Iron Making
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Lecture – 02
Iron Making Lecture 2

This section we are I would be giving an overview of the modern blast furnace.

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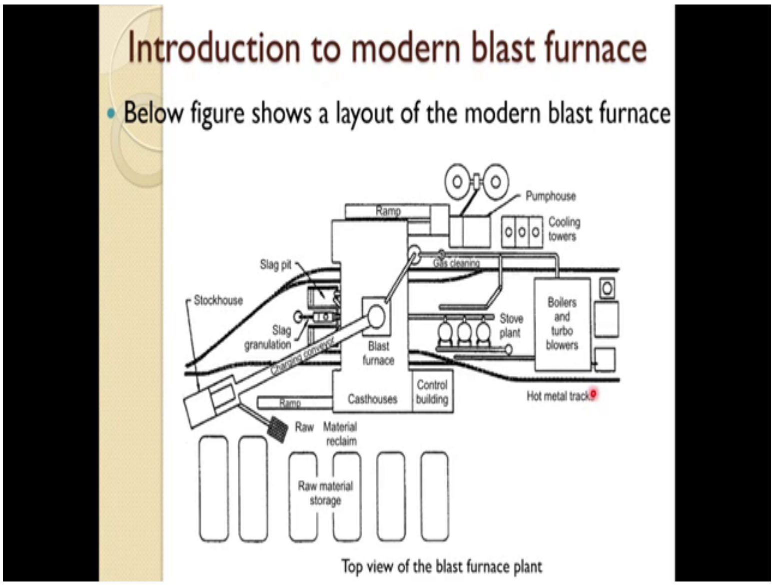

So, this below figures shows a layout of the modern blast furnace, it is a top view. So, this is showing about the raw material from where the iron ore, coke, flux, sinter or pellet whatever it goes to there and using the conveyor belt drops into the blast furnace. Then you have a slag granulations unit slag pit stock house, then you have a gas cleaning unit and juban the gas and the stove and you put it through the tuyere, the hot airs and hot metal track is over there.

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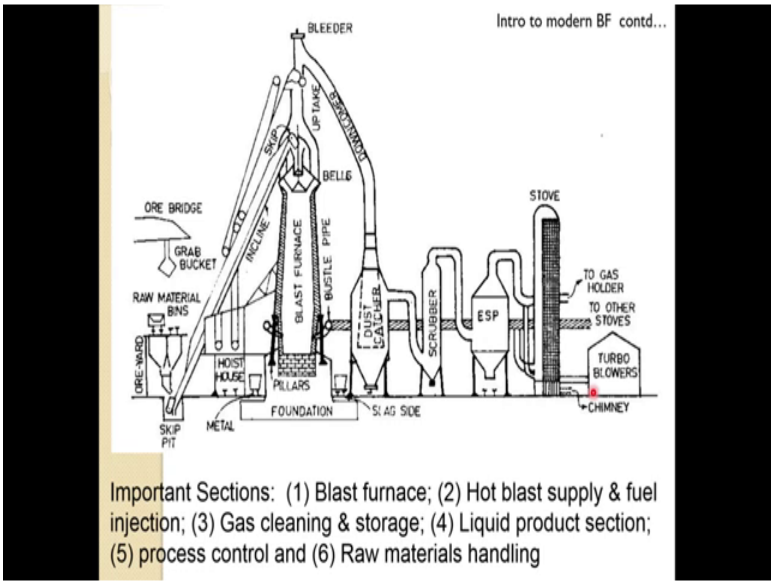

The next one is going to show you better will give you a better view of this. So, again here you have the raw material yard from where you can get the coke iron ore and sinters and through this conveyor wet skip using the top bell you charge the material into the blast furnace, and top gases comes out from here and to the dust catcher. So, you collect the all dust particles goes to the scrubber, for the collecting the dusts and then it goes to the electrostatic precipitator, where very fine dust can be separated and then this gas goes to stove to bond. So, these stoves are used to preheat the air and which goes to the tuyere in the blast furnace through the bustile pipe.

And slag and metal comes over there. So, the important sections of this is the blast furnace, hot blast supply that is stove and a gas cleaning and storage this is this part and then you have a liquid product section, where the metal and slag you take them out.

Process controls for the whole the plant and the raw material handling this is also a special section. So, I will go through it in an overview one by one.

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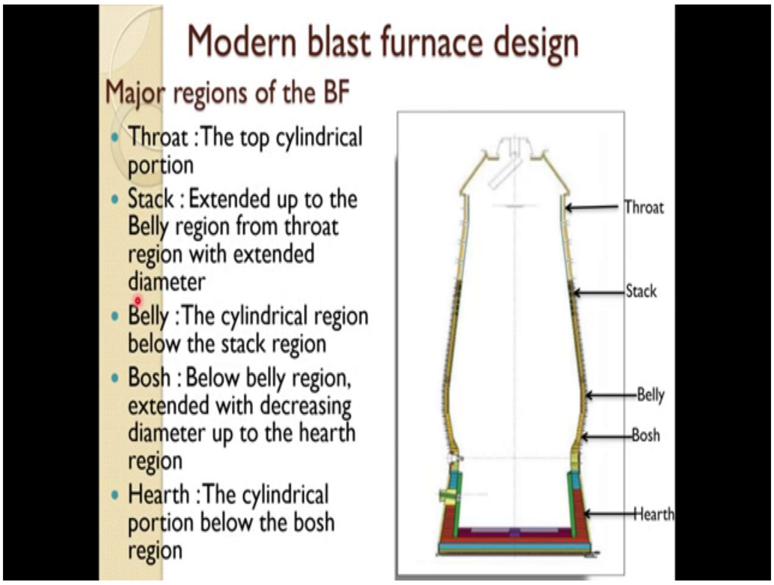

So, if we come to the blast furnace. So, major region of the blast furnace as you will see this is a throat the top cylindrical portion. So, it is a cylindrical in design the top portion which is known as throat then you have the stake region, which is extended up to belly. So, from here to here it is a stake region, which is continuously increasing in diameter and then you have that valley region which is again a cylindrical one and then you have a bosh region, which is reducing in the diameter and it goes up to the hearth region and then there is a hearth region.

Of course till now the hearth region used to be cylindrical, in order to accommodate more and more metals now in fact, this is also increasing in diameter is to go down. So, this is for the modern blast furnace, the capacity probably more than 10,000 ton per day where this sort of construction is taking place for the new blast furnace.

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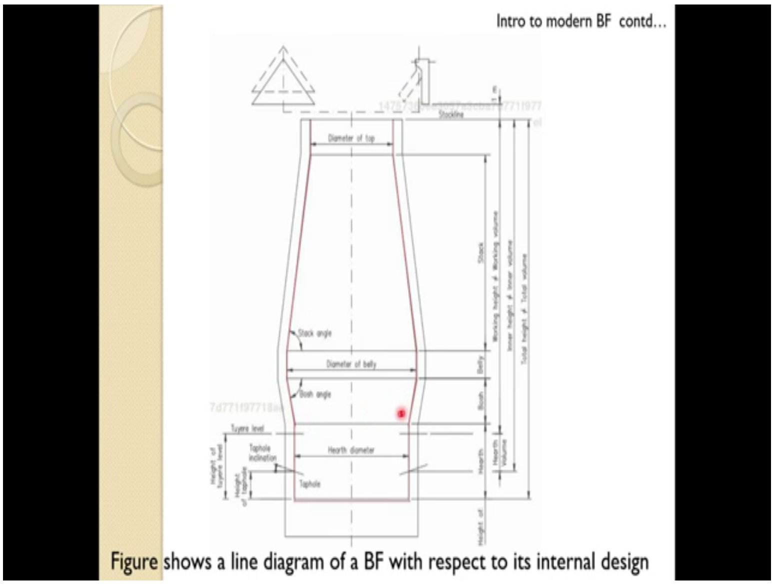

And this gives a line diagram of the internal design of the blast furnace. So, you can see for the throat region the diameter, and all this even this strake stake region and bosh region they have a particular angle like a stake angle and bosh angle and these are very important, depending on the quality of the raw material their (Refer Time: 05:00) angle and others. So, for a smooth flow of the solid these are very important.

Otherwise it can create quite a lot problem in functioning the blast furnace. So, these are very critical parameter similarly the diameter of valley and then you have a hearth diameter, tuyere level it just near the top of the hearth and then you have the tap hole, and other thing the armor plate comes over here. Even this height is very important and again this height of the stake region depends what sort of raw materials you are putting into it.

So, diameters keeps on increasing because swelling of the pellet and ore occurs and to accommodate that one had to keep on increasing the diameter during the indirect reduction and in the belly in bosh region direct reduction comes and cohesive zone. So, after that contraction of the or melting and fusion occurs. So, really it is start contracting. So, your diameter is start decreasing in the bosh region.

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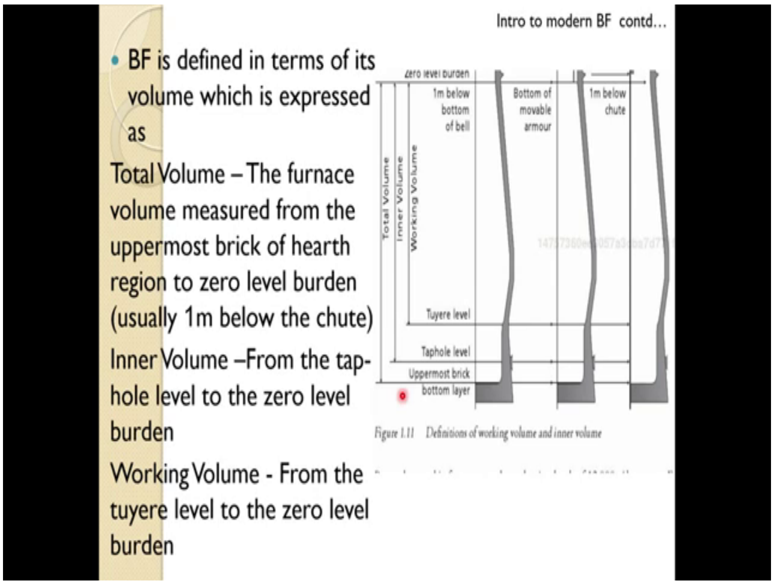

Blast furnace usually a characterized based on the total different types of volumes are their based on the volumes. So, one is the total volume and total volume measured from the uppermost break of the hearth, that the throat one. So, zero level burden in that and then up to the it goes up to the uppermost brick of that hearth region. So, that is the total volume and a inner volume from the tap hole, that is iron or select tap hole to the zero level of the burden. And the working volume which many times it is specified in terms of productivity, the working volume which is defined at from the tuyere level to the zero level of burden, and that is known as the working volume and most of the blast furnace many times are defined in terms of working volume and sometime in terms of inner volume.

So, that is gives you the idea when somebody says well the working volume of the blast furnace this must. So, it is around 5,000 meter cube nowadays or even a 6,000 has come by the time is passing. So, that is a huge volume, Glass furnace refractories and cooling.

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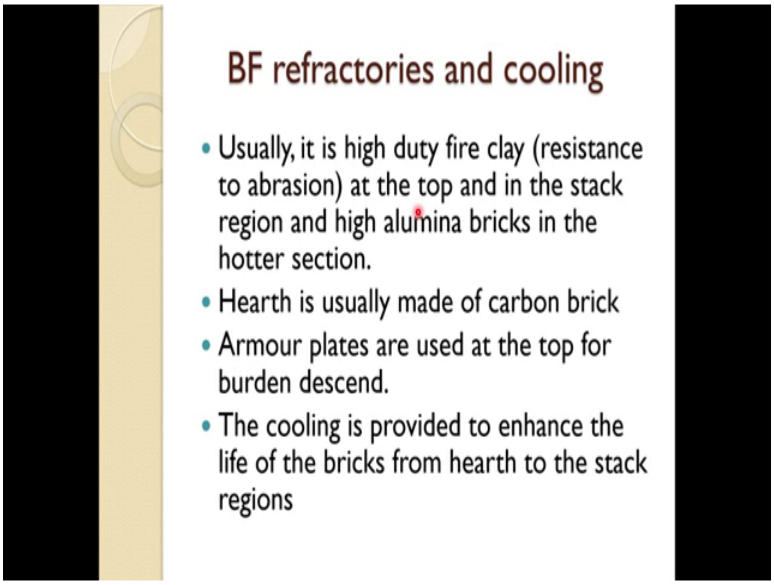

So, the second one about the blast furnace refractories. So, usually it is a high duty fire clay usually at the top and in the stake region, and high alumina brick in the hotter section. Not only these I think we will you will see later beside that cooling and other thing we use it because abrasion is a very important problem in the stake region when the throat region, because the all material is falling down over there and directly hitting the bricks. So, abrasion is a very important property for the refractories.

So, one has to be very careful in choosing the refractories in the top region, which has a high abrasion to put this raw material then for hearth is usually made of carbon brick because it is a high temperature and you do not want a very reactive brick also which can react with the metals. So, the natural choice is carbon and similarly arm Armour plates are used at the top of the burden design. So, this is where when the raw material is hitting to the Armour plate. So, that really give the protection for abrasion in there and cooling is provided to enhance the life of the bricks from hearth to stake region and that is in the next few slides you will see.

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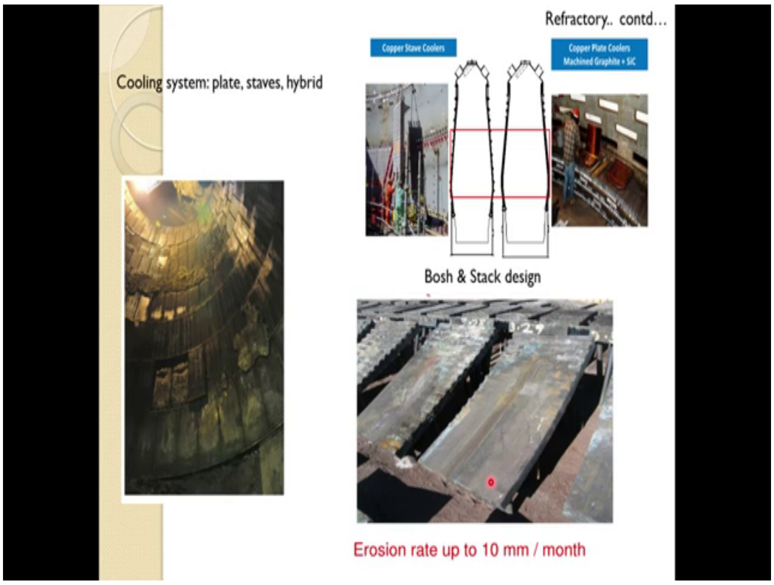

So, the cooling is a provided you have a plate type stave type and hybrid type. So, in the plate type cooling you put the copper plates actually the right one is showing though its not that much visible it is a copper plate cooler behind a brick which cooled by water, and this is copper stave cooler and these two types are used depending on the severity of temperature and that house you cooled a brick this essentially shows the arrangement of this stave cooler in the stake region, and as you can see the quite a bit erosion takes place up to 10 millimeter per month and this is the typical photograph of that erosion the upper in the upper zone. So, it is very important to select the right refractories and right cooling procedure to minimize the consumption of the refractory which are very expensive.

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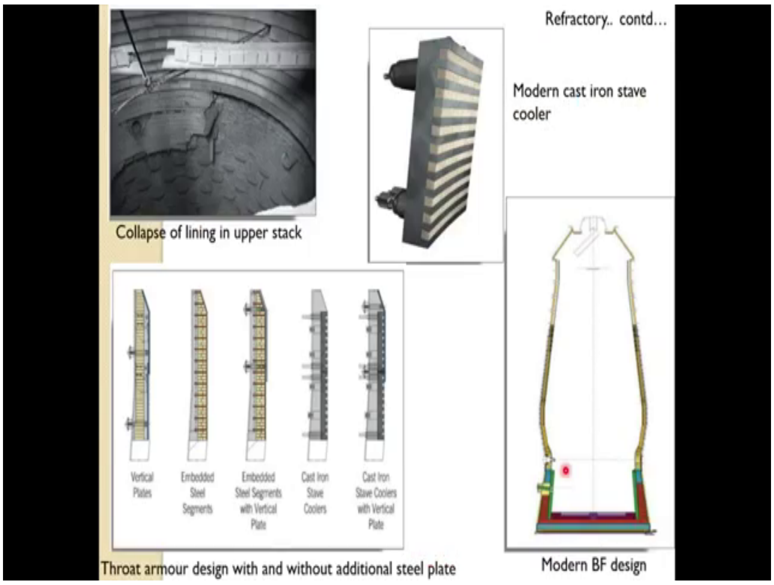

Ah. So, this is in the stake region and. In fact, this shows a little bit; now in the modern blast furnaces even a cast iron stave cooler is used. So, water goes through this and comes out. So, this is a cooling one time to collapse of lining you can see if the cooling has failed and other thing collapse of lining can occur in the upper region. The way these are inserted one is a vertical plate embedded steel segment, embedded steel segment with vertical plate. So, you can see this is sort of a Armour one in the upper region, where the raw material hits. So, it protect that. So, cast iron stave cooler and cast iron stave cooler with vertical plates. So, different types of cooler in a different and the different region depending upon the nature of the cooling they can be used.

So, this is sort of a design of the modern blast furnace which we discussed before. So, point should be noted here this is a throat Armour design that is actually is protecting the bricker. So, raw material when it falls down.

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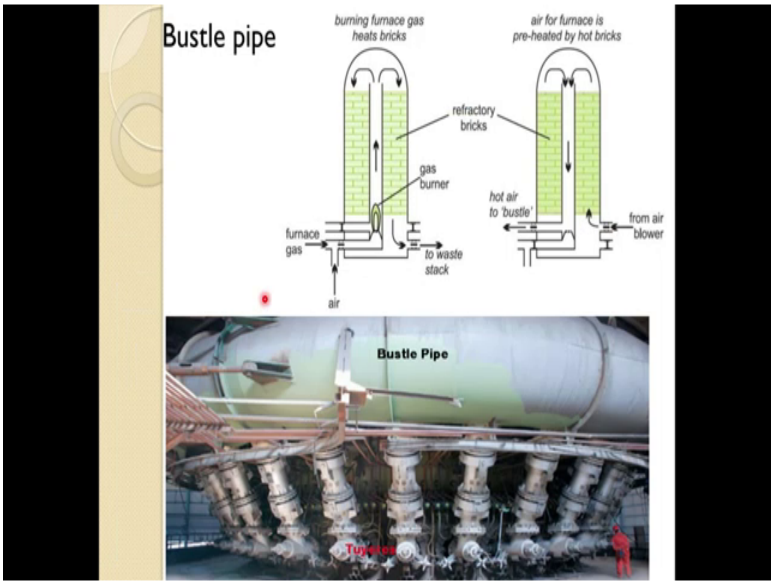

The bustle pipe this is actually if you look at that gas is injected gas and fuel other they can injected through the tuyere and this is very important person and that one. The point is this because they are about 30, 40 tuyeres around the circumference of the blast furnace, and it is necessary that all the tuyeres should have the right pressure and should deliver the right amount of the gas or fume.

So, it cannot be in one tuyere a less amount is going in another tuyere is high amount is going and that will create the operational problem, and other problem in the blast furnace. So, for that purpose the bustle pipe is needed and it makes sure that in all the tuyeres the pressure and feed read is maintained and that is the very important for this bustle pipe and these are the tuyeres through which the gases are going and fuel can be injected from the side and because it carries the hot blast air, which is which is coming from the stoves.

So, what you do in the stoves? The furnace gas which comes from the top as we saw in the previous slide these are burnt through that and these are the checker bricks which gets heated up, and the waste gas goes to the chimney and when you need a hotter air you reverse the cycle and that when you blow the cold air, and due to this checker which absorb the heat bricks you get the hot air which goes to the bustle pipe.

So, these are they stove which are used to pre hit the air and this one goes to the bustle pipe and this goes to the tuyere. So, usually the temperature depending it can range from 700 to 1300 degree Celsius in the blast furnace.

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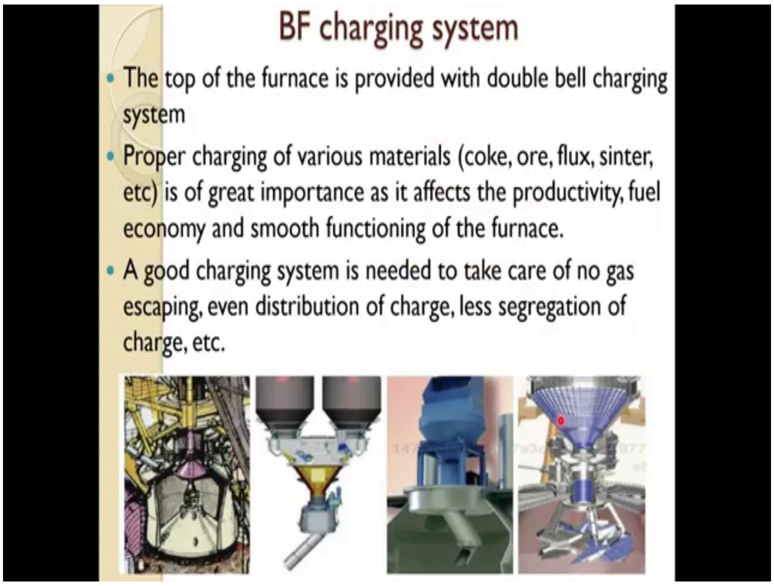

So, blast furnace charging system this is also very important. The top of the furnace is provided with the double bell charging system, even some of them nowadays is coming as a bell as. So, examples are giving up some of them here. So, proper charging of various material coke or flux sinter is of great importance as it affects the productivity, fuel economy and the smooth functioning of the furnace, we will talk about this later. So, a good charging system is needed to take care of no gas escaping even distribution of charge less segregation of the charge etcetera.

So, usually the double bell due to use for this. So, in the first one you get the material charge and the second one lower one is closed and then to lower the first one. So, material drop down on the lower one and it goes up. So, again it sealed. So, no gas can be passed through this, and then the materials this is lower down and materials fall through that. Then of course, you have a treat and that thing we distribute the material and the different form in the blast furnace and you can change the angle of this. So, what sort of angle the layer should have? Various layer of coke, sinter, pellets or. So, these are various designs by which you can control the charging of the material in a proper way and even the segregation up to some extent. So, these are also very important equipment in the blast furnace.

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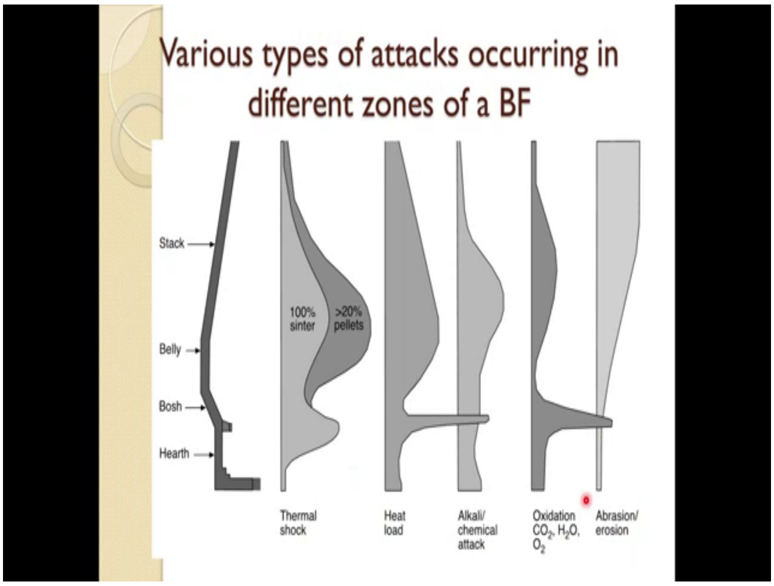

Now, we have a various type of attacks occurring in different zones of a blast furnace. So, if we look at this figure this is a typical blast furnace side beaker we have taken stake region valley bosh and the hearth. So, with respect to say you look at the thermal shock, thermal shocks is mostly the stress at thermal stresses which are created due to the contraction and expansion of the heat. So, you will see it maximum one is occurring in the stake region, where this raw material actually is subjected to quite a bit thermal stresses. So, if it is pellet, pellets are the more susceptible or maximum susceptible for the thermal stresses and in fact, they disintegrate. If they disintegrate then the permeability effects and then the products and will affect, and impede the blast furnace will not run smoothly.

So, it is very important to know about the thermal shock of the material, similarly the heat load because most of the heat is released in the compensation zone where the tuyere is. So, that is how it is showing the figure and then of course, the other reaction where some exothermic or endothermic reaction occurs and then you have a alkali and chemical attacks. So, most of the alkali actually vaporize here like sodium potassium these are the important one and I mean the zinc which vaporize and it condenses. So, it goes up because here temperature is quite high about 2000 degree celsius 1800 to 2000 and due to visit vaporizes in goes up here it reacts with other material again to N a 2 or K_2O and this actually deposited on the surface of the sinter or pellet or whatever material is it and it makes it sticky.

So, sometime in and then at it goes down because this is a colder region. So, it deposits. So, essentially its really not going out and when these pellets or thing comes down again it vaporizes here and goes. So, its a sort of a cycle in cycle form it is going. So, it builds and many times it attacks refractories. So, you get the scab folding and other thing over here. So, material get stuck over there where you get the scab folding and other thing. So, it is very essential that alkali content should be very low in the raw materials whatever is used in the furnace. And some of this alkali goes into the slag and very little in iron and some in the top gases.

So, similar is the oxidation. So, most of the oxidation actually its occurs here C plus O 2 CO 2 which is a exothermic reaction. So, that gives quite a big amount of heat and which you can see here. So, that is oxidation occurred there and then more coal is there and that. So, it start reducing all these gases and then mostly say reducing atmospheres here. So, most of the oxidation atmosphere prevails in front of the tuyere and not here again you have a FeO plus CO gives you bit F e and CO 2. So, bit oxidizing atmosphere comes over there.

But mainly its over here similarly abrasion and erosion as we discussed before. So, abrasion is very high in this area where the raw material is falling. So, that is a very high rate of abrasion here and then it becomes as it start reducing and like that and fusion and melting, really there is not much erosion in the down part. So, this gives you a an overview about the various type of attacks which blast furnace faces in brief.

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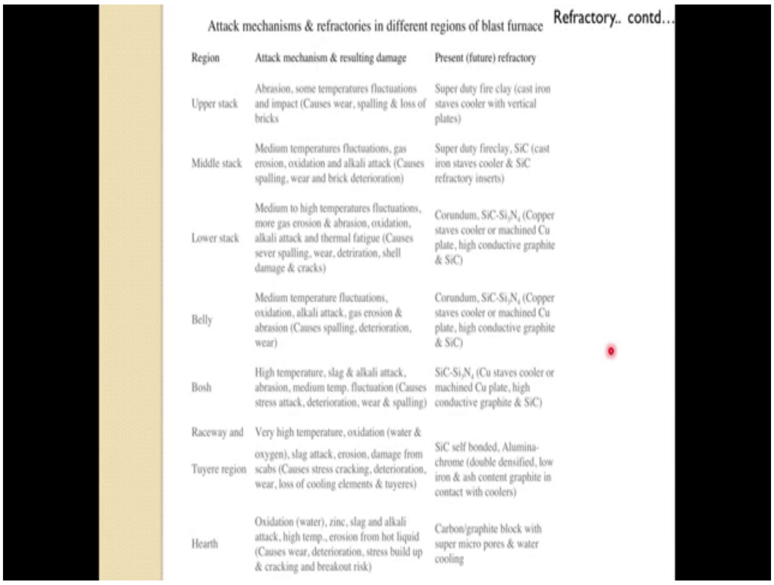

And this slide. In fact, gives you or shows you about the attack mechanism and the refracted which one should use.

So, now in the upper stake region because abrasion is a very important one, and some temperature fluctuation is less, but abrasion and impact these are the two men. So, you should have a super duty fire clay, cast iron staves cooler with vertical plate which we have seen in the previous one in the middle stake medium temperature fluctuation gas, erosion, oxidation and alkali attack.

So, causes spalling wear and brick. So, here you need a super duty fire clay and so, many time even the silicon carbide. So, cast iron steves cooler and silicon carbide refractory insert into that, that is the one in the modern blast furnace use it. In the lower stake region where its a high temperature fluctuation and more gas erosion which is coming from the tuyere in fact, from the cohesive zone actually it is coming and where the permeability of the coke is the is the one which can let the air pass then the fusion.

So, usually the velocity is little higher. So, gas erosion and abrasion oxidation alkali attack and thermal fatigue these occur which we discussed in the previous slide. So, what you need here corundum, silicon carbide, silicon nitride with a copper stave cooler or machined copper plate which we saw in the previous slides. So, the that sort of refractory you need it. In the valley region its a medium temperature again medium to high temperature, alkali attack, gas erosion and again you need a copper stave or machined copper plate cooling mostly machine copper plate in this region is used with high conductive graphite or silicon carbide (Refer Time: 23:51).

In the bosh region high temperature slag and alkali at a quite broad predominant in this abrasion medium temperature, fluctuation, you need a silicon carbide, silicon nitride brick mostly with the copper plate machine copper plate and high conductive graphite or silicon carbide can be used. Raceway is a very high temperatures oxidation water and oxygen slag attack erosion, damage from scabs, caused by stress cracking deterioration wears, loss of cooling element and tuyeres.

So, this raceway and tuyere region one has to take proper care. So, silicon carbide self bonded refractories are used. Alumina chrome, double densified, low iron and ash content graphite in contact with cooler. And for the hearth oxidation zinc slag and alkali attack occurs and because most of the alkali goes into slag high temperature erosion, when you are emptying it.

So, quite a big high velocity of the slag and metal and which causes quite a bit erosion. So, hot liquid causes wear and stresses buildup. So, do you need a carbon or graphite blocks, which super micro pores and water cooling for. These are the sort of a trend in the modern blast furnace, where these refractories are used in various regions and it is very important because one of the refractories or in one region falls products and gets affected. So, its a important that life of the refractory should be as high as possible and should protect all the material.

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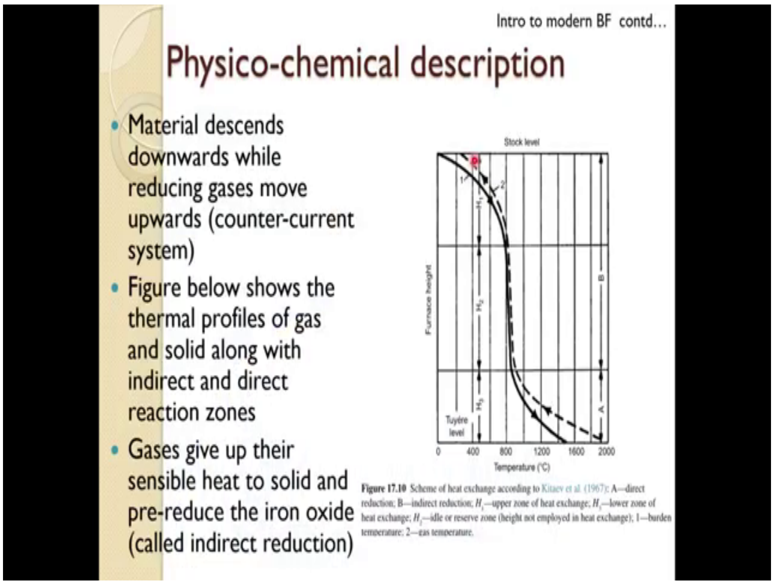

Now, we will describe a little bit about the physicochemical description. So, we discuss more about the design, about the refractories and different attack which blast furnace under goes. So, these are all mechanical type of things which we have discussed till now, now we will give a little bit description about the physicochemical thing which is happening inside the blast furnace. So, this figure shows is, the material descends downward by reducing gases move upwards. So, essentially blast furnace is a counter current reactor.

When we say counter current, it means the solid is coming down as you know from the top you charge the solid is coming down and gases are going up. So, in one way they are facing each other in a counter current form. So, this way it is called counter current. You have also co current where the suppose the gas in solid are going in the same direction then or even a liquid in the that condition, these are good terminology in chemical engineering then those sort of flaws you call them co current and you have a cross current when they one of the phases coming down or going up the other phase is actually going at 90 degree. So, that is called cross current.

So, most of the things in blast furnace counter current except in the region near the tuyere, where the cross current occurs because gas is going from the side and the all the liquid and solid is flowing down word direction, otherwise it is a counter current one. So, because the hot gases are coming from the tuyere where the combustion occurs, the temperature is very high. So, this dash line shows the gas temperature here and the solid line shows the raw material temperature. So, so the thermal profile of gas solid along with indirect and direct reaction. So, what is happen at the gas goes up which is having a very high temperature. So, it gives it temp temperature or sensibility to the solid.

So, solid temperature also increases in that. When you come to this region there is not much temperature different, and this region actually its a indirect reduction zone we will talk about that later as we move on and in fact, this region is known as mostly the direct reduction in terms of chemical reaction. So, this is indirect and this is a direct reduction this is like a preheating zone. So, once it crosses that stake region is come to preheating the gas temperature always is high. So, it comes out and the top gas temperature is around 250 degree celsius and that is how the temperature profile looking a typical blast furnace.