Theory of Production Processes

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Lecture – 16
Theory of melting: Types of Furnaces

Welcome to the lecture on theory of melting. So, in this lecture we will discuss about types of furnaces which are required for melting purposes in casting industries. So, what we need to understand that, the furnaces are very important the kind of furnaces they there are different types of furnaces, and also the furnace normally is a cell and there you have on the inner side you have the lining and the from the outer side you will have certainly to give a to give it a rigid shape you will have the metallic shell, and the lining also is important because that lining depends or it basically is dictated by what kind of material you are melting specially when you have slags of acetic or basic nature in that case you have to have appropriate type of lining.

So, now the furnace is the one where the molten metal is actually melted, and you will have certainly to have some heat source that is to be used for melting the metal or the charge. So, that is why now in certain cases in some foundries, when we you are basically melting the non ferrous material. So, you do not require that much of high temperature whereas, when you have to melt the ferrous materials like iron or a steel specially in steel in that case you need the furnace where the heat requirement is I mean which can give you large temperature.

So, when typically you are going to make these non ferrous materials like aluminium or magnesium or zinc or so, which has the lower melting temperatures you can go for the furnaces which gives you lower temperature may be like you can go for muffle furnaces, you can go for you know crucible furnaces or. So, whereas, when you require the melt steel in that case you required to have furnace which should give you very very high temperature also if you are trying to melt the material in a large quantity in that case you require the furnaces where the heat rate heating rate is quite high. So, in that case you go for the furnaces like electric arc furnace induction furnace or so.

So, basically depending upon the nature of material you choose the furnace, another furnace which has been very popular for iron melting has been the cupola. So, cupola is

used because you know in cupola we use the coke, and coke is a source of carbon. So, when we are basically melting iron that normally the variety of cast iron, in that case the carbon certainly carbon content is more than 4 or carbon value is more than 4 in that case. So, carbon percentage may vary from 3 to even 4 or so.

So, in those cases the coke acts as the rich source of providing the carbon. So, cupola is one of the you know very important furnace which is used in the casting industries, but because of the environmental concerns some furnaces are you know getting less or less importance with time like cupolas are not very much favoured in certain areas where the environmental concerns are there because it emits lot of gases greenhouse gases, which are basically doing harm to the environment or certainly to certain monuments like Taj Mahal or so, so that is why in those regions these cupolas are banned.

So, you have different kinds of furnaces, but as per as the furnaces are concerned its primary objective is, that here you are basically melting the metal and this molten metal is used for further pouring into the cavity. Now what we see is that you have the factors in a reason to production requirement and casting specifications, the all those factors which are important for the, what is the choice of furnaces first is metal chemistry.

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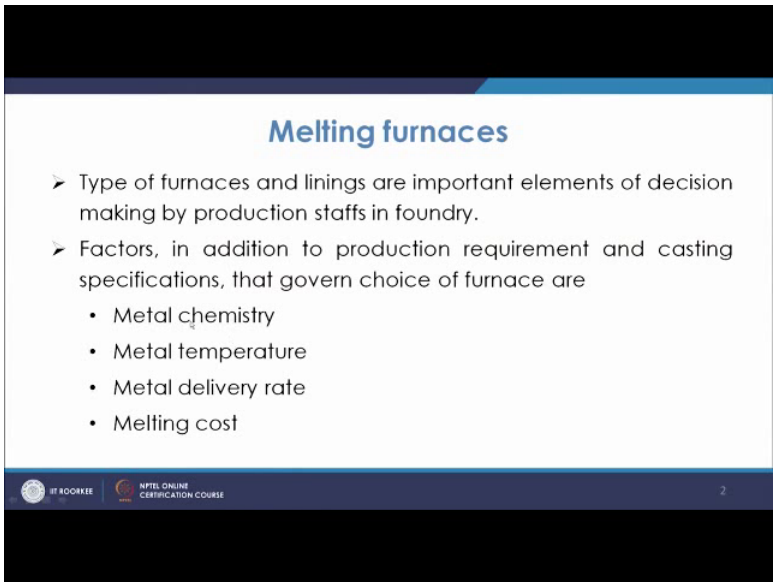

So, this metal chemistry like you have what kind of composition is there for the metal, you have whether the metal has a chilling tendency. So, that that way also it will be you

know decided then shape and composition of the available raw materials what kind of raw materials you have available.

So, based on that also you will have to have the choice of furnace. So, if the available raw material is bulky if the large pieces then certainly you will have to have the furnaces, which can melt them. So, you are required the furnace of larger heat input rate. So, that way depending upon even the you know raw material also you have to decide, what kind of furnace you have to select then comes the metal temperature. What temperature you required to achieve.

So, if you are required to achieve higher temperature very very high temperature, you will have to go for induction furnaces or electric arc furnaces whereas, if you go for lower furnaces lower temperature furnaces, and if the requirement is to achieve suppose close to 500, 600 or 700 or even 1000, in those cases you can go for other kinds of furnaces which do not require very large amount of investment. So, these electric arc furnaces or induction furnaces require large amount of investment, but the other furnaces require less amount of investment.

So, basically it is all because of the, you know temperature which you can achieve in those furnaces. Now again the next point is metal delivery date. So, what will be the metal delivery you are going to get in certain times? So, again that depends upon what kind of furnace you are you know going to choose. So, if you have the small furnace it will give you small amount of material if you are taking large furnaces, it will give you large amount of material in you know one lot, then for that you require to invest more you required to have a large furnace with more and more power input. So, that it can do the melting and it may can give you the material melted. Then the last point is melting cost. So, that is also important because depends upon that what kind of industry you have, if it is a small foundry it so, we will not try to go for very costly furnaces.

So, but then the melting cost if you look at may be if you see the melting cost that like we can say the induction furnaces or you can say the electric arc furnaces in the induction furnace, in a very quick time you are able to melt it. Although its investment cost is quite high, but then the if you look at the melting cost the characteristic cost which you is the input cost its very less not very high.

But then depending upon the type of fuel also in that case you have the type of fuel which is environment friendly whereas, if you go for using the coke or other kind of fuel sometimes that is not environment friendly. So, that also is one of the important factor. So, for that you will have to have an you know adjustment or in or a compromise between the investment cost and the you know cost, basically which is required for operating.

So, many a times you have investment cost is less and operating cost is more whereas, in some cases investment cost is more, but operating cost is less. So, you will have to have a compromise between the two and then you can select the appropriate type of furnace. The normal furnace which are normally used are the following type. So, the different type of furnaces which are used in foundries are like crucible furnace, open hearth furnace, reverberatory furnace, rotary furnace, cupola furnace, electric arc furnace, and induction furnace. So, these are the normally used furnaces which are used for melting the material and low to medium to even large foundries go for using the different kinds of furnaces.

So, we will go one by one to see that how some of the important furnaces, what are the typical characteristics of these furnaces what is the working principle of these furnaces.

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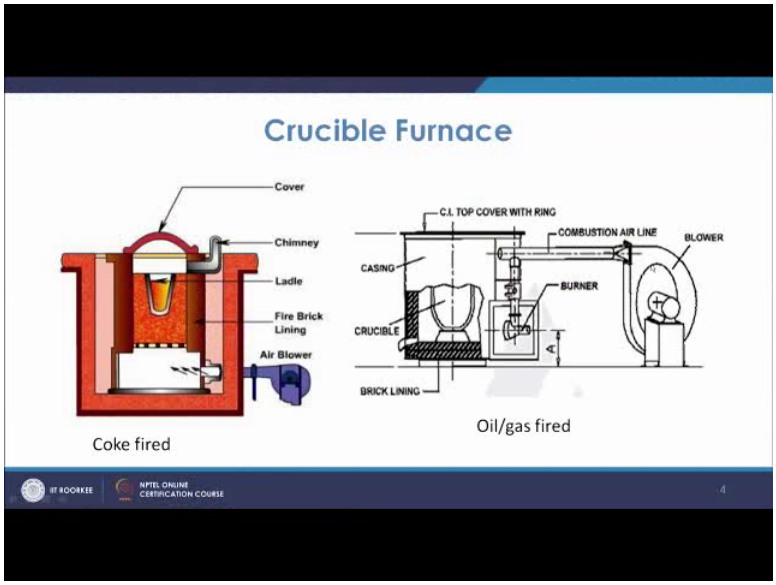

So, coming to crucible furnace as you see this is a crucible furnace. So, in this basically you have a crucible, which is normally made of clay or graphite and then this crucible

will be kept and there will be heating source, and through this heating source this crucible is heated and the molten metal which is kept in the crucible normally that is melted. So, normally it is used for very you know smaller quantity of material can be normally is a held, but you can have the larger crucible, you have the crucible numbers, sometimes you have different numbers and that is basically specifies by amount of copper which can be melted into that particular number of crucible.

So, k gs of copper which can be melted like that so, if this is a large crucible certainly you need a large (Refer Time: 11:06) and that it has to be put in you will have the refractory, which is rammed from the other sides and then you will have the heat source, and then using that heat source you can heat the liquid metal which will be melted. So, as you se you will have a ladle you have the fire brick lining and then this is a chimney this is the covers, you can take the cover out and this is a air blower. So, that will be blown and then this way the heating will be done, and due to the heat the metal is melted here.

So, it is normally convenient for a smaller foundries. So, that you know for handling these smaller quantities you have to take this crucible out. So, for a smaller foundries when you have to melt in small quantities, this crucible furnace are basically important. Now there may be basically coke fired or the oil or gas fired. So, basically when you have to use these normally for nonferrous melting, nonferrous metal these coke fired furnaces are used, and because you have the low installation cost in that low fuel cost and ease in operation. So, because of these reasons these coke fired furnaces are used for nonferrous metal. Now you have also the oil and gas fired furnace. So, as the name indicts you have oil or gas, which are used as the heating source in such furnaces. So, basically they are cylindrical in shape and then the flame is produced by heating of this atomised fuel.

So, they will combine with air and then they will be heated, and then they will be sweeping around the crucible. So, that way it will have the enveloped in enveloped in the crucible and then uniformly heat the crucible. So, this way you have the combustion products will be coming into the contact with the charge, then they will be heating it and then they that way you can melt them by tilting you can take the you know metal out and pour it into the mould.

So, you have certain advantages of this oil or gas fired furnace like you do not have any wastage of fuel. So, that is one of the. So, here if this is the oil or gas fired furnace you do not have much of the wastage of the fuel. So, you have more thermal efficiency in the case of oil or you know gas fired furnace, you have better temperature control by controlling the flow of this gases by controlling through a knob, you can have accurate control of the temperature, air contamination will be less in the case of this oil or gas fired furnaces. So, it will also save the floor space and you have also the low labour cost because here you need one person just simply to regulate these burners or so.

So, this way you have these crucible furnaces and they are the different types normally you will have this used by the smaller foundries, where you have low quantity of metal is to be melted then comes the open hearth furnace.

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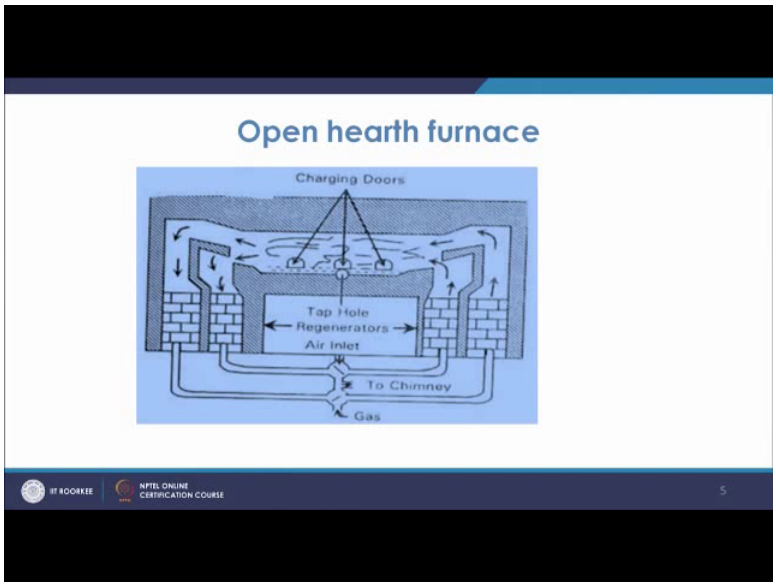

So, normally you use it for melting steel or producing steel from big iron. So, directly for casting so, that way this open hearth furnace is used. Now this furnace is used it has certain characteristic. So, basically the regenerative principle of heating is used. So, the combustion products which are basically coming out, they are further used so, for pre heating the gases fuel and air. So, the outgoing products of combustion will be used for pre heating these you know the fuel and the air.

So, this way the energy is basically utilised. So, and since it is pre heated. So, the thermal efficiency becomes more, it gives you know quickly it gets you know combusted and

that basically gives quite rise to the temperature which is attained. So, this is basically you have a shallow type of furnace the hearth is shallow, you have large length and width, but the depth is quite you know small. So, as you see these combustion products will go and from here you will these are the you know metal which are to be melted. So, because of this heat being in contact, they will be melting it. So, gaseous fuel which are used normally are like producer gas natural gas or coke oven gas these are the gases which are used for these open hearth furnaces.

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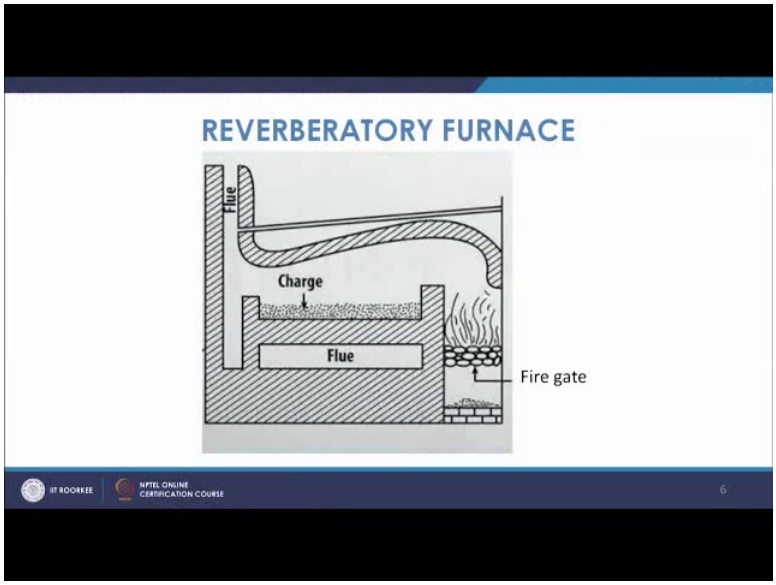

Next will be the reverberatory type of furnace, where you see you have again here is this furnace you have the fire gate is there and then the you will have charging and then this hood is there. So, refercatory hood will be there then these combustion products will go and then from there this this charge here you will have the metallic charge, which will be heated and you can use these heat for charge these for melting the material. So, this is kind of reverberatory furnace.

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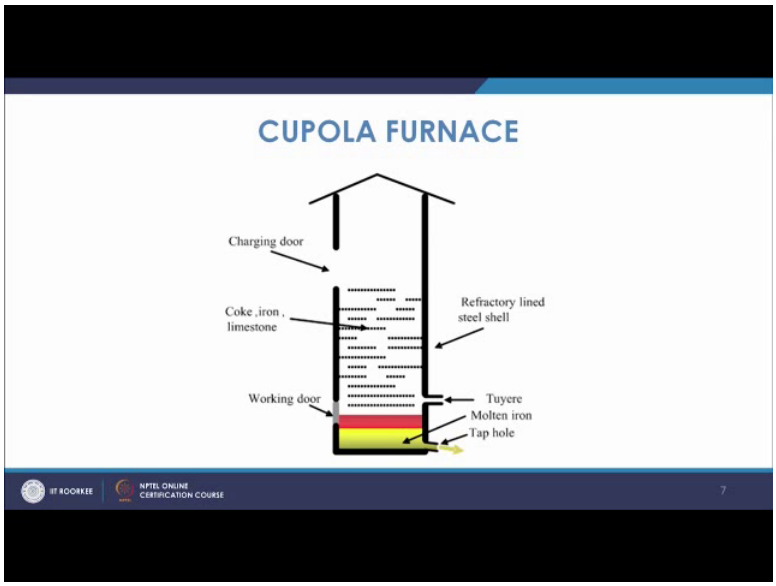

Now, further you have rotary furnaces also on the similar principle where you can have the other facilities. So, these are the furnaces not much used now a days, because of the incoming of new furnaces you know which are more popular, and based on other principles that we will see. One of the another important furnace, which I used for normally for iron melting that is gray cast iron or white cast iron or s g iron is basically the cupola furnace. So, as you see in this cupola furnace, here you have the; this is a refractory line is steel cell. So, this is the steel cell and it has it is a factory line from inside, and you have the charging door and what we do here is, you have the alternate layer of coke iron and lime stone. So, you have charged coke and lime stone. So, coke will be like a fuel, lime stone will be like a flux and you will have the charge that is metal scrap everything is there.

So, alternately that is they are kept one over other and you have the coke bed here coke bed is prepared in this region, and from here you want the through the Tuyere. Basically this Tuyere is the opening through which we supply basically air from here. So, you will have the Tuyeres. So, you will have the cylindrical cell and at different locations symmetrically placed normally, you will have the openings. So, that is known as the Tuyere. So, through that the air enters and then this air goes up and then this combustion takes place. So, you initially you have a coke bed, and this coke bed basically ignites initially you ignite. So, that is known as firing of the cupola, then basically what is once the firing is started then you provide this this is the charging of the cupola. So, you

charge this coke iron and lime stone in alternate layers and then after some time what happens this lime stone and coke there in between there is charge. So, it starts melting, and it trickles through that layer and ultimately it results through this coke bed.

So, through this coke bed it will come, and it will get deposited here. So, then you have a tap ole and in in the opposite side you have a slag hole. So, tap hole is at the lower end and that is slag hole will be at the upper end so that the slag which is deposited in the bottom at the top surface. They will go from another hole and the from the tap hole you can tap the liquid metal, you can get it get that and go for melting. So, basically this cupola furnace is very very popular for iron melting cases because here the coke which is used is a cheaper fuel and coke is source of you know carbon. So, the carbon pickup is quite high in this case, and normally the it is mostly used for making this iron castings and mostly used by foundries.

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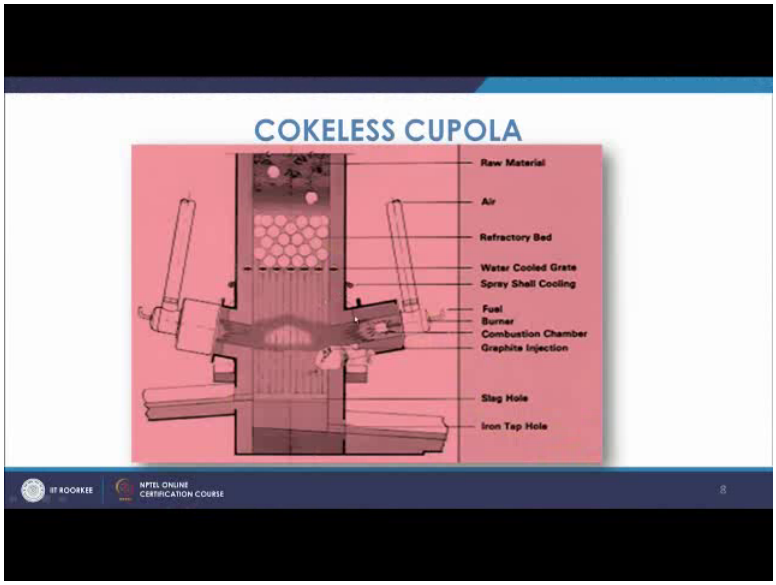

So, as we see further you see here in this case you will have the, this is the again the cupola, now this is the refractory bed. And now this is the case of cokeless cupola now what happened that due to the environmental concerns, because cupola have the use of coke and coke contains sulphur.

So, many a times the there are many gases which are coming out these gases are harmful. So, what happens there was due to the environmental regulations, and also because of the environmental concerns, we try to see that the you know coke should not be used

especially with the higher sulphate content cokes. So in fact, the cokeless cupola was you know suggested in place of the coke cupola where the coke is used, and in that case you have the this refractory particles are used ceramic particles are used, which are used as that bed. So, initial the bed of which was made of coke, now in place of that there is a refractory because and then you have the heating from the bottom may be done by the gases so that that burner you will have and then you have this fuel. So, this burner from here it will heat the burner the heat will come, and this heat will go up; and then above you have the charge so this will be basically melted. So, this may after melting of this charge this charge will trickle down slowly through this refractory bed, and then you can basically have the graphite injection to compensate the carbon pickup, because if you have coke then you have the chance of carbon pickup, because that supply is enough amount of carbon, but then if since we are not using the coke bed and we are not using the coke.

So, in this case you must have the alternative way to have this carbon pickup, for that you have the graphite injection is there. So, that way you get and then again you have the tap hole and the slag hole. So, this is the modification to the existing cupola. Apart from that you also many means to basically increase the efficiency of cupola, that is an and the varieties of cupolas are there on that name like hot blast cupola is there use of CA 2 is also done many a times you have oxygen enrichment is done in the cupola so that, its efficiency increases. So, for that these cupolas are used.

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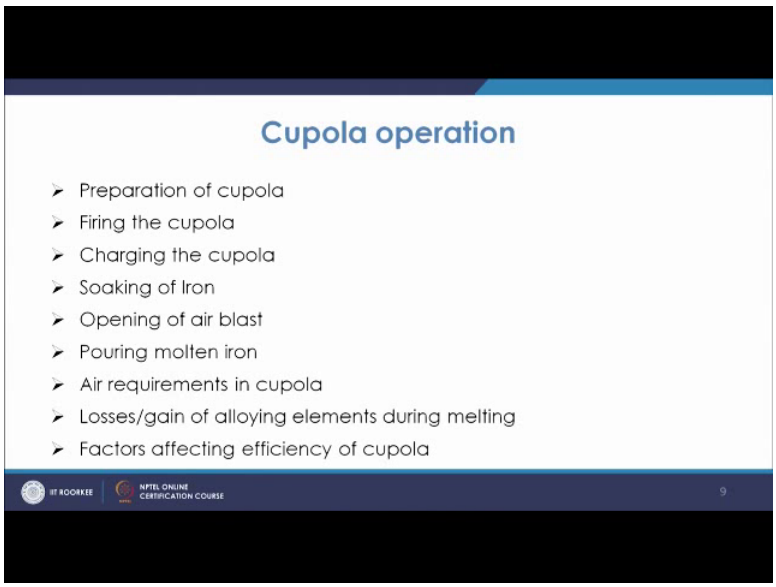

So, if you look at the operations which are performed in cupola. So, initially preparation of cupola means, you prepare the beds you have the tuyeres and in you know completely ready then you fire.

So, you fire you know ignite something at the bottom of the bed of the cupola and then this fire is started, and once fire is started then you start charging the cupola then after the melting starts soaking means the time for which the temperature is attained. So, it is soaked. So, it is reaching at that temperature remain there for some time, opening of air blast that is carried out and then at that time the molting melt starts tricking down and then you pour the molten metal in the you know mould. So, from there it will come through the coke bed it will reach to the bottom and from there you can take the metal out.

Now, there are certain you know conditions or there are certain data, which tells that what is the requirement of air what is the requirement of you know other input materials in the cupola operation. So, for that you that need to be understand understood that what will be the air requirements for these cupola operation. There will also be loss and gain of the alloying elements in cupola. So, that needs to be also understood like during the cupola many a times the alloying elements are like manganese are there or silicon is there, or even the carbon is there, whether it is there is a pickup or there is a loss. So, this is to be important wherever there is a pickup then you have to see that it is not go more if it is undesirable. And if it is loss you will have to compensate it by again addition of these ferrol oils or so. So that also is the concern like silicon is there n manganese is there they are likely to be lost sulphur may be pickup because of the presence of coke so, that basically is to be is one of the factor.

Factors affecting efficiency of cupola. So, there are many factors which affect the efficiency like coke rate blast rate you know temperature of the air which we use. So, there are the factors which affect the efficiency of the cupola. So, these are the I mean points which are required to be understood, when you studying the cupola operation.

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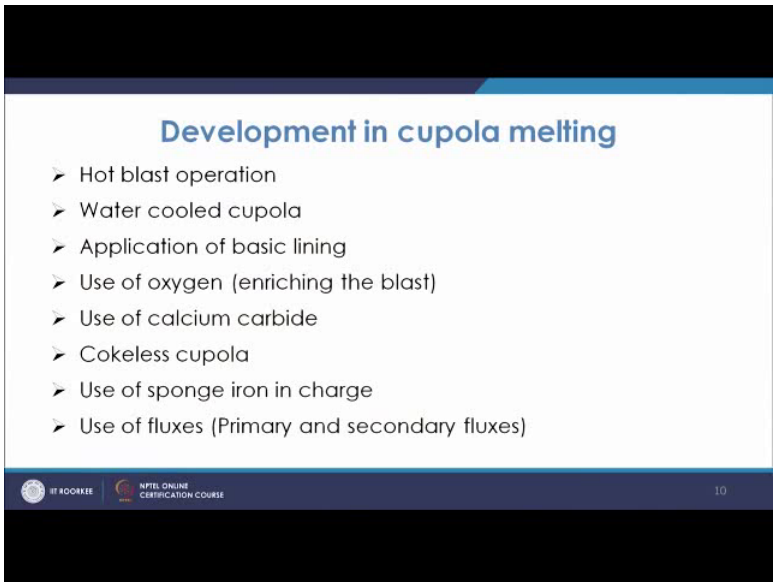

There has been developments in cupola melting as we discussed, you have the hot blast operation where the blast temperature is increased, you have water cooled cupola in which the in the in place of this refractory to decrease the consumption of the refractory you provide there the refract I mean water jacket so, that this lining life becomes more.

But that will certainly decrease the temperature so, that aspect is to be understood, then you have application of basic lining many a times you will have to keep that in mind that in many cases because of the sulphur presence, that is not you know advantageous for certain kind of melting like when you are basically melting the ductile iron castings or s g iron castings, in those cases the presence of sulphur of very deleterious.

So, you will have to adequately, you will have to properly see that what kind of lining you require. So, in case of acidic lining that sulphur you are not benefited. So, in that there is less freedom for you to control that. So, you use the basic lining in that case use of oxygen. So, if you enrich the blast with the oxygen that also increases the temperature.

Use of calcium carbide basically it also affects in that way, that this presence of sulphur it controls that way that that is controlled. Cokeless cupola we have already seen that we have the use of ceramic beds sorry ceramic refractory particles instead of the coke bed and then use of sponge iron and fluxes, these are also the ones which are used in cupola melting. Then the next type of furnace is the electric arc furnace. So, as it the name indicates this electric arc furnaces are based on the arc which are developed, and you

have many times these sometimes the arc is in direct contact with the metal which is to be melted, and sometimes indirect electric arc furnace also that arc that is created and this arc is created between the electrodes, and because of the temperature and because of the radiation which is there because of this arc which is in contact with the metal then metal is melted. So, you will have direct or indirect electric arc furnaces.

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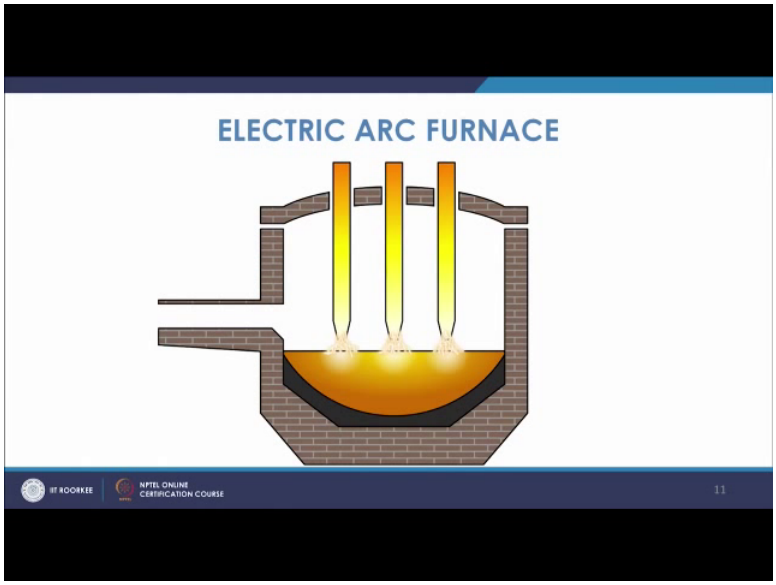

These are normally the furnaces which are used for steel melting or where the temperature of the molten metal is quite high.

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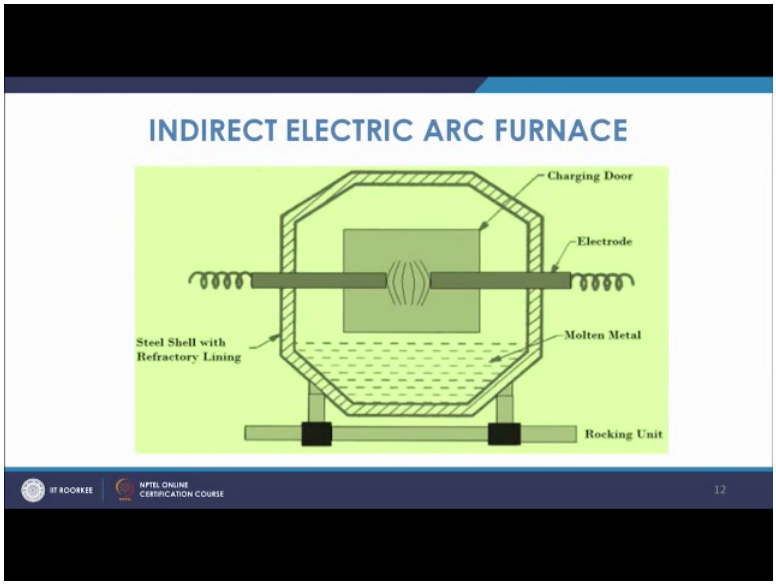

So, as you see you have the direct electric arc furnace and in this case, you have indirect electric arc furnace, where you see that these are electrodes these electrodes are basically you know here the flame is produced because of the spark which is which is created, you have the this the spark basically gives the temperature high generates high temperature, and that is able to melt this molten metal in this zone. So, this way you have either direct arc furnace or you have indirect electric arc furnaces.

Now, charging which is done normally in this arc furnaces electric arc faces, they are normally the steel scrap which is 40 percent of heavy scrap is there in these cases, and then you have 40 percent will be medium scrap 20 percent will be light scarp that way that priority should be there in these cases. And you will have basically melt in the melting practice what is there you will have either the acidic slag process or you have the basic slag processes. So, depending upon the lining you know either you have acidic slag or basic slag. So, if you have the acidic slag means you have silica that is saturated silica saturated iron manganese silicate. So, that is basically used in case of acidic slag and in the basic slag operation basically the attention will be paid on sulphur and pohsosporous contents.

So, that basically is there in the basic slag operation. So, you have use of ore and lime in case of basic slag operations. So, in the case of basic slag you will have slag that is CAO SiC2 FeO mno these are the constituents in the case of that basic slag further.

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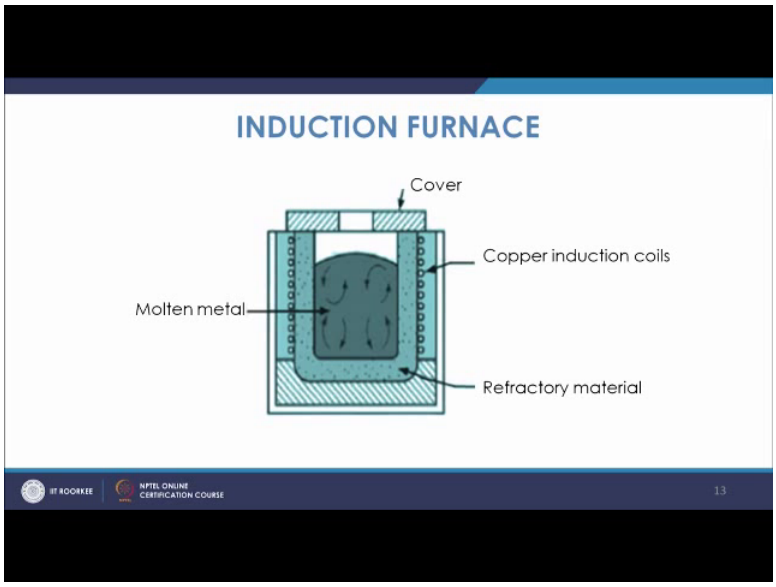

You have the more ah important furnace which is normally used which has very high productivity is the induction furnace. So, because of the induction effect of the current these furnace work. So, they are quite in operation electric arc furnace is create a lot of noise whereas, the induction furnace basically it is very quiet in operation because of induction effect, the charge basically melts very quickly and then here another advantage is that it has the churning effect. So, some many a times the mixing type of effect is also observed in such furnaces like induction furnaces. So, this is the induction furnace induction furnace is of two types normally, you have core type of induction furnace and core less type of induction furnace.

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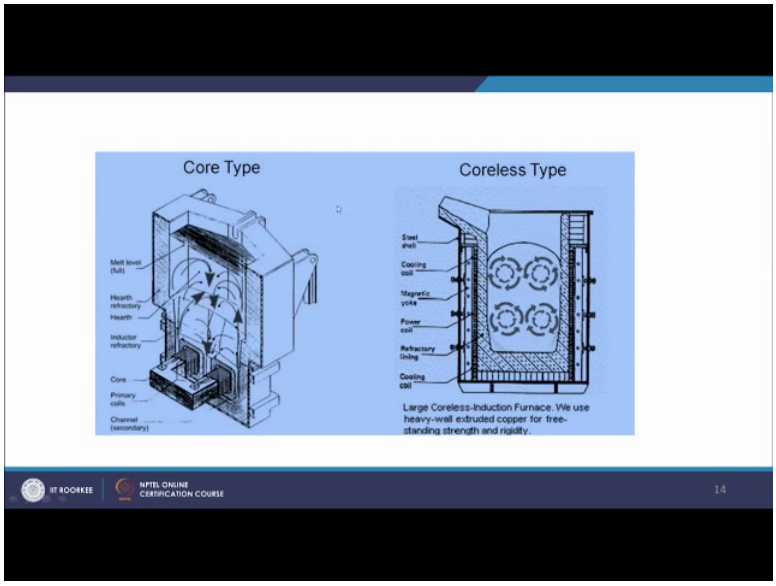

As you see you have core type and you have core less type of you know induction furnace, further you have the high frequency and also the medium frequency kind of you know this furnaces. So, the medium frequency furnaces are used for melting the cast iron whereas, the high frequency type is used for other applications like this.

So, in that you have lot advantages like it has high flexibility if there is high rate of melting for these induction furnaces whenever you require very high rate of melting you go for these induction furnaces, certainly you have you require the large investment the cost is quite high, and you know the no refining is possible. So, that is also one of the disadvantage. So, we have seen that you have different kind of furnaces and you must know these furnaces because when you go to the shop floor you must be conversant with

these different kinds of furnaces how they work what are the working principles, and that basically helps in understanding the mechanism of operation further the refining, which is done in many of the furnaces of different types or so.

Thank you very much.