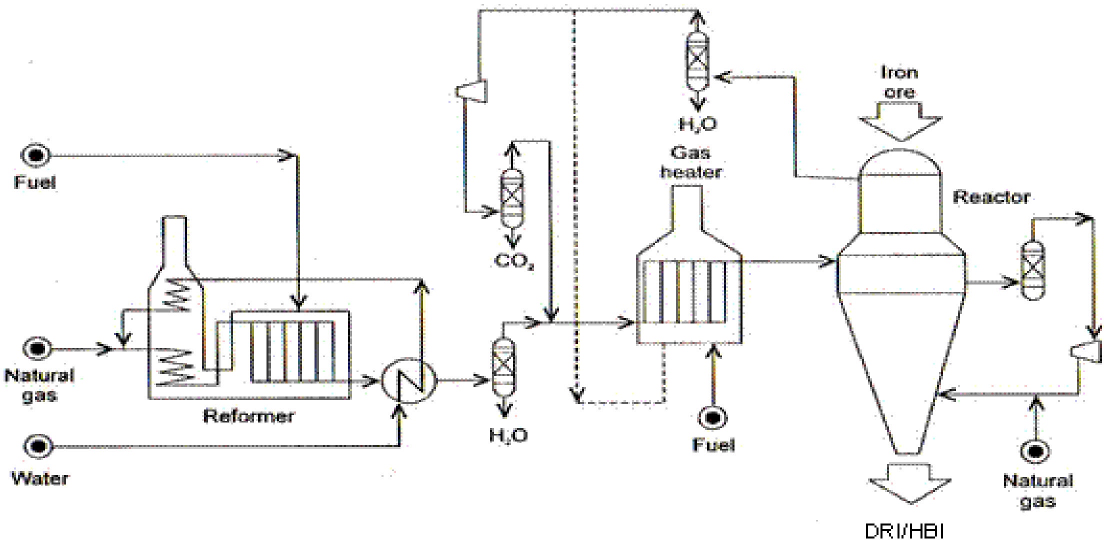

Figure 55.4: Schematics of HYL-III process.

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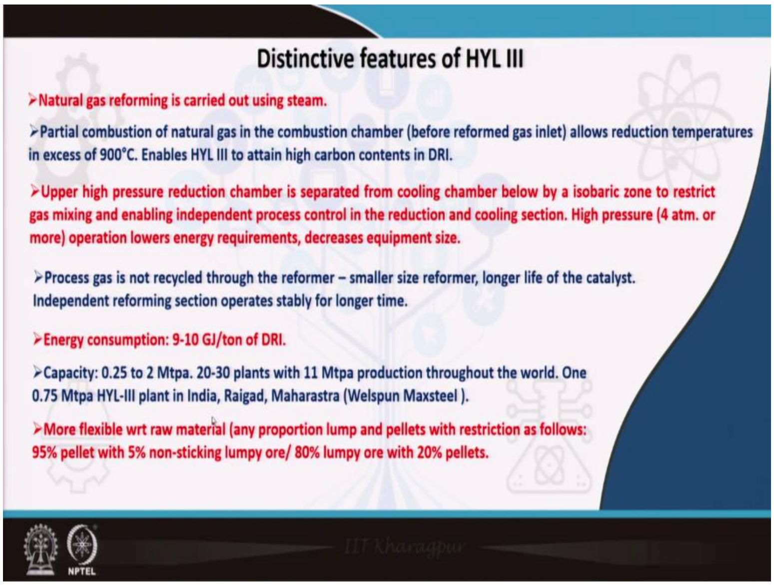

Some distinctive features of the HYL-III process are as follows.

(i) Natural gas reforming is carried out using steam in presence of nickel catalyst.

(ii) Before the reformed gas enters the reduction chamber, it is preheated to 900oC in gas preheater to enables HYL attain to high carbon in the DRI. For this purpose partial combustion of the natural gas along with recycled off gas is carried out in the in the preheater.

(iii) Upper high pressure reduction chamber is separated from cooling chamber below by an isobaric zone to restrict gas mixing and enabling independent process control in the reduction and cooling section. High pressure (4 atm. or more) operation lowers energy requirements, decreases equipment size.

(iv) Unlike Midrex, process gas is not recycled through the reformer. This results in smaller size reformer, longer life of the catalyst in absence of dust poisioning. Independent reforming section operates stably for longer time.

(v) Energy consumption: 9-10 GJ/ton of DRI.

(vi) Capacity: 0.25 to 2 Mtpa. 20-30 plants with total 11 Mtpa production throughout the world. One 0.75 Mtpa HYL-III plant exists in India, Raigad, Maharastra (Welspun Maxsteel).

(vii) The process is more flexible with respect to raw material. Both lump ore and pellets can be used in any proportion with only restriction in extreme cases like

95% pellet should be used with atleast 5% non-sticking lump ore and 80% lump ore should be accompanied with atleast 20% pellets.

The next part of gas based direct reduction (DR) process will be covered in the next lecture (lecture 56) and overall conclusion of the gas based DR process will be presented there.