Technical Textiles
Prof. Apurba Das
Department of Textile and Fibre Engineering
Indian Institute of Technology - Delhi

Lecture - 15
Filter Fabrics (contd.,)

Hello everyone. So, we will continue with the topic filter fabrics. So, what we have discussed the basic mechanisms of filtration then we have discussed the measurement techniques, of filters and efficiency and pressure drop and other fabric related parameters. Now, we will discuss various other parameters so, the pore structures as I have already mentioned.

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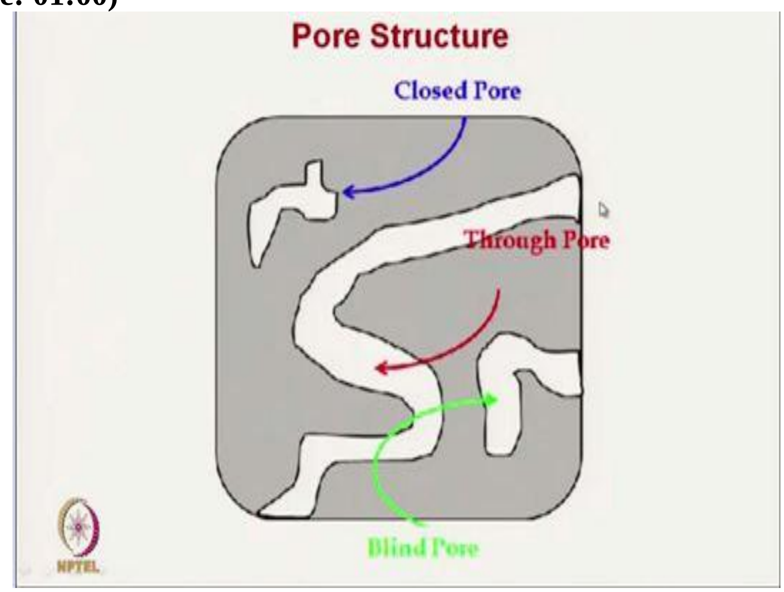

There are 3 different types of pore structures. One is closed pore, which is blocked from all the sides, blind pore its open from one of the surfaces and it ends within the structure and through pores that is the pores are that starts from one surface and ends at other surface. So, this through pores are basically important for filtration application.

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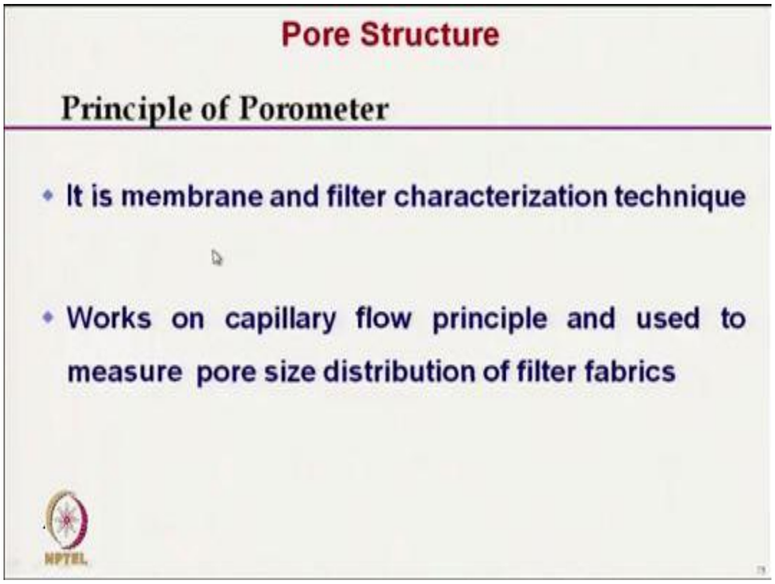

Let us discuss the measurement technique of pore structure. The pore structures are measured using porometer there are different types of porometers. So, these are used to measure the pore structure of membrane or filter fabrics and these are important for filtration characteristics. So, the basic working principle of pore measurement is based on basically capillary flow principle and this is used to measure the pore size distribution of filter fabric.

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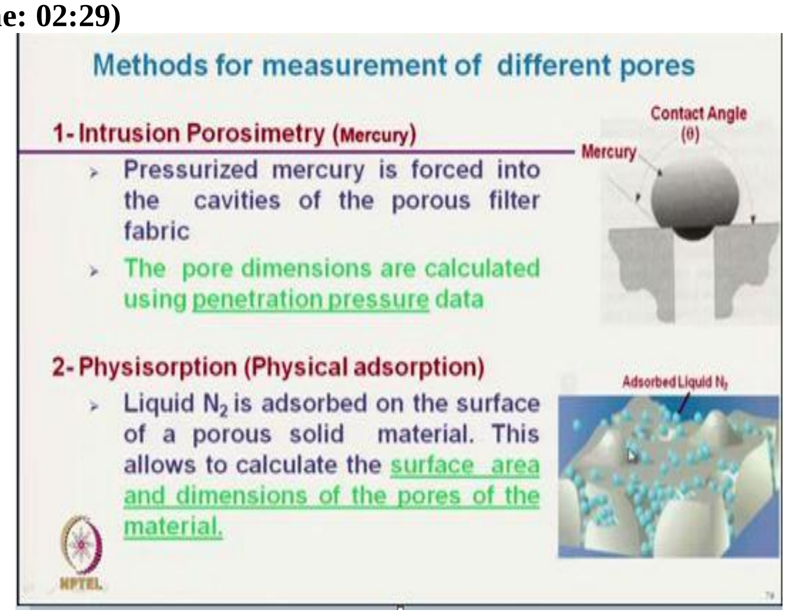

The techniques are, one is intrusion porosimetry that is mercury it is used mercury. So, here mercury at high pressure is forced into the cavity of the porous filter fabric. So, here mercury is being forced through this cavity and depending on the pore structure or pore size the pressure will vary. So, for finer pore size, we need higher pressure. So, poor dimensions are calculated using penetration pressure data. So, indirectly we can calculate the pore dimension.

Next principle is that physisorption that is physical adsorption here liquid nitrogen is used, this liquid nitrogen is adsorbed on the surfaces, different surfaces of porous solid, this allows to calculate the surface area internal surface area of the pores and indirectly we can calculate the dimension of pore.

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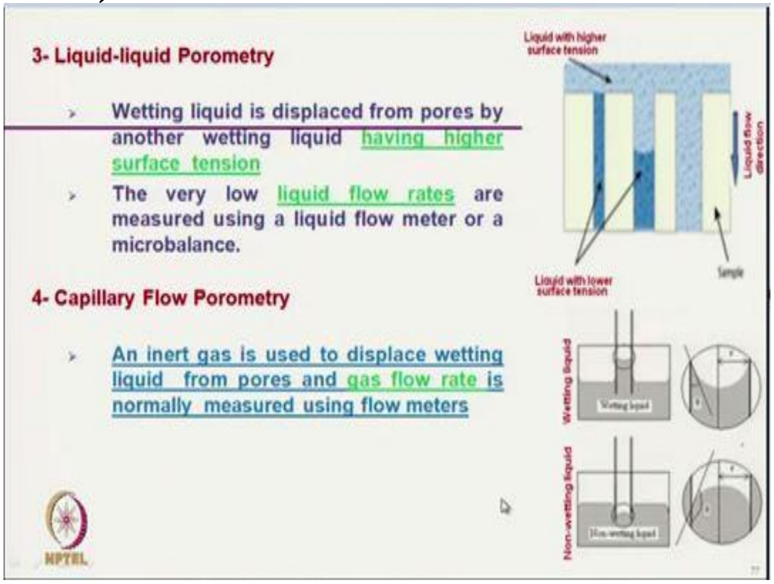

Next technique is that liquid-liquid porometry, here we use 2 different liquids one liquid is having higher surface tension and another is having lower surface tension. So, this dark color is strain the liquid with lower surface tension. That means, it can wet the surface easily, the wetting liquid is displaced from the pore by another wetting liquid with higher surface tension. So, this liquid with higher surface tension, when we allow it to pass at higher pressure, so, this liquid will force the other liquid with lower surface tension to push out.

And accordingly, we measure the pore dimension based on the liquid flow velocity. So, this this flow meter or microbalances are used. Next technique is that capillary flow porometry, here instead of this liquid with high surface tension, we allow the liquid to displace by an inert gas, inert gas is used. And based on the gas flow rate, we measured the pore dimension.

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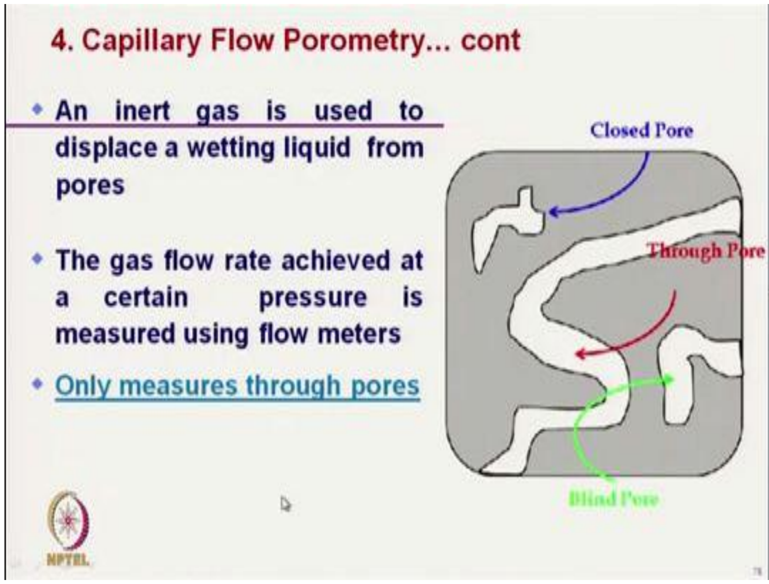

So, here capillary flow porometry the principle is that an inert gas is used to displace the wetting liquid from pores, the gas flow rate achieved at certain pressure is measured using flow meters. So, one full flow meter will be there. So, at certain pressure, we measure the gas flow rate and in this principle we measure only through pores, pore dimension of through pores which are important.

But if we see textile medium, most of the almost all the pores are through pores, because, the chances of closed pore and blind pores are rare because these are made from the discontinuous or continuous fibres. So, capillary flow poetry can be used to get idea about the pore dimension of filter fabric.

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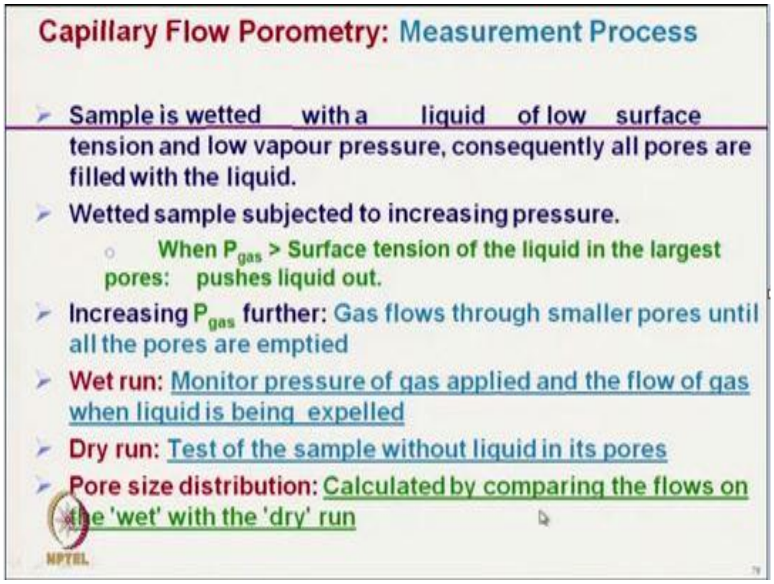

The process is that as I have mentioned here, the sample is first wetted with a liquid of low surface tension. So, that it gets wet easily and consequently all the pores are filled with that liquid. The wetted sample then is subjected to increased pressure of an inert gas. When this pressure of gas P gas exceeds the surface tension of liquid in the largest pore, it will start pushing out the liquid.

So, at largest pore the liquid can come out easily. So, it will start from the largest pore. So, gradually we increase the pressure P gas, the flow through the smaller pore will start and ultimately total liquid will come out from the structure. So, to get the actual result without without any error, we have to run the process in wet run and dry run principle. In wet run means, the gas is applied when the structure is saturated with liquid and dry run the sample is dry without liquid in the pore. The pore size distribution is then calculated based on the flow data in wet run and dry run. There are different parameters these parameters are first bubble point.

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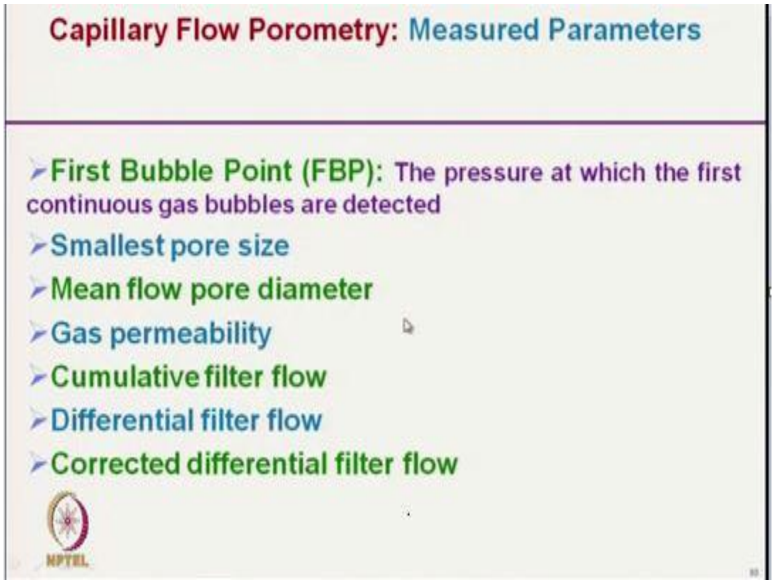

So, this is the pressure at which the first continuous gas bubbles are detected. So, if the pore size is more, this pressure will be less. So, from there we can get idea about the pore size, smallest pore size, mean flow pore diameter, gas permeability that means, when we use the dry run from there we can get to the gas permeability, cumulative filter flow, differential filter flow and corrected differential filter flow. So, these are the parameters we can get from the porometry result.

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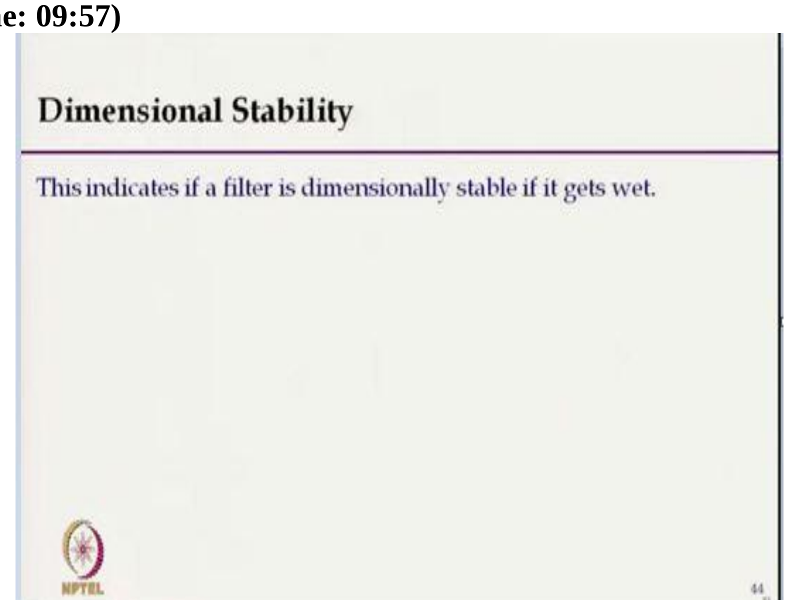

After pore size we must assess the dimensional stability whether there is a change in dimension during the application during wetting or even during heating that is very important for performance.

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Tensile strength characteristics, they are required. So, strip test, grab test. So, these are the different tests available. So, results are breaking force breaking extentsion, modulus. These are important because during application or handling we must know the tensile characteristics of filter fabric.

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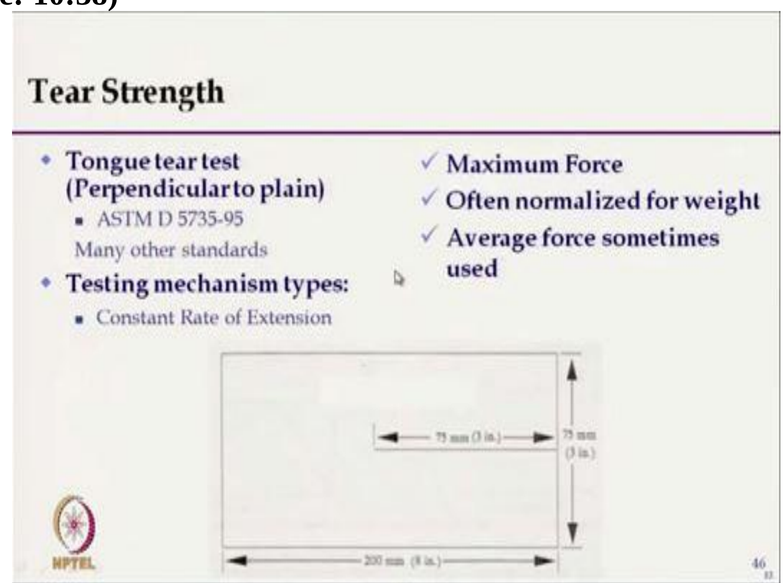

Tear strength is also important, tongue tear strength. So, testing machine any constant rate of extension machine can be used. So, here maximum force, average force of the tear strength sometime used. So these are the parameters which we can use for tear strength the measurement of filter fabric.

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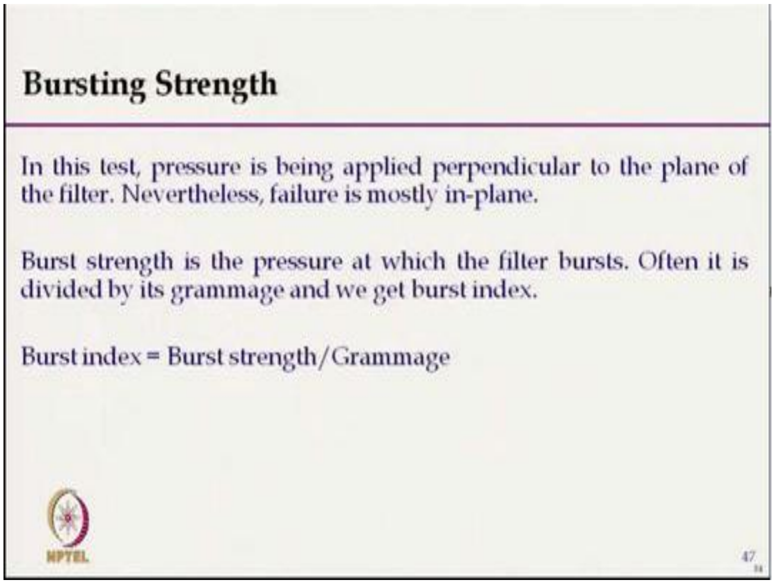

Busting strength is also very important particularly for filter fabric act when the pressure difference that is pressure drop is high. So it is measured based on the diaphragm type busting strength tester, so bust index is measured, which is actually busting strength per unit mass. Now, we will discuss different types of products which are available commercially. As far as the shape, we can divide the filter fabrics in different classes. These classifications are first flat filters.

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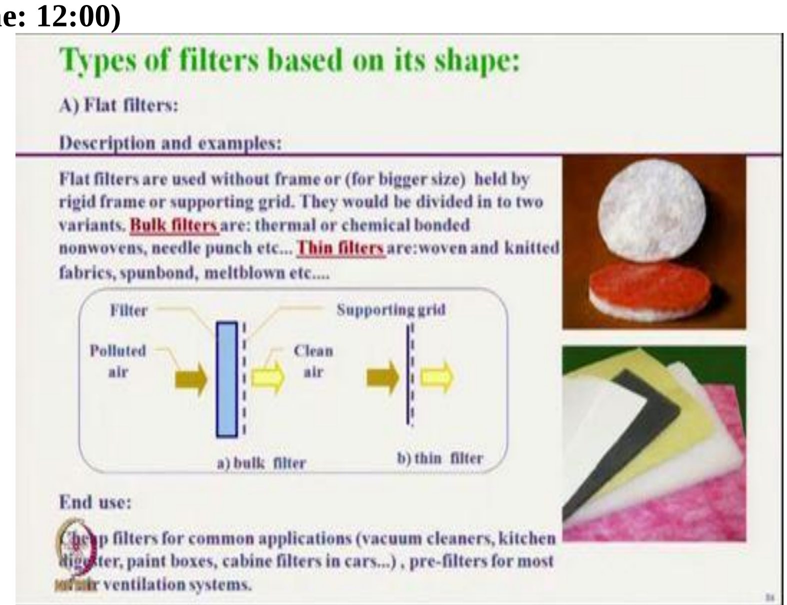

The flat filters are the filters which the shape is a flat and this can be used without any frame or we may sometime need frame. So, for smaller size with a thick or stiff filter fabric we may not need frame, these are used for bulk filters. So, that this bulk filters the thermal or chemical bonded nonwovens are used or sometimes needle punched fabrics are used, this bulk filters are basically used without any frame and thin filters are thin woven fabric and knitted fabric spun bond and or melt blown fabrics are used.

So, here we can see this is a supporting grid is there. So, this is bulk filter and thin filter, bulk filters are used where we need to have depth filtration and thin filters these are used where we need a surface filtration. So, this flat filters are used where cheap filtration solutions are required. Like vacuum cleaner, kitchen digesters, paint box, these are the applications where the bulk filters or thin filters are used in flat form. The main drawback of these filters are the high pressure drop although these are simplest in construction, we do not need any fabrication in bulk filter or flat filter.

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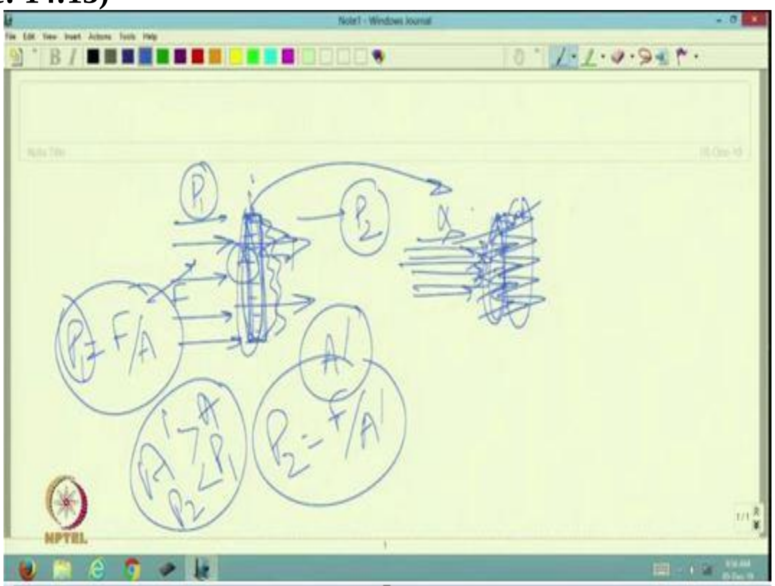

Suppose this is filter fabric air is passing through P 1 is the pressure on upstream side, P 2 is the pressure in downstream side. So, pressure here is basically the force per the unit area. This is the pressure exerted on the filter fabric and higher pressure means higher energy required. As I have already mentioned also, this high pressure will exert extra stress on the filter fabric. In that case the filter fabric may get deformed.

On the other hand if we want to reduce this pressure drop this pressure if we want to reduce or we want to increase the flow rate, so here the flow rate depends on the area of this filter. So, this area if we can increase the area, to say A dash, then we can reduce the pressure drop where A dash is more than A and P 2 will be less than P 1. So for same area of application, how can we increase the area of filter? So, the way is that if we can incorporate pleat so, the effective area or effective zone of filtration or airflow remains same, but the filters are pleated.

So, the actual area of filter fabric has increased. Therefore, the pressure drop on the filter pressure difference between the upstream and downstream side has reduced and as area of the actual area of the filter has increased, so we can have the air flow rate higher at higher rate, air can flow. So, the next type of filter based on shape, it is a pleated filter.

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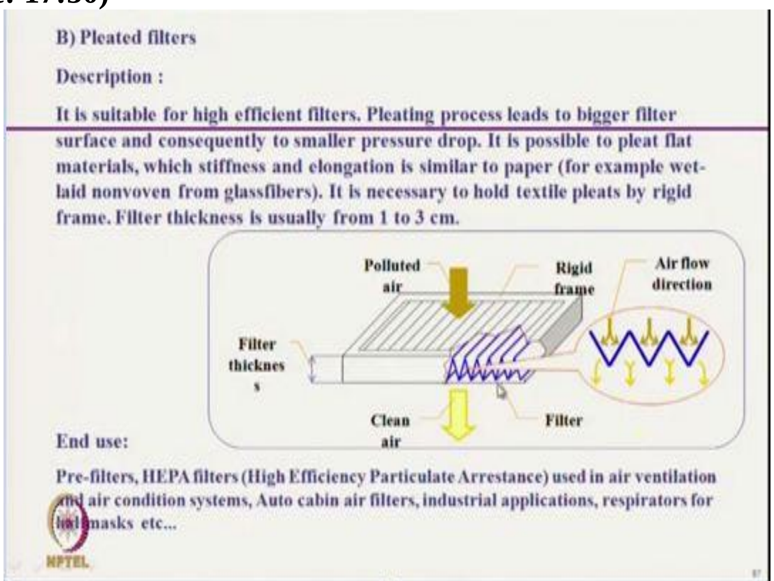

So, here we can see the filters are in the form of pleats, the pleats are incorporated and here the air is flowing with less pressure, pressure requirement is less. So airflow direction. So, this total area is been exposed for airflow we have got here. So, pressure drop is reduced this filter can be used for HEPA filter. So, high efficiency particulate arrestance as the filters and efficiency can be high with the lower pressure drop, we can use the filters with lower pore size. So, these are used in industry or cabin air filter.

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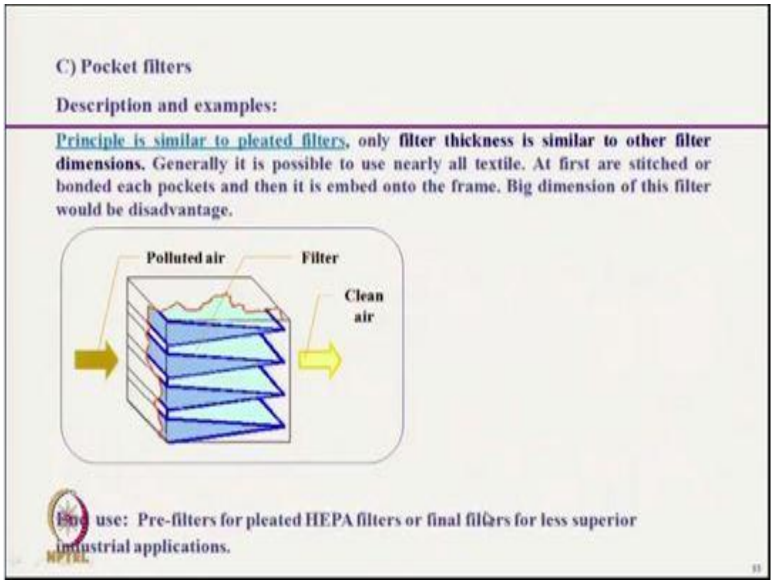

So based on shape, the next filter is that it is called pocket filter. The shape is almost similar to pleated filter, but here this filter is placed in a frame. Here filter thickness is similar to the other filter dimensions, at first the stitch or bonded to each other to form a pocket and then it is embedded to a frame, here frame is required. So main disadvantage here is that here, the dimension is high because we have pleats of very higher depth to form pocket, but main advantage here is that the pressure drop here is much lower than normal pleated filter.

Because all this inner surfaces are used for filtration. So, this we can use for pre filters in HEPA filter or final filters for less superior industrial application. So, this we can use for pre filters here from this site polluted air is entering and clean air is coming out. But, the basic mechanisms are similar to the pleat filter only difference is the dimension.

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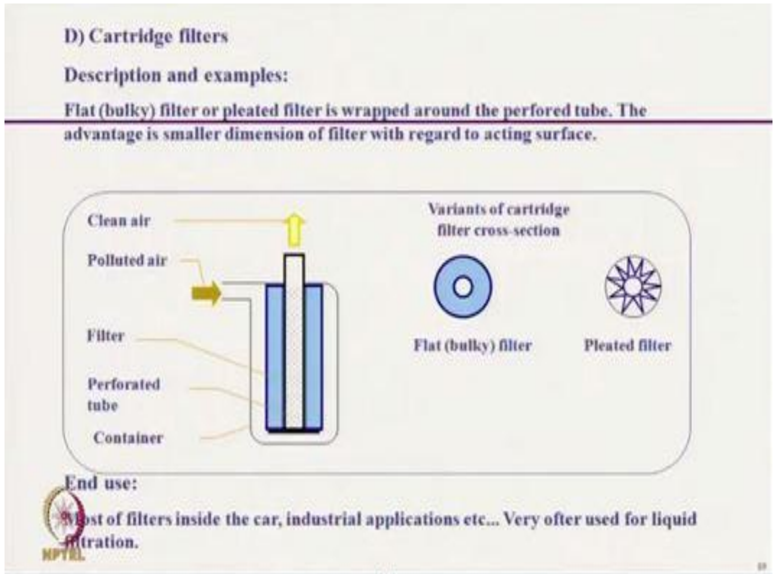

Next is the cartridge filter and which is very popular both for air filtration and liquid filtration and this cartridge filtration main advantage is that the space required, here it is very small. So, lower space requirement is here. These are basically in tubular in size.

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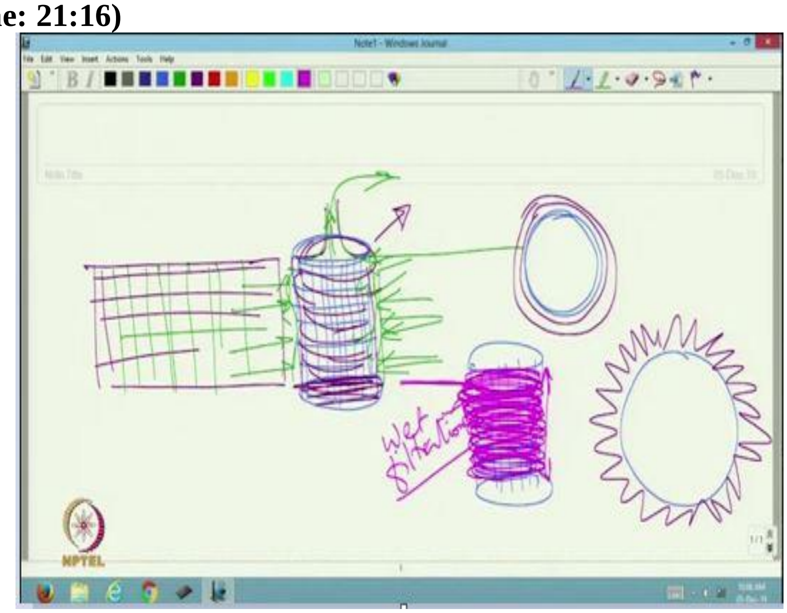

So we need 1 perforated frame for this and in this part this is perforated frame this is only for support. This can be metal mesh or maybe polymeric cylinder hollow cylinder with mesh. Now, on this we can wrap the filter fabric. So, we just wrapped the, this is the filter fabric it could be non-woven, woven, so, this is the filter fabric. So, if we just simply wrap around this and this will be effectively the cartridge filter and one side is blocked and other side is outlet is there.

So, this is the outlet side, now air or liquid penetrates from the surface that is polluted air entering from the surface and after filtration, the clean air is coming out. So, after certain time, we can just clean the surface outer surface to reuse this filter once again. If the filter is totally choked with the particles we can reuse the structure, we can remove the filter fabric and replace it with a newer fresh filter fabric or we can totally replace the cartridge. Another way to use the cartridge filter here what we have done we have used a flat filter medium.

So if we see the cross section, cross section here is a, this is the support and the filter is wrapped to form certain width if we want to enhance the filtration performance by increasing the filters and efficiency and reducing the pressure drop, we may use the pleated filter. So, the filter fabric is wrapped in pleated form, but here the stiffness of filter fabric should be high so we can use spun bonded heat bonded filter fabric here. Another way to use this cottons to wrap course yarn or roving if we wrap around this frame.

So this is the suppose this one is roving or course yarn typically we can use the core sheath type of yarn and if we wrap we must ensure that proper traverse speed so that there should not be any gap, we can have a number have layers and form the cartridge type filter. So, this type of roving based filters are used mainly for wet filtration. So, for liquid filtration we can use this type of filter.

So, flat or bulky filter directly we can use nonwoven fabrics and here the pleated filter and this cartridge filters are used where space requirement is less so that we do not have larger space. So, in those places we can use and at the same time we require higher filters and efficiency. So, inside the car the filters used inside the car or various industrial applications were the space available are less. So, this type of cartridge filters are used and this is very often used for liquid filters that water purifier or different types of liquid filters we use. So, the polluted air is entering through the surface and the clean air is coming out from the axis.

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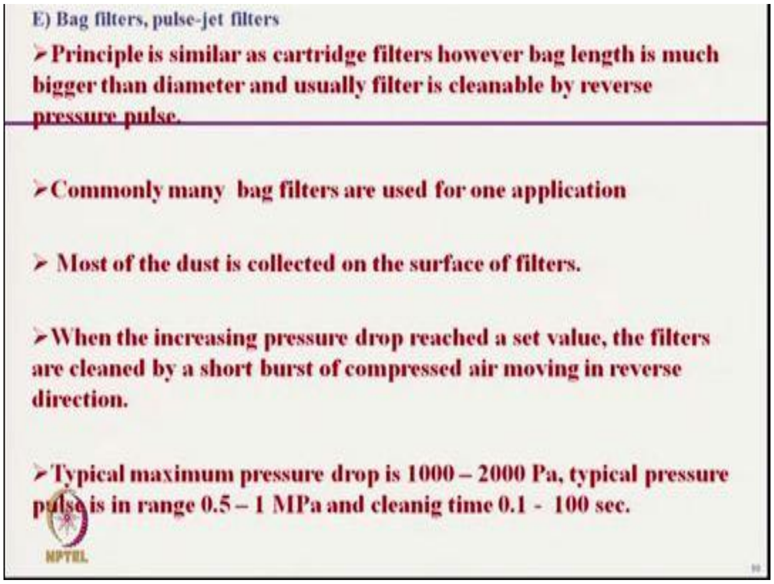

Next is that bag filters. So, the principle wise this is similar to the cartridge filter. So, if you assume that the size of cartridge is very big, then we can conceptualize the bag filter so, let us see the cartridge filter here.

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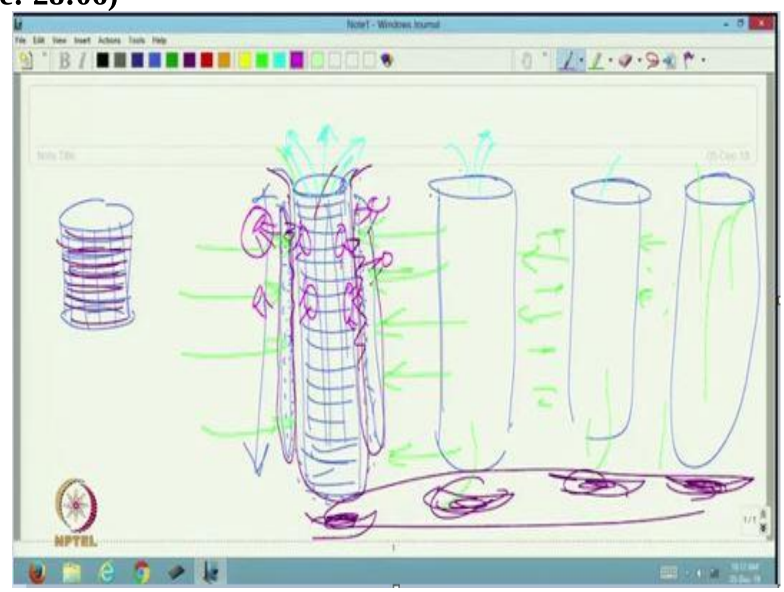

So cartridge filter what we have seen this is the cartridge and we wrap the filter fabric. This is a filter fabric but in case of bag filter we have larger size of frames very large frame. This is a metallic mesh. This is used just for support and the prefabricated bags, filter bags are used these bags are taken here and just placed over this, this is bag filter. This frame is only for support of the bag and frame is required otherwise the filtration process is not possible.

And here again the industrial polluted air enters through the surface and the clean air so this is clean air which comes out from this and it is getting mixed with the environment. So, we cannot throw the polluted air in this in the environment. So, this is these are used for same cement industry or textile industry where dust load is very high. So, these are the dust particles which are retained arrested on the surface.

So, in actual practice, we will see that number of bags are large. So, you know, big cement industry this can go maybe 100 in 100s. So, this type of bags. And this size, if you see actual, this size height, maybe 10 feet maybe 20 feet, this very big size. It is a total filter the bag filtration zone is it is a big hall. So there are 100 of such bags are there and the polluted airs are entering into these bags through the surface and we get the filtration. So, large amount of air is passing through these are clean air. These are the clean air and here it is a polluted air.

Now with the time what happened this surface is loaded with the filter. And gradually the pressure drop is becoming high. So this dust cake needs to be removed, cleaned. So, here we cannot remove these bags frequently because it as it takes time. And it is a loss of the production productivity. So what is done here? High pressure air, it is being injected. It is called pulse jet, very high pressure air is injected for a very small span of time.

So with a few second so, 1 second 2 second which will actually shake this filter media and the dust cakes formed in this on the surface of this filter get released and will be collected at this point. So, there will be dust collectors and this dust collector will actually collect the dust and it will be taken out. So, this is a dust recovery system. So, here like in cement industry we are not wasting this, this is a product basically fine particles this we can reuse these and the quantity is in huge amount.

And after certain time, so, after maybe a few months or certain time depending on the dust load or particle distribution. So, once these filters are clogged the, with the particles, so, we may replace or if in case of it is damaged we can replace this. So, commonly, many bag filters as I mentioned are used for one application there may be 100 s of bag filters. Most of the dust is collected on the surface of the filter when the increasing pressure drop reaches to a set value. So, it will measure the pressure drop.

The filters are cleaned by short burst of compressed air moving in the reverse direction so, typically the shaking we can place the, this blast inside also. So, this will give us the shaking and it will remove the dust particle, this is the diagram as I have shown here.

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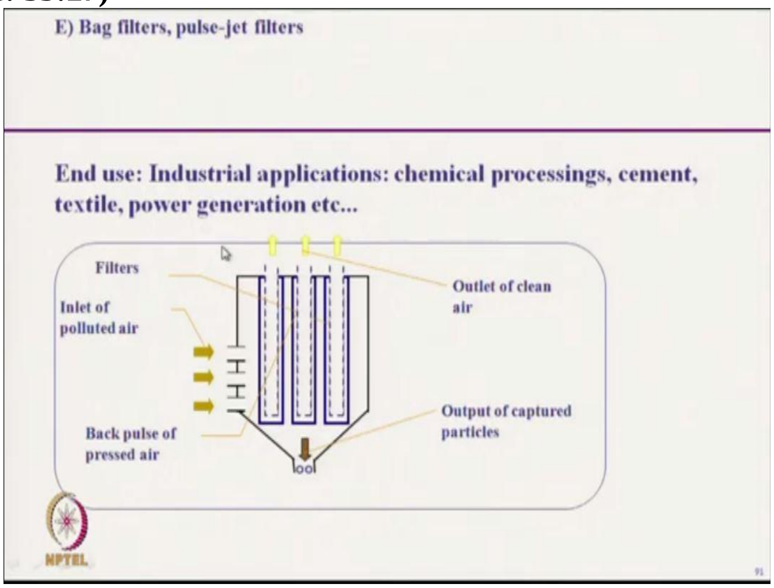

This is a dust collecting system. These are the filters here the dotted line the frames inlet of polluted air and this is a clean air.

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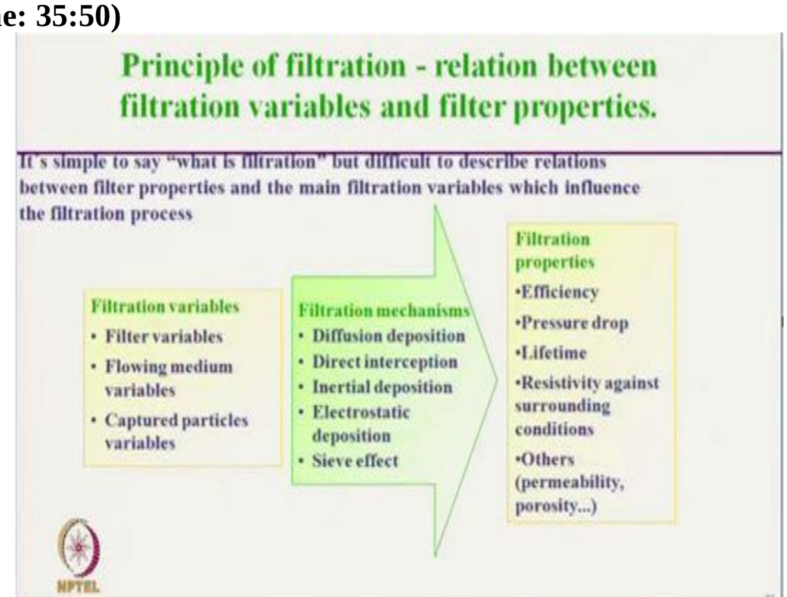

So, after understanding different types of filters based on their shape the relationship between filter variables and filter properties, this understanding it is extremely important for application. So, the filtration variables is that first is filter variable. So, for any filtration we must know what is the type of filter? What is this mass per unit area thickness, what type of fibres are being used, whether it is a head sealed or needle punched, whether it is woven or nonwoven.

So, these are the variables we must keep in mind before selecting the filter flow medium variables. So if we try to select a filter, we must understand we must know for which application, whether you want to use it for very sophisticated application or whether the dust load is high, do you want to use for cement industry or textile industry or maybe high performance that like hospital. So that those information, one should have. Another parameter we must know that is the particle variable. What is the particle dimension?

It is a very fine particle or is it a bacteria or it is a coarse particle. So, this type of information we must know before we go for manufacturing the filter, then filtration mechanism we must understand, we must take into consideration whether it is by diffusion we want to use by diffusion, whether it is a direct impaction, inertial deposition. So, these are the different filters and mechanisms we must take into consideration along with the filter variables, then what are the filtration parameters, properties?

We must take into consideration like whether do we need to have filters in efficiency? or do we want to reduce the pressure drop? Whether we need higher life or we can have at lower life. So, if it is very expensive or changing if its changing is difficult. So, we must consider for higher life, we must understand the resistivity against the surrounding condition. If the temperature is very high or stress is very high, so, accordingly we must select the filter fabric.

So, all these parameters we must understand like for say pre filter, pre filter of any system, we must concentrate on low pressure drop, we do not need high filtration efficiency initially, it must be gradual filtration. So, when air flow rate is very high, so, flowing medium variable like air flow rate is very high. In that case, we should not concentrate on filters and efficiency we must concentrate on pressure drop, but as air flow rate reduces, we must then take into account of the filtration efficiency.

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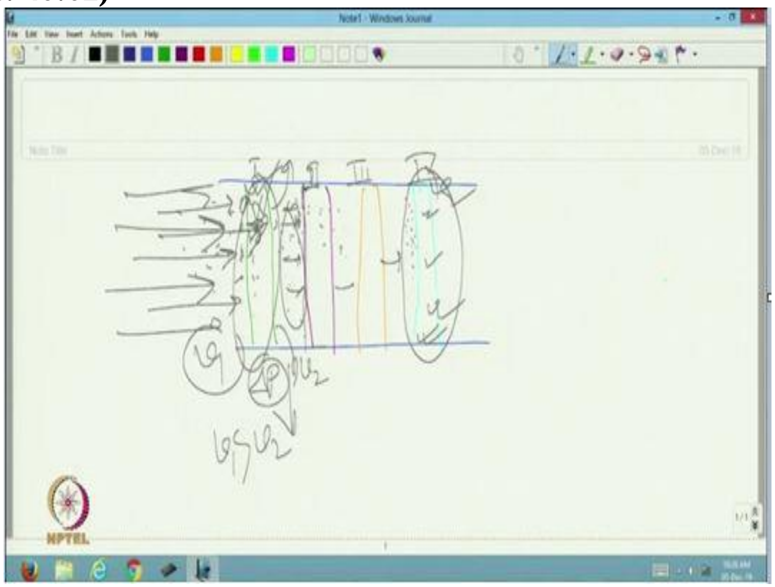

Now, let us try to understand, supposed a filtration system this is a filtration system. It consists of a number of filter layer. This is 1 filter, filter 2, filter 3, filter 4, these are the filter layers, here same air is dusty air is with dust particles, this filter 1 here if we target the maximum filtration efficiency, then total system will collapse. We must allow the air to pass through initially at certain velocity.

Here velocity of air is highest so, in this case, pressure drop should be as low as possible. So we will use a filter medium with low pressure drop with open structure. But when once it is coming, so air outlet is there, once it is coming in this next place, here we will have. So, this will add us to the larger particles. So smaller particle is again coming. So here the air velocity is reduced and smaller particle again much smaller particle will come.

So, gradually the air velocity will keep on reducing, but at this point here the very fine particles are coming out. So, if we try to see the mechanism which we would like to adopt here in first place we can adopt the inertial impaction because the larger particles will go at higher speed and it will get impacted and accordingly this will the filtration will take place, but at end point where very find particles are there and air velocity is very low. So, at this stage we must concentrate on the Brownian diffusion mechanism.

So, this mechanism wise we can select and accordingly we must select the fibre, fabric parameters, here we can also use the electrostatic filter. So, understanding this relationship is extremely important for proper utilization of filters.

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So, there is a parameter which is called MERV Minimum Efficiency Reporting Value as I have mentioned. So, this is one, this is the American system of grading the filter. MERV value source the filters and efficiency. So, dust holding capacity was added in ASHRAE 2007 dust weight arrestance was added.

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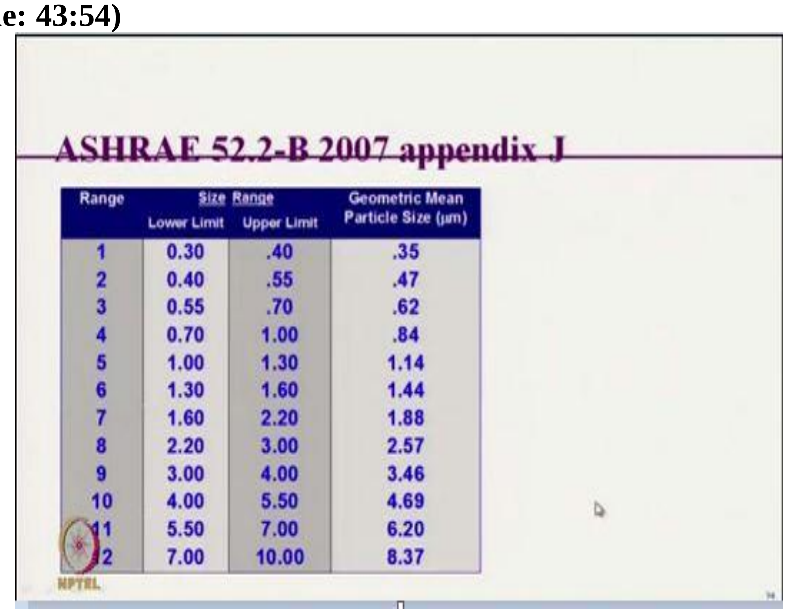

Range	Size Range: Lower Limit	Size Range: Upper Limit	Geometric Mean Particle Size (µm)
1	0.30	.40	.35
2	0.40	.55	.47
3	0.55	.70	.62
4	0.70	1.00	.84
5	1.00	1.30	1.14
6	1.30	1.60	1.44
7	1.60	2.20	1.88
8	2.20	3.00	2.57
9	3.00	4.00	3.46
10	4.00	5.50	4.69
11	5.50	7.00	6.20
12	7.00	10.00	8.37

As per this standard the lower particle size micron 0.35 or 0.5 around 0.5 micron size these are used for respirable size particles, these are the respirable size particles used for basically this fine filters are required and these are the coarser particles for daily common applications. And if we want to remove these particles, we need fine filters, filters with the higher filtration efficiency.

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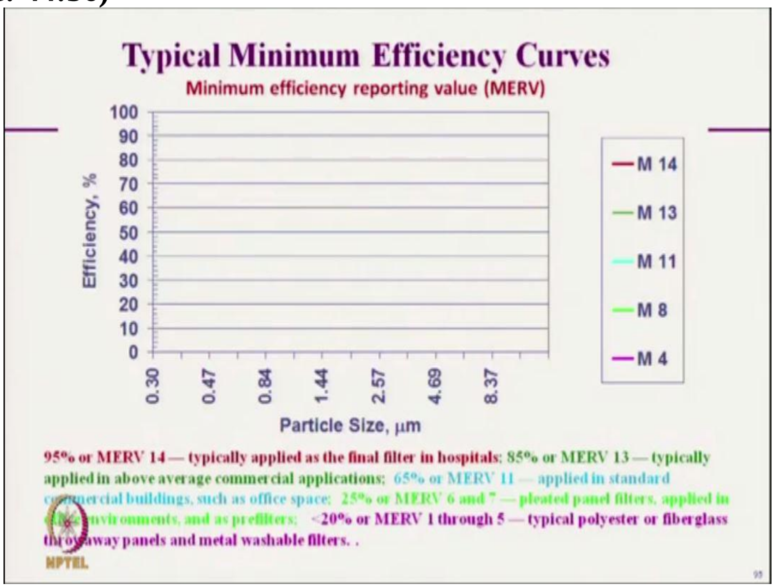

Let us see the filters with different MERV value and where are they used? Like MERV 14 which is very fine filter used for very fine particles. It is around say 0.4 micron to maybe 2, 3 microns is used. Used for filters in hospital application where we have to remove or eliminate the very fine particles, then MERV 13 with lower filters in efficiency the filters with higher pores, MERV 11 So, there are different applications. So, MERV 13 is used for average commercial applications, MERV 11 is applied in commercial buildings, MERV 8 pleated filters. So, these are used for air filters and these are the course filters used for as pre filters.

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Minimum efficiency reporting value (MERV)	Typical Contaminant	Typical Application
13 - 16	0.30 to 1.0 micron. All bacteria, most tobacco smoke, droplet nuclei, cooking oil,	Hospital inpatient care, general surgery, smoking lounges, superior commercial buildings
9 - 12	1.0 to 3.0 microns., lead dust, milled flour, coal dust, auto emissions	Superior residential, better commercial buildings, hospital laboratories
5 - 8	3.0 to 10 microns. Mold, spores, hair spray, cement dust, snuff, powdered milk	Commercial buildings, better residential, industrial workplace, paint booth inlets
1 - 4	Larger than 10.0 microns. Pollen, dust, paint spray, dust, textile fibres, carpet fibres.	Minimum filtration, residential, window air conditioners

So, MERV 13 to 16 means very high filtration efficiency with the particle size ranges 0.3 to 1 micron, all bacteria tobacco smoke. These are coming in this range, used in hospital general surgery. So, 9 to 12 its range between 1 to 3 microns, again used in superior residential buildings, hospitals, in laboratories, 5 to 8 particle ranging between 3 to 10 MERV 1 to 4 very larger very large particles that is 10 micron and more.

So minimum filtration, its residential window air conditioner, they use this type of filter. So, based on MERV value, we can select the filters at different applications. So if we divide the filters based on their filtration characteristics, there are different types of products.

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Products

- Air Filters
  - Heat Ventilation Air Conditioning (HVAC) Filter
  - High Efficiency Particulate Air (HEPA) Filter
  - Ultra Low Penetration Air (ULPA) Filter
  - Air purifying respirators
  - Bag Filter
  - ...
- Liquid Filters
  - Filter paper
  - Cartridge Filter
  - Bag Filter

HVAC filters, which is Heat Ventilation, Air Conditioning filter, HVAC filters, HEPA filter, High Efficiency Particulate Air filter, ULPA filter, Ultra Low Penetration filter, air purifying respirator, bag filters, there are different types of products available for air filters. And for liquid filters the filter paper, cartridge filter, bag filters are also used.

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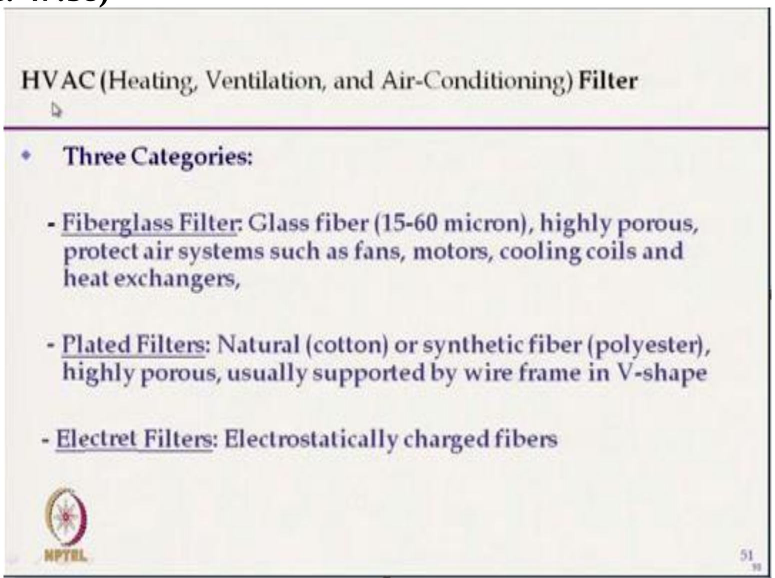

HVAC filters, are subdivided into 3 categories fiberglass filters basically the glass fibres are used with 15 to 60 micron diameter. These filters are basically used for pre filters with high porosity, protect air systems such as fans, motors, cooling coils, heat exchangers, fiberglass filters and pleat filters where natural and synthetic fibres are used and electret filters, electrically charged fibres are used here. So, HVAC filters are mainly used for course filters.

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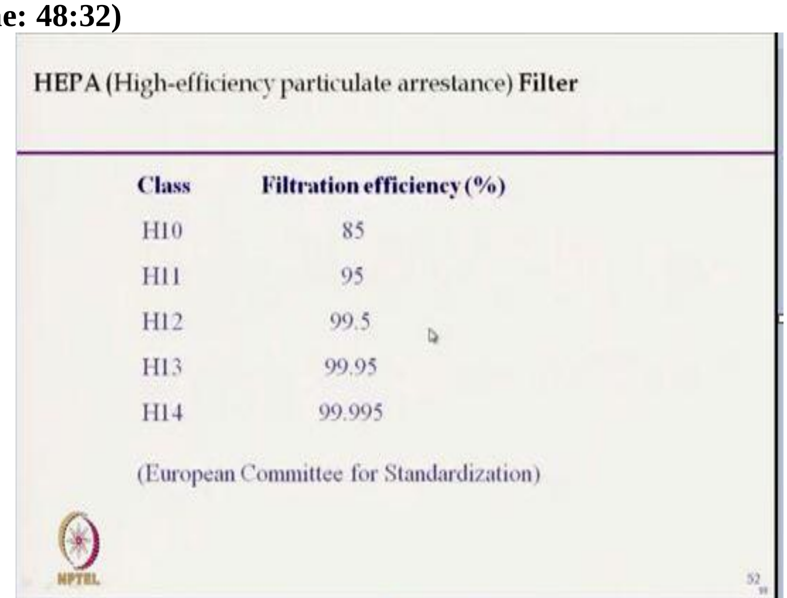

Next category is that HEPA filter, in HEPA filter. As far as European standard, these are classified into 5 categories starting from H 10, 11, 12, 13, 14 and this classification is based on the filtration efficiency. H 10 the filters and efficiency is 85 it goes up to 99.995 percent. HEPA filter is widely used for air filtration in general applications.

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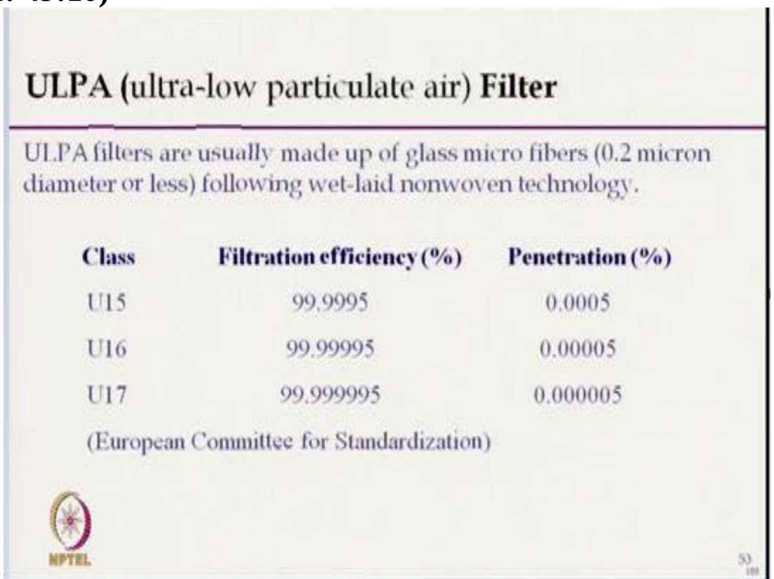

Third is ultra-low particulate air filter, where this series is starting from U 15 U stands for ULPA ultra-low particulate air in HEPA filters its ranges with H. So, U 15, 16, 17, their filtration efficiency are more than the HEPA filters. They are used for fine filtration. Here microfiber are used glass microfiber 0.2 micron fibers are used and mainly wet-laid nonwoven technologies are used to manufacture ULPA filter.

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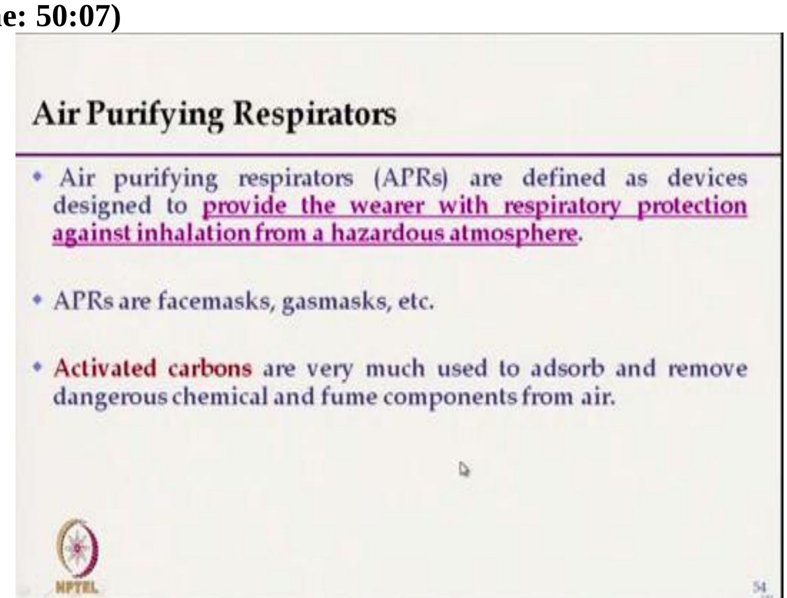

Next filtration is that air purifying respirator, this filters are defined as device designed to provide the wearer with respiratory protection against inhalation from hazardous atmosphere. So this is used for respiratory protection. The examples of APRs are facemask, gasmask. Activated carbons are used to adsorb and remove dangerous chemicals in addition to the particle filter or fumes in the air.

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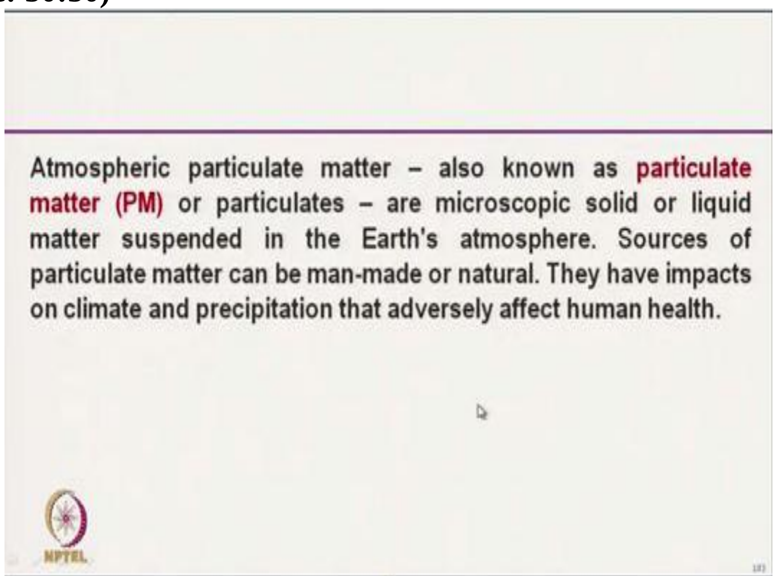

So, if we want to use the filter or APR, air purifying respirator, we must understand the particulate matter in the atmosphere. So, atmospheric particulate matter which is also known as particulate matter, these are microscopic solid or liquid metals suspended in the atmosphere, they are sources are different, maybe natural source or manmade source, but this particular methods are actually harmful for our health. And we must arrest this particular matter from entering into our body.

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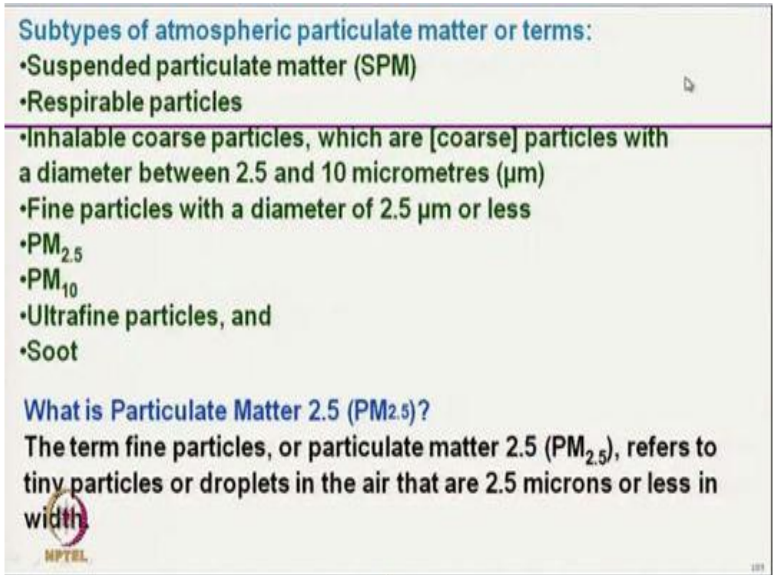

So, the different subtypes of atmospheric particulate matters are suspended particulate matter SPM respirable particles which are very small in size, inhalable coarse particle with a diameter of 2.5 to 10 microns. Fine particles with diameter 2.5 micron or low. So, we can express in terms of PM 2.5 that is the amount of quantity of particles present in the atmosphere with size 2.5 micron or place, PM 10 means particle particulate matter with size 10 micron or less, ultrafine particles suit there are different types of particles. So, what is particulate matter 2.5?

In short, it is called PM 2.5. The term fine particles or particulate matter 2.5 refers to tiny particles or droplets in the air that are 2.5 micron or less in width, that means if we try to express the fine particle we normally express PM 2.5 or if we try to express in terms of coarser particles, we normally express PM 10.

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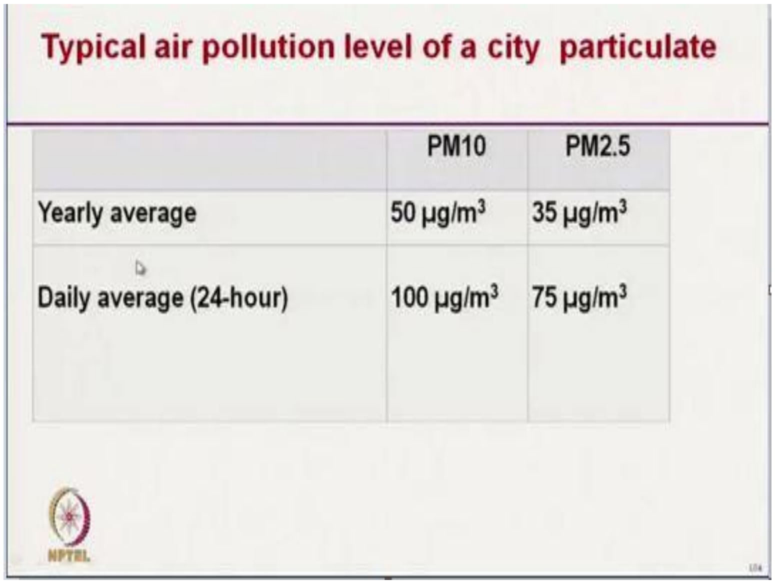

Now, this is the typical yearly average here. So, the early average 50 micron per cubic meter it is expressed in 50 microgram per cubic meter. So, PM 10 it is level 50 means, the particles of size 10 micron or less, if we take the total mass of particle in 1 cubic meter volume of air, it will be around 50 microgram. That is called 50 microgram per cubic meter. So, PM 2.5 will definitely be less than PM 10 value because here it is a presence here is the 2.5 micron or less. From here we can see in the air, the majority of the particles are of size 2.5 micron or less. So that is obvious because larger particles normally get settled due to their mass.

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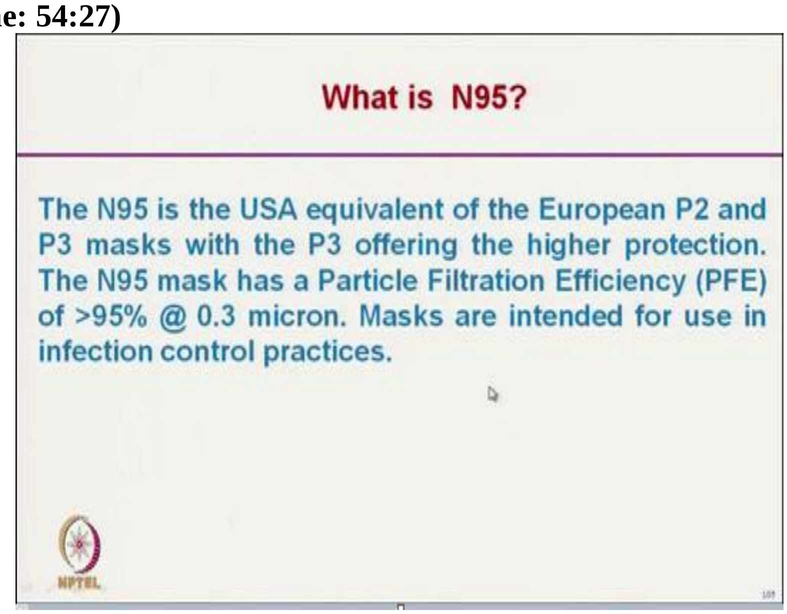

What is N 95? N 95, it is used in US. So, US standard N 95 mask, which is equivalent to European P2 and P3 masks with P3 offering higher protection. The N 95 means it is a particle filtration efficiency more than 95% with the particle size of 0.3 micron. So that is the standard mask which we use for infection control. So P 95 mask is used. Now we will end the session of air filtration. Thank you.