Testing of Functional & Technical Textiles
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Lecture - 15
Testing of Filter Fabrics

Hello everyone. So, we will discuss the topic that Testing of Functional and Technical Textiles, this is our subject. And this has got two parts; one is testing of functional textiles, and testing of technical textiles. So, in first segment, we have completed the testing of functional textiles. And now we are continuing with the second part which is testing of technical textiles.

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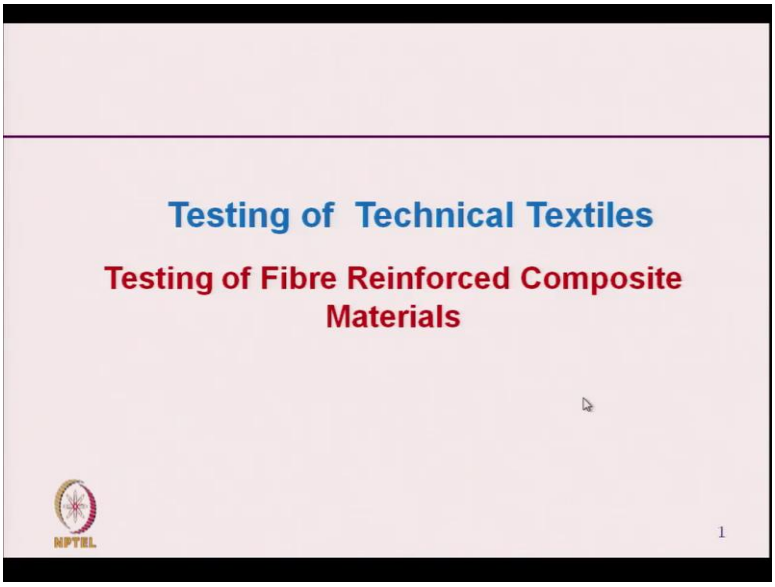

In technical textiles which we have discussed till now which is testing methods of fiber reinforced composite material.

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And today, we will start that testing of filter fabrics that is fibrous filter material.

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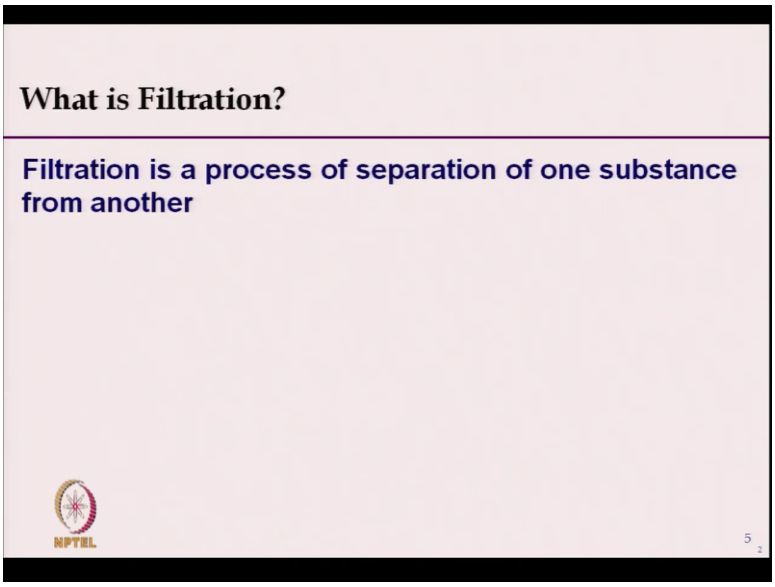

First let us try to understand, what do you mean by filtration. It is a process of separation of one substance from another.

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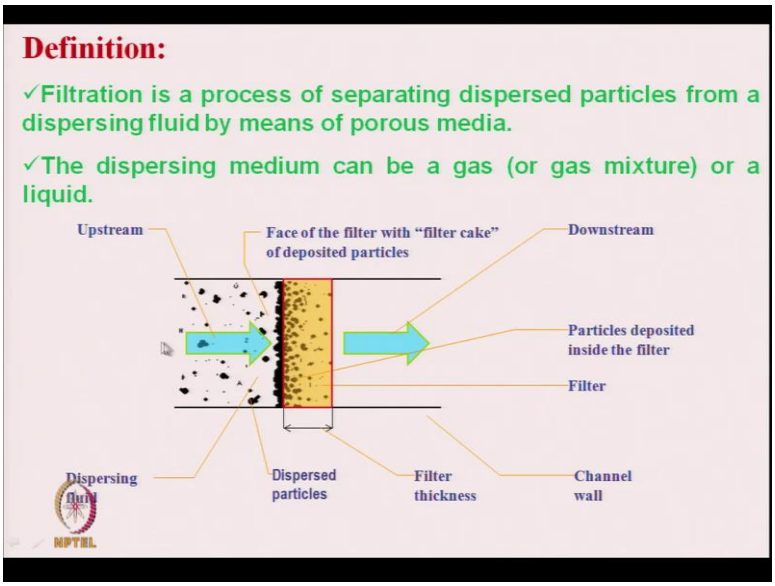

So, separation of one substance from another that means, it is a process of separating dispersed particles from a dispersing fluid by means of porous media. So, there will be dispersed particle in a fluid medium that may be liquid or maybe gaseous medium, and dispersed particles are normally small particulate material that is a solid material. So, this dispersing medium can be of gaseous type or mixture of gases or a liquid.

So, this diagram shown the details of filtration process. So, the particles which is dispersed in a dispersing medium is flowing in a stream. And this one is the filter medium, and this particle along with the dispersing medium which is dispersed particles, and dispersing fluid are flowing through the fabric medium, that is filter medium.

And depending on the pore size and pore size distribution, this particles will be arrested on the upstream side. And if there is 100 percent arrestance of this particles, the clean fluid medium will flow in the downstream side. So, the side where the particle along with the dispersing medium is entering into the filter medium that is called upstream side and other side is downstream side. So, the total particles along with the dispersing medium flows through a channel ok.

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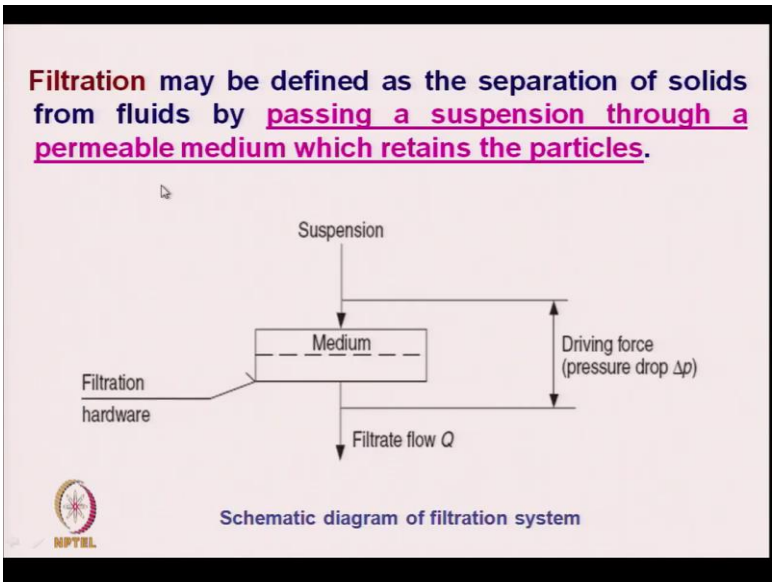

So, filtration may be defined as the separation of solid from full fluid by passing a suspension through a permeable medium which retains the particles. So, the filtration medium should be permeable enough, otherwise it will not allow the fluid, and the filtration will not take place. So, it should allow the fluid to flow through the medium, but at the same time it should stop the particles to pass through. And in this process a pressure will be generated across the filter medium that is the pressure drop, which is the driving force of the fluid to pass through the filter medium.

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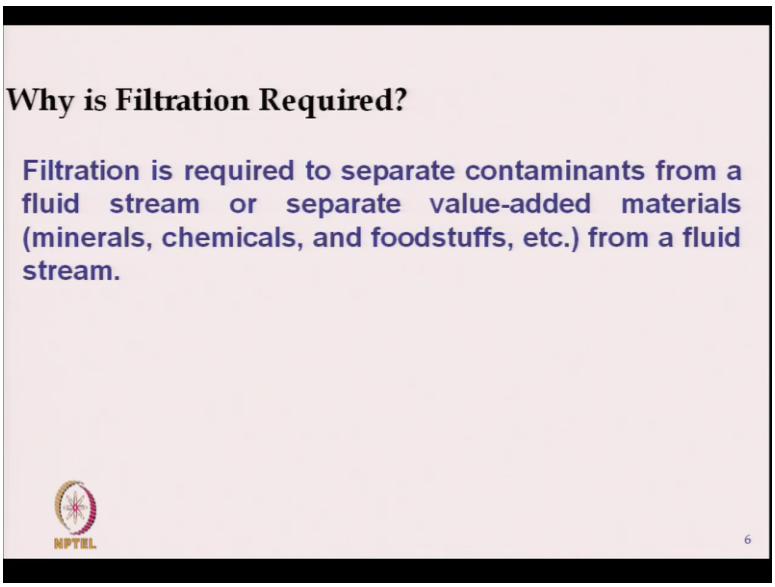

Why is filtration required? So, filtration is required to separate contaminants from fluid stream like the fluid stream maybe of contaminated air, contaminated water. So, if we want to separate the contaminated air the particles which are actually suspended in the air.

If we want to separate, if we want to clean the particle that requires filtration process or to separate value added material like mineral, chemicals, and foodstuff from a fluid stream. So, in this case the filtrate materials are value added material, which we have to extract from the fluid medium. In first case, the contaminants are actually suspended in air or water which is not desirable, so we have to separate it out.

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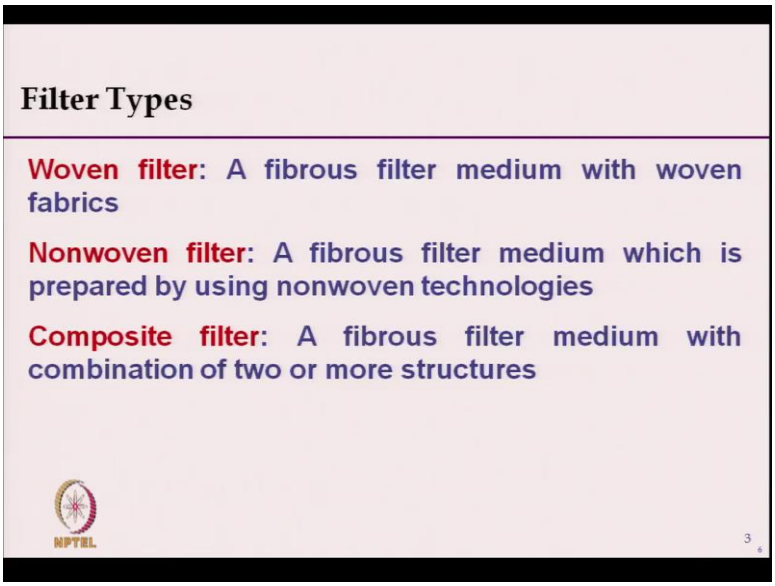

So, if we talk about the textile filter medium, there are basically three types of filter mediums are there; one is woven filter, non-woven filter, and composite filter. The woven filter is that fibrous filter medium with woven fabric structure. And non-woven filter is a fibrous filter medium which is prepared by using non-woven technology. And composite is a mixture of two or more structures. So, we have different types of composite structure. Even for non-woven filter medium, we can have different types of combined non-woven structures like spun bonded, melt blown, spun bonded which is in short SMS structure.

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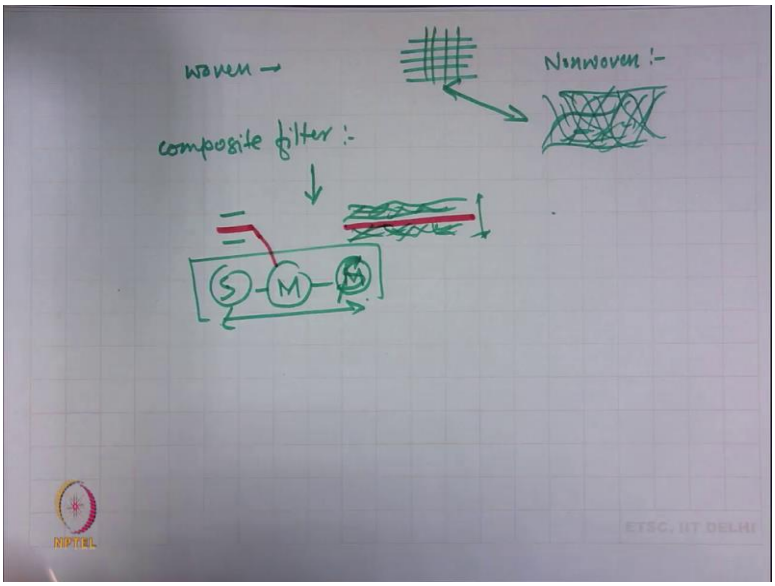

So, we can have composite filter medium. So, woven is that simple woven structure, we can also have knitted filter medium. So, non-woven we have non-woven structure, so which is very widely used made of directly fiber. And composite structures we can have combined structure of woven and non-woven like this is non-woven structure. And here in between we can have woven structure, and then also one layer of non-woven this type of structures are available.

And also we can have say melt blown, spun bonded, and melt blown non-woven structure. So, non this is although it is a non-woven filter medium, but here spun bonded and sorry this is spun bonded spun, bonded and spun bonded, this two spun bonded fabrics are there in both top and bottom layer. And in between we can have 1 melt blown structure. So, there are different types of combined structures, which enhance the filtration characteristics along with the mechanical characteristics.

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So, basic need of non-woven filters are its high energy saving; why is it high energy saving material? Because non-woven fabrics when used as filter medium, the pressure drop that means, energy required to flow through the filter medium is lower than other structure. So, pressure drop will be low, and energy saving will be there.

As far as cost of production is concerned. Non-woven fabrics are cheaper than the woven structure, and it has got high versatility. So, we can have different types of non-woven structures even combination of non-woven structures as I have mentioned just now. So, we can have different range of filters, and the filtration efficiency or different range of particles, we can separate out using non-woven filters. And non-woven filters are recyclable that means, we can protect our environment. So, by using the non-woven, after use we can recycle the structure again.

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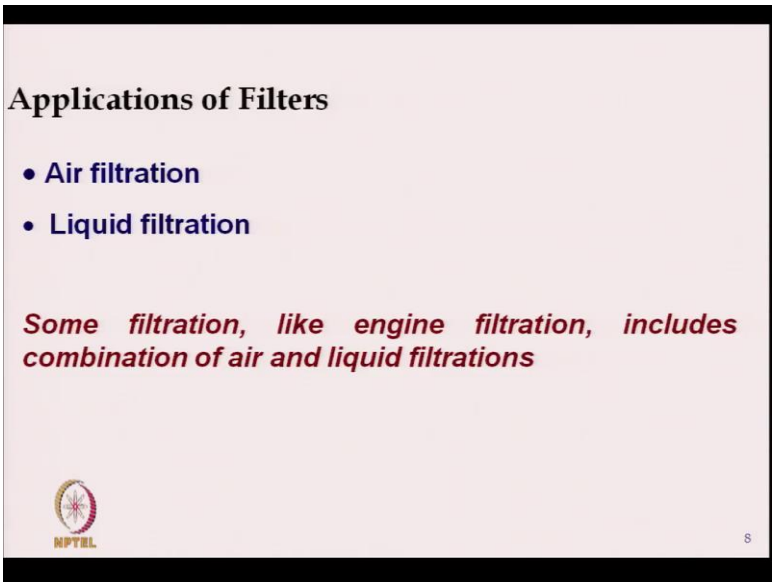

The application area if we see, non-woven filters or woven filters. So, fibrous filter we can use basically in two broad areas; one is air filtration, another is liquid filtration. In addition to this, there are some applications like engine filter which include combination of air and liquid filter. So, these are the application areas.

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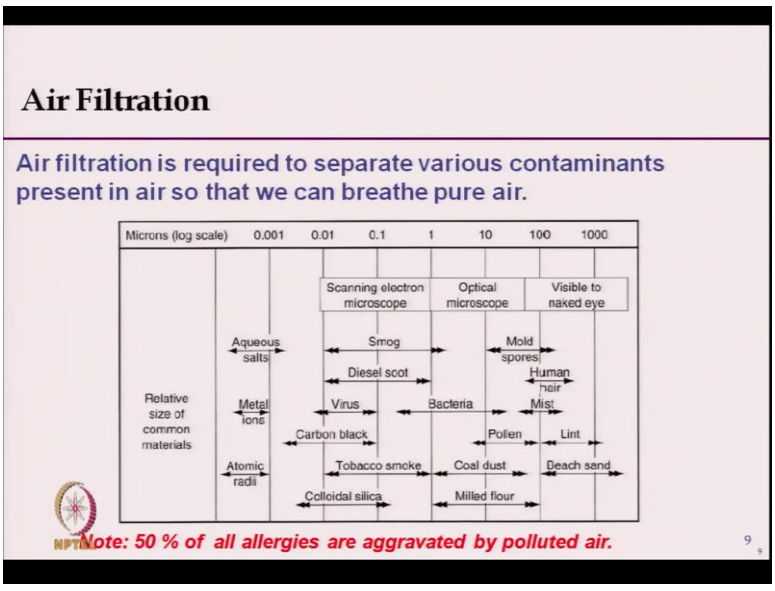

Now, let us try to see the type of the particles, which we need to filter out. So, air filtration is required to separate various contaminants present in the air, so that we can breathe pure air. So, if you see this row at the top, it shows thus particle size in microns.

So, this is 0.001 micron that means, 1000th time of a micron ok and similarly, 0.01, 0.1, 1, 10, 100, and 1000 micron.

So, here if we see this particles which are visible to naked eye larger particles, and this range 1 to say 500 or 600 micron we need optical microscope, and below that we need scanning electron microscope. So, these are the different types of particles which are actually contaminating our air, and we have to remove it from the air, pollen, coal dust, diesel soot, smog, so these are the different types of particles. And accordingly, we have to develop fibrous filter, just to protect us from this type of harmful particles.

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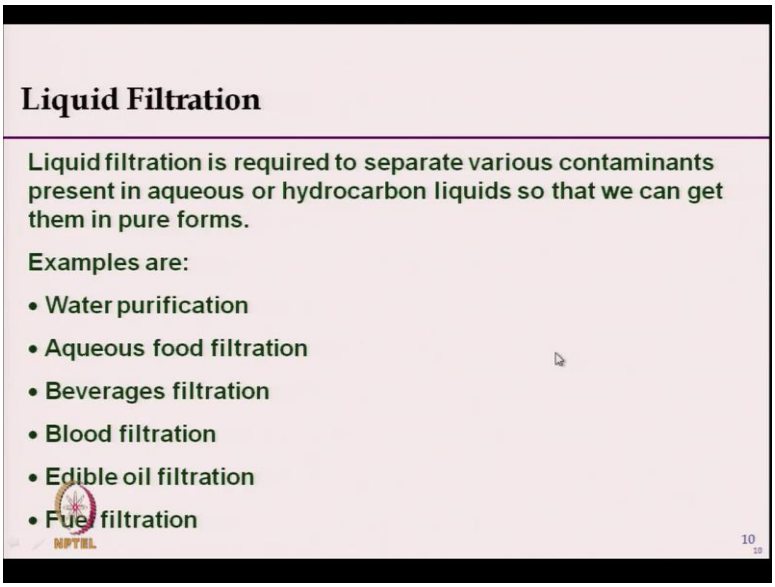

In addition to air filter, we have liquid filtration which is required to separate various contaminants present in aqueous or hydrocarbon liquids, so that we can get items in pure forms. These are of two types; one we want to get pure fluid or we want to get pure material that is which is the solid material. The examples are water purification. So, examples of liquid filtration are water purification, aqueous food filtration, beverages filtration, blood filtration, edible oil filtration, fuel filtration. So, all this areas we need fibrous filters to filter this liquids.

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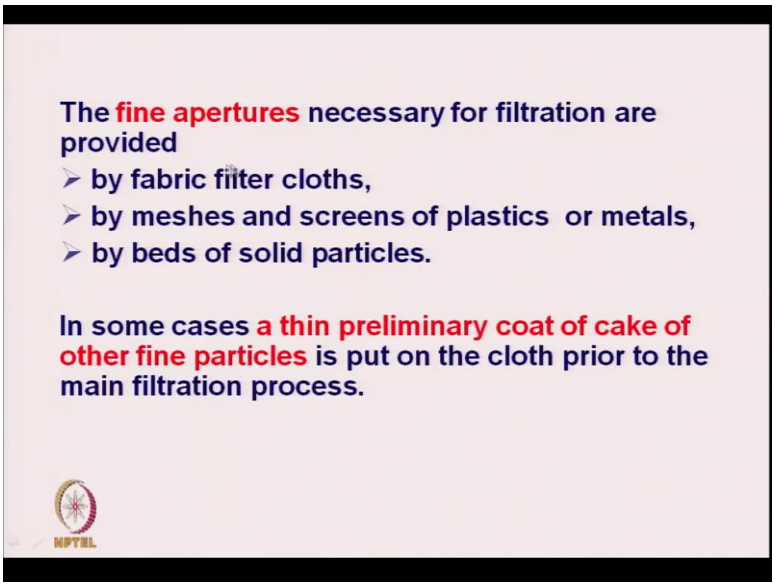

Now, the fine apertures necessary for filtration are provided by fabric filter cloth or by mesh or screen of plastic or metal. So, sometime we use the mesh or screen of plastics or metals or sometime we use beds of solid particles. So, bed filtration is also in some places we can use. In some cases a thin preliminary coat of cake of other fine particles like this solid beds are formed on a cloth ok, which is put on the cloth prior to main filtration process ok. Pre-caked filter clothes are also available, so that we get proper filtration efficiency.

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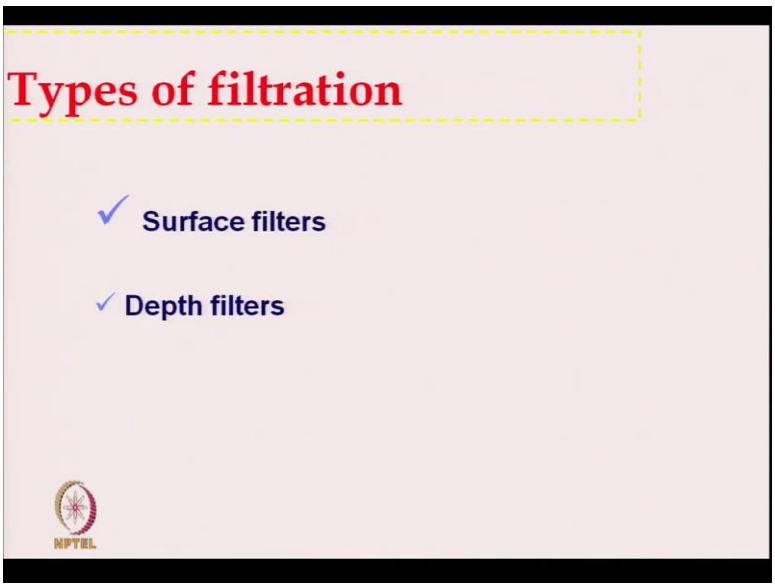

Now, if we see the types of filtration, we have two types of filtration. One is surface filter, and another is it is a depth filtration.

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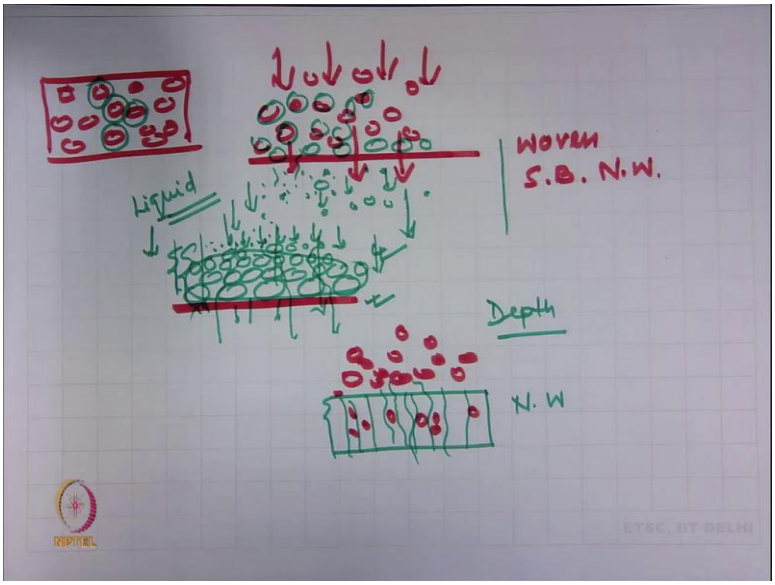

Now, let us see suppose we have very thin fabric, say woven fabric or spun bonded, non-woven fabric which are very thin. If we see the pore size, these are the pores certain pores are there, which are fixed. And the thickness is very low. Now, when the fluid contaminated with particles are trying to flow through the filter fabric, the particles which are larger than the pores will be restrained here will be stopped here. But, the particles which are smaller than the pores will try to pass through the filter.

But, gradually what will happen, this side the upstream side will be filled with the large particles initially, then it will form gradually the cakes. And ultimately, the cake will have much lower pore structure, lower pore size, so after certain time the proper cake formation will be there, and it will start blocking or stopping the smallest particle. So, initially there will be some small particles passing through, but after certain time when the cake is formed, then the smallest particle will also be arrested. And only the air, clean air will pass through the filter medium. And this type of filtration is known as surface filter, these are surface filters. And basically this type of phenomena is very common for liquid filtration.

If we see the geotextile filtration behavior, this is very common filtration behavior of geotextile. So, initially there will be piping of small soil particles, but after certain time

once the cake formation and filtration will be improved. So, it will allow only the clean liquid clean water, but will not allow the soil particle to pass through. Although initially the pore size of the filter medium was larger than the average or smaller particle size. This surface filter is used mainly for the liquid or in case of air, where the flow rate, the velocity of the air is low.

On the other end if we talk about the depth filtration in depth filtration, what will happen? The fabric will have certain depth like non-woven fabric, and there will be pores in the structure the porosity will be there. And the particles during its path will not be arrested on the surface, but it will try to penetrate inside the structure and will be arrested in the pores of the structure. And this is called the depth filtration.

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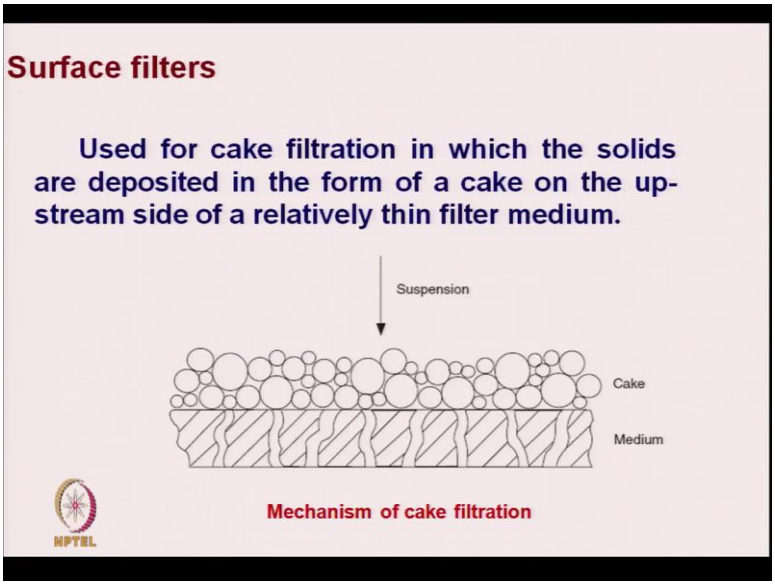

So, surface filtration, and depth filtration. Now, they used for cake filtration as I have mentioned in which the solid solids are deposited in the form of cake on the up-stream side of a relatively thin filter medium. So, this is very thin filter medium.

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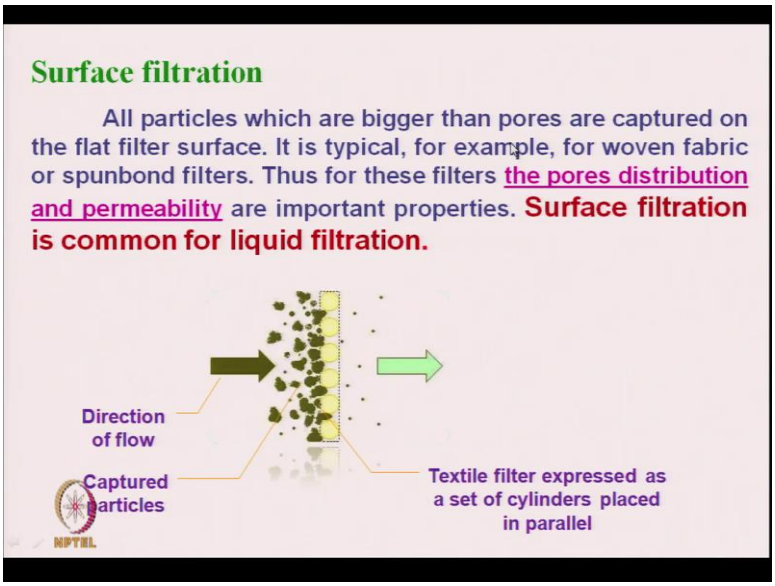

All particles which are bigger than the pores are captured on the flat filter surface. So, this is the flat filter surface the bigger particles will be captured; thus for these filters the pores distribution and permeability, and it is a fixed and the permeability are important properties. So, the pore distribution, the pores are relatively fixed like woven fabric or spun bonded fabric, and permeability characteristics are also important. Surface filter filtration is common for liquid filters. So, these are the captured particles, and we can see smaller particles are passing through the filter medium initially.

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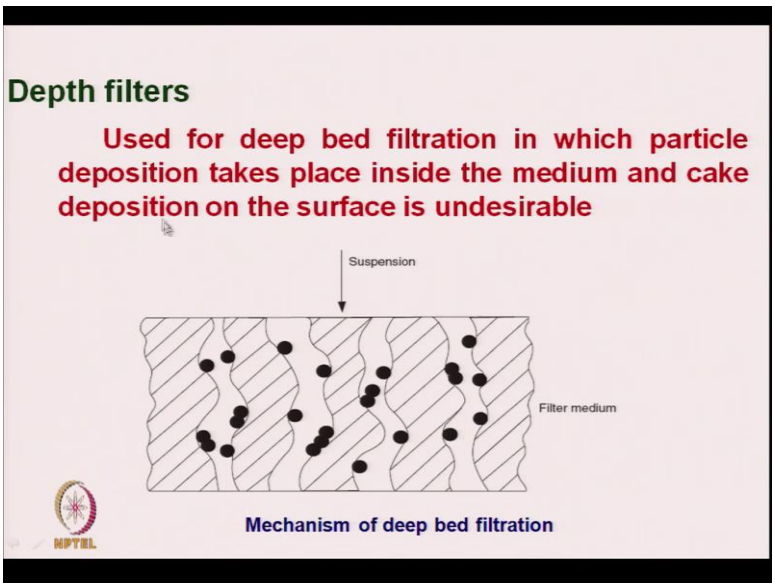

And in case of depth filtration, it is used for deep bed filtration. So, this is deep bed filtration in which particle deposition take place inside the medium and cake deposition on the surface is undesirable ok. So, the cake deposition will not be there, only the particles will be deposited inside the structure.

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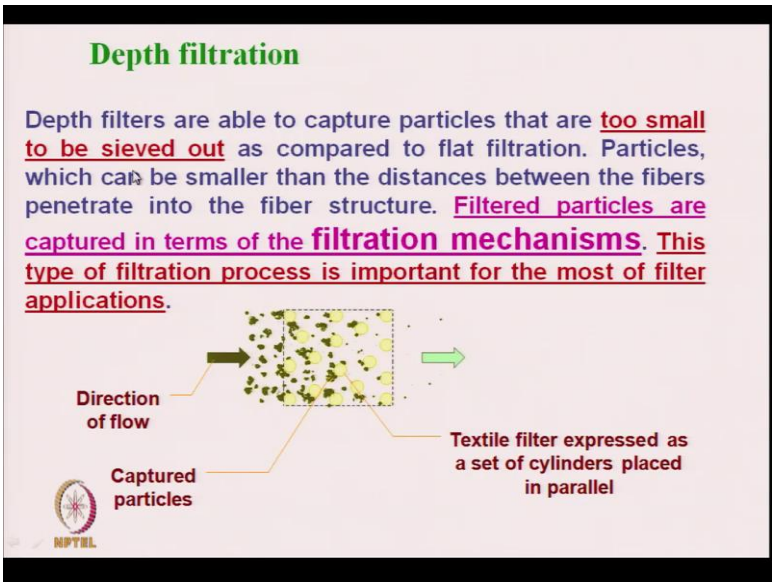

Depth filters are able to capture particles that are too small to be sieved out as compared to flat filtration which is surface filtration. So, in case of depth filtration, we can handle, we can filter very very small particles much smaller than the pore size of the filter. The particles which can be smaller than the distance between the fibers penetrated into the fiber structure.

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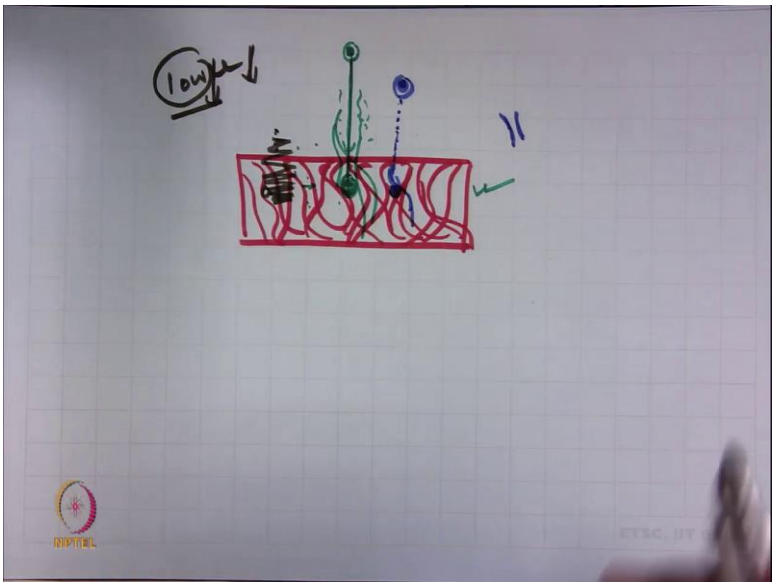

So, this suppose this is a filter medium, and these are the fibers. The particles which are much smaller than the distance between the fibers can also be filtered out using some mechanisms, that I will discuss. So, filtered particles are captured in terms of the filtration mechanisms, there will be different filtration mechanisms.

Even we can filter out the bacteria or virus using fibrous filter medium, where the distance between the fibers are much larger than the size of the particle. This type of filtration process is important for the most of the filter applications. So, depth filtrations are most commonly used filtration mechanisms. This is direction of flow, the captured particles as we can see are just inside the structure of the filter.

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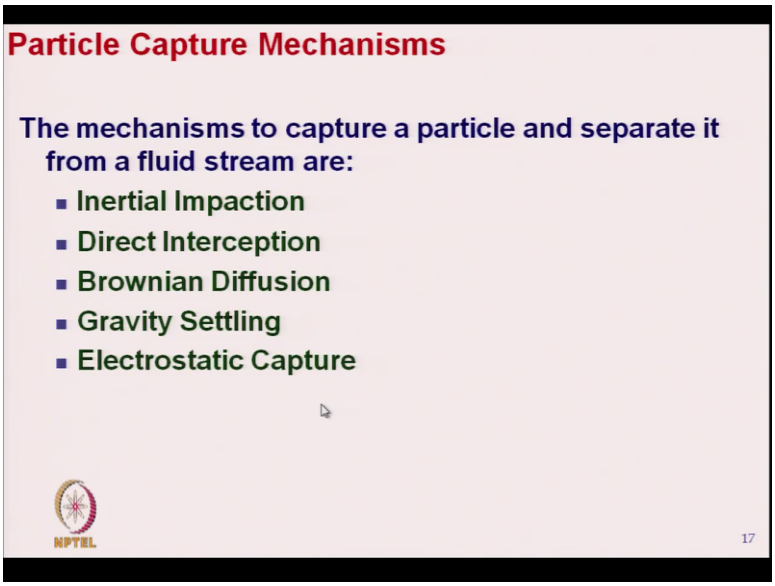

Now, if we talk about the capture mechanisms, there are different types of capture mechanisms. The mechanisms to capture a particle, and separate it from fluid streams are, first is the inertial impaction, what is that. Suppose, this is a filter medium, and one particle one particle is coming at high speed, and it is penetrating inside the structure on his path. In case of the filter medium, there will be some fiber. It will directly impacted with the fiber, and that will result the reduction of its speed, and it will try to settle down somewhere inside the structure. This phenomena is known as inertial impaction, the impact force is due to the inertia of the dust particle.

Here the size of the dust particles are large enough, so that it follows the straight path and the air will take its path. The air which is moving will take its path depending on the availability of the pores, but as the particle is heavier particle will try to follow the straight line path. And air will take its own path depending on the pores or the available passage. So, in this way the heavier particle larger size particle will have impaction with the fiber structure.

Next is that it is called direct interception. The direct interception it happens, when the fibers are relatively smaller in size. So, this is the fiber a particle with the direct impaction. And here the air is moving, and once the air enters into the structure depending on the path available air will try to take its path. As this particles are smaller in size, this particles will also try to take the path of the air. And the places where the

difference between the fiber, distance between the fiber is smaller than the size of the particle, at that position this particle will be intercepted. So, there will be some place during the path the suppose this is the position, where the distance between the fibers are smaller. At this point it will be captured, so that is why it is a direct interception.

Next is that it is called Brownian diffusion, so what is that. If the particles are very very small in size very small size particle ok, and the flow velocity is very low low flow velocity, and very small particle. As we know if the size of the particle reduces, it will have some Brownian motion. So, very small size particle will penetrate inside the filter medium, and will have Brownian motion as the velocity of air is low.

So, the Brownian motion will not get affected by the flow of the air. So, during its Brownian motion, this fiber will strike the fiber path, and will be settled on the structure. So, it will be actually captured inside the fibrous medium. So, this is the Brownian diffusion capture mechanism.

Next is the gravity settling, so the heavier particle will try to get separated automatically from the air stream due to its mass. Then electrostatic capture: so, if the fibers are electrostatically charged, the particles will be attracted by the fiber surface. And it will be separated from the, fiber will separate this particle from the air stream.

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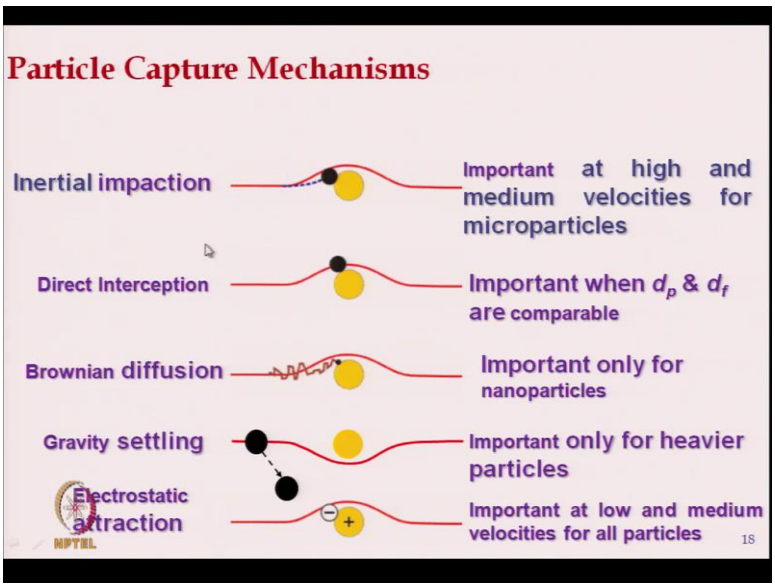

Now, this pictures shows the capture mechanism as has been mentioned that inertial impaction. The particles are heavier enough, and air the red path is showing the air movement. So, air is taking its own path where the passage is available. And due to heavier particle, it will actually not follow the air movement. So, the path will be separated, and it will strike the fiber so important at high and medium velocities for micro-particles. So, particles are little bit larger in size. And this is important, when our fluid medium velocity is very high.

Next is the direct interception important, when dp particle diameter, and diameter of fibers are comparable. So, the mechanism I have already explained. Brownian diffusion important only for nano-particles, when we get the Brownian motion; gravity settling means heavier particle will automatically get separated, this is only for heavier particles. And electrostatic attraction important for low and medium velocities for all particles that means, for high speed airflow. So, initial inertial impaction will be there and for very low motion, we can actually we can separate the nano-particles by using fibrous medium, where the speeds are very low.

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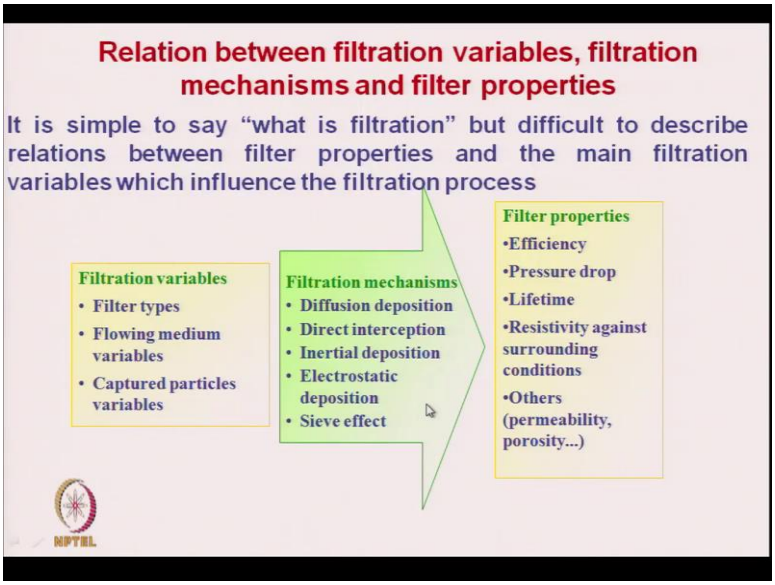

Filtration variables are the filter type, flowing medium variables, whether it is a air or liquid, whether it is a woven filter, non-woven filter or composite filter, and the type of particles, the Now, after understanding the mechanisms of filtration. Now, we must

understand we must have very clear understanding on the relationship between the filtration variables, filtration mechanisms, and filter properties.

So, we have discussed the filtration mechanisms. And filtration variables are the filter type, flowing medium variables, whether it is air or liquid, whether it is a woven filter, non-woven filter or composite filter. And the type of particles, the diameter of particle, the diameter distribution of particles, so all these things are important. And we must correlate this filtration variables with the mechanism, so which mechanism will it follow. Like if the captured particles diameters are very small, in that case as I had mentioned, it will follow the Brownian diffusion ok. So, Brownian diffusion will be followed.

If the filters are non-woven filter, so it will have different types of filtration like depth filtration will be there. If it is say mesh type filter, then sieving effect will be there. Along with these the properties, what type of properties are important, whether it is a filtration efficiency, pressure drop, lifetime, so all these properties are important. So, whether do we need highest filtration at a time or lowest pressure drop.

So, filtration efficiency and pressure drop if you see, they are actually contradictory requirement. We need maximum filtration efficiency with lower pressure drop, so achieving this two together is very tricky. So, we should use the knowledge of the filtration mechanism, and filtration variation variables, so we have to have combined knowledge. And interrelationship between all three aspects, then we can properly design the filter for a particular application.

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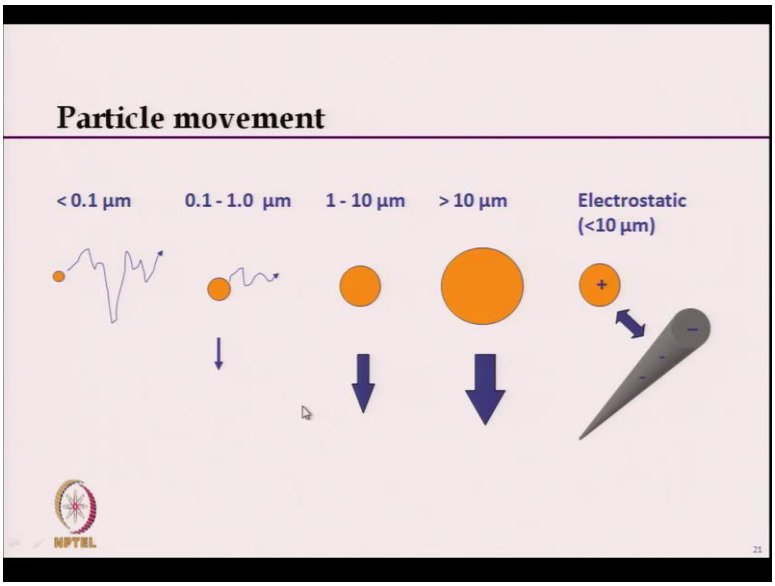

Now, if we see this is the particle, which is less than 0.1 micron, so this particle will have Brownian motion. So, this is another particle 0.1 to 1 micron, then 1 to 10 micron. So, this are the different type of particle size, and depending on the particle size different mechanisms are followed.

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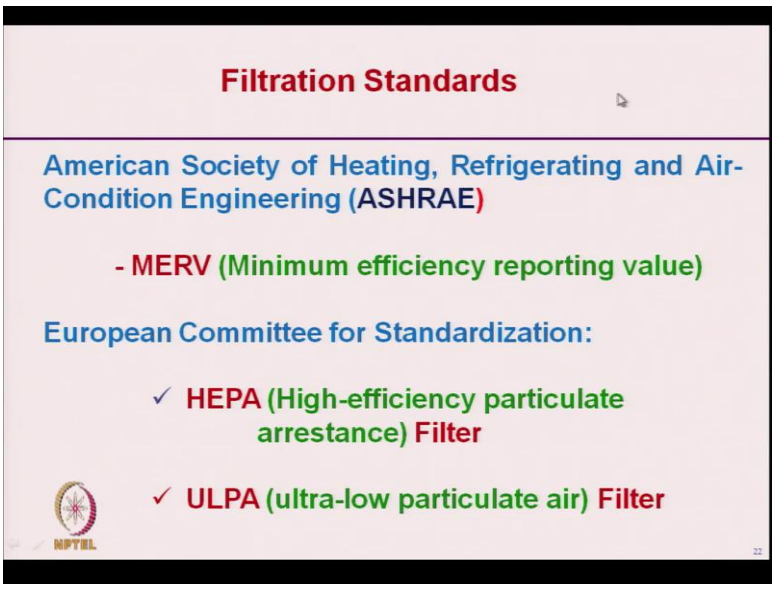

So, there are different filtration standards are available. So, most widely used filtration standards are one is American Standard, and other is European Standard. So, American standards is the American Society of Heating Refrigeration and Air-Conditioning

Engineering ASHRAE this is the standard. And where they follow MERV label, so which is Minimum Efficiency Reporting Value. So, it is typically from 1 to 14 ok. So, 1 means very coarse type of filtration, and 14 or 16 maybe it is a very fine filtration.

On the other hand, European committee for standardization, they have different types of filtration standards. Most widely used are HEPA filters HEPA High-Efficiency Particulate Arrestance. And ULPA which is Ultra-Low Particulate Air. So, HEPA and ULPA filters, they have different ranges and this ranges depend on the efficiency of filtration, so that I will discuss.

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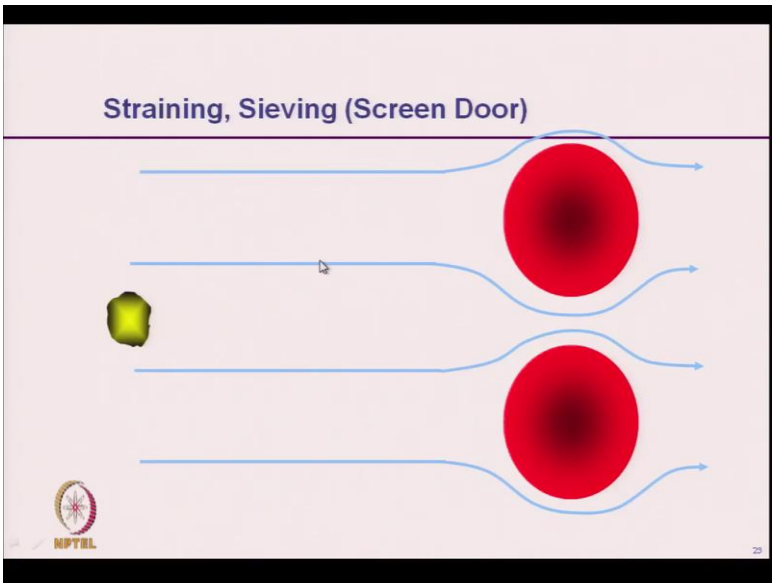

This animation shows the straining or sieving mechanism, where this particle is actual larger than the pore size. So, as it is larger than the pore size, so it will be separated directly by sieving action. The particles which are smaller than this dimension will be actually travelling along with the air so it pass through the filter medium.

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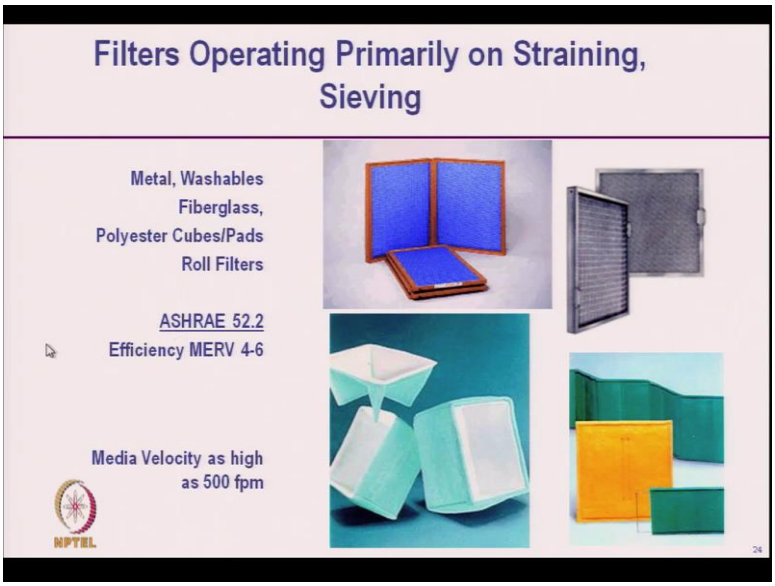

And the areas of application of straining or sieving are metal, washable, fiber glasses ok. Polyester cubes these are the different application areas. And here the efficiency as per American standard, MERV typically it is around 4 to 6 range and media velocity will be very high media velocity. So these are the applications, they are type of filter where we need to strain. We need to sieve some particles at very high speed 500 feet per minute ok.

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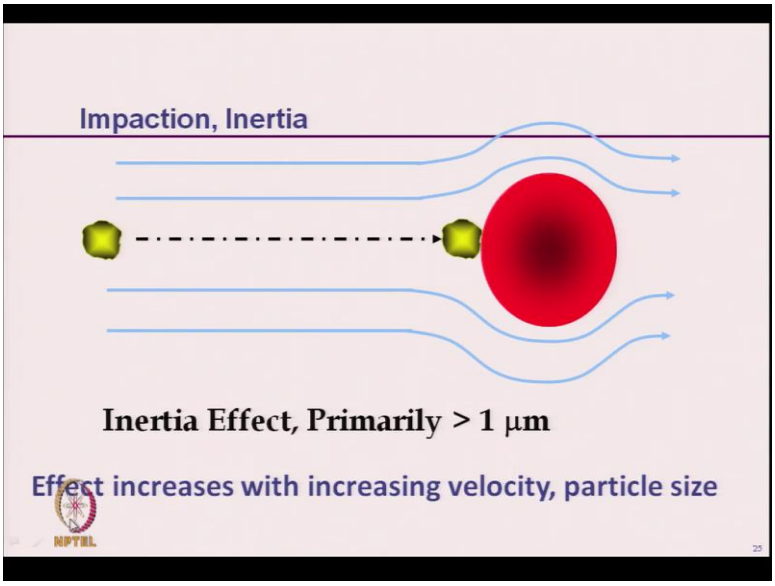

Next is that impaction that is inertial impaction, the particle sizes are smaller than earlier sieving. Here the particle will directly strike here, and inertia effect primarily the particle size is more than 1 micron. The effect increases with the increasing velocity, and particle size. So, as the velocity increases velocity of the fluid medium increases, the particle will have higher inertia. And we will try to strike follow the straight path and strike the fiber. And also as the particle size increases, this will directly have higher inertia will strike the fiber.

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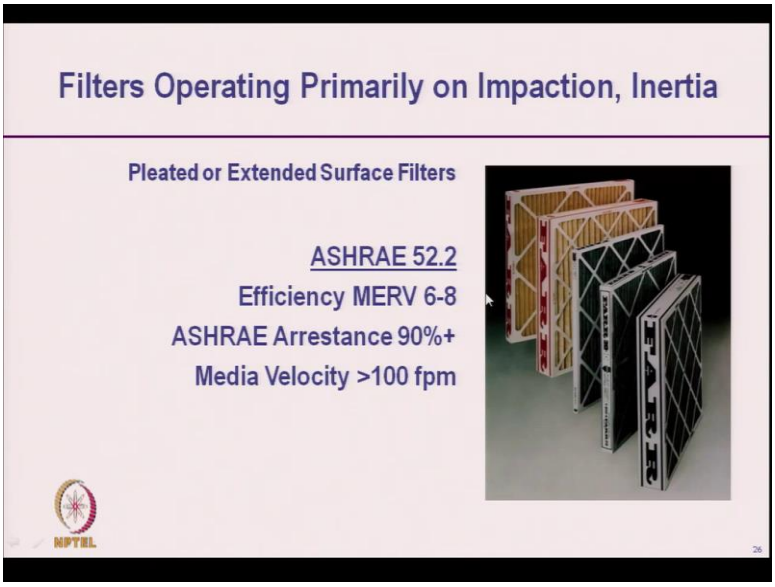

These are the applications area like efficiency is MERV 6 to 8 higher than earlier is and used in pleated and extended surface filters. So, this type of filters are basically using the impaction principle. And medium velocity is less than the sieving, it is more than 100 feet per minute.

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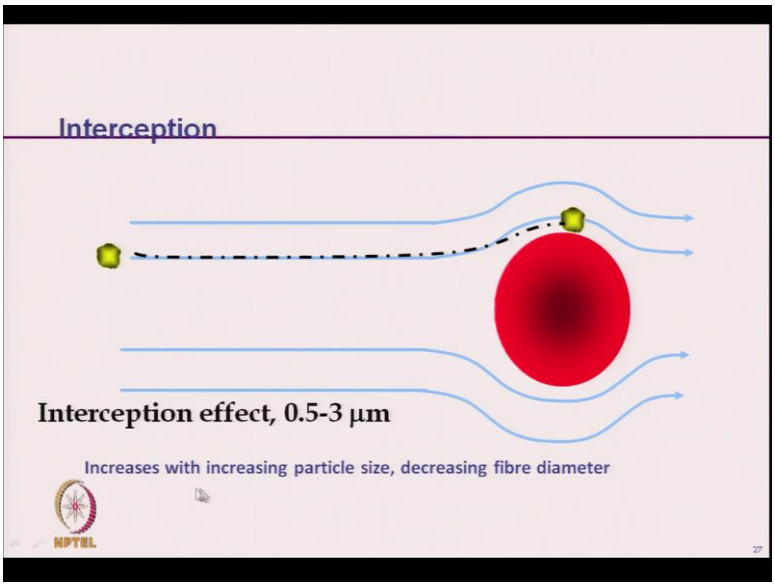

Then interception for interception mechanism, the particle size are 0.5 to 3 micron. And it increases with increasing particle size, and decreasing fiber diameter. As the particle size increases, so type of flow will change, but the chances of interception chances of entrapment in the fibrous structure will increase. Also as the fiber diameter decreases, the entrapment will increase, because the space between fiber will reduce.

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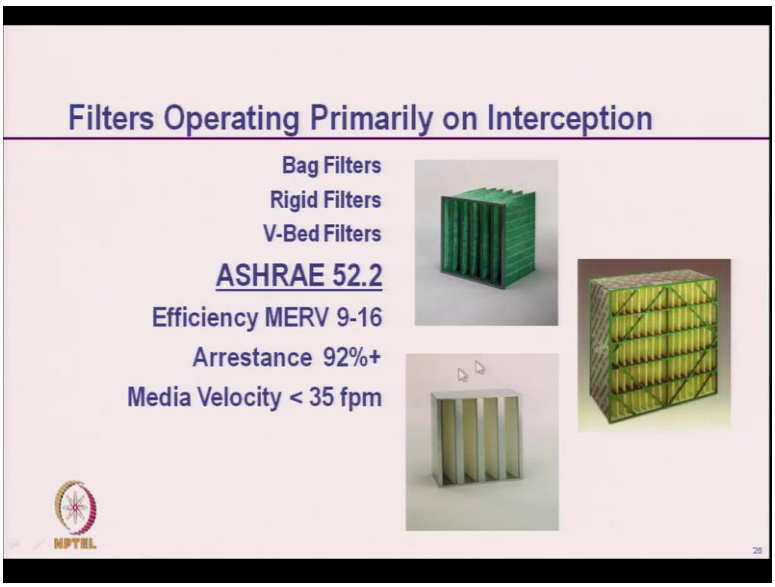

So, filters which are used with interception mechanism, it is a bag filter, rigid filters, V-bed filters. And here MERV value the efficiency value is higher than earlier, it is MERV

9 to 16, so higher MERV values are there. And medium velocity is less which is 35 feet per minute or less.

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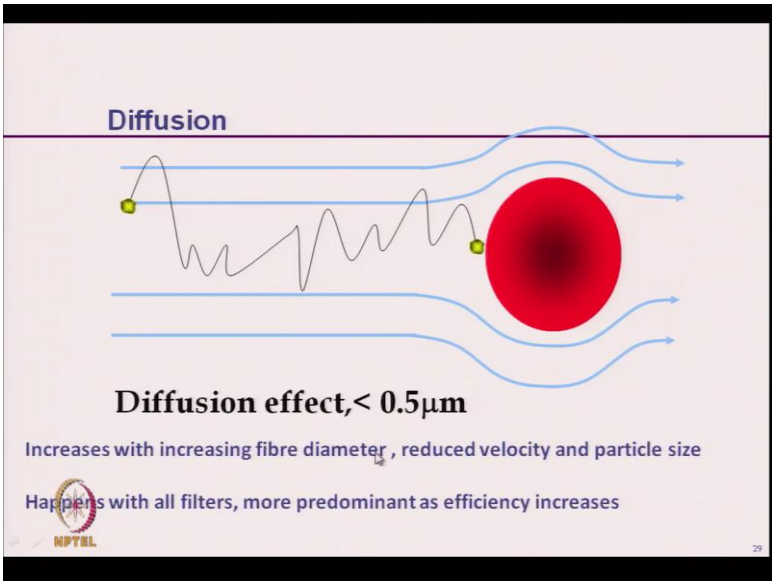

And diffusion as I have mentioned, it is for very small size particles, and particle sizes are less than 0.5 micron. So, if we increase the particle size, the diffusion effect will not be there. So, this diffusion effect increases with increasing fiber diameter. As fiber diameter increases that will actually increase the probability of fiber to be settled on the surface and as the velocity of air reduces, so there will have more Brownian diffusion and reduction in particle size ok. This happens with all filters, more predominant as efficiency increases. So, for most of the filter medium we see this type of diffusion mechanism, but for very small particles.

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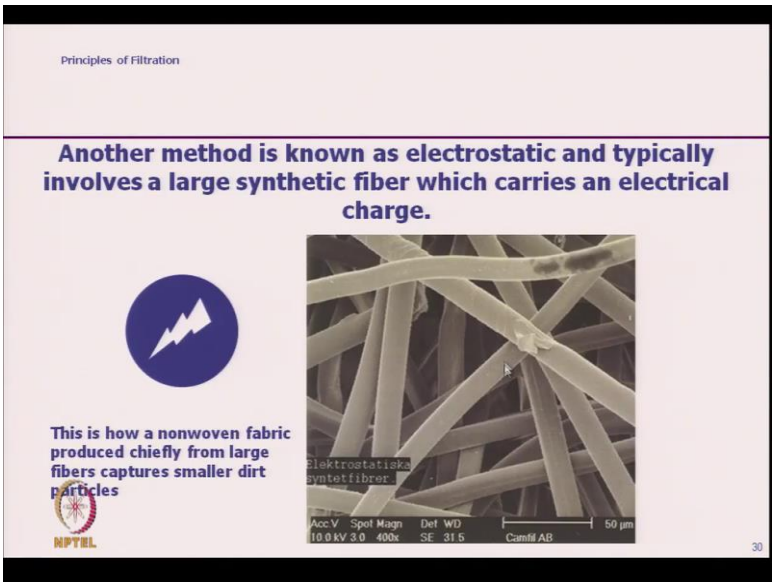

So, another method is that it is a electrostatic filtration. So, typically involves large synthetic fiber which carries an electrical charge. So, for natural fiber, so it is very difficult for those fibers to be charged. So, synthetic fibers can be charged like polyester, polypropylene can be charged easily. So, this is showing a charged fiber ok. So, this fibers are charged, and these are the charge.

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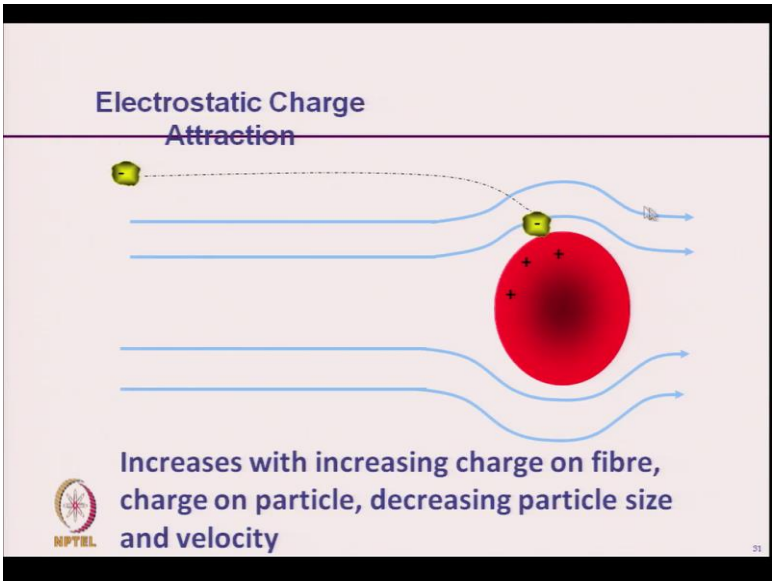

As the particles are attracted, so but this is the charge with positive charge, and particles are charged with negative charge. So, increases with increasing charge on the fiber, so of

this filtration efficiency attraction increases with the increase in charge, if we charge with the higher amount.

So, the filtration efficiency will increase due to higher attraction, and charge on particles, and decreasing particle size. So, as the particle size decreases, so the attraction will increase ok. So, for smaller particle the attraction will be more, because it will try to be attached with the fiber surface. And if the velocity is less, so electrical charge, so electrostatic principle works with coarser fiber, and smaller particle, and lower velocity.

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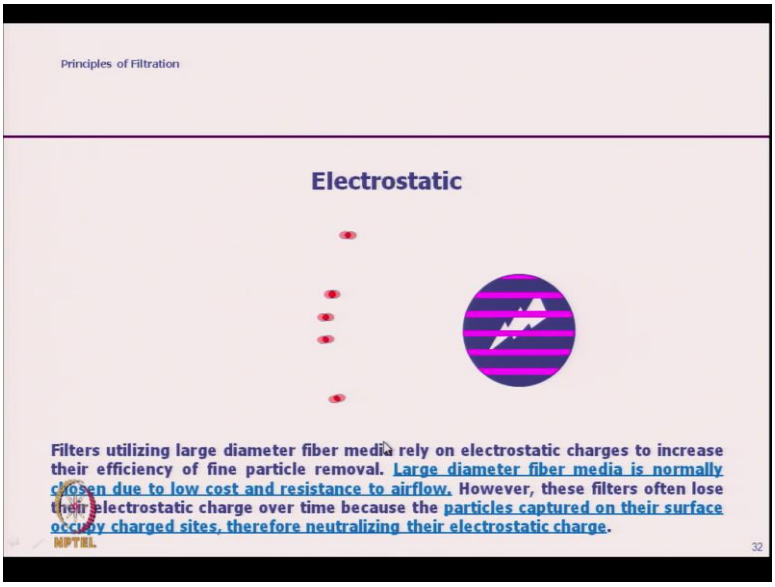

So, this is electrically charged fiber. So, as it is attracting the charged particle after certain time, this will lose its charge. Then after that, it will not be actually effective. So, either we have to recharge this filter again or we have to replace this filter. So, these are the different areas of applications.

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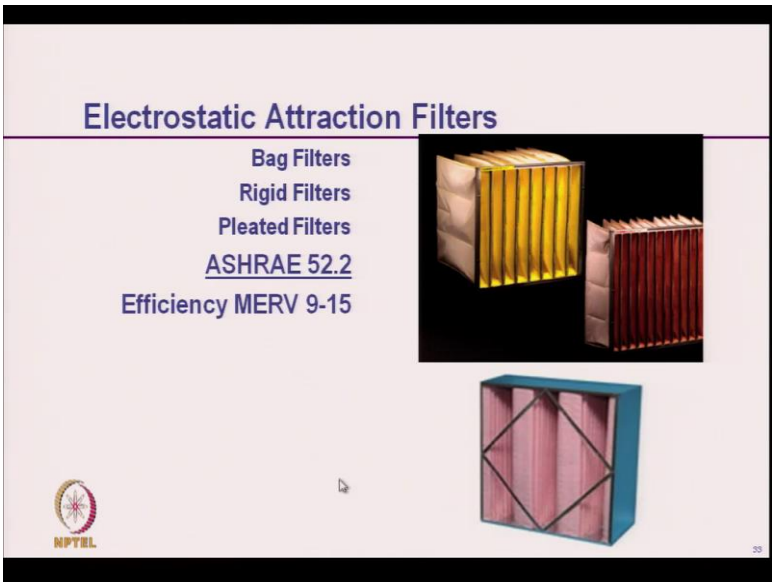

Bag filter we can use electrostatic principle, rigid filters, pleated filters, this we can use this electrostatic principle. Here the efficiency is relatively high 9 to 15 MERV value.

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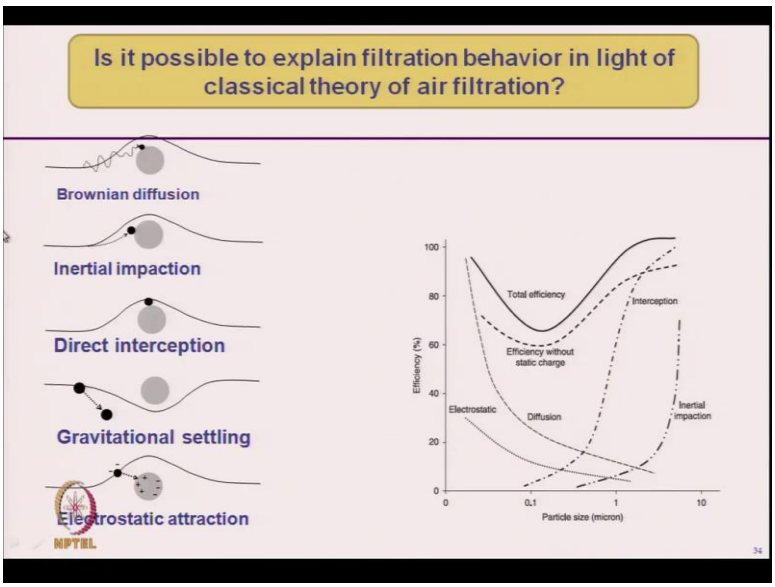

Now, if we see the filtration efficiency for different particle size with the particle size, and which mechanism is dominant, we can explain using this curve. So, if you see here, this is the interception. This curve shows the interception, and this is inertial impaction. Now, what does it show? It shows the around say less than typically 1 micron. So, if it is say 0.5 micron say, it starts with the 0.5 micron. So, above say 0.5, 0.6 micron, the

particle size the particle size which is actually start following the inertial impaction. So, as the particle size increases, there will be more and more probability of the particle will get captured. So, filtration efficiency will increase gradually as the size of the particles increases.

On the other hand, this curve shows that interception. For interception as the particles as to follow the direction of the air, it has to follow the path of the air. So, particle size should be less than the inertial impaction. So, here the particle size is typically less than 0.1 micron. And as we increase the particle size, the chances of particles being captured will increase, and filtration efficiency will increase accordingly.

But, if we see the mechanism of diffusion, the Brownian diffusion, so Brownian diffusion as I have mentioned it is prominent, when the particle size is low. So, as the particles are very small. For smaller particles, the Brownian diffusion will be more, and chances of particles being captured will be more. So, probability of particles being captured by the filtration medium will be more. So, filtration efficiency will be highest, when the particle size is very low.

And as the particle size increases, so it will gradually not follow the Brownian diffusion principle, so the filtration efficiency will reduce. And electrostatic attraction if the particle size is very low, then the chances of attraction, chances of the particle being attached with the fiber will be high. But, as we increase the particle size, the effect of electrostatic attraction will be reduced.

So, if you see the total efficiency, if we combine all these four principles, we are getting this and this curve. This is the typical shape of filtration efficiency curve which shows if the particle size is very low, then we have higher filtration efficiency. And we are talking about the mean particle size, and with the increase in particle size filtration efficiency initially drop. And after that, it increases again. And this two curve shows, this is without considering the electrostatic charge. And if we charge the particle charge the filter medium, in that case the efficiency will be higher. So, this curve is a combination of all four principles.

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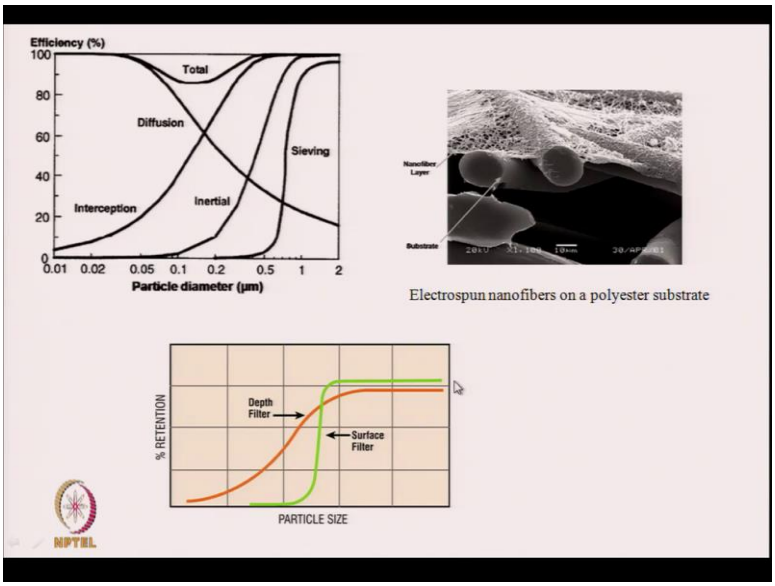

This is another picture here. And here we can have both depth filtration, and this is the surface filtration. What does it show here? Depth filtration gradually increases with the increase in particle size, so because this is deposited inside the structure and following certain mechanism; but, surface filtration initially for lower particle size.

So, most of the particles will start passing through the pores of the filter. But, after certain particle size, when the particles are larger than the pores, suddenly is the filtration efficiency will increase. So, these are all about the mechanisms of filtration. So, we have understood the basic mechanisms of filtration. And in next class, we will discuss the properties of filtration medium, and the measurement techniques of filter fabrics.

Till then thank you, thank you for patient hearing.