Introduction to Mineral Processing
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Lecture – 63
Flow Sheets

Hello welcome. So, we are at the last phase of this course, if you remember at the beginning what we said that mineral processing essentially is to provide a linkage between your mining operation and your the minerals to be found and in application; that means, when you are; what I try to say that when you are mining it, the minerals or the ores, it is not selective because you aim for mining large quantity of material per unit time.

So, most of the cases, most of the situations the mined ores may not conform to the quality requirement of your end users like your client, to be brief we can say that it is the value addition step, mineral processing is the value addition step of the mined minerals or the mined ores. Now the client requirements that is my end user requirement could be based on the sizes that is my end user mostly they are metallurgist even the grade of the ore, why do you have mined that may be adequate. Quality requirement imposed by the metallurgy people, but in terms of the grade but in terms of the size also they may require that will accept only the sizes in between this to that.

So, mineral processing does not always mean that you have to improve the grade of the minerals or the ores which you have mined; it is also sometimes linked with the particle size distribution. Now in some other cases it may be both, that is you need a specific sizes size distributions, plus your some improvement in the grade. So, the mineral processing operation also we have discussed that it cannot be done in a single stage.

So, we do it in stages, we have also discussed that when you try to improve the quality of my mined ore we have to understand that what is the liberation behavior of this mined ores; that means, that what is that oreses sized, oreses size of the practical where I will have enough liberation between the wanted and unwanted minerals so that I can separate them based on the physical property differences. So, and to have that your liberation we must have a combination circuit where the rocks are progressively broken with an aim that not to generate much of the finer products than what is required. Because it is a very energy intensive unit and the separation processes should be such that it meets the, my clients requirement with an aim that the recovery of the, my desired mineral should be as high as possible and that is what essentially dictated by the great recovery car and as we try to shift towards the right that is that your great recovery car.

So, you need a series of operations, but they are linked operations they are not isolated operations. And when they are linked in terms of a flowchart we call them a flow sheet. Now what are the priority information's we should have before we develop a flow sheet? As I had repeatedly said during this series of lectures, that the selection of a particular process should be dictated by the material properties as well as the requirement of my client with an aim to have maximum profit out of this business.

So, you have got economics, you have to always keep economic factors in your mind and your ore characteristics as well as the client requirement and I should have ideas that, what are the different equipment we can have to exploit this separation based on different physical property differences. What are those physical property differences? That is, one is your hardness, another one is the specific gravity differences, another one is your surface chemistry properties; that is your surface chemical properties differences, it could be magnetic property differences, it could be electrical property differences, many a times we need to apply the different equipment for different degree of up gradation.

So, to do this first what I have to know that, what is that mineral I want to separate from, what are the different impurities associated with it so; that means, I should have basic knowledge of some geological formation of that, then I should have some mineralogical characteristics based information, and I should always keep in mind that if I need to process that why my client requires all these specifications provided by them. I have to have a little bit of understanding of the metallurgical processes they will be using. So, first thing what I have to do? That is the characterization of my minerals.

For that characterization I need, because the characterization has to be done in a laboratory setup and for that I need a small quantity of material how do I collect a small quantity so; that means, your sampling strategies should be correct, your sampling equipment should be appropriate. If the sample what you have brought for characterization, if it is not truly representative of the entire population your entire selection of the equipment and the processes will be wrong.

So, and these topics are dealt in detail during this course and then what we have to do, that is we have to see the liberation behavior in a laboratory and then we have to think of selecting or designing my combination circuit processes; that is whether how many types of crushes we require, how many types of your grinding mills we require, what type of crushers, what type of grinding mills and then in between you have to always check the quality of those ground materials so; that means, whether I need screen. So, they need classifiers as well as how much of quantity per unit time I have to process.

So, that is about the combination circuit, then the separation circuits; that is, whether only gravity concentration will be enough for separation to meet the desired quality required by my client or whether we need a combination of gravity and your floatation or gravity floatation and magnetic processes like that. So, and in between we need the bulk material handling systems, because you have to store the materials, sometime you have to have your material to be transported from one unit to another unit, which I could not cover it in this your course, but they are also very vital operations for a your appropriate designing of a mineral processing plant. That is why I am not saying that this is a mineral processing plant design, I am talking about is the flow sheet development.

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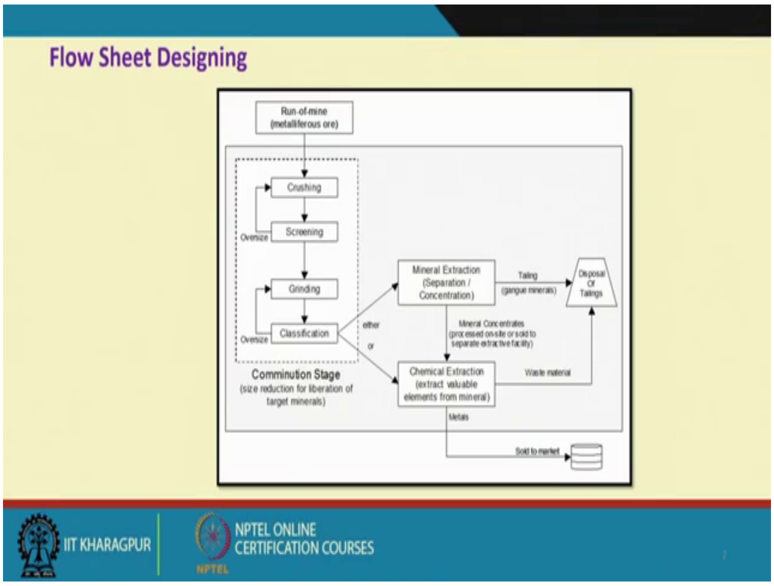

So, later let us see that if I put it into that in terms of a generic flow sheet we find that that you run of mine ore, it generally comes here into the combination circuit. So, that is the combination stage, now when you discussed about the combination we said that the combination, that is your crushing could be your open circuit crushing or closed circuit crushing. So, it can be either, when it is a closed circuit crushing there has to be a quality control device normally we use screens for relatively coarser materials, we use a classifier for relatively finer materials.

So, that is the selection process and you have to be very careful in following the arrows. The arrows tells us that how the material will be flowing from one unit to another unit. So, what this unit is showing that there is a crusher and there is a quality check that is a; so, it is a closed circuit crushing operation so, there is a screen. So the screen oversize again is sent back to a crusher so; that means, I need to crush the entire arrow more to a finer size than the screen aperture and the material which are already crushed below this your screen aperture size, they are sent to next equipment, communist and device that is called a grinding mill and then the grinding mill again because we cannot use a screen because of the fineness of the material you use a classifier again we put it into a closed circuit it can be open circuit also, but this diagram is showing that. So, again oversize is going to the grinding mill and you have got it material finer than this your set size of this your classifier.

So, in a flow sheet I have to first identify that what is that combinational circuit and at each stages what it is not shown here that how much a material you are feeding per unit time, normally we say per hour basis. So, depending on that you can select that what type of crushers you will be using and how many of them you will require and then how you are feeding to the next grinding mill. Because, your grinding mill feed may be coming from 2 parallel crushing circuits. Now, that parallel 2 parallel crushing circuits may be fade to a single grinding circuit or maybe 4 grinding circuits.

So, how the material is basically how the mass balances is being made, we have learnt also that and we have to know the material flow characteristic as well as their mass balances and if it is water based processes, we have to know the water balances and even when it is being transported as a slurry we should know the balances of the slurry also; that is, where it is going how much is going. So, if we just segregate the entire mineral processing circuit into 1 state that is this is what my combinational circuit this is what my separation circuit and when the separation occurs. So, how where my concentrates are stored and how it is being dispatched and when you have a concentrate you will definitely have some tailings. So, how the tailings are being handled; that means, how they are transported or they are being dumped or what is being done and what precautions we have taken to save it from environmental contamination and all these issues are there in a mineral processing plant.

But normally in this circuit, what we are trying to say it is a much more generic one that after this classification; that means. So, in the you have ground the entire material run of mine ore to below this your liberation size, then either they can be sent to mineral extraction processes; that is most of these processes we have discussed in detail or they may be sent to a chemical extraction, which has not at all been discussed in this course because of paucity of time. And then finally, you see that the metal means is the concentrate and then you are sending it to the market and the tailings that is your tailing disposal, this these areas are also are not discussed in this course. So, that is why the course name was introduction to mineral processing. So, essentially we have discussed only the very basic issues related to this subject and the like your sampling characterization, then your combination and then separation and mass balances like that.

Now, I will show you some examples, where I will try to focus on first these issues which have discussed, that is why I need to know my clients requirement as well as my ore which I want to treat, that is the mined ore. What is that quality requirement specified by the metallurgist and why do they require it? A little bit of understanding is required. So, that I know that how much of flexibility I have in this in your controlling of the grades or the essence of my final product and I can also based on that I can also guess that what would be the likely penalties imposed on the mineral processor if we fail to meet those targeted quality of the product.

One very important mineral or the ore is Iron ore. These days Iron ore beneficiation has become a hot topic. Why I am saying these days and I am giving this I am talking it on behalf of our countries situation that is India, you know India is blessed with very high grade of Iron ore in comparison to the Iron ore which is available in many countries in terms of grade.

So, but in Iron ore when we are mining it for so long now we are facing the problems, that the grade is deteriorating and great deteriorated means it will have naturally more of silica because the silicate had one of the most abundant minerals in this earth crust. Now try to understand this, that why we need to beneficiate Iron ore. Look at the clients perspective who are the user or the metallurgist, Iron ore beneficiation commonly we address about the hematite that is Fe 2 O 3 and how the Iron is Iron is extracted by the metallurgist, because you want large production of Iron, because you want to convert it into steel and various other forms. So, Iron is extracted in a furnace which is known as blast furnace. It is a huge gigantic furnace, height is around, it is minimum height is around 100 feet, where the Fe 2 O 3 the melting point of Iron is around 15-39 degree centigrade.

So, you have to if I want to extract the Iron from your hematitic iron ore, I have to maintain a temperature inside that furnace, which is more than 15-39 normally 16 around 60 degree centigrade temperature is maintained. So, when you require a temperature of that level you need a source of your energy. So, normally the coal is used in form of coke as an energy supplier. And at the same time, you need to reduce the oxygen from that Fe 2 O 3 matrix. So, you need a red reducing agent also for that oxygen. So, what is the reducing agent we use? Again the coke we use. So, coke coming from a coking coal is having, serving dual purpose that is, one is source for your heat another one is as a reducing agent.

So, fe 2 O 3 plus C it gives you now CO 2 and CO 2 plus C 2 CO like that and while taking out the oxygen the when Iron gets molten, now it is not the Iron where which you want to bring it into a molten stage, you need the impurities associated with it also to be in molten stage so that, I can have a separation between these 2 molten materials. Normally the Iron ores, they have got silica and this silicate also for that if you want to melt them, you need again the source of heat. So, that is some portion of coke also you require for heating the, my silica so, that they becomes in, they get converted into a molten form. Now there was there in molten form, the iron is much more heavier than the silica. So, you have got a gravity separation and the molten iron is separated out from a different level from the bottom of this blast furnace and at it is much more at a location and much more higher location, the molten silica we call it slag, that is being taken out.

And it is a continuous process now if I understand this much that is in brief I said that how the blast furnace works. Now we try to understand that if my silica content of Iron ore increases what will happen, which I forget to mention that even your coke will have silica, set aside that coke part.

So, if I have more silica content in my Iron ore, so I need more coke and your blast furnace has got a specific volume. So, if I have more silica that will occupy more volume and for that silica to be brought into a molten stage I need more coke so, essentially what will happen, my effective volume for by targeted metal, that is my Iron will be lesser, how lesser?. So, that is some figures I will give you.

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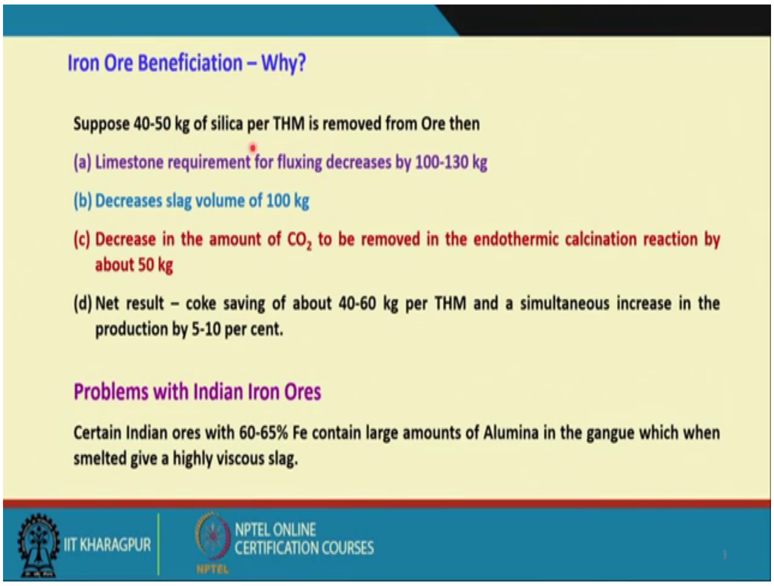

Suppose 40-50 kgs of silica, but turn up hot metal is removed from ore. Then limestone requirement for fluxing decreases by 100-130 kg. Limestone what happens, we also need to add limestone into a blast furnace operation it is CACO 3 at around 950 degree centigrade temperature this CA CO 3 gets dissociated to CA O and CO 2. And this CA O forms different complexes with my silicate. And that complex between the silicate and a calcium oxide helps in reducing the melting point of my silicates so, that they are mold, they are brought into a molten stage before the Iron is converted into a molten stage. So, that is why the number is, that is suppose 40-50 kg of silica per ton of hot metal is removed from ore by mineral processing, then the limestone requirement for fluxing decreases by 100-130 kg. So, you are not only removing 50 kg of silica, you are also reducing the consumption of limestone by 100-130 kg per ton of hot metal. So, and it decreases the slag volume of 100 kg, decrease in the amount of CO 2 to be removed in the endothermic calcination reaction by about 50 kg and I do not have to understand all these are basically a bit of background in metallurgy is required to understand. But look at the final result, the net result is the coke saving of about 40-60 kg per ton of hot metal and a simultaneous increase in the production by 5-10 percent.

This is very very important. So, only by removing 4 to 5 percent of silica that is 40 to 50 kg of silica per ton of hot metal in 1000 kg of hot metal, we will give you a benefit of increased production by 5-10 percent whether it is 5 or 10 percent that depends on other characteristics of your Iron ore and your impurities and other a associated things. And now, before we think of having a mineral processing plant for Iron ore beneficiation, we must know that, what is that meaning of 5-10 percent of benefit in increase in production in terms of economics and what is the cost of removing this 40-50 kg silica per ton of hot metal, that is your net smelter return, that your basic principle of mineral processing if you remember.

So, we have to do these calculations, based on that and which will enable you to take a decision that whether we should go for a mineral processing operation or not for this Iron ore which you are mining.

That means whether you are directly selling it; that is, a mined ore can directly be sold to my metallurgist people or to the metallurgical industries or. So, do we upgrade it and sell it to metallurgical industries. Naturally if you have a better quality you can ask for better price of your mineral of your Iron ore. So, this holistic view we must have before we decide that whether we should beneficiate my Iron ore or not, and this proves that I must understand a middle, of a bit of end use of my mined ore, also it is, I have to understand a bit of metallurgy, that is how the Iron is getting extracted and what are the likely problems in terms of economics my metallurgist friend will face if I have more of the impurities.

Now coming back to the, so keeping this thing in mined normally the flow sheets for Iron ore beneficiation and other mineral processing operations, they are designed please to remember that it is impossible to have a flow sheet, that is a mineral possessing plant which you design today it will give you a consistent product with the maximum recovery for next 40-50 years.

So, the, your processing plant should be flexible enough and with time, that is it should be dictated by your difficulty in separation imposed by your mined rock, you may have to upgrade your mineral processing separation units with time. So, now this is a good example of Indian Iron ore beneficiation industry, if you look at the problems with the Indian Iron ores certain Indian ores with 60-65 percent Fe. Now when you talk about Fe 2 O 3, what is the meaning of 60-65 percent Fe, I will try to explain you fast, that if I have a pure hematite that is a Fe 2 O 3, if you do a sty symmetric calculation you will find that a pure hematite can have only 70 percent Fe.

So, when you have even 60-65 percent Fe in your mined ore; that means, it is more than almost, more than 90 percent pure, but still we are saying that there are problems with Indian Iron ores, what is that problem? Now, this certain Indian Iron ores with 60-65 percent Fe contain large amounts of alumina in the gangue, which when smelted gave a highly viscous slag. Although the iron content is good, is very good, but you have got alumina and this alumina imposes the viscosity related issues with your slag. So, if the molten molten slag that flow ability is affected, then you cannot take it out at a rate commensurate with this rate of it is production inside the blast furnace.

So, what will happen, that will be an accumulation of this slag and your blast furnace operation the productivity will decrease. Now keeping and this problem is different from different mines product to mine product and even it is particulate deposit with time the problem is becoming more pronounced, more prominent and that is why the flow sheets are also changing. So, in the next lecture I will try to show you that over the years how the Iron ore beneficiation circuits are being basically changed to suit the material characteristics keeping in mined your clients requirement till then.

Thank you very much.