Non-ferrous Extractive Metallurgy

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Extraction of Zinc-Imperial Smelting Process

Well friends, I have started talking about imperial smelting process which is not exactly a modification of the lead blast furnace although it is similar. It is much more than a modified version because it has an attachment vital attachment for recovery of zinc which come out from the top as zinc vapors. You understand this now that whereas, the lead blast furnace is designed to take only the product of roasting of lead sulphide concentrates that is done in a sintering machine which produces lead oxide, lead sulphate. But this furnace is designed to take a mixture of oxides of lead and zinc which come out of roasting, sintering of zinc sulphide, lead sulphide combination.

So, from the ore which has both the sulphides we get them as a concentrate where both the sulphides are floated together, there is no attempt to separate them. The only attempt is to recover as much as possible of the sulphides that are present, then they will be calcined and roasted to produce the charge necessary for the imperial smelting furnace in this (( ))they have to be we have to have granular material, it cannot be very fine.

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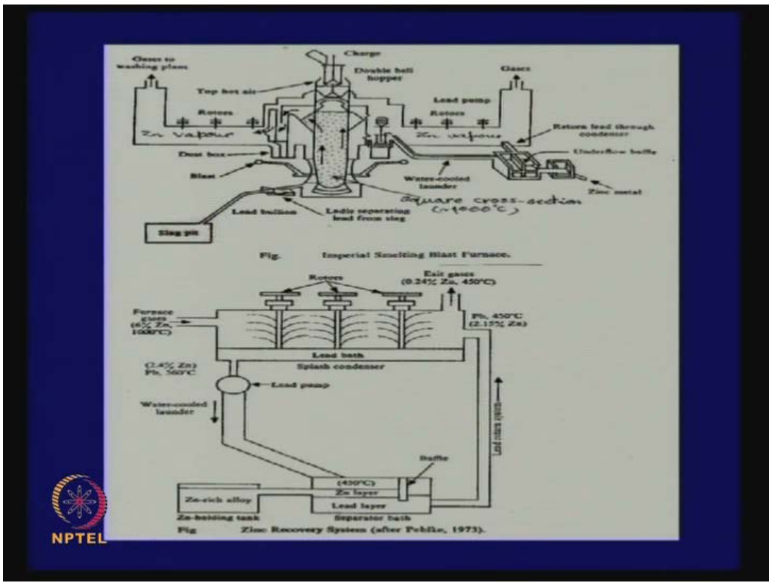

Fig. Imperial Smelting Blast Furnace.

Fig Zinc Recovery System (after Pehlke, 1973).

Now, I have also mentioned that this case the furnace is square cross section, operates at about 1000 degrees more or less similar to the (( )) blast furnace operations which operates at 1200 degrees. I did mention why it is called imperial smelting furnace, you should guess the very word imperial should tell us that it was developed in England. So, it has come from United Kingdom that is why they have named it as imperial smelting.

Now, the trickiest part of this entire operation is condensation of the zinc vapor which is based on a very simple principle of physical metallurgy, the phase diagram of lead and zinc. Now, here is the phase diagram of lead and zinc, this you should understand.

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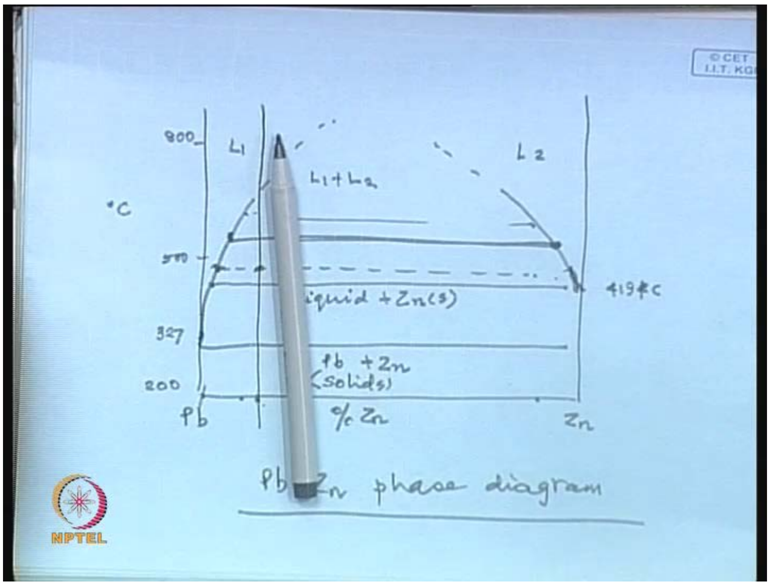

Lead has a melting point of 327 degrees zinc has a melting point of 419. If you go to these temperatures 2 liquids separate out, if you add at a temperature below 327 degrees then you have lead and zinc in a solid solution. If we exceed 327 degrees then lead will melt out. So, here you will have liquid lead and zinc. Zinc will be solid, lead will separate out as a liquid. If we go beyond 419 then we begin to get 2 liquids. One liquid is very rich in zinc, the other liquid is very rich in lead. If we go to a temperature like this we will have a liquid which is richer in zinc, we will have a liquid richer in lead and this actually comes down.

But if we are somewhere here just above the melting point on zinc there is very little zinc very little lead in that water, separate it out and the some amount of zinc which is in the other liquid. So, here we get 2 liquids this liquid and that liquid. Their relative proportion will depend on the lever rule, where we are and where you are standing.

If you are standing here, if this is the in the phase diagram if this is the composition then you this you will have this composition and that composition and the ratios will be inversely proportional. How much effort will be there.

This is made use of in the zinc vapor condensation. The principle is this, the vapors are coming out of top and these are the condensation chambers, this is condensation chamber is shown in magnified version.

The furnace gases which contain about 6 percent zinc vapors, the rest will be CO CO 2 as they come here they are splashed by lead liquid at a temperature of around 450 degrees. So, liquid lead is splashed on to the zinc vapor and that bath now has that zinc vapor in solution because if you go back to the temperature 500 degrees 450 or so. If you refer to this thing you will find now the lead can dissolve so much of zinc.

So, what happens is exit gases will have very little zinc in them only 0.24 percent and rest will be CO CO 2, but most of the zinc vapors are condensed and taken into a lead bath. Now, this lead bath would contain 2 to 4 percent zinc according to the phase diagram there on the right hand side then it is cooled and it gets separated out cooled only slightly, it will cool down from 500, 1000 degrees it is coming, lead bath is at about 500 degrees, it is cooled to 450 degrees and immediately 2 separate layers come out liquid lead and zinc layer as per the phase diagram.

If you go back to the phase diagram, if you come down to about 450 which is slightly here you are getting 1 liquid of this composition, another liquid of this composition. So, 2 layers are coming 1 zinc layer which is almost pure zinc and a lead layer which has very little zinc. This lead is again pumped back. This lead will go back for splashing again, the lead that is recirculated contains 2.15 zinc and the zinc rich alloy will come out here. So, this is what is happening.

You are, you are taking out lead with 2.4 percent zinc, bit of zinc separates out, some zinc is left behind, then it is recirculated in that process gradually you get a zinc rich alloy and you and the lead continuously recirculated. So, the it goes to a zinc holding tank it is all based on control of the temperature, liquid lead splashed on to zinc vapors it will dissolve zinc, then it will be cooled, it will give up zinc, it will remain liquid, it will be pumped back. This is the zinc recovery system of imperial smelting process

It is difficult because one has to pump a very heavy element like lead. So, it is a tricky proposition and it is the liquid is being pumped at a temperatures of 450 degrees, 450 degrees going and the and the entire operation is switching between 450 and 560 or so.

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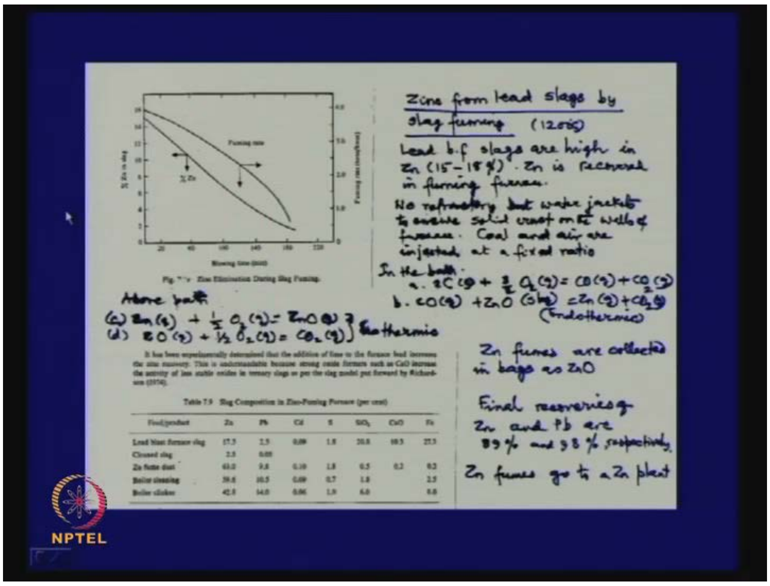

Fig. 7.? Zinc Elimination During Slag Fuming.

Above bath

(c) $Zn(g) + \frac{1}{2} O_2(g) = ZnO(s)$
(d) $CO(g) + \frac{1}{2} O_2(g) = CO_2(g)$ } Exothermic

It has been experimentally determined that the addition of lime to the furnace feed increases the zinc recovery. This is understandable because strong oxide formers such as CaO increase the activity of less stable oxides in ternary slags as per the slag model put forward by Richardson (1974).

Table 7.9 Slag Composition in Zinc-Fuming Furnace (per cent)

Feed/product	Zn	Pb	Cd	S	SiO_2	CaO	Fe
Lead blast furnace slag	17.5	2.5	0.09	1.8	20.8	10.5	27.5
Cleaned slag	2.5	0.05					
Zn fume dust	63.0	9.8	0.10	1.8	0.5	0.2	0.2
Boiler cleaning	59.8	10.5	0.09	0.7	1.8		2.5
Boiler clinker	42.5	14.0	0.06	1.9	6.0		8.8

Zinc from lead slags by slag fuming (1200°C)

Lead b.f slags are high in Zn (15 – 18 %). Zn is recovered in fuming furnace.

No refractory but water jackets to ensure solid crust on the walls of furnace. Coal and air are injected at a fixed ratio

In the bath.

a. $2C(s) + \frac{3}{2} O_2(g) = CO(g) + CO_2(g)$

b. $CO(g) + ZnO\ (slag) = Zn(g) + CO_2(g)$ (Endothermic)

Zn fumes are collected in bags as ZnO

Final recoveries of Zn and Pb are 89 % and 98 % respectively.

Zn fumes go to a Zn plant

Now, during my discussions you must have heard me say the word zinc recovery from lead slag’s because even in the slag that comes out of the imperial smelting process, some zinc will come out.

Lot of zinc will also come out of the lead blast furnace and lead blast furnace slags normally contain 15 to 18 percent zinc. Zinc in solution in lead slags. How do we recover that because it is there some kind of a silicate. Now, they do that we employ a process called slag fuming process at about 1200 degree centigrade in water jacketed reactors no refractory, but water jacketed for reasons I do not clearly understand. But if you have a water jacketed reactor and there is it is water cooled then there is always a frozen crust, solid crust all around which acts like the protective refractory.

In that furnace, in the bath you have to go to this temperature because you are treating slags and melting points of slags are around that little below, to that is added coal injected coal and air. So, you are actually gasifying coal inside a slag phase.

So, coal will form CO and CO 2 on gasification. This CO reacts with ZnO slag to form zinc vapors. So, it is a reduction reaction, there is zinc inside the slag, ZnO inside the slag phase itself you inject carbon and oxygen and these 2 react coal carbon as coal, these 2 react gasify coal the CO formed reduces zinc oxide, zinc vapors come out. This is an endothermic reaction. Because all oxide reduction processes by CO are endothermic.

So, it tends to cool the entire bath, the heat can be compensated like this, above the bath when zinc vapors come out, it reacts with the oxygen in atmosphere forms ZnO fumes, that is exothermic.

Also the CO that is coming out it will form CO 2 beyond as it comes out or it can be combusted to form CO 2, that is also exothermic. That will give heat to the bath. So, some heat is gained by oxidation of zinc and oxidation of CO. This is the fuming process by which you are recovering zinc from the slag essentially as zinc oxide fumes Now, this fumes zinc fumes on zinc oxide fumes are collected in bags. There are bag collection bags of zinc. If you can do that we can recover nearly 90 percent of zinc from the slag and then we will also improve recovery of lead about 19 percent.

The zinc fumes that come it will go to the zinc plant, to get zinc out of that it will either go for pyrometallurgical processing or for hydrometallurgical processing. Now, here is a small sketch to show how with blowing time the process will proceed, this is blowing time, blowing of carbon and oxygen in slag and this is percentage zinc in slag. Obviously, the percentage zinc in slag which is shown here and here will drop with time because gradually zinc is going out of the slag phase.

Whereas fuming rate the rate at which zinc is coming out which is shown on this side initially it would be high, but it blowing time gradually the fuming rate will drop because there is not enough zinc oxide left in the slag. So, typically we need in minutes say 120 to 140 minutes to come somewhere here and about 180 minutes about 3 hours of blowing of carbon and oxygen to recover most of the zinc oxide from the slag phase, that is where the fuming rate becomes very low.

Now, beyond this if you continue in the blowing your fuming rate actually it is already has dropped, it would drop even further and zinc in the slag has already dropped and may be its not going to drop any further.

So, somewhere here one has to draw a balance and you have to let go small amount, very small amount of zinc in the slag, it is not worth trying to recover that. So, you are coming to a situation which we often call the state of diminishing return. Means if we go on trying more the elemental advantage you get is not coming with the efforts you are putting in. So, somewhere it has to stop. So, this is called zinc fuming process which is which has to be applied for slags out of lead blast furnace for recovery of zinc.

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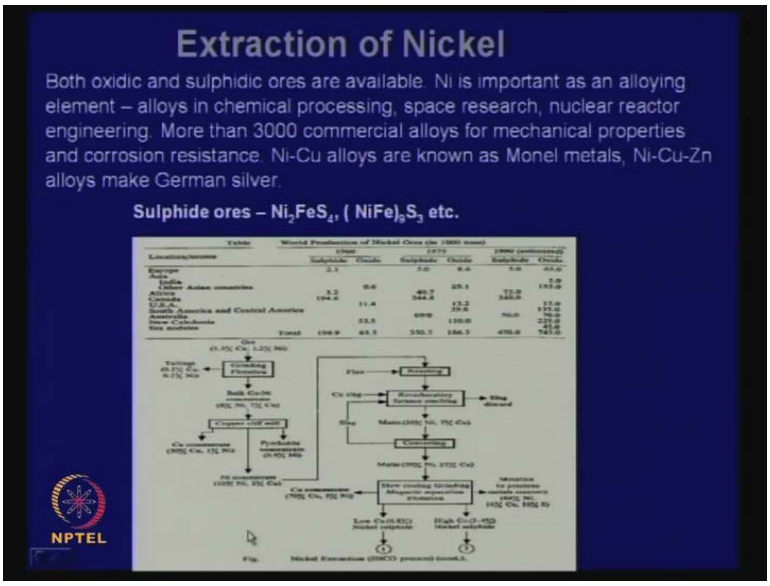

Extraction of Nickel

Both oxidic and sulphidic ores are available. Ni is important as an alloying element – alloys in chemical processing, space research, nuclear reactor engineering. More than 3000 commercial alloys for mechanical properties and corrosion resistance. Ni-Cu alloys are known as Monel metals, Ni-Cu-Zn alloys make German silver.

Sulphide ores – Ni_2FeS_4, $(NiFe)_9S_8$ etc.

I have talked about the (( )) process now. I would like to say few words on nickel. Now, you may wonder why I am discussing nickel now because earlier I have referred to nickel as a metal which comes from oxides sources.

The reason I am bringing in nickel at the stage again is because nickel is also obtained from sulphide ores and there are many countries in this world which has sulphidic nickel deposits. So, we can say that both oxides and sulphide ores are available and both of them need to be expert.

Why are we interested in nickel because nickel is a strategically important metal, you know when you use the word strategy you must know what it means, the word strategic has 2 implications. When we say this is of strategic mean it means in the long term perspective, it is required means you will need it for very long term to satisfy objectives even in the long term. It also means that it has military and defense applications.

Because military is of vital importance. So, many alloys would need nickel for defense and also there are many industries which will continue to (( )) nickel for a long time. So, nickel is a strategic importance. In India, like in many other countries it is a strategic importance, but import all our nickel. We do not produce nickel excepting for small quantities which we are obtaining from secondary sources. Let me talk about them first.

When I was working in (( )) Bhubaneswar, an entrepreneur met me saying that I live in Khanpur and there is an explosives factory there, there are fertilizers factories and many of them use catalysts in their operation and many of these catalysts have nickel in them. Now, after they are used they throw away those catalysts called waste catalysts and there are small hills of these waste catalysts and he went and found out they contain metals like nickel, copper, zinc in very good quantities much more than ores available anywhere. So, he bought them.

He said I would like to get nickel out of this. So, we tried to help him to establish a process for recovery of nickel from waste catalysts. In also in many chemical processes nickel is a very important catalyst. So, we have this waste catalysts in our country and people have here and there found some ways of recovering nickel. There are also some waste materials available from abroad may be alloys, may be chemicals etcetera which have nickel in them. The country buys them and some companies try to process nickel from them, these are secondary we can call secondary nickel.

But from ores available in the country we do not have a industry not even in a small scale industry to produce nickel.

Now, nickel is vitally needed as a strategic material because of its alloying properties. We may not use nickel as such, but nickel alloys are necessary in chemical processing because of their high strength properties, corrosion resistance.

In space research, nuclear reactor engineering etcetera for many alloys we need nickel. There are more than 3000 commercial alloys for mechanical properties and corrosion resistance qualities of nickel and of course, you know there is a group of metals called monel metals. These comprise of nickel and copper mainly with some other things of various proportions. There is in the market an alloy which looks like silver, it is called German silver. It is prepared by mixing zinc, copper and nickel, German silver.

Of course I even mentioned use of nickel as catalysts in many chemicals, but maximum uses in the form of alloys. So, for alloying if it is an iron based alloy we can use as ferroalloy, if it is not an iron based alloy then we have to put it as nickel metal. For example if we have to make German silver or you have to make a nickel copper alloy you cannot use a ferroalloy, we have to have nickel in elemental form. Now, in the world there are many places with the sulphide ores, average the mineral composition may be Ni 2 FeS 4 or NiFe 9 S 3 there could be other competitions.

But like copper, zinc, lead sulphides these sulphides are also mixed with some other sulphides because sulphides as I have been mentioning are very good solvents. Now, here are some figures about world production of nickel ores. I do not know whether you can read them, but I will just read out 1 or 2 figures. In Europe in 1960 2.1000 tons of sulphide ores were mined, in 75 5.01000 tons means 5000 tons of sulphide ores were mined, oxide ores mined were 8.6 oxide ores were more.

But in a place in Africa there are more sulphide ores as there are not and in 1990 75000 tons of sulphide ores were mined. In Canada huge deposits of sulphide, nickel sulphides and some 340000 tons of the sulphide ores were mined. In USA they have oxide ores, no sulphide ores There is only in Canada and also in that also in the form of sea nodules also has sulphides, but in most countries this sulphide ores are not there, Canada is an exception, but there are there nickel is there in oxide form in many countries.

And if you look at this figures India has very small quantities of oxide in oxide form and in the chromite overburden that we mentioned it has been estimated that we have already taken out some 185000 tons of nickel ores which are there. Now, how do we proceed for extraction of nickel from sulphide. Here is a flow sheet called nickel extraction inco. This inco is a very famous company which is based in Canada and you can see they are processing in the nickel ores like this. Because they are sulphides, the ores will be like copper sulphide very low grade. In this inco ore there is only 1.3 percent copper and 1.2 percent nickel as low grade as that, there will be ground and there will be floatation, tailings will lose a little bit of copper and nickel. But the bulk copper nickel concentrate will have 6 percent nickel and 7 percent copper.

So, we get a bulk concentrate. We float both of them together, then they separate copper concentrate and (( )) concentrate. Then, we will get a concentrate 30 percent copper and 1 percent nickel and we will get a main nickel concentrate which will have 10 percent nickel, 2 percent copper this becomes now the starting point. It will now undergo a pyrometallurgical processing very much like copper sulphide processing, where we will go through a matte route. Through a route that will involve sulphides.

So, this nickel concentrate sulphides which would have 10 percent nickel and 2 percent copper will go for roasting a reverberatory furnace smelting just like in the case of copper there will be slag discard and this will now produce a matte. If somewhere there is a copper slag available that can go in here because we need in the matte copper also. So, nickel sulphide processing also involves a matte which is a mixture of sulphides containing 20 percent nickel 7 percent copper, it will be it will go undergo converting like exactly like in the case of nickel the slag will go back to the reverberatory furnace.

In converting we will have matte 50 percent nickel, 25 percent copper there is a slight difference here. In the case of copper converting by converting a straight way we are producing blister copper. In this case we do not do that, we produce a product which goes for slow cooling, grinding and magnetic separation to finally, get a low copper nickel sulphide and high copper nickel sulphide. So, 2 products they aim at basically to produce nickel sulphide.

So, the matte processing will be to prepare like in the case of copper matte smelting you wanted to have white metal and then that will be converted to blister copper. No, here they first produce the nickel.

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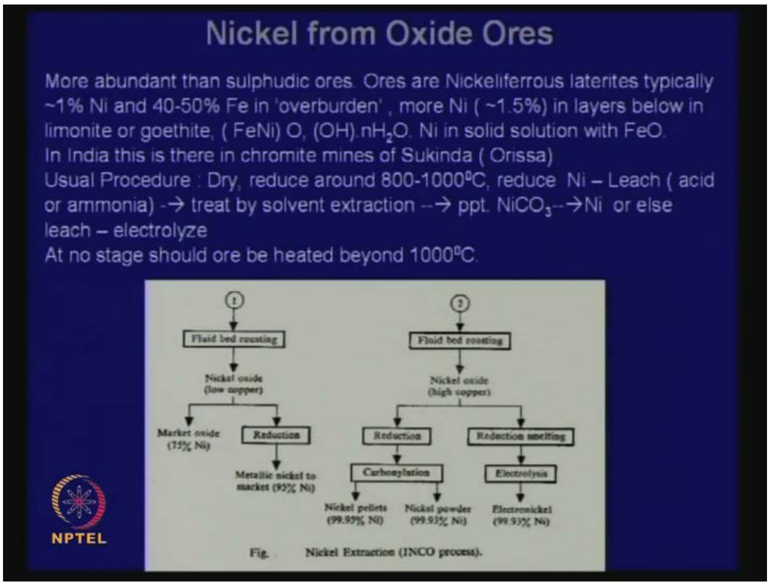

Nickel from Oxide Ores

More abundant than sulphudic ores. Ores are Nickeliferrous laterites typically ~1% Ni and 40-50% Fe in 'overburden' , more Ni (~1.5%) in layers below in limonite or goethite, (FeNi) O, (OH).nH_2O. Ni in solid solution with FeO.
In India this is there in chromite mines of Sukinda (Orissa)
Usual Procedure : Dry, reduce around 800-1000^{0}C, reduce Ni – Leach (acid or ammonia) -→ treat by solvent extraction --→ ppt. $NiCO_3$--→Ni or else leach – electrolyze
At no stage should ore be heated beyond 1000^{0}C.

Fig. Nickel Extraction (INCO process).

Then it will go to a different pyrometallurgical processing as you see here fluid bed roasting, nickel oxide it can be marketed as such or it can be reduced to produce metallic liquid for the market. It can go for fluid bed roasting to get nickel oxide, it can be deduced, this can be carbonylation means nickel pellets and nickel powder reduction smelting, electrolysis, electro nickel all these (( )). So, in the sulphide, nickel sulphide processing the aim will be different. The aim will be to go to a matte phase and not the metal directly, then the sulphide will be will undergo a pyrometallurgical processing through the oxide route.

Now, the oxide ores are much more abundant than the sulphuric than the sulphide sulfidic ores. It should be sulfidic and the oxidic ores are called nickeliferous laterites. They are associated with iron oxide deposits typically containing 1 percent nickel and 40 to 50 percent iron in overburden means in the top layers. There can be more nickel in layers below and typically this kind of a composition we can expect where nickel is in solid solution with FeO.

In India, this is there in chromite mines of Sukinda. Sukinda valley is in Orissa, it is full of chromite and lot of chromite mining takes place there. Now, during chromite mining they take the top layer out and they keep it at 1 stage and hoping that in future some day we will extract nickel out of that. So, when I was working in Bhubaneswar they said that you must go and see the chromite overburden which has nickel and we were interested in extracting nickel. So, I was taken there I was standing on top of a hill and then I asked some people Where is that chromite overburden? Where there is nickel? Then I was told that you are standing on top of that.

So, there is a there is a hill of that chromite overburden containing say around 0.7, 0.8 percent nickel which is waiting for somebody to come and extract nickel. The rest of the place after the top layer has come out they are doing chromite mining that is going on, but this nickel overburden containing overburden is simply waiting.

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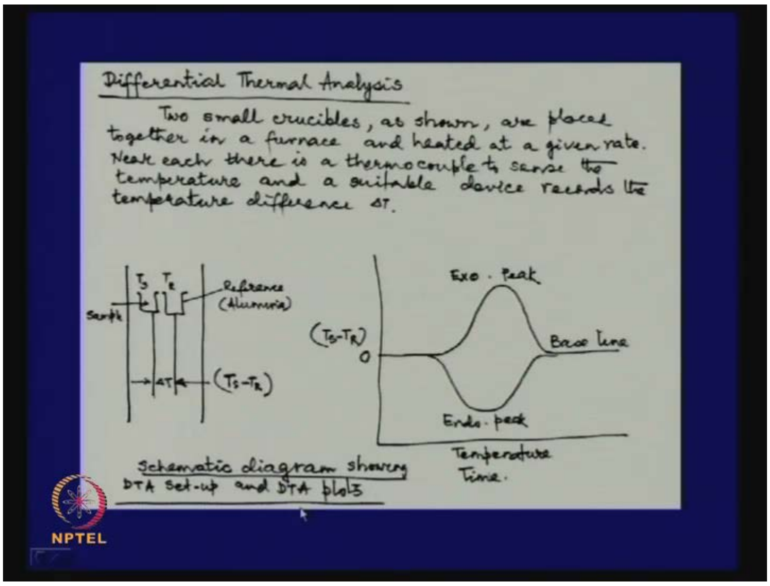

Differential Thermal Analysis

Two small crucibles, as shown, are placed together in a furnace and heated at a given rate. Near each there is a thermocouple to sense the temperature and a suitable device records the temperature difference ΔT.

Schematic diagram showing DTA set-up and DTA plots

What do we do with it, that in oxide oxidic ores nickel is associated with nickel laterites, laterites are iron oxides. Now, to understand the behavior of these ores when heated we can take help of differential thermal analysis which I have explained once. Let me explain it once again. In differential thermal analysis we have 2 small crucibles placed side by side as shown.

And they are heated in a furnace there are 2 temperatures, the there are 2 thermocouples attached to them measure the temperature difference between these. Now, the sample whose behavior we want to study during heating is kept in 1, the other crucible contains a reference material like alumina where nothing happens. Now, when we heat in a furnace these crucibles placed in such a manner that in the beginning the temperature difference between them is zero because they are both getting heated up.

But if something happens in this crucible either exothermic or endothermic then the delta T will be registered either this way or that way. Because if it is endothermic temperature will be arrested here this will go up, if it is exothermic temperature will go up here and the and it will go beyond this. Of course, this will not continue when it is over it will come back to the base line again.

The simple technique is used to understand the behavior of any ores and minerals during heating and I will come back to this in a later lecture about behavior of sulphides when they are heated.

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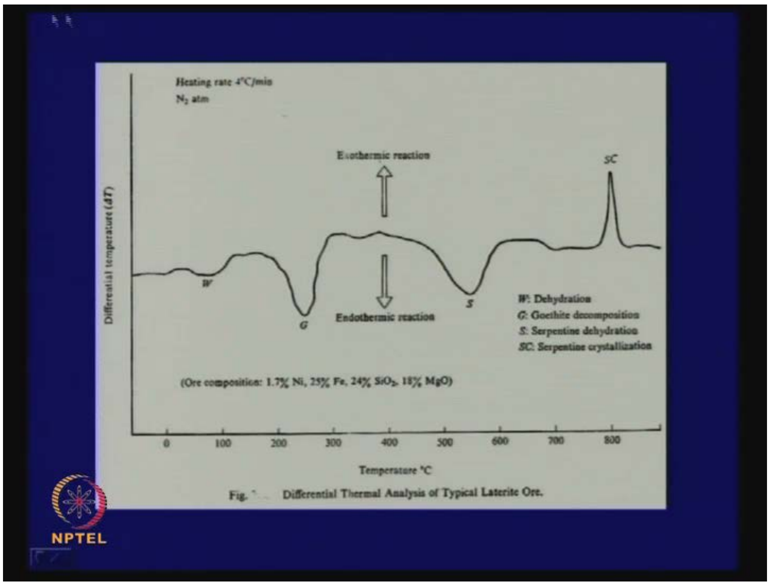

Fig. Differential Thermal Analysis of Typical Laterite Ore.

But let us discuss how nickel laterites behave during heating. Here, I show a typical sorry a typical d t a plot for a particular laterite ore composition is given here 1.7 nickel, 2.0 2.5 25 percent iron, 24 percent silica and 18 percent MgO. Now, as we heat this ore the d t analysis shows the following. The small endothermic peak at W which is at about 100 degrees is due to evolution of a small amount of water from an already dried sample which has been dried, sun dried some moisture is still left, the ore from the mines contain lot of water, some has moisture, some in combined form we have to remove that also.

So, the first endothermic peak shows endothermic evolution of water, it absorbs water. Now, there is another big endothermic peak at G. What is the G? The second endothermic peak G at about 230 degrees is due to goethite decomposition and goethite is 2FeO OH, this phase is called goethite and it decomposes into Fe 2 O 3 and H 2 O.

So, goethite mineral which is FeO OH it decomposes at about 230 degrees to give out Fe 2 O 3 and combine water H 2 O. Now, this is a very important observation because it has been found mineralogically that the nickel is actually always associated with the goethite phase.

So, before this temperature nickel is inside the goethite phase almost dormant, but the moment that goethite decomposition takes place, nickel that was liberated to goethite with was associated with goethite is now liberated. It becomes active, nickel oxide becomes active and it can be very easily deduced.

Then we come to the third endothermic peak, this third endothermic peak refers which has about 530 degrees, it refers to dehydration of serpentine. Now, serpentine is a mineral which is there in the ore its composition is magnesium 6 Si 4 O 10 OH 8 its very (( )) mineral. This oxide in the serpentine becomes active above 600 degrees. The next exothermic peak, this is very critical. The serpentine phase crystallizes that SC at about here shows crystallization of serpentine.

Now, the next exothermic peak SC at 800 which represents the re crystallization of the magnesium silicate which is liberated from serpentine into olivine, it is Mg 2 SiO 4. If this happens then nickel oxide is locked up in that phase. The (( )) substances is when you are heating a lateritic ore water comes out, goethite decomposes liberates NiO which was in the goethite.

Then the serpentine phase goes through decomposition and recrystallization. If that happens then nickel oxide goes into that serpentine phase and becomes in active. It is not available for reduction. So, whatever we do will have to be done below 800 degrees, this is the (( )) substance of that.

So, we can say that in ores which are lateritic everything has to be all pyrometallurgical operations must be below 800 degrees to ensure that nickel is not locked up in a serpentine recrystallize phase. However when there are limonitic iron ore which has which have more iron content 40 to 50 percent Fe that would not have the serpentine peaks. But a serpentinic ore with low iron content 8 to 10 percent Fe will not have the goethite dehydration peak of the lack of goethite mineral in the ore hence does not have the peak of serpentine.

So, there are some laterites which are easier to reduce than the serpentinic ores because of the olivine recrystallization and locking up of the nickel oxide in the olivine will not take place, what I am saying basically is not all nickel ores are alike.

And 1 has to first go through when the laboratory test to know what happens when we are heated, when is nickel oxide easily available for reduction and unless those things are done we simply cannot be a pyrometallurgical step.

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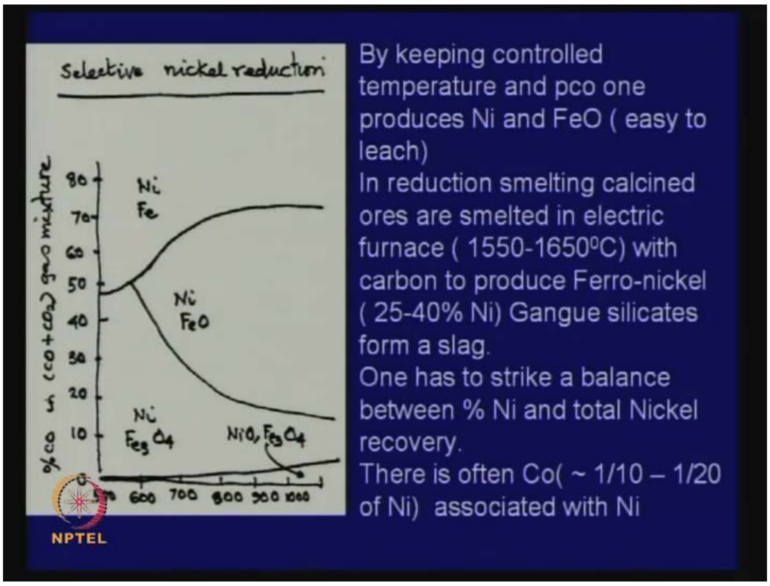

By keeping controlled temperature and pco one produces Ni and FeO (easy to leach)
In reduction smelting calcined ores are smelted in electric furnace (1550-1650°C) with carbon to produce Ferro-nickel (25-40% Ni) Gangue silicates form a slag.
One has to strike a balance between % Ni and total Nickel recovery.
There is often Co(~ 1/10 – 1/20 of Ni) associated with Ni

To understand now better what we will do for preferential nickel reduction we have to go see the simple phase diagram, not phase diagram that this diagram which shows that which shows the different phases at different (( )) as a function of percentage CO gas, it is something very similar to what you may have learnt in iron oxide reduction.

If we have temperatures in this range and CO in this range then we should have a final product nickel and Fe 3 O 4. If we maintain temperatures and CO CO 2 composition in this range, we can produce nickel, nickel FeO and of course, if we go to percentage CO higher than this in temperature ranges like this you can produce both nickel as well as iron metal elemental form. This is the kind of guidance we get from this diagram, you must have seen similar thing in the case iron ore reduction.

Now, 1 restriction we have put is in the ores, some ores where we have goethite serpentine and all these at least in Indian ores we never go beyond 800 degrees, all operations would be on this side. Now, if we can reduce the lateritic ore which has nickel oxide initially locked up in the goethite phase and then liberated, then we can very easily produce nickel Fe 3 O 4 or nickel and FeO. It is quite easy to do.

Nickel oxide is very easy to reduce. What we depend? We depend on the final processing. Now, by keeping control temperature and p c o one can produce nickel and FeO if we want to leach out FeO or you can leave nickel and FeO and Fe 3 O 4, we cannot handle nickel and Fe 2 O 3 that will not be desirable because Fe 2 O 3 is difficult to leach. In smelting, reduction smelting calcined ores are smelted in electric furnaces with 1550 to 1650 degrees.

Now, there we do not have to worry about all these. Whatever we have nickel oxide Fe 2 O 3 everything we can smelt at temperature of 1550 to 1650 degrees. We reduce both nickel from the oxide as well as iron for the oxide and you produce a ferronickel. And since we are using carbon as a reducing agent if you give long time more nickel will come out, more iron will also come out, nickel comes out earlier because it is very easy to reduce. So, initially we can produce a high nickel ferro ferronickel, but total recovery of nickel would be low because we need more time to take out all nickel.

So, one has to draw a compromise between recovery of nickel and the grade of ferronickel, but we can take out both iron and nickel as ferronickel from the charge. Now, in pyrometallurgy we go bit differently. We combine the initial reduction of the lateritic ores to such an extent that we produce nickel and FeO Fe 3 O 4 and this nickel can go for ammoniacal leaching. So, that charge which has been reduced under controlled atmosphere and there are furnaces, 1 is that rotating hearth furnace or it can be the rotary kiln that can now be sent for ammonia leaching, nickel can be easily leached by ammonia to produce nickel amine from which we can precipitate nickel carbonate and nickel carbonate has a easy market. Because nickel carbonate if it is added anywhere it will easily decompose and produce metallic nickel.

So, from these oxidic ores one can produce ferronickel, one can produce metallic nickel, for that we have to go for electrolysis by this by decomposing ferronickel carbonate into nickel oxide dissolving in an acid solution electrolysis it may not be necessary, if it is for alloying if we add nickel carbonate it will decompose very easily.

So, what we want is we have to keep in mind what it is what we want. If we want ferronickel we have to go for smelting, but we can also produce elemental nickel by initial this reduction roasting followed by leaching of nickel. Now, this sort of work has been done in India and I will in the next lecture come back to this subject and give you little more data and discuss it more thoroughly.

Now, let me end today’s lecture by discussing a subject which might become important in the future. See. So, far what we have done is that we talked about sulphides undergoing a floatation process. We can either get a copper fraction which goes for copper extraction or we take zinc sulphide concentrate goes for zinc or lead sulphide goes for lead extraction or copper lead and zinc together which goes for imperial smelting process.

But there are quite a few sulphide deposits which can which are known as multi-metal deposits or mix sulphide deposits which are not very easily amenable for differential floatation to get rich concentrate of this or that or the third metal, they may be very low grade also. Now, this mix sulphide deposits are growing attention in India because India is not very rich in terms of the deposits of copper, zinc and lead. How do we proceed to treat complex sulphides of lead, copper and zinc.

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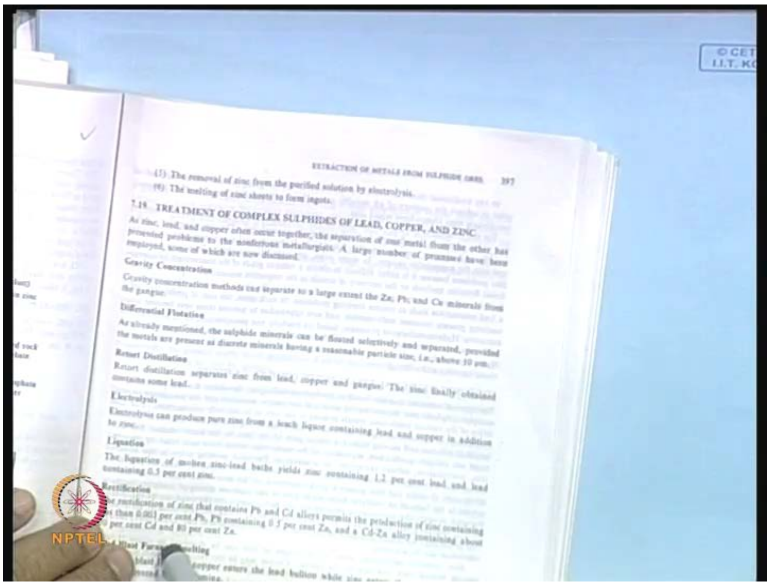

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(7) The removal of zinc from the purified solution by electrolysis.
(8) The melting of zinc sheets to form ingots.

7.18 TREATMENT OF COMPLEX SULPHIDES OF LEAD, COPPER, AND ZINC

As zinc, lead, and copper often occur together, the separation of one metal from the other has presented problems to the nonferrous metallurgists. A large number of processes have been employed, some of which are now discussed.

Gravity Concentration

Gravity concentration methods can separate to a large extent the Zn, Pb, and Cu minerals from the gangue.

Differential Flotation

As already mentioned, the sulphide minerals can be floated selectively and separated, provided the metals are present as discrete minerals having a reasonable particle size, i.e., above 10 μm.

Retort Distillation

Retort distillation separates zinc from lead, copper and gangue. The zinc finally obtained contains some lead.

Electrolysis

Electrolysis can produce pure zinc from a leach liquor containing lead and copper in addition to zinc.

Liquation

The liquation of molten zinc-lead baths yields zinc containing 1.2 per cent lead and lead containing 0.5 per cent zinc.

Rectification

e rectification of zinc that contains Pb and Cd alloys permits the production of zinc containing s than 0.003 per cent Pb, Pb containing 0.5 per cent Zn, and a Cd-Zn alloy containing about per cent Cd and 80 per cent Zn.

Now, here are some simple some hints, but this I may discuss later on. First of all we need to find a concentration technique, floatation is 1, we can also employ gravity separation to separate large extent zinc, lead, copper altogether, differential floatation is something we employed on sulphide minerals, total recovery of all the sulphides or fraction this fraction separately. But for this we need that the minerals are present at discrete minerals. Suppose, we want to separate copper, lead and zinc the minerals must be discrete.

Zinc, sphalerite, galena, copper pyrites if they exist as distinct minerals, then differential floatation is possible. But very often they are not distinct minerals, they are all mixed together like in copper pyrite you have Cu 2 S and FeS not as a solid solution, it is a separate mineral CuFeS 2 there can be such minerals which combine this elements if that is there then by floatation you cannot get different fraction.

If you do a retort distillation we can separate zinc, like in the retort process for zinc if you take a calcine which has both lead and zinc like in imperial smelting process, zinc can be separated out, lead copper will be left in the gangue.

And the zinc finally, obtained contain some lead there will be some lead. We can think of electrolysis to produce zinc from a leach liquor containing lead and copper in addition to zinc. Now, this I will discuss I have to think 1 can apply liquation to produce molten lead zinc bath containing 1 to 0.2 percent lead, lead containing 0.5 percent zinc something that we have been employed in imperial smelting process.

So, many things have been thought of as to how you handle a mix sulphide, but ultimately people think that when you have a sulphide deposit all kinds of sulphides, the best way to go will be to employ a hydrometallurgical technique. And here the aim will be of course, the technique will have to be depend on the gangue minerals and the percentage compositions of various nonferrous (( )) present in the ore and the bulk concentrates, it will always depend on that. But the first major step in hydrometallurgical method will be absorption of nonferrous metallic values in solution and leaving behind a major part of iron in the leaching (( )). Iron is the part in the sulphides is not what we want.

So, if there is a bulk sulphide concentrate. We have to find a way to take all the metals in the solution, copper, zinc, lead and others, but not iron in the solution. Iron must be rejected that if we can do that we have a very big very good starting point.

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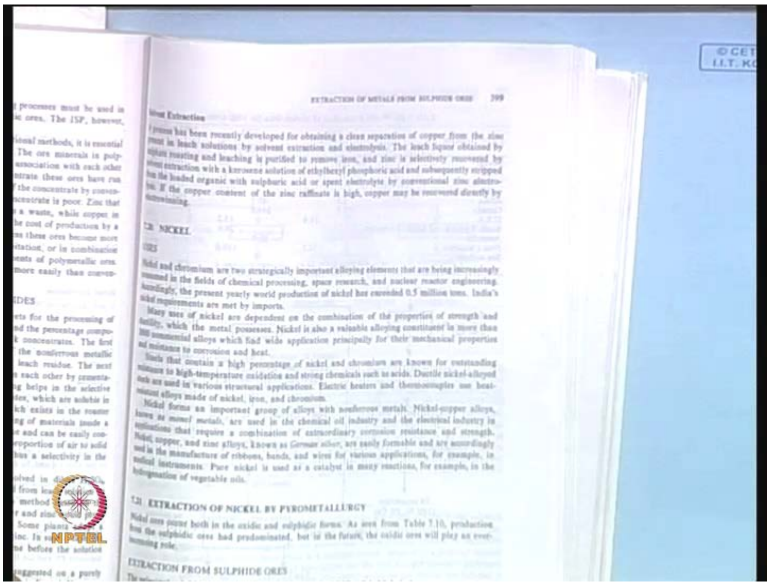

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Solvent Extraction

A process has been recently developed for obtaining a clean separation of copper from the zinc present in leach solutions by solvent extraction and electrolysis. The leach liquor obtained by sulphate roasting and leaching is purified to remove iron, and zinc is selectively recovered by solvent extraction with a kerosene solution of ethylhexyl phosphoric acid and subsequently stripped from the loaded organic with sulphuric acid or spent electrolyte by conventional zinc electrolysis. If the copper content of the zinc raffinate is high, copper may be recovered directly by electrowinning.

7.20 NICKEL

ORES

Nickel and chromium are two strategically important alloying elements that are being increasingly consumed in the fields of chemical processing, space research, and nuclear reactor engineering. Accordingly, the present yearly world production of nickel has exceeded 0.5 million tons. India's nickel requirements are met by imports.

Many uses of nickel are dependent on the combination of the properties of strength and ductility, which the metal possesses. Nickel is also a valuable alloying constituent in more than 3000 commercial alloys which find wide application principally for their mechanical properties and resistance to corrosion and heat.

Steels that contain a high percentage of nickel and chromium are known for outstanding resistance to high-temperature oxidation and strong chemicals such as acids. Ductile nickel-alloyed steels are used in various structural applications. Electric heaters and thermocouples use heat-resistant alloys made of nickel, iron, and chromium.

Nickel forms an important group of alloys with nonferrous metals. Nickel-copper alloys, known as *monel metals*, are used in the chemical oil industry and the electrical industry in applications that require a combination of extraordinary corrosion resistance and strength. Nickel, copper, and zinc alloys, known as *German silver*, are easily formable and are accordingly used in the manufacture of ribbons, bands, and wires for various applications, for example, in medical instruments. Pure nickel is used as a catalyst in many reactions, for example, in the hydrogenation of vegetable oils.

7.21 EXTRACTION OF NICKEL BY PYROMETALLURGY

Nickel ores occur both in the oxidic and sulphidic forms. As seen from Table 7.10, production from the sulphidic ores had predominated, but in the future, the oxidic ores will play an ever-increasing role.

EXTRACTION FROM SULPHIDE ORES

Then the next step should be solution, purification, separation nonferrous metals from each other by cementation, precipitation, solvent extraction, oil electrolysis, fluidized bed roasting helps in selective conversion of nonferrous metals in the ores and concentrate to sulphates. If you have fluidized bed roasting where p s o 2 and p o 2 are controlled then from the calcine selectively we can get sulphates and oxides and sulphates can be of a particular metal, can be can go dissolve in water and taken out and things like that.

So, this after flow solid roasting we can have soluble, soluble’s in dilute acid or water and to that will give a some separation etcetera many other things are possible. Right now we are not doing that, mainly the industry is working on concentrates which are very rich in copper pyrites CuFeS 2 goes for copper extraction. And on concentrates which are zinc and lead, if they are separated by floatation that goes for zinc extraction, lead extraction separately. If they are floated together it goes for imperial smelting process, this is the state of affairs in our country. But very soon we will have to deal with some deposits where we have to do something for when there are all the 3 metals present there, we have to find how effectively we can extract them in separately. I will discuss that some other time. Thank you