Metal Casting

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Module – 03
Melting, Fluidity And Solidification
Lecture – 01
Melting Furnaces And Practice

Good morning friends. In the previous classes, we have been learning about the different steps involved in making a green sand casting. We have learned how to prepare the green sand and we have seen how to design a gating system. And in the previous 2 lectures we have seen the different casting defects that could evolve during the what say manufacture of a green sand casting, now in this lecture, let us see the melting furnaces and practice.

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Melting & Pouring Temperatures

S. No	Metal / Alloy	Melting temperature (°C)	Pouring temperature range (°C)
1.	Gray Cast Iron	1370	1510 – 1590
2.	Cast steel	1480	1600 – 1720
3.	Copper	1083	1130 – 1200
4.	Nickel	1453	1500 – 1590
5.	Aluminum	660	700 – 760
6.	Zinc	420	450 – 480
7.	Lead	327	350 – 380
8.	Tin	232	280 – 290
9.	Cu- 4.0 Ni alloy	1175	1220 – 1280
10.	Gun metal (Cu-85%, Sn-5%, Zn-5%, Pb-5%)	1040	1100 – 1180

Now before go learning about different furnaces used in preparing the molten metal. Let us see the melting temperatures and pouring temperatures, for any metal or for any alloy there will be 2 temperatures, one is the melting temperature at which the solid metal actually melts means, the there the phase change takes place.

Now there is another temperature that is the pouring temperature means this pouring temperature is always greater than the melting temperature, because if we just pour at the melting temperature then the molten metal cannot flow into the entire cavity. In order to

ensure that the molten metal flows into each and every corner of the mold cavity the pouring temperature of the metal or the alloy should be little greater than the melting temperature.

Now, for gray cast iron the common melting temperature is 1370 degrees centigrade, and its pouring temperature varies between 1510 to 1590 degrees centigrade. And for cast steel the melting temperature is 1480 centigrade and the pouring temperature ranges between 1600 to 1720 degrees centigrade, and for copper the melting temperature is 1083 degree centigrade, and the pouring temperature varies between 1130 to 1200 degree centigrade, and for nickel the melting temperature is 1453 degrees centigrade, and the pouring temperature varies between 1500 to 1590 degrees centigrade, and for aluminum the melting temperature is 660 degree centigrade.

And the pouring temperature varies between 700 to 760 degrees centigrade, and for zinc the melting temperature is 420 degrees centigrade, and the pouring temperature ranges between 450 to 480 degrees centigrade, and for lead the melting temperature is 327 degree centigrade whereas, its pouring temperature ranges between 350 to 380 degrees centigrade, and for tin the melting temperature is very low. We can see; it is 232 degree centigrade whereas, it is pouring temperature ranges between 280 to 290 degree centigrade.

Now, let us see the copper and four percent nickel alloy the melting temperature is 1175 degrees centigrade whereas, the pouring temperature ranges between 1220 to 1280 degrees centigrade. And for gun metal where the copper percentage is 85 percent, tin these 5 percent, zinc is 5 percent, and the lead is 5 percent, and its melting temperature is 1040 degree centigrade whereas, the pouring temperature varies between 1100 to 1180 degrees centigrade.

So, these are the melting temperatures and pouring temperatures of important alloys cast alloys.

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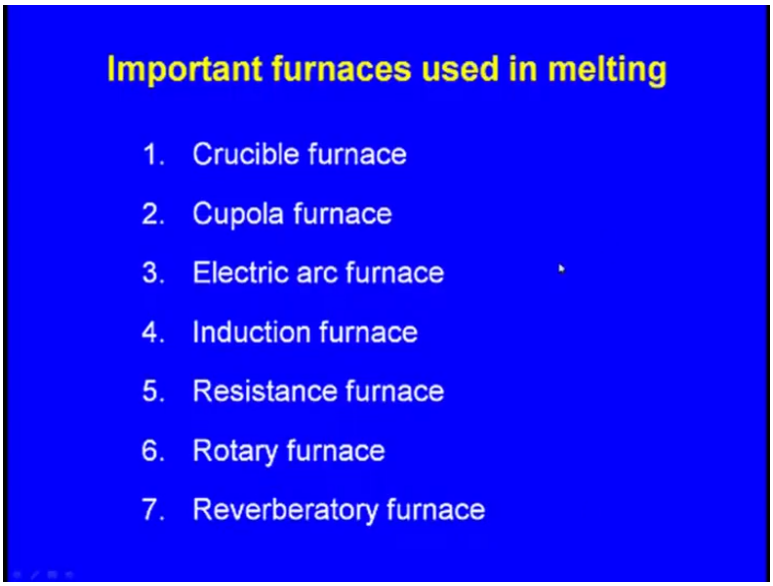

Now these are the important furnaces used in the melting, one is the crucible furnace, next one cupola furnace, next one the electric arc furnace, next one induction furnace, next one resistance furnace, rotary furnace and reverberatory furnace. We will see all these one by one.

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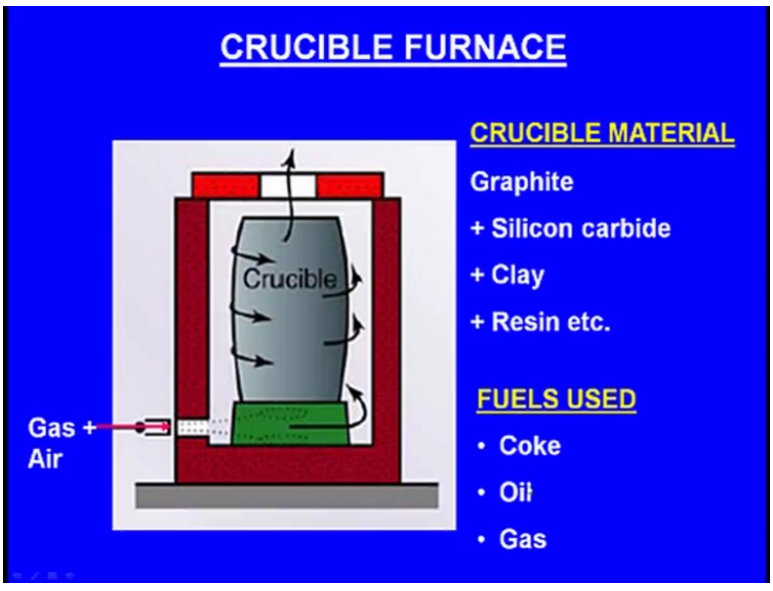

First let us see the crucible furnace. Now crucible furnace is the most simple furnace, there is a crucible we can see here inside this is the crucible. It is made up of graphite, plus silicon carbide, plus clay, plus resin, and some more binders will be there it say

simple furnace. Now the fuel used in the crucible furnaces is it can most commonly it is the coke or oil and sometimes even gas is used.

Now here we can see crucible is kept here, gas and mixture of gas and air will be passing here inside it will be burning and the charge will be kept inside the crucible after some time the charge will be melting and the molten metal is ready for tapping.

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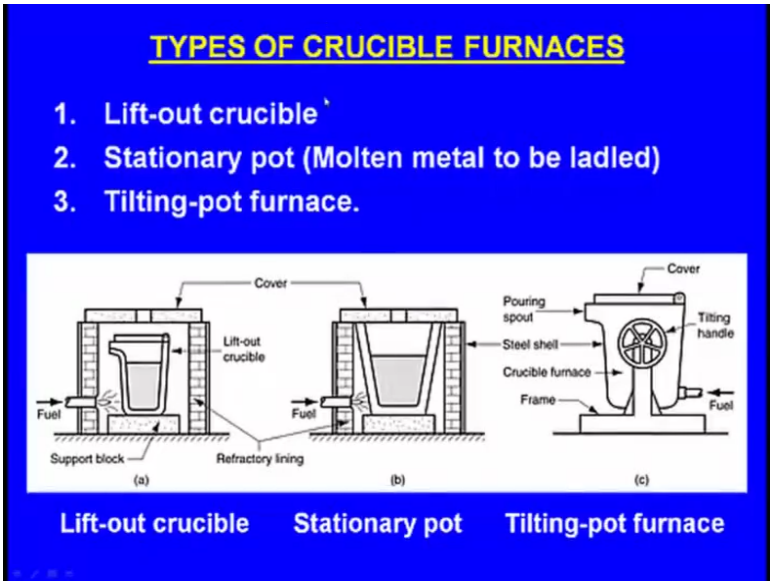

Now, again there are three types of crucible furnaces. One is the lift out crucible, second one is the stationary part means molten metal is to be ladled, next one tilting pot furnace. Now here we can see this is the lift out to crucible means say here there is a structure is there inside a what say ceramic structure we place the crucible, and we place the charge inside the crucible, and we burn the fuel and the air mixture and after some time the charge; charge, means the metal to be melted or the alloy to be melted that is the charge. The charge which is inside the crucible will be melting, then we have to remove this cover and we have to lift up the crucible. So, that is all about the lift out crucible.

Next one is the stationary pot means, here we can see this is the what say ceramic structure and this is the crucible, and this cannot be lifted only thing is we need to tap the molten metal from the stationary part, next one we can see tilting pot furnace here we can see yes inside there is a crucible is there. And the system is such that this can be rotated by rotating this wheel this can be tilted one side or even to the other side. Now

we put the fuel or we put the charge inside the crucible let the fuel burn or something the charge inside the crucible will be melting, and it is ready for tapping.

Now unlike in the case of the lift out crucible what we done after mel what say melting is so boil, we have lifted up the crucible and we were able to take it to a what say the convenient place of pouring, but here we cannot lift the crucible means, we have to bring another crucible and we have to tap the molten metal by tilting, so that is the tilting crucible furnace. So, this is the tilting pot furnace, so these are the what say three types of the crucible furnaces.

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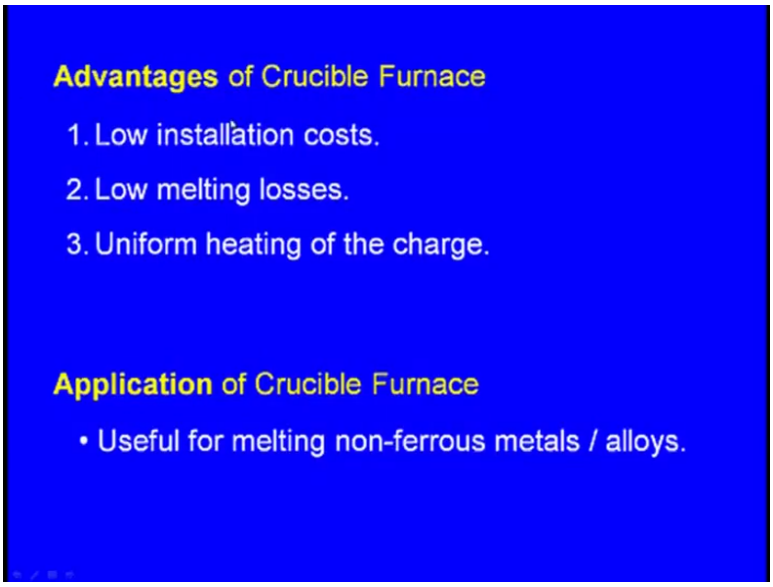

Now these are the advantages of crucible furnaces one is the low installation cost there is nothing just a crucible and a structure to support, it there is no high tech machinery and no melting losses, now here we are coming across a new term called melting loss what is this is what is this melting last means, generally in every melting there will be loss of material. Suppose if we melt say 100 kgs of cast iron, we would not get 100 kgs of molten metal, maybe we may get 95 percent of molten metal means 5 cases of melting losses there, so this is the melting loss, but in the case of the crucible furnace the melting loss will be very minimum.

Next one uniform heating of the charge this is not a very big furnace, this is a small furnace that is why the unifo; what say heating will be uniform. Now what is the application of the crucible furnace useful for melting non ferrous metals and alloys?

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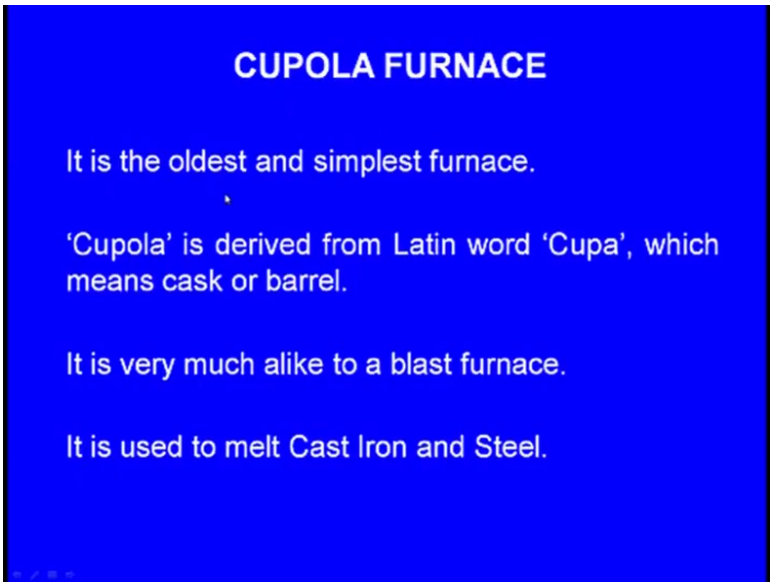

Next one let us see the cupola furnace; cupola furnace, is the oldest and simple furnace cupola is derived from Latin word Cupa, which means cask or barrel. It is like a long barrel, it is very much like a blast furnace it is used to melt cast iron and steel. Now this is these are this is the construction details of it cupola furnace just now we have seen that the cupola means a cask or a barrel.

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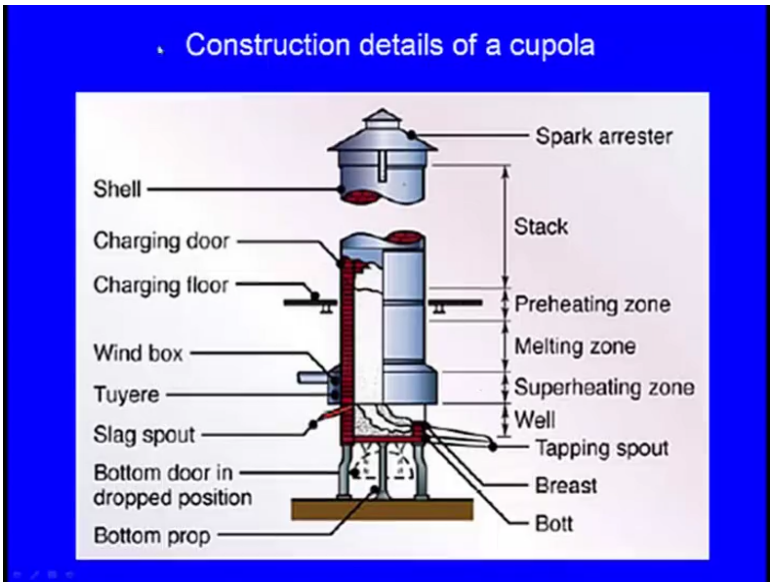

Now, here we can see there is a barrel kind of structure a cylindrical structure or a barrel, now there is a steel ceramic shell will be there and this is the charging door charging

means a entrance through which we place the what say charge, charge means the molten metal or the solid metal to be what say melted that is the charge. We place the charge along with that we put what say fuel and also reflects right, so this is the charging door and this is the charging floor and here we can see the wind boxes.

Next one, tires this is the slags spout means through which we collect the slag. Now here we can see there are bottom doors and they can be dropped down. So, that the entire after the melting is over if any the ashes present any unwanted what say material is present everything can be dropped down. So, that is the purpose of the drop doors or the bottom doors, and here we can see this is a spark arrestor means when we are burning the coke and we release of a what say air at a way high pressure, and because after the hot to burning coke may fly it is that time the spark arrestor will prevent the burning coke to run away or to fly away from the cupola.

Next one this the preheating zone and the melting zone, and here we can see again there is a what say the tapping spout is there here, some time back we have seen this is the slag spout means through which we collect the slag, and here it is the tapping spout means it is the spout or it is the what say entrance through which we collect the molten metal.

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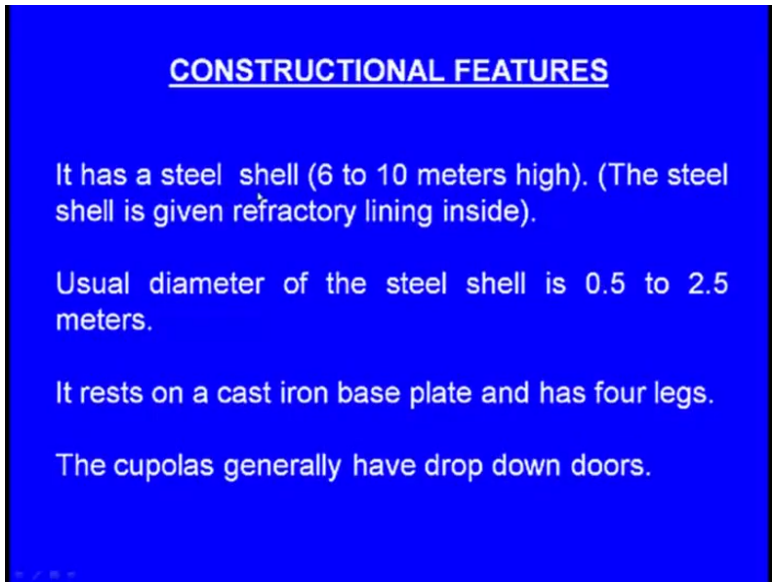

Now, it has a steel shell 6 to 10 meters high the steel shell is given refractory lining inside. And the usual diameter of the steel shell is 0.5 to 2.5 meters. It rests on a caster and base plate and has generally four legs, the cupolas are generally they have drop

down doors. Yes here we can see this is the shell and these are the dropdown doors, at the bottom there is a tap hole to remove the molten metal.

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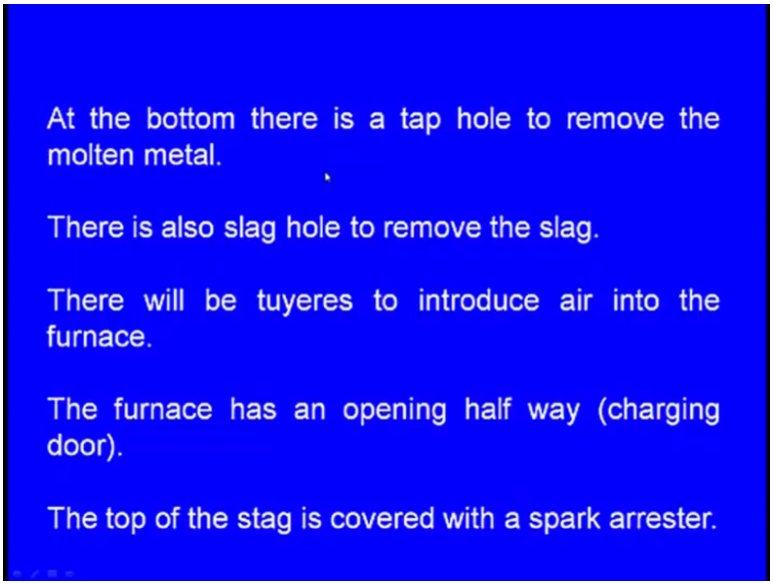

We have already seen, and there is a slag whole to remove the slag there will be tire tires to introduce air into the furnace, the furnace has an opening of way that is the charging door the top of the slag stage is covered with a spark arrestor that also we have seen.

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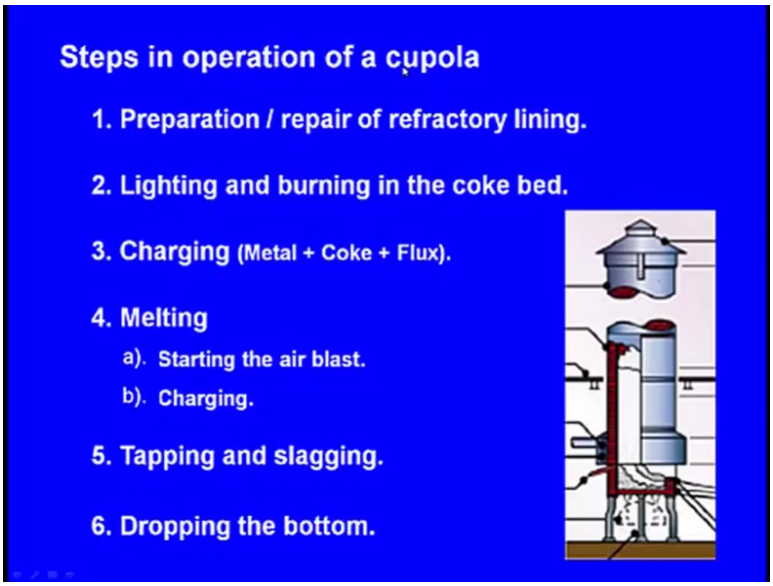

Now, these are the steps in operation of a cupola. One is the repression repair of refractory lining, the furnace might have been used previously and what is this, for this it

is a very simple furnace, it is a steel cylindrical shell and inside there is a refractory lining is there.

Now it might have been used previously and the refractory lining might have been damaged. Now we need to repair it, next one what about the what say at things at the bottom there, might be unwanted ash might there, or unburned coke might be there or sand unwanted sand might be there at the doors, so those must be removed they must be cleared. So, that is the preparation and repair of refractory lining.

Next one lightning and burning in the coke bed, after we prepare the what say close the bottom doors yes we place the coke and we have to lighten it and we need to burn the coke bed. While the coke is being burned charging is done, charging means introducing metal coke and flux one by one into the furnace that is the charging. So, that we will do after lightening the coke we do the charging, then when we do the charging it will be melting yes melting will be going on starting of the then when the melting is going on starting the air blast we need to introduce the air. And again we also need to do the charging; charging, means what say the sanding metal coke flux inside the furnace dropping, and after some time this will be the whole what say mixture or this charge will be melting of the molten metal is ready, then we need to tap before that we need to tap this slag unwanted slag will be floating above the molten metal first that should be removed, after the tapping of the slagging is over then we need to tap the molten metal into a ladle.

Next after the burning is over then we need to drop the bottom means there will be what say unwanted coke will be there, unburned coke will be there, unwanted sand will be and ash will be there so, all these should be released from the furnace then that is the dropping the bottom.

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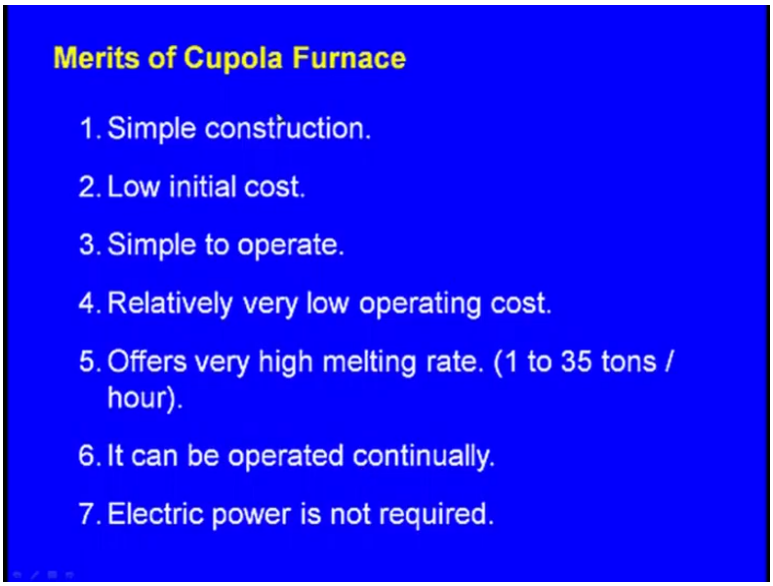

These are the merits of cupola furnace simple construction, what is cupola furnace, it is a cast or a barrel just a cylindrical shell. No initial cost it is not very costly, and it is simple to operate relatively very low operating cost, it see cost of operation is not high we need fuel maybe coke or an oil and offers very high in melting rate. You see 1 to 35 tons per hour can be melted that much charge can be melted per hour, it can be operated continually means what say it can be operated intermittently means so today we have say 2 tons of what say charges there bring what say load that 2 tons of charge into the furnace, after this melted after the molten metal tapped you stop the furnace.

On the other hand you can keep on loading what say charging you can keep on charging, and you can keep on melting, and you can keep on tapping the molten metal, that is the what say operation of the cupola furnace continually. Now most important thing is it does not require electric power no electricity is required that is the, what say one of the advantages of the cupola of furnace.

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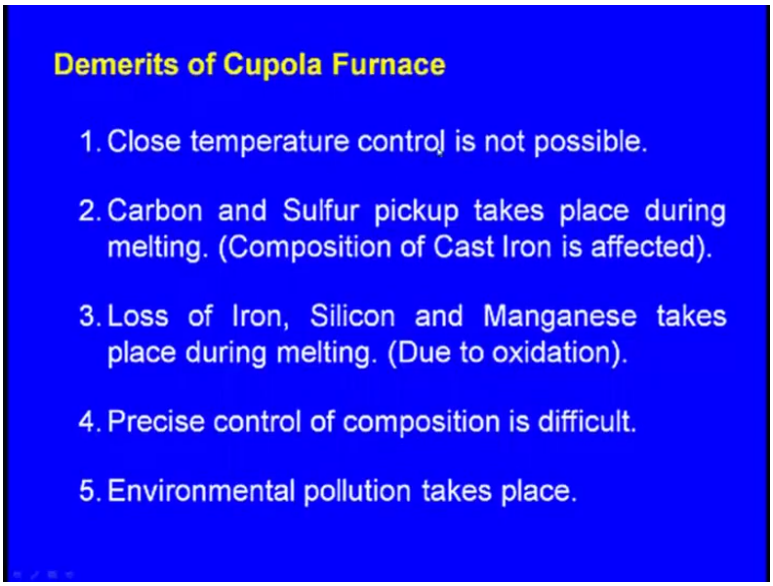

Now these are the demerits of cupola furnace close temperature control is not possible. Suppose we are melting the cast iron and we require say some 1600 degree centigrade, and you aim 1600 degree centigrade, and you heat it and try to melt it accordingly finally, you will melt or you will end up 20 degrees or 25 degrees more or 20 degrees less. Exactly it may not be possible to get 1600 degree centigrade that is the most temperature control is not possible.

Next one carbon and sulfur pickup takes place during melting. Yes this cast iron contains carbon and sulfur let us see the composition of the cast iron.

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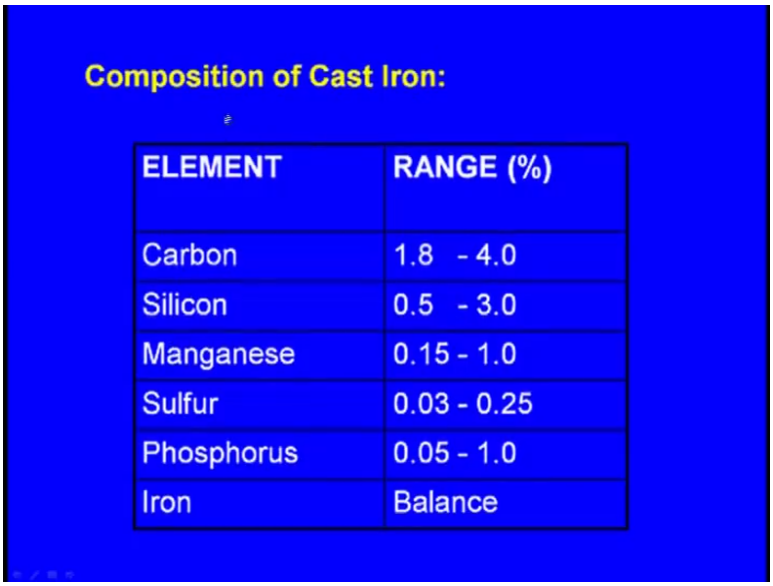

So, this is the typical composition of cast iron carbon is present say 1.8 to 4 percent, silicon 0.5 to 3 percent, manganese 0.15 to 1 percent, sulfur 0.03 to 0.25 percent, phosphorous 0.05 to 1 percent, and the balance is iron. So, this is the typical composition of cast iron.

Now here we can see sulfur is present and carbon is present, and when we are operating the cupola furnace we generally we burn coke what does this coke contain the coke contains carbon. Coke contains sulfur and because we are burning to coke inside the cupola furnace, carbon from the coke will be entering into the molten metal, sulfur from the coke will be entering into the molten metal, but this is the limit for the carbon 1.8 to 4 percent, and for sulfur this is the limit 0.03 to 0.25, but because we are burning coke the limits will be increasing more sulfur will be there and more carbon will be there, then finally, what will happen the properties of the cast component will be changing, sometimes the what say cast component becomes brittle and its leads to cracking. So, that is one of the demerits of cupola furnace.

Next one loss of iron silicon manganese takes place during melting due to oxidation, yes iron is present, in the cast iron silicon is present, manganese present, these are useful alloying elements in the cast iron.

Now this iron will be reacting with oxygen and forms iron oxide and it goes along the slag same is the case with the silicon, silicon reacts with oxygen and forms silicon

dioxide, and goes along with the slag same thing can happen with manganese; manganese, reacts with oxygen goes along with the slag finally, the component or the properties of the cast structure or the cast component will be different, then what are what have been gained. So, that that is what can happen that is the loss of iron silicon and manganese during the cupola operation.

Next one precise control of composition is difficult, yes why because we may aim certain composition, but because the sulfur pickup is there carbon pickup is there, and loss of silicon loss of manganese, because of these things this will go without the knowledge of the operator or without the intention of the operator finally, we aim some compositions, but finally we will arrive at some other composition. So, precise control of composition is difficult. Next one environmental pollution takes place cupola releases lot of smoke, and because that environmental pollution takes place.

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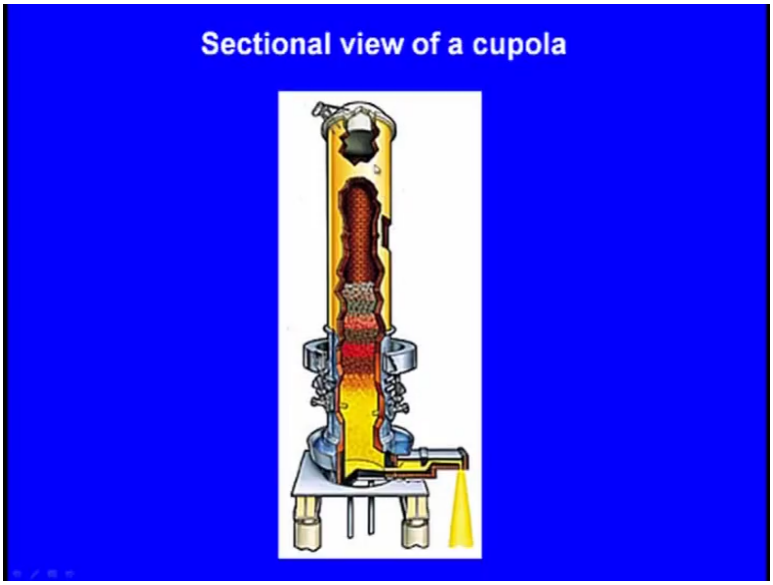

So, this is the sectional view of a cupola. Now, let us see the electric arc furnace.

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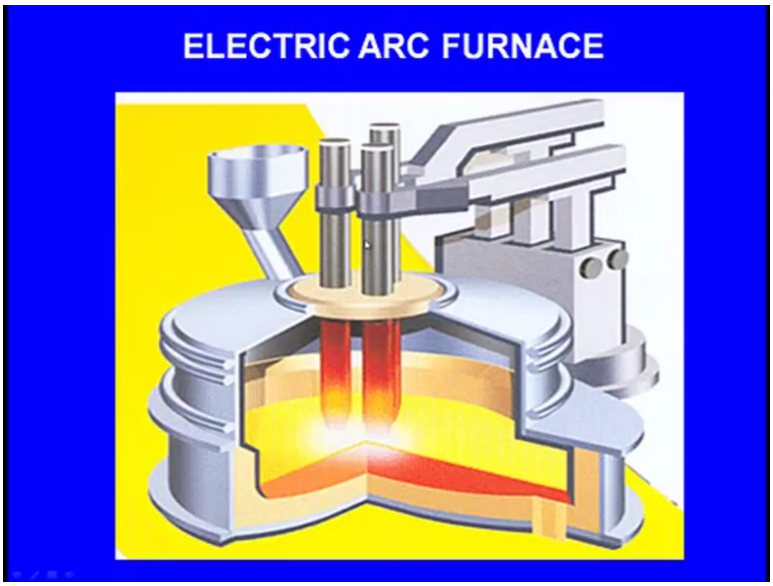

Now this is the electric arc furnace, and here we can see these are the electrodes, and the an arc will be created, and because of the high temperature of the arc the charge will be melting. So that is the simple principle of electric arc furnace.

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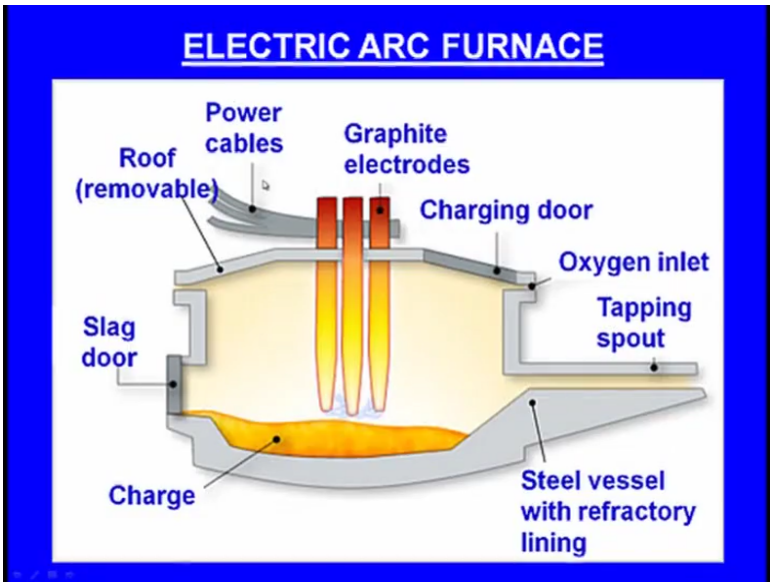

Now these are the what say different components that are inside the electric arc furnace, and here we can see this is a steel vessel. The whole furnace is a steel vessel with the refractory lining inside, this is a steel vessel with the refractory lining inside, and this has got a removable roof is there this is the removable roof. And this is the charging door

means this can be opened and can be closed and charge will be dropped through this door to inside the furnace this what is the charge; charge, means the molten what say solid metal to be melted along with the flux.

Next one here is the slag door these are the construction details through which we can separate the slag from the furnace and finally, here is the tapping spout through which we can what say extract or we can get the molten metal, we can tap the molten metal from the furnace, and at the center we can see these are the graphite electrodes are there. And there is power supply is there to the graphite electrodes. So, these are the construction details of the electric arc furnace, and here we can see the charge is what say kept here and because of the arc created the charge will be melting.

Now, let us see yes when these what say electrodes come in contact with the charge what will happen or will be created there will be initiation of arc.

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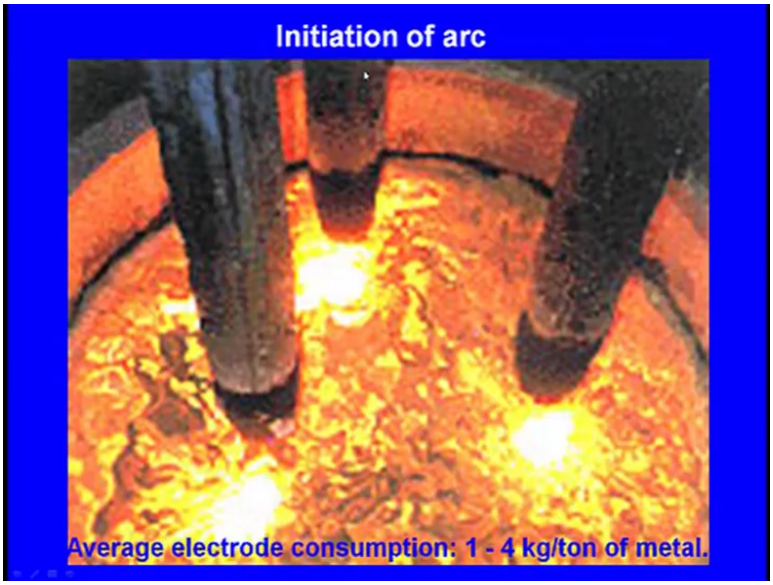

Now here we can see average electrode consumption is 1 to 4 kgs per ton of metal. So, this much; what say electrode will be consumed. So here these are the consumables electrodes.

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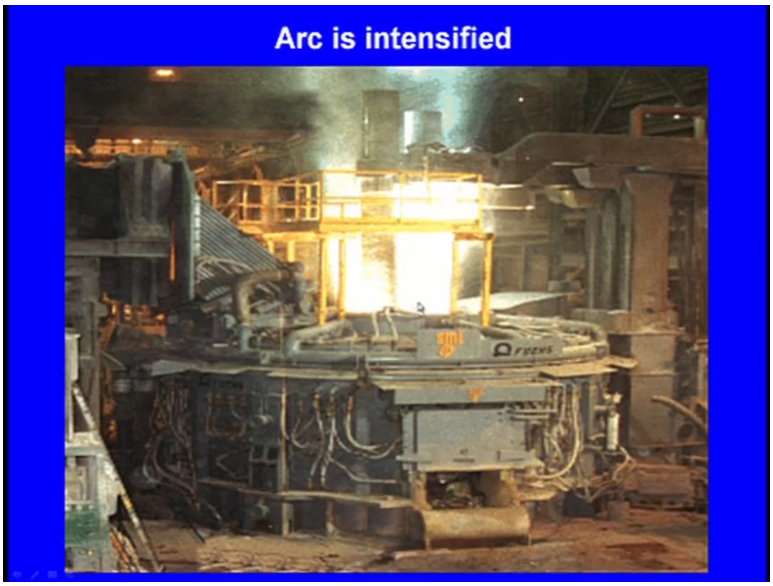

Now, arc is intensified here we can see arc is intensifier. So, this is the furnace.

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Now, the molten metal is ready for tapping.

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Now tapping of the molten metal is like this, yes it is here, we place a ladle and into this ladle the molten metal is tapped.

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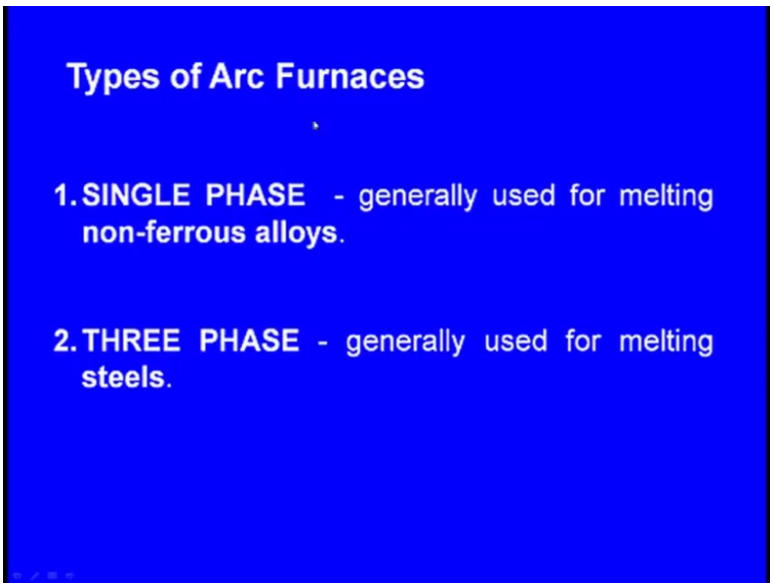

Now these are the types of arc furnaces one is the single phase arc furnace and this is generally used for melting non ferrous alloys. Next one this is the three phase arc furnace and it is generally used for melting steels.

Now, let us see the advantages of arc furnace precise control of composition is possible. In the previous case in the case of the cupola the greatest demerit of cupola furnace is

that precise control of composition is not possible, because there will be sulfur pickup there will be carbon pickup, and there will be manganese loss, there will be silicon loss, because of that there would not be precise control of composition, but in the case of arc furnace there will be precise control of arc what say composition.

Next one close temperature control is possible, again this is what say another demerit we have seen in the case of the cupola precise control of temperature was not possible due to several reasons, but here close temperature control is possible.

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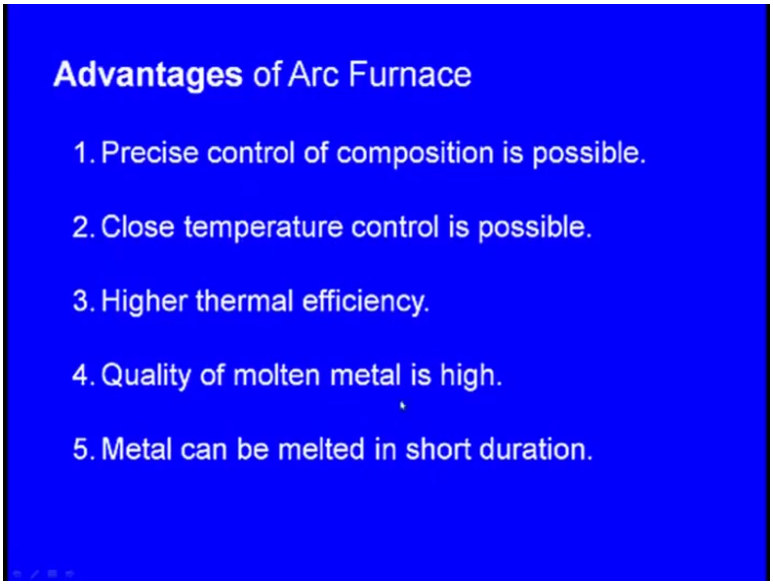

Next one high thermal efficiency quantity of molten metal is high, what is this in the case of the melting with the cupola furnace the what say the quality of the molten metal may not be very high, why there will be impurities will be there we are burning coke; and coke, contains what say ash and slag will be collected at the top and all these can mix with the molten metal. So, that is how the molten metal coming from a cupola furnace is not very clean its quality is not very high whereas, in the case of arc furnace the quality of molten metal is high, molten metal can be melted in short duration

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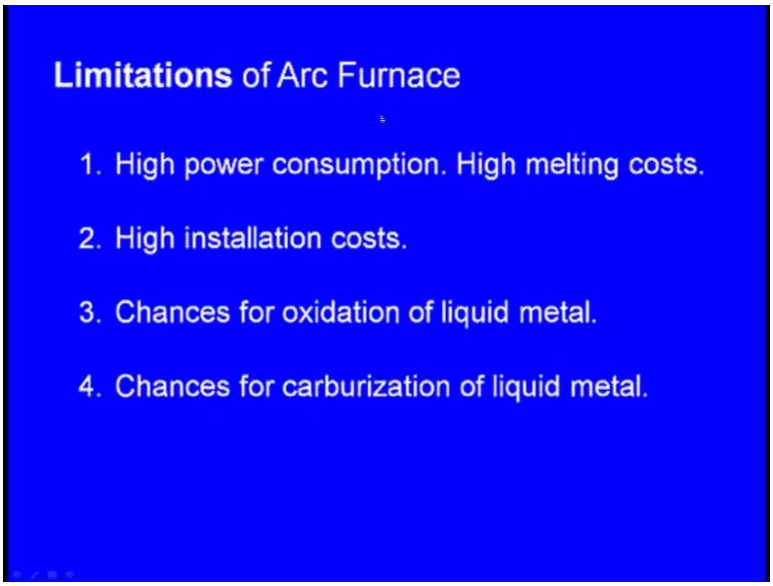

Next one these are the limitations of arc furnace, high power consumption, high melting cost very high power is consumed that is how it results in high melting costs. Next one high installation costs, chances for oxidation of liquid metal. Next one chances for carburization of liquid metal why because we are using graphite electrodes, because of that the carbon in this graphite electrodes will be entering into the molten metal that is how carburization of liquid metal takes place carburization means addition of carbon into the molten metal.

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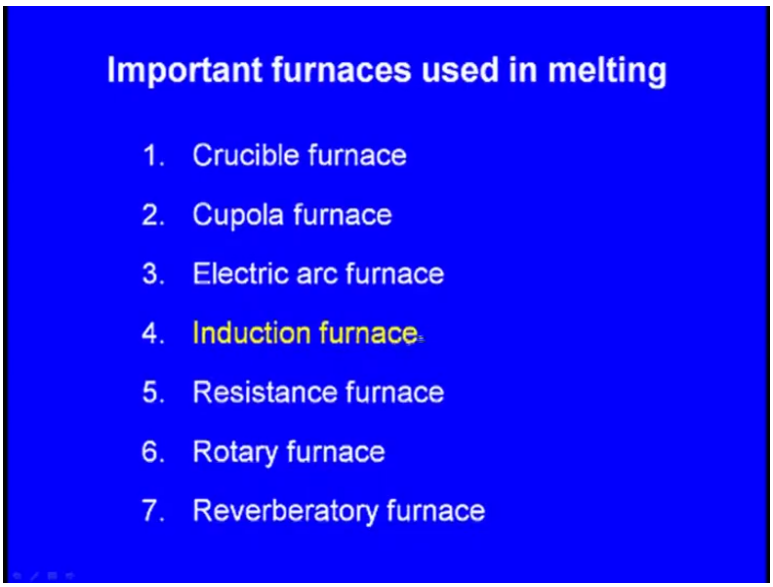

Next one let us see the induction furnace.

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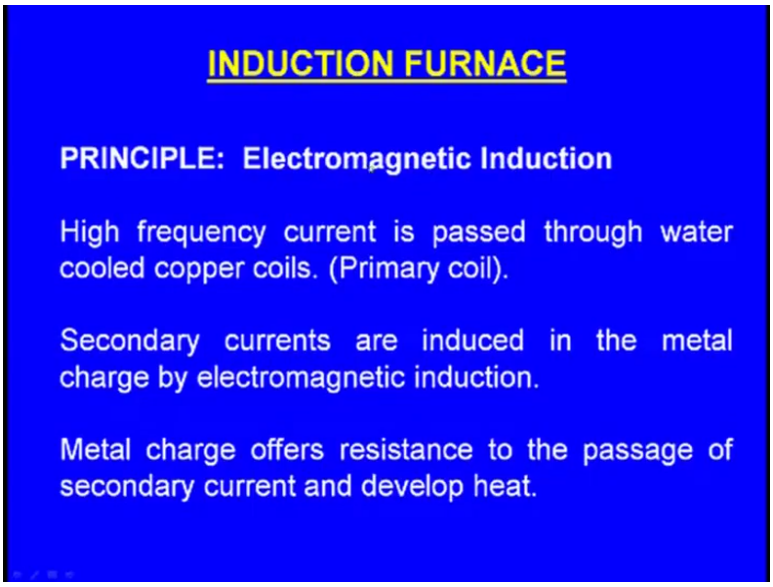

Now what is the principle of induction furnace it is the electromagnetic induction, high frequency current is passed through water cooled copper coils this is known as the primary coil, there will be what say primary coil will be the copper coil and high frequency current is passed through this coil, then what happens secondary currents are induced in the metal charge by electromagnetic induction.

Now this is secondary current we be passing through the charge means the solid metallic blocks to be or solid metallic pieces to be melted, now this secondary current will be passing through the this is what say charge blocks or the metallic pieces, then what happens the metal charge offers resistance to the causes of secondary current and develops heat. When what say current secondary current is passing from one piece to another it encounters resistance, and because of this resistance heat will be developed and this heat will be utilized for melting the charge.

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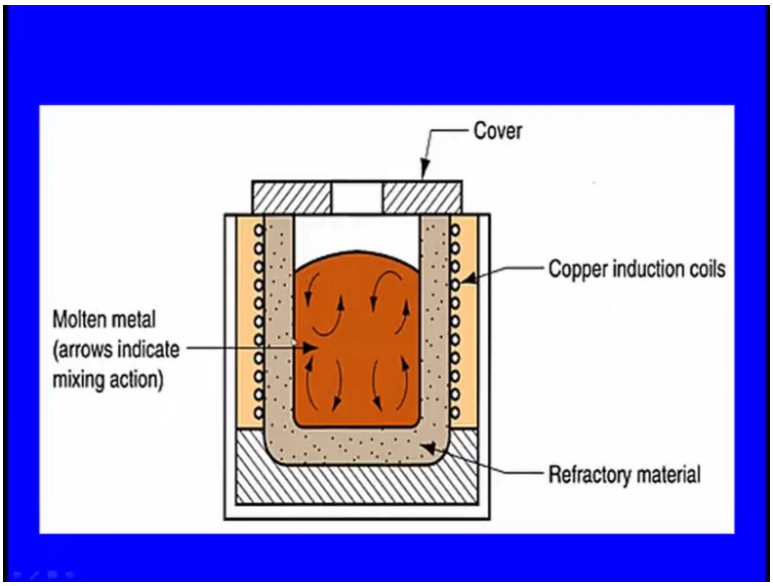

Now, this is the typical construction of an induction furnace. And here we can see these are the copper induction coils and this is the refractory material and around the refractory material there is a copper induction coil is there. Now inside yes this is a structure and this can be closed there is a cover, and inside we have kept the molten metal.

Now when we pass the electricity high frequency current through this what say copper induction coils, what will happen because of 2 magnetic induction there will be secondary current will be passing through the charge; charge is this one, the red colored one is the charge. Now this will be passing from one piece to another and that is so, it will be generated because of the resistance that the current encounters while passing from one piece to another.

Now, here we can see there is a electromagnetic mixing is also there, here yes manual steering may not be required, and because of the electromagnetic induction there will be magnetic mixing will be there so, mixing will be uniform.

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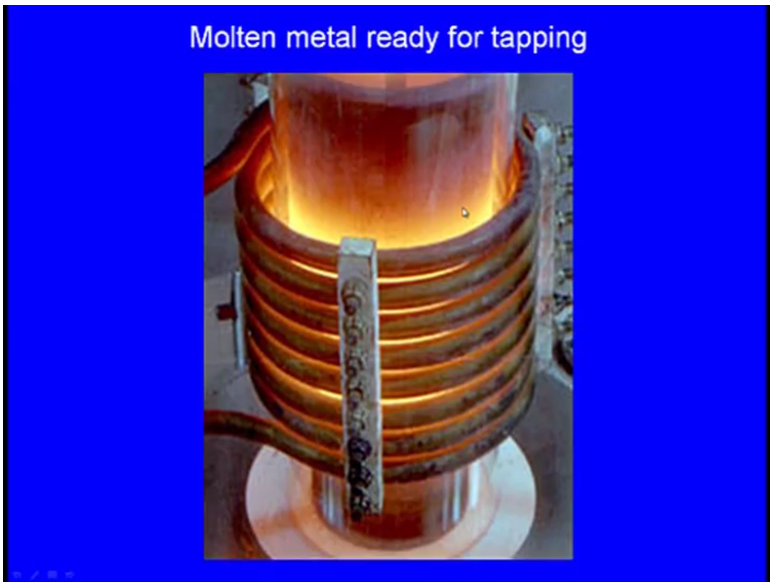

And here we can see this is the actual photograph of an induction furnace. And this is the what say copper coil and through which high current is passed and inside there is a what say refractory crucible is there and inside the crucible we there is a charge, now because of the secondary current, yes heat is generated and that heat will be melting the charge that is kept inside the crucible yes after melting is over yes we are tapping.

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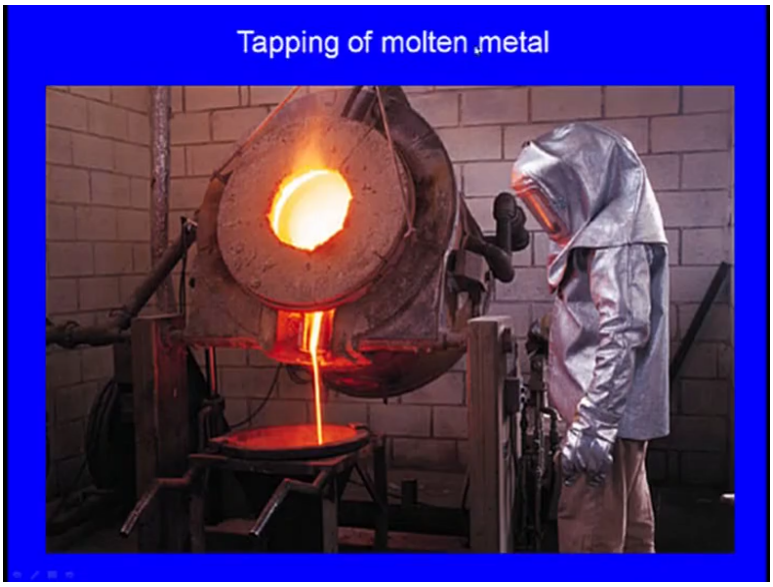

This is that is how it can be tilted by rotating a wheel it can be tilted and the molten metal is being tapped.

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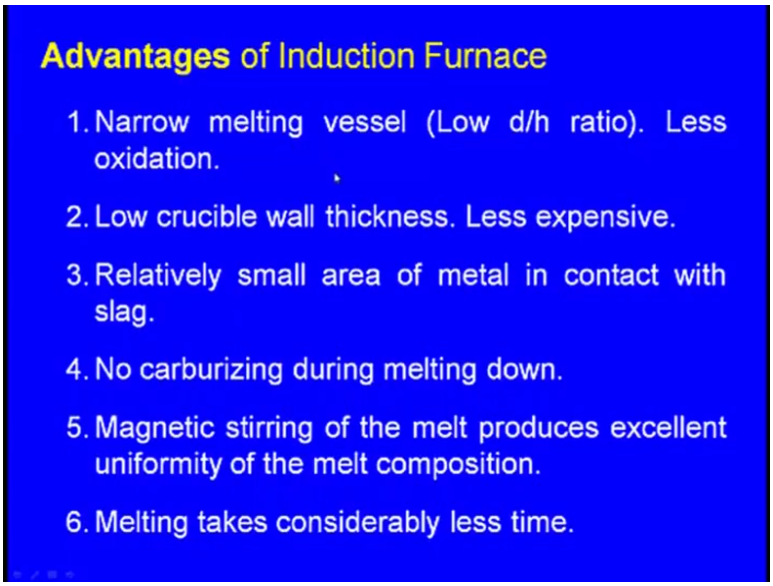

Now, these are the advantages of induction furnace. Narrow melting vessel lower diameter to height ratio and less oxidation, now here the what say diameter will be less height will be more for the crucible in which we place the charge, because of that what will happen lesser diameter means lesser area is expose to the atmosphere, then in such a case there will be less oxidation will be there. So, that is the first advantage of induction furnace next one low crucible wall thickness and less expensive.

Next one relatively small area of molten metal is in contact with the slag. Now one; of the what say the problems, that can encounter in melting is segregation of the slag from the molten metal, most of the times we leave somewhat say slag inside the molten metal or while connecting the slag we also remove the molten metal.

Now, what happens here the what say the area of contact between slag and the molten metal is very low why because the diameter itself is low, in such a case what will happen the chances of removing the molten metal along with the what say slag will be less, no carburizing during melting down, that is what we have seen in the case of the cupola furnace there was carbon pick up, and even in the case of the arc furnace there was carbon pick up means extra addition of carbon into the molten metal which is not required that is the carburization or carbon pick up that wont arise in the case of the induction furnace.

Next one magnetic stirring of the melt produces excellent uniformity of the melt composition, the charge will be stirred magnetically that is how there will be excellent uniformity of the melt composition. Next one melting takes considerably less time within few minutes we can get the molten metal.

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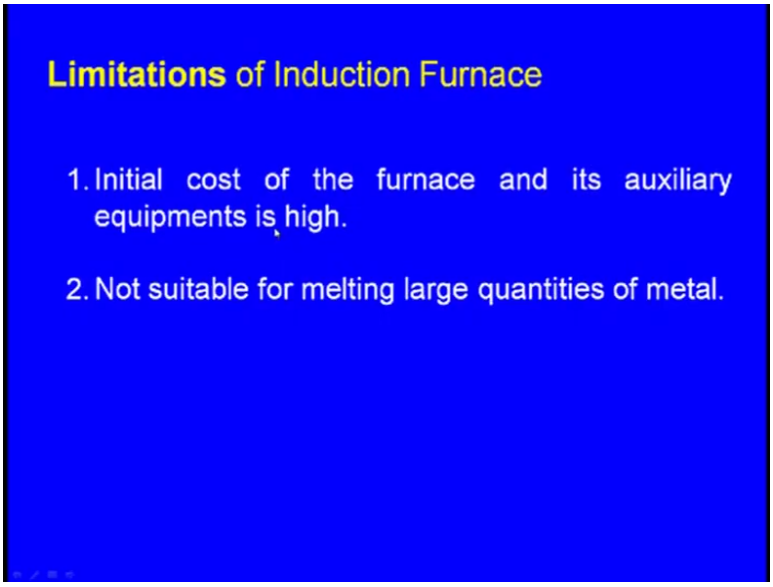

These are the limitations of induction furnace initial cost of the furnace, and its auxiliary equipments is very high and it is not suitable for melting large quantities of metal maybe it may be suitable for small quantities or the moderate quantities not very large quantities, but we get molten metal of high quality.

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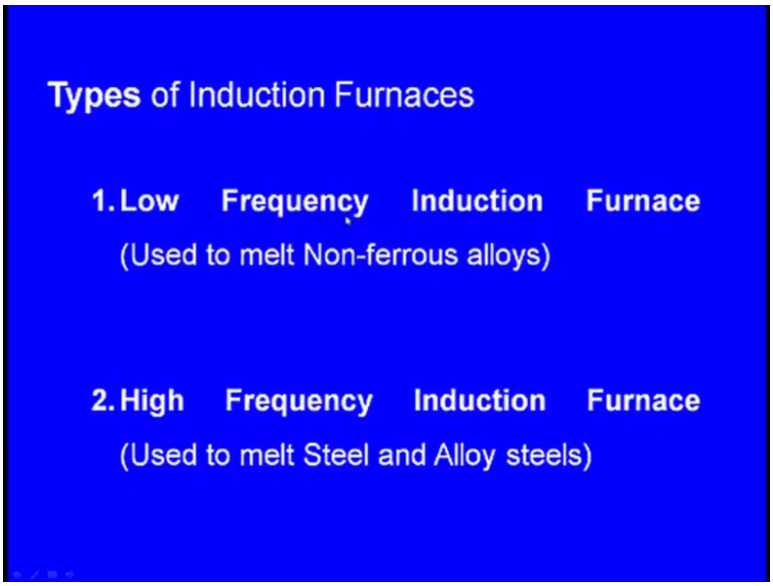

Now, these are the induction furnaces types; types of induction furnaces, one is the low frequency induction furnace and it is used to melt non ferrous alloys. And the second one is the high frequency induction furnace and it is used to melt steel and alloy steels.

Next one let us see the resistance furnace, now the what is the principle of operation resistance element is heated by passing high electric current that is the simple principle of resistance furnace, there will be a resistive element will be kept inside the furnace and when we pass the electric current that will be heated up and that heat will be utilized to melt the charge.

These are the advantages of resistance furnace accurate temperature control is possible, because we keep a thermostat control to hold the liquid metal, sometimes we used to add say certain additives or what say some modifications we used to do to the molten metal, we add certain things like grain refine grain refiners, or alloy additions, or inoculants we used to add that time we need to hold the furnace at a certain temperature.

Most of the times this may not be possible to hold the temperature at a particular temperature, but this resistance furnace has a thermostat control, we can set the temperature at that temperature is a temperature will continue as long as we on the furnace. And at that particular temperature we can hold the liquid metal after making these what say additions after adding these modifications

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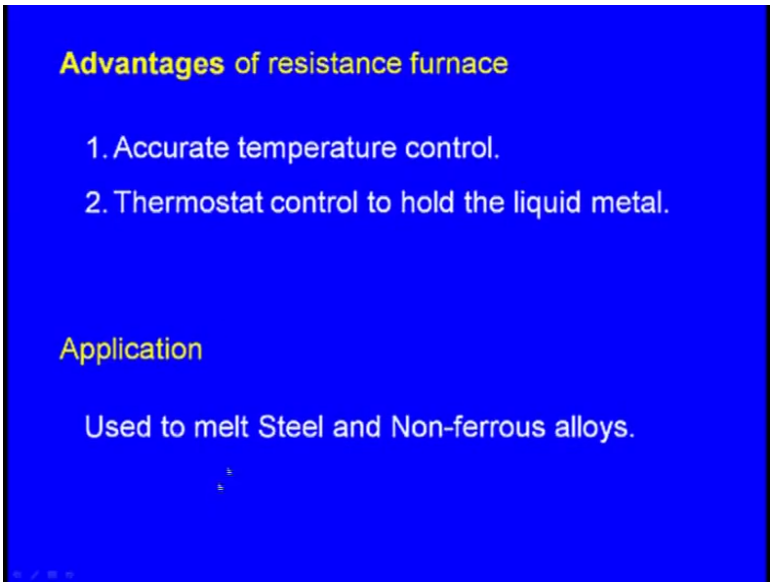

Next one application it is used to melt steel and non ferrous alloys. Next one let us see the rotary furnace.

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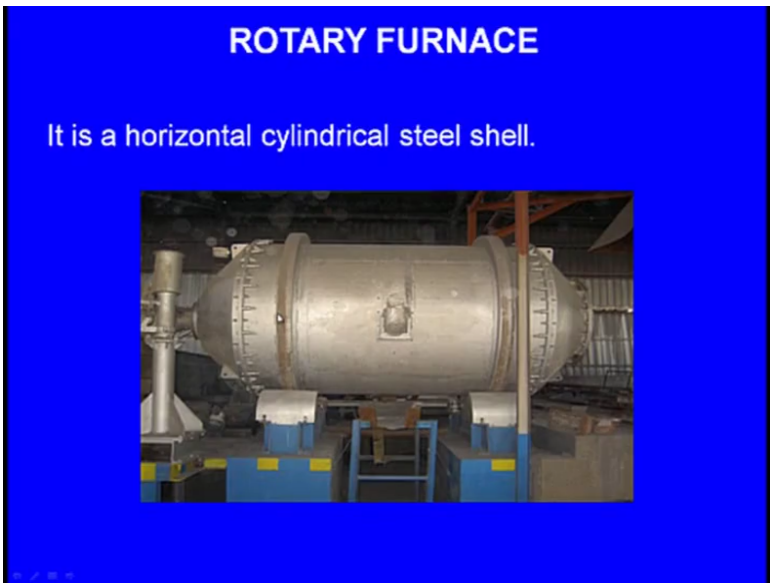

What is a rotary furnace, it is a horizontal cylindrical shell you can see here this is a horizontal cylindrical shell.

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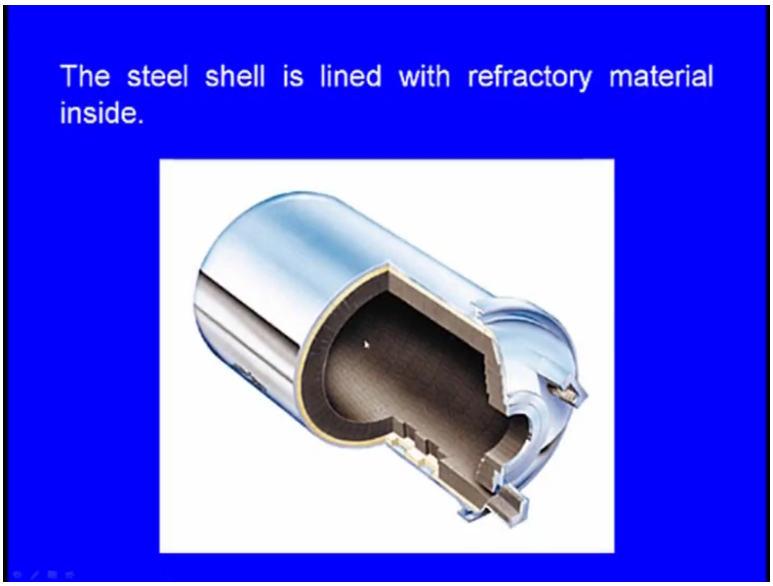

The steel shell is lined with refractory material inside. So, we can see here there is a steel shell inside, we can see there is a refractory material is there or the refractory lining is there inside.

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Now the shell is mounted on rollers. And here we can see these are the rollers here is one roller, and here there will be another roller this side there will be a one more roller third roller, and one more roller will be there generally there will be four rollers will be there.

Now these rollers will be rotating as these rollers are rotating, this what say furnace also will be rotating, at a very small speed low speed maybe at one revolution per minute slowly it rotates.

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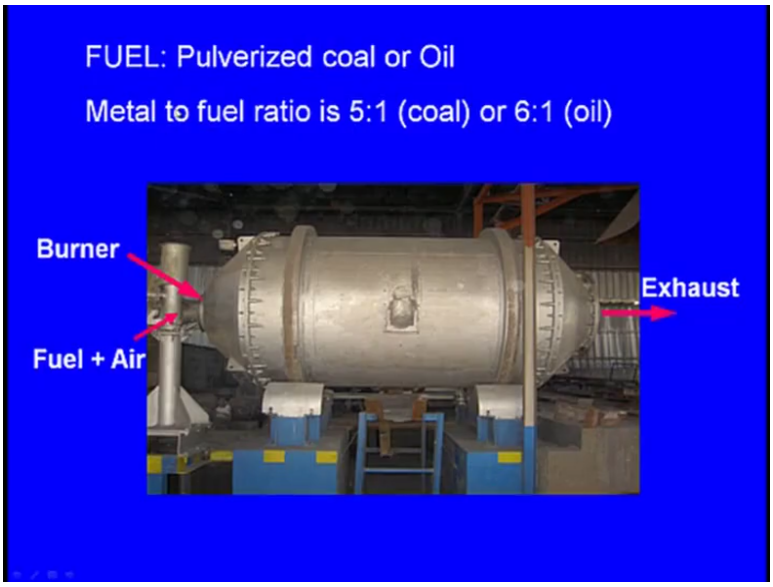

Now, what is the fuel used in the rotary furnace. Pulverized coal or oil metal to fuel ratio is 5 is to 1, when we are using the coal or 6 is to 1, when we are using the oil what does it mean; means for, 5 kgs of charge, 1 kg of coal is to be used or for 6 kgs of charge, 1 kg of oil is to be used.

Now here we can see certainly this is a cylindrical shell horizontal shell, now here we can see there is a burner is there inside which the, what say fuel and air will be burning, and there is a what say inlet fuel plus air inlet is here. So, through this inlet the mixture of air and fuel will be going inside or it may be oil plus air or the pulverized coal or air will be going inside and it will be burning here. Now here there is an outlet is there, so this is the exhaust outlet through which the hot gases and smoke will be going out of the furnace.

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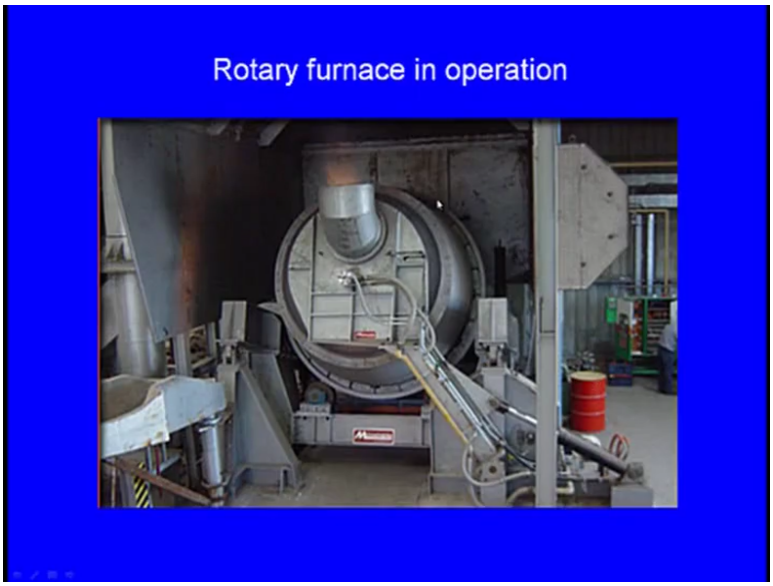

Now yes the furnace is in operation we can see when it is being in on condition yes, it is being fed and it will be slowly it will be rotating yes.

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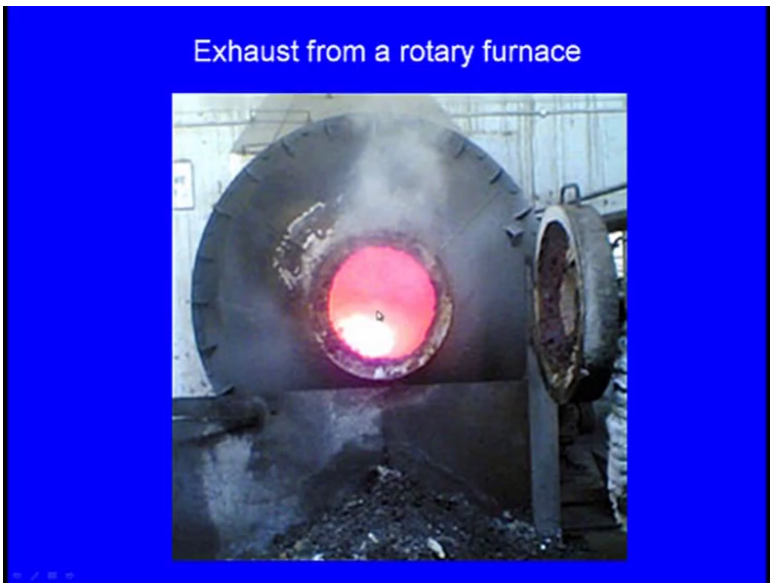

We can see here we can this, the exhaust from a rotary furnace yes. Now this is the tapping of the molten metal.

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Now these are the advantages of rotary furnace.

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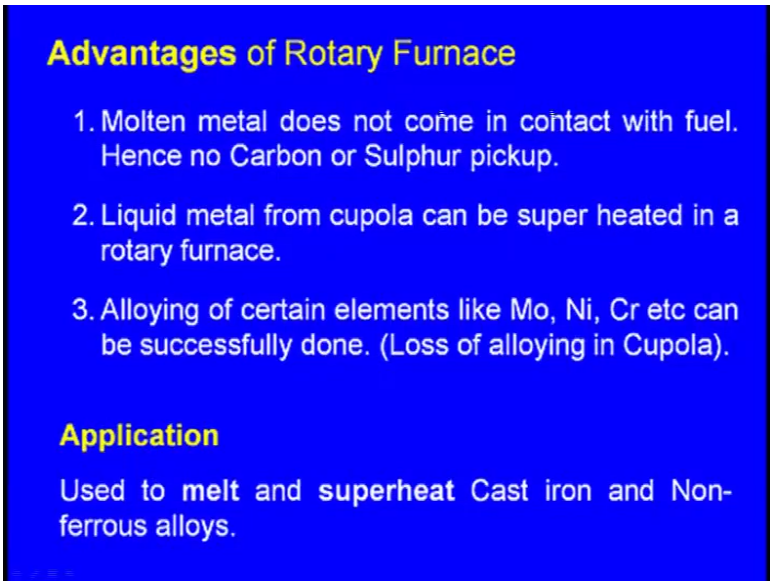

Molten metal does not come in contact with the fuel hence no carbon or sulfur pickup, certainly we are using the coal which contains carbon and sulfur, when we are using a fuel which contains carbon and sulfur, certainly there must be carbon pick up and sulfur pickup, but fortunately in the case of the rotary furnace low carbon pickup takes place no sulfur pickup takes place, why because the molten metal does not come in contact with the fuel.

Only we are burning the mixture of fuel and air on one side, the hot guests will be just passing above the molten metal and they will be living, but that they are not penetrating into the molten metal that is how no carbon from the cone comes into the molten metal, no sulfur from the coal comes inside the molten metal, hence there is no carbon pickup and there is no sulfur pick up.

Whereas in the case of the cupola furnace, we have seen there was carbon pickup why the carbon or the coke we are burning that is going the carbon from the coke is going inside the molten metal. The sulfur from the coke is going inside the molten metal, such thing would not happen in the case of the rotary furnace, and next one liquid metal from cupola can be superheated in a rotary furnace. Now one of the drawbacks of the cupola furnace is that the pouring temperature cannot be raised maybe, we can just heat the molten metal by the time we tap it becomes the viscosity becomes very thick high, and it is very difficult to fill the cavity with a molten metal, because the pouring temperature is not very high.

So, super heating this is known as the super heating means what say heating the metal above its melting point is known as the super heating. So, sometimes super heating becomes a difficult with the cupola furnace whereas, large quantities of charge can be melted very easily melted in a cupola furnace problem comes with the super heating, now this rotary furnace can be used for super heating.

Now, we can tap the liquid metal from the cupola furnace and that can be what say loaded inside the rotary furnace, now you on the rotary furnace and you burn the mixture of air and the pulverized cool coal, now because of that the temperature of the molten metal which is already inside the rotary furnace will be raising up, we can what say cause the super heating to the molten metal which we are bringing from the cupola furnace using the rotary furnace.

Alloying of certain elements like molybdenum, nickel chromium, can be successfully done every time when we melt an alloy we add some additives these are known for the purpose of the alloying. So, these are known as the alloying elements, so to get the required compositions we add maybe molybdenum is required, we add molybdenum little molybdenum, maybe little nickel is required we add nickel; nickel, our little

chromium is require we add a little chromium. So, this is known as the addition of the alloying elements.

Now, what happens if we try to do it with cupola furnace yes, we you add nickel or chromium these they will be reacting with oxygen, and they become oxides, and they will be removed along with the slag. So, addition of the alloying elements in the cupola is difficult, now fortunately we have the rotary furnace. Now you tap the molten metal from the cupola furnace and bring it and pour inside the rotary furnace, now you add the alloying elements like nickel or chromium and you so heat it during this time as it is rotating the alloying elements also will be melting and they will be mixed thoroughly with the melt and finally, we get a very uniform composition along with the alloying elements. So, alloying of certain elements can be successfully done using the rotary furnace. Now what is the application used to melt and superheat cast iron and non ferrous alloys.

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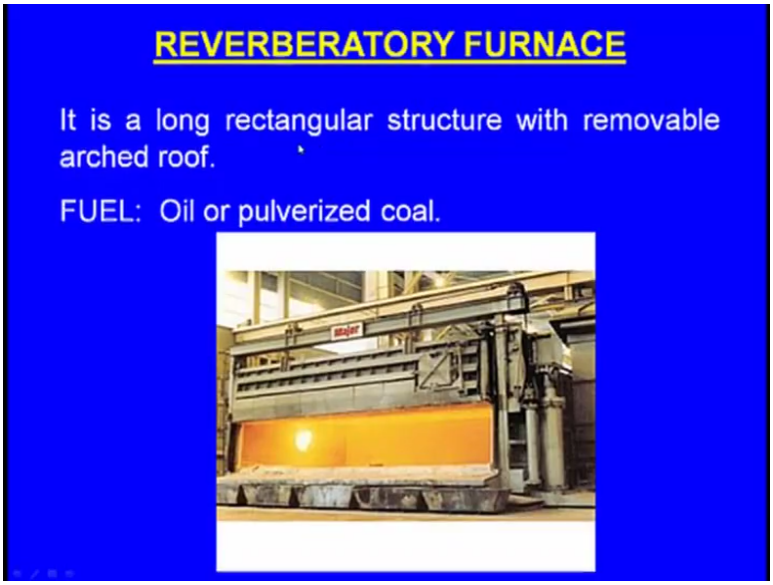

Next one the reverberatory furnace, what is this it is a long rectangular structure with removable arched roof. It is a all the most of the fine lines are cylindrical in the what say in their shape, but reverberatory furnace is rectangular is a rectangular structure with a removable arched roof, we can see what is the fuel used oil or pulverized coal.

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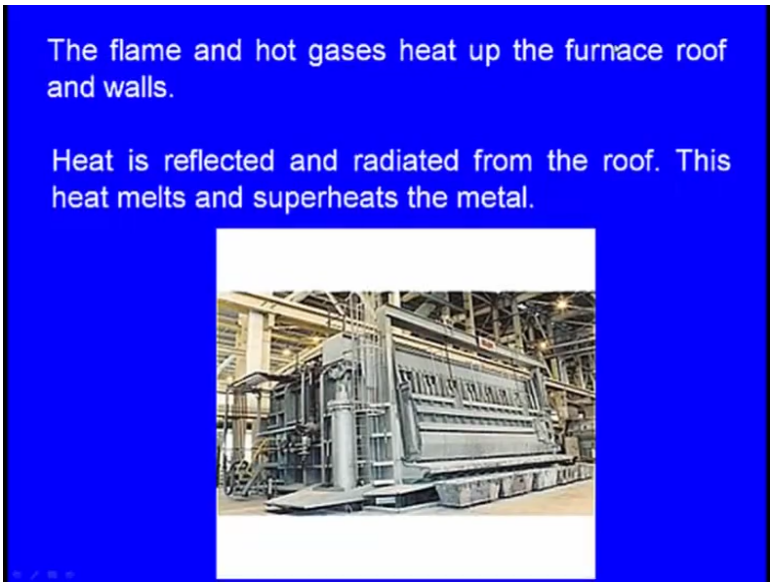

Now the flame and hot gases heat up the furnace roof and walls, heat is reflected and radiated from the roof this heat melts and super heats the metal, here we can see something interesting. In the case of the what say cupola furnace the fuel is going inside the melt and contaminating, where is in the case of the rotary furnace the fuel is not going inside the melt, but just passing above the melt, but here in the reverberatory furnace it is the fuel is not even going above the what say charge, but it first it is going and touching the roof, and it heats the roof and from the roof radiation comes, and because of the radiation there will be super heating of the metal or melting of the metal.

So, that is the most what say interesting and special feature along with the reverberatory furnace, and here we can see yes this is the what say reverberatory furnace.

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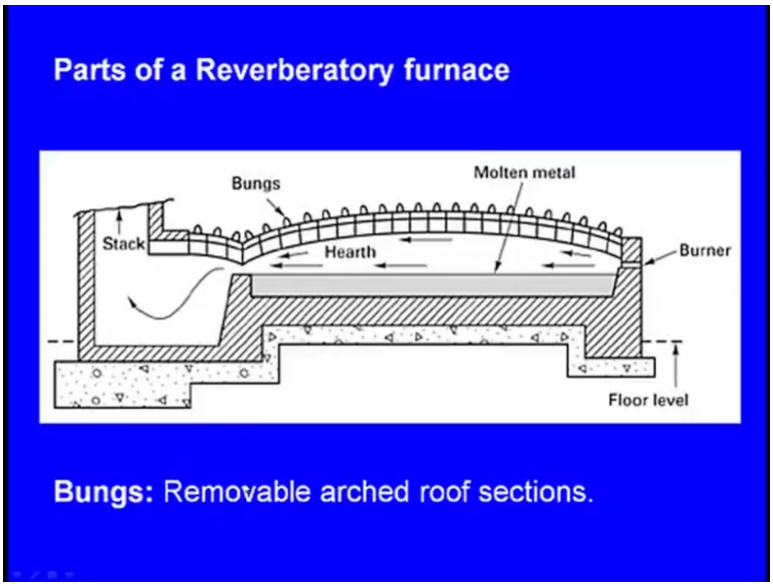

And here we can see this the burner and the fuel and this is the roof, this is the roof and here the hot gases will go and touch the roof, and the radiation comes and strikes the charge, and here we can see this is the stag through which the hot gases can escape.

And this inside chamber is known as the hearth, and you can see here this is the molten metal and remember that in the reverberatory furnace the fuel does not come in contact with the molten metal it, even does not go above the molten metal as in the case of the rotary furnace. It first strike the roof and the radiation comes and heats the charge that is the what say interesting what say phenomenon that can takes place inside a reverberatory furnace.

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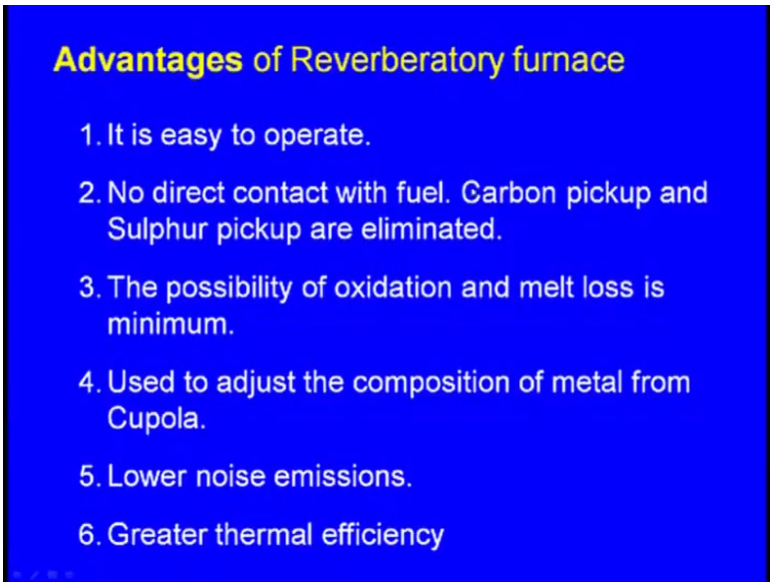

Now, these are the advantages of reverberatory furnace it is easy to operate no direct contact with the fuel, yes that is what we have discussed just now, hence carbon pickup and sulfur pickup or eliminated, as the fuel does not come in contact with the molten metal no carbon pickup no sulfur pick up.

The possibility of oxidation and melt loss is minimum, it is used to adjust the composition of the metal from cupola yes, again this can be used in conjunction with a cupola furnace, just like an rotary furnace can be used in conjunction with a cupola furnace, what are the drawbacks of the cupola furnace the most advantage of the cupola furnaces its simplicity, and large quantities of melt can be melted using a cupola furnace.

But accurate composition control is not possible in a cupola furnace, but that can be achieved in a reverberatory furnace, yes we can tap the molten metal from the cupola furnace. And we can what say pour it inside the reverberatory furnace, and here we can adjust the composition of the molten metal what is required if some other element is required we can add here, that is how we can adjust the composition of the molten metal from the cupola using this reverberatory furnace, and here lower noise emissions lot of noise is not generated as in the case of the cupola furnace or in the case of the arc furnace.

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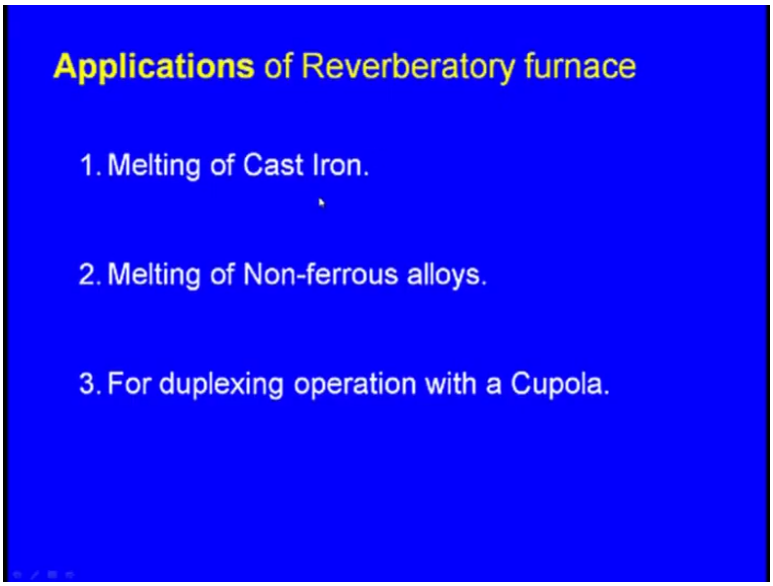

These are the applications of reverberatory furnace melting of cast iron, melting of non ferrous alloys, for duplexing operation with cupola, what is this duplexing operation means so, say in the inside the cupola furnace say accurate what say composition is control is not possible.

So, tap the molten metal from cupola and put it inside the reverberatory furnace, then you add the required alloying elements that is the what say the composition accurate control of the composition or temperature control, inside a cupola furnace accurate temperature control may not be possible, then obtain the molten metal from the cupola and pour it inside the reverberatory furnace. Now you heat inside the reverberatory furnace the temperature of the molten metal can be increased to a required level or to a satisfactory level. So, that is the duplexing operation with the cupola.

Now let us see the selection of melting furnaces. So, how to select a melting furnace what are the factors that will be coming into picture. The first factor is the initial cost of the furnace. So, what is the cost of the furnace what is your budget accordingly this pattern has to be considered, if the what say cost budget is very less one has to go for the cupola furnace and fuel and operating costs.

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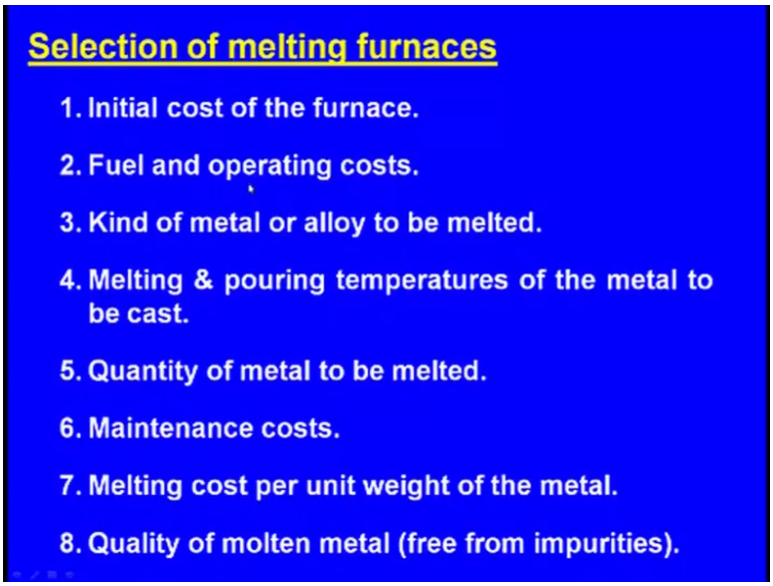

So, this is another factor what fuel is available, and what are the operating costs, next one kind of metal or alloy to be melted what is your metal, or what is your alloy, is it the ferrous or non ferrous accordingly one has to choose the furnace.

Next one melting and pouring temperatures of the metal to be cast what are the pouring temperatures to be obtained. So, this is the another interesting what say important factor to be considered, next one quantity of metal to be melted whereas, a we know that to cupola furnace can be used for what say melting large quantities whereas, an induction furnace can used for melting small and moderate quantities of charge. So, what is the quantity of metal to be melted accordingly one has to choose the furnace.

Next one maintenance costs, this is another important factor, next one melting cost per unit weight of the metal, how much what say melting cost per unit weight of the metal. So, this is another important factor, next one quality of the molten metal what is the quality required do require high quality molten metal, then certainly cupola furnace is not the right choice maybe induction furnace is the right choice, next one let us see the overall comparison of melting furnaces. Now you can see here this is the crucible furnace and mode of melting is solid fuel oil or gas, and application is most of the alloys accept steel.

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	FURNACE	MODE OF MELTING	APPLICATION
1.	Crucible furnace	Solid fuel, Oil or Gas	Most of alloys except steel
2.	Cupola furnace	Coke, Oil	Cast iron, Steel
3.	Electric arc furnace		
	Single phase	Arc on metal charge	Non-ferrous alloys
	Three phase	Arc on metal charge	Steels
4.	Induction furnace		
	Low frequency	Electromagnetic induction	Non-ferrous alloys
	High frequency	Electromagnetic induction	Steel and alloy steels
5.	Resistance furnace	Resistance caused to the current	Steel, Non-ferrous alloys
6.	Rotary furnace	Pulverized solid fuel, Gas or Oil	Non-ferrous alloys, Cast iron
7.	Reverberatory furnace	Solid fuel, Gas or Oil	Non-ferrous alloys, Cast iron

Now, this is the second one is the cupola furnace, and mode of melting using coke and oil, and application it is used for melting cast iron and steel electric arc furnace again there are 2 types, one is the single phase, and another one is the three phase. Single phase in both the cases arc is utilized for melting the charge, single phase is used for non ferrous alloys whereas, three phase arc what say furnace is used for melting steels.

Next one is the induction furnace again in the induction furnace there are 2 types one is the low frequency, and another one is the high frequency. Low frequency induction furnace in both the cases electromagnetic induction is the mode of melting whereas, in the case of the low frequency induction furnace it is used for non ferrous alloys, high frequency induction furnace is used for melting steel and alloy steels.

Next one resistance furnace is there now, it is mode of melting is resistance caused to the current flow of current and what are the applications it can be used to melt steel and non ferrous alloys an, next one is the rotary furnace what is the mode of melting by burning pulverized solid fuel gas or oil. And this can be used to melt non ferrous alloys and cast iron, next one reverberatory furnace what is the mode of melting solid fuel gas or oil, and this can be used to melt non ferrous alloys and cast iron, and remember that rotary furnace and reverberatory furnace can be used for the purpose of duplexing in conjunction with the cupola furnace means for adjusting the composition and for raising the what say super heating, means raising the pouring temperature for these purposes

rotary furnace, and reverberatory furnaces can be used for duplexing accordingly seeing considering all these factors one has to choose the furnace.

Nowadays the sophisticated methods have come the vacuum melting has come. It is quite expensive, but one can get accurate temperature control very high quality composition without any impurities, even these; what say vacuum furnaces are, but; however, these vacuum furnaces are costly.

So, today in this lecture we have seen different furnaces, and their construction details, and their mode of melting, and their applications. And in the next class let us see the next topic that is the solidification.

Thank you.