

Fundamentals Of Particle And Fluid Solid Processing
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Lecture - 35
Filtration (Contd.)

Hello and welcome back to another class of Fundamentals of Particle and Fluid Solid Processing. We were discussing about Filtration. Now in this filtration we have seen several stages like the flow through incompressible cake, flow through compressible cake, how to calculate the time required for a certain volume of filtrate processing and also we have seen the processes that how this happens. Today we will discuss some points and we will briefly tell you about the different types of filters that are available and most commonly used.

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Filter selection

- minimum overall cost + a high overall filtration rate
- cost is directly related to the filtering area
- use of relatively high pressures, restricted by mechanical design parameters
- choice of continuous (usually runs at reduced pressure) vs. batch operation
 - high cake resistance!!
- ease of filter cake discharge in a convenient physical form
- assessment of the filtrate quality from each section of the plant
- common types:
 - filter presses
 - leaf filters
 - continuous rotary filters
 - bag filters, disk filters

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Now, to select an appropriate filter for any operation, the primary thing that we have to consider is the minimum overall cost with a high overall filtration rate. This is the important thing and these two things basically dictate that what should be the appropriate filter equipment for your operation. Now when we talk about the overall cost this cost is directly related to the filtering area for any filtration equipment.

So, if you select a filter that provides say larger filtering area per unit volume ok, with the minimum cost then that can be an optimum selection. But there are also certain other

points before you zero down to a certain type of filter or the equipment. Now typically this filtration operations or the filter equipment should handle a relatively high pressure, but that the maximum limit would be restricted by its mechanical design parameter or the consideration.

So, when we think of choosing a particular filter, first of all we have to decide that what kind of operations or which mode of operations we should be operating; is it a batch mode operation or a continuous mode operation. Now, typically this continuous mode of operation usually runs at a reduced pressure, because it is continuously running the expense of mechanical energy that is required for this pumping or the pumping cost should not be exorbitantly high compare to batch operation. Now the scenario you can imagine that say there is a very high cake resistance.

Now in such case say a suspension is depositing on the filter media and the cake resulting cake has a high resistance. Now in case of continuous operation in order to have a certain filtrate rate this pressure will keep on going or the requirement of pressure will be continuously higher and higher. In such case this batch mode operation can be helpful because, once that is deposited we can take out that cake we can separate that and we can again start the operation. So, instead of continuous operation in certain cases this batch mode of operation is of useful.

The other thing that has to be in consideration is that the ease of filter cake removal and that too in its convenient physical form, that is when the cake is deposited and if this is the solid particles is our valuable product of the desired product, then this has to be easily removed from the filter medium. Now the equipment that helps in such is operation that would automatically gets the priority in the selection and as it is mentioned that it has to be removed in its convenient physical form.

This filtrate quality assessment of this filtrate quality at each section of the of this whole filtration plant should be easily done. The filtration equipment should provide that facility or should have those options that you can test the or assess the filtrate quality at different level of the filtration or at different points of the filtration process, because it is not only a single operation, this filtration process goes through cascade of operations. So, at each and every point say you have a series of filters and at the end of each filter as well as somewhat in between. If you want to test or determine the filtrate quality how

good operation is happening that should be easily done. So, such kind of provisions should be there when you choose or when we choose this filter for a particular process.

Now, the common types of filters that are frequently used are the filter presses, leaf filters, continuous rotary filters, bag filters, disc filters; this last two that are mentioned here is specifically designed for certain specific operation. These are not as much frequently used, this are used in certain specific applications and we will see those.

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The slide is titled "Types of filters" and lists the following categories and their characteristics:

- **Bed filters:**
 - works on the principles of *deep bed filtration*, where the particles move into the slits of the bed
 - purification of water with the solid content $< 10 \text{ g/m}^3$
 - granular bed of grain size 0.6–1.2 mm and 0.6–1.8 m deep
- **Bag filters:**
 - long thin bags attached to horizontal feed tray
 - extensively used for dust particles removal from gases
- Plate and frame press
- Pressure leaf filters

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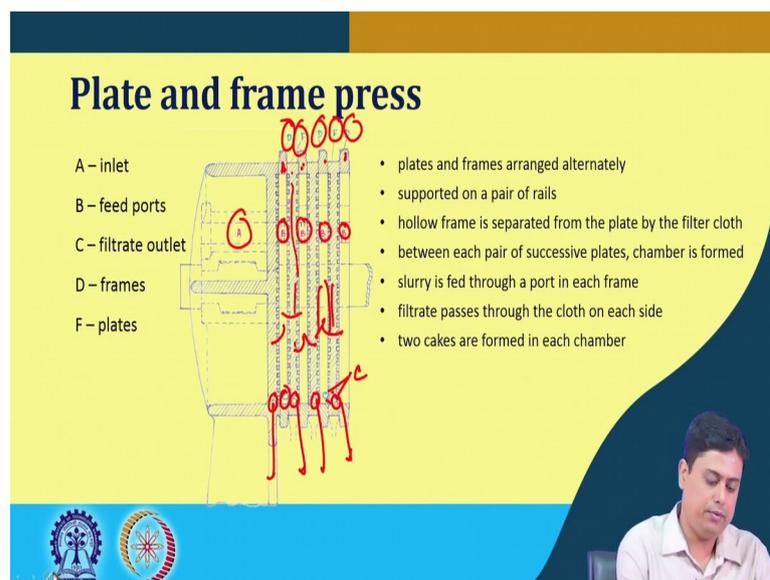
So, if we go for different types of filters, the common or say the simplest one is the Bed filter. Now this kind of filter works on the principles of deep bed filtration that is where the particles penetrates into the pores of this bed of the interstices of the bed and then it is followed by the deposition of the particles on the surface of the filter or the bed.

So, typical example that such kind of filters where it is applicable or where it is applied at the purification of water with let us say solid content less than 10 grams per meter cube. In such cases it has been seen that instead of conventional or the old traditional sand filters, if that bed is replaced by this granular bed that has a grain size of 0.6 to 1.2 millimeter and a depth of 0.6 to 1.0 meter of height. This effectively separates the suspensions from the water for the solid particles from the water. The other filter as the specifically I mentioned that such filter are specifically designed for specific application is say the bag filter. Now this bag filter are now it is obsolete in case of liquid filtration, these are still used when it comes for the dust particle removal for from gases.

So, this typically this bag filters consist of long thin bags attached to a horizontal feed tray. So, in such cases the surface area that is available is lower and the filtration is very low. So, for high throughput operation such filters as I mentioned is now obsolete, but when it comes to the dust particle removals from gases these are still in use. The most frequently or I would say most popular filters are the plate and frame filters pressure leaf filters and the vacuum filter.

So, we will see these filter descriptions sketchily and we will not going to the design consideration of this filter, we will just see the pros and cons or when it is used why it should be used. For the details I have a reference that I have given at the end of the slides for the future reading or the further reading and that is also mentioned in the course website that is Coulson Richardson's volume two chemical engineering, ok.

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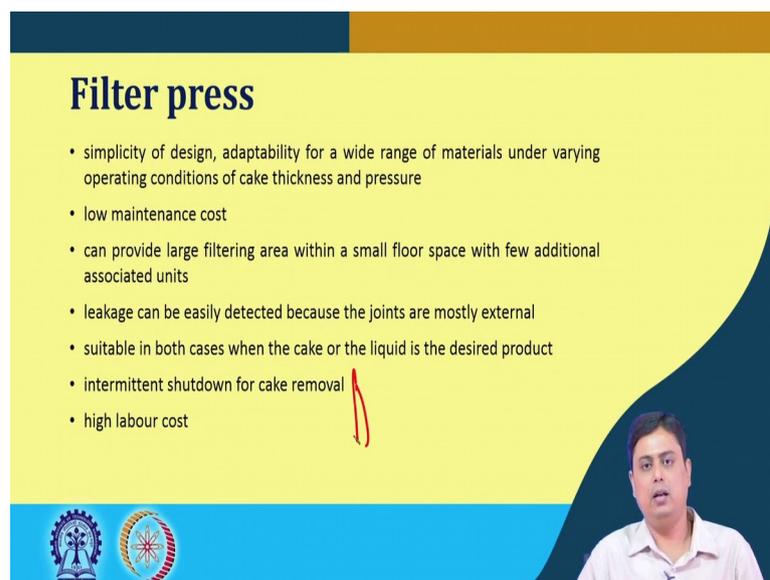
So, if we now go to the details of this plate and frame filter press this basically consist of plates and frames that are arranged alternately and these are supported by a pair of rails. The hollow frames are separated from the plate by filter cloth and between each pair of successive plates, so that means a chamber is formed because there we have on the both sides we have the filter cloth. So, something like this, these are the chamber views. So, here what we have this inlet is happening this through point A or the section A; the feed port is this holes that are there on the frames. The filtrate out late are these points this holes that are mentioned, so C that is mentioned here.

So, these are the C points, these are the frame; this D this is the frame and these are the plates which is designated by F. So, which means the feed comes through the inlet ports of B and it flows on both the sides of say this kind of flow is there because, the filtrates are collected from these outlets. So, which means when the slurry is fed through the port of each frame filtrate passes through the cloth on each side, on each side the filtrate crosses. That means, two cakes simultaneously forms on both the sides.

The unique or the beneficial part of having such plate and frame arrangement is that this each and every compartment can be taken out isolately; this can be isolated without disturbing the other arrangement such kind of configuration is there. So, when this filter media is now clogged with the cake formation that is coming from both the sides and cake has formed it has filled that chamber, this operation is stopped, these are; this engaged each and every part the filter cloth is cleaned the filter cake is washed and again it is assembled.

So, which means it is intermittent in operation, it is very simple in design simple to understand, but it operates in intermittent manner. That means, it is operation filtration operation time the total filtration time is basically the operation time plus it is cleaning time, which is considerable in certain cases.

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Filter press

- simplicity of design, adaptability for a wide range of materials under varying operating conditions of cake thickness and pressure
- low maintenance cost
- can provide large filtering area within a small floor space with few additional associated units
- leakage can be easily detected because the joints are mostly external
- suitable in both cases when the cake or the liquid is the desired product
- intermittent shutdown for cake removal
- high labour cost

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So, the advantages of this filter press this particularly plate and frame press, this is one of the variation of filter press in general that it is simple in design. It can easily adapt a wide

range of material under varying operating conditions of cake thickness as well as operating pressure.

It has low maintenance cost, it can provide large filtering area within the small floor space with few additional associated units, ok. Since as I mentioned that this is simple in design and this concept of assembly that it should be easily disengaged during the cleaning operations, that means this joints are mostly external. So, if leakage happens that can easily be detected and can be repaired, and it is suitable in both the cases where cake or the liquid phase either of these are the desired product or the valuable product, in both the cases or both the scenario we can use this instrument or equipment.

But the disadvantages are as I mentioned these are intermittent in operation, because the cake has to be removed and that results in where of the filter cloth. The damage of the filter cloth after several assembly and disassembly. It also has high labour cost, because at a certain interval of time all these has to be disengaged and again it has to de assemble. So, quit understandably there is the association of high labour cost with this filtration equipment, but again this is a very basic in design and very versatile filtration equipment.

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Pressure leaf filters

- used for final discharge of solids under completely enclosed and fully automatic conditions
- one or more filter elements or leaves of circular / rectangular shape in pressure vessel
- synthetic fibre or other fabrics, or metallic mesh as filter medium
- handling of edible oils, molten sulphur, effluents, foodstuffs
- various clarification processes and particularly for handling high flows of liquids with a low solids

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Then did the other variation is the pressure leaf filters, these are used typically for the final discharge of solid under completely enclosed and fully automatic conditions. So that means, say you have a sequence of filtration operations, this comes nearly at the end of that process because this actually delivers the final discharge of the solids.

So, here one or more filter elements or the leaves that is the name is a leaf of circular or rectangular shape are used in a pressure vessel, because these are the positive pressure filtration equipment's. The filtration medium or the filter medium can be made of synthetic fiber, several different kind of fibers metallic mesh etc. These are typically used in handling edible oils, molten sulphur, effluents, foodstuff etc. These are used in various clarification processes and particularly handling high flows of liquid with low solids.

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Cartridge filters

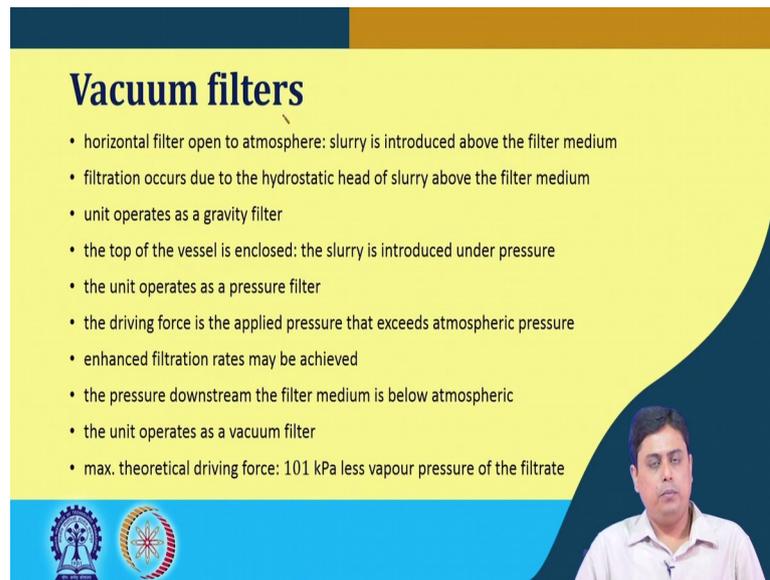
- a category of pressure filter that is extensively used for clarifying liquids containing small quantities of very fine suspended solids
- domestic water, organic solvents, oils
- economical in use as there is no filter cloth
- the bed has to be replaced
- labour charges are low

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The other types or the category is the cartridge filter. So, it is a basically a deviation from the pressure filter or a category or sub branch of a pressure filter that is extensively used for clarifying liquids that contains very small quantities of very fine suspended solids. The examples of these cartridges are frequently occurred in our domestic water purification.

In several water purification unit in our domestic uses such cartridges are there and you possibly have seen then the when the service man comes they replace this cartridges. So, these basically are economical in use because there is no filter cloth, but that means the bed ones it saturated it has to be removed or it has to be replaced completely; consequently the labour charges are lower in this cases, because we are throwing the whole cartridge itself debate itself.

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Vacuum filters

- horizontal filter open to atmosphere: slurry is introduced above the filter medium
- filtration occurs due to the hydrostatic head of slurry above the filter medium
- unit operates as a gravity filter
- the top of the vessel is enclosed: the slurry is introduced under pressure
- the unit operates as a pressure filter
- the driving force is the applied pressure that exceeds atmospheric pressure
- enhanced filtration rates may be achieved
- the pressure downstream the filter medium is below atmospheric
- the unit operates as a vacuum filter
- max. theoretical driving force: 101 kPa less vapour pressure of the filtrate

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Possibly the most useful or the most popular filters are the vacuum filters. So, what happens this is the principle behind all this filters. Say you started with a horizontal filter that is both sides are open to what atmosphere and the slurry is introduced on the above on the top surface of this filter medium and top and bottom, both surfaces are open to atmospheric pressure. So, the filtration occurs mainly due to the hydrostatic, in fact only due to the hydrostatic head of slurry that above the filter medium and which should be sufficient for this operation to happen. Now this operates the flow the filtration rate exist until this hydrostatic head is maintained, a certain hydrostatic head to come across this resistance of the filter and the cake.

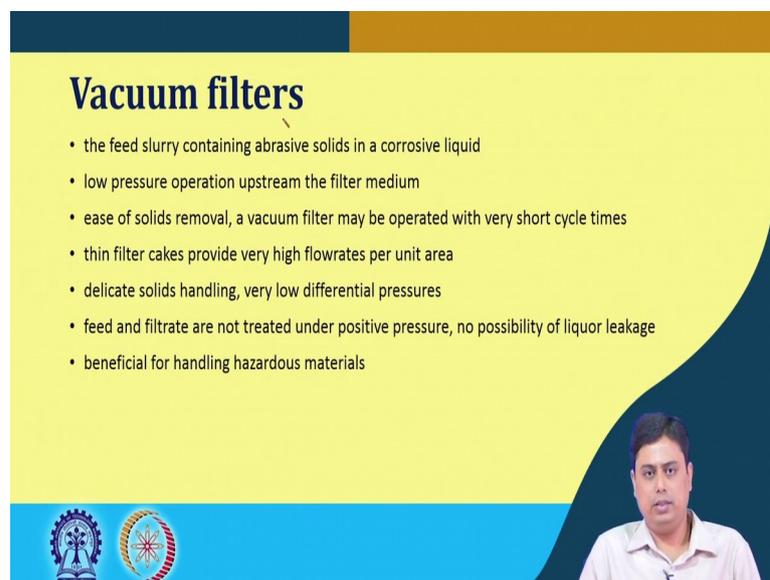
Now, so that means this kind of filter operates as a gravity filter. Now you consider the top surface is now somehow enclosed and the slurry is introduced under pressure, then this whole system is called the pressure filter and example we just have seen this pressure the pressure leaf and the plate and frame filters and that is etcetera. Now the here the driving force is the applied pressure that is in excess of the atmospheric pressure.

So, we can achieve enhanced rate of filtration than the conventional or let say the gravity filtration. Now the other scenario is that instead of the top surface, the bottom surface is now somehow below the atmospheric pressure you have maintained and then this whole unit operates as a vacuum filter. Since this pressure below this filter medium is lower

than the atmospheric pressure we call this as the vacuum filter, which means at the upstream of the filter medium or that upper surface the filtrate can come with the normal pressure or at say at the atmospheric pressure, then if the filtration rate is accelerated due to the suction at the bottom the creation of the vacuum.

So, maximum theoretical driving force can be in this case the atmospheric pressure less than the vapour pressure of the filtrate. Now this can significantly enhance the filtration rate than the gravity filtration.

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Vacuum filters

- the feed slurry containing abrasive solids in a corrosive liquid
- low pressure operation upstream the filter medium
- ease of solids removal, a vacuum filter may be operated with very short cycle times
- thin filter cakes provide very high flowrates per unit area
- delicate solids handling, very low differential pressures
- feed and filtrate are not treated under positive pressure, no possibility of liquor leakage
- beneficial for handling hazardous materials

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So, and this kind of filters there are several variations of a vacuum filters, but this kind of filters actually is helpful in handling the feed that contains slurry of abrasive solids and corrosive in nature the filtrate. So, in such case what happens that this low pressure operation at the upstream of the filter medium. So, it passes through let say the only the feed section with the normal pressure or say the atmospheric pressure. It need not require anything extra and that is helpful for the whole equipment, because this feed is not only carrying the abrasive solids, it also has the corrosive filtrates.

So, the low pressure operations will be definitely beneficial in this case and that is what is achieved in vacuum filters the ease of solids removal, because the up top surface of the filter media where the feed is coming is basically easily accessible. So, if there is a huge cake depositions within short cycle this can be quickly removed and once it is remove this thin layer of cake actually provides very high flow rate per unit area of the filtration.

It is also beneficial for delicate solids handling because there you can operate at a very low differential pressure and since the feed and filtrates are not treated under positive pressure, there is no possibility of liquor leakage in the system, which is beneficial for handling hazardous materials as well.

There are different variations of vacuum filters different configurations of vacuum filters one of the popular one is a rotary vacuum filter.

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Filter selection

- specific resistance of the cake
- filtration amount
- solids concentration
- free-filtering materials:
 - rotary vacuum filter due to its very high capacity for its size
 - does not require any significant manual attention
- Cake washing required:
 - rotary drum is preferred over the rotary leaf

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So, basically to sum up this filtration; the filter selection depends on the three main criteria, that are the specific resistance of the cake filtration amount and solids concentration, this three would dictate your choice of selection of filtration equipment.

Now, typical suggestions are there, there are exhaustive suggestions in the textbook that I mention or the reference book that I have mentioned. For example, the free filtering materials rotary vacuum filter is of efficient application because, it provides very high capacity for it is size, it does not require any significant manual attention. When cake washing is rigorously required then the rotary drum is preferred over rotary leaf filter.

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Filter selection

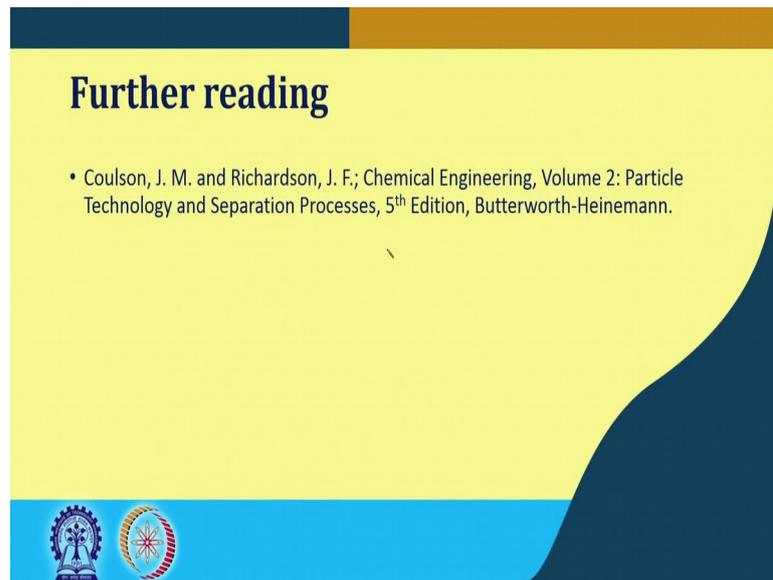
- large-scale filtration: a rotary vacuum filter should not be used
- high specific resistance: a positive pressure filter will be required, filter press may well be suitable
- low solid content may help in avoiding the frequent dismantling of the press
- efficient washing required: a leaf filter is effective, because very thin cakes can be prepared
- risk of channeling during washing is minimum

The slide features a yellow background with a dark blue header and footer. A red arrow points to the text 'a positive pressure filter will be required'. In the bottom right corner, there is a small video inset of a man in a white shirt. The bottom left corner contains two circular logos: one with a gear and a tree, and another with a sun and a gear.

In large scale filtration typically this rotary vacuum filter that I mentioned is of very popular in nature for the application should not be used in couple of cases and those are when there is very high specific resistance there a positive pressure filter should be reused. Because it has to come across that high specific resistance for the flow and in rotary vacuum filter there is a low pressure differential. So, a filter press may be useful in such cases where there is high specific resistance of the cake. And low solid content may help in avoiding this frequent dismantling of the press, so if you have a low solid content in the suspension that is an added advantage to this specific scenario that the positive pressure is applied as well as there is low solid content. So, this frequent dismantling of the filter press is not required.

The other scenario where this rotary vacuum filter should not be used or should be avoided is that the efficient washing required, if you require frequent and washing efficient washing of the cake. Then a leaf filter is effective because a very thin cake can be prepared in such scenario and the risk of channeling during washing is minimum in those equipments. So, similar kind of suggestions are given by several researchers these are few of them.

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Further reading

- Coulson, J. M. and Richardson, J. F.; Chemical Engineering, Volume 2: Particle Technology and Separation Processes, 5th Edition, Butterworth-Heinemann.

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For details on the design as well as and the other suggestions please refer to this reference book for in depth understanding of these filters. With this I will conclude this section that was on the filtration particularly on the liquid filtration. In the next class I will see you with another new topic and until then thank you for your attention.