Non-ferrous Extractive Metallurgy

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Lecture No. # 15

Extraction Aluminum

Friends, I am now going to spend a few lectures on aluminum extraction, and I will put a lot of emphasis on aluminum, because it is an extremely important metal, not only a very important non-ferrous metal as such. But it in context of India's economy, aluminum is very important. India is fortunate that India has a lot of deposits of bauxite aluminum ore.

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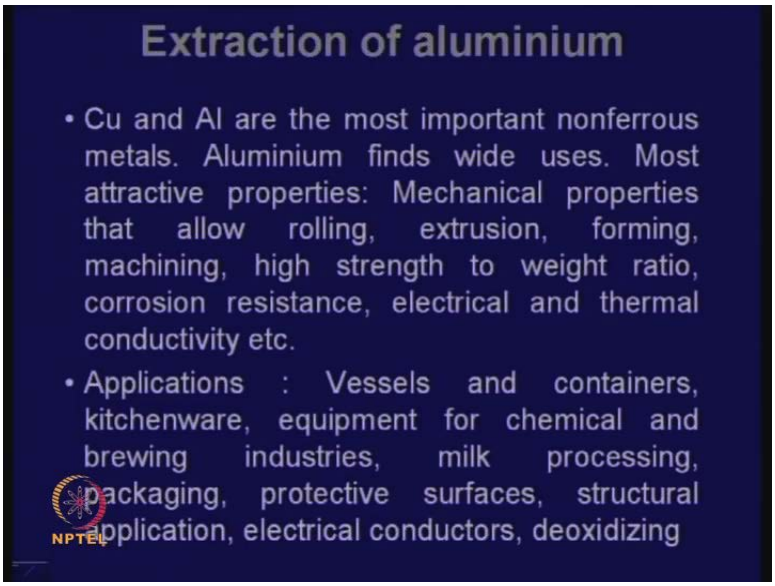

This is a plus point, the minus point is that aluminum extraction is extremely energy intensive, because the metal is obtained by electrolysis of alumina dissolved in a molten salt called cryolite. Some 40 percent or more of the price of aluminum will pay is the price of electricity, and the electricity can come from thermal power plants or from hydroelectricity. Unfortunately India is not rich in terms of energy, you see energy shortage is everywhere, energy is required for the industry, for domestic consumption, for running pumping a water, for irrigation all kinds of things, aluminum industry cannot

have an easy access to as much energy as it likes, and yet we have aluminum plants crying for expansion in our country, because alumina is available, personal is available, knowledge is available, successful plants are running which wants expansion, labor force is available, all conditions available, but power is not available, some of our successful aluminum plants are trying to set up aluminum plants abroad, some may have already come up, like some in Vietnam; Vietnam has is a surplus energy country they produce lot of hydroelectricity in where that river going through.

Or so in places like Dubai energy is no problem at all, there is already a plant called Dubal, Dubal aluminum company, they can import all the alumina they want, they can import all the technicians they want, they have the energy they say they produce the aluminum. In our country we have everything but not the energy, but India has to find an answer to this question and how do we find the answer, now there was a time when India depended on cheap electricity from hydro projects, remember that Hirakud dam near Hirakud dam there is also an aluminum plant, the idea was the dam to produce hydroelectricity and give it to aluminum plant, some aluminum plants were then allowed to set up their captive power plants, again based on coal thermal power plants, and they could use all the electricity they produced and if they had a surplus they could give it to the grid, Nalco national aluminum company in Orissa they have their own captive power plants.

But now there is a human cry in this world about thermal power plants, because they generate carbon monoxide, carbon dioxide, they generate global warming gases so people do not want thermal power plants anymore, you cannot setup hydroelectricity projects either, because you want dams, incidentally you should know that India is utilizing some 50 percent of the hyder potential, in theory if you could build more dams it will cost money all right. But then you could produce electricity with no problems as relates to global warming, because there what you do is water flows runs generator you generate electricity, but then setting up hydroelectricity hydro projects are become a problem, because many people do not consider them to be safe, they think once you have those dams built they can trigger earthquakes, but more important when you build dams firstly you displace a whole lot of people, there is a question of the rehabilitation and when that word dam collects the water it submerges huge areas.

It can submerge villages, archeological sites, old temples, heritage buildings, roads, rice fields whole kinds of things, so naturally many NGOs as well as government institutions do not favor building of more dams, you already know the fewer that we have about Sardar Sarovar dam there are also few wrote about other dams, but hydro electricity is one of the cheapest ways of producing electricity, not many people know that only a few years ago china has build one of the biggest dams ever, and that is generating a substantial part meeting a substantial part of the energy needs a vast areas of china.

Now, during the process of building that dam also many people were displaced, nearly half a million may be more, but china has a different kind of government, they can take a decision they can implement and perhaps they can argue that for better good of the country, for good of more people, perhaps they are more efficient in rehabilitating the people who have been displaced.

But in our country I do not think we can build more hydroelectric dams, we still have to wait on thermal power plants or power plants from liquid fuels, the other option is nuclear metallurgy, nuclear reactors, now a lot is said about that but still they still long way offered in a future, you know as of today only about 3 or 4 percent of energy need of the countries met by nuclear power plants, more than twice that is being met by wind mills which many people do not know, wind power is progressing very well in our country, and the wind power also has its disadvantages it is seasonal and it cannot guarantee certain output all the time, when the wind blows when the circumstances were right they generate electricity part of it is consumed part can go into the grid etcetera.

So, the basic contention that I have to say is that we have to aluminum ore, but we do not have sufficient power for rapid expansion of our aluminum plants, but that is a different matter, I am not here to discuss that but I thought you should be aware of this problem, I am here to discuss how is aluminum produced from bauxite, before I go to that I should say why aluminum is so important?

You see aluminum everywhere perhaps in future you see aluminum in many more places, look at the cars we drive on the roads everybody wants that they should be more fuel efficient, how do you make a car fuel efficient? Why is a Maruti or a Nano or any small car so much more fuel efficient then the old age ambassadors and other cars? It is not because they have a more efficient engine modern engine that is one reason.

But the basic reason is on the hold they are lighter they are smaller cars, when the body is lighter it needs less power less energy to move it, not so much when you are going on a plane or you are cursing, it is more important when you are climbing a hill when you are accelerating when you are starting from 0 speed to certain speed, that is where the weight counts, can we not use aluminum and replace steel by aluminum so that the car would be lighter for the same size.

Now, many people think this is not possible because the aluminum apparently looks to be not so strong a metal, like if you take a strip of aluminum, take a strip of steel you can see steel is seems much stronger then aluminum, but what if you make the aluminum thicker, it will become stronger. Now, the strength by weight ratio for a aluminum is much more than that of steel, as of now in aluminum is almost 25 percent in weight in density steel is four times higher.

So, if you make the aluminum strife thicker, for the same weight and dimensions aluminum piece will be stronger, or in other words if you want to keep this strength same a weight of aluminum required to or get that strength would be less than the weight of steel will get, so there is today competition between aluminum and steel, still steel has an advantage because it is easier to produce, it is cheaper to produce, it costs less.

But aluminum has the its potentially more advantages, because it has a higher strength bio weight ratio, it has another advantage it resists corrosion where steel does it, so the ferrous metallurgy is trying very hard to produce steel with low alloy content, they occur low alloy high strength steels, where for the same dimension strength will go higher, the idea is for a lesser weight they want to acquire higher strength, so as to compete with aluminum if there is such a competition right now there is it, but aluminum is finding many uses where strength is not that important to criteria, like say you see the windows, window frames, door frames being made of aluminum, because the aluminum having a low melting point is easier to cast, it is easier to be given different shapes.

So, aluminum has the advantage of formability, advantage of low melting, has the advantage of corrosion resistance, its only disadvantage is it needs too much of energy for production as of now, nobody has been able to come up with the process where you will produce aluminum which substantially less energy. So, let us go to what I have written here, that copper and aluminum are the most important non-ferrous metals,

aluminum as I have just mentioned finds wide uses, most attractive properties are mechanical properties that allow rolling, extrusion, forming, machining, high strengths to weight ratio, corrosion, resistance electrical and thermal conductivity these are also advantages, I missed out in the beginning.

Accordingly if large number of applications, you see vessels, containers, kitchenware, equipment for chemical and brewing industries, even milk processing packaging, it is also not a toxic substance means they will keep milk in aluminum container and milk will be safe. So, you will see that aluminum containers used by our milk men to transport milk, alumin also are used in processing packaging aluminum foils for example, protective surfaces there are structural applications and it is also used in electrical conductors.

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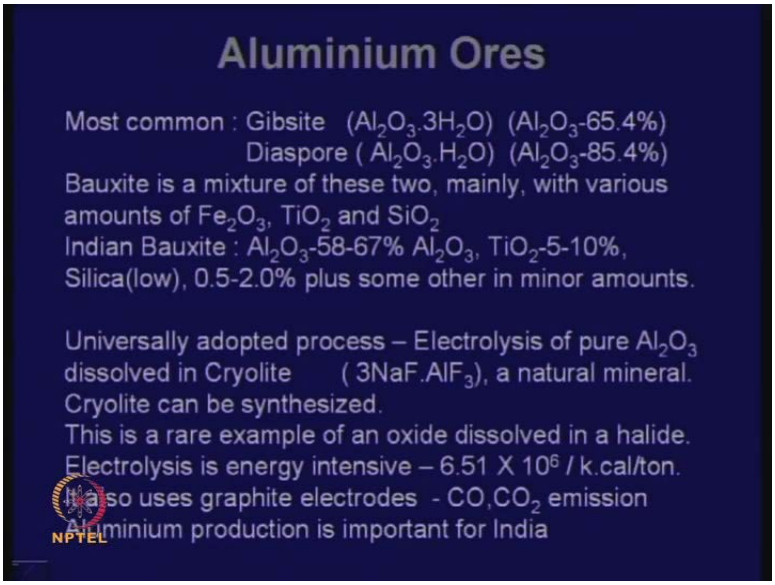

Then there is applications in metallurgy in deoxidation, only we have oxidized steel you add aluminum to remove that oxygen from steel, so oxygen aluminum has a wide application range, in structural applications it is potentially very important, because strength by weight ratio, and many people have given calculations to show that even today if you make a bogie, say a bogie of a locomotive of aluminum same dimension, same strength it will be thicker of course, it is going to be much less energy consumer consuming transportation.

And after several years it is going to save your energy, in the beginning you require more energy to produce the aluminum required to make that bogie, you do not recover the money immediately, but because it is lighter mind you it is equal to strong but it is lighter, less fuel will be require to for its transportation, so you will gain in transportation energy cost, after 6, 7 years you recover and then it is gain all the way. So, some people called aluminum metal a energy bank, that is from where you can recover energy profits in the long run, unfortunately the world very often is not able to see things in a long distance vision.

What we how is called a visual horizon? Suppose you have a car and somebody says that I will give you a gadgets it will cost you some money, but you will make the engine very efficient, but after 2 years you will recover the cost, chances are people will not buy that, because the subjective horizon means for the subject to think in that long term is absent, if I tell him that it will cost 2000 rupees you fixed that after 2 months you will recover that money, and then you continue to get a benefit they might buy it, but if you tell him your subjective horizon is 2 years which means you spend some 10000 rupees now you slowly begin to recover money after 2 years make break even and after that you seen advantage people are reluctant, because we do not have a long subjective horizon.

So, even though we may be educated we may know facts we may have the information knowledge, people would be reluctant to invest in aluminum in a big way assuming accepting that it will give the benefits after 8 years only, that is another reason why it cannot find immediate application in many places. So, aluminum has to improve its act, it has to come up come down cheaper, it has to consume less energy, it has to make itself more attractive, it is attractive already,

And mind you its corrosion resistance it is a fantastic property, aluminum will not be corroded you leave it in air for months years it remains as it is, why it remains as it is because you know in theory alumina aluminum becoming alumina is a feasible reaction, but kinetically it is not feasible, because the initial oxidation and nitridation puts a coating of aluminum nitride on top of aluminum, and further reactions does not take place, so kinetically it is not allowed, there is thermodynamic feasibility, it is not true for more steels unless you go for stainless steel which is much more expensive, most steels you corrode.

So, aluminum is a metal of their future, if only the energy prices came down, if you learn to produce aluminum using less energy, nobody can stop aluminum from competing very effectively with team. Where do we get aluminum from? The most common sources of aluminum are written here, they are gibbsite and diaspore, gibbsite is written as Al 2 O 3, 3 H 2 O means in the molecule there is more water, it has 65.4 percent aluminum theoretically, and diaspore is aluminum oxide containing less amount of water in the molecule, and obviously aluminum percentage is higher, now you might be tempted to think that because diaspore has more aluminum, it is a better ore fact is that is not so, gibbsite is a more attractive source of aluminum.

Because eventually we have to leach this ore by a leachate sodium hydroxide, and that does not leach diaspore very effectively if it is very difficult to leach, they one with more water it is easier to leach, therefore, gibbsite actually is a more attractive raw material. By bauxite we generally mean something which is a mixture of these two, some gibbsite some diaspore with various amounts of other oxides, like iron oxide Ti O 2 Si O 2, so Indian bauxites contained 58 to 67 percent alumina, 5 to 10 percent Ti O 2, low amounts of silica, plus some other miner amounts of other things, and it is mixture of diaspore and gibbsite.

Now, there are some deposits in India which have that verity diaspore, aluminum content very high, but they are not technologically very attractive, because they are not very easily leachable, people will rather go for gibbsite which as lower aluminum content. Now, the way aluminum is produced is that using this bauxite ores which contains alumina along with other oxides, from this we produced pure alumina, now for that we need a hydrometallurgical process, alumina would be leached by sodium hydroxide solution and aluminum will be taken into sodium hydroxide solution as sodium aluminate, most of the other oxides like Fe 2 O 3, Ti O 2 etcetera will not go into solution they will remain as insoluble's, when the solution is taken out this insoluble's form what is known as red mud, this red mud is a big new sense of the aluminum industry, and one of the biggest environmental issues in today's industry.

The other one is fly ash, that when you produce power from thermal power plants, coal has a ash from the carbon part of coal you produce power C O C O 2, what is not combusted, is left behind as ash which is oxides alumina, silica etcetera, that fly ash is a problem, people are trying to use it that is one problem, and in the aluminum industry a

huge amounts of red mud that are produced, and you will see how much of red mud is produced. You can easily find out I have said that alumina is 58 to 67 percent Indian bauxite, Al 2 O 3 is 5 to 10 percent, I have forgotten to write Fe 2 O 3, Fe 2 O 3 is about 40 to 50 percent they guessed, so 30 to 40 percent so almost a third or more of the alumina you take will produce that insoluble mass, they are simply deposited at one place, till today in spite of hundreds of r and d project nobody has found a full proof method of using red mud, they say that in the west indies which has a thriving aluminum industry every year some 7 to 8 soccer field size areas are used to dump red mud, which will be many feet high, they are simply dumped in dams and they are they rest there, hoping that someday we will find a proper use for that red mud.

In India also where red mud is where aluminum leaching takes place huge land areas are taken simply for dumping these insoluble mass red mud, in theory red mud actually is a low grade iron ore because 30 to 40 or even more percentage of iron is there in that red mud, may be in some other countries where there is no iron ore they will they will think this is very attractive, but is has a problem because we do it has come out an alkali leaching processes it contains alkalis residual alkalis, and when you have a residual alkalis in a material it becomes very unsuitable for use either in the blast furnace or as a building material, because alkalis are corrosive substances, even if you are able to build some kind of a tiles or bricks and other things for this red mud alkalis will create problem, unless you remove the alkalis by some means.

I will come to a detail discussion of use of red mud towards the end of this course when I discuss environmental problems, but let me you hint let me just mentioned one tremendous idea and that has been proposed by the American aluminum company Alcoa, Alcoa has suggested a process which will kill two birds with one stone, see there are thermal power plant generating power for the aluminum industry, you are generating C O 2 there, the C O 2 is a culprit for global warming, climate change and there are lot of work going on how to take care of the C O 2, where to dump it, how to store it, what they propose is take that C O 2 put it in the red mud to neutralize the alkali.

Because C O 2 is acidic when you put it in the red mud it neutralizes the alkali they will produce carbonates, and then you get a mass which is ideally suited for many applications, may be building materials maybe we can get out of that artificial rocks to be used in a river side artificial coral reefs and many other things, good in theory but

there is a problem again, the problem is very often the thermal power plants which generate power for the aluminum industry, aluminum electrolysis which far removed from where bauxite is leached for aluminum production.

So, how do they come together, this is the problem we have in Orissa, and say analko in a place called Damanjodi that is where you are producing alumina red mud is there, far away in Andhool near Orissa Bhuvaneshwar is where aluminum electrolysis is taking place power plant is here, had them in closer you can think of that C O 2 going to the red mud, but any way that are answers to this questions or I will say these are the contradictions in the industry.

Anyway I wanted to say that the impurities that are there in bauxite are critical, they cannot be disposed off easily they will give rise to red mud, what it universally adopted root to go to for aluminum production, the root is take bauxite leach by sodium hydroxide solution and very often this leaching is done in an autoclave under pressure, so that you can go to a temperatures much higher than the normal boiling point of water, to show that you can accelerate the leaching rate, you get a leach licker, from there you precipitate the alumina, then this alumina will be electrolyzed, in a dissolved in a salt called cryolite, which is written as 3 N a F A l F c or N a 3 A l F 6 it is a natural mineral it can be synthesized also.

Now, this is a very interesting example, generally oxides do not dissolve in halides, halides dissolve in halides, oxides dissolve in oxides, it is a very rare example of an oxide dissolving not completely to some extent in a halide, why halide as a solvent is important, because alumina can dissolve in a slag, but slag will be viscose thing it will not be easy to electrolyze, where as cryolite is a salt in a molten state around 982000 degrees, alumina will dissolve in that will electrolyze to get alumina, it is very energy intensive about 6.5 into 10 to the power 6 kilo calories per ton is required. It also uses graphite electrodes so it will produce C O C O 2 emission problem, there is no answer to this problems people are trying to find the answers, and I will try to tell you what kind of answers people are looking for.

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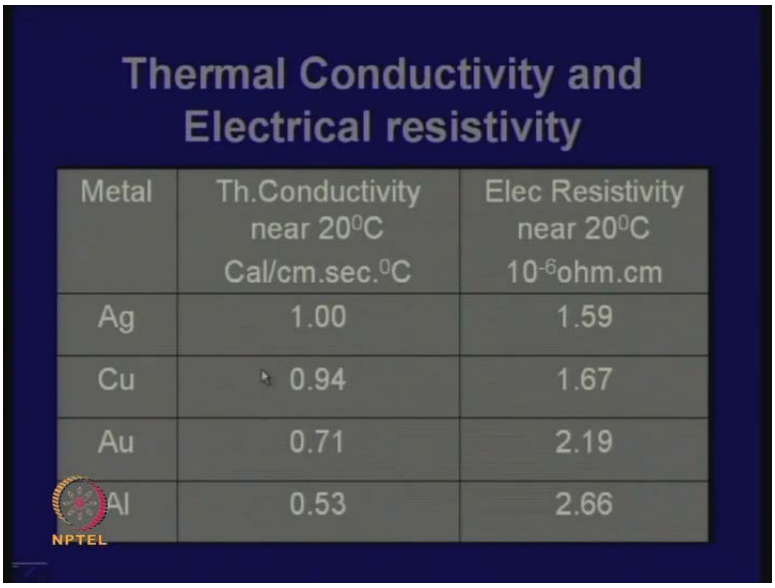

Now, I mentioned earlier that aluminum has an advantage, has several advantages over steel, one is high strength by weight ratio, second is corrosion resistances, and this is the third one, it also has high conductivity, electrical conductivity as well as thermal conductivity. If you compare the thermal conductivity, then nobody can beat silver; also in electrical conductivity nobody can beat silver, I should have plot shown both the conductivities, but I have put here thermal conductivity and electrical resistivity, so conductivity will be reverse of that. You see if you see the as a conductor - thermal conductor, silver if it is taken as a 1, copper is almost there 0.94, gold is 0.71, aluminum is 0.53, steel will be far below, in terms of electrical conductivity, the silver again is on top, below that is copper, below that is gold, below that is aluminum.

So, aluminum is a good conductor electrical electricity, and many attempts have been made to replace copper in many electrical application by aluminum, because copper at one time was very expensive, perhaps you know some 20, 30 years ago India went through a phase where this slogan was import substitution, they do not import materials substitute with indigenous material.

Now, we were importing copper so the argument was why use copper use aluminum instead, save foreign exchange, and many researchers worked on it they developed alloys also, like one conductor was developed called P m 2 conductor, which replaced copper conductors overhead wires, many other applications even transformers they tried

aluminum in place of copper not exactly pure aluminum, but aluminum alloys, but there is a catch again, copper can be very easily joined they can be very easily you know joined together, but aluminum cannot be so easily joined, because if you try to join aluminum at the joint aluminum oxide may occur because the aluminum oxide founds very easily a stable oxide.

So, you have to need a an inherit environment to produce a joint where aluminum oxide will not be rare between 2 pieces, this sort of problem is not there with copper wires where a flux will do you can join 2 copper wires very easily. So, even though we tried out in this country we have abandoned that idea, now that slogan is also gone, the now today we know the best policy is that use the metal that is best suited of the job you have attend, and do not try to bring this substitute or that substitute, but there in the long run that does not pay, look at Japan, they have no raw materials they only have their brain power they are importing everything they import the best material, the best material exactly suited for the job they want to do.

So, today nobody wants to bring in aluminum again for electrical application, aluminum or other applications so we rather produce copper or we buy copper, so we have abandoned that, so the research on aluminum a conductors etcetera are not as rigorous as they use to be at one time, there may be need for researching this area for some very special with applications, anyway coming back to this aluminum again is attracted because of its conductivity values.

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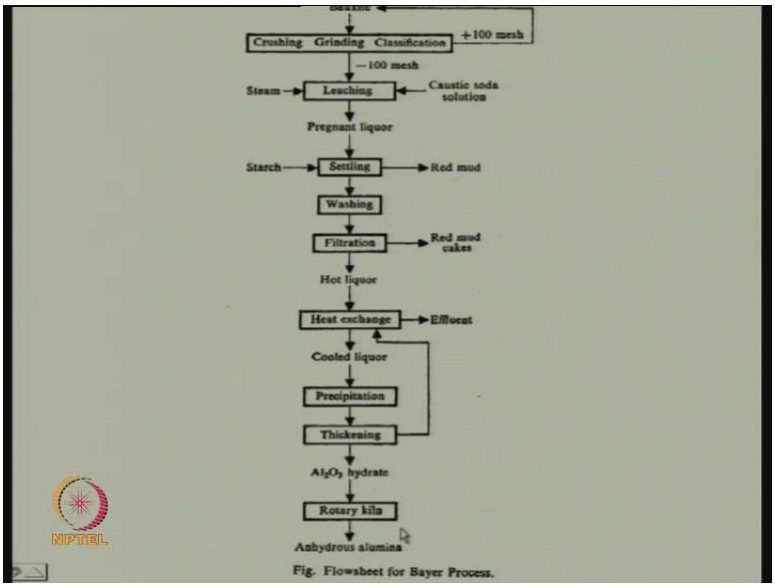

Fig. Flowsheet for Bayer Process.

Now, let us come to the question of leaching of bauxite, the process is called Bayer's process, now in the history there are some very interesting coincidences, in the case of aluminum it is quite remarkable, that in the same year somewhere in the second half of 19 century I will mention the year little later when I remember, 2 gentleman in two different continents came up with the same process, Hall in the America and Haroult in France.

So, today the electrolytic process carries both the name Hall Heroult process, somewhere I have read that these two gentleman happened to die in the same year also, but I do not have the facts with me, but Hall and Herould propose the same process, in the second half of 19th century where they proposed electrolysis of alumina dissolved in cryolite, now fortunately just a decade or two before that electricity generation had become in reality, there was no electricity in the early part of 19 century, there was no question of producing aluminum in large quantities, may be aluminum could be produced in grams by very special techniques, I have heard stories of some emperor's who served their guests ordinary guests in silver and gold plates.

But he had some very special guests who were other kings, he served them in plates of aluminum, because aluminum was so expensive at that time, it was produced in a very small scale, everything changed when electricity became available in large scale, and when electricity became available Hall Heroult process became industrially very

attractive, because then you pass electricity through a solution of alumina in cryolite we produce aluminum, that process is still continuing this 130 years old or something which are modification we are not going to replace it.

Now, that is not enough, another very interesting coincidence took place just about that time, aluminum electrolysis is required pure alumina which was to be dissolved in cryolite if so happened a gentleman call Bayer came up with a process just about that, as to how to produce large amounts of pure Al 2 O 3 from bauxite that is called Bayer's process. So, three things happened in more or less in about a same time electricity availability, Bayer's process, and then Hall and Heroult process, and that established aluminum as an industry or metal.

Let us start with Bayer's process, Bayer found a process of producing pure alumina by following this route, now again I am saying these are this is something called a flow sheet as to how you go from one step to another, I will show you many flow sheets you do not have to remember any, but I need to give you these flow sheets, because that is how processes are summarized, but I will try to tell you the why is behind this process and some stories as I just said.

We start with bauxite it will be crushed ground and there will be classification, the idea will be to bring it to minus 100 mesh then it will be leached, I have said steam and caustic soda solution, which means it is goes up to above 10 degrees, why above 100 degrees, because the higher the temperature a faster will be the leaching, but if you want to go beyond 100 degrees you need autoclave, means pressurized vessels with no leaks they are completely covered under pressure, and today there are pressurized vessels which will operate under 20, 30 atmospheres so that the boiling point goes up to above 200 degrees, so practically they have become bombs, if anything happens if there is an explosion it is a bomb, so it is a autoclave under high pressure normally people may not go up to that.

But many atmospheres are common 130, 140 degree which is common, so you need injection of steam under high pressure to carry on this leaching at a higher temperature, and then finally, you get what you call a pregnant liquor, pregnant liquor means a liquor which contains some substance that is allowed to settle, settling is helped by adding starch, starch is a settling material, is it is a surface phenomenon of the thing that want to

settle with (( )) which settles them, what settles is red mud see in settling tank we will separate red mud that is discarded, as of now we are not finding any use for red mud.

If some of you can come into this area you will find an extremely exciting area of research, research and development a commercial phase can come out of that, not that people are not working in a market in India there is a product from (( )) that they mixed with some polymers and red mud's they make pipes. So, red mud is a filler material in some polymers, red mud has been used in making building materials in wood substitute, but nothing has come out in large scale in India, now after filtration we are getting a liquor which is hot liquor it will go to heat exchangers, because we want to recover the heat in the liquor, some effluence that will discarded, liquor will be cooled then we will there'll be a precipitation process, by cooling and adding some reagents we will precipitate alumina Al 2 O 3 hydrate, and that goes into a rotary kiln to produce anhydrous alumina which is ready for the Hall Heroult's process.

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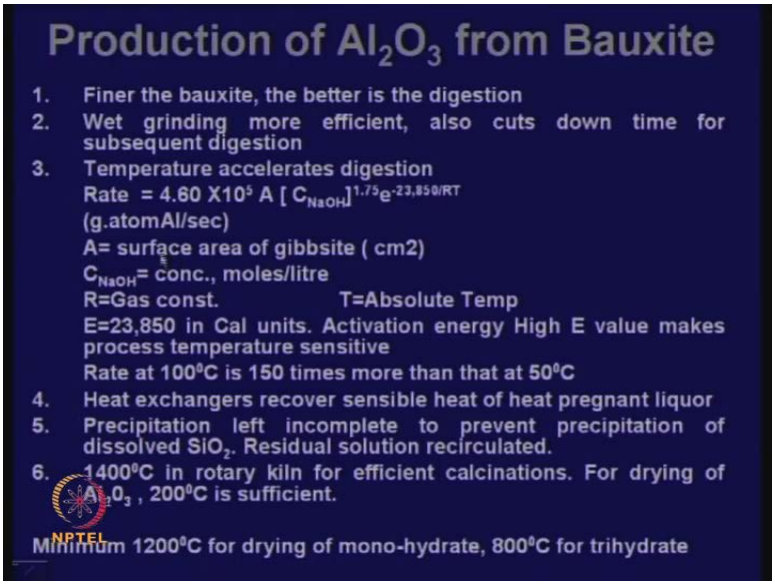

So, basically this is a process of a solid dissolving in a liquid, like sugar dissolve in a new water, we want to accelerate this process, and there are people who have worked almost their whole life on just this area called Bayer's process leaching part only, how to accelerate leaching? There are people who are working only on precipitation, how to precipitate pure alumina? Because this alumina will not only go for aluminum production this alumina would also find many other applications for example, in

toothpaste the base is fine alumina powder, alumina will go into many medicines, now their requirement are different what should be the particle size what should be the particle shape.

So, there are researchers who are working on precipitation of alumina in different particle ranges, different kinds of shapes, different kinds of purities, and this kind of research is going on in j n r d d c in Nagpur, Jawaharlal Nehru aluminum research design research development and design center, j n r d d c there a whole lot of people are working only on the leaching part, leaching kinetics, parameters, product characteristics, then product uses etcetera, we will not talk about use of alumina in other uses.

But in India remember we also produce alumina for selling in the market, some alumina fine is also exported, but bulk of the alumina that we produce is for the aluminum production, and that is where I am going to concentrate, now I mentioned it is basically a solid being dissolved in a liquid and so these are some of the things that should be understood very easily, finer the bauxite the better is the digestion, not only recovery with time but speed, weight grinding is more efficient like you know when you do an Ayurvedic medicine you prepare or anything you do in a motor you put little bit of water and grind grinding is very efficient.

So, when you are grinding bauxite is start with for subsequent leaching it has to be a weight grinding, then temperature accelerates the reaction we all know this, here is a equation that has been developed approximate equation the rate is this depends on concentration of sodium hydroxide obviously, the stronger the sodium hydroxide concentration more is the rate, and here it depends on temperature, if temperature is higher this will more, so this will be less, so this will be more. Now, this is the activation energy and this activation it is supposed to be very high actually, which means it is very highly temperature dependent, it is also dependent on surface area of gibbsite that is why it is called a means if you grind it more, then rate will be more.

Here R is gas constant, T is the absolute temperature, and energy activation energy in calorie units is high, and it implies that at 100 degrees the rate will be 150 times more than that at 50 degree centigrade; if you go to 150 degrees it may be 150 or more times faster. So, the higher the temperature higher will be the rate, but higher the temperature means more pressure you need you have to operate it hire better technologies. Many

people today argue that this is unnecessary risk taking and not a risk taking more expensive, because if you bring an autoclave that will operate under high pressures you need lot more expensive reactors, they will be thicker walls many fixtures and other things.

So, there are companies which operate with much lower temperature operations, almost with that autoclave they would rather go for very finer bauxite grind it much finer, use stronger alkali etcetera. So, this is an example of why a one company and other company may not to do the same thing, in India there are 4 or 5 aluminum companies, they do not have the same conditions for Bayer's process they have different conditions. But basically these are the parameters, now there will be heat exchanges to recover sensible heat from the pregnant liquor, because liquor that is coming out of this autoclave if the autoclave is operating an 150 degrees the liquor will be around at 150 degrees.

Now, we will first cool it down recover the heat and from the cool thing we will precipitate alumina, now here there is a trick now, when alumina is being dissolved in by Bayer's process it is not very selective, it is not that only aluminum will dissolve and nothing else will dissolve. Some silica would also definitely dissolve, so in the solution you have alumina, you have small amounts of silica also, now so one has to be very careful now, because if you precipitate alumina silica would also precipitate. Now, this is where a compromise has to be made between total recovery and quality, it has been found that when you start precipitating the adjusting p h etcetera first aluminum will precipitate silica will come later.

So, the idea would be to go for incomplete precipitation, which means you do not take out all alumina, but you take out alumina which is totally pure, because your fused salt electrolytic this is process will not tolerate impure alumina. If silica goes in there it is not going to get electrolyte, so which time it will deposit in the cell create havoc we do not want that we want purest alumina, so we need to prevent precipitation of silica and to do that will be by doing incomplete precipitation of alumina. Now, there is some alumina left what we will do will re-circulate that, so from what we are precipitating we take out alumina incomplete whatever is left will mix with the original thing

So that we are not loosing that alumina again we will try to get alumina, then after we have precipitated that alumina there will be at about 1400 degree centigrade would be

required and for that we need rotary kiln, for efficient calcination means it completely dry out remove all Al 2 O 3 you break everything aluminum hydroxide you completely break into l 2 O 3 and all moisture at 200 degrees is totally removed, minimum 1200 degree c for drying off monohydrate 800 degrees for trihydrate.

So, depending on precipitate if it is a monohydrate it is going to require higher temperature for drying if it is a trihydrate low temperature. So, these are the steps I hope you have understood that you have taken bauxite, you have leached under pressure using caustic soda, you got a liquor the insoluble's form red mud, the liquor is cooled heat is recovered from the liquor you precipitate incomplete precipitation of alumina, and that alumina under rotary kiln would finally do this.

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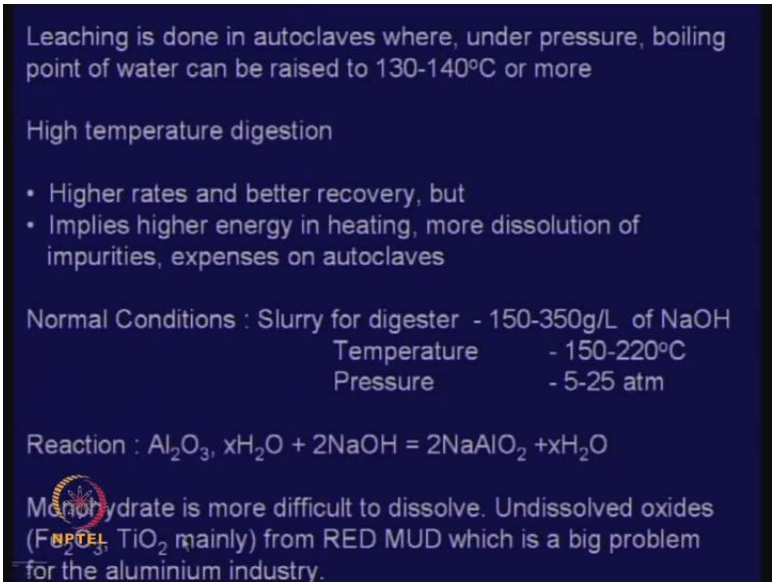

So, there are some contradictions that higher temperature digestion means higher rates better recovery, but higher energy in heating more dissolution of impurities also expenses in autoclave. Normal conditions will be 130, 50 to 350 gram per liter of Na O H, temperature 150 to 220 degrees, pressure 5 to 25 atmospheres, reaction is this, alumina 2 NaOH alumina; monohydrate is more difficult to dissolve; undissolved oxides Fe 2 O 3 Ti O 2 mainly from the red mud, which are big aluminum for the aluminum industry. I will stop here now, and I will proceed next time with the electrolysis area. Thank you.