**Iron Making**
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**Lecture - 03**
**Iron Making Lecture 3**

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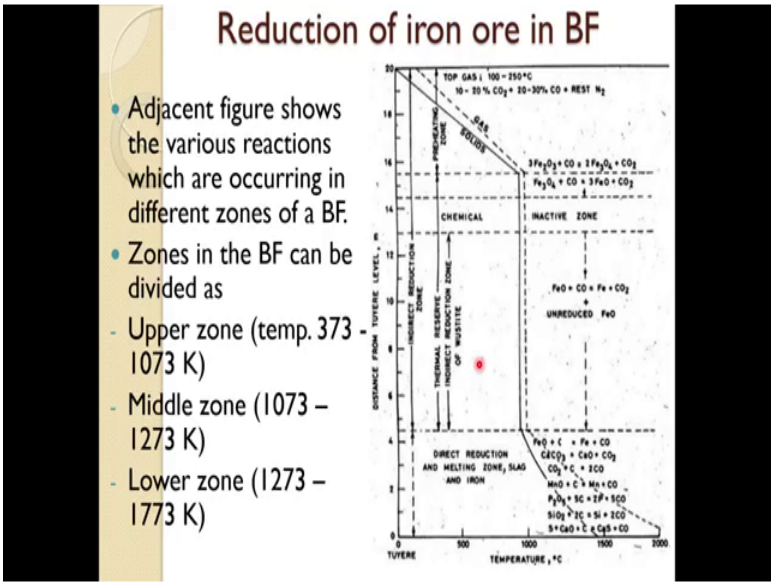


The direction of iron ores and blast furnace so, this figure shows the various reaction which are occurring the blast furnace, as we which is you know there various region the throat region, as we said throat throat region, stack region, belly region, bosh and hearth.

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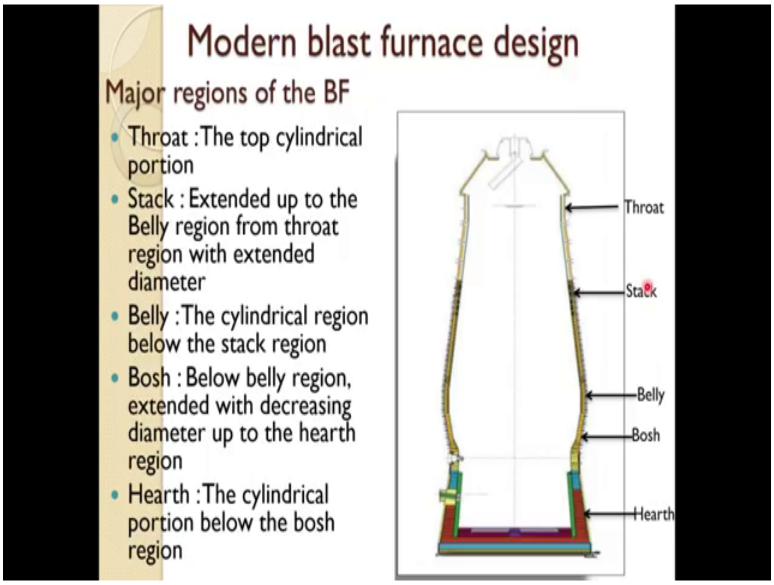


So now, we would be talking 1 by one about the, what sort of reaction that occurs? So, this is actually it is a distance from the tuyere level. So, we were talking about a combustion occurs and this is at the top, from where the charges material is getting charged.

So, this is the top reasons the stack region. So, in this region gas temperature top gas temperature 250, but really it is a going somewhere from 7, 800 to 250. So, this region most of the zone water, get about evaporated. So, free moisture and chemically bonded moisture get evaporated and some of the reaction ah, we will you will see in the other slide. So, mostly F e 2 O 3 or hematite reduced to magnetite, in this region and then magnetite to F e O this is sort of an inactive zone in between, and this indirect reduction takes place F e O with CO the reducing gases which are coming out from here, which is C O mostly which gives a reduced F e O iron oxide into iron and C O 2.

Though we have put in terms of F e O, but stoichiometrically is not the correct come representation of iron oxide, oxygen contains vary from 0.95 to 1.05. So, usually you write it F e O x. So, the zones in the blast furnace can be divided, upper zones, middle zone this is a middle zone and this is the lower zone, where direct reduction of carbon is taking place, we will describe this on the next slide.

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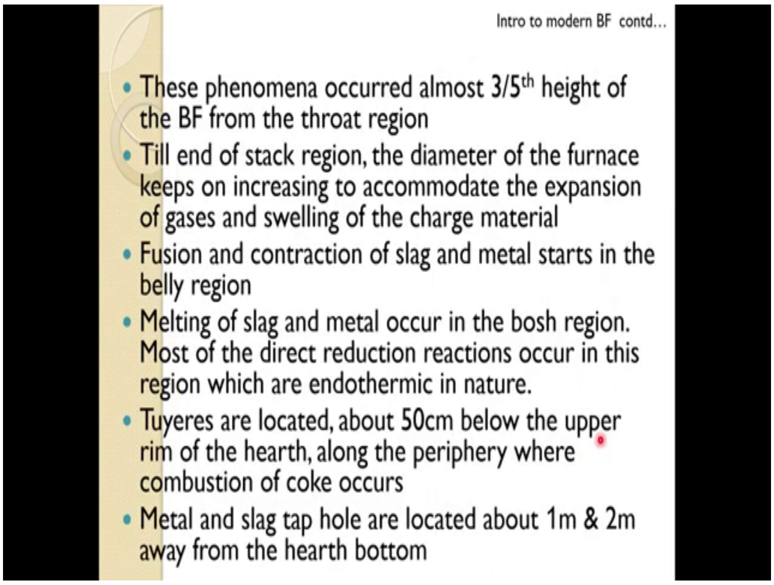


So, this phenomena which described in the previous 1, this occurred almost 3 5th height of the blast furnace, from the throat region. So, most of the indirect reduction and. In fact, decomposition of carbonate, except the calcium carbonate to magnesium and other carbonate this occurs. So, in this region and this height it look at almost the 3 5th of the blast furnace, where the all these phenomena are occurring.

So, till end of this take reason, the diameter of the furnace keeps on increasing to accommodate the expansion of gases, and swelling of the charge material. fusion and contraction of slag and metal start in the value region, as we discussed before and melting of slag and metal occur in the bosh region, most of the direct reduction reaction occur in this region, which are endothermic. So, as you can see these are the reaction which is occurring in this and all of them, actually are endothermic as such. So, tuyeres are located about 50 centimeter, below the upper rim of the hearth as we I mentioned during the design of the blast furnace, that to your location is about 50 centimeter below, the upper rim of the hearth.

So, along the periphery where combustion of coke occurs, metal and slag tap hole are located about 1 and 2 meter away from the hearth bottom.

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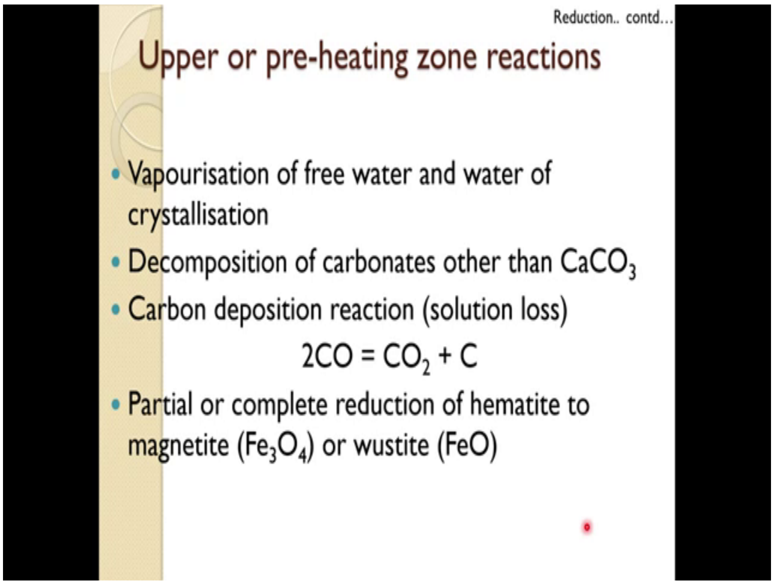


So, we now look at the various zones, in the blast furnace in terms of reaction, what we will see? In the first one in that upper zone, which is known as also the preheating zone. So, vapourisation of free water in water of crystallization that is the chemically bonded water, that occurs usually this is around 100 150 and this can go up to 400 degree Celsius, then decomposition of carbonate occur other than calcium carbonate, with that occur at higher temperature, smoothly magnesium carbonate or the magnets carbonate these occurs in this region. Even if you have a carbonate iron ore, that also occurs in this region..

So, carbon deposition reaction can occurs in this region where, C O decompose it into C O 2 plus C and keeps that carbon. So, that carbon deposition reaction what called solution loss reaction, they also occurred in this region and partial or complete reduction of hematite, hematite to magnetite or wustite to some wustite, also get to reduced from hematite to wustite, wustite is again F e O x. So, because the stoichiometry oxygen content is different and, but it goes into the series it to reduce, but hematite then magnetite and then wustite.

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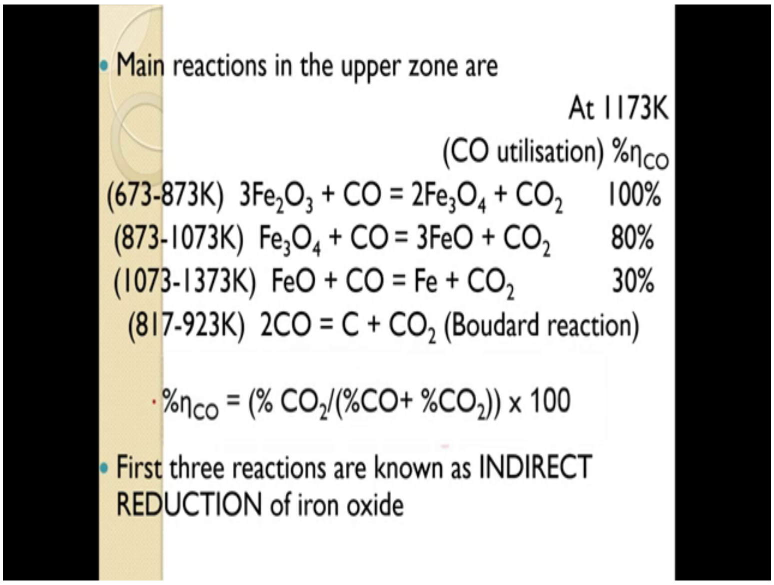


So, in the second cell form to again in the upper zone, whereas, I said the temperatures go to 800 or. So,. So, there sort of a utilization of carbon monoxide or in terms of percentage of carbon mono oxide efficiency ah, this is 100 percent is called the first from magnetite ah, from hematite to magnetite in this region up to 873 means about 600 degree Celsius, and then magnetite to F e O it is a efficiency is about 80 percent of cos utilization ah, and this reaction little bit it occurs in the stake region actually, a middle one not that much in upper zone, but some amount can occur which has a 30 percent cos utilization, and we said the solution loss reaction or boudard reaction, it is sometime known as occurs in this region.

The efficiency when we talked about the C O, it is given by these percentage of C O 2 divide it by total percentage of C O plus C O 2 in the case to 100. So, first 3 reaction are known as the indirect reduction of iron oxide, as you can see indirectly it is releasing.

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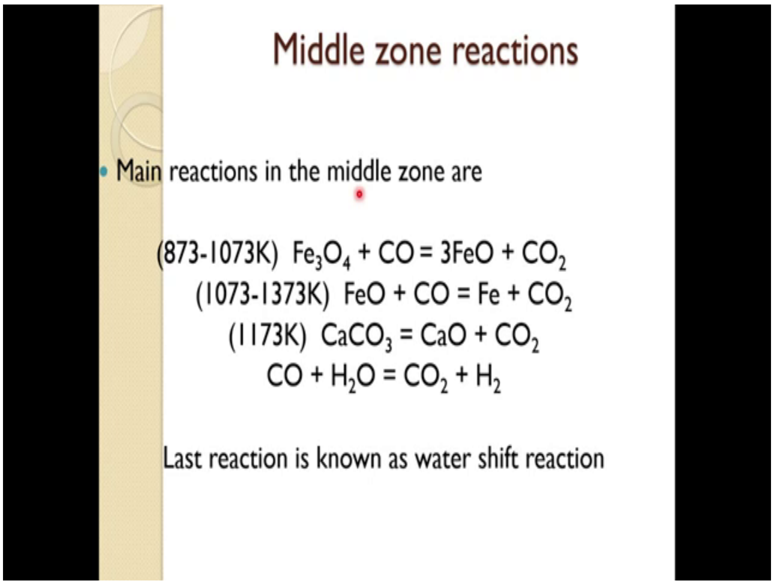


Through the case and the middle zone reaction, the main reaction again some magnetite to wustite, it reduces and from wustite to iron. So, most of the iron get reduced in this region, but not all may be up to 70 percent or. So, and calcium carbonate decomposes in this region and this C O 2 react with the carbon, and from C O again and even they whatever some moisture is there, that also react with the C O and keep C O 2 and hydrogen, and as you know hydrogen is much better reductant than C O.

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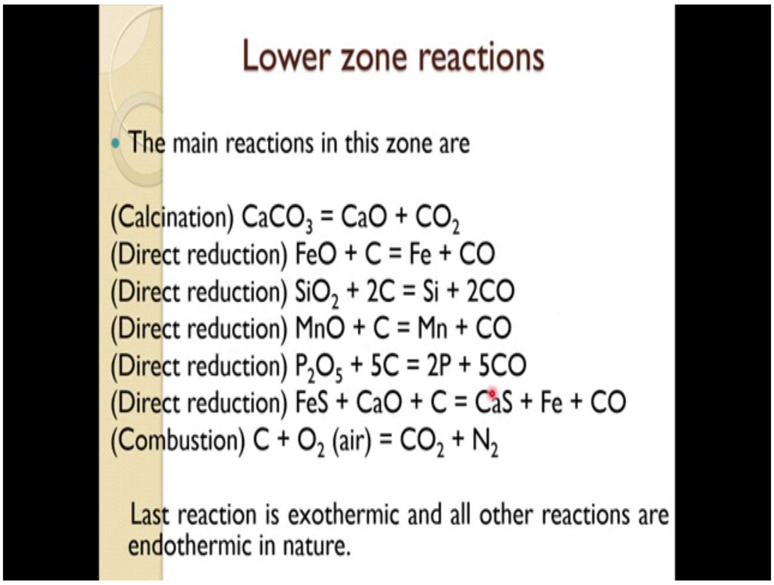

So, reducibility of the gas increases by these hydrogen. So, this reaction is also known as the water shift reaction. So, these sort of the reactions occur in the middle zone, and in the lower zone of the blast furnace ah, we have these reaction these all reaction are endothermic first. So, calcium carbonate decomposition, whatever is left from the middle zone it decomposes in the lower zone, which has a very high temperature range 1500 or. So, and direct reduction of F e O occurs in this region.

So, as you can see with solid carbon F e O is getting converted into F e, even S I O 2 reduction occurs in this and the silicon vapors can form, and this is the one which contribute to toward the high, silicon in metals and it get a absorbed by the liquid iron, the manganese get released manganese oxide get reduced into manganese, similarly phosphorous pentoxide get reduced to phosphorous. Again, if there is a sulfur associated with iron, it goes this line and from calcium sulphide and iron get reduced in that, and the combustion it said occurs in this region also, and that this is the oxidation you can see and as it leaves the raceway region, it is react with the remaining coke carbon and from the C O.

So, this is the only reaction which is the exothermic and produce quite a lot heat, but when it react with excess carbon C O 2 plus C equal to 2 C O that is again an endothermic reactions, of one had to see the net heat what is released from that reaction?

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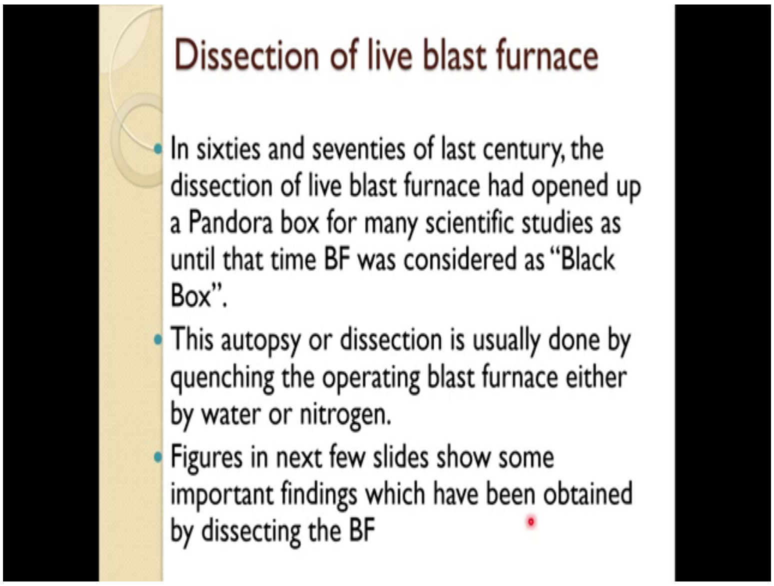

And so, coming to another part of the. So, before anyway coming to the dissection of this, these are the main important tricks and which are taking place, and one has to be very careful especially, with the silicon pick up this reaction and this is very important reaction in the blast furnace, mostly what you need you need a less silicon in the hot metal, otherwise it lead to desiliconization another operation, after the metal is tapped.

So, that is again an expensive one and it is a sort of increase the cost of the steel ah, but these are the few reaction, which we will discuss in detail, similarly about the phosphorous and sulfur and the later stage and how do the affect the chemistry of the liquid iron and slag? And the further processing so now, I will come to the next topic of dissection of the live blast furnace, whatever we have discussed till now, we got most of the knowledge from the dissection of live blast furnace, before that the blast furnace used to be considered as black box.

So, the used to be considered block black box, because it is all enclosed and it is very hot in salt one cannot see anything, what is happening it set a speculation this is the thing which could happen, a cold model study or like that and nobody was sure, what is happening inside of it how the various section look like, we say the cohesive zone, we say the middle zone, we say the stake region, then we say about the tuyere region.

But what is happening there? really nobody knew about it. So, till the dissection of live blast furnace came. So, people especially in Japan and U S A U S A. In fact, a probably the first one who put it and then Japan actually started that, they quenched the blast furnace the live blast furnace the operating blast furnace, and the quantity is using water or nitrogen, from the top and then they dissected it, opened it and this is these are the actual operating blast furnace, and in Japan many blast furnace almost 10 to 12 blast furnace in one go they did it, and next few slide will show you some important findings, what they have obtained from these? And you would be amazed to look at the different region, which they have got it? And this all the study is about 3 to 4 decades old, and blast furnace since then has improved a lot, and that is what we discussed in the previous slides about the modern blast furnace. But before that what was the status of the inside the status of the blast furnace, you can see in these figures.

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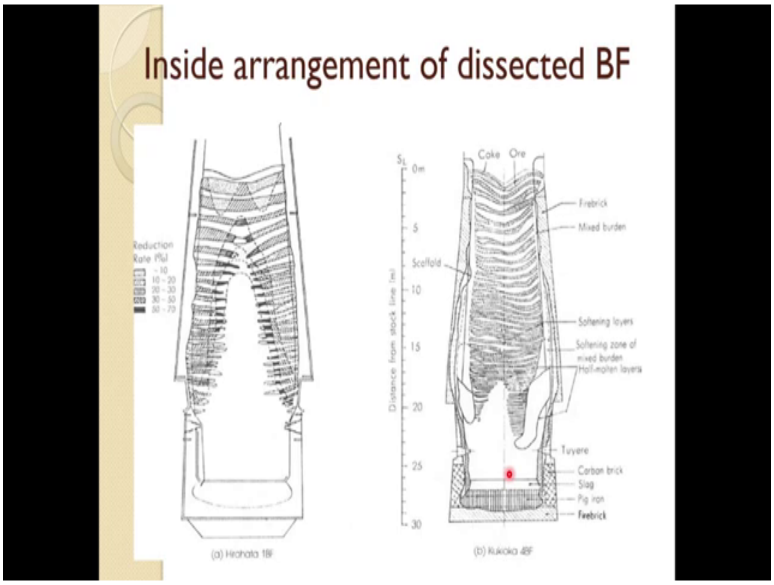


So, this is the inside arrangement of dissected blast furnace, as you will see this is a hiro hirohata blast furnace, this is kukiaka blast furnace of Japan and these are different different blast furnace, I am not going into the detail of these operation, but because they were operating with a different raw material, different operating condition, different flow rate, blast rate and with different conditions which of course, can we seen in the literature one can read those, but what it is pointing out, see when they operate in a different way, the cohesive zone this is actually a cohesive zone which is like a semi fused iron and slag and coke layer, and here this is the cohesive zone.

A very big difference between these 2, while this is extent up to the stake region on top of that almost and this is just below the stake region and beside that you have. In fact, a layer of this fused mass, which is like a fused iron and coke that, has extended till to your level in this one, while this is quite away which normally ideally, we expected, and this is due to the irregularities and this furnace is not operating in a proper way, as you can see also escape hole in this.

So, this is clearly showing the furnace is not operating, with 100 percent efficiency in a good form and you are getting various things in the furnace over here, in comparison to this and, but this whole arrangement, how it is coming at you? Look at closely as you can see the this, is actually the ore raw material which could be sinter pellet or iron ore flux and this reason the white one is coke.

So, alternative layers they are coming and you can see these are getting fused and narrow and narrow, the layers of raw material except the coke and when it reaches to this high temperature zone, your ore becomes a semi molten in the region or masses zone what you call it, but this white zone the coke retains it is a structure.

So, most of the gases then passes through this, because they cannot pass through the masses zone due to very high resistance. So, this there is a permeability issue here. So, a structure of cohesive zone is very important, because this is the one which is letting air go out, into the other zone and the reducing zone. So, that is why cohesive zone is a very important one and on which it affect the permeability, of the bed and further reduction in the upper zone.

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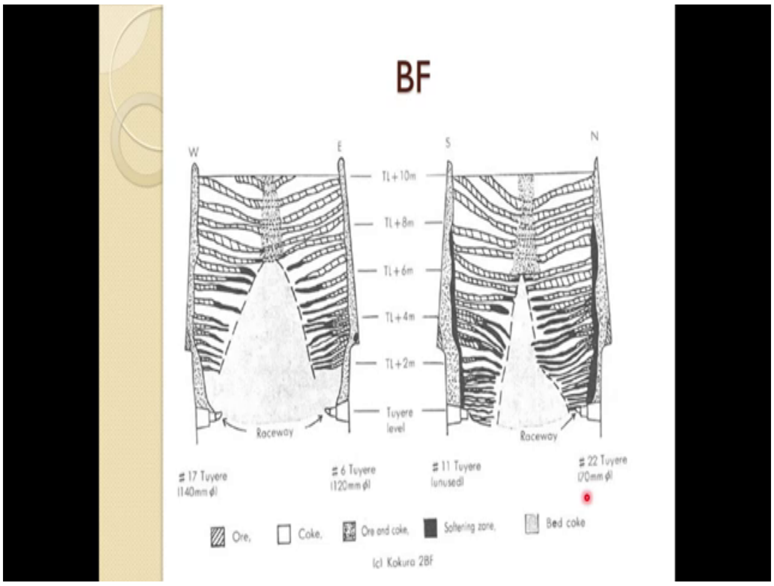


So, this clearly shows how they are arranged in this way, it is kept holding another thing. Look at the this figure you can see also it changes, the cohesive zone nature is changing, this is one tuyere number, but it is about 14 centimeter in diameter this is 12-centimeter diameter. So, how the diameter is affecting the cohesive zone? And how this layer structure is taking place? Similarly, you can see in this one and in this one. In fact, there was no gas through one tuyere. So, this is a unused. So, your all fused mass has come up to here.

So, the no direct melting has occurred, it has come tilt tuyere region and tuyere region is really in the hearth. So, you can see it quite a lot F e O is directly entering into the hearth region, this is 70 7-centimeter diameter tuyere and that is how the. So, this is all softening zone and various zones are there. So, this gives a very good idea how inside of the blast furnace look like, when you quench it and dissect it and belt on that many study have been taking place and it has been improved, and that is how the modern blast furnace look.

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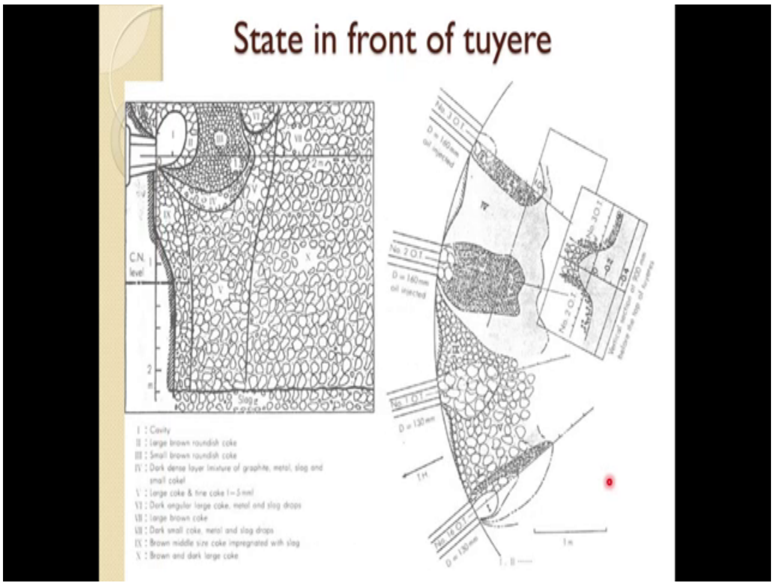


Now, this again about the dissection of that blast furnace and when they look at the raceway region, because that is a very important reason on which, the whole reduction permeability aerodynamics of the blast furnace defense.

So, you can see when gas is injected, the immediately in front of the tuyere there is a region where there is no coke it is a cavity, what we call raceway then you have a different different type of coke. So, just after that they they high large brown roundish coke , you get it and this is sort of a racing around that and that is how the name is raceway and then you have a finer coke actually, finer in dense coke. So, permeability is less there. So, somehow one has to get rid of that and this also later on extent to for the dead man, this actually reason is a dead man and then do you have a other different types of coke, angular large brown coke and then brown dark coke and if you look at the top view of that, you can see the oxygen level is almost by middle of the raceway 0 oxygen.

So, all oxidation reduction has occur by it is. So, this is the one which is oxidized region and after that, reducing gases is thought. So, C C O 2 form react with carbon and C O started forming and front of that, raceway you have a higher size coke and side of it, because lots of abrasion and other thing is occurring here. So, fines are generated which get deposited further down on that one. So, this is a typical stage of the blast furnace raceway, of the quenched one and this is again, I would say 4 decade old and many things have changed. So, lots of attention is paid, now on the coke quality due to this.

Because you do not want lots of disintegration and generation of fines and other things should occur. So, quite a bit research has gone and not only these, similarly about maintaining this structure, say about the raw material preparation about the coke preparation, these are very important for a smooth functioning of the blast furnace.

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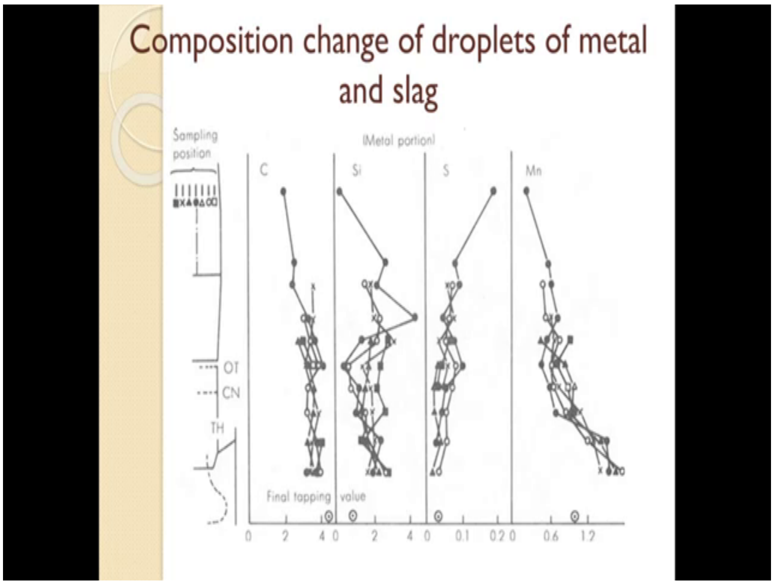


This gives an again idea again from a dissected blast furnace, the change in the composition of metal droplet of metal and slag. So, these are sort of a sampling position from where they picked up, the metal and slag droplets and as you can see this is actually the sort of tuyere region. So, temperature is high in this region.

So, carbon pick up by, slag and metal is very high. So, it is a that is how you say the carburizing addition, of the carbon occurs here. So, which goes 4 percent or more? So, liquid metal always has carbon 4 to 4.5 percent, similarly the silicon pickup erratic, but mostly silicon pickup is occurring, between quite high in this tuyere and above in the bosh region and valley region, because this paper goes up and absorbed by the droplets of metal and slag and slick on level increases in that one. So, you can see silicon level can go up to 3 percent that is very high. So, you need a desiliconization.

Sulfur pickup of course, depending on the temperature and basicity and other thing of the slag, this sulfur content and decreases that it goes near the hearth or tapping side, it continuously decreases of course, the manganese pick up it is height especially by the metal. So, manganese goes mostly into them metal. So, these are all sample which was taken out at various places in the blast furnace, operating one and that shows the composition of all these important element, which are there in the metal and slag and this gives an idea that how the situation prevails in the blast furnace, inside the blast furnace and how one can improve it.

Nowadays in fact, you would not find silicon percentage of that high, this is again as I said all 4 decade all minimum, 4 decade all dissection study, so many improvement have occurred and silicon goes a very low. Now, with the preparation of proper raw material and temperature and other thing not in goal easily 0.5 percent or.

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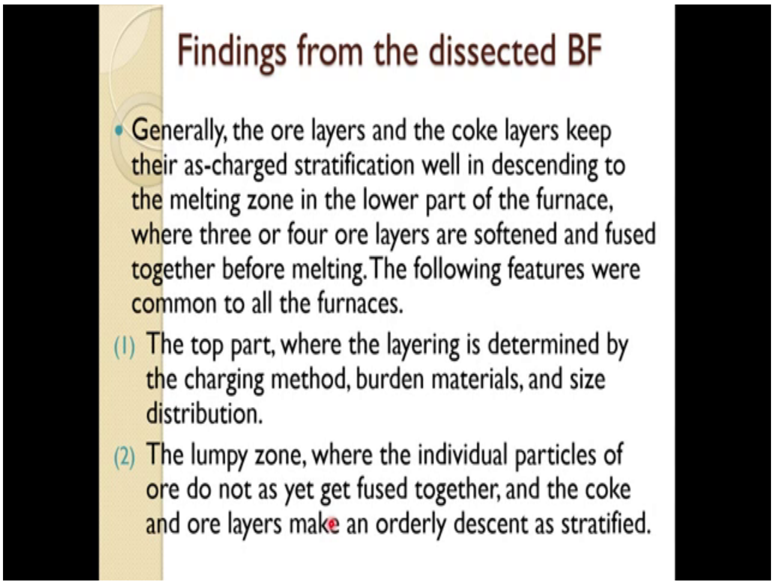


So, so finding from this dissected blast furnace, generally the ore layers and coke layers keep their as charged stratification, well in descending to the melting zone which we have seen it, they are in the layer form and the descent maintaining that one.

The lower part of the furnace we had 3 or 4 or layers are softened and fused together before melting. So, there it can thin down and they are fused together, and the other important feature the top part where the layering is determined by charging method, burden material and size distribution, the lumpy zone where the individual particles of ore do not as yet get fused together and the coke and all layer make an orderly descent, as stratified. So, as long as they are not fused and temperature is not very high, in a very orderly manner they descent into the lower portion. So, it does not pour that much problem to the permeability of the blast furnace, and further reduction of the choice.

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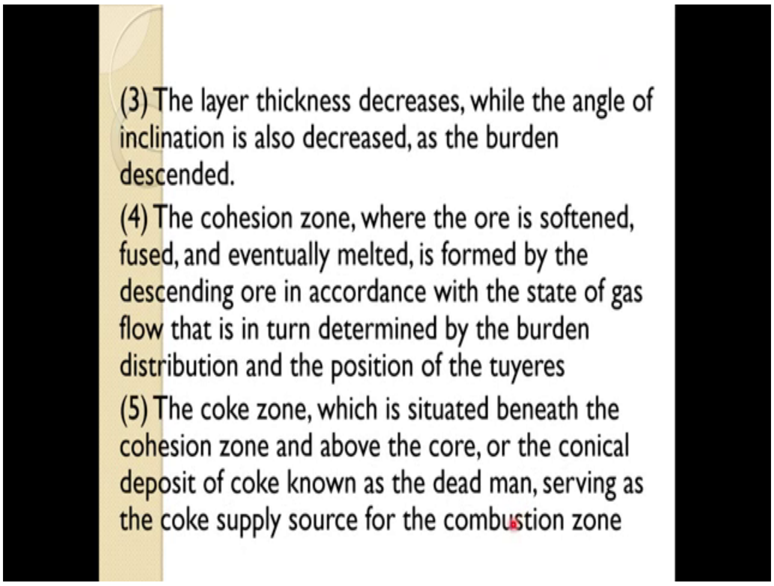


The layer thickness decreases, while the angle of inclination is also decreased as the burden descended, I think this you might have noticed this that you can see, how we get the inclination angle in the starting of the layer? But at it comes down, these decreases and of course, the thickness is also decreasing of the layers. So, that is about the point, which says the cohesion zone is nothing the cohesive zone where, semi fusion molten metal is there material, where the ore is softened fused and eventually melted is formed by the descending ore, in accordance with the state of the gas flow, that is in turn determined by the burden distribution and the position of the tuyere.

As we saw about the position of the tuyere, the operation of the tuyere has a profound effect, on this softening of the material. The coke zone which is situated beneath the cohesive zone, and above the core or the conical deposit of the coke known as dead man, serving as the coke supply source for the combustion zone. So, this dead man is a very important ah, if you look at a we have a raceway. So, and then we have a one coke conical shape, which is just sitting over there extending up to the hearth and that is called the dead man, because it does not take part as such in any chemical reaction or other thing.

However, it gives the mechanical support, to the whole burden. So, that is very important important and not only that, it also provide the permeability. So, all molten material is percolate through that, and it also supplies the coke for combustion. So, that dead man is a very important part of the blast furnace.

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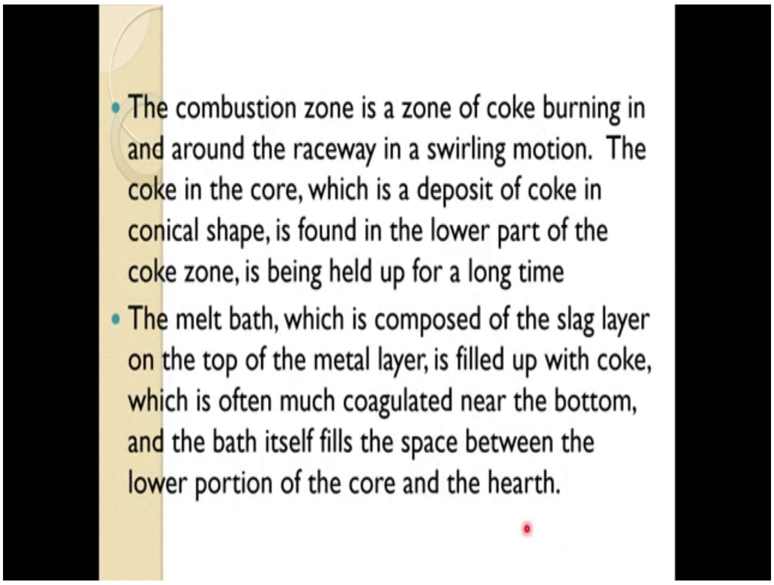


So, the it is about that, which we are talking. So, the combustion zone is a zone of coke burning in and around the raceway, in a swirling motion the coke in the core which is a deposit of coke in the conical shape, is found in the lower part of the coke zone is being held up for a long time. So, this actually gets the coke in the dead man zone.

It is a like a 14 days to 18 days or more, it would be sitting there before it is replenish or replaced by the other coke. So, residence time is very long, of the coke in the dead man the melt bath which is composed of slag layer on the top of the metal layer, is filled up with coke which is often much coagulated near the bottom, in the bath itself fills the space between the lower portion of the core and the hearth. So, essentially all the slag and iron is sitting in between the holes of the dead man and when the metal production is more, and sometime lots of metal is there, in the hearth this a dead man floats on the liquid iron, because liquid iron density is about 7000 kg per meter cube and the coke density you know it is very low about 800 or. So, in fact, with the bulk density could go up to 5600.

So, it floats on the liquid metal, but not exactly when you start taking out the liquid metal, it sinks down. So, all the liquid metal and slag it is a sitting within the pores of the dead man, and then you drain it out. So, it is x like a strainer for this metal and slag.