Manufacturing Processes – I
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Module - 2
Lecture - 8
Metal casting

Good morning. In the previous episodes, we have been learning the principle of metal casting process. We have learnt different types of metal casting process and in this episode, let us see The melting furnaces and practice.

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This melting is very important phase in metal casting process. After we prepare the mould, we have to pour the molten metal. To prepare the molten metal, we need a melting furnace. So, in this lecture, let us see the different furnaces used for melting in the metal casting process. And before that it is necessary for us to know the melting temperatures of certain important cast metals and alloys.

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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-Ni alloy (Cu -96%, Ni -4%)	1175	1220 – 1280
10.	Gun metal (Cu-85%, Sn-5%, Zn-5%, Pb-5%)	1040	1100 – 1180

If we see the gray cast iron, the melting temperature is 1370 degree Centigrade and again the gray cast iron has got certain composition. It contains Silicon; it contains Carbon, Sulfur and Phosphorous, and depending upon the composition of these elements the melting temperature varies, but this is the typical temperature. And for gray cast iron, we can see the pouring temperature is starting from 1510 degrees to 1590 degree Centigrade.

There is a difference between melting temperature and pouring temperature. Melting temperature is the temperature at which the solid metal melts; it is starts melting, but to pour the liquid metal into the mould, if we heat the metal up to melting temperature it is not enough. By the time we tap the molten metal from the furnace, next minute it will be solidified. So, if we have to pour the molten metal, if we once we tap it from the furnace we have to carry till the ladle; then we have to pour it in the mould. So, that pouring temperature must be higher than the melting temperature.

So, for gray cast iron, the melting temperature, the typical melting temperature is 1370 degree Centigrade, whereas the pouring temperature it varies between 1510 degrees to 1590 degree Centigrade. When we are casting thick sections, even if the pouring temperature is low at the order of 1510 degree Centigrade, we can successfully cast. But when we are casting thin sections, the melting pouring temperature should be high; it should be high up to 1590 degree Centigrade.

So, the pouring temperature varies over a range and for cast steel, the typical melting temperature is 1480 degree Centigrade; that is the melting temperature. And the pouring temperature is 1600 to 1720 degree Centigrade.

And for Copper, the melting temperature is 1083 degree Centigrade and the pouring temperature varies between 1130 degrees to 1200 degree Centigrade. And for Nickel, the melting temperature is 1453 degree Centigrade and the pouring temperature varies between 1500 to 1590 degree Centigrade. Aluminum - the melting temperature is 660 degree Centigrade and pouring temperature varies between 700 to 760 degree Centigrade. Zinc - the melting temperature is 420 degree Centigrade and the pouring temperature is 450 to 480 degree Centigrade. And the Lead - the melting temperature is 327 degree Centigrade and the pouring temperature varies between 350 to 380 degree Centigrade. And for the Tin, the melting temperature is 232 degree Centigrade and the pouring temperature is 280 to 290.

And Copper Nickel alloy in which Copper is 96 percent and Nickel is 4 percent, the melting temperature is 1175 degree Centigrade and the pouring temperature varies between 1220 degrees to 1280 degree Centigrade.

And if we take the gun metal and whose composition is Copper 85 five percent, Tin 5 percent, Zinc 5 percent and Lead 5 percent, the melting temperature is 10040 Centigrade and the pouring temperature varies between 1100 to1180 degree Centigrade. So, these are the melting and pouring temperatures of some important cast alloys and metals.

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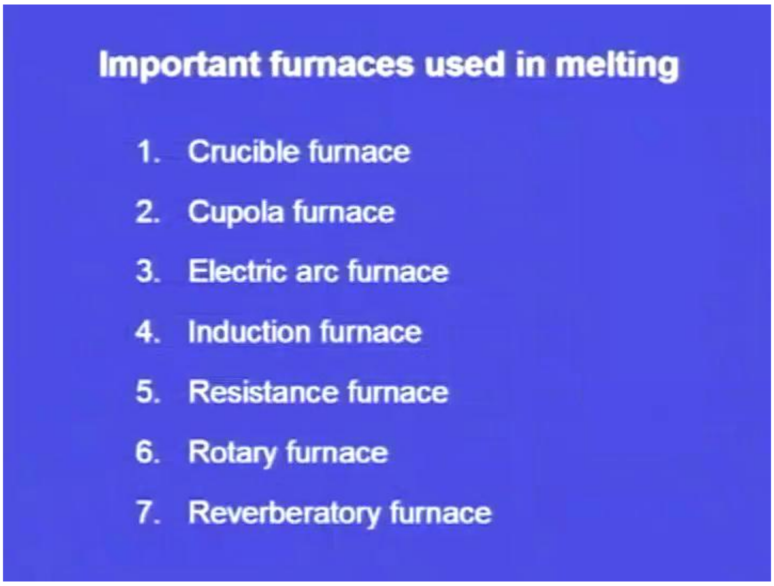

And let us see the important furnaces used in melting. One is the crucible furnace; second one the cupola furnace; third one electric arc furnace; fourth one induction furnace; fifth one resistance furnace; sixth one rotary furnace; seventh reverberatory furnace.

So, these are the important furnaces and let us see the construction details of these furnaces and how they work. Let us see their working principles, applications and advantages.

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First, let us see the crucible furnace.

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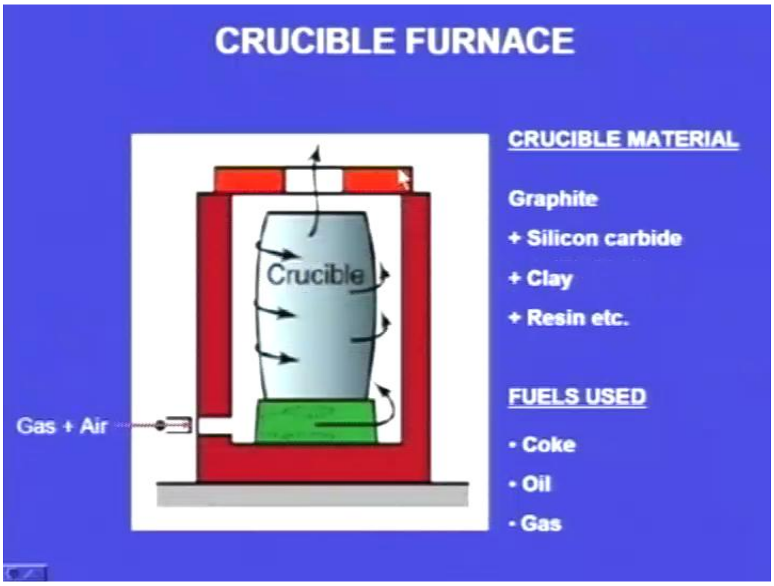

This crucible furnace has been in use for a long time and it is very simple. It is made up of crucible and this crucible is made up of Graphite plus Silicon carbide plus clay and plus some resin. The crucible is made up of this material and the fuel used is coke, oil is used, and gas is also used. And here we can see gas and air is passed through this hole and here it is burnt and the flames are passing around the crucible, inside we keep the charge, metallic charge, and it will be melting. Instead of gas, oil can be used. Oil will be sprayed and it will be burnt. Instead of gas or oil, coke can be used. Coke will be filled inside and it will be burning, and the metal will be melting. So, this is the simple principle of the crucible furnace.

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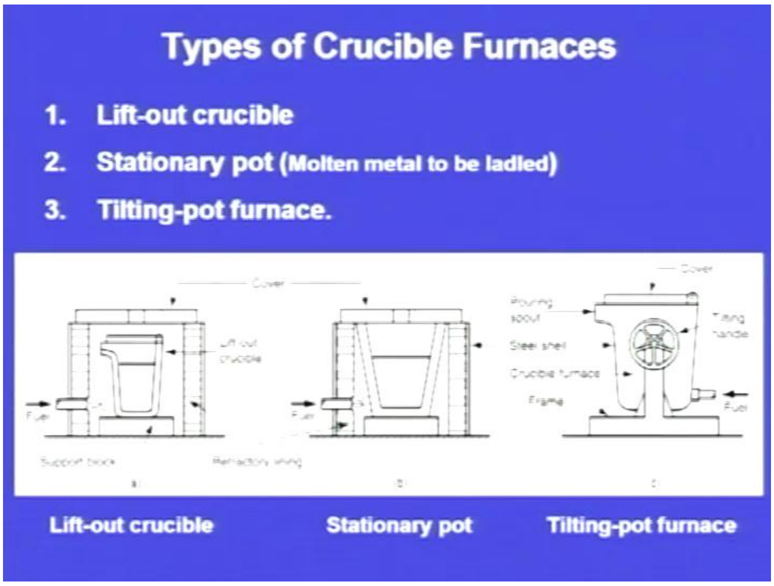

There are three types of crucible furnace: one is lift-out crucible; second one is stationary pot in which molten metal has to be ladled; third one is tilting pot furnace.

In the lift-out crucible, so, this is the crucible and we are burning it here either by gas or oil or by coke and after melting is over, we take the crucible out of this chambers and we will take it to the place of pouring; directly we will pour through this crucible. So, this is the lift-out crucible and it is very simple.

Second one is stationary pot. So, this is the stationary pot; this is little bigger. So, the principle of burning is the same, but that we will not take it. In the previous case, we have taken out the crucible out of the chamber. Here, we would not be taking the crucible out of the chamber, instead we will be taping into another ladle. So, that is the principle of this stationary pot and the third type is tilting pot furnace.

Here the principle of burning is same. It is bigger, but again the molten metal will be taped into a ladle and it will be tilted. Here we can see a wheel. So, if we rotate this wheel, this handle, this can be tilted. This can be tilted and the molten metal can be taped into a ladle. So, this is the tilting pot furnace. So, these are the three types of crucible furnaces.

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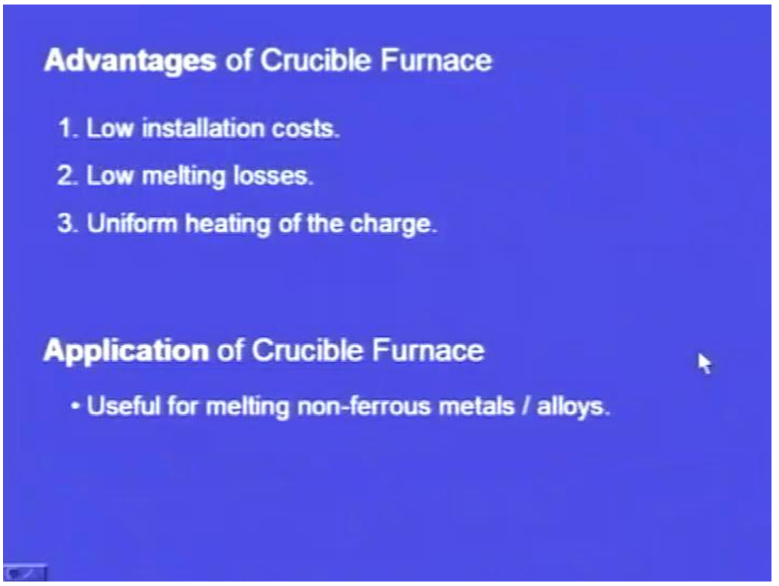

Advantages of crucible furnace: first advantage is low installation cost. After all only a crucible; we are not using any machines and low melting losses. So, here we are coming across one melting loss; what is this? In general, when we melt a metal, about five percent will be lost. If we melt 100 kgs of cast iron, we make at only 95 kgs of molten metal. So, 5 kgs of cast iron is lost. So, that is the melting loss. So, in the case of the crucible furnace, melting loss will be minimum.

Uniform heating of the charge: so, that is another advantage. And what are the applications of this crucible furnace? Useful for melting non-ferrous metals and alloys.

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Let us see the cupola furnace.

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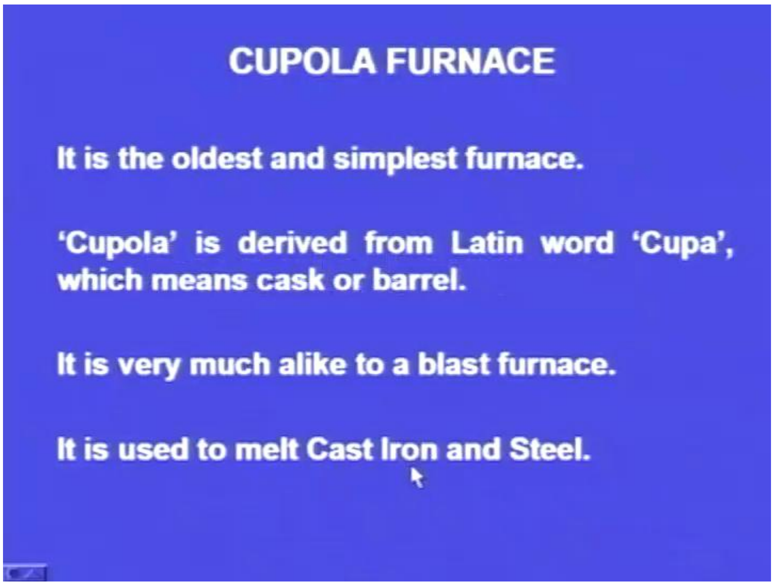

Cupola furnace is the one of the simplest furnaces ever known. The cupola is derived from the Latin word cupa which means cask or barrel, barrel or a shaft; it looks like a shaft and it looks like a blast furnace. Of course blast furnace is very big and the principle of operation and the purpose are different, but appearance wise it resembles the blast furnace and it is used to melt cast iron and steel. Let us see the construction details of the cupola furnace.

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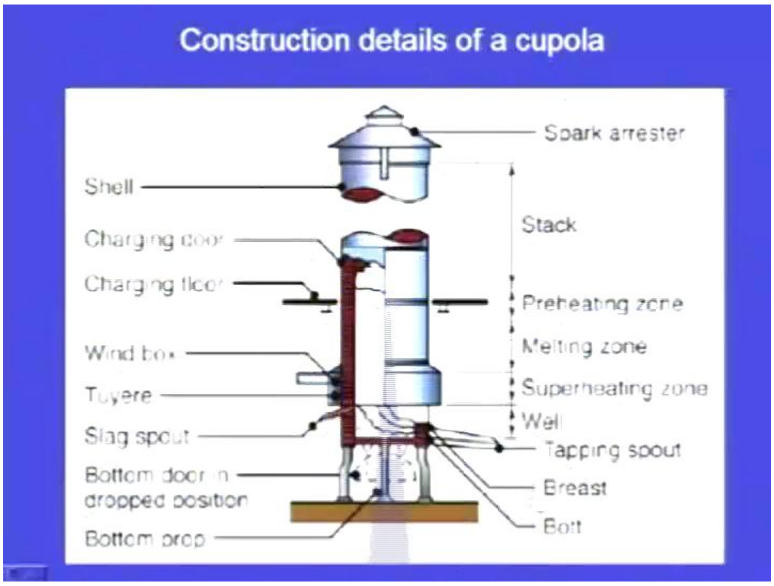

So, this is the construction details of the cupola furnace. Here we can see the furnace. These are the different components of the furnace. Let us study these different components of this cupola furnace.

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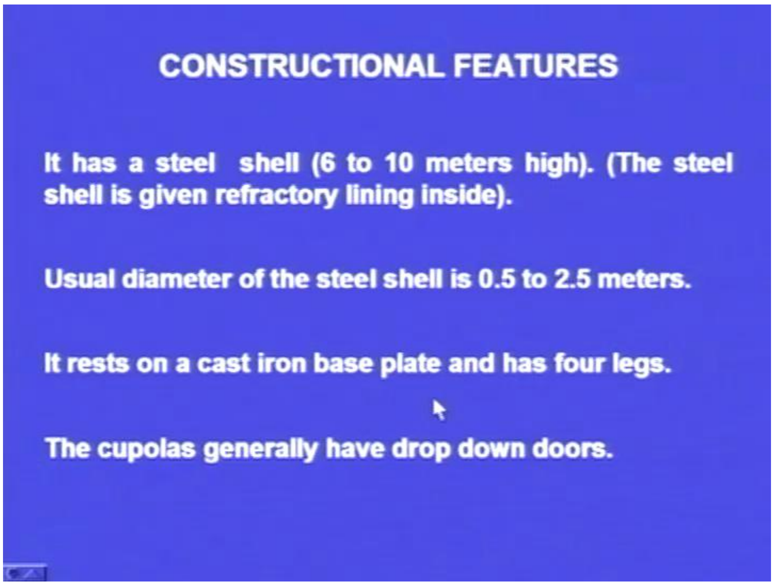

It has a steel shell 6 to 10 meters height. So, that is the main component of this cupola furnace and this steel shell is given a refractory lining inside, and the usual diameter of this steel shell steel shell is between 0.5 to 2.5 meters, and it rests on cast iron base which has got four legs and at the bottom it has got a drop down door.

So, here we can see, there is a shaft; this is the shaft. So, this shaft it is height is 6 meters to 10 meters and its diameter varies between 0.5 meters to 2.5 meters and here we can see cast iron base and we can see cast iron legs are there.

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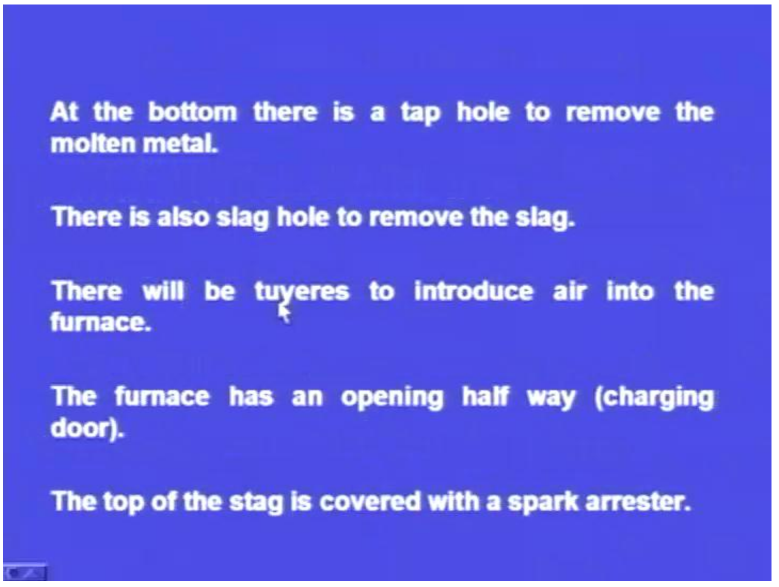

Next one, at the bottom there is a tap hole to remove the molten metal. There is also slag hole to remove the slag. There will be tuyeres to introduce air into the furnace. The furnace has an opening which we call it as charging door. The top of the shell is covered with a spark arrester. So, here we can see. So, this is the tapping hole and this is the slag hole. These are the tuyrers through which we send air into the furnace. So, here we can see the charging door through which we put the metallic charge and the coke and the lime stone inside the furnace and this is the charging floor, and here we can see this spark arrester.

So, when the cupola furnace is in operation, fire will be generated. Sometimes burning cokes will be flying. So, these have to be stopped; these have to be arrested. So, this is the spark arrester.

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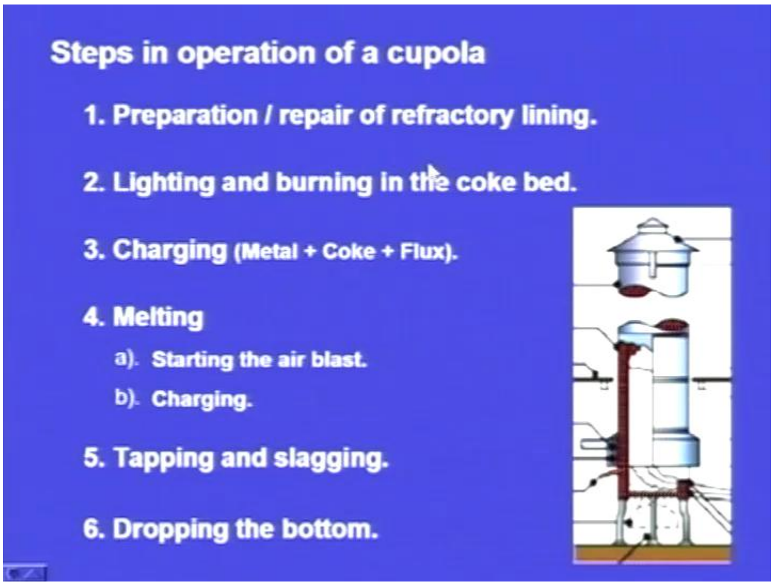

Steps in operation of a cupola furnace: first one is preparation or repair of the refractory lining. Since the cupola furnace is a steel shell, inside there will be refractory lining. So, first thing we have to do is we have to see that this refractory lining is proper. Because of the previous use, the refractory lining might be damaged. If so, then we have to repair it. So, first step is preparation or repair of the refractory lining. Second step - lighting and burning in the coke bed; yes, here we prepare a coke bed. Of course, beneath that there will be a sand bed. Above the sand bed, we prepare coke bed and we have to light it; we have to burn the coke bed.

Next one, when the coke is burning we charge the furnace. Charging means we feed the furnace with metal coke and flux. Initially we charge metal; next we coke; next we charge flux; next layer by layer; next we charge metal; next we charge coke; next we charge flux. And this metal to coke ratio will be generally six; means for 6 kgs of metal, we use 1 kg of coke and if the quality of the coke is high, this ratio can be increased. It can be even up to 10; means for 10 kgs of metal, we can use only 1 kg of coke.

Next one, it is then the charge starts melting. Next is the melting. When the charge is about to melt, we have to send the air blast. Here are the tyrers. We send the air inside the furnace and because of this air, the combustion intensifies and completely melts. And after the molten metal is ready, next step is tapping and slagging. We have to tap the molten metal into a ladle and before that we have to tap out this slag. And after the combustion is over, after we tap the molten metal, if we do not need any molten metal, then we have to shut it down. Then here, there are doors are there. If we open these doors, whatever is inside will be falling down; the sand bed, the coke bed, everything, the ashes, everything will be falling down; with that the operation will be closing. So, these are the steps involved in the operation of a cupola.

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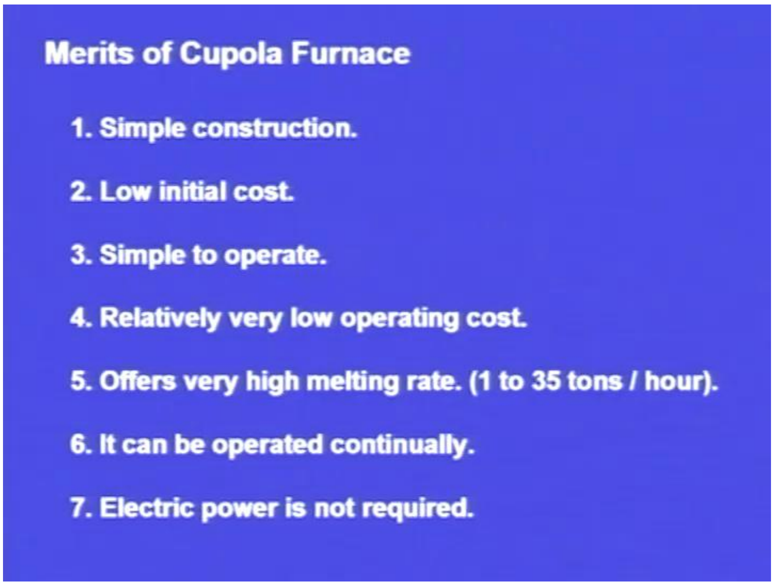

Merits of cupola furnace: First merit is construction is very simple. It is just a steel shell. It is a barrel; construction is very simple; low initial cost. Next it is simple to operate. Next one, relatively low operating cost. Next one, offers very high melting rate and in one hour, we can melt from 1 Ton to 35 Tons and another advantage is it can be operated continually. Means we charge the molten metal, sorry we charge the metal, we charge the coke, we charge the flux and combustion takes place. And after sometime, we get the molten metal; again we charge it; the metal, the coke, the flux will be charging; we get the molten metal. So, this can be continued as long as we need the molten metal. So, the furnace can be operated continually.

Another advantage is electric power is not required. Especially in some places, at sometimes, there is scarcity of electricity. So, it that place, at that time, use of cupola furnace will be very good because we do not have to depend on electricity.

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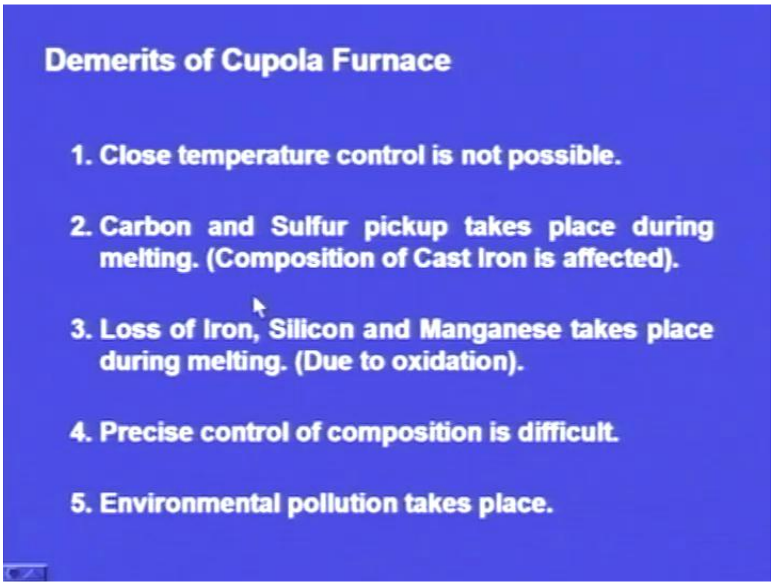

Demerits of cupola furnace: One of the drawbacks is close temperature control is not possible. Suppose if we want say 1500 degree Centigrade, keeping that temperature we run the furnace. Finally, we get little higher temperature or little lower temperature; accurate temperature we may not get. That is the drawback of the cupola furnace. Next drawback is Carbon and Sulfur pickup takes place during melting. What is this Carbon pickup? It means the cast iron, if we are melting cast iron, there will be Carbon content; there will be Sulfur content; that will be increasing.

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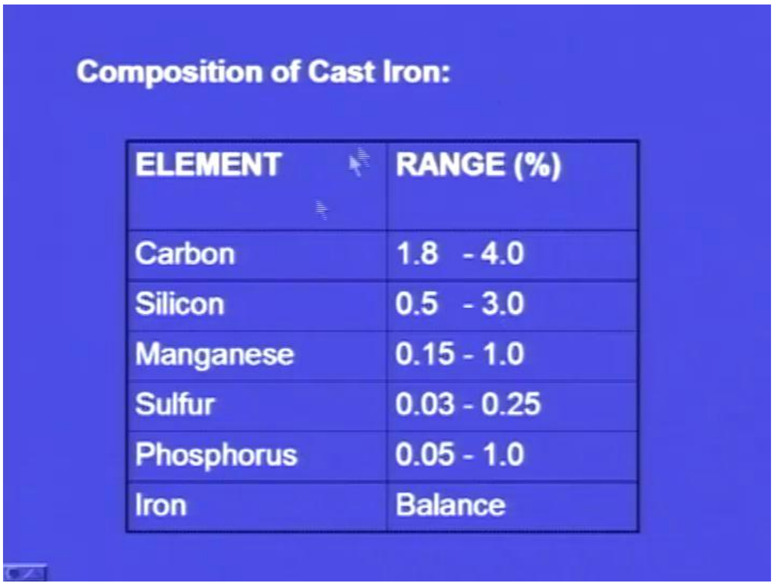
Composition of Cast Iron:

ELEMENT	RANGE (%)
Carbon	1.8 - 4.0
Silicon	0.5 - 3.0
Manganese	0.15 - 1.0
Sulfur	0.03 - 0.25
Phosphorus	0.05 - 1.0
Iron	Balance

Yes, this is the composition of the cast iron. In the cast iron, these are the alloy elements. The Carbon varies from 1.8 to 4 percent; Silicon varies from 0.5 to 3 percent; Manganese varies from 0.15 to 1 percent; Sulfur varies from 0.03 to 0.25 percent; Phosphorus from 0.05 to 1 percent, and the rest is Iron. So, these are alloying elements of cast iron and if this range is not maintained, the melting metal will not be of any use; the purpose is lost. Now, what is happening?

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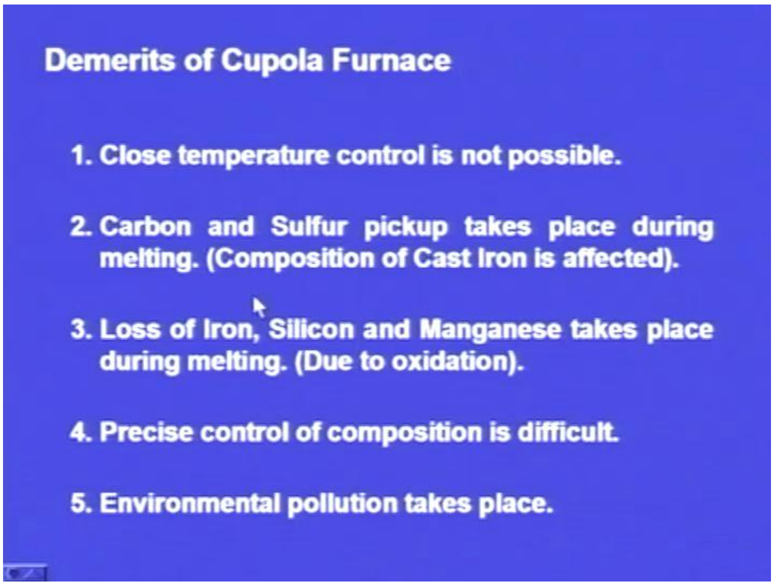

The Carbon, the permitted limit is 1.8 to 4 percent and Carbon pick up takes place means Carbon will be added to the molten metal. How? We are using coke for the combustion purpose. Coke contains Carbon. The Carbon from the coke enters into the molten metal and final content, Carbon content of the cast iron will be increasing. We are unable to control it. We are finding it difficult to control it. So, that is how Carbon pick up takes place.

Next one Sulfur pick up takes place; yes, cast iron contains Sulfur. There is a limit, but we are using coke for combustion. Coke contains this Sulfur and the Sulfur from the coke enters into the molten metal and the Sulfur content of the cast iron increases; that is the Sulfur pick up. So, Carbon pick up and Sulfur pick up takes place during melting. So, finally, the composition is altered. So, this is another drawback.

Next one, loss of Iron, Silicon and Manganese takes place due to oxidation. We are sending air during combustion and there is Oxygen. Oxygen reacts with the molten iron and forms Iron oxide. Silicon reacts with Oxygen and forms Silicon oxide. Similarly, Manganese reacts with Oxygen. Once they form oxides, they will be eliminated. So, this is loss; loss of alloying elements. And due these reasons, precise control of composition is difficult. If we expect some composition, keeping that composition in mind, if we run the furnace, we may get some other composition. So, this is another drawback.

Finally, the environmental pollution takes place. We are burning coke; smoke is emitted continuously. Sometimes even burning coke pieces, they fly out. It is harmful to the environment. The environmental pollution takes place. This is another drawback of the cupola furnace.

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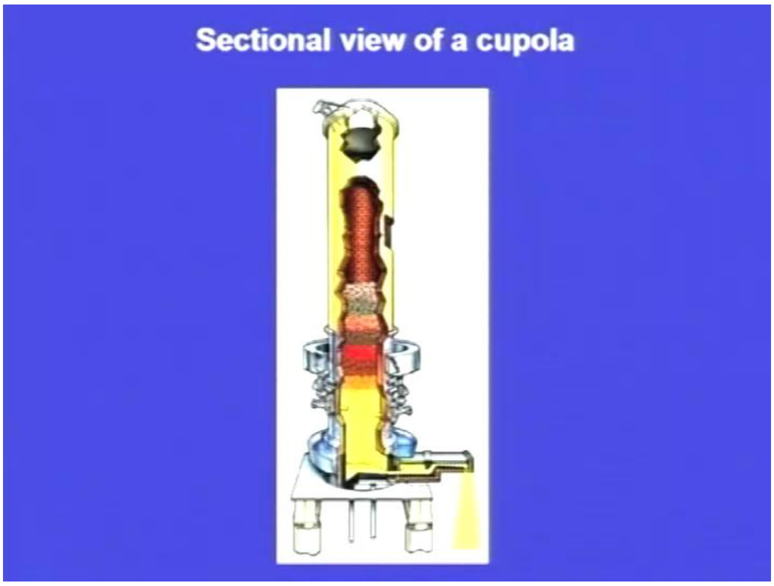

So, this is the sectional view of the cupola furnace. Yes and here we can see the molten metal being tapped.

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Next one, let us see the Arc Furnace.

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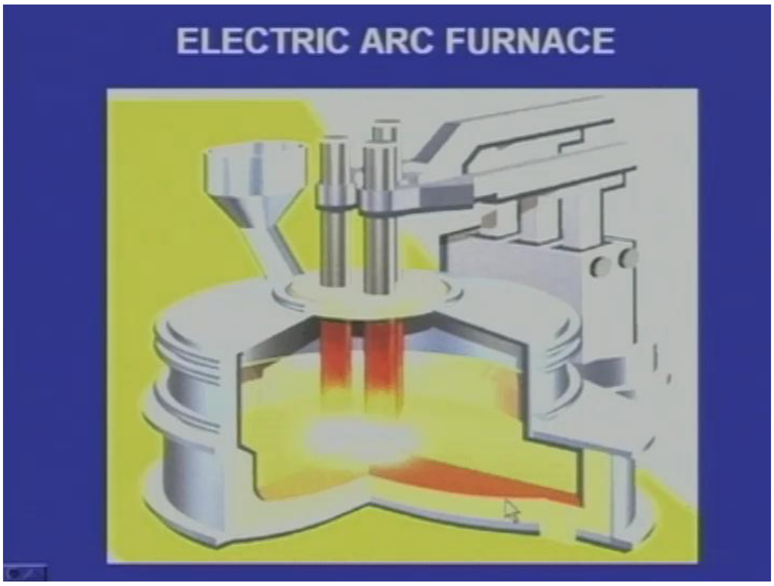

So, this is the cut sectional view of arc furnace. Here we can see the electrodes; graphite electrodes are there. And this is a shell and inside there is a charge, metallic charge, which we want to melt. The power supply is connected between the electrodes and the charge, and we strike these electrodes and sparks are created, and that continues into arc. And because of this arc, the molten metal is prepared; the charge melts. So, this is the principle of the electric arc furnace.

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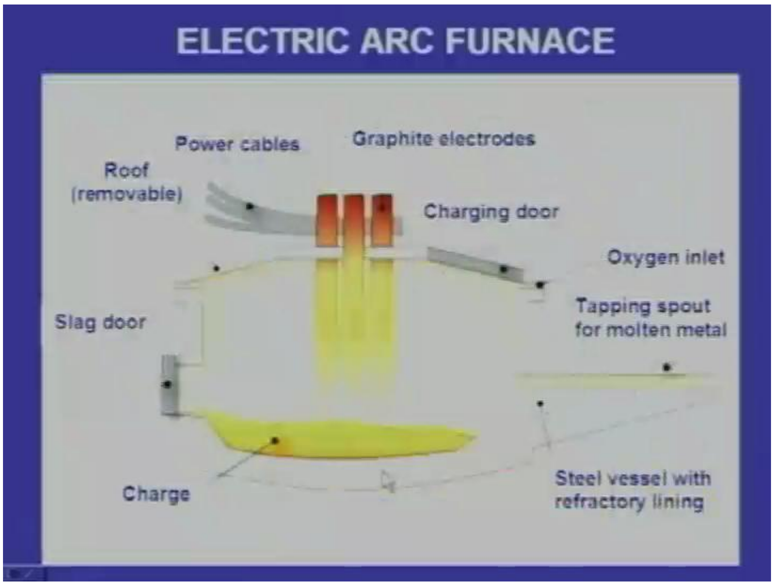

So, these are the different components of electric arc furnace. So, it is a steel shell. Here we can see steel vessel with refractory lining and here we can see the slag door through which we remove the slag. Here we can see the removable roof. This roof can be removed wherever necessary, whenever necessary. And here we can see the charging door through which we charge the metallic iron or metallic pieces. And this is the hole through which we send the Oxygen and here we can see the graphite electrodes. And these are the power cables; power cables connected to the electrodes and they are connected to the charge.

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This is the initiation of the arc. The power is connected to these electrodes and is charged. The electrodes are struck, charged and the arc is created. So, this is the initiation of arc and because of this arc, the electrodes are consumed; the graphite electrodes are consumed. And the average electrode’s consumption is 1 to 4 kg per Ton of metal. So, this is the consumption of the electrode.

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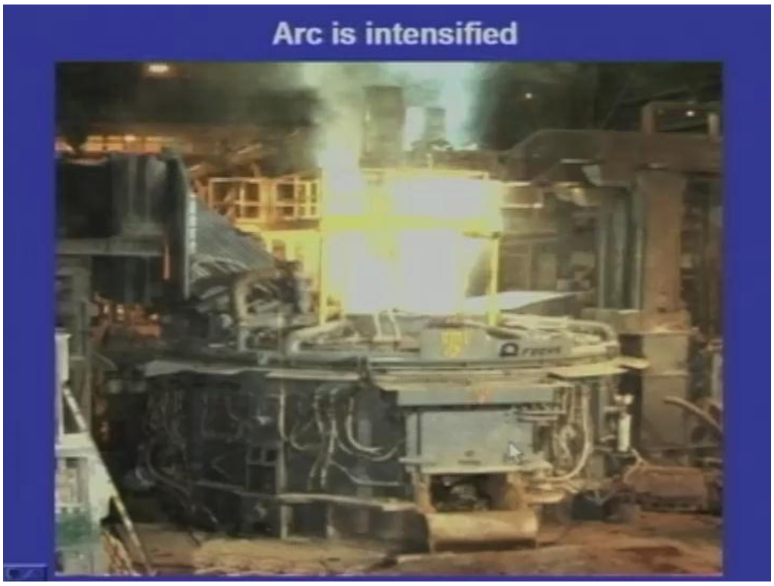

Now, here we can see the arc is intensified. Yes, here we can see the arc is intensified and inside the metallic charge is there, and that starts melting because of this intensified arc.

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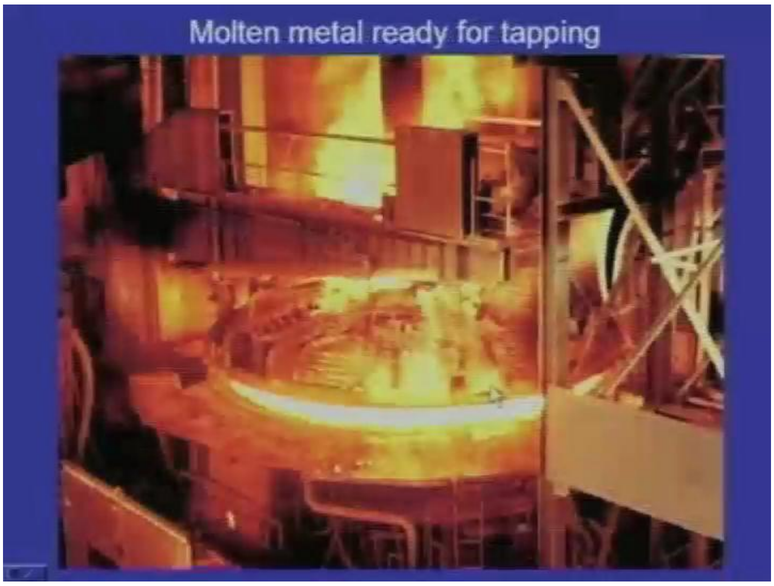

Next one, here we can see the molten metal is ready for tapping; inside we can see the molten metal.

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And here we can see the molten metal is tapped from the furnace.

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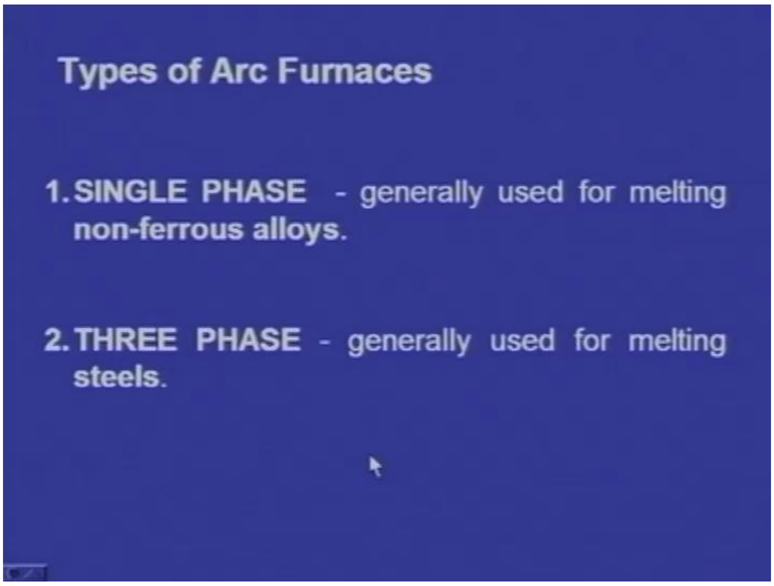

Types of arc furnaces: There are two types of arc furnaces: one is single phase and other one is the three phase. The single phase arc furnace is generally used for melting non-ferrous alloys and the three phase arc furnace is generally used for melting steels.

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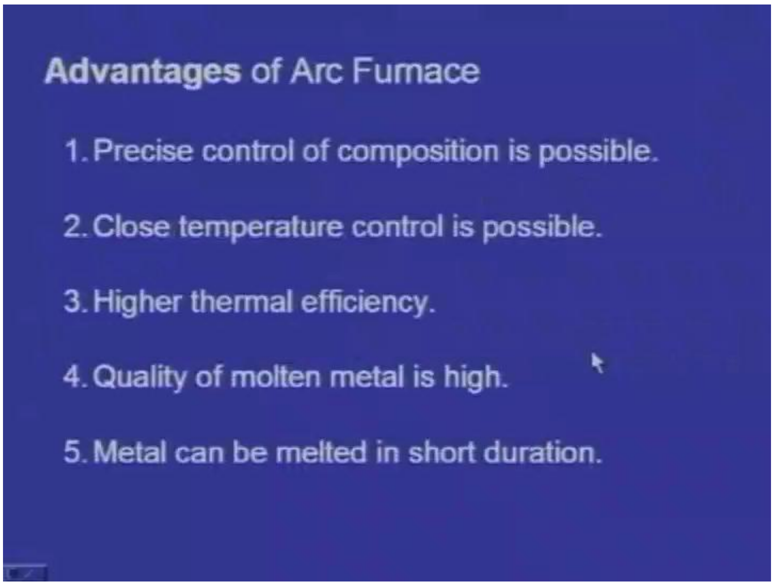

Advantages of arc furnace: Precise control of composition is possible. We have seen that in the case of the cupola furnace, precise control of composition is difficult, but here precise control of composition is possible.

Again in the case of the cupola furnace, we have seen that close temperature control is very difficult, but here close temperature control is easy, and this furnace offers higher thermal efficiency. And here the quality of the molten metal is high. In the case of the cupola furnace we are using coke and the coke will be burning, and there are impurities in the molten metal, but here the molten metal is free from the impurities; that is another advantage. And next, finally, the metal can be melted in short duration; in very short time, we can melt the metal.

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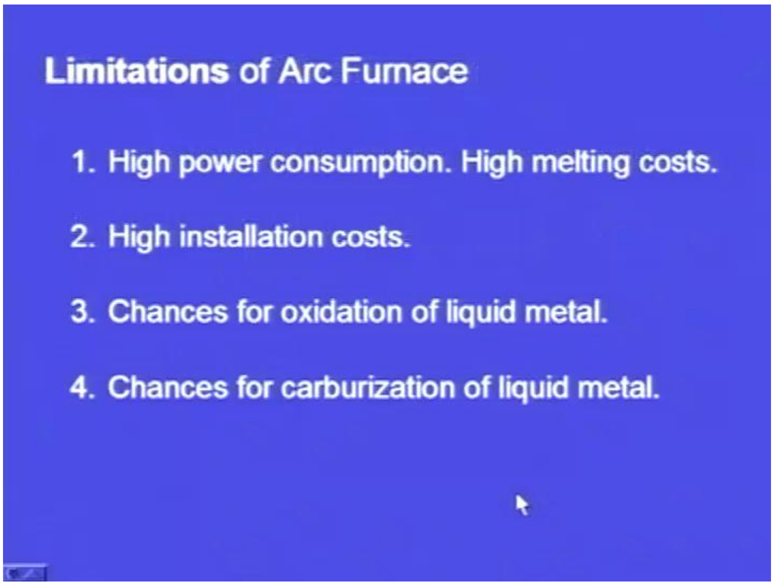

Limitations of this arc furnace: one is high power consumption. Because of this the melting cost will be high. High installation cost; the furnace itself is very costly. Chances of oxidation of the liquid metal takes place. Yes, we are sending Oxygen; this Oxygen may react with the molten metal and if the passes of the Oxygen is not controlled properly, it will be reacting with the molten metal and forms oxides. So, chances of oxidation for the liquid metal.

Next one, chances of carburization in the liquid metal. Carburization means the Carbon content increases. We are using graphite electrodes. These are consumed and because of this, the Carbon content of the molten metal rises.

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Next one, Induction furnace.

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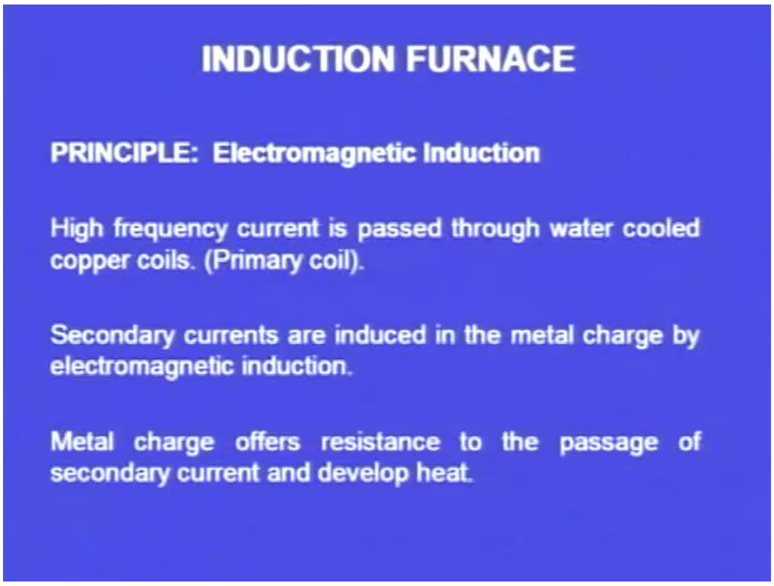

The principle is the electromagnetic induction. The furnace works on electromagnetic induction. High frequency current is passed through the water cooled Copper coils. So, this Copper coil acts as the permanent primary coil and secondary currents are induced in the metallic charge by electro magnetic induction. So, we are passing electricity through primary coil and this primary coil is around the crucible. Inside the crucible, we place the metallic charge and secondary current is induced inside the metallic charge. And the metallic charge is not a continuous block; there are continuous discontinuous pieces; so, the electric charge is passing form one piece to another piece. Each piece offers resistance to the flow of current and because of this resistance heat is generated, and because of this heat the charge will be melting. So, this is the principle of the induction furnace.

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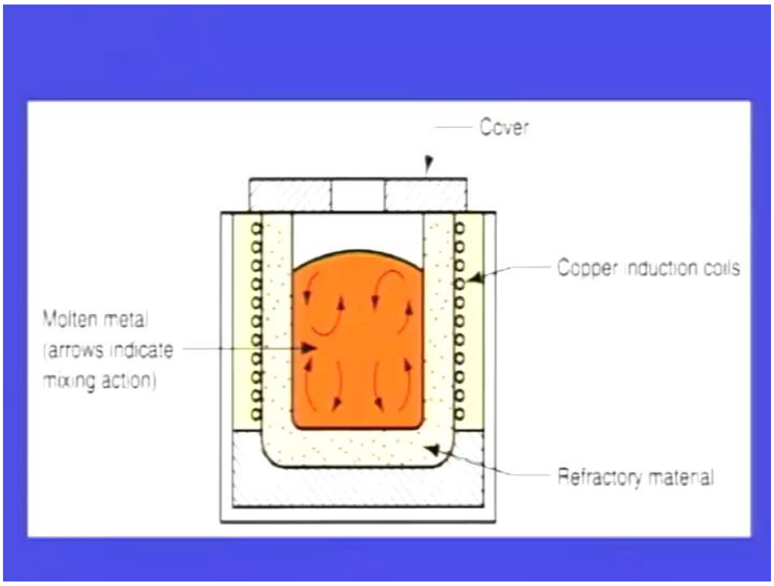

So, here we can see. This is the primary coil, Copper induction coil. So, this is the primary coil through which we pass the current, high current. And this is the crucible made up of refractory material. So, this is the crucible and inside we place the charge. So, when we pass the electricity through this coil, that is the primary current, secondary is produced inside the charge and resistance is offered by the charge to the flow of the current. And because of this resistance, heat is generated and this heat thus generated will be melting the charge.

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Here, we can see the induction furnace in operation. So, this is the coil and this is the crucible. And inside the crucible, we have kept the charge. So, heat is generated and the charge inside the crucible is melting.

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And here the molten metal is tapped from the induction furnace.

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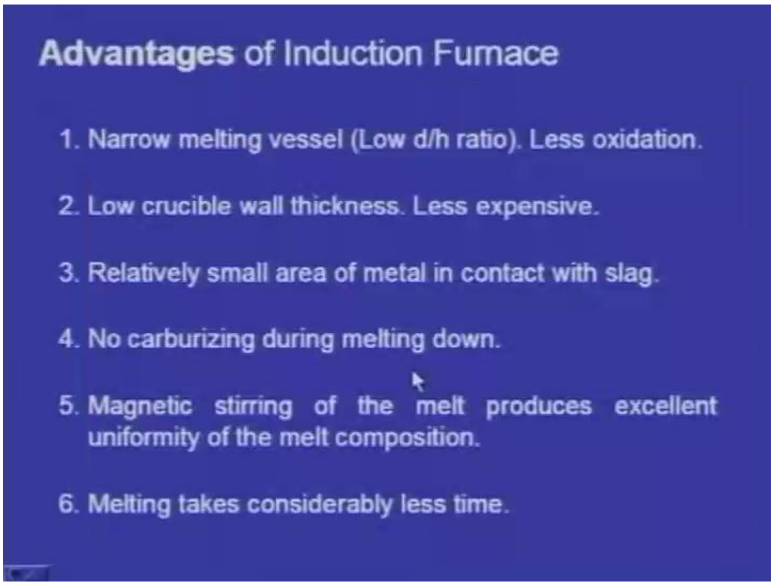

Now, let us see the advantages of the induction furnace. Here, we use the crucible. The diameter to height ratio will be low; means we use narrow crucibles; diameter will be less and the height will be more. Then what happens if this is the case? Every time when we melt in a crucible, the upper surface is exposed to the atmosphere. So, that will result in oxidation and here the diameter is low. Because of that lesser surface is exposed to the atmosphere. So, this results in lesser oxidation. So, this is an advantage in the case of induction furnace.

Even the thickness of the crucible will be low. Hence, the cost of the crucible will be less and relatively small area of metal is in contact with the slag. This is also because of the low diameter of the crucible. So, at times it becomes difficult to segregate this slag from the molten metal. Sometimes in the molten metal slag enters and even the slag goes into the mould cavity. But when the diameter of the crucible is small, when it is a narrow crucible, at a small surface these two are separated - slag and the molten metal; so, segregation will become easy. No carburizing during melting down.

In the case of cupola furnace, we were using coke and the Carbon from the coke was entering into the molten metal. So, Carbon pick up took place. In the case of the arc furnace, we were using graphite electrodes and the Carbon from the electrodes was entering into the molten metal. That is how Carbon pick up took place or the carburizing.

Here no carburizing is taking place during melting. So, this is another advantage of the induction furnace.

And here, magnetic stirring takes place. The crucible which is inside the primary coil is subjected to electromagnetic induction and this electromagnetic induction stirs the charge. Because of the electromagnetic induction, the charge is stirred; so, there would be uniform melting of the charge. So, this is another advantage of the induction furnace and the melting takes considerably less time.

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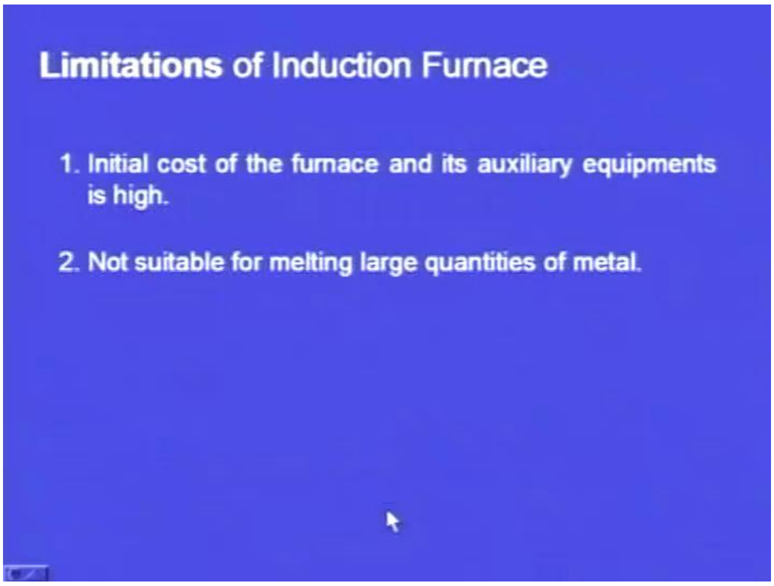

Now, let us see the limitations of induction furnace. Initial cost of the furnace and it is auxiliary equipments is high and this is not suitable for melting large quantities; only for small quantities.

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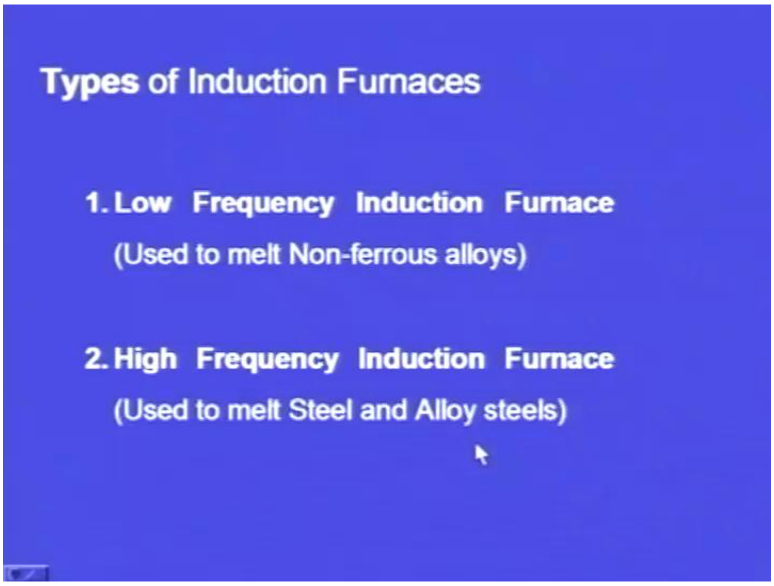

Types of induction furnaces: There are two types: one is low frequency induction furnace and this is used to melt non-ferrous alloys like Aluminum, Copper and so on, and the other type is high frequency induction furnace and this is used to melt steel and alloy steels.

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Next, let us see the resistance furnace.

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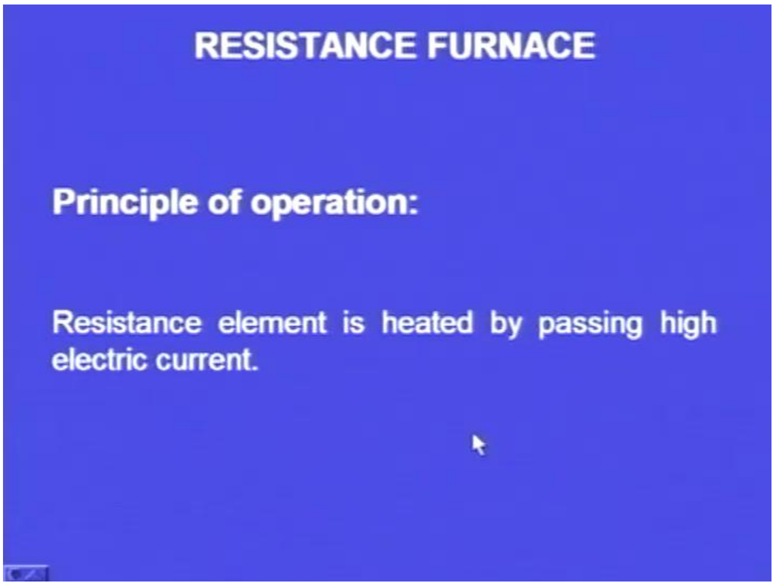

The principle of operation is resistance will be there in the furnace; when we pass electricity through the resistance, the resisting element will be heated up and this heat will be utilized to melt the charge. So, that is the principle.

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And here we can see the furnace and this is the chamber in which there will be resistance element and when we pass the electricity through the resistance element, it will be heated up and the charge will be melting.

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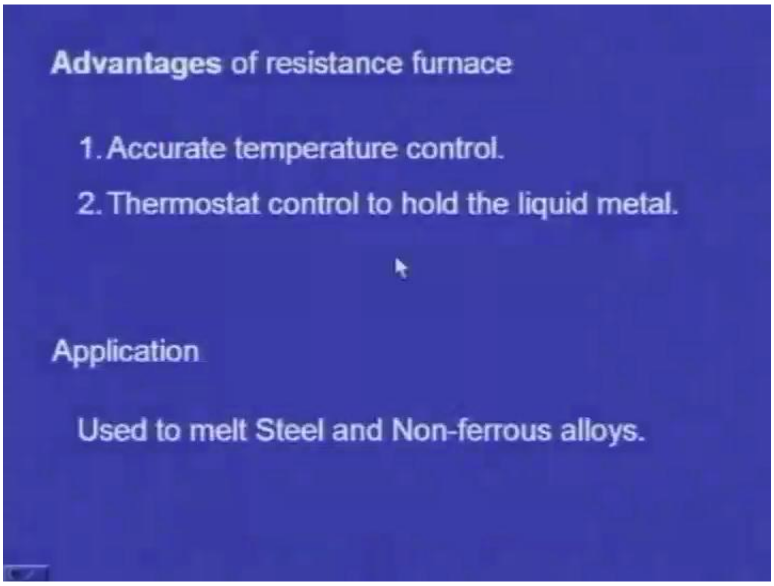

Advantages of resistance furnace: Accurate temperature control is possible. Yes, we can get the accurate temperature and at times it becomes necessary to hold the molten metal at certain temperature for sometime, during which we add some alloys. For that time, for that purpose, we have to hold the molten metal at certain temperature for certain time. That may not be possible in the case of the cupola furnace; that may not be in the case of arc furnace, but that holding the liquid metal is possible in the case of resistance furnace and its applications is, it is used to melt steel and non-ferrous alloys.

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Next, let us see the rotary furnace.

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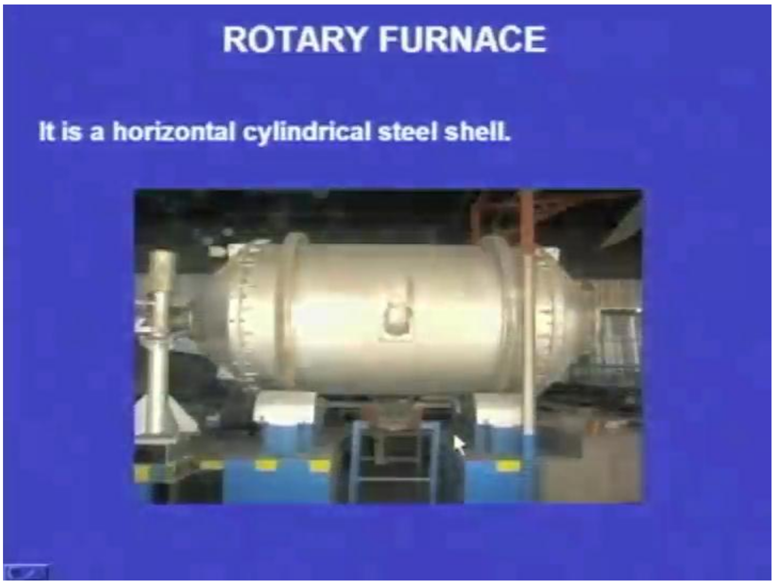

It is a horizontal cylindrical shell. Yes, we can see this is a rotary furnace. It is a horizontal cylindrical shell.

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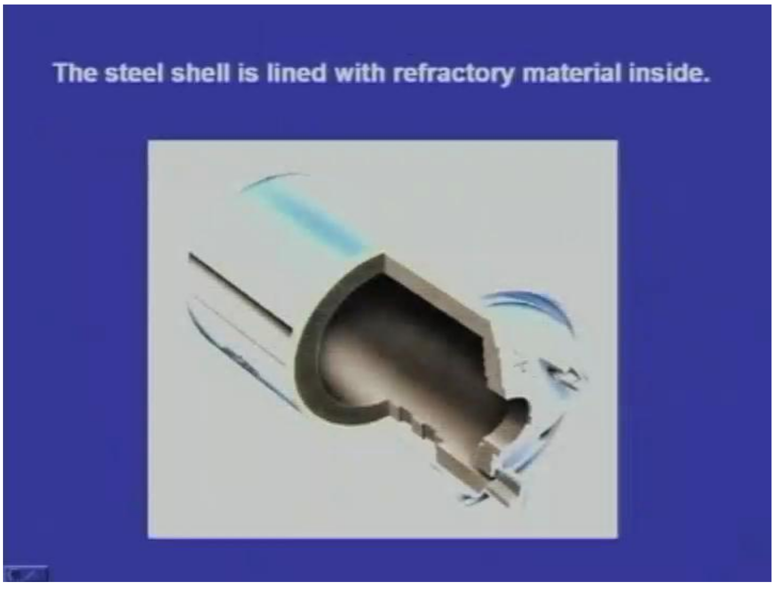

And the steel shell is lined with refractory material inside; inside there is a refractory lining. Yes, this is the cut sectional view of the rotary furnace. Inside there is refractory lining.

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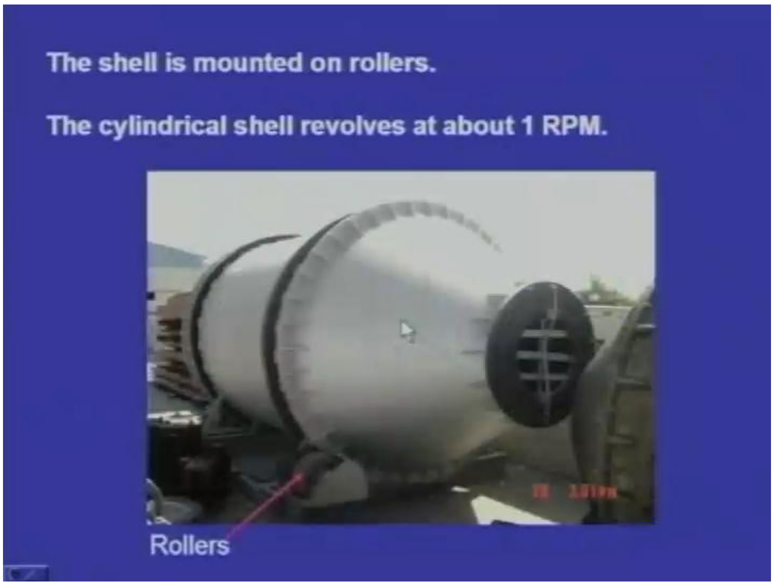

And the shell is mounted on the rollers. Here we can see the rollers; the rollers will be rotating. As these rollers are rotating, the steel shell will be rotating in the other direction. And the cylindrical shell revolves at about one revolution per minute. Slowly it will be rotating and inside the melting takes place.

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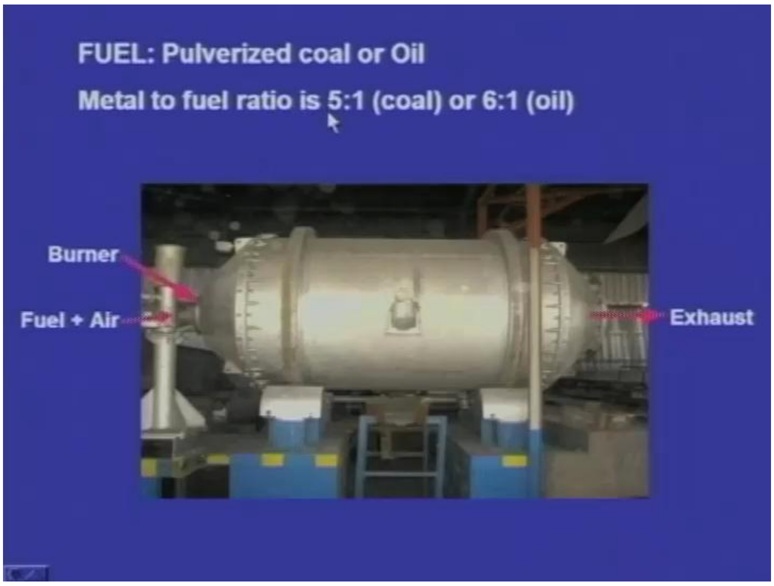

And what is the fuel? pulverized coal or oil. Metal to fuel ratio is 5 is to 1 in the case of coal. That is the metal to fuel ratio is 6 is to 1 in the case of the oil, if we use oil as the fuel. And inside the shell, there will be burner here and we are passing fuel and air this way, and this mixture of fuel and air will be burning here. And inside, the combustion takes place and the exhaust gases will be going this way. And this will be rotating and the metallic charge will be fed in the beginning; so, that will be melting. So, this is principle of the rotary furnace.

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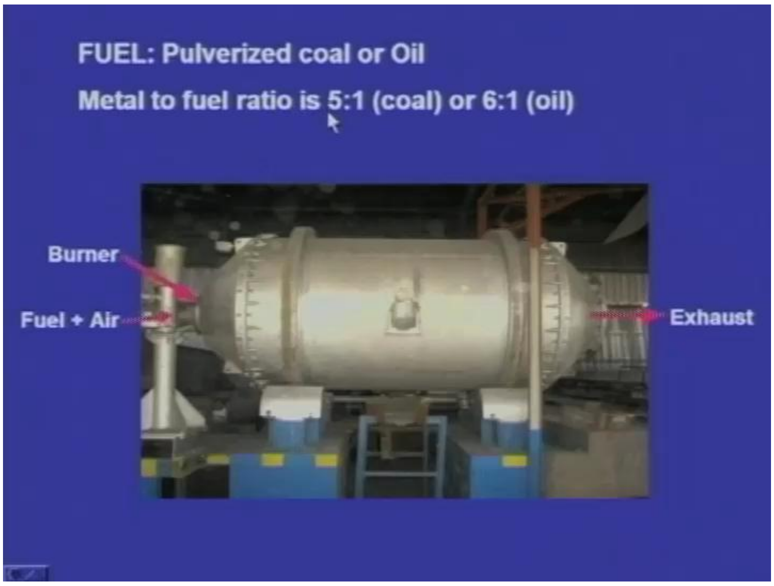

Yes, rotary furnace in operation we can see. This it is slowly rotating and here we can see the exhaust going out.

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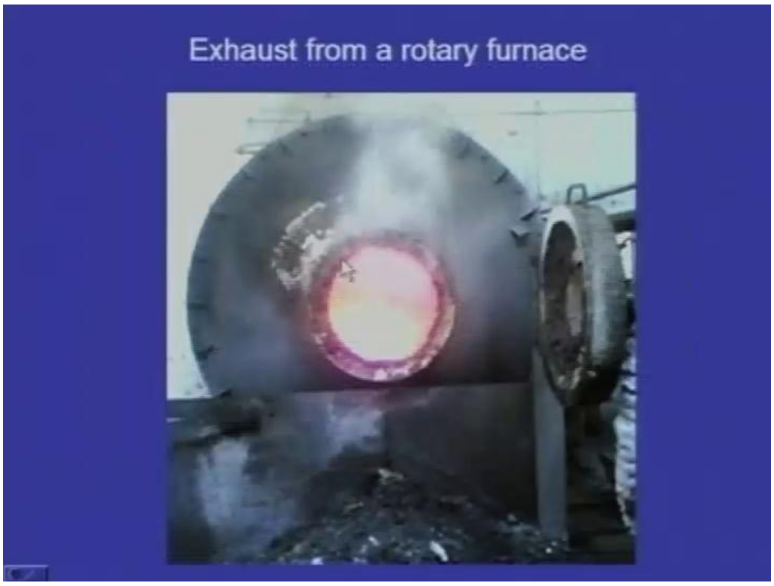

And here also we can see the exhaust going out.

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And here we can see the molten metal being tapped from the rotary furnace.

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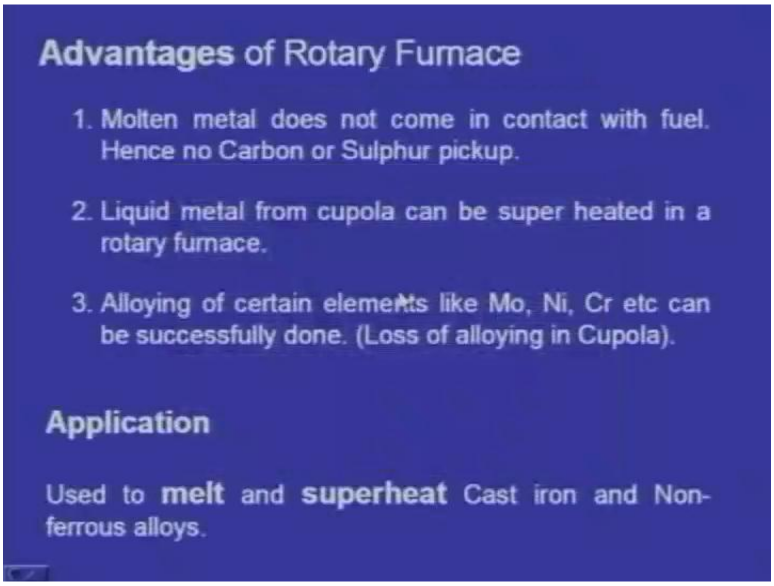

Let us see the advantages of the rotary furnace. Molten metal does not come in contact with the fuel. In the case of the cupola furnace, the molten metal sorry the charge metal and the coke, they were fed continuously; we were charging the metallic charge and we were charging the coke. So, the coke and charge, they come in contact with each other.

Here, the metallic charge and this one that is the fuel, they do not come in contact with the each other. So, hence no Carbon or Sulfur pick up takes place. Liquid metal from the cupola can be super heated in a rotary furnace. Sometimes super heating is required; super heating of the molten metal. In a cupola furnace we can melt the metal, but if we want a higher temperature we have to heat it further; means we have to add more coke. So, more Carbon pickups takes place which we do not want or more oxidation takes place which we do not want. So, the liquid metal from the cupola can be tapped and it can be fed into a rotary furnace. And here, the temperature can be increased.

Especially when we are casting thin sections, the liquid metal should be at a higher temperature and the temperature which we obtained at cupola furnace may not be sufficient to cast thin sections. In such cases, we can tap the molten metal from the cupola furnace and we can feed it to the rotary furnace, and inside the rotary furnace it can be super heated and the required temperature can be obtained. And it can be used for alloying of certain elements like Molybdenum, Nickel, Chromium. If we want to alloys are these elements using cupola furnace, these will be oxidized; within no time they will be oxidized and we will be losing them. So, instead, we tap the molten metal from the cupola and we feed it inside the rotary furnace. And here we add the required alloying elements Molybdenum or Nickel or So on and here they are not lost; here alloying can be successfully done. And the application is used to melt and super heat cast iron and non-ferrous alloys. This is used for melting and also for super heating.

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Next, let us see the reverberatory furnace.

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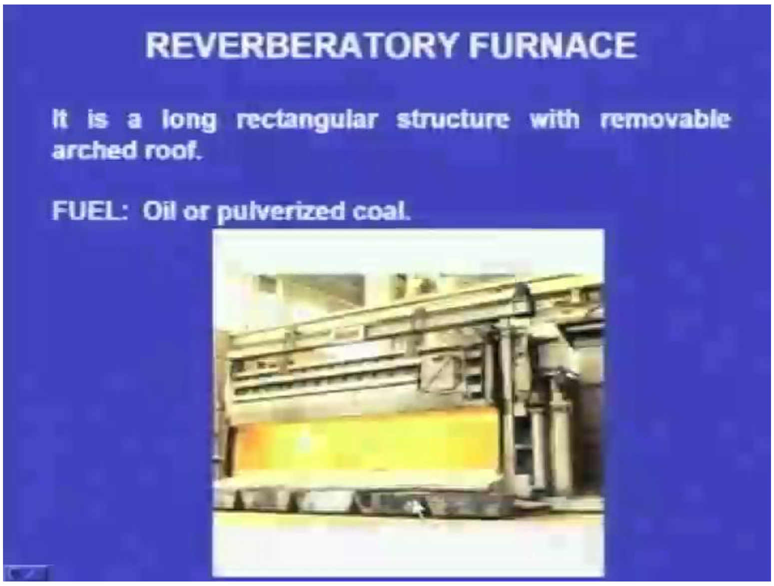

So, this is the typical appearance of a reverberatory furnace. It is a long rectangular structure with removable arched roof and the fuel used is oil or pulverized coal.

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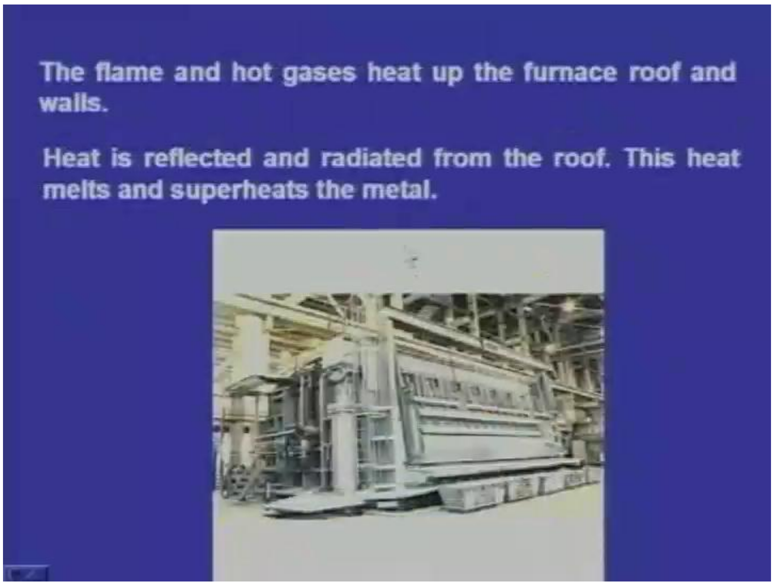

The flame and hot gases heat up the furnace roof and walls. The heat reflected and radiated from the roof will be melting and super heating the metal. Here, one thing we can notice. We use the fuel, the fuel is burning and the heat is generated, and the flame and the hot gases, they are not directly heating the charge. First they will heat the furnace roof; they will heat furnace walls; the heat is reflected and radiated from the furnace roof and the walls; the reflected heat and the radiated heat is coming down and it is striking the metallic charge; then that heat melts the charge. So, this is the specialty of the reverberatory furnace.

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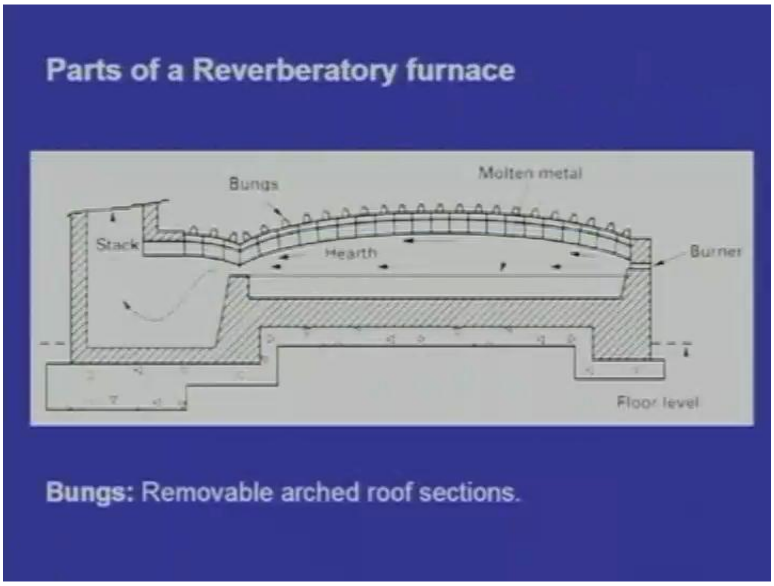

So, these are the parts of a reverberatory furnace and here we can see the hearth and here we can see the burner. And here we can see this is the place where we place the charge and these are bungs; bungs means removable arched roof sections.

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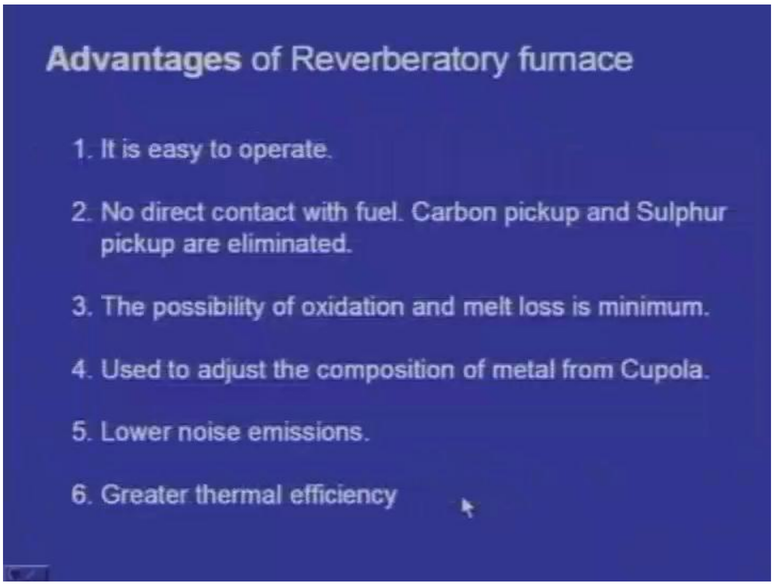

Advantages of the reverberatory furnace: It is easy to operate. No direct contact with the fuel. We have seen, we are not heating the metallic charge directly with the fuel. The hot gases are heating the furnace roof and the walls, and the heat reflected and radiated from the roof and the walls are coming and heating the charge. So, there is no direct contact between the fuel and the charge. So, Carbon pick up and the Sulfur pick up which are arising in the case of the cupola furnace are eliminated when we are melting the charge in a reverberatory furnace. The possibility of oxidation and melt loss is minimum.

Next one, it is used to adjust the composition of the metal from the cupola. Again, one of the drawbacks of the cupola furnace is we cannot control the composition accurately. If we aim some composition and if we run the cupola furnace accordingly, we will get some other composition.

Instead, after melting is over we tap the molten metal from the cupola and we feed it to the reverberatory furnace. And here, whatever alloying elements are required we add the required alloying elements. In the case of the cupola furnace, if we add some alloying elements, they will be oxidized and they are lost. Here they are not oxidized; here they are not lost; here the alloying can be done successfully. And here, lower noise emissions; noise is less and it offers greater thermal efficiency. So, these are the advantages of reverberatory furnace.

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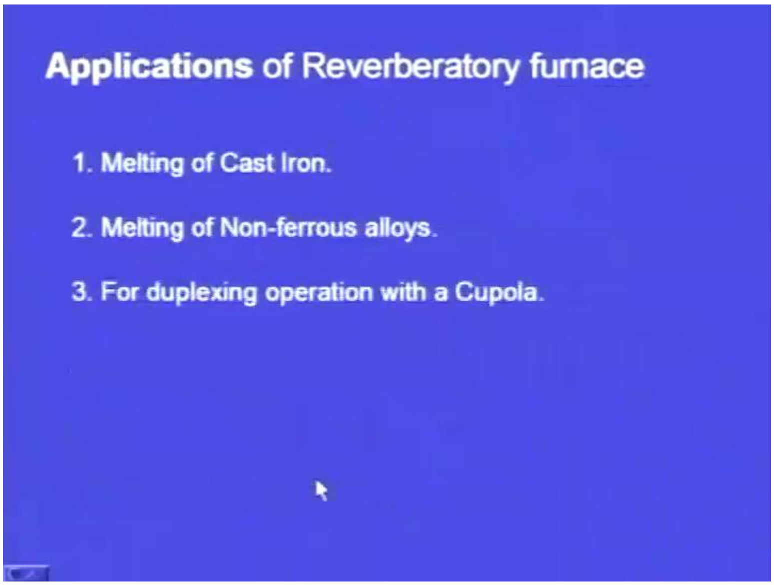

Applications of reverberatory furnace: Melting of cast iron. For melting we use reverberatory furnace; not only for melting, even for super heating. Super heating is not possible the case of the cupola furnace because oxidation takes place. So, we tap the molten metal from the cupola and we feed it to the reverberatory furnace. Here we can increase the temperature. Especially we are we when we are casting thin sections, higher temperature is required, higher pouring temperature is required and that is difficult to obtain with cupola furnace and that such a higher temperature can be obtained using reverberatory furnace. So, we tap the molten metal from the cupola furnace and we feed it in the reverberatory furnace. So, this is super heating. So, this can be used for melting and also for super heating. Next one, this can be used for melting non-ferrous alloys also.

For duplexing operation, that I have already told; we tap the molten metal from the cupola and we feed it in the reverberatory and we increase the temperature. For increasing the temperature, we use this reverberatory furnace or for alloying, for adding certain alloying elements, we tap the molten metal from the cupola and we feed it in the reverberatory. So, this is the duplexing operation. Duplexing operation can be done along with the cupola.

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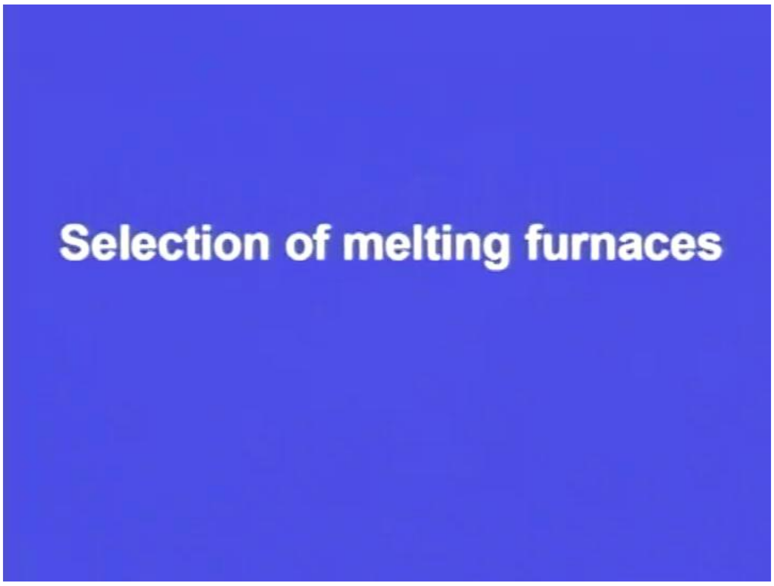

Next one is the selection of the melting furnaces. We have learned some important furnaces; their advantages we have seen; their applications the demerits we have seen. And what is the criteria for selecting the melting furnaces?

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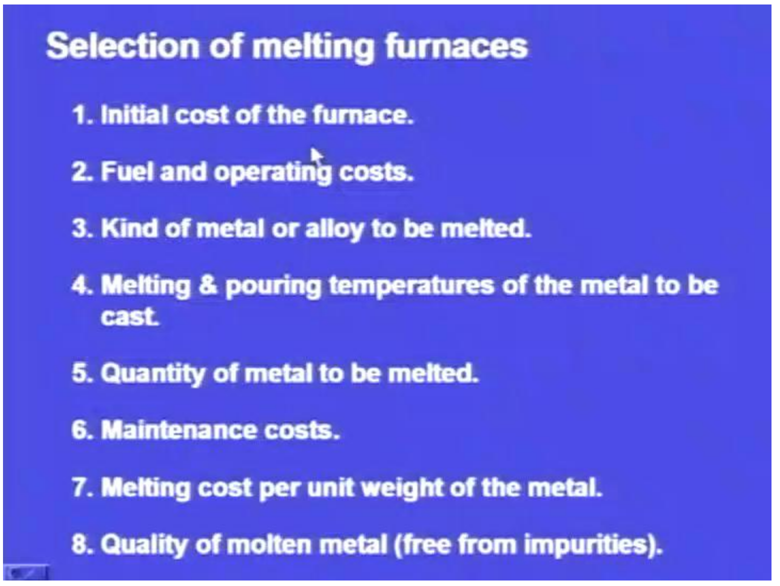

First one is the initial cost of the furnace. What is the initial cost? The cost of different furnace is different. The budget, keeping the budget in view we have to decide. Crucible furnace may be the cheapest. On the other hand, induction furnace is very costly; arc furnace is very costly. So, keeping the cost of the furnace in mind, we have to choose. And second one, what is the fuel available? Depending up on the fuel available, we have to decide the furnace. And what is the operating cost? This is another factor while choosing the furnace.

And what is the kind of metal or alloy to be melted? If it is cast iron, we have to go for cupola or reverberatory furnace. If it is some aluminum, we can even go for induction furnace or arc furnace sorry resistance furnace. Melting and pouring temperatures of the metal to be cast. What is the pouring temperature required? So, this is another factor to be considered. And quantity of the metal to be melted; cupola can produce large quantities of molten metal. Same is the case with the arc furnace, whereas resistance furnace can produce small quantity; induction furnace can produce small quantity; cupola furnace sorry crucible furnace can produce small quantity. So, depending upon the quantity of the molten metal required, we have to choose the furnace.

What are the maintenance cost? Depending upon the maintenance cost, we have to decide which furnace we have to buy. Next one, what is the melting cost per unit weight of the metal? So, this is another important factor. Next one, quality of the molten metal; this is very important.

In the case of cupola furnace, the quality is not so high. The ash is mixed. We use coke; coke and charge. They are mixed together. So, there are impurities in the molten metal. On the other hand, when we get the molten metal from an induction furnace, it is pure. The impurities are very less. So, the quality of the molten metal, what is the degree of quality required, depending on that we can choose the furnace.

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So, next let us see the overall comparison of the melting furnaces that we have studied.

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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

So, these are the different furnaces that we have studied. We have studied crucible furnace, cupola furnace, electric arc furnace, induction furnace, resistance furnace, rotary furnace and reverberatory furnace. So, these are modes of melting. How the charge is melt. So, this is the mode of melting and here I have shown the applications of these furnaces. So, in the case of crucible furnace, the mode of melting is by burning solid fuel or oil or gas. The application is most of alloys except steel. Coming to the cupola furnace, the mode of melting is by burning coke. Nowadays, even oil is used to operate a cupola furnace and its application is cast iron, for melting cast iron and steel.

And we have learned electric arc furnace and there are two types: One is single phase arc furnace. Here, arc is used to melt the metallic charge and this is used for melting non-ferrous alloys. And the other type of the arc furnace is the three phase arc furnace. Here also, arc is used to melt the charge and this is used to melt steels.

We have learned induction furnace. Again there are two types in it. Low frequency induction furnace and the mode of melting is because of the electromagnetic induction, secondary currents are generated inside the charge, and the charge offers resistance to the current, secondary current and heat is generated. And because of the heat thus generated, the charge melts. So, that is the principle. And this low frequency induction furnace is used to melt non-ferrous alloys. On the other hand, the high frequency induction furnace is used to melt steel and alloy steel. We have learned the resistance furnace and what is the principle? The mode of melting is the resistance is heated up when we pass the current and because of that heat, the charge is melting and it is used to melt steel and non-ferrous alloys.

We have also learned the principle of rotary furnace and the mode of melting is by burning pulverized solid, fuel, gas or oil and its application is it is used to melt non-ferrous alloys and cast iron. This is also use for super heating liquid metal which is tapped from the cupola furnace.

Next one, we have seen the reverberatory furnace and the mode of melting is by burning solid fuel, gas or oil and its application is for melting non-ferrous alloys and cast iron. We use this furnace for melting cast iron; not only for melting cast iron, also for super heating. We tap the molten metal from the cupola and we feed it in the reverberatory furnace and we super heat it and we get the required temperature; not only for super heating, for accurate control of the composition. Sometimes in cupola, the accurate composition control is not possible. We tap the molten metal from the cupola and feed it in the reverberatory furnace. Here, we can control the composition; we can add the alloying elements; that is how we can control the composition accurately. So, this has got multi purposes, this reverberatory function furnace and rotary furnace.

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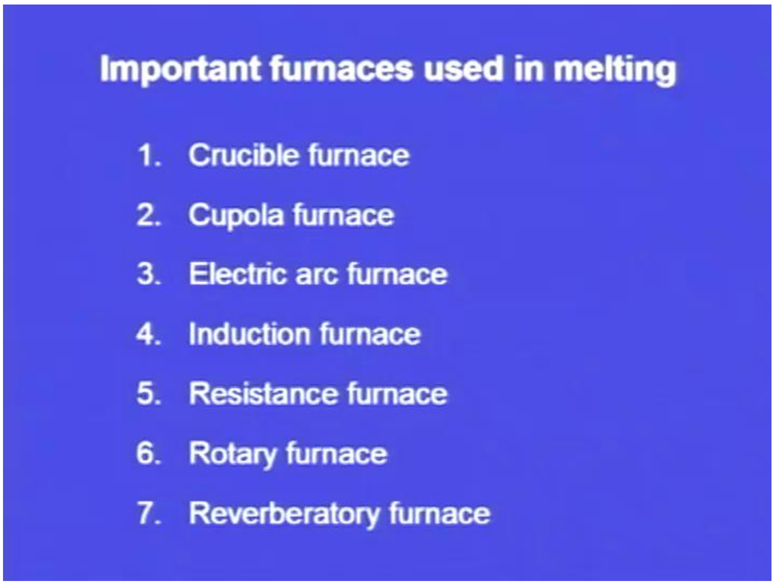

So, in this episode, we have seen the operating principles of crucible furnace, cupola furnace, electric arc furnace, induction furnace, resistance furnace, rotary furnace and reverberatory furnaces. We have seen their applications and demerits, and we have also seen the construction details of all these furnaces. And in the next episode, we will see the gating system and solidification.

Thank you.