Steel Making

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Module No. # 01
Lecture No. # 14

Modern Steelmaking I, Oxygen Steelmaking

Today, we will be discussing lance profile. Lance profile means change in lance distance as a function of time. So, what I have done in the plot, I have plotted say lance distance against blow time.

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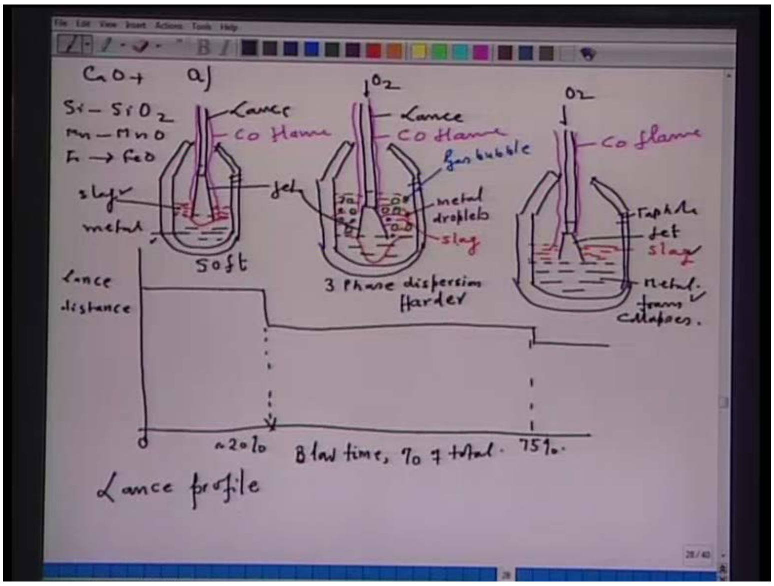

Now, this plot is simply schematic because different converters have different lance profile. What I wanted to illustrate is a general lance profile which is valid in all converters irrespective of the capacity.

So, this particular profile shows that in the beginning say, for example, if we have 0 percent blowing time. In the beginning lance distance is kept high and as the blow proceeds, after around 20 to 30 percent of the blow, lance distance is decreased and then for a considerable period of time say upto 75 percent of the blow, the lance is more or less kept constant and blows at a constant lance distance.

After 75 percent to rest of the time, the blow continues either at a reduced lance distance or at the same lance distance; that depends on practice to practice. Now, before I go further in detail, what I have done? I have superimposed on this lance profile, the physical and chemical interaction between oxygen jet and molten bath.

So, if you see in the figure a, as lance distance is higher, what happens? Oxygen jet hits the bath and the red that you are seeing is the depth of penetration. As the oxygen jet hits from a relatively higher distance, the depth of penetration is shallow and as a result of which silicon gets oxidized to SiO_2, manganese to MnO and iron to FeO. Now, as I said in some of the practice, calcium oxide is also added in order to form a slag for removal of phosphorous.

The initial period of blow consists of oxidation of impurities, as well as iron and beginning of slag formation, which starts with the dissolution of calcium oxide because unless calcium oxide dissolves and a basic lime slag forms, there is no chance for removal of phosphorous in the later periods of the blow.

So, that is what the ‘a’ figure which is superimposed on a higher lance distance side shows, that the physicochemical interaction between jet and the bath are little bit of oxidizing in nature; that means, the depth of penetration is low, the droplets of metal they are little bit in some amount they are generated and the slag is formed as I have shown in the red line; that is, here the slag will be formed which is a metal and also as I blow oxygen, some amount of carbon also begins to oxidize to carbon monoxide, but then it is a very low rate.

So, in the beginning as the blow proceeds, at the mouth of the converter first of all brown fumes will appear. Soon after the brown fumes, red fumes begin to appear and that indicates that silicon oxidation is over. Now, red fumes means iron is getting to oxidize to Fe_2O_3 and the slag will be highly oxidizing in nature.

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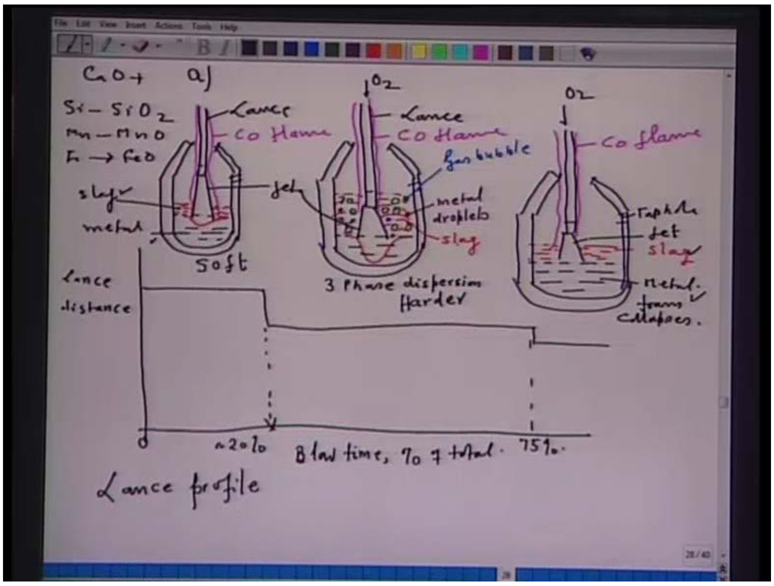

Now, it is the time to decrease the lance distance; that is a very important indication to the operator. The change over from brown fumes to red fumes and all of a sudden in between the red fumes, a white colour fume begins to appear and that shows that the carbon oxidization has also begun in the process.

So, that is what this particular purple colour shows the evolution of carbon monoxide is exiting from the mouth of the converter. Now, after around 20 to 25 percent of the blow, the lance distance is reduced. The reason for reduction of the lance distance is, because if we blow at a lance distance, which we have done in the beginning then the depth of penetration will be low; most of the oxygen will be supplied at the bath level or just below the bath level.

So, oxidation of iron will be very high and as such, we have a very highly oxidized metal and that may, towards the latterly period fume and ultimately, slag may come out of the vessel. That is why, immediately after the silicon oxidation period, which is indicated by the appearance of slight reddish and white fumes at the mouth of the converter, the lance is reduced.

Now in this reduced distance of lance, the jet becomes harder. So, in our terminology, this particular situation we started with the soft jet, we have made the jet here, harder.

How we have made it harder? We have just decreased the lance distance, which was originally upto here; now, we are blowing at this particular lance distance.

What happens, if we reduce the lance distance? If we reduce the lance distance, the depth of penetration will be larger. As you see, the depth of penetration which is shown by the red line, it is deep into the bath.

What is the consequence of this? As a consequence of deep penetration of oxygen jet into the bath, more oxygen will be available in the bath and as such, the reaction between carbon and oxygen will begin at a very high rate. So, you see a continuous flame of carbon monoxide is evolving, continuous flame of carbon monoxide will be appearing at the exit and that indicates that the refining reactions are going on perfectly well.

So, that is one of the condition or one of the indication to the operator that the CO flame should continuously appear at the mouth of the converter in between 20 to 75 percent of the blow.

If in between this period, if the flame disappears for some reason, then it is an indication that CO bubble is continuously entrapped into the slag and caution is required that slag should not come out of the vessel. So, the deep penetration helps the removal of carbon, but at the same time what happens? In the earlier period, we have formed already a slag which is limey and basic.

So, already we have a slag over here. The penetration of the jet is deep into the bath, droplets will also be produced and as a result of production of the droplets, the droplets will be entering into the slag and part of the carbon monoxide bubble which are smaller, they will also be entering into the slag and as a result, slag will form and that is what is shown by say purple, they are the metal droplets and the red layer is shown as a slag one and the gas bubbles are shown by a green color.

So what has happened now between 20 to 75 percent of the blow time? Three phase dispersion has been formed. 3 phase dispersion consists of slag, metal droplets and gas bubbles. Now, the metal droplets have a very high interfacial area and a very high reaction rate is possible because the droplets which have immersed from the metal or from the hot metal during the blow, they might have a carbon content of 2 percent or one and half percent; it depends upon at which time they have entered into the slag.

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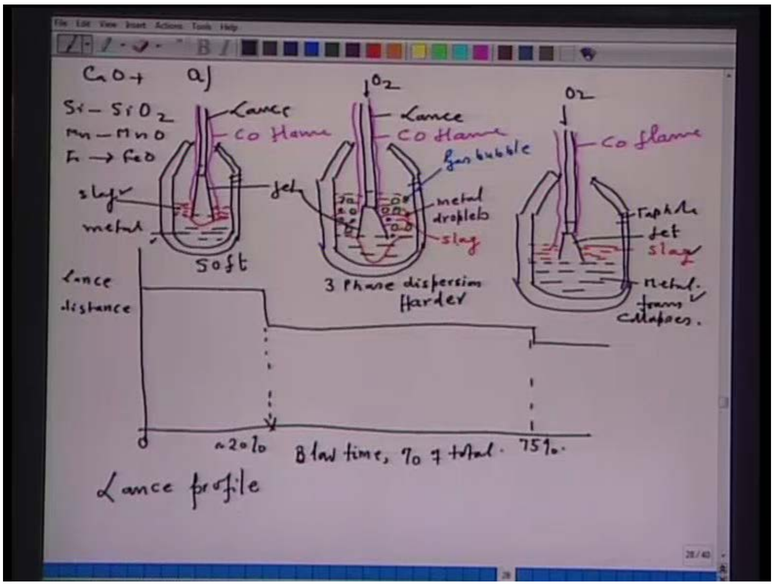

So, a higher amount of carbon in the droplet and these droplets may also have phosphorous. A higher amount of carbon in the droplet, they will also begin to react with oxygen that is FeO of the slag and as a result, CO bubble may also form in the slag and on account of that, slag will form and that forming of the slag has to be controlled.

So, in the main part of the blow, what an operator should do? The operator should do or the operator should control not only slag formation, but we should also control the continuous evolution of carbon monoxide at the mouth of the converter. At the same time, we should also see that the carbon removal rate should not be excessive; it should be excessive only after the removal of phosphorous. Once carbon gets removed, then the temperature of the bath gets high and as you recall, the high temperature does not favour the de-phosphorization.

So, it is again the operator’s judgment. He has to adjust the removal of carbon and removal of phosphorous such that on one hand, the carbon monoxide flame always appear at the exit of the converter, but on the other hand phosphorous also gets removed.

What I wanted to say is that carbon removal is a gas metal reaction; phosphorous removal is a slag metal reaction. In between the main part, he has to control such that both the reaction go simultaneously, but well, at a pace so that phosphorous removal becomes over and then carbon removal is on.

So, that is what is the main part of the blow a slag metal or other slag, metal droplet and gas bubble dispersion is created. Now, this dispersion which we have created is collapsible in nature; that means, once the metal droplets are refined, they become heavier, they fall back into the bath and the slag has become less viscous, then the gas bubbles will also be leaving the slag phase.

So, the slag metal or the dispersion which has been formed, it collapses. In this beyond 75 percent of the blow, it has been ensured that all the phosphorous have been removed. Now, only whatever extra carbon that has to be removed, that will be removed.

So, a lance is slightly reduced beyond 75 percent till the end of the blow, where the blowing is complete. Now, well here, the lance should be reduced or not that again depends on the profile or that depends again on the specification and that again depends on the operator’s choice. Some prefer not to decrease the lance distance; some prefer to decrease the lance distance, but the main objective of decreasing slightly this lance distance is to take care of the carbon which is left in the hot metal.

So, whatever amount of carbon is there, it will also be removed and the dispersion which is formed, it also collapses and later, we have slag and metal form as collapse and now the metal is ready for the tapping.

That is what in short is the lance profile and how they behave, the physicochemical interaction between the jet and the molten bath proceeds, as the blow proceeds. Now, here one thing also to note that from the beginning to the end, there is a continuous removal of carbon. However, in the beginning, the removal weight of carbon is very low because most of the oxygen is being utilized by oxidation of silicon, oxidation of manganese and oxidation of iron.

In the main part of the blow, now since silicon and manganese are totally oxidized, now whatever oxygen that is incoming it will be used for carbon and phosphorous reaction. So, in the main part of the blow mostly carbon reaction and phosphorous reaction are proceeding.

Removal of carbon forms carbon monoxide. The jet is penetrating deep. So, carbon monoxide bubbles, they also begin to form deep in the metal bath. So, bath is continuously stirred in the main part of the blow. Towards the end of the blow that is from 75 percent onwards, carbon content of the bath is decreased. No matter, how hard you blow when there is no carbon or when there is less carbon, the removal rate of carbon has become slow. So, evolution of carbon monoxide bubble will also be low.

As a result, the bath stirring is also poor. If towards the end part, not precaution has been taken then iron will also oxidize. Before this happens, the blow is taken off; analysis is done and metal is tapped from the tap hole. So, that is what the interaction between jet and the molten metal along with the lance profile.

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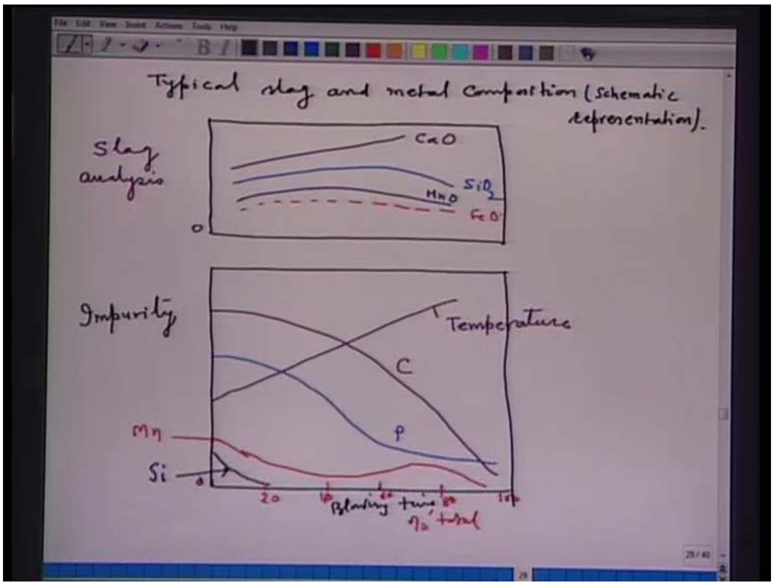

Now, let us see the evolution of typical slag and metal composition. Now, again I have given here, a schematic representation. The whole idea is to let you know how the removal of various elements and how the formation of slag commences. For the detail or for any values, one can consult any standard book the reference I have given at the end of lecture.

Now, coming back to the removal of impurities and formation of slag, if you concentrate for example, the x axis shows the blowing time in percentage of the total, 0 percent, 20, 40, 60, 80, 100 percent; the y axis is a concentration of impurity, concentration of carbon is higher than phosphorous than manganese and then silicon. As you blow oxygen, silicon oxidizes very fast. As you have seen that silicon oxidation is mostly complete less than 20 percent of the blow; about manganese, the next element which to oxidize is the manganese.

Now, you see that manganese concentration also decreases at 40 to 60 percent, but after 60 to 75 or 80 percent of the blow, again slight increase in concentration of manganese occurs. Remember, this point is important and we will discuss once again.

Main thing is to see the carbon and phosphorous reaction. As I have said earlier, both the reactions, they go parallel and they go simultaneously and that is what the requirement of converter steel making process.

Both reactions can take place simultaneously because we have made the slag limey or basic slag much earlier. Now, one slag is there of the right basicity, the right chemical composition, of the right lime and at a right temperature then there is no reason why phosphorous reaction should not occur.

Once you allow carbon to proceed at a faster rate, then the phosphorous will not be able to remove because phosphorous requires lower temperature as compared to carbon. All efforts have been made that the rate of carbon removal is increased only when sufficient amount of phosphorous is removed and that is what you see from here also.

Now, as regards the slag formation, you see as the time proceeds, the calcium oxide continuously increases naturally because calcium oxide what you added as a solid form, it dissolves and as such, the concentration of calcium oxide will increase as the blow increases. SiO 2, MnO because we are not adding any Mn or Si outside; so, whatever it is there, it is there. Now, the FeO concentration, in the middle it increases and then slightly it levels off.

Remember, the FeO concentration in the slag is very important from the point view of de-phosphorization reaction. Now, once de-phosphorization is over then all attempt must be made to recover as far as possible, the iron content of the slag to the metal because whatever iron which has been lost in the slag that is a loss to the (( ))

So, in order to that the FeO content of the slag should be reduced to the extent possible, most of the converter in steel making processes, they work at 14 to 18 percent of FeO in the slag.

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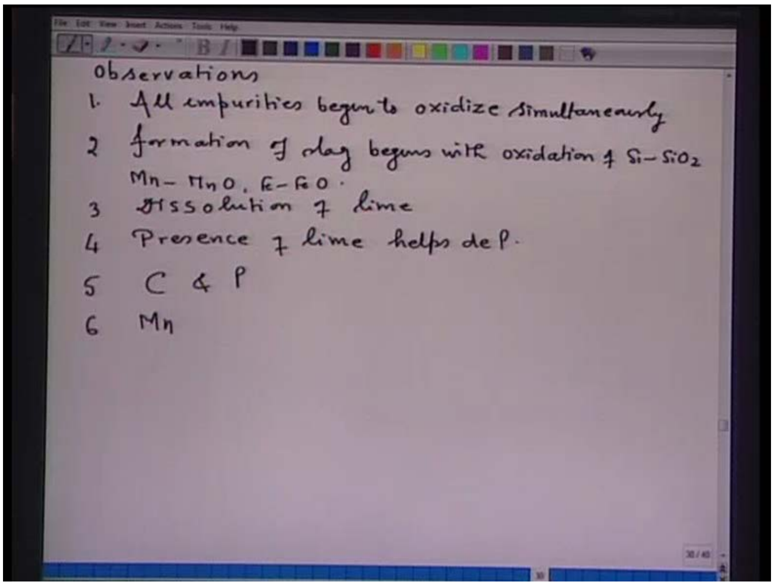

Observations

1. All impurities begun to oxidize simultaneously
2 formation of slag begins with oxidation of Si – SiO_2 Mn – MnO, Fe – FeO.
3 dissolution of lime
4 Presence of lime helps de P.
5 C & P
6 Mn

So, now summarizing these observations, I will write few important points. See my observation number 1: all impurities begin to oxidize simultaneously. Second observation is that formation of slag begins with oxidation of silicon to SiO 2, manganese to MnO, iron to FeO.

Remember, in the initial period of the blow, purposefully iron is oxidized. Presence of FeO, it helps dissolution of lime. So, purposely iron oxidation is kept little higher side on the initial side so that calcium oxide dissolves in the early stage for de-phosphorization.

Third: dissolution of lime, it increases as the blow proceeds. Fourth: presence of lime helps de-phosphorization; Fifth observation: carbon and phosphorous reaction both occur simultaneously, but however the phosphorous removal rate is somewhat faster as compare to carbon because of the reason I have already mentioned.

Sixth: about the manganese content, the manganese content of the bath it decreases initially after a later stage of the blow. So, between 60 to 80 percent of the blow, the manganese content of the bath increases. Why it increases? Because as the blow proceeds, the activity of FeO in the slag decreases because of the carbon boil, temperature also increases, basicity also increases and on account of which, the magnesium content of bath it increases.

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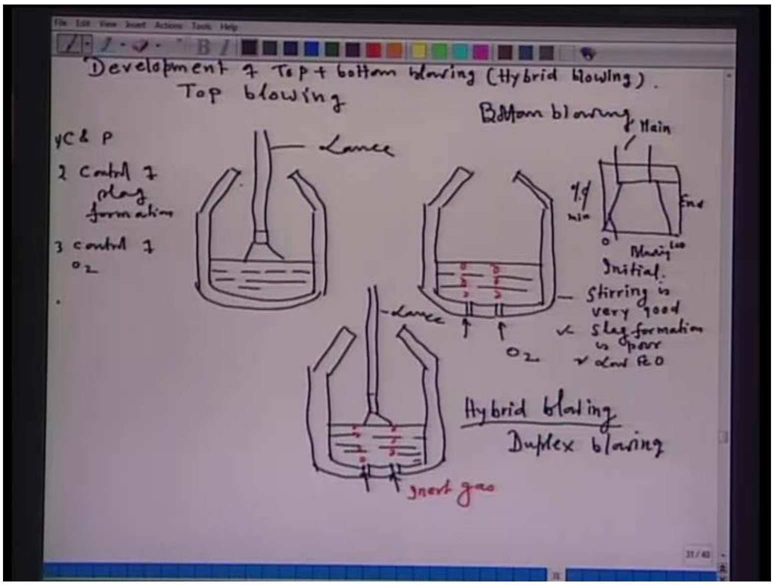

Development of Top + bottom blowing (Hybrid blowing).

1 C & P
2 Control of slag formation
3 control of O2

The development of top plus bottom blowing also called hybrid blowing. Now, the concept of development at top and bottom blowing is this de-carbonization curve. This is percentage carbon per minute against blowing time 0 to 100 percent in the main part of the blow. So, this if I can put it, this is the main part of the blow, main blow; this is the end blow and this is the initial blow.

In the main part of the blow, there is a considerable amount of CO is evolved. So, bath is stirring is very good. Towards the end, when the carbon content is decreased, the CO evolution is also decreased. So, iron oxidization will increase because the bath agitation is again very poor.

Similarly, in the initial part of the blow, carbon oxidization is not allowed to proceed at the rate which is required because of the slag formation. So, in the initial and in the later period of the blow, the agitation is weak and this is based on the fact that top blown oxygen does not give enough agitation to the bath; the agitation whatever is provided is provided by the carbon monoxide gas.

Now, having thought this idea, then it is been thought that there is a bottom blowing process also. In the bottom blowing, what is being done? As I have shown over here, in the bottom blowing say, oxygen is blown from the top. Some of the advantages of bottom blowing process is that stirring is very good, Slag formation is poor, low FeO because when we are blowing oxygen through the bottom, then oxygen will always find its carbon and carbon monoxide will proceed and the slag formation will be delayed.

Say, if you want to remove phosphorous, that is not possible in the way in which top blowing steel making does. That means, it is possible only when large amount carbon is removed and then the slag will form because for the removal of phosphorous, you require a lime slag, you require calcium oxide, you require SiO 2, you require MnO so that slag will only form when large amount of carbon has been removed.

The main advantage of this bottom blowing is the stirring is very good. Now, in case of top blowing, carbon and phosphorous can be removed simultaneously; that is one particular advantage; second advantage is that control of slag formation. How we can control the slag formation? By simply raising or lowering the lance distance, which is not there in case of bottom blowing because we can only form slag, when large amount of carbon is removed.

Third advantage is that control of oxygen distribution because a deep bath or the deep penetration of the jet into the bath, more oxygen will be available deep into the hot metal by lowering the lance distance. So, control of oxygen is also very easy, but one of the disadvantages is that there is inadequate bath stirring, as I have said particularly in the initial and towards the end period.

So, why not the advantage of one process be combined with the advantage of another and that is what has given birth to the process which is called top and bottom blowing which is shown at the bottom. This is also called hybrid blowing; this is also called duplex blowing and this is also called top blowing and bottom stir processes, top blowing and bottom blowing. There are several names of that. So, what this process is that oxygen is supplied from the top as well as the inert gas is stirred from the bottom in some of the version.

Some plants, they use oxygen through the bottom. Well, there are different practices here, but essentially what it does? It combines the advantages of both and gives a new process which is called top and bottom blowing processes.

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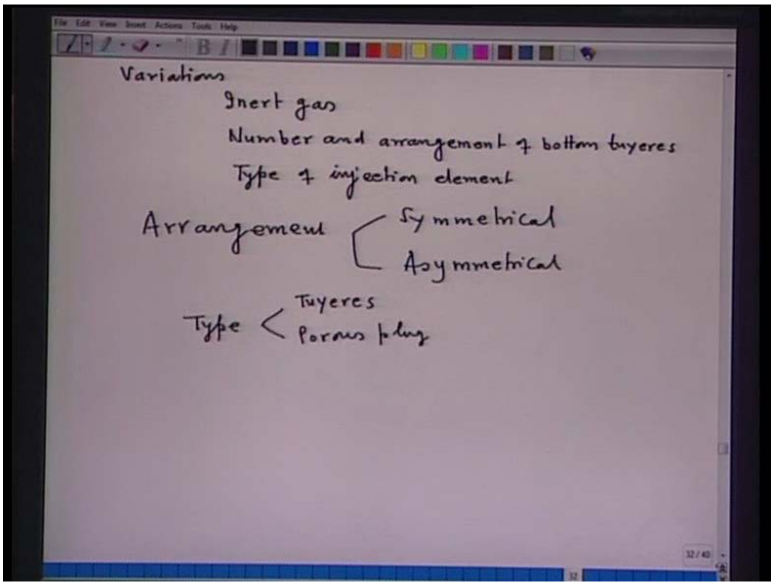

Variations

Inert gas

Number and arrangement of bottom tuyeres

Type of injection element

Arrangement < Symmetrical / Asymmetrical

Type < Tuyeres / Porous plug

Now, all the variations of this process, they differ in the following aspects. The variations of top and bottom blowing: variation that differ in terms of amount of inert gas, then number and arrangement of bottom tuyeres.

Because once you have decided to inject the gas through the bottom, naturally question arises what should be the amount? Because you need that amount which just stirs the bath, not more than that. If the inert gas is there because reactive gas is being supplied from the top so additional bottom gas you are providing just for the stirring purpose you require a minimum amount of gas.

If you decided on the amount then what should be the number of injecting elements and how they are arranged? Third thing is also, what is the type of injection element?

Now, coming back to the inert gas, well, you have to decide what should be the optimum amount of inert gas because once you put the tuyere or the injecting element at the bottom of the converter, then you have to blow minimum amount of gas otherwise, tuyere will be locked. So, once you have decided that amount, the next will be number and arrangement of bottom tuyeres.

Now, the number may vary from 2, some plant 4, some plant 8, some plant 12. All these numbers vary because this top and bottom blowing, it just requires to develop a technology. I cannot say in a class room, well, this is the technology which is going to help. There are several plants, several different types of people, several different technologies have to emerge and that is why you have the very different technologies of bottom blowing.

As regards top blowing, it is same as it was done in 1950, as late as Linz and Donawitz. As regards bottom blowing, it is differing from plant to plant, it differs on the amount of inert gas rate, they differ on the number of injecting elements and they also differ on the arrangement of the injecting elements.

Now, the arrangement of bottom tuyere could be, some plant go for symmetrical arrangement, symmetrical to the axis of the converter; some plant prefer to go for asymmetrical; both have reasoning, both have positive points. Asymmetrical design, it rather allows the bottom gas to stop at the time of tapping.

So, symmetrical have their advantage; asymmetrical also have their advantage. I cannot comment anything on that because ultimately, the whole idea of top and bottom blowing practice is to improve the performance of the converter, is to increase the productivity, is to decrease the iron content of the slag, and is to decrease the dissolved oxygen content of steel. Almost all variations of top and bottom blowing process, they claim that they tap steel at reduced iron content of the slag and reduced dissolved oxygen content of steel; both are the technological indices. So, as regards the output is concerned, whatever variations you have, it is all the same.

So, the important point or the important part of the development of the technology lies in what is the amount of inert gas? What is the number of the bottom injection element and how they are arranged?

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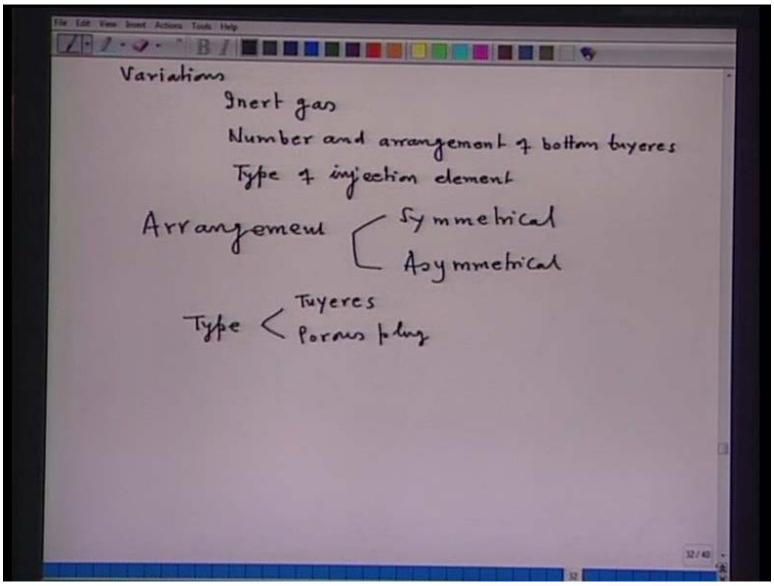

Variations

Inert gas

Number and arrangement of bottom tuyeres

Type of injection element

Arrangement < Symmetrical / Asymmetrical

Type < Tuyeres / Porous plug

Now, about the type of injection elements: So, type of injection elements: some plants prefer to have tuyeres. Tuyeres are straight pipes. You can easily blow; not much pressure differential is required.

Whereas, some plants prefer to go for porous plugs; porous plugs require higher pressure differential. So, I said the problem would be there because you have to insert them through the bottom.

So, the refractory material of the porous plug should match with the refractory of the bottom of the converter. All these are the technological issues which cannot be addressed in a lecture room; it has to be seen; it has to be felt.

So Tuyeres and porous plug Now, in the porous plugs, again several designs are there; that could be straight path or the path could be little bit archuos. Some wants to have with a higher pressure differential; some wants to have with a lower pressure differential. So, this is about the variations in technology and as such, there has to be different variations as already available in the practice. The blowing schedule is now to be adjusted - that means, lance profile has to be slightly adjusted.

Now, in top and bottom blowing converter, the top lance simply can supply the oxygen because the stirring part will be taken care by the bottom injection.

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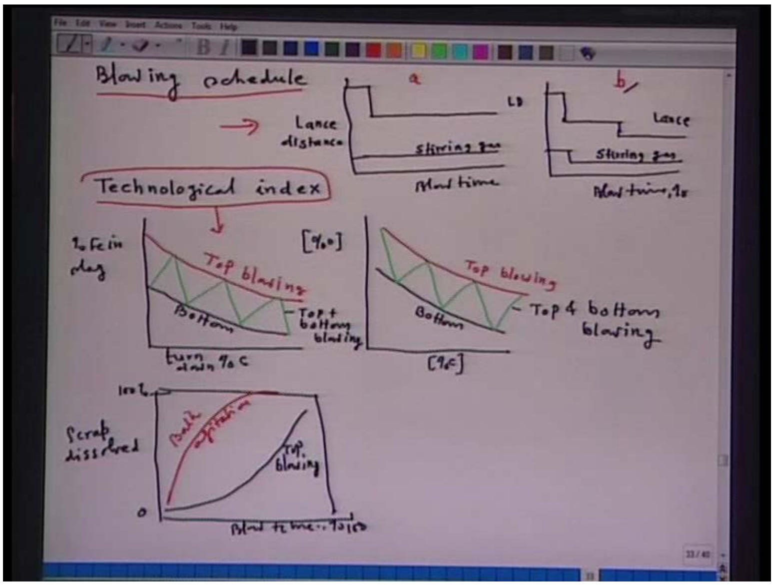

Blowing schedule

Technological index

So, there are again here, different variations. In one practice, for example, after having a higher distance in the beginning, say this is the practice a; this is the practice b.

So, in practice ‘a’, after a higher distance in the beginning, the lance is lowered and then is kept at a constant distance and stirring gas amount is constant. There are some practices that work on this. Another practice which is shown by ‘b’ is after a higher starting lance distance, lance distance is slightly lower, then again it blows at a constant distance and then again lowers and then again blows at a constant distance.

Some plants, they prefer to have a higher stirring gas rate as shown here and then decreases and then blow at a constant stirring gas amount; this is again a technological issue. The bottom tuyere should not be plugged. Here and there, it will have little variations in the lance profile, the amount of bottom gas rate will differ from plant to plant, but all will have towards the end, the technological indexes as reported in the bottom figures.

Now, the technological index: one technological index is percentage iron in slag. If you is plot it as turndown percent carbon, now this is in fact, is turndown percent carbon then for top blowing for any turndown percentage carbon, the total iron in the slag is much higher.

Now, it is compared with the pure bottom blowing remember, pure bottom blowing. Then for the pure bottom blowing because of the intimate reaction between carbon and oxygen in the bath, so for any turndown carbon content of the bath, the iron content of the slag is lower. The green portion, this is for the operation for top plus bottom blowing.

So, the percentage iron in slag or the turndown percent iron in slag is lower than top, but could be little higher than bottom for almost all top and bottom blowing processes.

Now similarly, another technological index is the turndown oxygen content. The turndown oxygen content is plotted against here turndown carbon content. Again for top blowing, the value for any turndown carbon content of the steel, the oxygen or dissolved oxygen in the steel is higher for top blowing, is lower for bottom blowing and the green colour or the range which I have shown because different processes are there; so, this range is for top and bottom blowing.

Because of the poor stirring in the bath, the rate of dissolution of the scrap in top blowing is slower as compared to when the bath is highly agitated. So, as you see when there is a bath agitation or a good stirring in the bath then the temperature equality will be faster and the scrap dissolution will also go at the faster as compared to top blowing.

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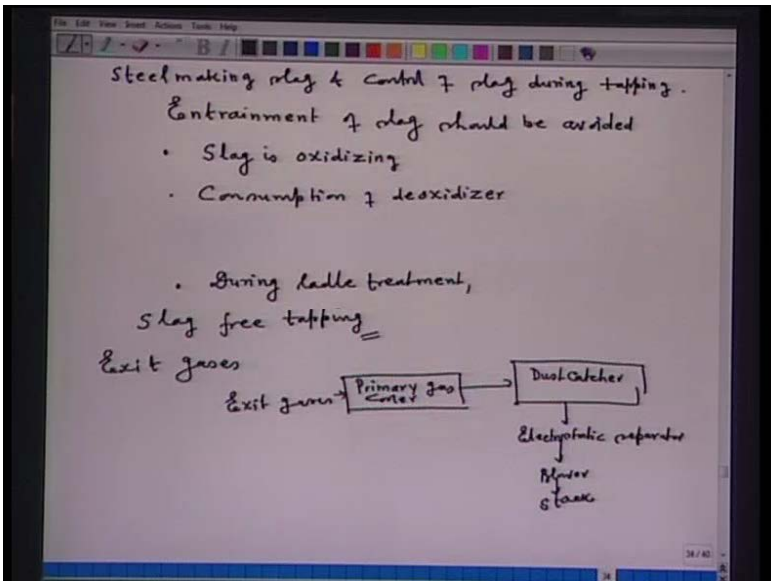

Steelmaking slag & Control of slag during tapping.

Entrainment of slag should be avoided

- Slag is oxidizing
- Consumption of deoxidizer

- During ladle treatment,

Slag free tapping

Exit gases

Now, coming to the last thing in the steel making slag and control of slag during tapping.

Now, during tapping the entrainment of slag must be avoided because slag is highly oxidizing in nature; it has MnO, it has FeO and as such, it is highly oxidizing in nature.

So, consumption of deoxidizer will be higher in the ladle also because larger amount of FeO and MnO content of the slag, more oxygen will transfer into the metal and more amount of deoxidizer is required.

Then during ladle treatment, some phosphorous can also revert to the metal because the metal which you have tapped in the ladle, if it is entrained by the slag, then slag also has P 2 O 5.

So, what is required during tapping is to have a slag free tapping. is required. Slag free tapping to the extent possible is required and for having slag free tapping, various methods are there; tap whole plug, slag cut ball method, pneumatic slag stopper and slag detection methods are all reduced for having the slag free tapping.

Now, about the exit gases: exit gases, they contain carbon monoxide and entrant solid particles and so on. So, these gases they have very high calorific value as well as the sensible heat because the gases are going out of the converter at around 1300, 1400 degree celsius. A large amount of CO is produced. So, the gas has sensible heat as well as calorific value. This exit gases are cleaned. So, this exit gases are taken into the primary gas cooler.

From there, they go to the dust catcher because you have to remove the dust; a very large amount of dust is there and this dust is purely Fe 2 O 3. So, you recover and send it back to the blast furnace and is dust to dust catcher, it is subjected to electrostatic separator for removal of very fine particle, electrostatic separator and then it goes to the blower and the gas ultimately discharges into the stack.

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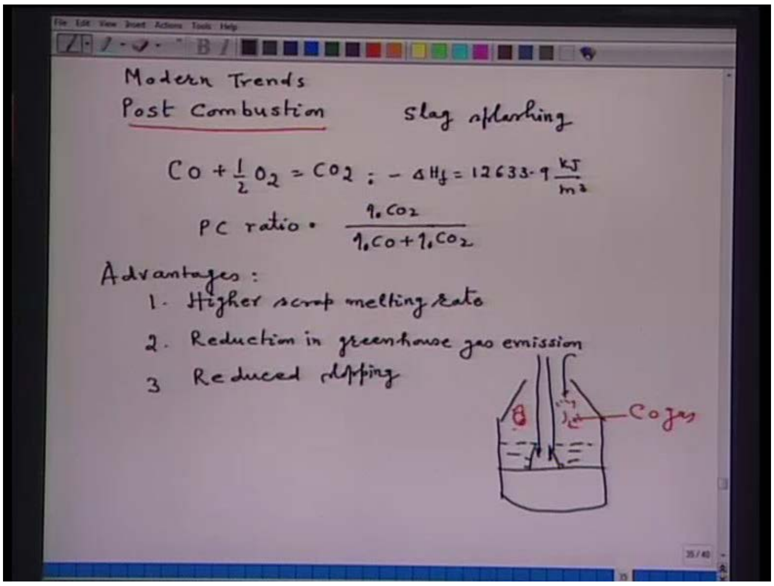

Modern Trends

Post Combustion slag splashing

$$CO + \frac{1}{2}O_2 = CO_2 \; ; \; -\Delta H_f = 12633.9 \, \frac{kJ}{m^3}$$

$$\text{PC ratio} = \frac{\%CO_2}{\%CO + \%CO_2}$$

Advantages :

1. Higher scrap melting rate
2. Reduction in greenhouse gas emission
3. Reduced slopping

So, let us see modern trend. So, one modern trend is post combustion and another is slag splashing. Let us take first of all post combustion.

Now, post combustion is in fact, the energy conservation measure. Post combustion had been adopted earlier also in 60s and 70s, but now the advantages of post combustion has been realized and some of the plants, they are adopting post combustion practice also.

Now, what this post combustion does? Post combustion means combustion of CO inside the converter by supplying additional amount of oxygen.

So, that means CO plus half O 2 that is, equal to CO 2 and the heat of formation and a very large amount of heat is being created by combusting CO gas inside the reactor.

Now, this combustion of carbon monoxide offers a potential source for energy saving in the top and bottom blowing converter technology.

This post combustion has to be done inside the converter. The post combustion ratio, it can be defined as percentage CO 2 upon percent CO plus percentage CO 2. Some of the advantages of post combustion are because then first is higher scrap melting rate.

Why higher scrap meting rate? It is because temperature will also increase and hence, the scrap will melt at a little faster rate. Second advantage which is claimed is reduction in greenhouse gas emission.

Now, this reduction in greenhouse gas emission occurs because now you can charge more amount of scrap into the converter and less hot metal. Third: reduced slopping because now the temperature increases, slag becomes less viscous and hence the chance of sloping also minimizes, but what is important for the post combustion technology is again the development of a system to blow additional amount of oxygen for the post combustion purposes.

Now, see the problem. What is the problem here? So, if I draw a converter over here, this is my main oxygen which I am blowing through a lance, this is my hot metal and this is the slag. CO gas is somewhere here; this is the CO gas. What I have to do for realizing the post combustion? I have to supply O 2 over here.

So, where lies the essence of post combustion technology is again to develop a suitable lance for blowing the extra amount of oxygen at a lower velocity because higher is the velocity of oxygen for post combustion, it will not be able to combust all amount of CO because CO, it disperses in the large area of the vessel. You have to blow oxygen at a very small velocity and also, disperse over the entire surface area of the converter.

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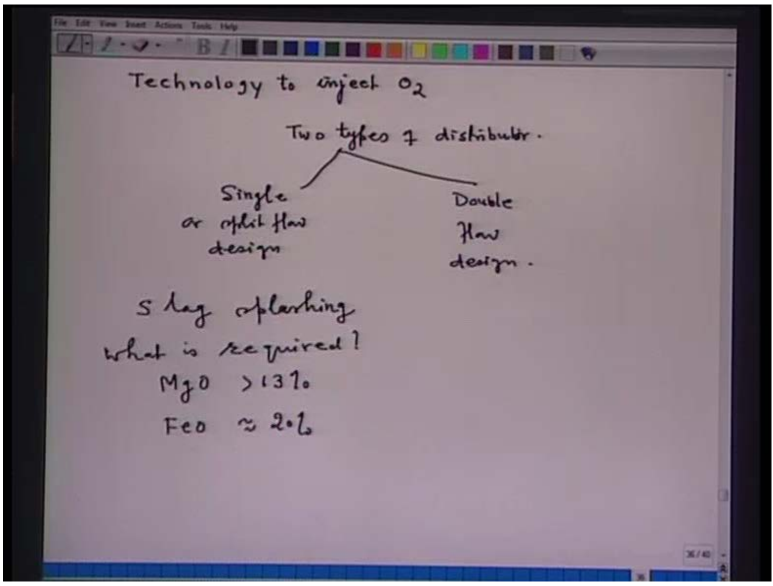

Technology to inject O_2

Two types of distributor.

Single or split flow design

Double flow design.

Slag splashing

what is required?

MgO > 13%

FeO ≈ 2%

So, what is required is to develop technology to inject oxygen for post combustion.

Now, the simplest technology that you can see is you have a lance strip and outside the supersonic nozzle, you provide few small holes. Whatever fraction of the oxygen that comes out from the small holes that can do the job of post combustion because it will come first of all at a very small amount and then second, it will be distributed over a little area. That practice is also being done. Now, another practice is that you add a second tip or distributor between the bath and the oxygen tip.

Now, there are 2 types of distributors: one is a single or a split flow design and another, a double flow design. In the single or a split flow design, one oxygen supply and one inlet you have.

A small percentage of oxygen is split inside the lance for post combustion purposes. Now this is again a design issue. In case of double flow design, separate oxygen inlet and oxygen control system, dedicated only for post combustion is required. So, that is here and control is easier. Another development is called slag splashing.

Now, slag splashing is done to increase the lining life of the slag. In some plants, slag splashing has resulted in a very high liming life, the order of some plants claim greater than 60000 heats could be one particular example.

What is slag splashing? At the end of BOS process, steel is vent and slag is retained in the vessel. Now, in the same top oxygen lance, nitrogen is blown and high pressure nitrogen is used to splash molten slag on the walls of the BOS vessel for a period 2 to 4 minutes.

As a result of blowing of high pressure nitrogen, the slag is blown and it adheres to the lining of the refractory wall and as such, you get the slag splashed coated refractory lining. Now, what is required for slag splashing?

Some composition of the slag, it should be required. What is that? First of all, the slag should have MgO content around greater than 13 percent because MgO will react with Fe 2 O 3 and it will form a high temperature phase.

At the same time, FeO content of the slag should also be approximately around 20 percent because the FeO content of the slag, it will form a low melting point phase as well as it forms a good adhesion between the slag and refractory. MgO content of the slag, it forms a high melting phase. So, both are combined together; then a very good coating of the slag results on splashing of the slag.

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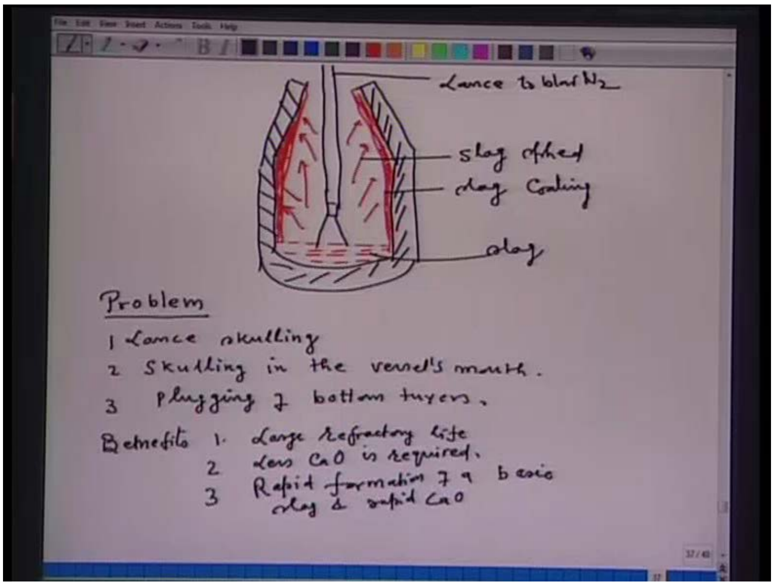

Problem

1 Lance skulling
2 Skulling in the vessel's mouth.
3 plugging of bottom tuyers.

Benefits 1. Large refractory life
2 Less CaO is required.
3 Rapid formation of a basic slag & rapid CaO

The diagram shows how slag splashing is done. Beginning, the red tier, which shows the slag, lance is blowing nitrogen at 4 to 5 bar pressure and as a result of blowing of nitrogen, the nitrogen jet penetrates into the slag and then slag begins to splash and it adheres to the wall of lining and the red one shows the slag coating. That is how the slag splashing is being done.

Now, some of the problems in slag splashing say, lance skulling is one problem because slag is relatively viscous. So, lance skulling is one of the problems; another problem could be skulling in the vessel's mouth.

Then third, if it is top and bottom blowing tuyere then the plugging of bottom tuyeres. Benefits of slag splashing: First: large refractory life and some plants claim the order of 60000 heats - a huge number; second: since the splash lining already contains MgO, less CaO is required.

Third: left over slag has some amount of calcium oxide, some MgO it is being enriched. So, if this slag is being coated on the lining lime and when the heat starts then already calcium oxide and an MgO is present. So, rapid formation of a basic slag and rapid CaO dissolution condition exists right in the beginning of the slag.

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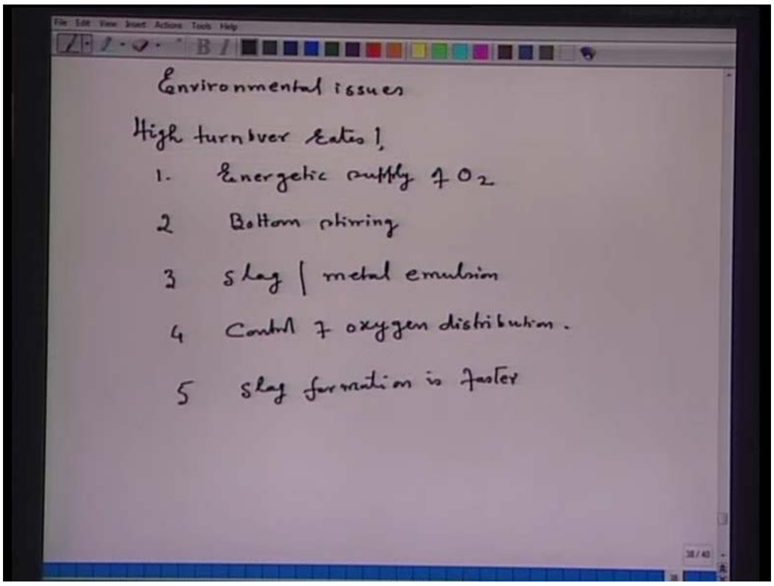

Environmental issues

High turnover rates!

1. Energetic supply of O_2
2. Bottom stirring
3. slag / metal emulsion
4. Control of oxygen distribution.
5. slag formation is faster

Now, here some of the environmental issues in oxygen steel making. Control of emissions during hot metal transfer, de-sulfurization station, exposition of slag, recycling or disposal of collected oxide melts, capture and removal of contaminants in hot and dirty exit gas on the converter, emission of CO, sometimes you may require excess amount of air at the mount of the hood to burn the CO and the energy could be used, particulate matter. So, all these are concerned with the environmental issues which must be taken care.

Now, again there is a question. Why there is a high turnover rate? As you recall, a 200 to 400 tons converter, it takes 60 minutes; a 400 ton of hot metal is converted to steel in a matter of 60 minutes.

So, the high turnover rates, the reason being one: energetic supply of oxygen, second: bottom stirring is another reason for high turnover rates, then the formation of slag metal emulsion because of the increased surface area, fourth: control of oxygen distribution and slag formation is faster.

These are some of the reasons for faster turnover of say, basic oxygen furnace in particular top and bottom blowing. More reasons, you can think.

Now to conclude the lecture, I will say only the top and bottom blowing converter technology is the future. This particular technology has already attained very high maturity level. The development of dynamic control and the development of slag splashing and also, the development in the refractive technology have made the top and bottom blowing converters technology very strengthful.

So, in the years to come, it is very hard to replace this technology by any other means. Thank you very much.