Introduction to Mineral Processing
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Lecture – 61
Magnetic Separation

Hello welcome. So, we will briefly discuss another topic of separation based on the physical property differences that is called the magnetic separation.

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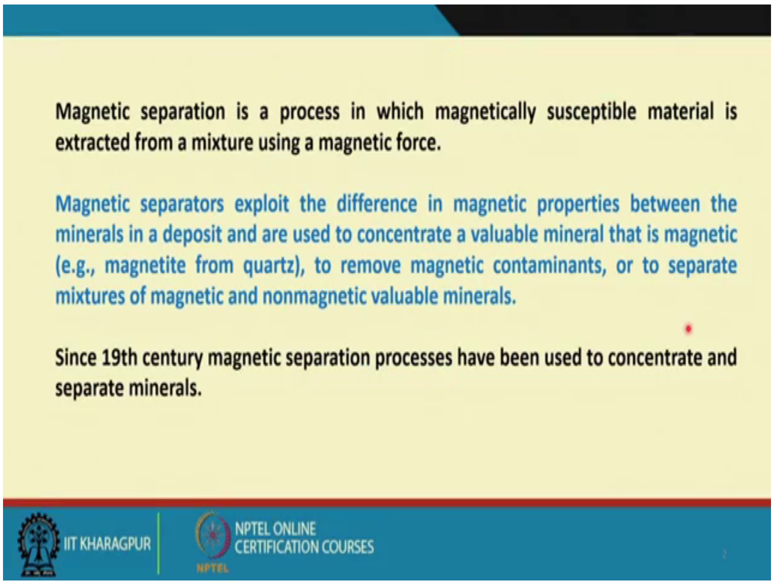

This magnetic separation is a process, in which magnetically susceptible material is extracted from a mixture using a magnetic force. That means, if I have a mixture of particles and if there are magnetic and non magnetic particles; that means, the particles which are susceptible to magnetic force and the particles, which are not susceptible to the magnetic force they are separated using a magnetic field.

It may look simple, but when you deal with very large quantity of materials at a finite sizes, which is required for its liberation then that equipment design and related to how you will create that magnetic field, how you feed your material to the separator, how you collect your separated product these are all engineering challenges.

So, I will discuss some of the developments that what is being done, but before that let me discuss about briefly about the bit of fundamentals of the magnetic separation processes. So, essentially magnetic separators exploit the difference in magnetic properties between the minerals in a deposit and are used to concentrate a valuable mineral that is magnetic; like if I have a mixture of magnetite and quartz we can easily separate magnetite particles by using a magnetic field, because quartz essentially is non magnetic.

Now, it can be used also for removing magnetic contaminants like when you are reading a mind rock, it may have some broken pieces of machines which are basically metallic; there we can have a magnetic field to take it out to set up our equipment, because the equipment may be damaged because of those metallic materials because they are much more harder than the rock or two separate mixtures of magnetic and non-magnetic valuable minerals. There are instances where you can have a mixture of valuable minerals some of them could be magnetic, some of them could be non magnetic. So, they are also we can separate this. This magnetic separation since 19th century, processor have been used to concentrate and separate minerals.

That means it is an old process, but the modern technologies, modern magnetic separations a aiming at as I had already mentioned that at what fine sizes level the particle sizes level it can be used effectively and what should be the capacity of this machines; that means, it demands the low grade minerals demand, that we need to have more capacity of these machines. So, how these designs have changed they should be the main theme of this discussion.

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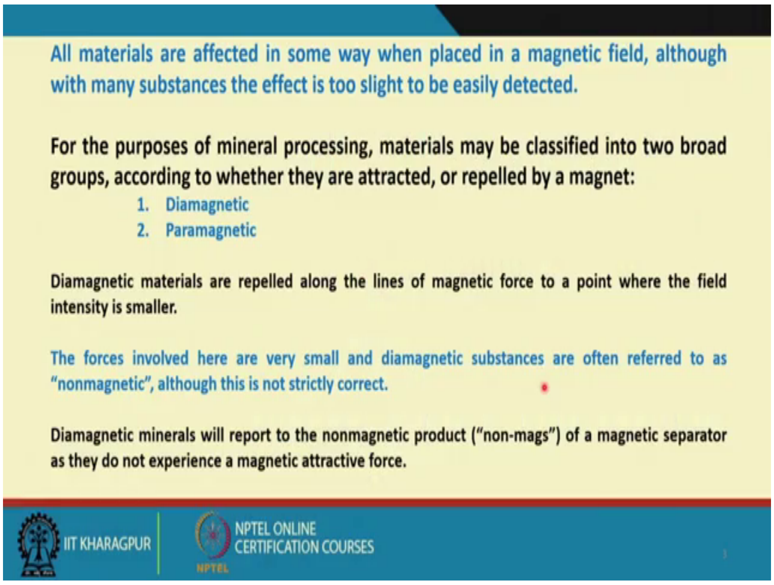

Actually all materials are affected in some way when placed in a magnetic field. Although with many substances the effect is too slight to be easily detected; that means, when any material you put it under a magnetic field, they have got some effect on this magnetic effect, but in some of the cases the effects are very pronounced in some of the cases, they affect our slide to be easily detected.

For the purpose of mineral processing, materials may be classified into two broad groups according to whether they are attracted or repelled by a magnet they are diamagnetic and paramagnetic particles what are the diamagnetic particles? The diamagnetic part materials are repelled along the lines of magnetic force to a point, where the field intensity is smaller the forces what are the forces involved? The forces involved here are very small and diamagnetic substances are often referred to as non magnetic although this is not strictly correct if you look at from the point of view of physics. But from a mineral producing point of view, we call them non magnetic particles.

Diamagnetic minerals will report to the non-magnetic product, that is of a magnetic separator as they do not experience a magnetic attractive force.

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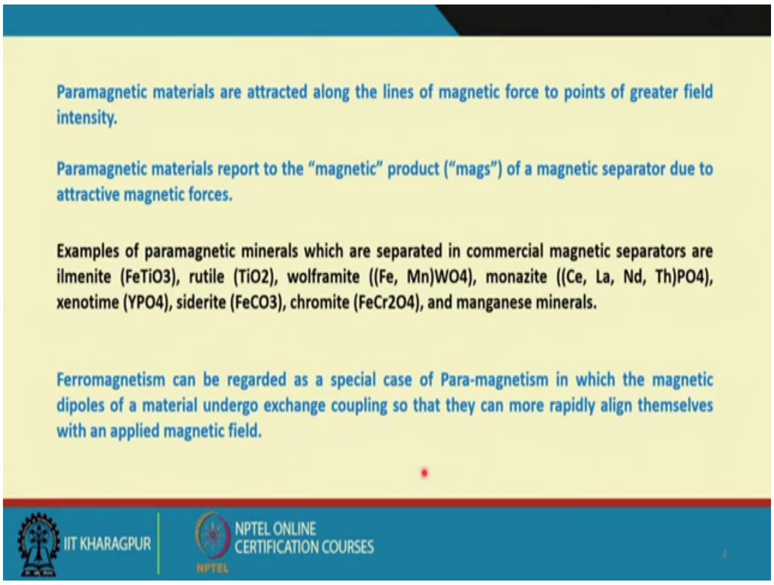

Now, paramagnetic particles or paramagnetic materials are attracted along the lines of magnetic force to points of greater field intensity. That means, the diamagnetic particles they do not respond much to the magnetic field, but paramagnetic particles they responds quickly when they are put under a magnetic force. So, that is why the diamagnetic power materials are called nonmagnetic particles at paramagnetic particles are basically we call it that they are susceptible to the magnetic force. That means, they will be attracted to the magnetic your such a source of the magnetic force.

So, paramagnetic materials report to the magnetic product of a magnetic separator due to attractive magnetic forces I will show you how these separators are designed. A very simple example of this suppose I have got a coercion magnetite mixture, spread evenly on a paper and if I have a hand magnet what I will find that the magnetite particles are basically attracted to the magnet, but the quartz particles they remain on the paper. So, now the magnet there is a separation because the magnetite particles are all basically get added to the surface of my hand magnet whereas, it will leave behind the quartz particles in the paper. So, that is how you can have a separation.

Now, how it is being done in a large scale, that is by some means in a continuous mode those are called the magnet magnetic separators. Some of the examples of paramagnetic minerals which are separated in commercial magnetic separators are ilmenite Fe Ti O 3 or Fe or Ti O 2 rutile T iO 2 wolframite Fe Mn WO 4 monazite Ce La Nd tTh PO 4 xenotime YPO_4 sederite $Fe CO_3$ chromite $Fe Cr_2 O_4$ and manganese minerals. Ferromagnetism can be regarded as a special case of para magnetism, in which the magnetic dipoles of a material undergo exchange coupling so that, they can more rapidly align themselves with an applied magnetic field.

So, there can be a subcategory of the paramagnetic particles like your ferro magnetic particles.

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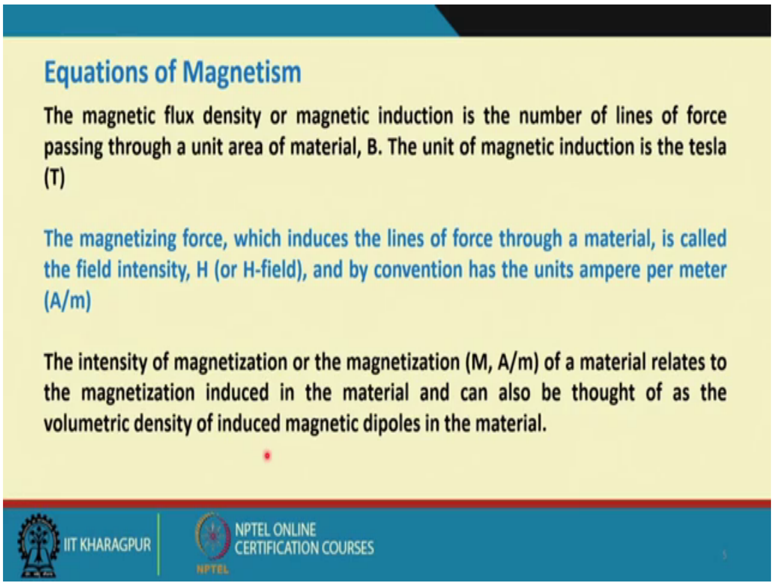

Now, just to recollect the basic physics regarding the magnetism applied to magnetic force. So, when it is applied to minerals, it is just a brief discussion on that that is called the magnetic flux density or magnetic induction is the number of lines of force passing through a unit area of material B.

So, what are the magnetic flux density or magnetic induction? That is the number of lines of force passing through a unit area of material that is B. The unit of magnetic induction is the tesla represented normally as capital T. The magnetizing force which induces the lines of force through a material is called the field intensity H or H-field it is represented at capital H and by convention has the units ampere per meter A by m.

So, one is the magnetic flux density another one is the magnetic force magnetizing force. The intensity of magnetization or the magnetization that is M of a material relates to the magnetization induced in the material and can also be thought of as the volumetric density of induced magnetic dipoles in the material. The magnetic induction that is the field that is the B it is called the field intensity.

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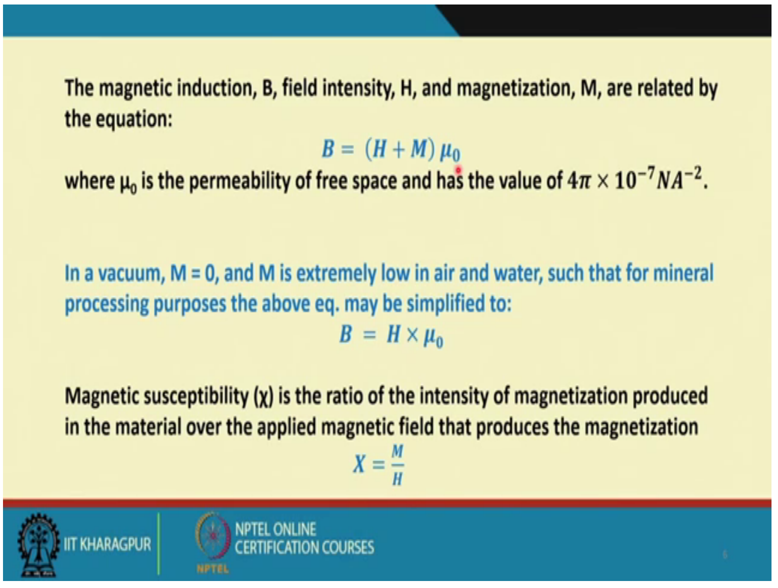

Now, magnetic induction represented as B, field intensity represented as capital H and magnetization as capital M, they can be correlated by the equation B is equal to that is your magnetic induction is equal to field intensity plus magnetization M multiplied by mu 0 what is mu 0? The mu 0 is the permeability of free space; permeability of free space means at vacuum what is the permeability of that force and as the value of 4 pi into 10 to the power minus 7 newton per ampere square.

in a vacuum the M is equal to 0 that is your magnetization is equal to 0 and M is extremely low in air and water; that means, in a medium of air and water the it is the value of M is also very less. Such that for mineral processing purposes the above equation may be simplified to B is equal to H into mu 0; that means, we can neglect the effect of M. Now there is another parameter it is called magnetic susceptibility what is magnetic susceptibility?

The magnetic susceptibility is the ratio of the intensity of magnetization produced in the material over the applied magnetic field that produces the magnetization let me repeat it. Magnetic susceptibility is the ratio of the intensity of magnetization produced in the material over the applied magnetic field that produces the magnetization and this magnetic susceptibility in terms of equation we can write is equal to M by H.

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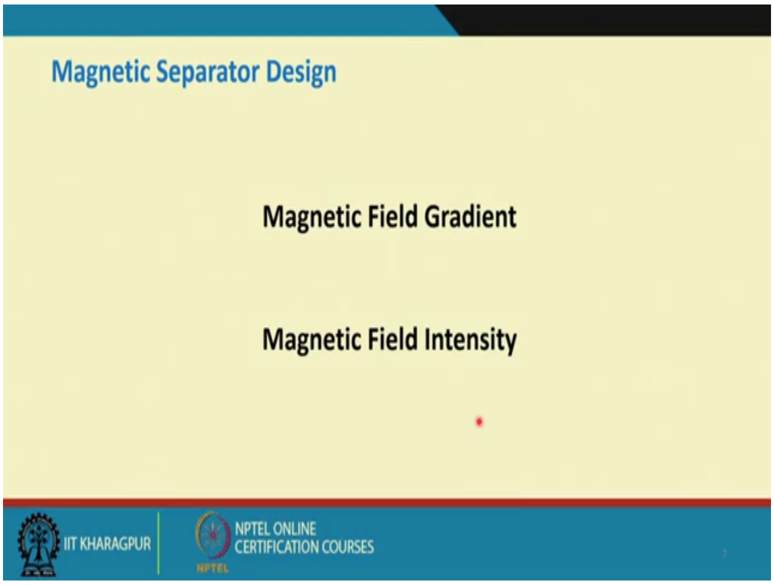

Now, based on this basic information, now let me get into directly to the commercial processes, where we use this theory of magnetism to separate the minerals based on the principle of some minerals could be diamagnetic and some material minerals could be paramagnetic, but how do we generate this field gradient, how do we collect them separately these are the integrate challenges of the magnetic separated design. So, two very important thing is the magnetic field gradient and magnetic field intensity in magnetic separated design. So, there are broadly two types of magnetic separators.

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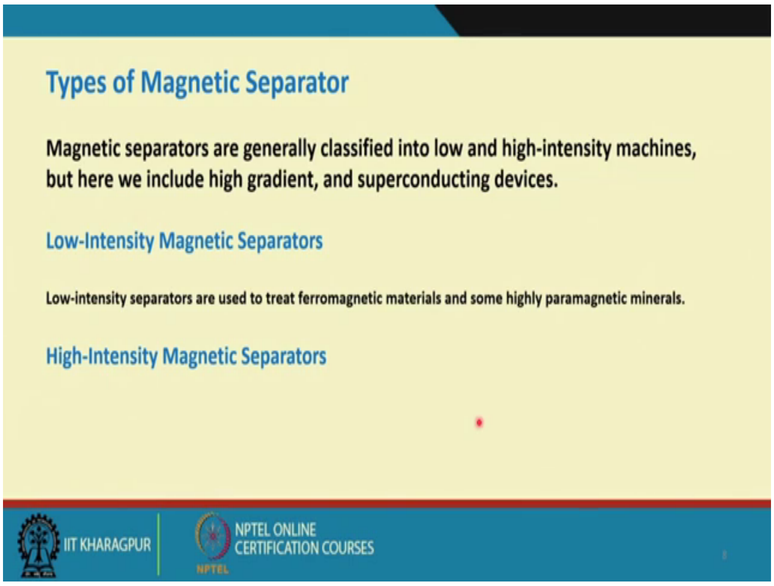

One is low intensity magnetic separator, another one is high intensity magnetic separator. So, magnetic separators are generally classified into low and high intensity machines, but here we include high gradient and superconducting devices. Like low intensity magnetic separators are used to treat ferromagnetic materials and some highly paramagnetic minerals. We do not require that type of your high magnetic force to separate them out because they are ferromagnetic, they have got inherent properties to be attracted towards the even a mild magnetic field.

High intensity magnetic separators are basically used for separating the minerals, which are weakly magnetic materials.

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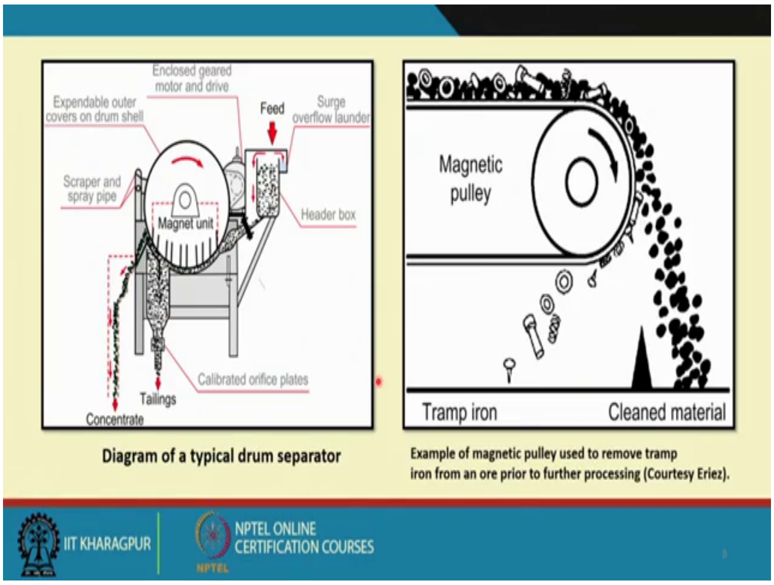

These two are showing the two commercial designs of magnetic separators. The magnetic separators this is called a typical drum separator. So, what happens here see that there is a rotating drum and their drum rotates in this fashion why it has to rotate? Now because you have to transport the feed material from one point to another point. So, what happens here the feed it may be as a dry feed or it may be in a slurry form.

So, it is fade through here and the material is forced to pass through these passage and when it comes here because of gravity because it is in a height. So, it is the material passes through that and then because of the rotation of the drum, the material is being transported further.

But this portion inside there are some magnetic unit there are some magnets installed they are fixed positions so; that means, the drum is rotated and inside that zone I have got some magnets. So, what will happen in this case the non-magnetic particles will not be affected by the your magnetic force created by these magnets.

So, because of the mid gravity the material is coming here and you have an escape route here. So, that is the nonmagnetic particles will be collected from here. Whereas, the magnetic particles they will be attached to the surfaces of this drum, now say suppose the magnetic particle is attracted here now because of the rotation it will be transported up to there and then when it goes there then there is no magnet.

So; that means, you are withdrawing the magnetic field and there you have got a collection system. So, there the material the magnetic materials will be transported up to this much and then they will be discharged through a concentrate collecting system. So that means, the nonmagnetic particles are collected from here a magnetic particles are collected from here. Now you can have a different other attachments like the some particles may still get added to the surfaces of that. So, they are magnetic particles, but he can have scrappers. So, that it scraps that your surface of your drum so, that these particles they should not again start rotating.

So, that is called the and then you have got there some other mechanical features that is how you drive it and all this. So, you see that its a continuous process so; that means, there is a continuously the feed is coming and the there is a separation between your magnetic and nonmagnetic particles, but here the issues are that your feed rate will essentially be controlled depending on the nature of separation occurring here now suppose your this this layer this has got a specific volume and this zone. So, your feet rate is essentially controlled by the your material transport rate, depending on the available volume in this region.

So, if the drum rotates faster. So, what will happen? The magnetic field generated here will have lesser time to direct it to get directed towards the attracting the magnetic particles. So, he may lose some of the magnetic particles from here also because they have not been yet exposed to the magnetic field, if it is rotated at very high speed. So, I will have your huge losses of my valuable minerals or maybe if my magnetic particles are not wanted materials, I will be having I will not be having much more cleaner product as I want it.

So, the drum speed plays a critical role and it depends on what is the transport behavior in this region so; that means, to optimize the parameters here, we have to understand also the material flow characteristic from here to there and then how the materials are being transported here and then how this magnetic field they affect or say they affect the my particles, that is your magnetically susceptible particles to get attracted towards the surface of this drum. Because just imagine that if the particles if a magnetic particle if it is in the bottom most layer. So, it has to be the my magnetic field has to pass through the entire your material zone that is the entire depth, and it has to induce that magnetic field onto the surface of that particle.

Now, that particle has to have your free path to get attached to the get added to the surface of my drum. So, if that path is not given then the material although it is magnetic particle they may directly report here. So, how much is the residence time from here to there and at what feed rate and at what size and what is the field intensity you have created, these are all basically the variables and we have to optimize as this.

This is another one a separator like in this case what is happening? You can have a conveyor belt type of system, that is material is transported through a conveyor belt we have got magnetic and nonmagnetic particles like it is normally they are dry processes and suppose I want to separate out all these type of your nails and other your say tramp material, tramp iron from my material. So, that it does not go to the my subsequent processes, because they are not only unwanted material, but they can damage my equipment also. So, when the material is transported through a conveyor belt, now again you have body your drum type of your say your arrangement here and you can have magnet magnets installed up to this portion.

So, what will happen the nonmagnetic particles will just fall here and your magnetically susceptible material that is a metallic tramp irons, they will be attracted up to and they will be transported up to that region, where you have got magnetic field. So, and then you can when you are withdrawing, the magnetic field they will be dis lost because it will now behave like a nonmagnetic part it will it will be the magnetic field is withdrawn. So, because of gravity they will fall.

So, the important issue here is this your splitter, that is where my splitter will be positioned. So, that will depend that up to where the magnetic materials will be transported; that means, up to what region my magnets are there, and then what is the your the flow path of my clean material, because in this case I do not want magnetic materials that is their tramp irons.

So, I have to know the flow path of this. So, that flow path of this material also will depend on the at how at what speed my belt is being operated; what is that how much our material is being transported and then because the splitter positioning will be based on these parameters and this one that is where this material will fall that is your magnetic materials that also we have to understand because we have to collect them.

So, these are apparently looking very simple separators and we can use it, in industrial scale when we have varieties of situations.

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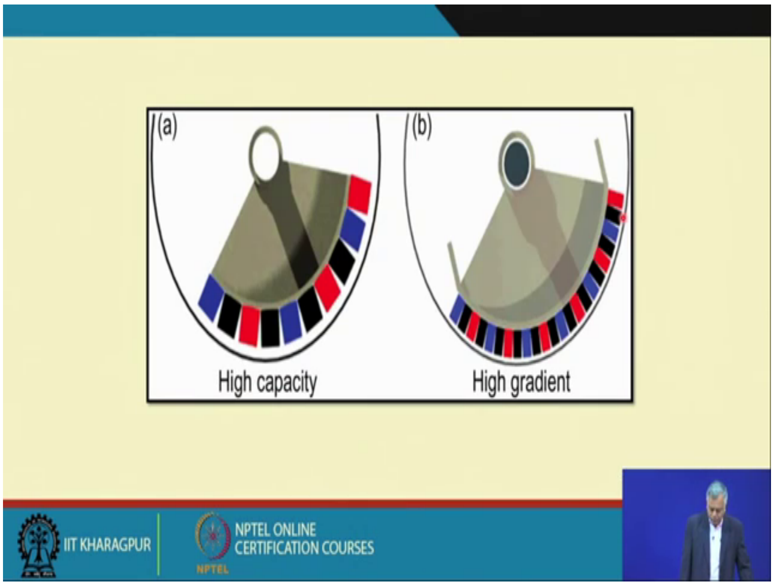

This is another one as a high capacity one like it is the only as schematic, I am showing that your material may be fade here. So, there is a high capacity because your nonmagnetic materials you can collect from somewhere here, but magnetic particles will be added to the surfaces, and then when you are withdrawing the magnetic field they will be dislodged from somewhere here.

Now, this is a basically high gradient magnetic separator. So, what you can do. So, that you can have your the gradients like how the magnetic field is being imparted on the surface of my material, which direction because if you have a magnetic force in this direction then the magnetic field will be generated in that direction. So, based on that principle you can design, that is how these gradients will be monitored and. So, that all the particles which are magnetically susceptible they are separated.

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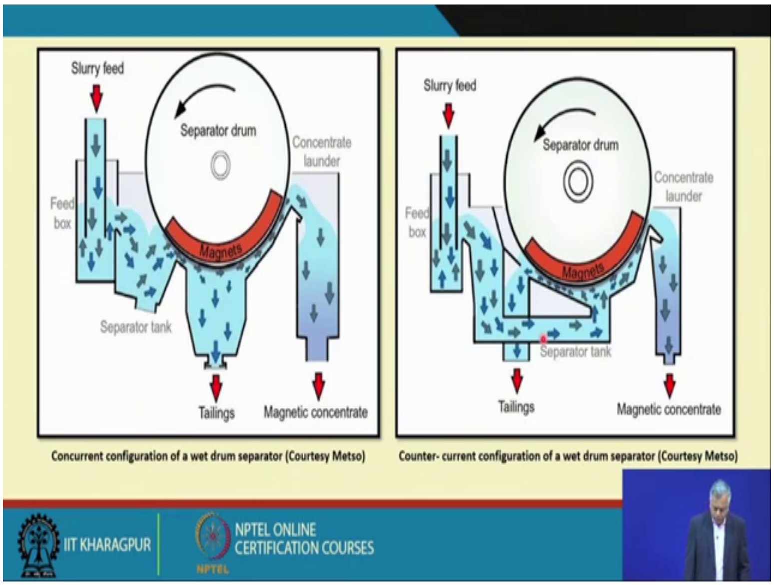

Now there are some other designs also available, it is called a weight drum separator it is again they are again taken from the metso website I gratefully acknowledge that, look at the designs here. You have got a separated drum the same mechanism, but look at the how the material is being fade and how the separated material are being collected and then how we are they are trying to improve the quality of your separation, that is the separation efficiency. Though the drum rotates in this direction and you have got fixed magnets here, we have got fixed magnets here so; that means, this region is you are inducing magnetic field.

Now, slurry that is in the form of a mixture of water and your material they are being fed from here in the form of a slurry and now there is a separated tank, now because of this overflow nature. So, that is called the feed box and from here there is a basically material is going through that and what is happening because this is how you are this is the feeding mechanism and a to the separator, and then because of the overflowing nature over through overflow where as the material is being fed.

Now non magnetic particles will immediately be collected into these tailing launder whereas, because of the drum rotation, the; and the magnetic if there are magnetic particles they will be added to the surfaces. So, they will be transported from here to here and when you are withdrawing the magnetic field, there will be again dislodged from the drum surfaces and that is how we can collect the magnetite magnetic concentrate, that is a concentrate of magnetically susceptible materials.

That is how you can separate you can have a separation between your magnetic and non-magnetic minerals. This is another design where we want to show that how a different design is being made like you have got a slurry pit, it is similar to that and then because of the over through a overflow mechanism, the material is now fade at this point. Now what will happen? Now when the material is fed directly almost at the center location where the magnetic is there, then the drum is rotated in this fashion.

So, now when the material is transported in this fashion, now you have got a gradient here. So, your non magnetic particles will be collected because of your overflowing nature of these entire volume, and your magnetic magnetically susceptible material will be carried towards this and they are separated. So, these are all the intricate details of your the different designs, just for your a your example I am showing it.

So, the magnetic your this separators designed vary from manufacturer to manufacturer, and the it also varies based on the material characteristic like their particle size distribution their nature of your magnetic properties and the nature of impurities and the degree of your accuracy of the separation processes you desire.

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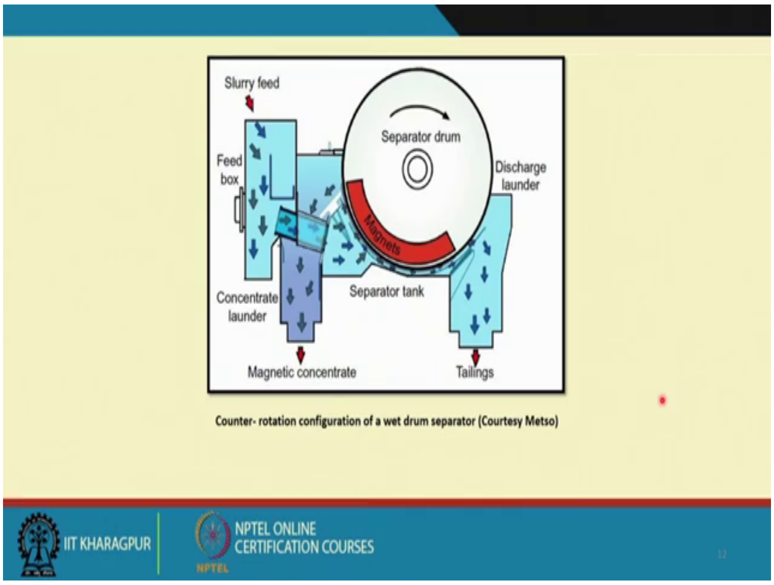

Counter- rotation configuration of a wet drum separator (Courtesy Metso)

This is another design again by metso, this is based on your counter rotation that is slutty is fate through this and now the drum is rotated in this direction not in this direction and magnets are basically held up there. So, magnets are there. So, now, what will happen? Now when the it is moving in this direction so; that means, the material is being fade here and the magnetic particles are transported up to there and they in the as dislaws.

So, you are getting a magnetic concentrate here that is called concentrate launder and the tailings because of your because of the overflow where a mechanism, they will be coming the discharge through these. So, that is how a separation based on your counter flow. Counter flow means the flow is in opposite direction of your say your drum rotation. So, these are in short the some of the designs of the commercial magnetic separators. We will continue this discussion in the next lecture till then.

Thank you very much.