Environmental Air Pollution

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Lecture No. 18

Aluminum Production and Air Pollution – 1

Today, what we will do is talk about the aluminum production and the air pollution aspects associated with aluminum production. If we little look at the process of aluminum making, we can divide this into three parts.

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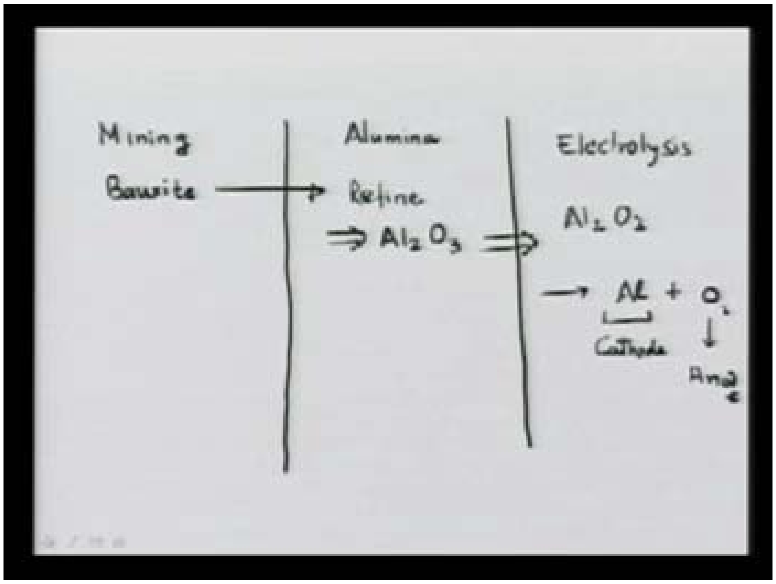

One is mining, so let us write that. We all know from high school that the ore for aluminum making is bauxite. Once the bauxite is mined, it must be brought to a plant called (if I can divide this into three parts) the alumina plant. What we are really doing is that we are refining the bauxite – this bauxite comes to the alumina plant – and then we are essentially refining the bauxite in such a way that we can concentrate more and more of Al_2O_3. So refine the bauxite to form more and more of Al_2O_3 – we refer to that as alumina. Once we have the alumina ready, the next step is to take this aluminum oxide (or alumina as I said) through the process called electrolysis process. What we do here is to produce the aluminum through electrolysis. In this process, you can say that Al_2O_3 can go in the process of aluminum plus oxygen. This goes to anode, I am sorry this goes to cathode and the oxygen that will come out will go to anode. We will see in a moment what really happens as we go by.

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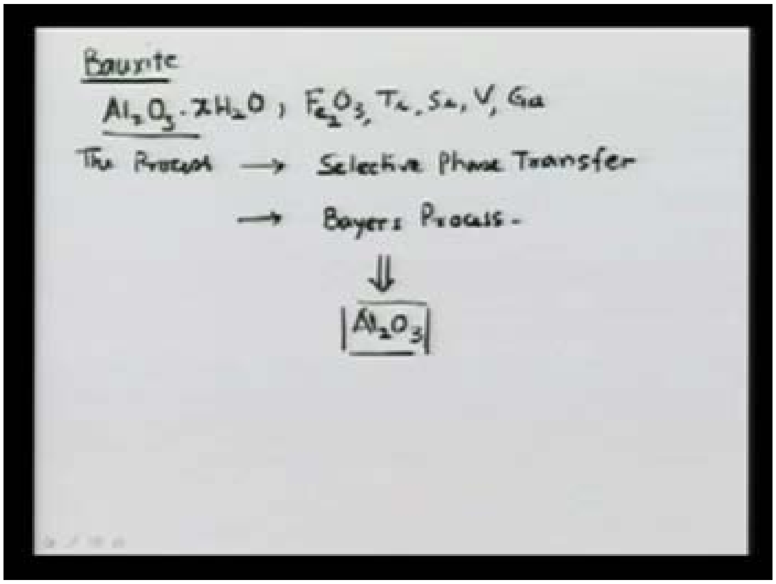

Bauxite

$Al_2O_3 \cdot xH_2O$, Fe_2O_3, Ti, Si, V, Ga

The Process → Selective Phase Transfer

→ Bayers Process.

$\Downarrow$

$\boxed{Al_2O_3}$

If we go to the next board if you look at the bauxite, it is essentially Al_2O_3 that is hydrated, so let us write the hydrated part as x molecules of water plus it has lots of impurities – the impurities are largely Fe_2O_3 – iron oxide but it can have titanium, it can have silica in various complex forms, it can have vanadium, it can have gallium and various other metals. The process through which we would like to enrich the alumina out of the bauxite is something we can refer to as the selective phase transfer. We will see how this selective phase transfer is done. This process of going through the selective phase transfer is also called as the Bayer's Process. What we will do now is specifically talk about the Bayer's Process and how out of all the things present, we can produce from Bayer's Process very good quality, high in purity Al_2O_3 – that is our objective and we will see in a moment as to how we can do it.

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It might be a good idea just to have a look at the aluminum plants in India. What you see here are those, the rectangle boxes. Here, we have Hindalco (Refer Slide Time: 05:13) – a large aluminum plant, you have National Aluminium Company in Orissa – that is again a very large aluminum plant, we also have a plant called BALCO – that is in Korba in Chhattisgarh, then we have other plants under the same name as Hindal as you see here – part of it is in Hirakot and another unit is in Alupuram in Kerala and there is also a small plant of the Madras Aluminium Company in Tamil Nadu.

India is by and large self-sufficient in aluminum production. In fact, we also export part of the alumina to different countries, but let us now go over to the process flow sheet of how alumina is made. As I said in the beginning, there are three parts in mining but we are not discussing that in this lecture. The second part of aluminum making is alumina making – that is Al_2O_3 and the third part is the electrolysis of Al_2O_3 to produce aluminum metal. Let us talk about the making of alumina.

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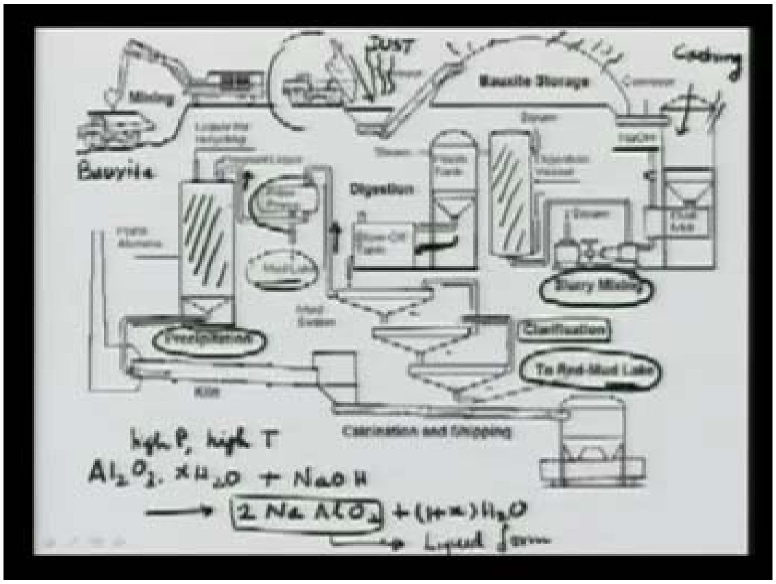

In this process that you see on the screen, we are trying to make here what we call as alumina from the bauxite ore. What we will do is that we go through this flow sheet and also in the process see what the various air-polluting sources are and what are the reactions – the chemical reactions that go on here. As you can see here, the mining is taking place for bauxite, so let us write here bauxite mining. Then, it is transported to the alumina plant. The alumina plant can be far away from the bauxite mining area or it can be very close to the bauxite mining area – there are many factors to decide where the plant should really come up. Let us not get into the siting of the plant but let us get into more of the processing.

Here, the bauxite is transferred through loaded trucks – could be railway tracks or even through ships. The bauxite that is here is brought to the alumina plant and then it is dumped – you see that the loader is dumping the bauxite (Refer Slide Time: 07:47). What happens as you are loading it here is that there may be emissions and that emission will be that of dust. Wherever we see dust emissions, we should think of control. Let me make it a little better here. Here, you have emissions and these emissions are really that of dust or particulate emission. There are various ways to handle the dust emissions –you can provide fogging nozzles so that you can have little moisture content in the air or in fact, you can enclose the entire area, so that no dust comes out from there. If you recall in one of the earlier lectures, we said that fugitive emissions were of great significance. When you go to the plant, as a pollution control person when you are planning pollution control, you should just not look at the chimney. I tend to repeat this again and again because the fugitive emissions are sometimes very very important and they cannot be ignored – we should look at the emissions in totality rather than just what is going through the process or going through the chimney.

Nonetheless, the next step is through the conveyor belt. The conveyor belt can also sometimes be a little source of emission of the particles and then there is a huge area where the bauxite is stored. Again, if you recall, there can be some emissions from the bauxite storage area – you can see I am trying to make a little drawing here for you. Finally, it comes to the ball mill as you can see here. What we are really doing in the ball mill is crushing – we are trying to crush the bauxite into I will not call it fine but about 100 micron size so that we can do further processing of the bauxite.

As you can see here after the ball mill, once the ball mill is opened, this can also be the source of emissions. Once we have the bauxite after the ball mill, we mix it with sodium hydroxide – let us just underline it rather than circling it; the sodium hydroxide is added here and we will talk about the use of sodium hydroxide in a moment, but what you see here is along with steam, the sodium hydroxide is made and then what you are really getting here is slurry of bauxite – the slurry with water and NaOH.

This slurry is pumped into something called the digestion vessel, so let me indicate that –this is my digestion vessel (Refer Slide Time: 10:58), the container that you see. In the digestion vessel, what happens is digestion. Let me explain what digestion really is. In digestion, what we are doing is we are trying to dissolve the alumina part into NaOH and the other impurities will not be dissolved and so what we are basically doing is phase transfer. What happens is, if I can write the equation for you, the following.

What we can do here is let us write that equation Al_2O_3, x H_2O was there and I am making it react with NaOH as if I made the slurry with NaOH and what it gives is sodium aluminate in the dissolved form. This produces 2 $NaAlO_2$ plus you will see that amount of the water that will be taken out from there, so (1 plus x) of water. To make this reaction happen, we need high pressure, let me write pressure as P and high temperature, let us call it T. Those are the conditions that are maintained in the digestion vessel – you can see here that is my digestion vessel.

What we have achieved with this process is that we phase transfer the Al_2O_3 and make it dissolved and make another compound here and this compound is in the liquid form. Like anyone else, you will wonder what happened to all other impurities that we talked about. The other impurities were Fe_2O_3 and silica, titanium, gallium and vanadium. The interesting part of this is that they will all remain in the suspended form. What we have achieved through the digestion is we are able to separate out the Al_2O_3 component, which is now in the liquid form in the form of sodium aluminate, whereas the rest of the impurities are in the suspended form. What I can do now is to remove the suspended impurities.

The next step is what you see is flush tank that you pass through the steam. The flush tank you come to the blow-off tank is essentially a kind of flush tank into which you can transfer things and then bring to the various settlers or I can call this clarification – you will probably recall the clarifiers that we use (or clarification). Essentially, what we are trying to do is separate out the suspended solid components, which are the impurities. What you see here is a settling tank number one, then it becomes concentrated here (Refer Slide Time: 14:27) – the sludge, then it goes in here; this is the first one, the second one, the third one; the design can vary but the concept is that you are trying to remove all the impurities. Once the crystal-clear water is there, that is pumped into this, then into the second one, then into the third one, finally, into a leaker that is very clear and then taken further for processing – for that, you see the arrow; after the removal of the suspended impurities, the clear liquid is taken up.

But you can also see all that impurities that we got, we made them settled, they become sludge or in fact we call that as mud – not only mud, we call that as red mud (you see that here); the impurities are taken out as red mud and this is put through a system, which we will call as red mud pond or sometimes red mud lake. These impurities can go to the red mud lake. Let us get back to the process after having dissolved the Al_2O_3 in the form of the sodium aluminate and see what happens. There may still be some impurities. Therefore, what we do is we pass the liquor or the clear liquor into the filter press – this is my next step. The filter press will effectively remove almost all suspended impurities and once suspended impurities are gone, again the impurities are separated out, as you see here – you can see that here as the mud lake. Where will this be sent back? It will be sent back to the red mud lake. This is also going to the red mud lake, this component you here (Refer Slide Time: 16:29) and this also is going to the red mud lake because these are the impurities and we need to separate them out.

From here, after the filter press (let me make this arrow here), where we take this is to the precipitator. After this point, after all the impurities are removed, I have a crystal-clear liquid, which is largely sodium aluminate or again I repeat $NaAlO_2$. The idea is just simply not to stop at $NaAlO_2$ but our objective is to form Al_2O_3. How is that done? That is done through the process called precipitator where we can precipitate out. The whole column you can see here is what is called the precipitator. You can see here, let me mark it as the precipitator and I can hatch it just to make sure that we understand – this is the precipitator. In fact, this liquor is also called pregnant liquor. Why do we call it pregnant liquor? It is because it is pregnant with the sodium aluminate. Now, the idea here is to precipitate out the aluminum hydroxide and we will see how this is done.

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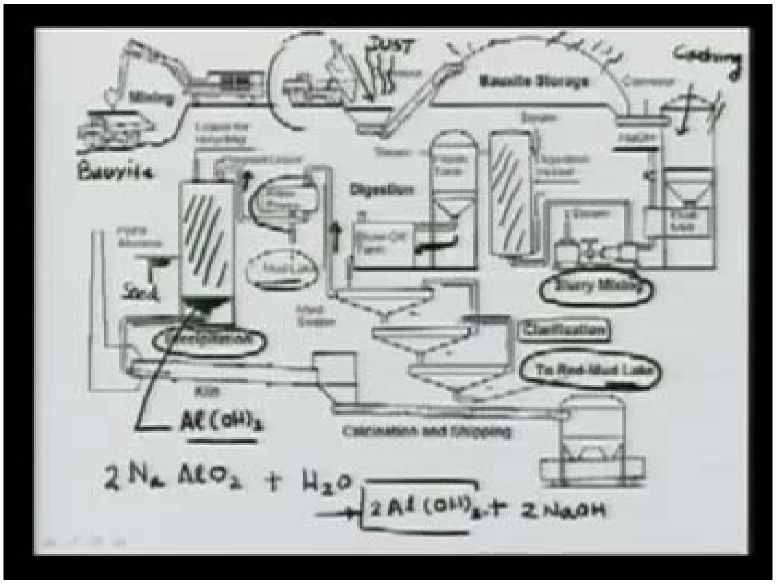

What I will do is I will remove this. In the precipitator, what we do here is that this sodium aluminate…. Let me write the reaction here as to how this precipitation is made possible.

What we had was sodium aluminate and if we add some excess water in there or there is water, what we form is aluminum hydroxide plus let us not forget that we will recover the NaOH. Let us try to balance this equation. 2 sodium, so this has become 2 sodium here (Refer Slide Time: 18:53) and aluminum is 2, so let us make this as 2 here. What we are really doing is we are trying to precipitate this out – we started with sodium aluminate and we precipitate the aluminum hydroxide.

Aluminum hydroxide is very gelatinous flocks and we can make them settle again. What we are doing here is that we are making the aluminum hydroxide settled – you see the little container here indicating that we are trying to settle the aluminum and I can say that this really is really aluminum hydroxide. Let us see where we go from here. This solution of sodium aluminate is supersaturated, so we put some seed here – seed that will help in the precipitation, what you say as the ppt of alumina or some seed is also added – seed is again from the Al_2O_3. Now what?

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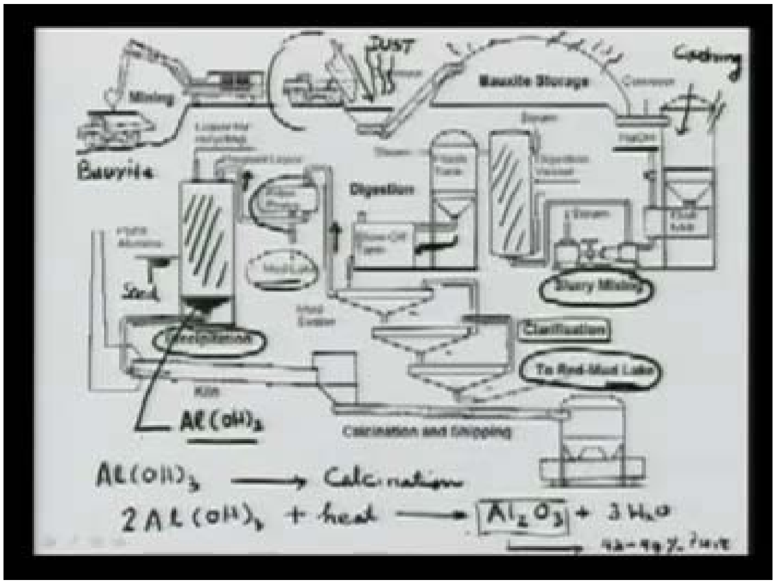

$Al(OH)_3 \longrightarrow$ Calcination

$2Al(OH)_3 + \text{heat} \longrightarrow \boxed{Al_2O_3} + 3H_2O$

Let us again remove this. Now, in the process, what we have got is aluminum hydroxide. Recall where we want to reach – we want to reach alumina. What was alumina? Al_2O_3 Now, we have to apply something so that we produce the Al_2O_3. Whenever there is hydroxide and you want to get the oxidized state, what we do is the process called calcination. We will do the same thing – calcination. This may be moist and aluminum hydroxide is passed through the….

What we do is go through the process called calcination. We will see in a moment how the calcination is done, but let me write the reaction as to how the calcination will occur. What we really need for calcination to be accomplished is we need to supply some heat and if we apply heat, we get Al_2O_3 (that is what we want to get) plus we should get the water out (the idea is to get the water out) and get the calcined alumina. Let us balance it. This should be 2 here and Al_2 is fine and O_3 O O is 6, hydrogen is 6. Hydrogen is 6, so let us put 3. I think that is the balanced equation. This is what I wanted to achieve – right from the beginning, that is what my objective was and I am able to do this. The interesting part is this alumina is about 98 to 99 percent pure. But we have not looked at the calcination part and how this calcination is really done.

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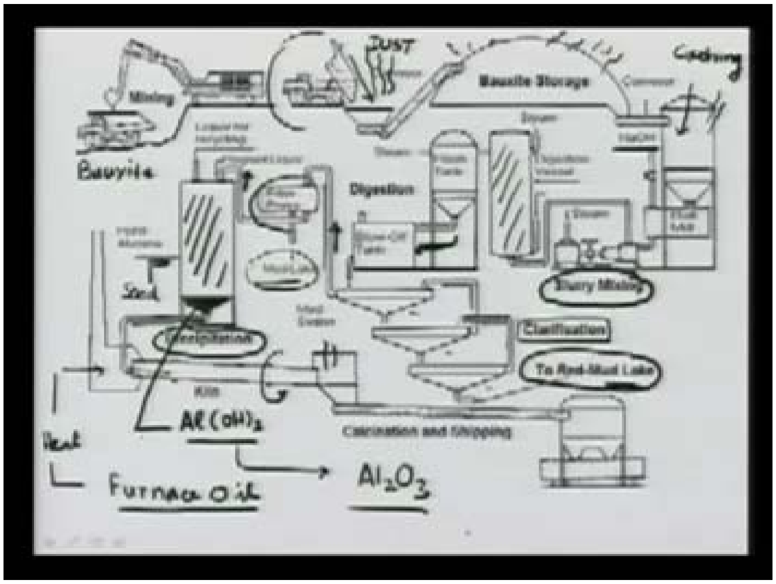

Here, we had the aluminum hydroxide that is passed through the kiln. A kiln is a rotating tunnel – let us make the arrow rotating to indicate that things are really rotating. Then, we are supplying the heat through the furnace – supply heat. For heating, most of the time, we do not use coal because coal will make our alumina very impure. What we use generally (again, this varies from plant to plant) is furnace oil or other cleaner fuel. What you are getting here is in the kiln, the heat is supplied, so aluminum hydroxide breaks down or rather gets calcined to Al_2O_3, but the moment we are firing a fuel, there are emissions here. What are these emissions?

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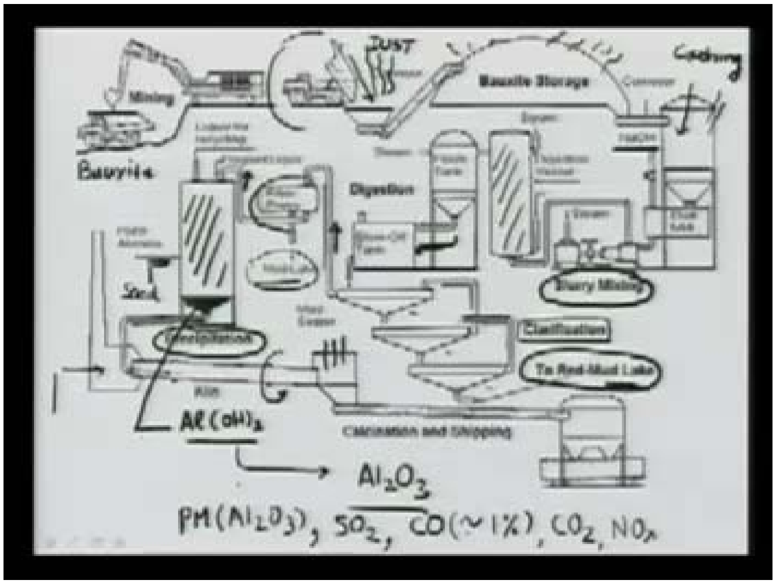

Our focus here is to understand the air pollution aspect. Because you are firing the furnace oil, this can give a large amount of particulate matter. What are the particulate matter? This particulate matter will be not from the furnace oil but this will be the alumina particulate matter, because alumina is produced and alumina will be in the form of very fine particles and so there will be particles that will be largely alumina – let me write Al_2O_3 in the bracket so that there is no confusion.

Then, it can also produce significant amount of SO_2. Why SO_2? It is because the fuel oil or the furnace oil that we are firing will have sulfur – that sulfur will be burnt out as sulfur dioxide and so you can see sulfur dioxide. It has also been reported that a little amount of carbon monoxide of the order of about 1 percent is also emitted; of course, CO_2 has to come out and some very little amount of oxides of nitrogen are also expected but this amount will be very very small. What you can see from here is again the rotary kiln is nothing but a calciner and calciners have now become a significant source of air pollution. This is the rotary kiln and the interaction between the aluminum hydroxide and the heat produces Al_2O_3.

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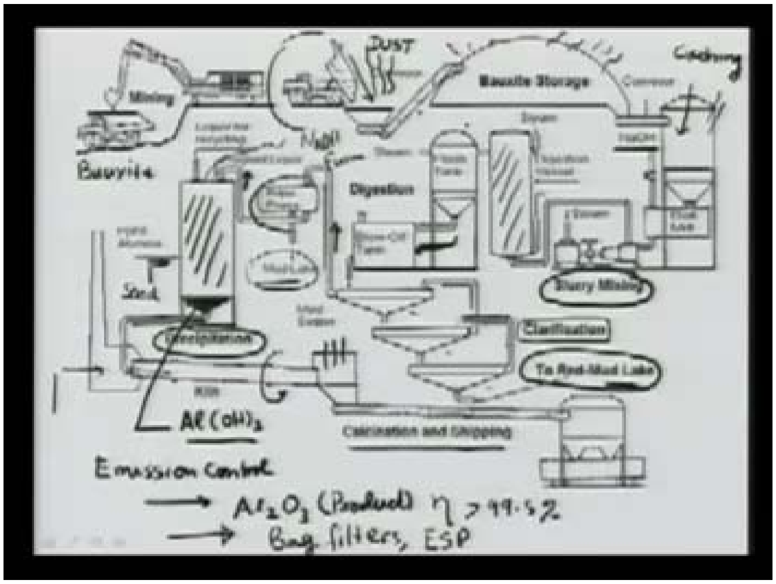

Emission control

→ Al_2O_3 (Product) $\eta > 99.5\%$

→ Bag filters, ESP

Emissions have to be controlled. Emission control here has to be very stringent, very tight. We cannot say let us control 80 percent of it – no, because what we are really losing is the Al_2O_3 itself, which is my product. Most of the plants will have control, so control efficiency will be.… I write the efficiency as eta will be greater than 99.5 percent. I want to capture everything because if I do not capture it, it is not only the pollution problem but also a loss of the product.

Normally, what we use to control is we use bag filters as the control device here or we can use electrostatic precipitators, which I will write in the short form as ESP. Very high efficiency control devices are used for trapping the particulate matter. This is the final thing. Then, once we are getting the calcined alumina, then you can either ship it or transfer to the area where you have the aluminum plant, because this was the process that we discussed and so finally, it is shipped to the aluminum plant.

This is how it is, but let me also tell you one point that we missed here about the air pollution aspect – when you are doing the precipitation, things are opened at the top and once it is opened, you can also get fumes of NaOH. One more thing we must not forget is that once we are doing the precipitation, we are recovering NaOH and that NaOH is sent back in here. In which process are we recovering the NaOH? If you recall, whenever we are making the aluminum hydroxide here, the NaOH was recovered (Refer Slide Time: 28:06) and that recovered NaOH is recycled back here – it is recycled back as NaOH, that you see here.

This is in brief the aluminum or rather alumina production process. We can quickly see the sources of pollution – that is what is of interest to us, sources of pollution. Let me pinpoint for you the sources of pollution – dust emission is a source of pollution, bauxite storage is a source of pollution and also, let us not forget the conveyor belt. We need to control all these sources. We cannot say that these are not major sources – these are major sources. In fact, alumina plants are not really very well maintained, they are hugely dusty.

We also get some emissions from flash mixing, we get emissions from the precipitation area, do not forget that we also get the solid disposal problem – that is from the red mud that is collected here and sometimes, we have many precious metals also recovered from the red mud area. That tells us about the making of alumina, which is Al_2O_3. Once we have made the Al_2O_3, the next process is of course making the aluminum. We said that aluminum is made through the process of electrolysis. Let us go through the next step and see what this is.

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Red Mud Lake (pH > 8.5)

This picture you see is essentially just to get a little feel of what is the, let us write it, red mud lake. There can be a serious problem. This is a huge amount that needs to be disposed of. Do not forget that the pH will be high here because we have been using alumina – it will be certainly greater than 8.5. The disposal of this becomes a serious problem. There have [30:19], there have been attempts to use this for road making, for brick making, but still a method that is largely acceptable is still under process.

Now, we will begin with the making of aluminum from alumina. So far, we had seen how the alumina, Al_2O_3 was made. There were certain issues, environmental issues, issues of air pollution from various stages and there was also the issue of the disposal of the red mud. But now, we will begin from the point where we have produced Al_2O_3.

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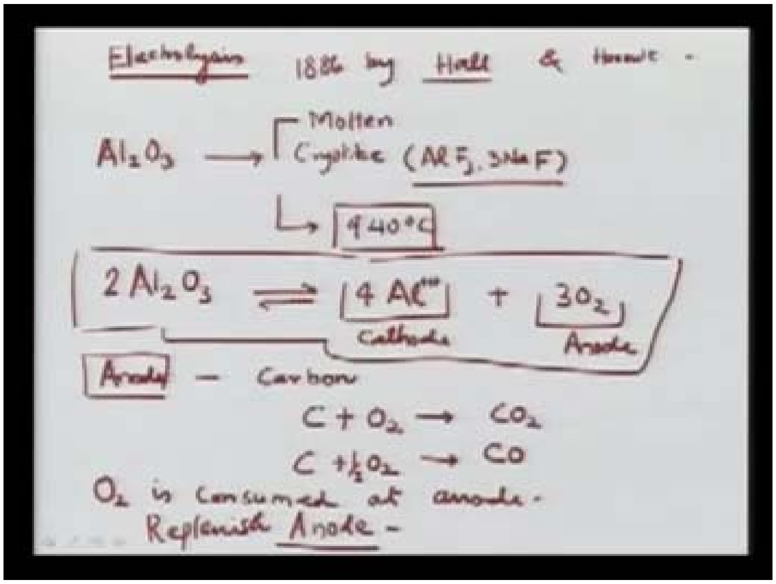

Electrolysis 1886 by Hall & Heroult -

$Al_2O_3 \longrightarrow$ Molten Cryolite ($AlF_3 . 3NaF$)

$\longrightarrow \boxed{940°C}$

$2Al_2O_3 \rightleftharpoons \underbrace{4Al^{+++}}_{Cathode} + \underbrace{3O_2}_{Anode}$

Anode - Carbon

$C + O_2 \rightarrow CO_2$

$C + \frac{1}{2}O_2 \rightarrow CO$

O_2 is consumed at anode -

Replenish Anode -

As I said earlier, the process of making aluminum out of Al_2O_3 is electrolysis. Let us write electrolysis. This method was developed in 1886 by two gentlemen called Hall and Haroult. One was an American and the other was French. They did not know each other – that is the interesting part. They independently developed this method to make aluminum from alumina through electrolysis. Their point was that Al_2O_3 can be dissolved in a compound called cryolite – it can be dissolved in cryolite. What is cryolite really? It is AlF_3 point 3 Na – this is cryolite. They could dissolve Al_2O_3 in cryolite or let us call it molten cryolite.

When something is dissolved in something, the electrolysis process can be used. The Al_2O_3 can be dissolved in molten cryolite and we can proceed with the electrolysis. The interesting part is that this Al_2O_3 can be melted at about 940 degree Celsius. The Al_2O_3 can be dissolved in this molten cryolite and then, we can run through the process called as electrolysis. Let us talk about the electrolysis process. Al_2O_3 is in the dissolved form now and we are going through the electrolysis process.

It will produce aluminum and it will produce.… Let us also balance it as we go by. We have 6 here, so 2 will be here, it will be 4 here, aluminum plus plus plus. This goes to the cathode as we said and this goes to the anode. The anode is made of carbon and so when the oxygen reaches the anode, it can react with this carbon anode and produce CO_2 and it can also produce CO. Balance that.

What you are really seeing is that aluminum is constantly produced and oxygen is also produced. Let us write it here so that we do not forget – oxygen is consumed at the anode. What we need to do is replenish the anode because that is being consumed. This is in brief the process with which we can make aluminum. If we can further divide, we need an electrolyte cell, we need this process to go on, but we also need to produce the anode – let us not forget that.

Why produce? It is because the anode is being continuously removed or continuously being consumed. When we are talking about electrolysis and we are talking about aluminum making, we again divide the whole thing as if we need two different parts: one is for making the anode because the anode is being consumed and the other is the electrolysis process. What we will do is we will first see the electrolysis process and come back to see how the anode is made.

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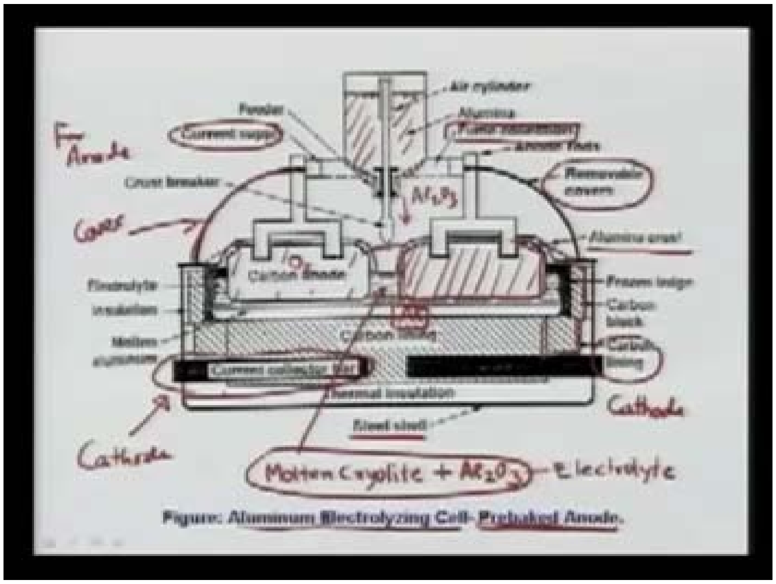

Figure: Aluminum Electrolyzing Cell- Prebaked Anode.

It might be little interesting to see the electrolysis process inside the cell. This picture you see here is the aluminum electrolyzing cell and this is what you will call as the prebaked anode. I will explain the meaning of what a prebaked anode really is, but let us focus a little bit on this picture. First of all, this is the shell made of cast iron – steel shell, as you can see here; it can be either cast iron or steel shell. Then, you pass the current through this. This is my thermal insulation as you can see, because we need constant heat here; the current is supplied here.

Let me go one by one. You see here these are the anodes and these are the anodes (Refer Slide Time: 37:32). This is the carbon lining as you see here and that portion I will try to show you this way – this is this carbon lining and this forms what we call as cathode. Here, what you see is the… let us make an arrow… you have molten cryolite and dissolved Al_2O_3 in it. The current supply for the anode is here and the current supply for the cathode is here. This is for the anode and this is for the cathode.

As I said, this is molten cryolite plus Al_2O_3 – we should really call this as the electrolyte. This white strip you are seeing will be molten aluminum. Why do we call it as molten aluminum? As you see here, this is the cathode or carbon lining. Aluminum will tend to go towards the cathode and the oxygen will tend to go to the anode. Here is the oxygen that will come and attack and here will be your aluminum that you will get at the cathode. This is the process, but the other thing we need to really see is that in the center, this is where you are trying to put your constant supply of Al_2O_3 because that is continuously consumed and is continuously used up to form the aluminum.

What you see here is that as we are putting the Al_2O_3, Al_2O_3 gets dissolved and partly it will make a little crust on top of this – you can see this crust, that is the alumina crust. The whole thing is covered fully. Whenever you want to supply Al_2O_3, what you do here is you bring what is called a crust breaker, you break and put the alumina down there. As you see here, the whole thing is filled with Al_2O_3. First, you break the crust. There is a hopper you see here and alumina is dropped in there. Once the alumina is dropped, it will dissolve into the cryolite and [41:07] electrolyte, the [41:09] will go, there will be production of aluminum, the oxygen will be going to the anode and the anode, which is made of carbon, will be continuously consumed here.

The other thing is the whole thing is covered by hoods. See here and this is also my cover. In fact, this cover can be removed because we need to do some operation in here – we can remove the covers. The other thing that you see here is the fume collection system – it will become clear in a moment when I show you another picture. Here, there is a lot of possibility of emissions occurring here because we have high temperature. We also have some volatilization of the fluoride material and then the fluoride material tends to go out as soon as…. The emissions are especially very large when the crust is broken, because the whole thing is opened up and as a result, there will be emissions.

We will talk about the emissions in a moment, but here, what you have to remember is this is the electrolysis process that is going on and the anode is being consumed. What you see here is the anode is already prebaked, it is in the solid form. When you go to the bakery, you find baked solids like biscuits – they are baked, not a paste. Since it is already baked, we call it as prebaked. But why do we need to say prebaked? This system that I am defining to you right now is the prebaked anode, but there are technologies where the anode need not be prebaked and we will see those in a moment. Let me see if I can give you a picture. Let us see this picture.

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This picture is taken from the Internet. This is the aluminum plant and these are the … if I can draw a line here… we call them as potline because here, we have a series of series of electrolyte pots. I can also show you perhaps a little bit….

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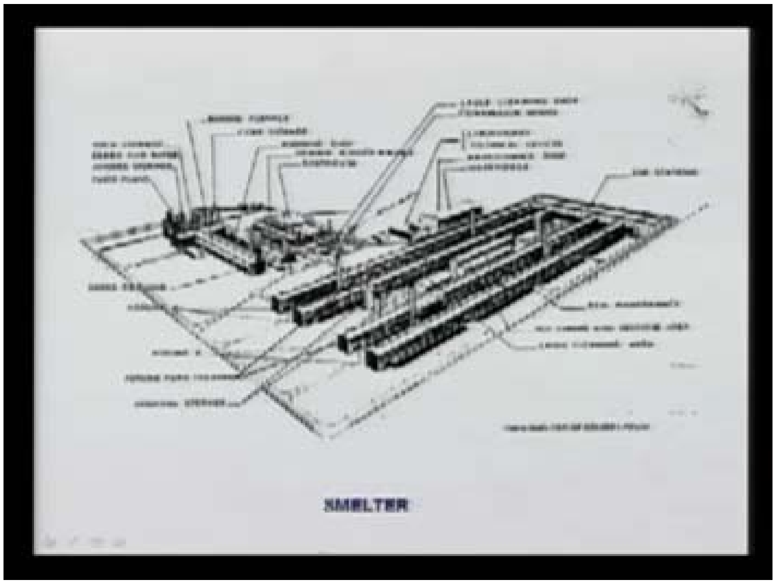

SMELTER

Again, this is more of a schematic.

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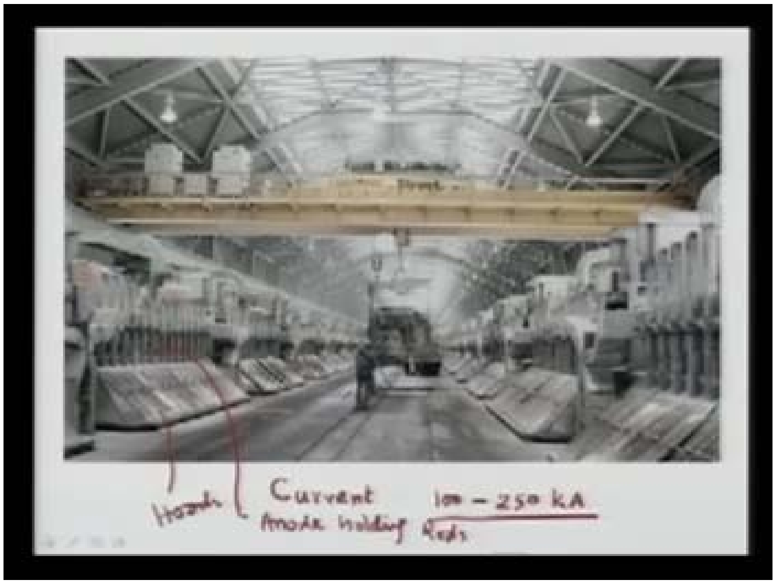

This is a picture from the inside. What you see here are the various electrolyte cells and the whole thing is connected in series and current is being supplied. To give you a little feel as to how much is the current it needs, the current can be anywhere from 100 to 200 or 250 kiloamps – this is to give you a little feel. The regular power supply that you see in houses is hardly 5 amperes or 15 amperes, but the kind of electrical energy that we need to produce aluminum is a huge amount. The current supply is here and as I explained to you earlier, these are the covers or hoods that can be removed.

These are the anode holding rods and then whatever the operation that needs to be done, the crane is moved. As you can see, there is a big crane here that moves through the pot room and the operations are done in [45:39] pot. You also see that some of the operations can be done by opening the hood here and there is a machine that can also be hooked to the crane. You can also see the dusty conditions and emissions. We will talk in a moment about those emissions.

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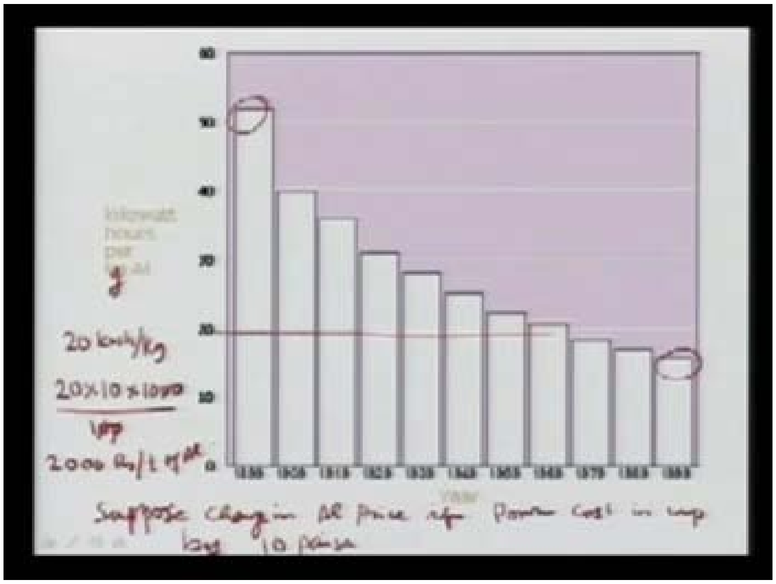

This is to give you a little feel of how much energy is used up in aluminum making. This also makes sense because whatever the energy, the electric energy that we make, that is also a source of air pollution. The success of the operation of the plant both from the pollution point of view as well as from the production point of view is in the energy that you consume. In this little figure you see, this is the kilowatt hour of the energy that is used per ton of the kilogram of aluminum produced. You see here the earlier processes that used huge amount of energy (Refer Slide Time: 46:39). There have been more and more technological developments and the energy requirement has been brought down significantly. A company that can produce aluminum with less energy consumption or keep the cost of energy low will have profitable aluminum production – you can see that here and you can also estimate. Let us quickly do that.

Suppose you want to see the change in the aluminum price if the power cost goes up by 10 paise – small amount of 10 paise. Suppose your plant is operating at these conditions and you are using 20 kilowatt hour per kg, let us say, the cost that will go up will be 20 into per unit 10 paise is up, this is so much paise and then you want to find out per ton, so you multiply this by 1000 and divide by 100, because you want to get in rupees. This goes off in there and then you have Rs. 2,000 per ton of aluminum. I think we did it correctly. This is just for you to see that if the rise in the cost of electricity is 10 paise per unit, it may result in the cost going up for aluminum by about Rs. 2,000 per ton – that is a very very significant amount.

Let us now talk about anode breaking. If you recall, in the aluminum production, we had the electrolyte cell and in the electrolyte cell, there was an anode. The anode was continuously consumed because the oxygen was consuming the anode and finally what we were producing was CO_2 and oxygen – CO_2 and CO sometimes. We need to have the anode making as well – anode making is an integral part of aluminum production.

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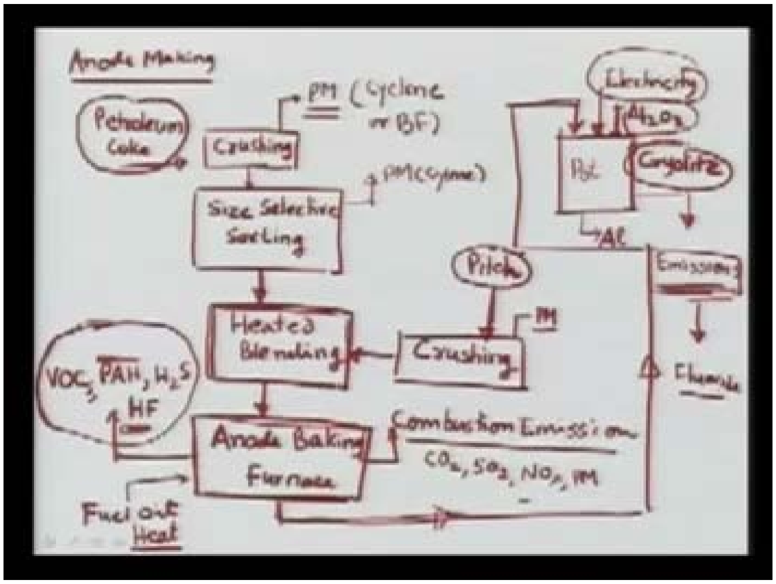

We will discuss here the flow sheet that you see here. I will go with this flow sheet to explain what anode making really means. As you can see, the anode is made of carbon. We start with petroleum coke that we get from refineries. This is the solid form, this is crushed and the moment you do some crushing, particulate emissions are there – you can again see dust emissions and they need to be controlled through either cyclones or bag filters.

Once the crushing is done, it is very important that when we are making the anode, we need to make the anode in various sizes. We have a process called size-selective sorting as we do sieving, for example, to sort the various particle sizes – it is essentially sieving that we do; here also, the sieving is done and lot of particles come out of the petroleum coke. Again, the particulate matter must be removed by the use of cyclones. Then, once the selective size sorting is done, we need to finally make the anode, but the petroleum coke does not have the quality of binding itself and so, we need to put some binder. That binder we call as pitch and it can again come from the petroleum refinery or from other sources.

You see here that pitch is used for binding the petroleum coke to form the anode, but before the pitch can be used, pitch is processed through the crushing operation as you can see here. Again, the moment you see crushing, there is lot of particulate matter emissions and after the crushing is done, it is mixed or blended with the petroleum coke, which is already in the fine particulate form. Then, you supply some heat here as you can see because both are made viscous and then we get the heated blending here.

You have reasonably good paste that you are getting here but then, we cannot stop the operation here because we need to make the prebaked anode – the baking has to be done. What we do is we pass this material in a particular shape to the anode baking furnace. Here, you see the anode baking furnace – I have drawn that for you. You need to supply the heat for baking. The heat is supplied through the combustion of fuel oil, for example, so let us write here so that there is no confusion – it can be fuel oil or heat, but remember that the flue gases from the fuel oil do not come into direct contact of the paste anode – otherwise, the anode will start burning itself; it is indirect heating – at one point, there is a block of anode and there is another conduit or pipe that is carrying the heat and so indirectly, the anode is heated. Once it is heated, it is baked and once it is baked, then it is in the solid form. But in the process of baking, a lot of emissions occur. One of the emissions will be combustion-related emissions that you can see here. Why combustion-related? It is because we are burning the fuel.

What you will get here is… do not forget that you will get CO_2, you will get some amount of sulfur dioxide because sulfur can always be present in the fuel oil – you can see that here, there can be a little bit of NO_x also [53:33] controlled firing – you can get some NO_x also, not so much but at times, you can also get particulate matter. That is one side of the story. The second side of the story is that we are having coke that is here (that came in the process) and we are having pitch that came in the process here and so, there also, impurities are emitted. Otherwise, these impurities will go in your cell in the potline or in the pot. Once it goes in the pot, the quality of the aluminum in your aluminum production will go bad.

What happens is that once you are heating it up… I am not calling it firing but the anode is being heated up in the paste form. Whatever the volatile organic compounds, those VOCs will be emitted. VOCs can be benzene, toluene or other organic compounds that are in the volatile phase and they will be emitted. They are very very harmful. From this process, some of the PAHs can also be emitted – polycyclic aromatic hydrocarbons. Some of the H_2S will also be emitted – some hydrogen sulfide, because coke will have high amount of sulfur and the pitch can also have sulfur. Apart from that, some amount of hydrogen fluoride acid, HF can also be emitted. One can ask why HF here or the fluoride.

As you recall, the used-up anodes are also recycled in the anode baking plant. As a matter of fact, these anodes were in the pot and we are using lot of fluoride in the pot. The fluoride will somehow become part of the used-up anode and once they are brought up and used again, some of the fluoride emission can also take place. You can see here that this has a very high potential of air pollution. Not only high potential of air pollution but this also has the potential for very carcinogenic, toxic compounds that can cause serious problem in the environment. So you can see the emissions from the anode making. You can also see that this causes problems with respect to emission of carbon dioxide, sulfur dioxide, NO_x and some amount of particulate matter. Once this anode baking is done, as you can see here, these things are supplied back, they need to be taken to the pot where they will be used in the electrolysis and form the anode. If I can say this is my one pot here, the anode is used up here.

What else do we need? The electricity needs to be put in, here is the cryolite and it needs to be put in and so is the alumina, which constantly needs to be put in. One side, the process will give me aluminum, no doubt about it – that is what is my objective, but this process also gives me some kind of emissions as you can see here. These emissions are very…. I will explain to you in a moment these emissions are generally fluoride emissions if I can go to the next slide. We will see how these fluoride emissions occur. Having said that you need an anode baking plant, some of the technologies do not do anode baking here.

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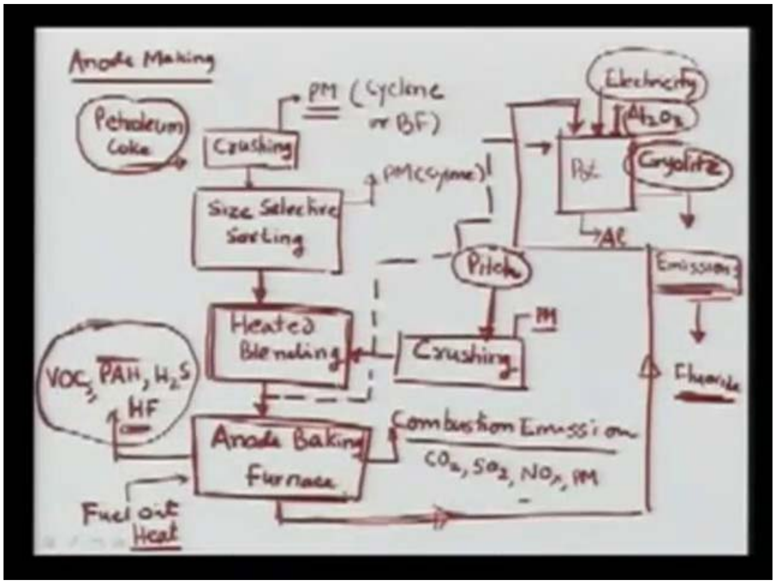

I can show you that right from this thing, let us make this line as a dash, they do not do anode baking but they use the paste and then this paste that I am taking up is put in the pot. Some of the technologies avoid anode baking itself. Why do they avoid anode baking? The argument is that the temperature is high in the pot and that this high temperature itself will be enough to make that paste in the solid form. That technology where they are using the paste but not prebaked anode is called Soderberg technology. What I will do is I will remove the stuff here.

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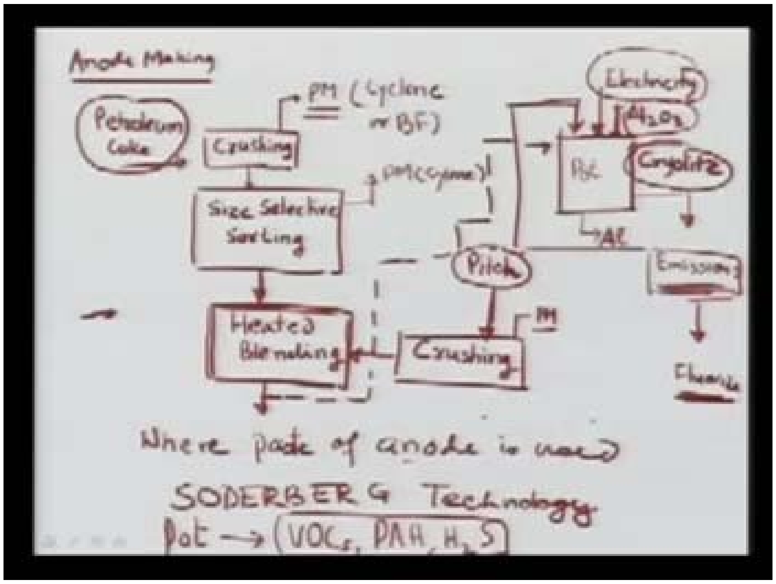

You see here in this process, we are not baking the anode previously, but in fact, the paste itself as you see here in the dash form is sent to the pot. This method where the paste of the anode is used is called Soderberg technology, based on a technology given by a Norwegian. What you see in the Soderberg technology is that whatever is the paste of the anode, it is directly put into the pot and then hopefully in the pot or in fact it is is solidify and the baking takes place inside the pot – we are using the heat available in the pot to do the baking of the anode.

But in the process, once we are doing the baking here in the pot room, the emissions will also be that of the VOCs because the baking is taking place inside the pot and so inside the pot room, there will be emission of VOCs, PAHs and some H_2S. This becomes a very serious problem in the pot room but right now, people are using more of prebaked technology. So far, what we have seen is the aluminum production. The first is alumina production, then we did aluminum production and we went through the electrolysis process. In the next lecture, we will look more into the emissions, how they happen and how they can be controlled.