Non-ferrous Extractive Metallurgy

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Lecture No. # 24

Extraction of Lead

We have been discussing extraction of lead from galena, and we have seen that it follows a very logical route, you take lead sulphide that is roasted to form oxidized substances lead oxide, lead sulphate etcetera and we do that in a sintering machine. So, that during roasting it get sintered also. We do not produce fine products, we produce particulate matter particles which are nice and hard which can go into the blast furnace. It is necessary, because the concentrate that is coming out of rotation is very fine. If we just roast it as it is then whatever you get will be very fine, we do not want that. So, the roasting is done in a sintering machine, Dwight Lloyd sintering machine, which is a continuous operation. So, from the concentrate we get the particulate matter sinters, which are suitable for going into the blast furnace.

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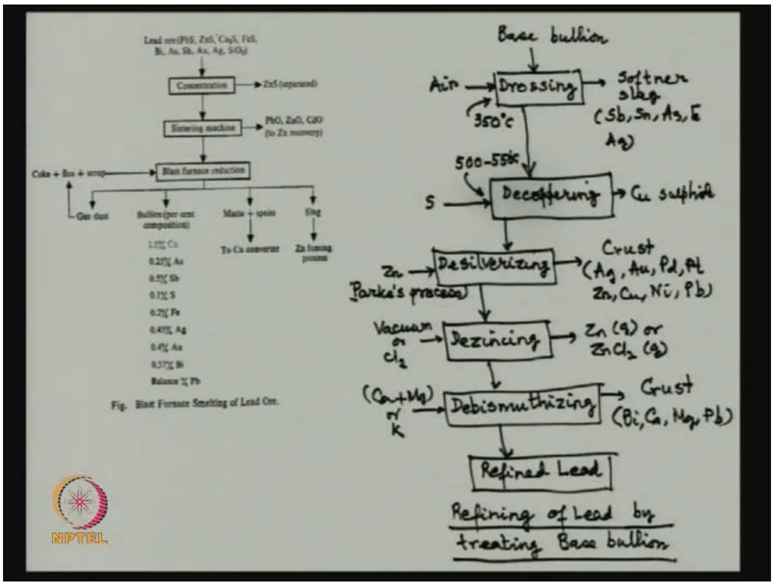

Fig. Blast Furnace Smelting of Lead Ore.

Refining of Lead by treating Base bullion

Now, if you look at the flow sheet this is what is happening that we start with a lead ore that is mostly lead sulphide which always contain some zinc sulphide, may be some copper also, definitely iron sulphide, other impurities, some valuable impurities after concentration most of zinc sulphide can be separated by differential flotation.

In the sintering machine now we are going to put, we are going to produce the blast furnace feed sinters, during the process some fumes will go out z n o, p b o etcetera that will go for zinc recovery and in blast furnace reduction process reduction by coke, we need to add coke plus flux plus some iron scrap for recovery of lead. We produce several layers on top will be a slag, this slag will necessarily contains some zinc and it as to be treated for zinc recovery.

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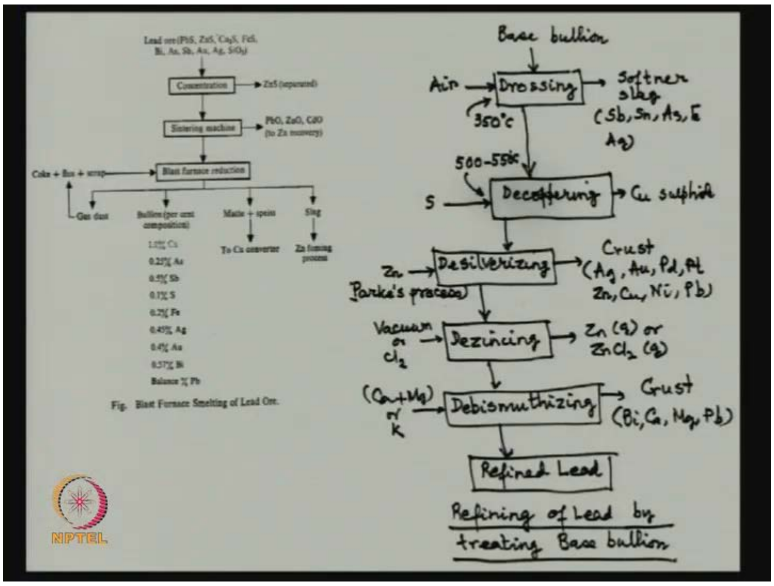

Fig. Blast Furnace Smelting of Lead Ore.

Refining of Lead by treating Base bullion

We will have a matte and spice, 2 separate layers or may be 1 layer, it has to go to copper converter. The main output we are aiming at is the base bullion of lead which will contain whole lot of impurities and the precious metals. Now, this base bullion is treated where there are some standard chemical treatment steps. They have been used for centuries and they have evolved out of trial and error, some I may have referred to earlier and or I will just quickly go through them now. First of all there is this step of dressing, you now the melting point of lead is very low 327 degrees, the base bullion is kept just above the melting point in a suitable furnace, air is allowed to blow mild air blast and continuously if it is stirred there are many impurities which will form oxides and float up and they are skinned off.

After that it will go to a slightly higher temperature 500 to 550 degrees, when sulphur is added copper is taken out as copper sulphide, then it goes to a desilverizing step, it is a very famous process called Parkes process which will come again and again in many metallurgical steps, there if you add zinc, then zinc takes out all this precious metals and forms a crust, solid crust separates out.

Then there may be excess zinc that we have added to lead. So, either the zinc is separated by vacuum or we can add chlorine and that chlorine will form zinc chloride which would also be a vapors, after dezincing it goes for bismuth recovery, the standard taking for removing bismuth is addition of calcium and magnesium or potassium. These forms intermetallic compounds with bismuths and a it will form a crust, it will go out, after removal of bismuth, zinc, precious metals, copper etcetera and all these you get a refined lead which will be the refined base bullion, this is the treatment.

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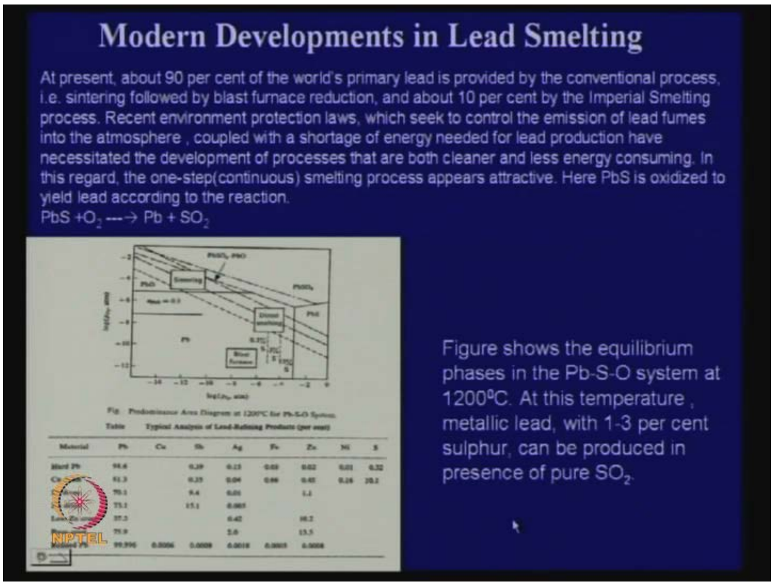

Modern Developments in Lead Smelting

At present, about 90 per cent of the world's primary lead is provided by the conventional process, i.e. sintering followed by blast furnace reduction, and about 10 per cent by the Imperial Smelting process. Recent environment protection laws, which seek to control the emission of lead fumes into the atmosphere , coupled with a shortage of energy needed for lead production have necessitated the development of processes that are both cleaner and less energy consuming. In this regard, the one-step(continuous) smelting process appears attractive. Here PbS is oxidized to yield lead according to the reaction.

$PbS + O_2 \dashrightarrow Pb + SO_2$

Figure shows the equilibrium phases in the Pb-S-O system at 1200°C. At this temperature , metallic lead, with 1-3 per cent sulphur, can be produced in presence of pure SO_2.

Now, people have argued that the blast furnace process for zinc for lead production although it is a convenient and well known process it has the drawback or potential lead environmental problems coming from lead. We may have electrostatic separators in the top, we can have bags to collect fumes, but still people have been looking for some alternate process.

Now, at present 90 percent of the world's primary lead is provided by the by the conventional process of sintering followed by blast furnace reduction and about 10 percent by what is known as imperial smelting process to which I will come little later. It is a process that is applied for simultaneous production of zinc and lead from concentrates which contains both zinc sulphide and lead sulphide and such concentrates are very common and we have imperial smelting process operating in Rajasthan in Khetri.

But now the recent environmental protection laws which seek to control emission of lead fumes into the atmosphere coupled with shortage of energy needed for lead production, dependence of coke etcetera have necessity of the development of processes that are both cleaner and less energy consuming. One way it will be less energy consuming will be if we combine the roasting, sintering and a reduction steps into 1 reactor.

If we can like copper production have continues production of lead in a reactor then of course, we will save on energy, the things would also be it will be higher technology, the this such a smelting process 1 step continues smelting process appears attractive and there the principle will be to directly go from lead sulphide to lead, not to an intermediate oxide sulphate and all that. Start with lead sulphide, go to lead. Like in the case of copper we start from copper pyrites concentrates go straight to copper and roasting, smelting, converting they are all combined.

In theory it is possible for lead I have given a phase diagram, but the this diagram is little more complicated actually I have shown in the equilibrium phases in lead sulphur oxygen system at 1200 degree centigrade. At this temperature metallic lead with 1 to 3 percent sulphur can be produced in presence of pure S O 2, you see it for yourself, but I would rather go to another diagram that in theory straight from lead sulphide, we can go to lead at around 1200 degree centigrade and it will contain only 1 to 3 percent sulphur provided we have very high P S O 2 value.

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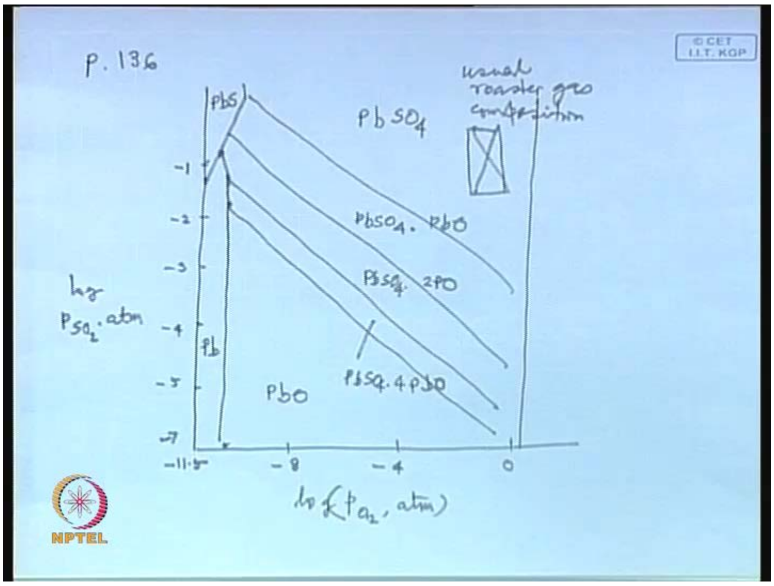

Now, you recall that in the very beginning when I was discussing general principles of extraction I had shown you a diagram, some typical diagrams for sulphur oxygen metal systems. I do not remember whether I have shown this diagram,, but diagrams are like this. Say for consider we want to see what will happen if lead sulphide is oxidized by oxygen.

Whatever will be the reaction you produce S O 2. So, we can actually analyze the equilibrium between different phases and draw these lines. I remember having drawn some lines also. So, typically it is not accurate representation, but if you plot a diagram at a given temperature between P S O 2 and P O 2 we get can get a boundaries of different phases, we can go from lead sulphide to P b S O 4, we can get from lead sulphide to P b S O 4, P b O, P b S O 4 to P b O, P b S O 4 4 P b O, only P b O.

In theory one can go straight from lead sulphide to lead also, provided you can control the P S O 2 value and that is what is the aim of some new developments that people are trying. Of course, they are not be very successful now their commercial processes.

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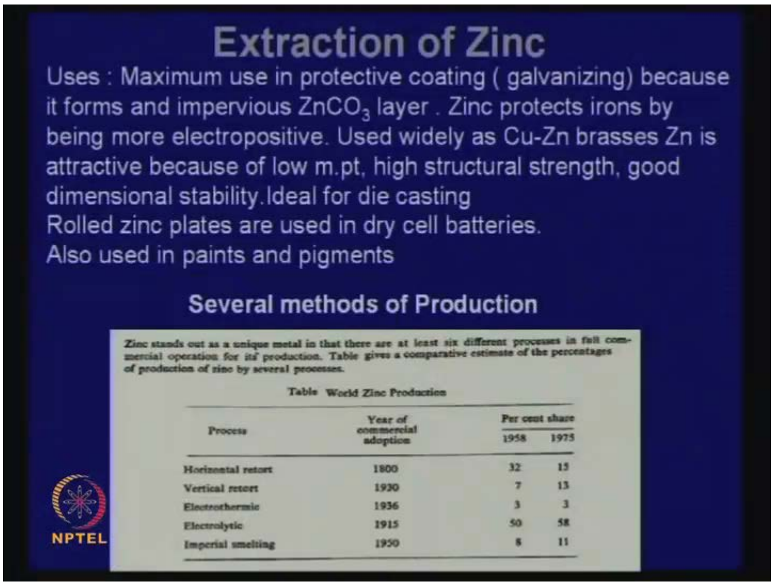

Extraction of Zinc

Uses : Maximum use in protective coating (galvanizing) because it forms and impervious $ZnCO_3$ layer . Zinc protects irons by being more electropositive. Used widely as Cu-Zn brasses Zn is attractive because of low m.pt, high structural strength, good dimensional stability.Ideal for die casting

Rolled zinc plates are used in dry cell batteries.

Also used in paints and pigments

Several methods of Production

Zinc stands out as a unique metal in that there are at least six different processes in full commercial operation for its' production. Table gives a comparative estimate of the percentages of production of zinc by several processes.

Table World Zinc Production

Process	Year of commercial adoption	Per cent share	
		1958	1975
Horizontal retort	1800	32	15
Vertical retort	1930	7	13
Electrothermic	1936	3	3
Electrolytic	1915	50	58
Imperial smelting	1950	8	11

But if we could do that then we will make things very simple and take lead sulphide in the reactor, it will produce lead and of course, it will produce S O 2, it can be collected, it can go for lead recovery. Now, let us leave leads aside and go to extraction of zinc. Indecently we do produce lead in our country as I mentioned in Tundooby the blast furnacing about 15000 to 20000 tons per year there and as well as in Vizag also we produce lead, but it is only by the blast furnace lead, some lead is being produced elsewhere by imperial smelting process which I will discuss in the next lecture.

We will now talk about extraction of zinc. Now, I need not tell you about the importance of zinc. We should know about some common usage of zinc, the maximum use is as protective coating of steel, we call it galvanizing. So, if you have steel pipes we dip in molten zinc and when you take it out there is a thin layer of zinc on top of the steel pipe, all the galvanized pipes you see in the market that will used for plumbing they are all coated by zinc, the zinc does 2 things. Firstly, it forms an impervious zinc carbonate layer by reacting with C O 2 in the atmosphere. So, it is a physical barrier where the any corrosive atmosphere liquid or gases cannot come in contact with the steel pipe.

It also protects electro chemically because zinc protects irons by being more electro positive, if you remember the electrochemical series zinc is above iron. So, if there is a corrosive atmosphere that wants to attack iron, zinc will get attacked preferentially and unless all the zinc is gone iron will not be attracted. It is similar to the catholic protection using magnesium that I discussed some time ago, if magnesium is hanging from a undersea structure and it is kept in contact to this structure, in a corrosive atmosphere this magnesium which will be sacrificed and the undersea structure would be protected. Similarly, the zinc layer will react with a corrosive environment in preference to the steel pipe it is covering the. So, that is electro chemical protection, there is also a physical barrier of zinc carbonate.

Then there is very wide use of zinc as brasses, copper zinc alloys of many kinds. They are zinc, extent of zinc can vary, zinc is also attractive because of its low melting point, high structural strength, good dimensional stability and it is ideal for die casting because of dimensional stability, rolled zinc plates are used in dry cell batteries, all the batteries we are using there is a zinc in them, it is also used in paints and pigments. So, zinc has very wide application.

We have moderate reserves of zinc in the country and we have been producing zinc industrially for quite some time, but remember my first lectures India is the first country to produce zinc in the world and India started producing some around in the fifth century AD or sixth century AD and the industry in Rajasthan peaked around the eleventh, twelfth centuries before the Muslim invasion, then things became secretly they did not stop till until about seventeenth century after the decline of the Mughal power when the Marathas invaded, then the mines were abandoned.

But many of those artisans went down south, but indigenous production of zinc suffered because around ninth eighteenth century the westerners learnt how to distinct zinc. The reason why ancients could not produce zinc is that zinc oxide when reduced by carbon produces a zinc vapors which escapes. So, you have to have a way of condensing the zinc, you need the retort process and Indians had mastered the retort technique both vertical retort as well as horizontal retort distillation process long ago and those retorts are even seen today, hundreds of them in the hill sides many with charges intact because they have been abandoned very suddenly.

That method continued for a long time. That is a pyrometallurgical technique, there was no question of hydrometallurgy because hydrometallurgy culminates in electrolysis, electrolysis was not known till about 200 years ago. So, there is no question less than 200 years ago

So, there was no question of a hydrometallurgy of zinc and zinc could not be precipitated by cementation like copper can, if you have copper sulphate solution if you put iron fillings, copper will precipitate because copper is a very low in the e m f series, but it is difficult to take zinc out of zinc solution zinc. So, mostly world was the zinc was been produced in the world by pyrometallurgical processes until electricity became available as in industrial commodity. But till today zinc stands out as a unique metal in that there are at least six different processes in full commercial operation, in its production there are 6 processes still competing with each other and they all have their utilities. There are certain areas where 1 method would be more appropriate in another place another will be more appropriate.

Now, I had made an estimate some 20- 30 years ago this may have change a bit to just to give you the names of this processes; one is the horizontal retort process, commercially adopted in 1800. Vertical retort process commercially adopted in 1930, but this horizontal and vertical retort process was there in India for centuries, but of course, in the older form. Then there is electro-thermal means instead of the heat is supplied by electrodes in reactors then there is the modern electrolytic process in hydrometallurgy and there is imperial smelting process which I have been mentioning repeatedly with a blast furnace process for simultaneous production of lead and zinc, lead will come out at the bottom zinc will come out as vapor on the top and it will be condensed.

Now, you see the relative proportions about a one third or say about 25 percent was being done by the pyrometallurgical processes, more than half was by hydrometallurgical processes, electro-thermal process is almost negligible and imperial smelting processes at that time was about 11 percent. This I guess is increasing. So, is increasing and pyrometallurgical processes perhaps will slowly decline.

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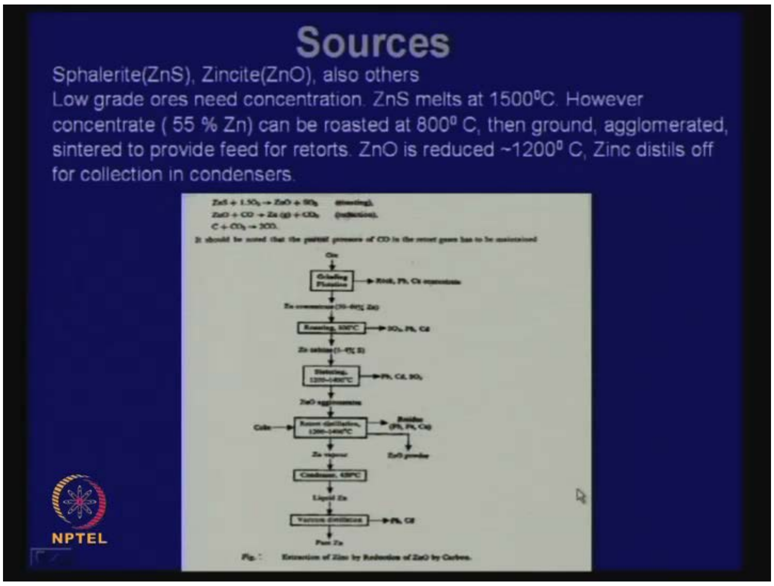

Sources

Sphalerite(ZnS), Zincite(ZnO), also others
Low grade ores need concentration. ZnS melts at 1500⁰C. However concentrate (55 % Zn) can be roasted at 800⁰ C, then ground, agglomerated, sintered to provide feed for retorts. ZnO is reduced ~1200⁰ C, Zinc distils off for collection in condensers.

Now, the sources of zinc are several, but generally we talked about Z n S which is sphalerite, this is the main mineral. It does not mean you get zinc sulphide, I repeatedly tell you this sulphide, zinc sulphide will always be associated with many other sulphides, also gang materials and in nature it will be a few percents at the most. It can also have some oxides associated, but these low grade ores can be concentrated by flotation and it can jump from a few percent 1 or 2, 3, 4 percent to 55 percent zinc in 1 go, as good as that.

Now, zinc sulphide is a mineral, which is a very high melting point, but the concentrate can be roasted at much lower temperature 800 degree centigrade to produce zinc oxide, this oxide will be ground, agglomerated because again you retorts you cannot feed absolute powders because some permeability is required, you may not need big particles or sinter, but we need agglomerates. Even the ancient Indians used to make small balls of zinc and carbon and then put it in the retort because there also gases have to come through discharge. So, they can be agglomerated or sintered to provide feed for retorts, zinc oxide reduction takes place at around 1200 degrees, zinc distils of for collection in condensers, they have to be designed very carefully.

The reactions are this roasting gives you zinc oxide then for reduction zinc oxide will be reduced by carbon monoxide at 1200 degree centigrade and the flow sheet will like this or grinding floatation, lead and copper concentrate are differentially floated out, rock is separated because it will settle means there are ways and means of using floatation reagents, where you float out 1 sulphide, remove it then you can float the other sulphide. So, you can get 2, 3 concentrates of different with different metal composition.

We can get a zinc concentrate 50 to 60 percent zinc after roasting we get zinc calcite S O 2 lead cadmium this fumes will come out, this is only the pyrometallurgical step, but after one gets a zinc calcite which would always have some sulphur, then we need go for sintering, some cases or other kinds of agglomeration to make small particulate matter. Again some fumes will come out, then the agglomerates go for retort distillation. Retort distillation will be 1200 to 1400 degrees and you will get zinc vapor, the residue will have lead iron copper and Z n O powder, the zinc vapor will be condensed at about 450 degree centigrade, will get liquid zinc, melting point of liquid zinc is around 420, from the liquid zinc will be treated by vacuum and vacuum distillation will be pure zinc, what will be left behind will be lead and cadmium. It is a simple flow sheets for extraction of zinc by reduction of Z n O by carbon. The thing is same for vertical retort or horizontal retort, it is the same thing.

Now, for the I do not want to give you the design of the retorts that is not very important and besides the pyrometallurgical process of zinc is also note as important as the hydrometallurgical processing of zinc. We will come to the hydrometallurgical processing of zinc now. The flow sheet for the hydrometallurgical extraction process for zinc is based on the following scheme. First, dissolution of zinc calcite in sulphuric acid. You take zinc in solution, you precipitate cadmium by adding zinc dust, a cementation process. Zinc dust to lead solution, this cementation process some cobalt and copper can also be removed.

Now, a very important point to note is that cadmium is always associated with zinc. So, whenever there is a zinc plant, it necessarily produces cadmium. In our country we produce cadmium from the zinc plant and that takes care of our cadmium need. Thirdly, we precipitate cobalt from the each solution and for precipitation of cobalt there is a standard reagent called alpha nitroso beta naphthol you may have done it in chemistry classes.

Fourthly, adjustment of p h of the leach solution to about 5.3 to hydrolyze aluminum, iron and addition of M n O 2 oxidize iron to the trivalent state and to produce a precipitate that is flocculent and can absorb the entire quantity of arsenic antimony and germanium.

Now, these are all chemical process steps, chemistry and you need not know all these excepting some very standard techniques that are been used, that will be clear if you look at the flow sheet. After calcinations and treatment with H 2 S O 4 interesting thing is cementation, you have zinc in solution, you put some extra zinc in solution, then cadmium will come out, that is the cadmium recovery. Filtration the precipitate mainly will be cadmium because cadmium is cemented out by addition of zinc and then the filtrate will be treated by alpha nitroso beta naphthol, the standards chemical for precipitation of cobalt.

The solution now goes for electrolysis, it will give zinc 99.95 percent pure, it will liberate H 2 S O 4 which can be recalculated because you need it for leaching on the calcite. So, I had mentioned once that in acid leaching we generate acid whereas, in alkali leaching of anywhere you consume alkali. So, in this acid leaching you actually can generate the acid and circulate that.

Let me stress 1 or 2 important points, there is a step here even in this hydrometallurgical route there is a pyrometallurgical step of roasting that zinc sulphide has to be, has to undergo combustion to form zinc oxide, this is a very critical operation because it has been found that if you over oxidized means if the roasting temperature is not right then you form a ferrite which is (( ))compound you can write it also as Z n F e 2 O 4, this ferrite is not easily leachable, it is not reducing means 1 makes a refractory compound. So, at no stage should this form, 1 must not form this compound Z n O F e 2 O 3 that is the most important point.

Then. Secondly, is this point that zinc is high in electro chemical series and therefore, the electrolytic solution must be free of cadmium, lead, copper, iron, silver etcetera etcetera or else zinc deposited on the cathode will be contaminated, try to understand this. We have zinc in solution, we have some suppose there are some other things in solution which are less reactive than zinc.

Then once you deposit zinc on the cathode that zinc will react with these impurities which are less reactive, precipitate those and it will dissolve means there will be cementation of this impurity elements at the cost of zinc from the cathode, we do not want that.

It is necessary absolutely necessary that if we have to go for an electrolytic process for zinc recovery for a solution, the solution has to be absolutely pure. So, before going to electrolysis, there are lot of precautions, lot of chemical steps to ensure complete removal of impurities from the solution that will be electrolyzed. Now, there is a very interesting situation here. We can live with zinc which is less pure because most of the zinc that will produce will go for galvanizing. Galvanizing does not need 99.95 or 99.99 percent pure zinc, it can do with less pure zinc because in galvanizing all that we need is that the iron pipe, steel pipe will be dipped into a layer of zinc and get a zinc layer covering that we could do, with zinc which is not that pure.

But you cannot afford to produce impure zinc in electrolytic process. So, we are compelled to produce a zinc of a purity which is really may not be required for many applications, but there is no other way. We cannot settle for lower purity in electrolytic process and therefore, we end up producing a zinc which is very pure and purity will be 99.95 or 99 because there is no impurity in the leach liquor that we are electrolyzing.

Try to understand this again leach liquor has to be pure because if it has impurities that are less reactive than zinc, then zinc after it gets deposited in on the cathode will re-dissolve to cement out this impurities. Hence, purification is necessary prior to electrolysis. For copper we do this afterwards remember we produce copper by electrolysis, but the copper produced in cathode is not pure. So, we have an electro refining step where we take anode copper which is thick, we take a sheet of pure copper and from the anode copper during electrolysis copper is transported to the cathode impurities that are very noble, precious metals they fall off as insolvable at the bottom of the anode, impurities that can go into solution they go into solution.

So, in the case of copper we do not need very pure leach liquor for electrolysis in the case of zinc we do because zinc is a highly electro positive metal not very highly, but it definitely is above hydrogen whereas, copper is far below hydrogen.

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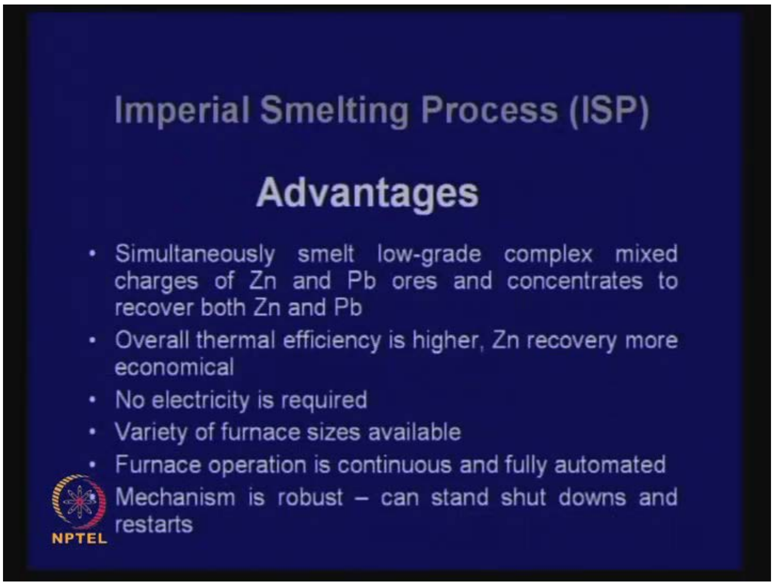

Imperial Smelting Process (ISP)

Advantages

- Simultaneously smelt low-grade complex mixed charges of Zn and Pb ores and concentrates to recover both Zn and Pb
- Overall thermal efficiency is higher, Zn recovery more economical
- No electricity is required
- Variety of furnace sizes available
- Furnace operation is continuous and fully automated
- Mechanism is robust – can stand shut downs and restarts

So, this basically is the scheme for this. Now, let us see whether we have let us see what we do in the zinc plant that we have been debarring, it used to be called Hindustan zinc limited, it was a government owned company, but now it belongs to sterilite. So, it is called sterilite they are producing the zinc for the country today.

The from the Zawar mines we get lead sulphide, zinc sulphide concentrate and of course, some miscellaneous things. The concentration plant at the mines produce lead zinc, lead rich concentrate this goes to lead blast furnace as I mentioned Tundoo in Bihar.

There we get lead, silver as by product. The zinc sulphide part of flotation the concentrate containing 55 percent zinc goes to the zinc smelters in Debari where it is roasted to produce Z n O, it is dissolved in H 2 S O 4, then there has various hydrometallurgical steps, pure liquor electrolyzed you get zinc, the cadmium rich precipitate goes through various hydrometallurgical steps to produce cadmium and of course, there are various other precipitates we need not discuss.

The basic steps are treatment of ores to obtain a concentrate rich in zinc, roasting of the concentrate to convert the zinc in a solvable form, the treatment of the concentrate to form a zinc sulphate solution, purification of the solution by precipitation of impurities, removal of zinc from purified solution by electrolysis, then melting of zinc sheets to form ingots. These are the steps followed in (( )).

Now, let us come to the imperial smelting process which I was mentioning now and then. The imperial smelting process aims at producing simultaneously lead and zinc in a blast furnace.

So, the advantages would be simultaneous smelting of a low grade complex mix charges of zinc and lead ores, to recover both zinc and lead. We would aim at over all thermal efficiency which is higher and zinc recovery also will be more economical, no electricity will be required like you know if we go for an electrolytic route you are using electricity, there will be no electricity requirement. Of course, you require some coke because you are going to do a blast furnace operation.

The furnaces available today are of variety of sizes means 1 can choose a size appropriate for the production that 1 aims at. This furnace operation is continuous and fully automatic, I mean it goes on and on and on provided you deliver a uniform input, the controls take care of minor radiations, there are automation all around and it will work for months together until the furnace has to be stopped for repair, it could be after 2 or 3 years because you know any blast furnace needs change of the lining etcetera after sometime.

This mechanism is robust by robust means it can stand shut downs and restarts if there is a problem it can be shut down and it can be started again. This is not possible in the case of an iron blast furnace because it is too huge enough here and iron blast furnace once shutdown cannot be started or again it is not possible, this is a smaller affair and it is possible to achieve that in this case.

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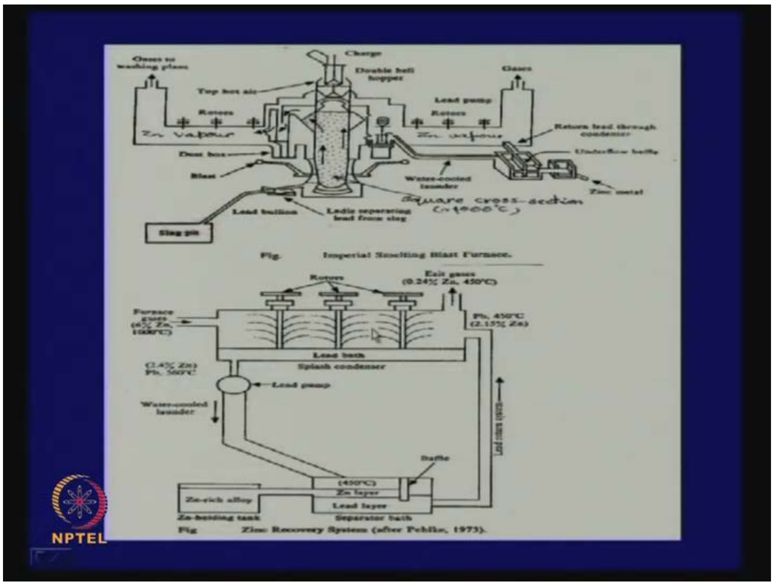

Fig. Imperial Smelting Blast Furnace.

Fig. Zinc Recovery System (after Pehlke, 1973).

So, what is the imperial smelting process? Here is a schematic diagram of the imperial smelting process, at the center is the blast furnace and it has you know if you have taken a course in steel make iron making it has also the bell hopper you know the charging mechanism very much like what you have in a blast furnace, but of course, this furnace is smaller, it also happens to be of square cross section because in the, the reason why the blast furnaces for iron making has a particular shape. It is quite historical, it has evolved over centuries.

Because specially to use agglomerate sometimes they expand. So, to allow the expansion of agglomerates they provide in bigger volume downwards, there are also other reasons, but here we do not have that kind of a taper excepting towards the bottom there is there is a taper because by that time the mass of the charge begins to get reduced because some zinc oxide, all the oxygen is going out we are beginning to have liquid zinc. It will occupy less volumes. So, there is a taper here. Now, what happens when this blast furnace, it is operating like a lead blast furnace, lead oxide is being reduced by carbon.

So, zinc is vapors would have to come out from the top, lead and slag will come out from the bottom. So, here that lead will containing lead would separating lead from slag. So, there is a separation process which takes out lead bullion here and the slag will come out from the top here.

Now, in the case of iron blast furnace we have 2 separate outlets, 1 for slag, 1 for pig iron. They both are very high temperatures you may remember. Remember, in the case of lead the melting point of lead is very low. So, as soon as it flows out lead will get frozen and slag can flow on top of that. So, we can take it out from the same outlet, we have the tubers also exactly the way there are tubers for in the blast furnace. Incidentally you should always know why the tubers look like this why it is not straight down, why it is not straight down

I use to wonder until I found out actually if it is like this you can have a wind over here through which you can see what is happening in the tuber zone. So, there is a it is possible to view the tubers from here. Now, the other things here are mentioned the zinc vapors that are coming out from here will be treated in a chamber, in a very special manner. This diagram is downwards and I would explain same here the zinc vapors that are coming out is entering into a region of a very special treatment on zinc vapors.

Other things are fairly simple and I would explain that a little later. Now, in case there is copper in the charge in some imperial smelting processes another layer comes on top of lead that contains a matt layer which will have copper unfortunately that is not very desirable and operation suffers, generally the imperial smelting process offers best when the only product is lead and the fumes come out from the top.

I will go to the next part little later in the next lecture because I will have to refer to the phase diagram to show you how the zinc vapors condensation is accounted for. So, let us review what we have done so far. Today, we started with treatment of base bullion. Now, the lead that is coming out in the imperial smelting process is also a kind of base bullion.

So, it will also have to undergo all the steps for refining that lead that is coming out is no different in the imperial smelting process than what is coming out from the blast furnaces because that is also blast furnace, this is also blast furnace. The only difference is that in the imperial smelting process we are taking a feed which has zinc oxide, we do not have that feed in the normal lead blast furnace otherwise so, far as the blast furnace side is concerned the operations are similar.

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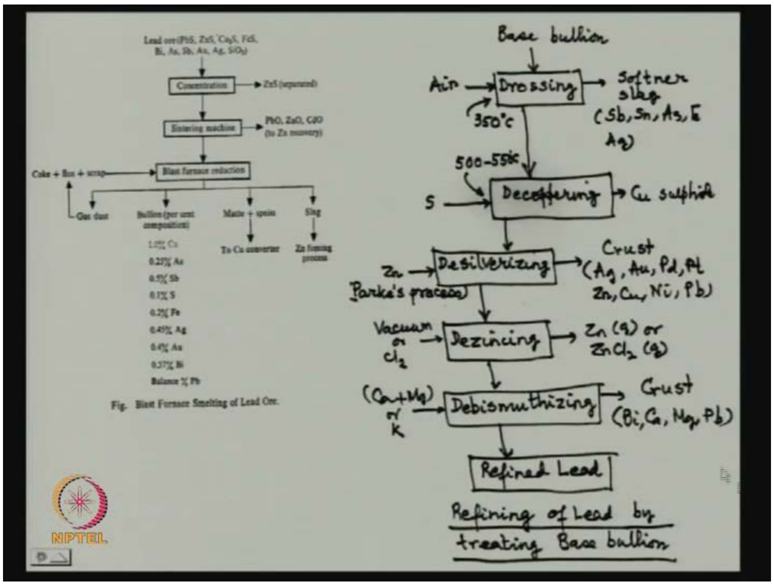

Fig. Blast Furnace Smelting of Lead Ore.

Refining of Lead by treating Base bullion

So, we will have all this steps for the lead that is coming out of imperial smelting process and these are standard processes, drossing, sulphur treatment for copper removal, Parkes process where zinc is added for removal of silver, gold etcetera in the form of a crust, these dissolve in zinc and they come out, dezincing by chlorine and vacuum is a standard process, removal of bismuth by calcium magnesium potassium is a standard process, these processes will be applicable in imperial smelting process also.

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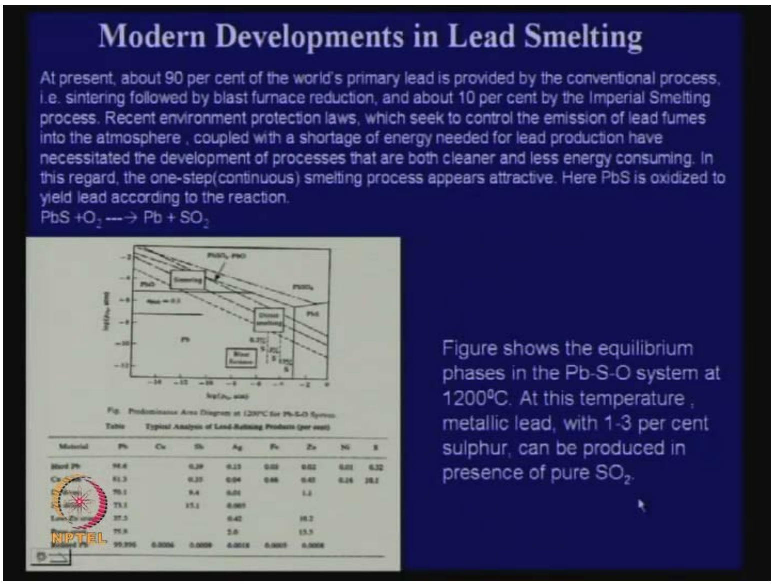

Modern Developments in Lead Smelting

At present, about 90 per cent of the world's primary lead is provided by the conventional process, i.e. sintering followed by blast furnace reduction, and about 10 per cent by the Imperial Smelting process. Recent environment protection laws, which seek to control the emission of lead fumes into the atmosphere , coupled with a shortage of energy needed for lead production have necessitated the development of processes that are both cleaner and less energy consuming. In this regard, the one-step(continuous) smelting process appears attractive. Here PbS is oxidized to yield lead according to the reaction.

$PbS + O_2 \dashrightarrow Pb + SO_2$

Fig. Predominance Area Diagram at 1200°C for Pb-S-O System

Table Typical Analysis of Lead-Refining Products (per cent)

Figure shows the equilibrium phases in the Pb-S-O system at 1200°C. At this temperature , metallic lead, with 1-3 per cent sulphur, can be produced in presence of pure SO_2.

We are now jumping from ordinary lead furnace to imperial smelting furnace where lead is coming and zinc is coming. We still are not able to find a process where you can start directly with lead supplied to produce lead in a continuous manner.

I have mentioned it is possible in theory if you look at the phase diagram 1 can go from lead sulphide to lead, if you have the right control of P S O 2 and P O 2,, but such a process has still not been put into practice, it may be conceptualized, there may be in some laboratory developments, but there is no industrial process.

We are going for a continuous operation of a different kind that imperial smelting process which is a modified version of the lead blast furnace that can operate with both lead and zinc inputs as we got zinc and we discuss imperial smelting process after zinc because in India lead concentrates are available where zinc concentrates are available. So, the imperial process of lead, zinc extraction is in Rajasthan. It is very near that Rana Kumbha’s that memorial, it is very near Queen Padmini’s palace and where and all that historical places, what is that place called? I will just recall it later.

But if it is only zinc sulphides in the concentrate then we go for the hydrometallurgical treatment where zinc supplied is roasted and the calcite is taken into solution and from the solution we will have to go for elaborate purification step and then it will go for electrolysis that is the standard process for zinc. In imperial smelting again we are we need this process specially in India because the lead sulphide concentrate is coming with zinc sulphide concentrate in Rajasthan, there is no coke there, we cannot have lead blast furnaces operated there.

So, that comes all the way to undue lead blast furnaces also operated operating Vizag, I think they get imported concentrates also. It will be advantages to produce lead then and there itself. So, imperial smelting process makes it possible and this is the diagram of the imperial smelting process. Now, I have started discussing zinc by saying that there are some 5 processes of making zinc of them there are 2 horizontal and vertical retort processes or pyrometallurgical processes, there is also 1 electro thermal where you know you have the electric furnaces, but that is not much in operation, then you have the electrolysis process and the most recent is the imperial smelting process, but it is a metal where we had multiple options. In India we only have the hydrometallurgical method.

I do not think there is anything else that I need to recapitulate now. I would start with a very interesting thing of imperial smelting process. How do we condense zinc vapors to recover zinc and ensure that there is no back reaction, mind you with zinc also coming carbon monoxide, carbon dioxide vapors and it is operating at a lower temperature than say iron blast furnaces there will be C O 2 there. There will always be a chance if you do not take adequate precaution zinc will back react with C O 2 and forms Z n O.

In ancients what they use to do we have seen those retorts I had shown they had found the way of a retort distillation where a part of the retort always came out of the furnace, there by air cooled I do not know why they did any other kinds of things. So, the vapors as they came out of a came out the condense there and there was an escape route for gases very nicely designed. We do not do that kind of thing we do not depend on natural condensation of a zinc vapors, this is a very special way of condensing zinc vapors that I will discuss in the next lecture. Thank you.