Mechanical Unit Operations

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Lecture 13

Conveying of Bulk Solids

Welcome to the MOOCs course Mechanical Unit Operations. The title of this particular lecture is bulk solids. So bulk solids conveying, the bulk solids conveying adds additional cost to the installation as well as the operational cost of the given a process industry in general. So why do you need conveying a bulk solids in such kind of process industries, which adding additional cost for this conveying?

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Because you need to supply from the point of supply to store or to process. Sometimes you need to supply this material or convey the solids between stages during the processes where the unit processes or unit operations are taking place. Sometimes after the production packaging and distribution for that purpose also, you need to have a kind of a proper conveying facilities for this bulk solids.

So because of these reasons the conveying of bulk solids adds additional cost to the existing plants or to the plant design and then operational cost it adds additional. So there are several types of conveying equipment are available which includes something like conveyers, elevators, cranes, trucks, pneumatic systems etc. And then these kind of system, the method of motion, whatever the motion of material is taking place that may be because of the gravity or by simple labour activities or by employing some mechanical power.

So the method of motion provides a basis for subdividing this conveyor further subdividing these conveyors or the conveying equipment is very difficult. Different types of classifications of conveying equipments are in general possible for the given type of bulk particulate or powder material. However, the most appropriate one is presented here. So there are 4 primary types of conveyors are available. So one is the belt conveyor another one is the chain conveyor, the next one is screw conveyor and then pneumatic conveyers.

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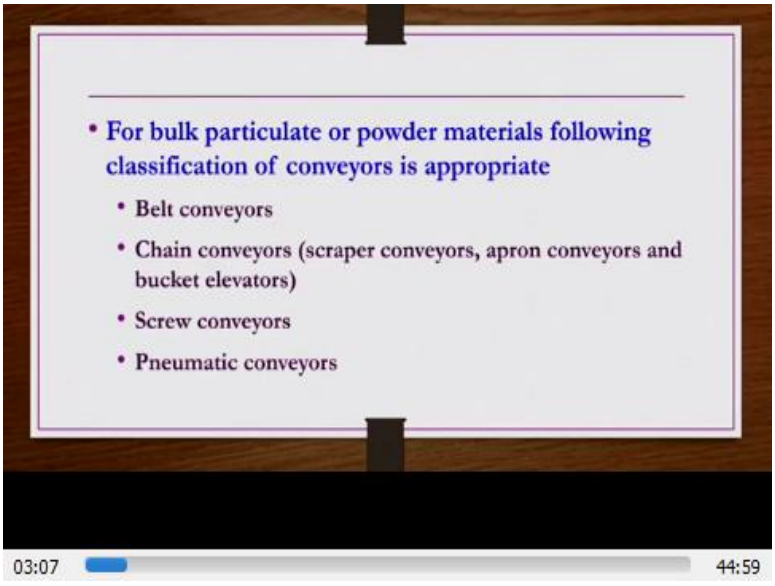

So this belt conveyor, chain conveyor and screw conveyors are a kind of conveying equipment which acts a kind of a because of the mechanical means that the material carrying element rotates between given two different points. So that is the basic principle. Where as in the pneumatic conveying, there may be a kind of pressure is involved, there the positive pressure or negative pressures are involved.

Under the case of chain conveyors, depending on how they have been designed for a given duty there may be different classifications further sub classifications are possible like scraper conveyors, apron conveyors and bulk elevators. We are going to see some basics of this convening equipment because individual details like a specific details like design, working principles and then what types of industrial conveying, conveyors are available under each category can be a kind of interest of separate subjects.

So to the level of undergraduate studies, we will be seeing only the basic of this conveying equipments now. Belt conveyors; so belt conveyors consist of an endless belt operating between two or more pulleys, friction driven at one end and carried on an idler drum at the opposite end. So actually basically the process is something like this. You have a kind of a pulleys or something like this. They are rotating, on to which there is a kind of belt

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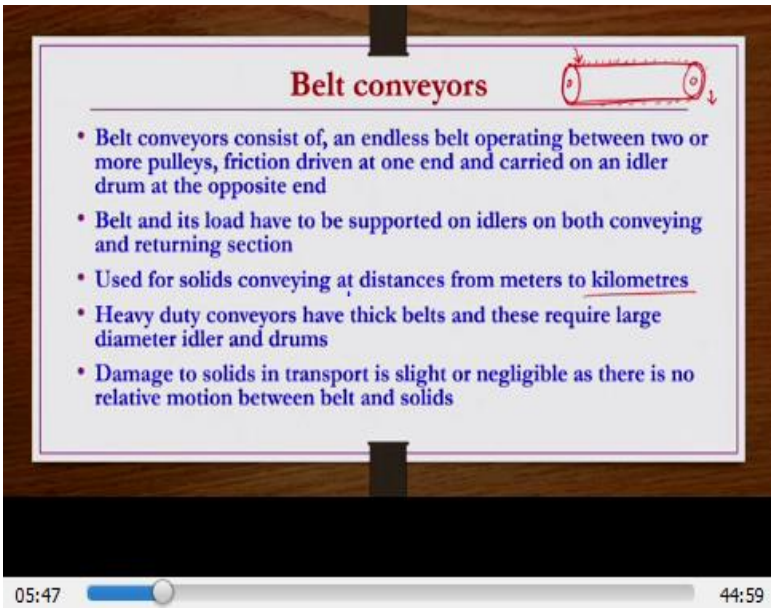

So it is a kind of endless because it is continuously rotates between these two only, there is no any kind of thing. Whatever the material is coming something like this from the loading point, so the material will be taken here and then that as the belt moves, that material will be carried to the subsequently section and then will be collected at the kind of a discharge section.

So this belt rotates like this and then it will be continuing operations something like this. So this is the basic principle for this belt conveyor. In general for the chain conveyors also similar kind of principle are there, but only thing that in place of belt we may be having different types of chains there for the given operation and not necessarily we need to have a kind of horizontal one we can have a inclined one.

We can have more than two pulleys or something like that. Depending on the applications, we can only have horizontal, we can have the vertical. We can how to both the horizontal and vertical, we can have the inclined conveying facilities as well. So this is the basic method how a given belt conveyor operates. So belt and its load how to be supported on idlers on both conveying and returning sections.

And these are used for solids conveying a distance from meters to several kilometers as well. It is a heavy-duty, service you can expect from the belt conveyors. Heavy duty conveyors have thick belts and these require large diameter idler and drums, so that to have a kind of mechanical strength. Damage to solids in transportation by belt conveyor is almost negligible or very small because there is no relative motion between the belt and solids.

Because of that one in general there will not be a kind of loss or damage to the solids which are being conveyed by using this belt conveyors. The carrying capacity of belt conveyors in general is very high. That is the one of the most important advantage of this belt conveyors. In general, this high-capacity belt conveyors can be operated in a horizontal plane. However, there is also a possibility or can be taken for the conveying with a restricted angle of elevation of 15 to 20 degrees, so not necessarily completely horizontal.

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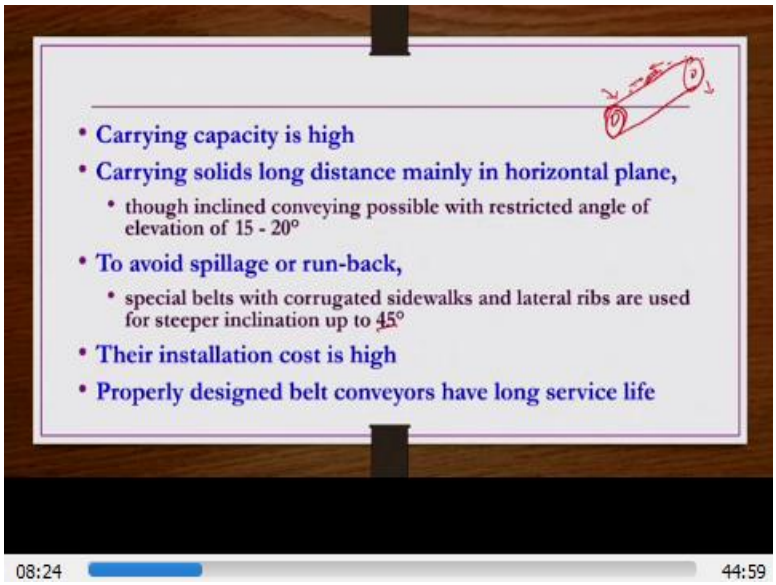

Sometimes you can take a kind of elevation of the system with 15 to 20 degrees maximum elevation. You can even have further higher elevation also but under such conditions what happens sometimes, run back of the material may take place. Like, let us say you have a system of kind like this, these things are there. So if you have only plane belts and the material coming here, and then that is supposed to be discharged something like this here.

So then because of the higher elevation, what happens this material rather moving in the direction like this some of the material may be running back like this also. So that is again possible in some cases. So however, one can avoid that one also. So that is, that means, you can have a kind of a higher degree elevation also.

But you have a higher degree elevation then there is there is a kind of danger of spillage or run back under such conditions. You can have special belts with corrugated sidewalks and lateral ribs, so that that can be used for steeper inclination up to 45 degrees. Though these belt conveyors are having several advantages are shown like high capacity; you can take them for longer distance and then you can have a kind of heavy duty service.

You can have a horizontal inclined services,etc. Itis having a kind of advantage of high installation cost. This is one disadvantage; the installation cost is high. However, even if the installation cost is very high, once properly designed and install belt conveyor can give a kind of

long service. It will have a long service life in general. So in that perspective also, whatever the high installation cost is there that should not be kind of a major factor for not considering belts conveyors.

So overall this belt conveyors are having several advantages as discussed here, like high-capacity, long distance, different orientations of the solids conveying etc. The this kind of the advantages are there, in addition to the long service life. So then what are the elements present in a given a kind of belt conveying systems?

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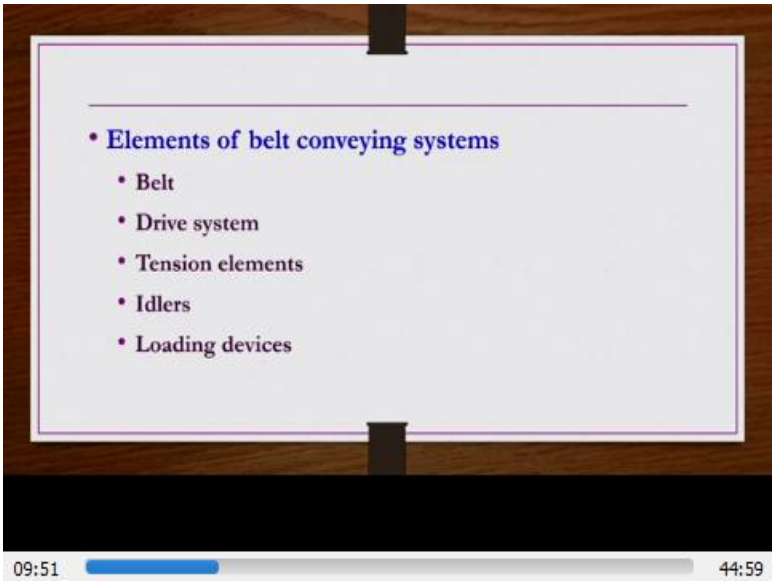

So it is not just a kind of belt there are different things are there like idler drums, trippers for discharging, feeder system and then pulleys and then pension system etc. should also be there in order to have a kind of complete belt conveying system. So we will see what are these say elements. First one is the most important one is the belt, on which the material is being conveyed and then next is a driving system where these belts are rotating.

Then there should be kind of tension element so that , the whatever the load, etc that should be properly hold on. Then idlers; idlers are very important because this belt whatever are there, they are supported on this kind of idlers only. Then loading devices, so you should have a proper loading devices as well to load the material onto the belts and then through the belt, it will be discharging to the some other location. So you need to have a proper discharge device as well.

So these are the main important elements of a given belts conveying system. We will see some of them; some details of these elements as well now. So belt; belt is what in general, it is a kind of stitched canvas or solid woven balata and rubber belts. In general these kinds of belts are used and these belts must be flexible enough to conform to the pulleys. And then wide enough to carry the quantity and type of material, and they should have sufficient strength to stand up under expected load and operating tension, and they should also possess resistant surface.

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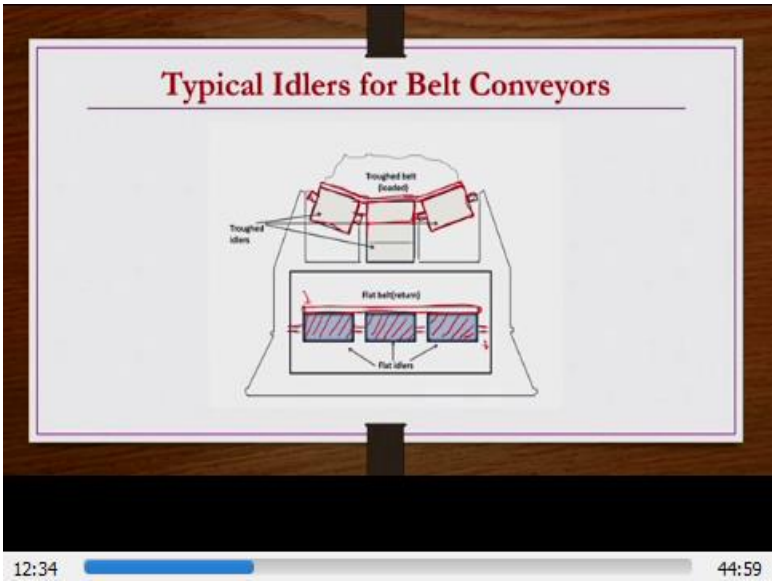

So these are the minimum number of important characteristics of the belts. Any belt that you select as per your duty, as per your, type of material that you are transporting. So this kind of that belt should have a kind of minimum this kind of characteristics. Those belts should fulfill these kind of characteristics. So idlers for belt conveyors. Let us say you have a kind of flat belts like this like this.

So then these belts are in general mounted on a kind of idlers like this since this belt is flat belt. So here idlers are also having a kind of a flat orientation and they are connected like this. So,

these things are supporting these drums in general. So when the material comes in here, so these things are moving so then belt is also moving, so the material is taken away like this.

So idlers are in general moving slowly in a direction in which things need to be transported. Sometimes you need to have a kind of troughed belt like this. Then what happens under these conditions. The idler should also be troughed like provided here something like this. So this, these are again connected interconnected like this. So these are very important element of this belt conveying system because belts are supported on this idlers.

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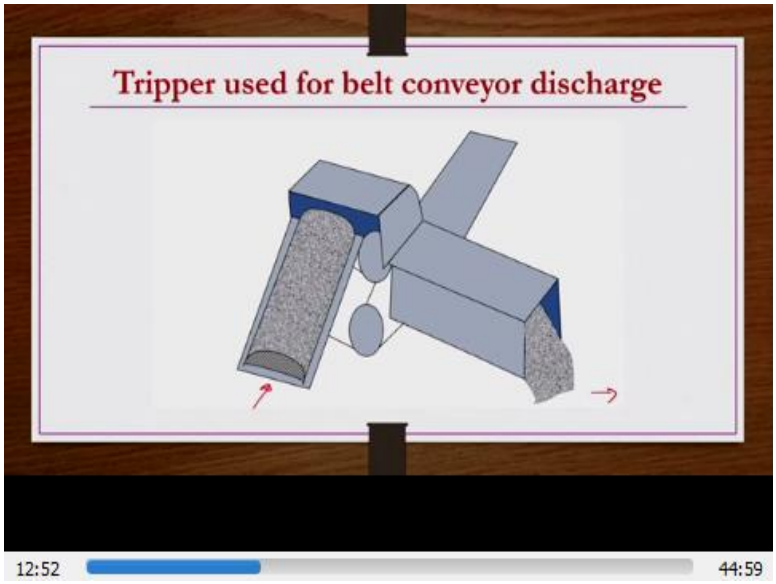

Then we have trippers which are used for discharging of the material. Let us say typical tripper is given like this. Whatever the material comes in here through belt conveyors that will be separated out here and then we can get a kind of discharge from here. Trippers are kind of that actuate the kind of given operation. So this also requires some kind of power. These are used in general for discharging of the solid from the belt conveying system.

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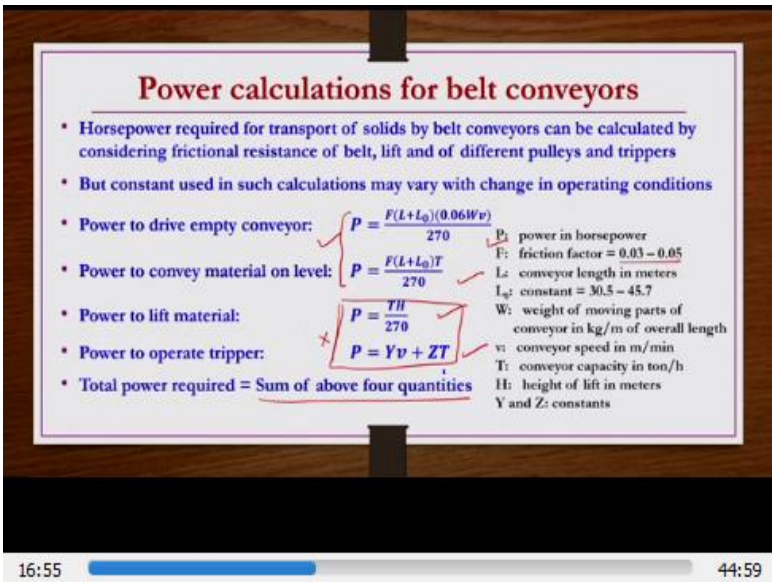

Then power calculations for belt conveyors. So we have seen there are different elements are there in the belt conveying system. So each of may be requiring some kind of energy, power is required or some amount of power is required for operation of each of them. So that is the, if you need to know the power requirement horse power requirement for the entire belt conveying system.

You need to calculate the power requirement for individual element and then add them together. How do you do that one? You can do with a simple calculation by considering the frictional resistance amongst the elements like, belts, lift and pulleys, trippers etc.So however when you do these calculations, you may be coming across several constants which maybe vary with the type of the material and then operating conditions.

So rather going into details of those derivations and all those we take acceptable equations for these power requirements. So the power requirement for the individual element will take and then we see the equations whatever the acceptable equations without going into the derivations and all those things. However, though these derivations are simple, one can consider the frictional resistance amongst these elements are then calculated this power requirement.

Let us say you have empty conveyor. So what is the power requirement to drive empty conveyor? Then the power should be

$$P = \frac{F(L + L_0)(0.06W_v)}{270}$$

.Then on to this if you have a some kind of load, so what is power to convey material on level? Then the

$$P = \frac{F(L + L_0)T}{270}$$

In such case, if you have a kind of lifting of material. Power to lift the material that should be

$$P = \frac{F(L + L_0)T}{270}$$

Then in order to operate the trippers, the power requirement is

$$P = Yv + ZT$$

So if you have any given operation if you need or if you are having all these components then whatever the power is there or obtained by the individual components like these 4 equations; they all should be added together, .

So that is total power required for a belt conveying system is sum of all 4 quantities. But however, let us say in a system; if you do not have a kind of lifting of the material and then you do not have a kind of operator, or the tripper kind of operator. So then you do not need to consider these two elements. You need to consider these two elements and then calculate individually and add them together.

So it depends on in a given system all of them including or all of them are existing or not. If all of them are existing or all of them are being operated, then the power required for all this component should be calculated and added together. But if you have only couple of them, let us say you have a simple conveyor on which materially you are taking, So then you can take only first two cases in the add them together.

So whatever the power is there for the individual elements; all of them should be individually calculated and added together in order to get the total power required for a belt conveyors. Next further in this equation P is nothing but power in horsepower, F is nothing but friction factor which varies in general between 0.03 to 0.05.

L is the conveyor length in meters, L_0 is a constant which very general 30.5 to 45.7. And W is weight of moving parts of conveyor in kg per meter of overall length. V is the conveyor speed in meters per minute. T is the converter capacity in tons per hour 1 and H is the height of the lift in meters if it all lifting of material is there. Whereas the Y and Z are constant in general they are available, if you need to calculate the power required for the tripper. This is a about the belt conveyors.

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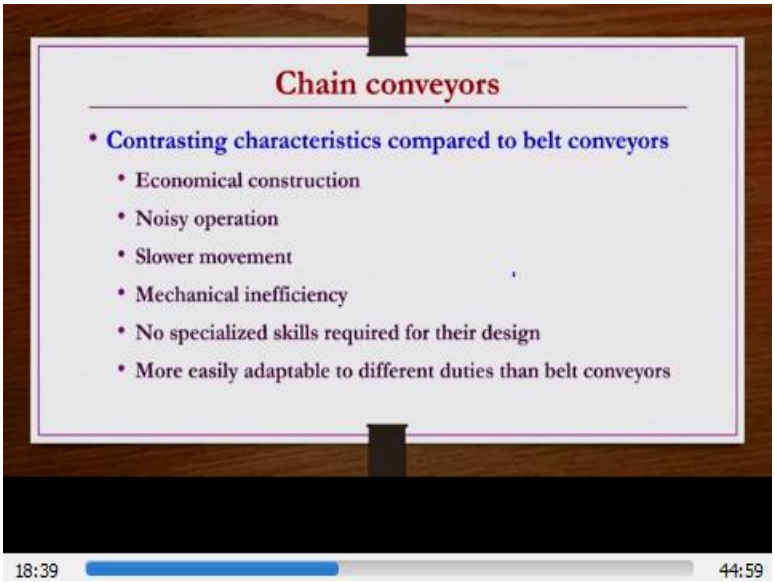

Now, we see chain conveyors. So principally they also have a kind of similar operational things, but only thing that here in place of, instead of belts we will be having chains. But their characteristics are drastically different compared to the belt conveyors. They are having very contrasting characteristics compared to the belt conveyors. We see some of them know.

First of all, they are not expensive like belt conveyors. These chain conveyors are economical construction. But they are very noisy operation- noisy operation. Then the movement is a very slower movement. Whereas in the belt conveyors, you can have a kind of high-speed motion as

well. Whereas that is not possible in the case of chain conveyors. The mechanical efficiency we have seen in belt conveyors is very high.

But you cannot expect to have such high mechanical efficiency in the case of chain conveyors. And then no specialized skills required for their design. They are very simple and these chain conveyors are more easily adaptable to different duties than belt conveyors. Then what are the main components of chain conveyors? In general, chain conveyors consists of chains, moving elements and drives.

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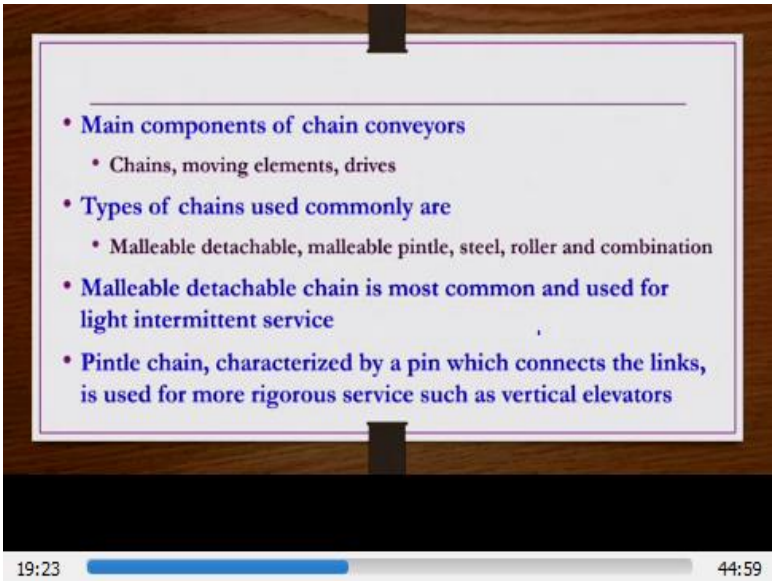

So what are the types of chains used commonly in this in these types of chain conveyors are malleable detachable, malleable pintle, steel, roller and combination. So we see individual of them. Malleable detachable chain is most common and used for light intermittent services in general. Whereas malleable pintle; pintle or something like pin or bolt kind of thing which are used to connect the links. So this pintle chains are used for rigorous services such as in the case of vertical elevators. Steel chain is used where high-strength or good wearing qualities are both are needed.

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Roller chain is fitted with rollers or wheels to minimize friction and reduce wearing of the equipment. Combination chain, sometimes what happen if a given duty you may be thinking that it may not be possible to do using individual chain conveyor, like steel chains, or pintle chains, etc. Then what you can have a you can have a kind of combination of this more than one type of this chains one can use in order to fulfill the required duty, required service.

So in such case, whatever the combined combination of different types of chain conveyors are there so that you called combination chain conveyors. So malleable metal adapted things are like this. So they have typical structure like shown here individual units like this. So these units are detachable or adjustable here. So these are the kind of things where you can have a kind of attaching or detaching kind of thing.

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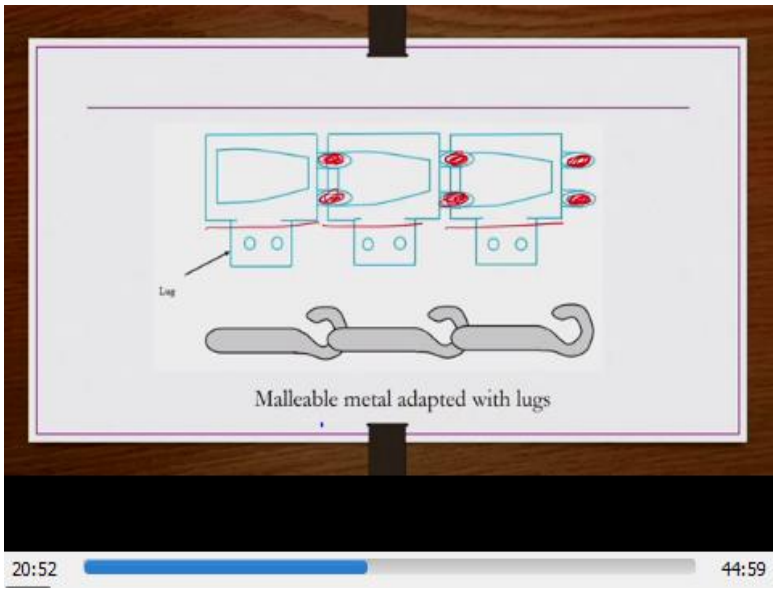

So you can add several number of such kind of these things and then you can have a kind of length as per the requirement. You can reduce some of them as per the requirements. There may also be connected like this as given like this. Then chains in general have like this. The chains are, this kind of chains are there so they are also detachable in general kind of the thing or they can be fixed also.

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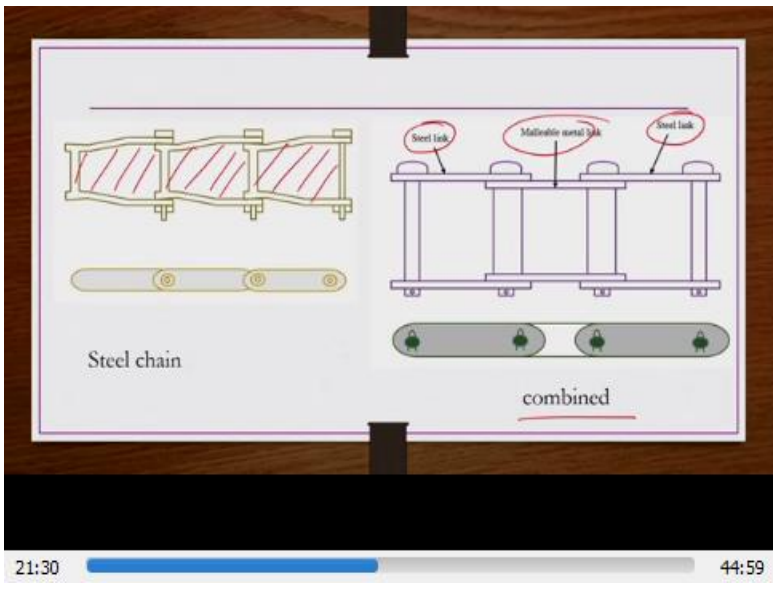

So whereas if you have a kind of combined thing you can have a kind of combination of steel link, malleable metal link followed by steel link and followed by the other ones. If you, if you believe that for your operation is going to be important, so then you can have a different combination of all three types of chain conveyors. So that is what the combined conveyors or combination thereof.

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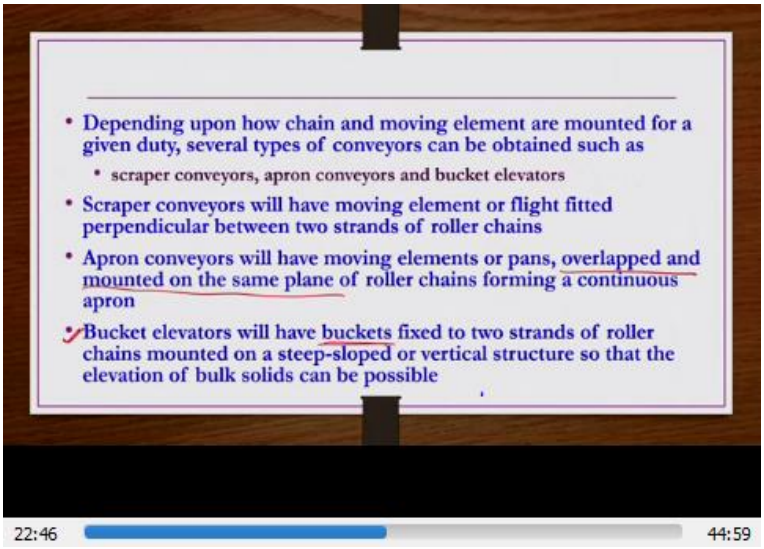

So depending upon how chain and moving element are mounted for a given duty, several types of conveyors can be obtained, such as scraper conveyors, apron conveyors and bucket elevators. Now, we see individual details of these conveyors. So scraper conveyors will have moving element our flight fitted perpendicular between two strands of roller chains.

Whereas apron conveyors will have moving elements or pans over lapped and mounted onto the same plane of roller chains, so that to form a kind of continuous apron. On the other hand bucket elevators will have buckets fixed to two strands of roller chains mounted on a steep sloped or vertical structure so that the elevation of bulk solids can be possible. So in general this bulk elevators are used to wear the material the solid materials need to be conveyed in a kind of elevation higher elevation or vertical elevation something like that.

So they are very much important in such kind of vertical elevation transport of solids; these bulk elevators are very much important. So we see the scraper conveyors which are having moving element. Or flight fitted perpendicular between two strands of roller chains like this. So whatever

the feed material is coming here,so that will be transported in something like this, like this and then that will be discharged something like this.

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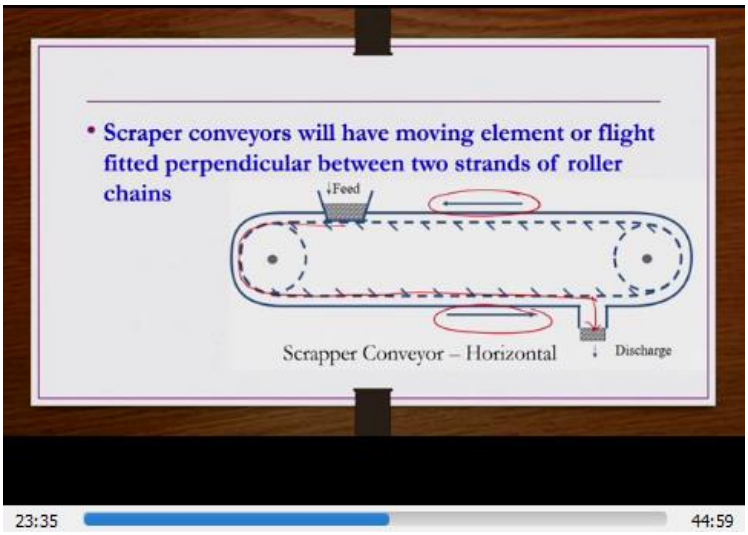

While the movement, the movement of this rollers are roller chains are in this direction. So the top one is moving from right to left and then bottom it is left to right it is going in and then continuously moves like this, while carrying the material from feed point and then discharging at the discharge point. This is a kind of horizontal scraper.

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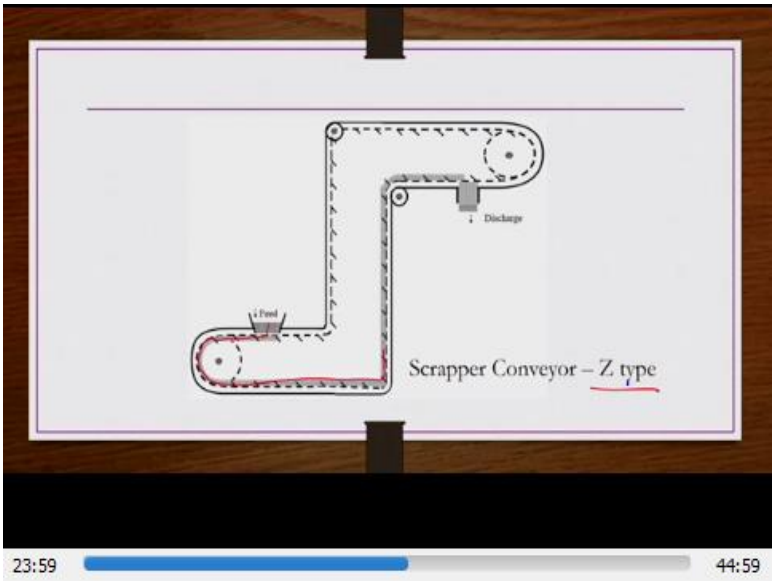

We can have more than two strands of roller chains also and then we can have a more pulleys and then we can have a kind of Z type scraper also shown here. So here also, we can do a kind of slight elevated operations here, which is not possible easily for using the other kind of operations. So here the feed whatever that is coming here that will be carried in the direction the way the chains are rotating and then collected from the discharge point.

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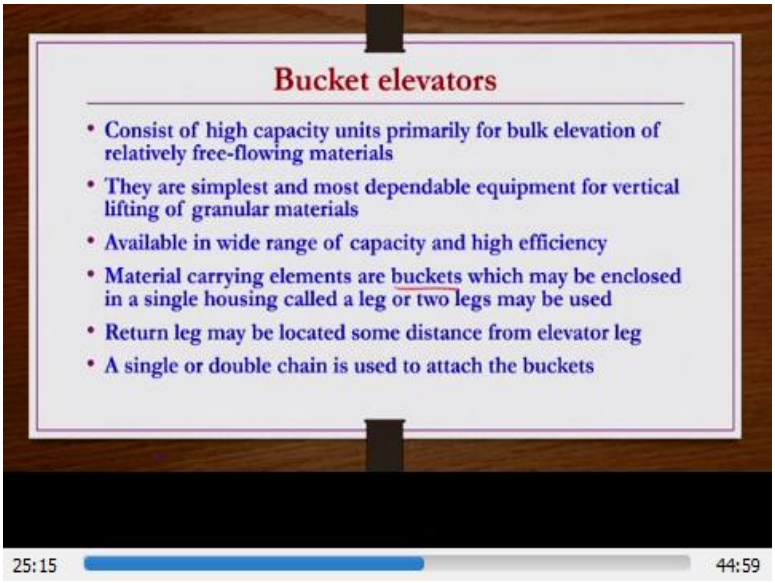

Next is the bucket elevator. Bucket elevators are in general to the chains, buckets are mounted and then these chains are rotating in a kind of vertical direction so that the material can be transported in a kind of a vertical direction. So they consist of high capacity units primarily for bulk elevation of relatively free flowing material. They are simplest and most dependable equipment for vertical lifting of granular materials.

They are available in wide range of capacity and high efficiency. Material carrying elements are in general buckets, which may be enclosed in a single housing called a leg or two legs may also be used. Return leg may be located some distance from the elevator leg in order to avoid a kind of a interference between these two. A singular double chain is used to attach the buckets depending on the design what kind of design you have a for given bulk elevators.

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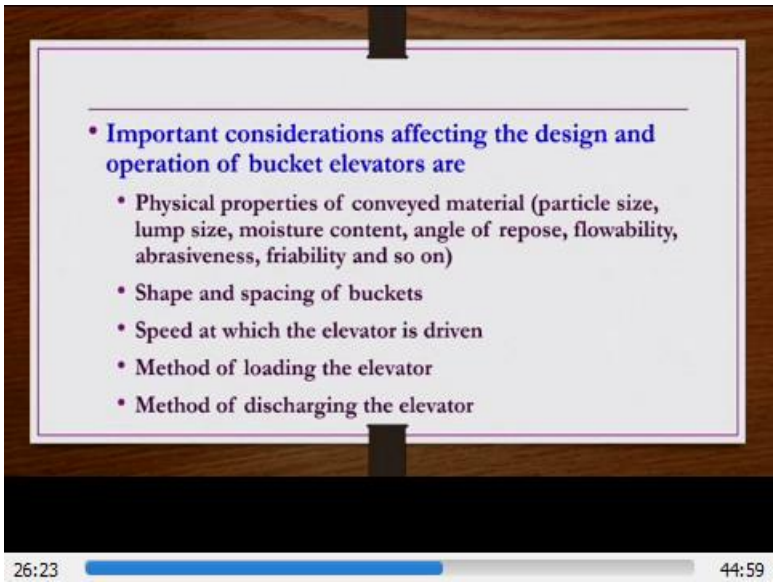

You can have a single or double chain. We will be seeing them. So then what are the important considerations that you believe may be affecting the design and operation of bulk elevators. The very first important thing is the physical properties of conveyed material. That is the particle size; if they are lumps there lump size, moisture content angle of repose, flow ability, abrasiveness, friability, etc. Then shape and spacing of buckets also is important.

Sometimes you can have a kind of spaced bucket elevator. Sometimes you need to have a kind of continuous bucket elevators. In the continuous bucket elevators, the gap is very much small. They are closely mounted onto the chain very close to each other. The shape is also important. Then speed at which the elevator is driven that is again a kind of important factor and then method of loading the elevator.

The method of loading the elevator and then method of discharging the elevator both of them are kind of important in order to have a kind of efficient operation of effect given bucket elevators. So depending on how the mounting of the buckets has been done on to chain. And then what is the spacing between the buckets that will conform into a specific elevator design in general.

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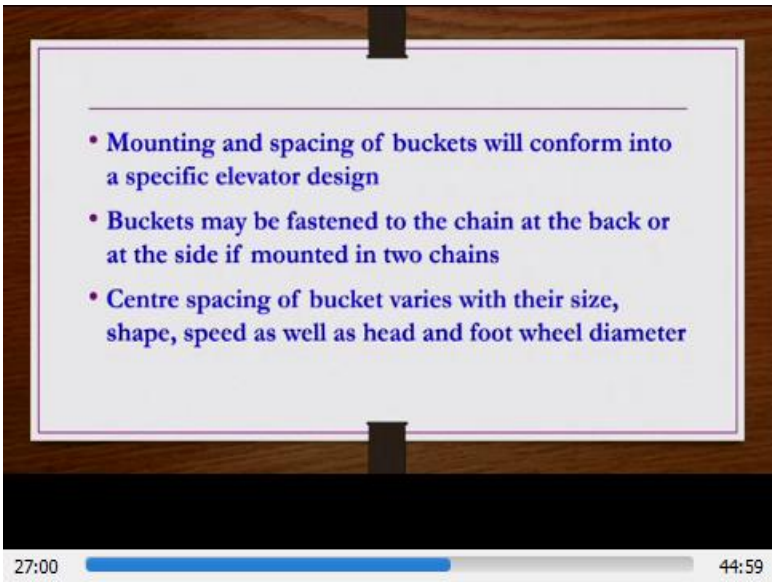

So both mounting and spacing are a kind of important factors to have a kind of different designs. Buckets may be fastened to the chain at the back or at the side, if mounted in two chains. Center spacing of bucket varies with their size. How big is the bucket and then shape what is the shape of the bucket and then speed as well as the head and foot wheel diameter. So now we see some of the bucket elevator designs.

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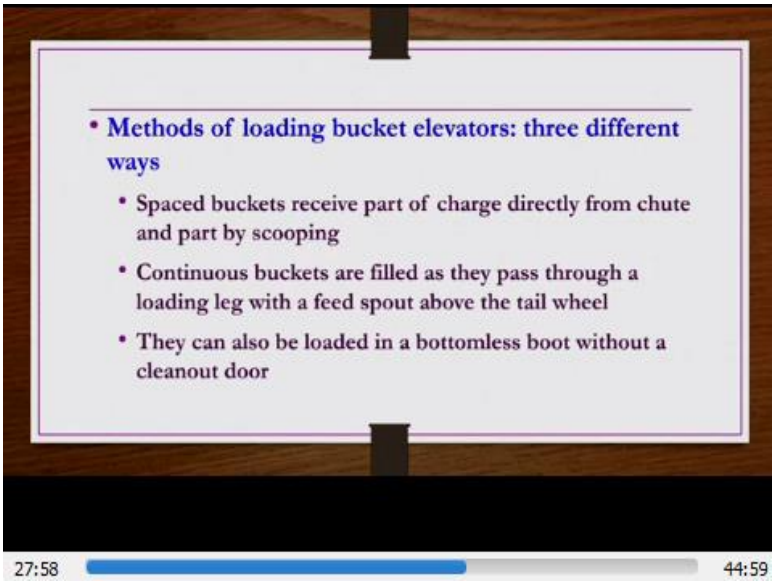

So especially we see with respect to the loading and discharging. Methods of loading bucket elevators: there are 3 different ways are there. Spaced buckets, that is, between the buckets the enough space is there. So spaced buckets receive part of charge directly from the chute and part by the scooping methodology. Whereas the continuous buckets are filled as they pass through a loading leg with a feed spot above the tail wheel.

So continuous buckets, the buckets are closely mounted on to the, on a given chains. The gap between these bucket is almost negligible or very small. This continuous buckets can also be loaded in a bottomless boot without cleanout door. Next coming to the methods of discharging of bucket elevators. Here also, 3 different ways possible.

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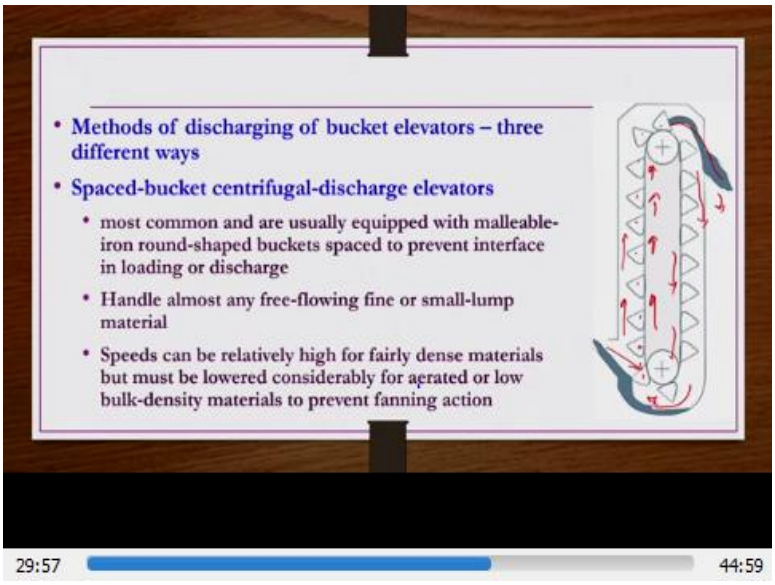

The first one is the spaced bucket centrifugal discharge elevators are most common and are usually equipped with malleable iron rod shaped buckets, space to prevent interface in loading or discharge. Typically if schematically if you see so the schematic is given here. So whatever the material that is there, that comes onto the buckets like this and then this buckets, let us say is number 1, number 2, like this it moves on.

So it moves, the pulleys is rotating in this direction. So then while it rotates like this, it is rotating like this. So the bucket also moves on because now these buckets are connected to this chain. So these chains onto which buckets are connected the material is there. So this material is carried

upward elevation direction. And then this end, the direction, this movement is there in the curvature direction of the pulley.

So in this direction the buckets will also rotate here because the chain is rotating like that. So then from here you can get a kind of a discharge. Once the discharge empty buckets will be traveling downward again here, and then they will be moving up here again after getting a loading here; like this. This operation continuously goes until the complete conveying of solids takes place.

These can handle almost any free-flowing fine or small lump materials. For them, the speed can be relatively high for fairly dense materials, but for low bulk density materials, it is advisable to reduce the speed as much lower as possible in order to prevent fanning action. Then is spaced bucket positive discharge elevators principle it is same as a kind of a spaced bucket centrifugal discharge elevators, but here the buckets are mounted on two strands of chain and snubbed back under head sprocket to invert them to allow positive discharge.

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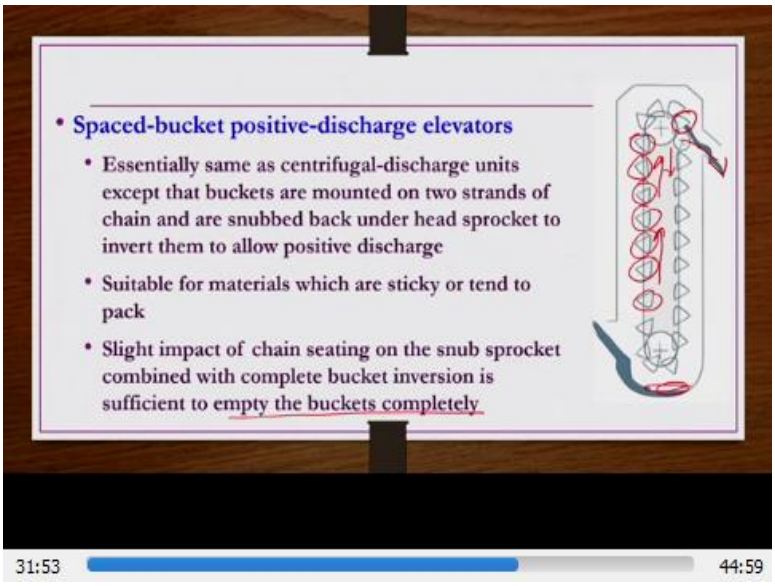

Schematically, it is the same here, but only thing that this now these buckets are mounted onto two strands of chain, and then snubbed back under head sprocket to invert them. Moment they come here,so the inversion may become very comfortable so that the positive discharge of the solids take place and the bucket can be completely emptied without further taking any material.

If it is not completely empty, further it is taking material, so that may be spilling over nearby the floor here within the casing and that maybe abstracting the operations. So or you need to have a kind of separate provision to move material that is fallen at the bottom from the buckets while buckets are coming down, which is, material is coming down buckets are coming down.

So while going up so they are carrying the material. While coming down they should not carry any material everything should be discharged here. So in order to discharge here, a proper inverting of this bucket should be taking place. In order to have this complete inverting these buckets; these are snubbed back under head sprocket to invert them and to allow positive discharge.

And they are suitable for materials which are sticky or tend to pack and then whatever the slight impact of chains seating on the snubbed sprocket combined with complete bucket inversion is sufficient enough to empty the buckets completely which is very much important. Then we have continues bucket elevators pictorially can see now compared to the previous figures. Now you can see in this previous figures what happens, the gap, there is a gap between this buckets, between these buckets there is a kind of gap

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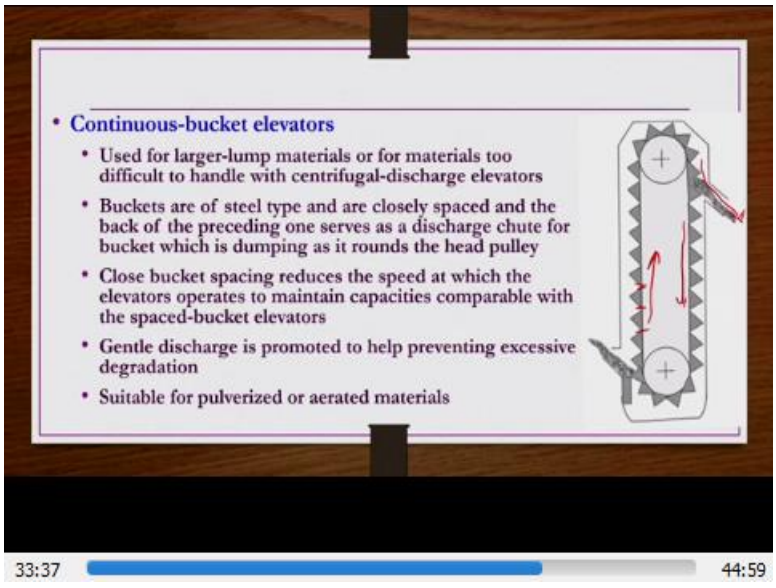

Whereas in a kind of continuous bucket elevators between the buckets the gap is very small or negligible, so that a kind of continuous formation takes place. Here the material that comes in

here so that will be filled in buckets and then this rotates upward. Whileit is moving upward, the material will be carried up and then here when they reach at the top, the inversion of the buckets take place and then material will be the discharge point and then empty buckets will be coming down here, and then from here again, they move up.

So while the pulleys are moving, so then again material will come here and then the operation continues until they complete conveying of solids takes place. These are used for larger lump materials or for materials too difficult to handle with centrifugal discharge elevators. The buckets are of steel type and are closely spaced and the back of the preceding one serves as a discharge chute for the bucket, which is dumping as it rounds the head pulley.

Close bucket spacing reduces the speed at which the elevator operates to maintain capacity comparable with the spaced bucket elevators. And then gentle discharge is promoted to help preventing excessive degradation of the material. These are suitable for pulverized or aerated materials. Then super-capacity continuous bucket elevators. They are quite similar to continuous bucket elevators.

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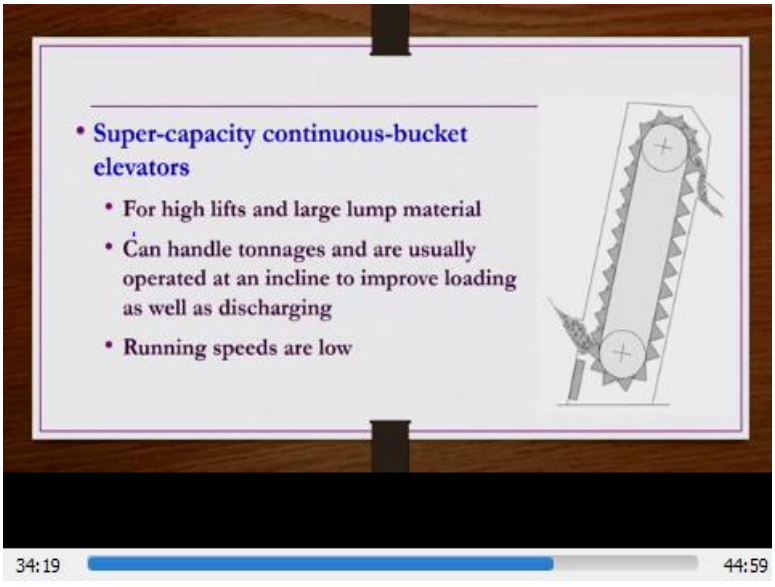

Only thing that here we have a kind of inclined design so that we can have a kind of a large amount of material can be comfortably transported to the discharge point. These are for high lifts and large lump material can handle tonnages and are usually operated at an incline to improve

loading as well as the discharging. However, the running speeds of this super-capacity continuous belt elevators is a bit small, a low-velocity, the speed running speed is slow compared to the other bucket elevators.

So these are the four discharge type of elevators, bucket elevators are available. Now, we see bucket elevator horse power requirement. So we have to have a different equation for spaced bucket elevator as well as the continuous bucket elevator. You cannot have the same equation for both of them. For spaced buckets $P = \frac{TH}{152}$. Whereas for continuous buckets with loading leg $P = \frac{TH}{167}$ where T is bucket capacity in ton per hour, H is lift in meters.

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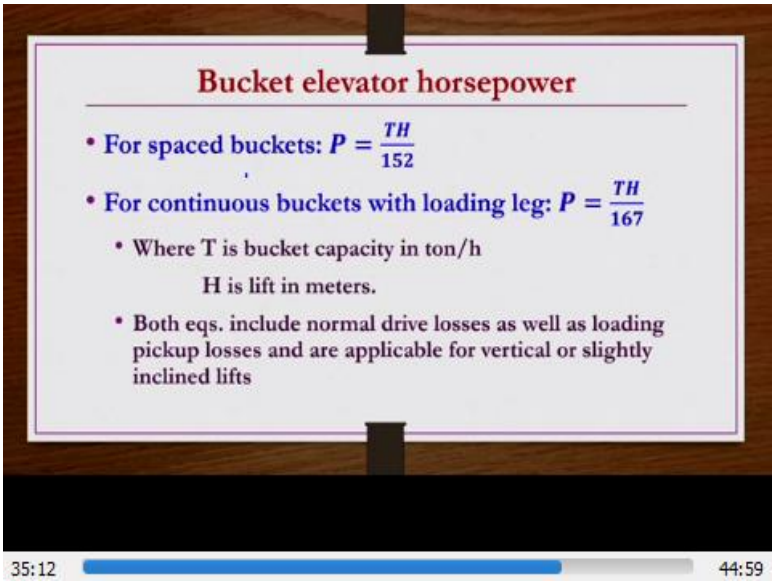

Both these equations include normal dry losses as well as loading pick up losses and are applicable for vertical or slightly inclined lifts as well. So this is a about the belt conveyors and chain conveyors we have seen. Within the chain conveyors, we have seen the scarper conveyors, apron conveyors bucket elevators. Now, will be discussing about the screw conveyors.

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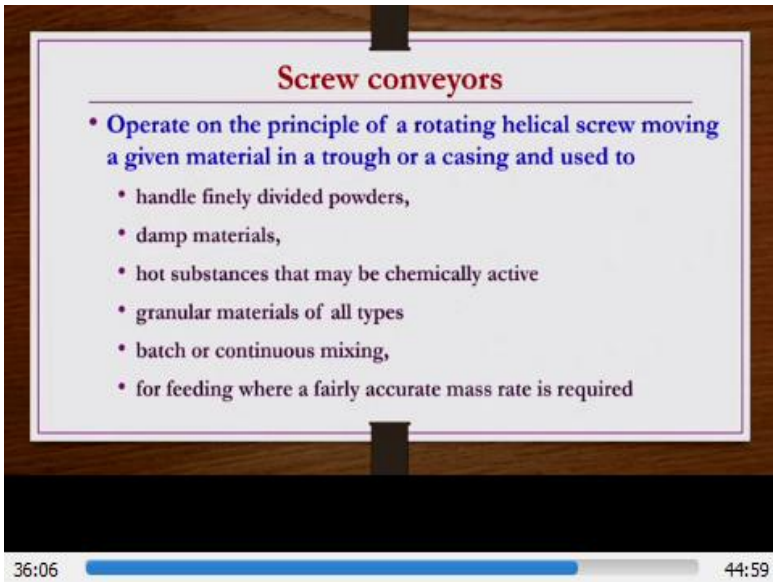

Screw conveyors operate on the principle of a rotating helical screw moving a given material in a trough or a casing and used to handle finely divided powders, damp materials, hot substances that may be chemically active. They are not only for transport of the granular materials of all types but also they are used for batch or continue mixing. And then especially when you need to have a kind of a fairly accurate mass rate, then these kinds of screw conveyors are kind of more reliable.

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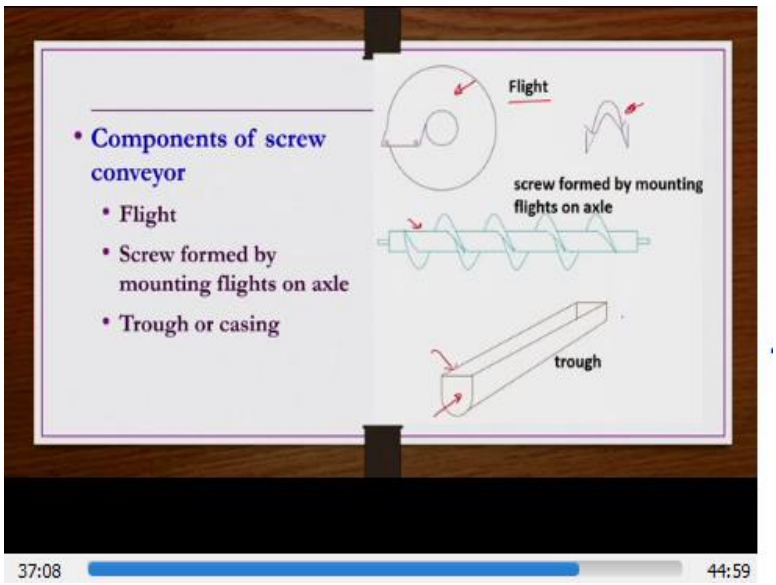

So that is for feeding, where a fairly accurate mass rate is required then it is better to go for a screw conveyor. Then screw conveyor have a following components: like flight, screw formed by mounting flights on axle and trough or casing. So schematically if you see flights like,if you see the frontal view of the flight, it looks like this thing. If you see a side view of the flight so they will be like this.

So now, this 'N' number of flights, if you mount on a kind of axle like this, so then you can have a kind of this, screw formed by mounting flights on axle. So these materials whatever that material comes here. So when it is rotates, it takes the material to the next level, something like that. And then during this process the every kind of mixing is also takes place. So this screw set; what it will be it will be taken in a trough or casing and then material coming here and then taken out here.

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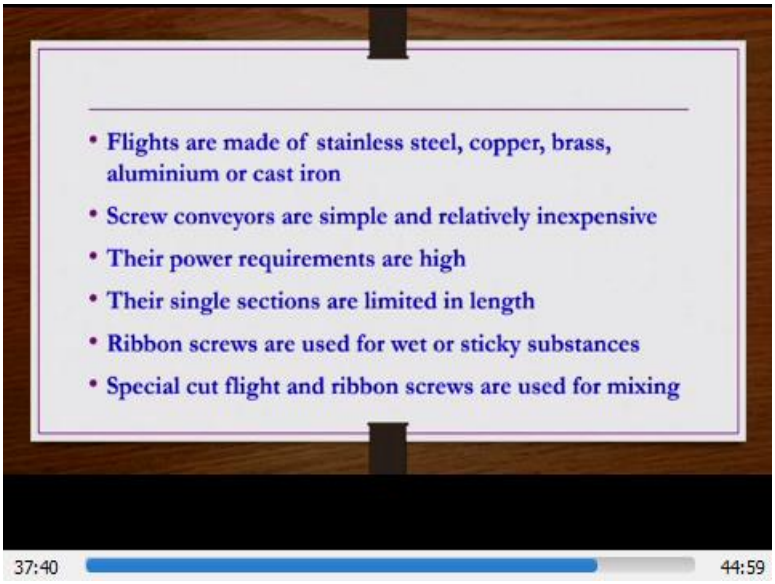

So this can be covered sometimes, they can be opened as well. Flights are made up of stainless steel, copper, brass, aluminum or cast iron. Screw conveyors are simple and relatively inexpensive. Their power requirements are however high. Further the disadvantage is their single sections are limited in length. You cannot have a kind of screw conveyors for kilometers in general.

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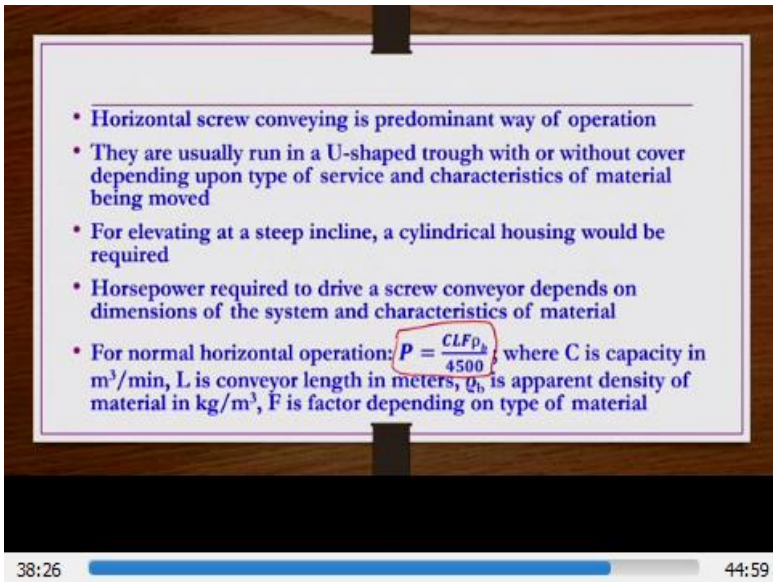

Ribbon screws are used for weight or sticky substances. Special cut flight and ribbons screw are used for mixing as well. So horizontal screen conveying is kind of predominant way of operation in general. They are usually run in a U-shaped trough with or without cover depending upon type of service and characteristics of material being conveyed. For elevating at a steep incline a cylindrical housing would be required. And horsepower required to drive a screw conveyor depends on the dimensions of the systems and the characteristics of the material.

For a normal horizontal operation, this power requirement $P = \frac{CLF\rho_b}{4500}$; where C is the capacity in m^3/min, where L is the conveyor length in m, ρ_b is apparent density of material in kg/m^3 , F is a factor that depends on the type of material are available in general in a standard text books. So this is about the screw conveyors. Now we go to the last step that is the pneumatic conveying systems.

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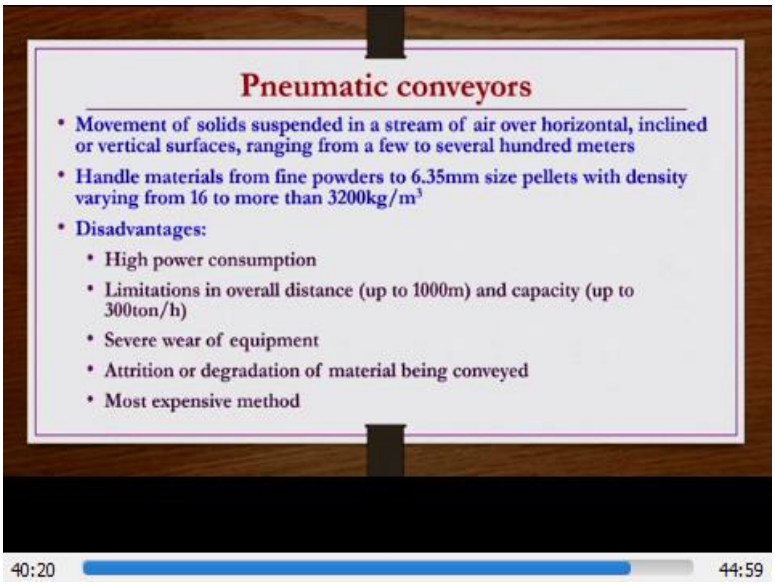

So pneumatic conveyors, where the movement of solids occurs by suspending in a stream of air or horizontal or inclined or vertical surfaces ranging from a few meters to several hundred meters in general. However, they can handle fine powders of few microns size to the pellet size 6.35 mm in general. They can also handle different density materials. They can handle low-density material as low as 16 kg/m^3 to as high density material has more 3200 kg/m^3.

But it is having several disadvantages. The first one is the high power consumption. The next one is the limitations in the overall distance. You can a go or the convey the material for kilometers. Maximum you can go up to 1,000 meters and then capacity is also moderate. You can go only up to 300 tons per hour. Then severe wear of equipment in general experienced.

While the material is being transported or transported or conveyed from one location to the other location, a kind of attrition takes place because of that one. Size reduction or degradation of material may take place which may not be useful in majority kind of operations. Then it is kind of most expensive method as well. So these are the kind of disadvantages of pneumatic conveyors.

However, they also find in many applications suitable to have a kind of pneumatic conveyors. Pneumatic conveying can be categorized in a number of ways depending on their motion as well

as type and magnitude of operating pressure .Based on relative solids loading and then velocity of system they may be classified as for: dense phase system and then dilute phase systems.

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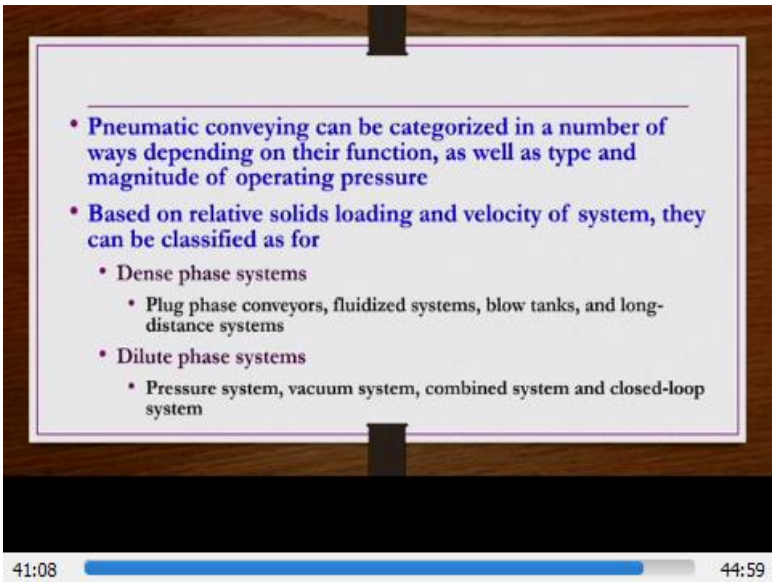

For dense phase systems, we can have a plug face conveyors, fluidized systems, blow tanks and long-distance systems. Whereas for dilute phase systems, we can have pressure system, vacuum system, combined system and closed loop system. The detailed design and operational principle of this pneumatic conveying, we are not going into details. So if you are interested more in this the design details you are suggested to refer the book ‘Unit Operations of Particulate Solids ‘by Ortega Rivas.

That is one of our reference book for this course. So this is about all four types of conveying equipment; bulk solid conveying equipment that we have seen. Belt conveyors, chain conveyors, screw and various and then pneumatic systems we have seen. So now how to choose how what should be the criteria for selection of a given solid conveying that depends on several factors, but however, based on the orientation or the function of the conveying we can have a kind of a proper selection of this conveying system.

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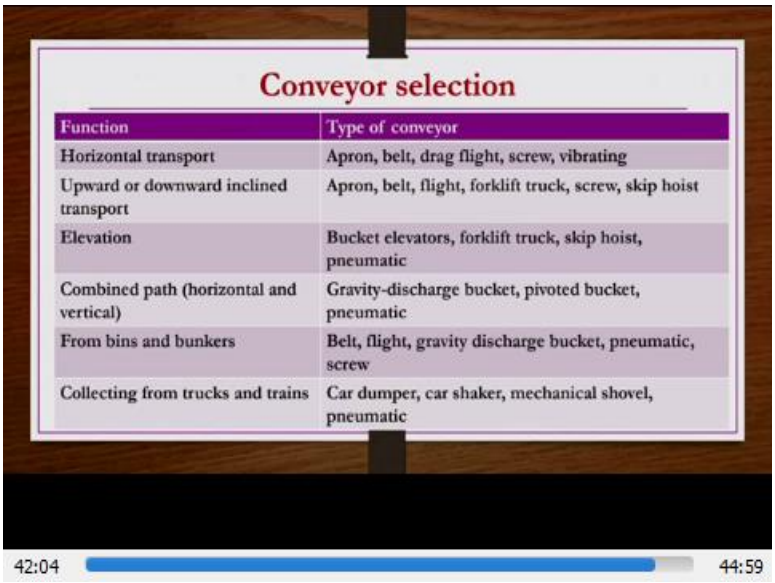

So what are those proper selections we can see here in the table. If you need to have a horizontal transport, then you can go for apron, belt, drag flight, screw, vibrating conveyors. If you want to have a kind of upward or downward inclined transport then apron, belt, flight, forklift truck, screw, skip hoist conveyors are more suitable. If you have an elevation then the best option is the bucket elevators.

You can also use to forklift trucks, skip hoist pneumatic conveying system as well. But if you have a combined path that is both horizontal and vertical then gravity discharge bucket, pivoted bucket and pneumatic systems are suitable. If you want to collect material from bins and bunkers; then belt conveyors, flight conveyors, gravity discharge, bucket conveyors, pneumatic systems, screw conveyors can be used.

If you are collecting from trucks and trains then car dumper, car shaker, mechanical shovel, pneumatic systems can be used. So we have a completed four modules. In the four modules, we have seen the unit operations associated with the solid contacting unit operations only. Will be discussing next module we will be discussing about the size enlargement principles of size enlargement and then what are the types of size enlargement equipments.

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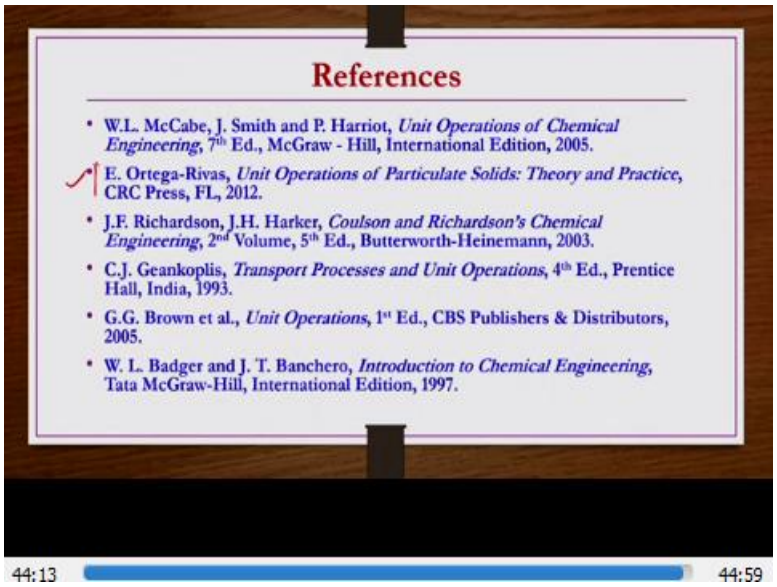

Reference for this lecture: The entire lecture has been prepared by taking this reference. So the entire details presented in this lecture have been taken from this book -'Unit Operations of Particulate Solids' by Ortega Rivas.. However, we can find few details of these aspects in 'Unit Operations of Particulate Solids: Theory and Practices'by McCabe, Smith and Harriot. Other reference books are 'Coulson and Richardson's Chemical Engineering' second volume by Richardson and Harker.

'Then Transport Processes and Unit Operations'by C.J.Geankoplis. Then 'Unit Operations'by Brown et al.Finally'Introduction to Chemical Engineering' by Badger and Banchero. In these books also, we can find a kind of details about the solid conveying systems. So though other books can also have a kind of reference. Majority of the details are taken from here, but some details can also be found in this book 'Introduction to Chemical Engineering'by Badger and Banchero.Thank you.