Testing of Functional & Technical Textiles
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Lecture – 05
Testing of Transmission Characteristics of Textile Fabrics (contd…)

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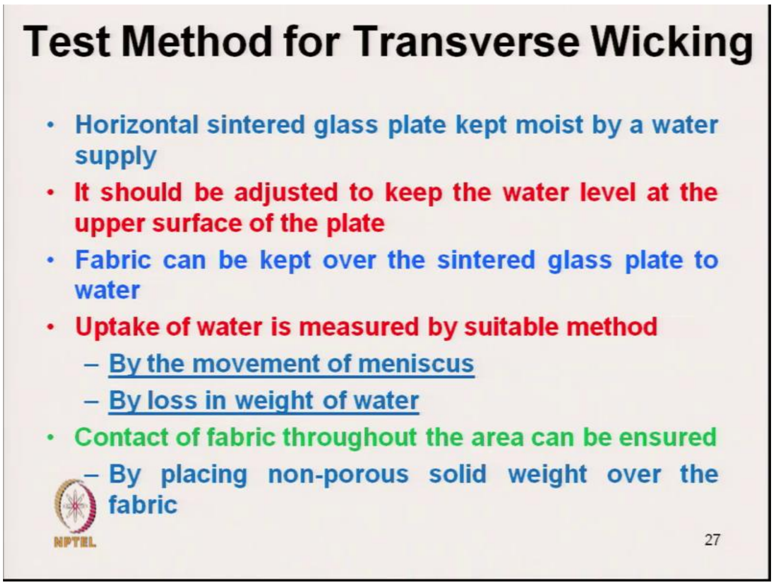

Hello everyone, we will continue with the test method for transverse wicking, it is a horizontal sintered glass plate which is kept moist by water supply. It should be adjusted to keep the water level at the upper surface of the plate. So, always the water levels should be at the upper surface as we have discussed in last class, because then that the fabric will get constant supply of water. Fabric can be kept over the sintered plate for actually getting constant supply of water. Uptake of water is measured by suitable method that is by movement of meniscus or by loss of weight of water. The contact of fabric which is very important throughout the area has to be ensured and that can be ensured by placing non-porous solid weight over the fabric.

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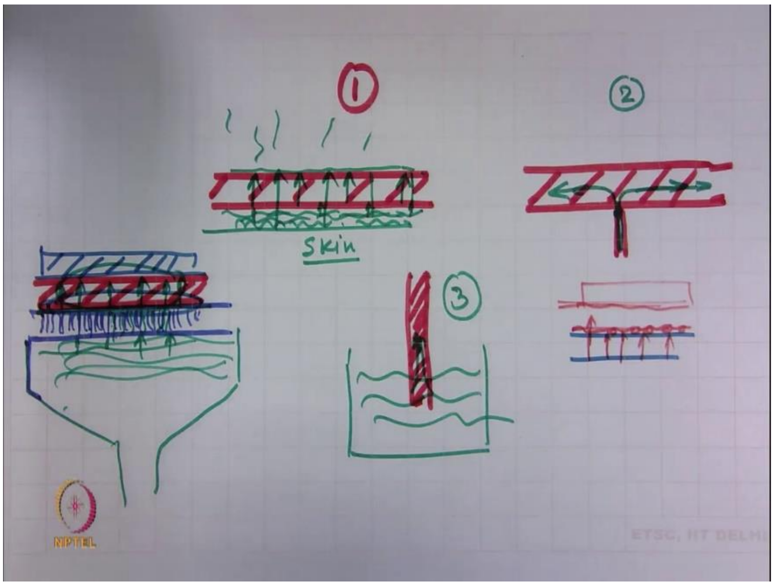

Like we can see in earlier picture, this is the picture here. And if the fabric is kept on the sintered plate, suppose this is the sintered plate, and if the fabric is kept, there will be definitely some open area which is not in contact with the sintered plate. If in this non-contact zone the liquid transmission will not take place, the liquid will only get transmitted through the contact point. That means, to ensure perfect contact, we must use some load, some plate we can use here which is non-porous plate if we use here which will apply certain load which will make sure that this bottom surface of the fabric is actually constantly in touch with the sintered plate. So, by placing the non-porous solid weight over the fabric, you are ensuring that contact of the fabric throughout the area of the sintered plate.

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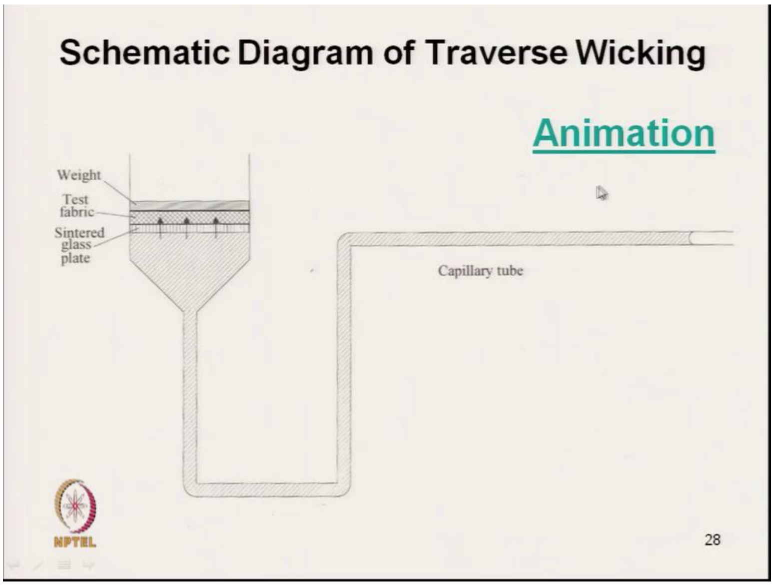

So, this is the schematic diagram as I have explained early, this schematic diagram and the process we can see through the animation here.

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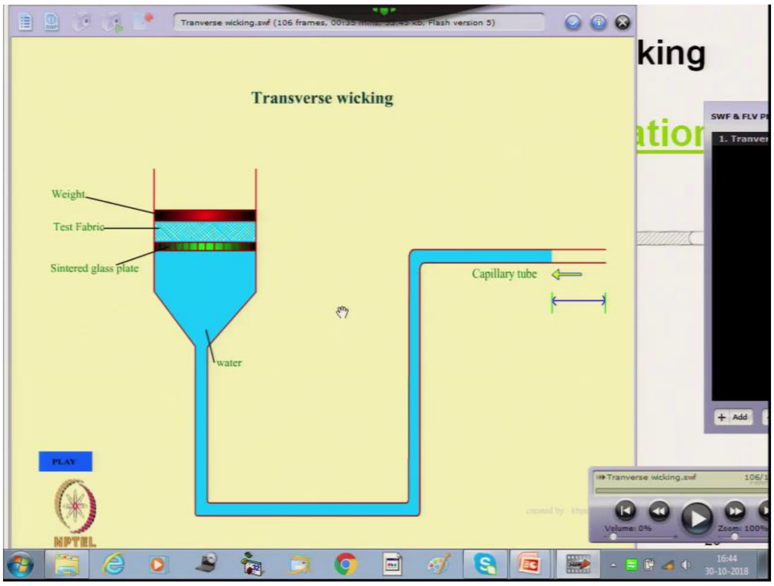

Here this blue colour which shows the water ok. And this is the capillary tube. And here this green colour - this plate, it is a sintered glass plate with pores. If we start, so after that this the fabric will be placed on the sintered plate. So, the fabric is placed onto the sintered glass plate and then we are plating we are placing another plate just to ensure the proper contact. After that placing, so the water will be wicked through the cross section of the fabric across the plane, and the movement of this meniscus shows the quantity of the liquid transmitted per say unit time. So, this distance we can measure. So, this will show the amount of water. And this movement per unit time can also be plotted. So, if we can record this movement per unit time so from there we can calculate the wicking rate.

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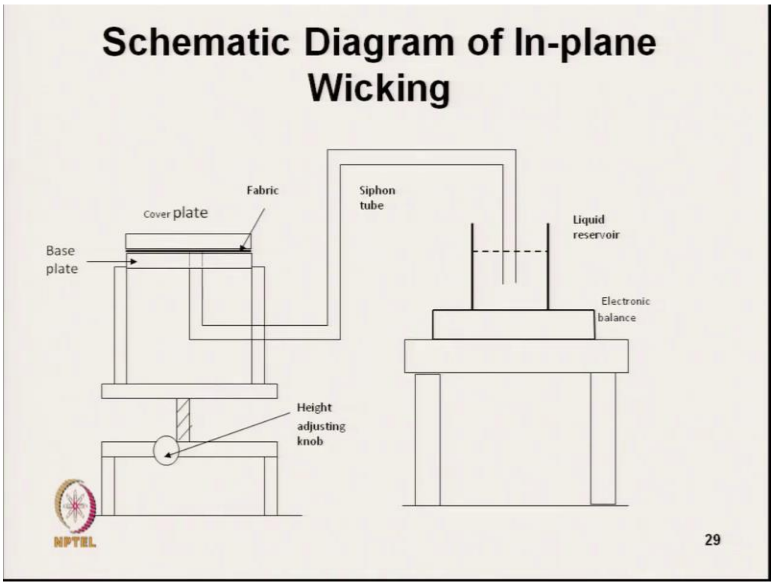

So, after this cross plane wicking the trans planar wicking, now we will discuss the method of in plane wicking measurement. So, the in plane wicking measuring system, here the plate cover plate is there. And this is the fabric surface fabric sample which is shown in black colour now.

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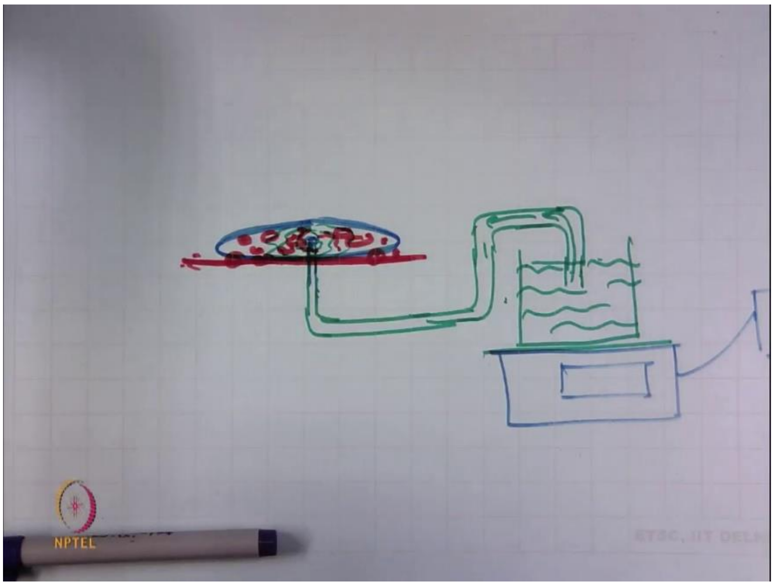

In this system, suppose this is the fabrics specimen at the center, we have certain hole. And the water is supplied through the centre of this. At the centre the water is supplied here, and this is actually it is a flexible tube, this is a system ok.

Now, here as the water is supplied at the centre due to the wicking, the water will get transmitted gradually, and through this Siphon system it will start taking up the water. So, water level will reduce, so it will take the mass of water. So, this change in the mass of water is recorded using one balance. This is a balance which is connected with the computer. So, from there, the amount of liquid wicked is recorded ok.

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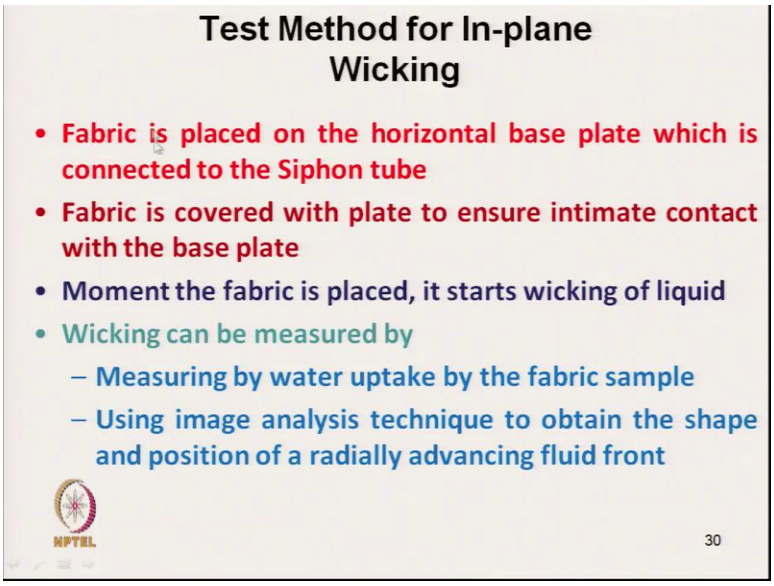

And the fabric is placed on the horizontal base plate which is connected to the Siphon tube as I have shown that is Siphon tube is there. Fabric is covered with plate to ensure intimate contact with the base plate. Moment the fabric is placed, it starts wicking of liquid. The wicking can be measured by measuring water uptake by the fabric sample, or using image analysis technique to obtain the shape and position of the radially advancing fluid front.

Now, image processing technique we can use, but it has got its limitation. For very thick fabric, when liquid is not reaching to the upper surface, in that case liquid will get transmitted through the thickness of the fabric, and image from image processing will not be actually useful. Image processing is only useful for thin fabric, thin fabric and also for say white colour fabric. If we use the coloured liquid that will give us the better measurement.

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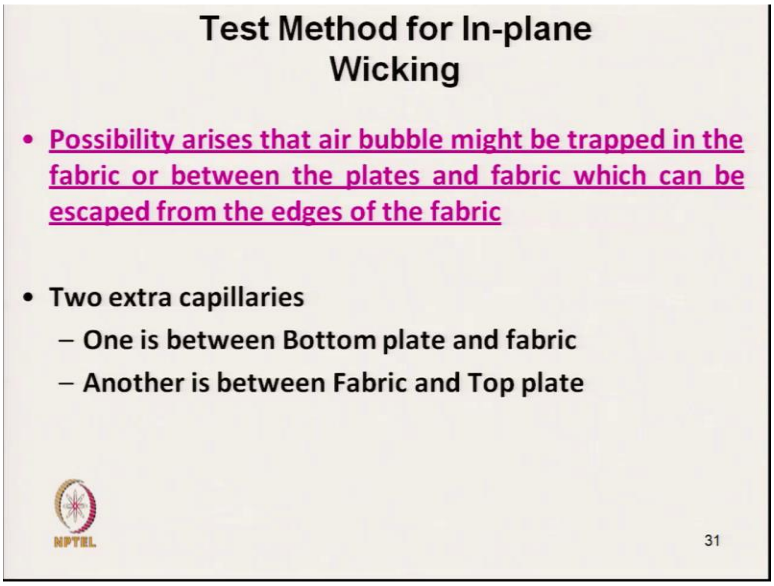

Possibility arises that air bubble might be trapped in the fabric or between the plate and the fabric which can be escaped from the edge of the fabric. Now, the problem is that here suppose this is the plate on which the fabric is being placed. And air bubble can be there between fabric and the plate, and also air bubble is present within the fabric also. So, during the transmission, it will affect the result.

So, two extra capillaries are also created in addition to the capillary within the fabric structure. So, if it is the plate and we are placing the fabric, so there will be capillary between the bottom plate and the fabric. And also once we are placing the another plate top plate, so there will be another capillary between the fabric and the top plate, so that will actually some time give the wrong result. So, these two capillaries one between the bottom plate and the fabric, another is between fabric and the top plate.

So, this total liquid transmission in plane is in addition to the fabric through the fabric plus this two capillaries. So, actual transmission of liquid through the fabric will get affected. So, this is the schematic diagram of the in plane wicking arrangement, and the mass absorbed mass wicked by this fabric is measured using the electronic balance.

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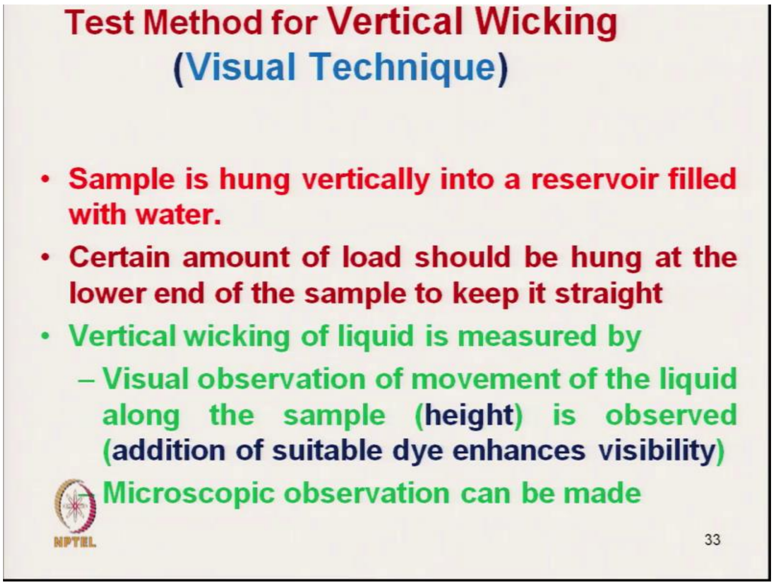

Next is that vertical wicking measurement. And visual technique is the technique which is very commonly used. A sample is hung vertically in to a reservoir filled with water. Certain amount of load should be hung at the lower end of the sample to keep it straight. Why do you need to keep it straight? Because if the fabric is not straight, so if there is a wrinkle, that means, if the suppose this fabric is not straight, suppose, suppose it is a wrinkled form, and if we are placing this fabric end in the reservoir, in that case it will follow a longer path, so that will give us the wrong result. So, we have to keep the fabric sample straight.

Vertical wicking of liquid is measured by one is the visual technique by visual observation of movement of liquid along the sample that is the height we can measure, which is observed addition of suitable dye enhances the visibility. That means, if we use normal water, that means, visibility some time is not perfect, because we have to measure the liquid height, manually or if you want to measure through the camera, there also we need to use some dye, so that it enhance the visibility. Microscopic observation can be made so using microscope. So, we can actually measure, the height which is actually the height actually taken by the liquid.

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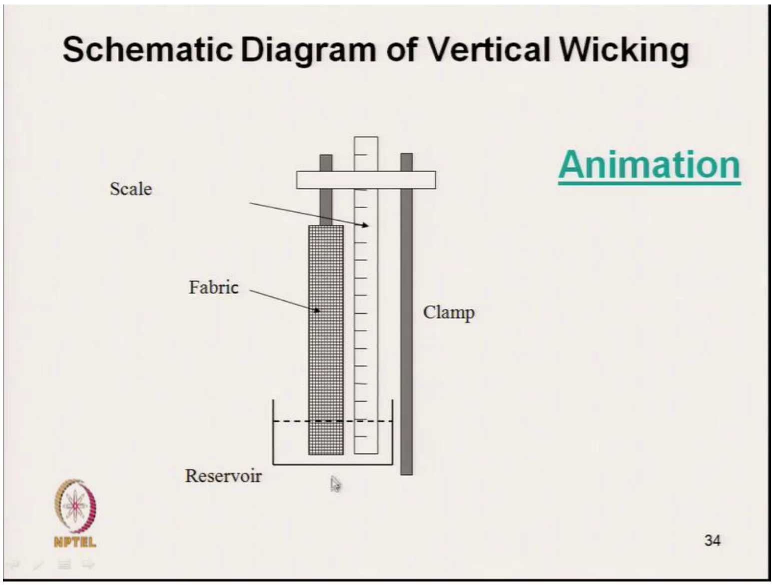

Now, this is the test system. This is fabric and reservoir is there and scale.

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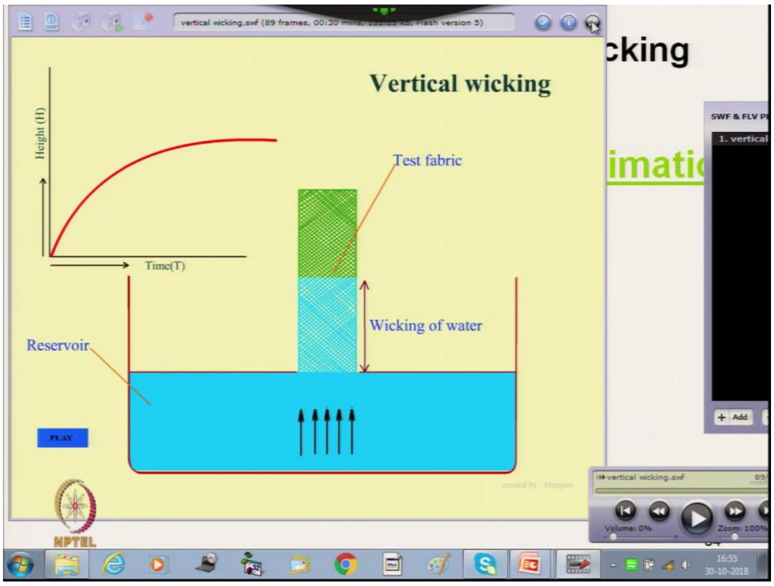

Now, if we see the animation here, this is reservoir here. And fabric is placed this is the test fabric. We are putting the fabric on the on the reservoir. And as soon as the bottom portion is in touch with the reservoir, water is wicked at certain height. And with the time we can plot the wicking height versus time. So, this we can plot manually. And there are other techniques where we can use the electronic method of measurement the wicking height with the time. So, this is manual method of measurement liquid of transmission that is vertical wicking.

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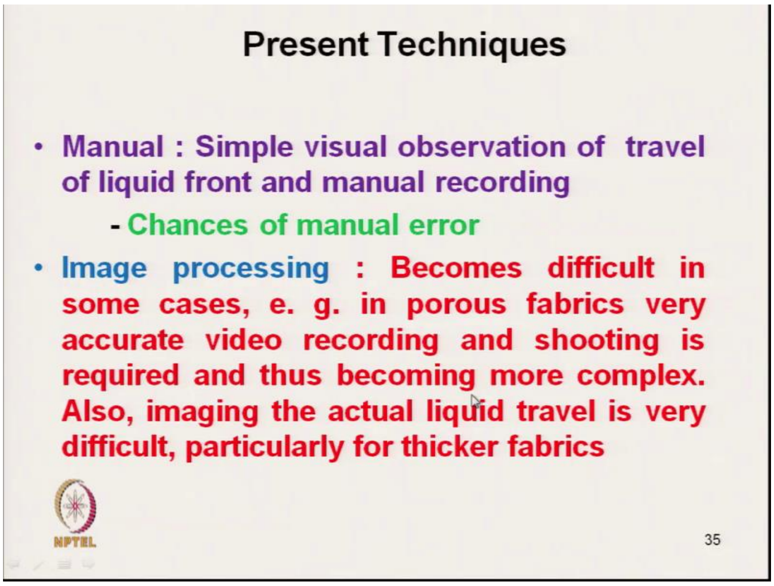

So, the present techniques are manual, it is a simple visual observation of travel of liquid front and manual recording. So, we can manually record, and which is there is a chance of manual error. Another technique which is image processing technique and which becomes difficult in some case, as per example in porous fabrics very accurate video recording and shooting is required and thus becomes more complex. Also, imaging the actual liquid travel is very difficult, particularly for thicker fabrics. As I have mentioned for thicker fabric, the liquid flows through the center through the actual thickness; and in image processing the liquid has to be in the surface. So, for thin fabric image processing is useful. But for thick fabric we have to see some alternate method of measurement.

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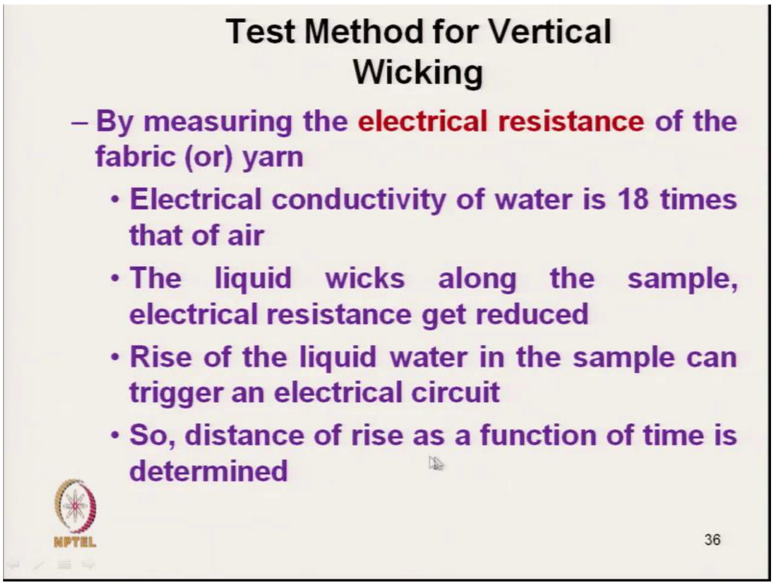

So, the alternate method is that by measuring the electrical resistance of fabric or yarn. So, we can measure the vertical wicking by measuring the electrical resistance. The electrical conductivity of water is approximately 18 to 20 % to that of air. So, typically it is 18 times to that of air which means if the air inside the yarn and fabric, if it is actually replaced by water during wicking, the conductivity of the material will increase.

So, by measuring the electrical conductivity or electrical resistance, we can record the electrical that is the wicking characteristics, the wicking height we can record which will be very accurate, we do not have to depend on the manual technique we do not have to depend on the image processing technique. The liquid wicks along with the sample, electrical resistance get reduced, so that I have already explained. Rise of liquid water in the sample can be triggered and which will be actually it will trigger an electric circuit ok.

So, the distance of rise as a function of time is determined. So, when the liquid is actually rising, it will trigger an electrical circuit and that we can actually plot with the time. Now, we will discuss few instruments which is based on resistance and capacitance principles. So, there are couple of instruments.

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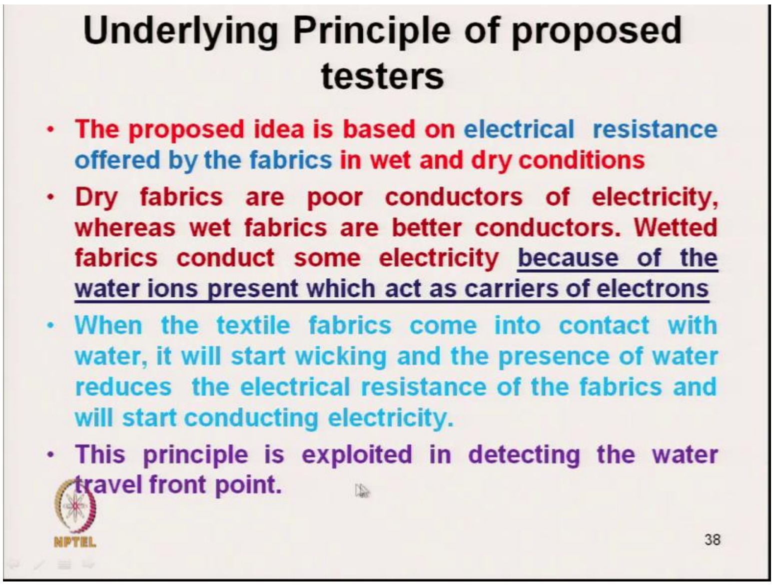

So, first instrument the underlying principle of the proposed instrument is that the proposed idea is based on electrical resistance offered by the fabric in wet and dry conditions. Dry fabrics are poor conductor of electricity, whereas the wet fabrics are better conductors. Wetted fabrics conduct some electricity because of the water ions present which act as carriers of electrons. So, in wet fabric, the water ions are there which actually carriers by electron that is why the conductivity is much more than the dry fabric. And by measuring this conductivity, if we can actually measure the conductivity, we can measure the presence of water.

When the textile fabrics come into contact with water, it will start wicking and the presence of water reduces the electrical resistance of the fabric, and will start conducting the electric current. So, this the electricity, we can actually measure the distance travelled by the water through the fabric by measuring the conductivity of the electricity. This principle is exploited in detecting the water travel front of the fabric.

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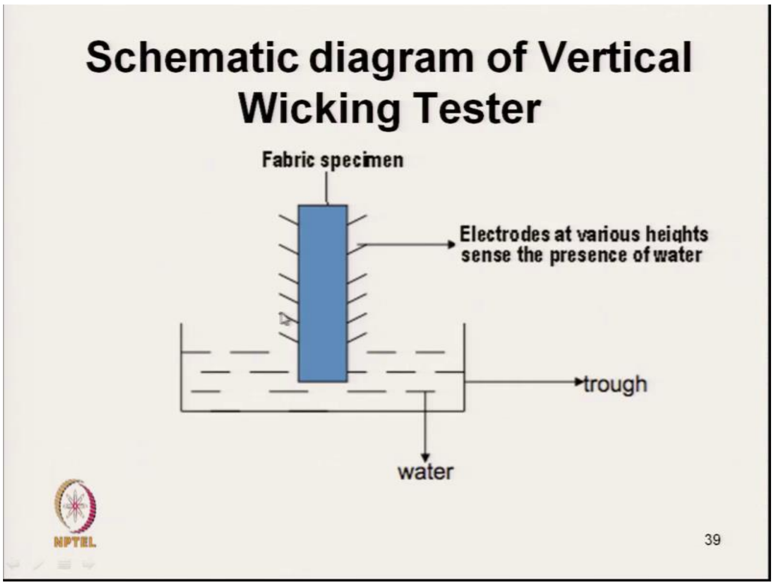

The schematic diagram which is shown here; in this diagram, this is the fabric specimen which is shown with the blue colour. And the fabric is actually placed in a frame, and the frame is actually connected with the series of electrodes. The electrodes are placed at different predetermined height. Now, this, there are two electrodes at each height. Now, as soon as the fabric specimen is placed on the trough the water will start wicking. And the initially there was no current flowing, because the presence of dry fabric the circuit is not completed as soon as the water is wicked.

Suppose, the lowest electrode it reaches as at this height, this circuit will be actually complete. The circuit will complete, and this will start flowing the current. The current will start flowing and one LED will be there, LED lamp will be there that will glow. So, similarly, we have different LED lamps, depending on the fact which LED is glowing, we can sense the height of the liquid traveled. And here the assumption is that the fabric is wicked, that liquid is wicked in horizontal fashion. The problem is that if the liquid is wicked in non-uniform fashion, then it may give some wrong result. So, for that it is suggested the width of the fabric should be as low as possible, so that the waterfront remains almost horizontal.

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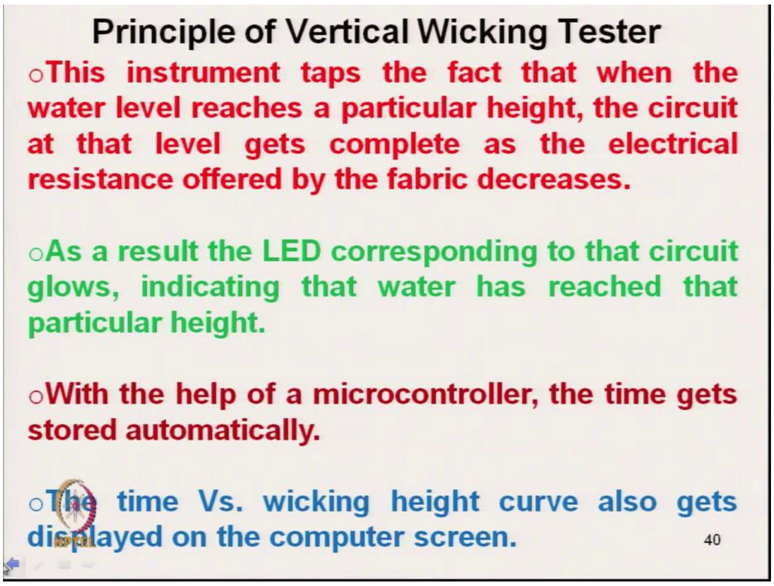

This instrument taps the fact that when the water level reaches the particular height as I have already mentioned, the circuit at that level gets complete as the electrical resistance offered by the fabric decreases. Immediately the electrical resistance will decrease and circuit will be completed. As a result the LED corresponding to that circuit will glow, indicating that water has reached that particular height. With the help of microcontroller, the time gets recorded automatically. So, this time versus height, so time is automatically recorded, and the height is known using the LED glowing.

So, we can plot the time versus the vertical wicking height. The time versus wicking height curve also gets displayed on the computer screen automatically. So, this instrument gives perfectly correct result. And what we have done we have done, experiment where we have tested fabric manually and also using the instrument. And we have plotted and we found there is insignificant difference. So, this actually both the curves are following the same path.

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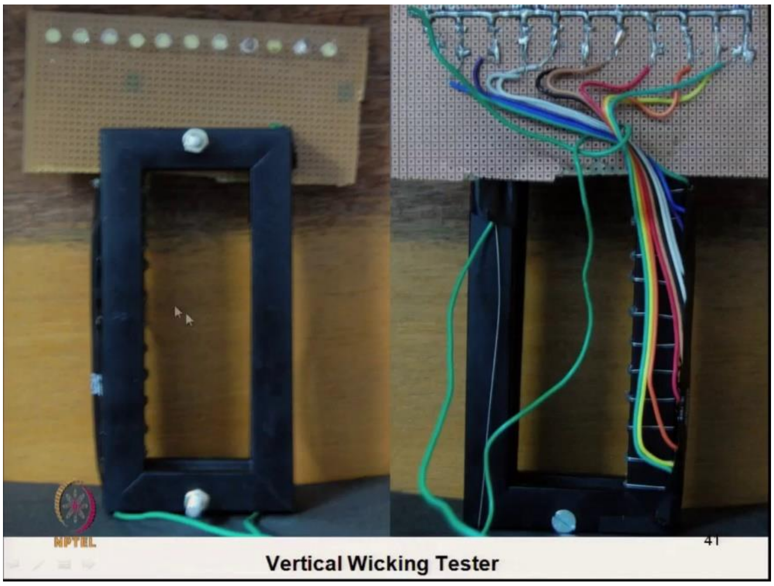

So, this is the actual setup. It is a holder fabric holder, and this is the circuit, and here these are the LED lamp.

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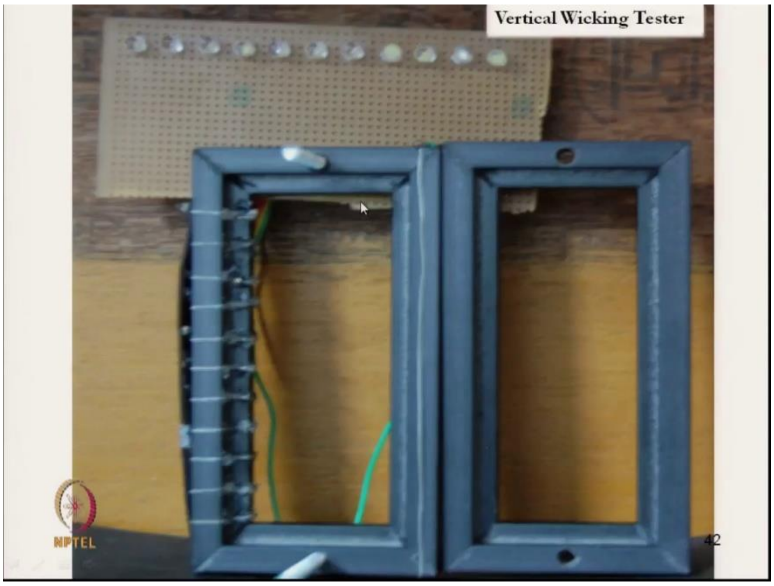

From other side.

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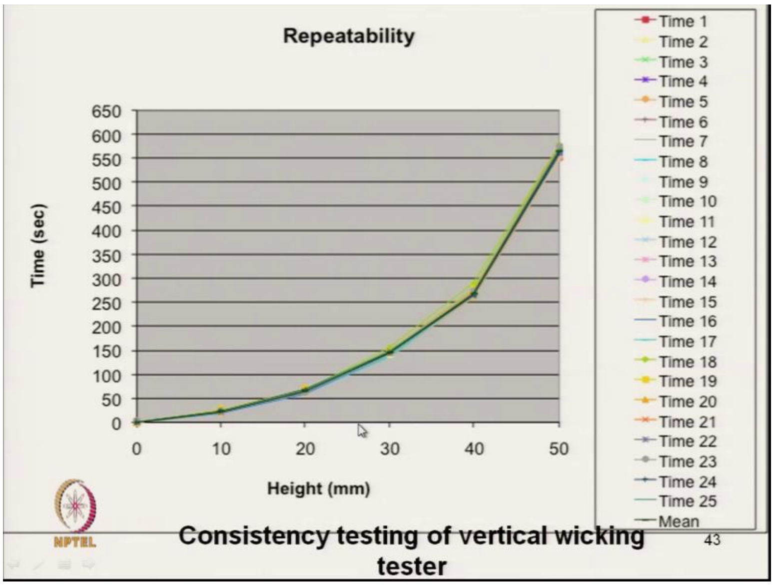

Now, here what we have tested the consistency of vertical wicking tester. And we have tested a particular fabric. And this fabric is tested 25 times, there are different time that fabric is tested. And what we have achieved we have achieved the exactly same reading. So, these curves are simply over lapping, which shows the repeatability of this tester say consistency of the testing of vertically wicking tester.

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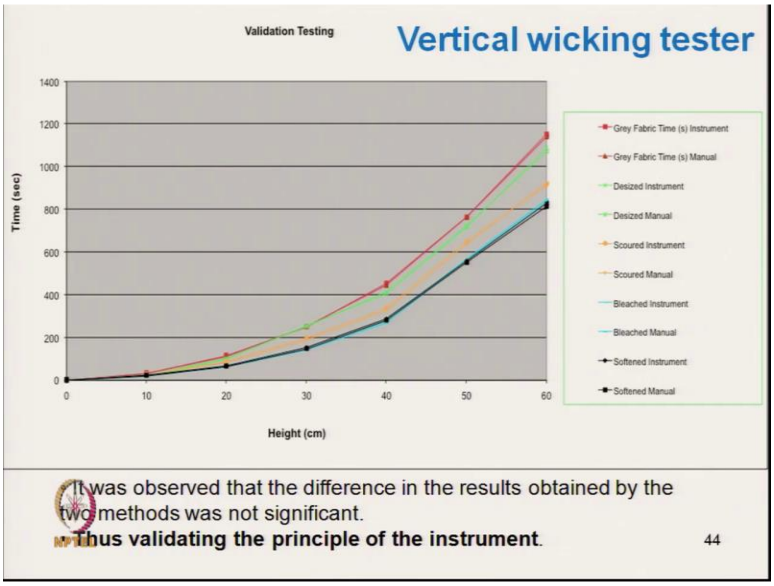

In another experiment what we have tested, we have tested different fabrics different fabrics, but we have tested in two methods one is using this instrument developed instrument, in another case we have used manual technique. And in most of the cases we found that both manual and this instrument, they give the exactly same reading. It was observed that the difference in the results obtained by two methods was not significant, they are not significant, thus validity of the principle of the instrument is proved. So, this instrument which gives perfectly same result so using the electrical resistance technique which is actually you are getting the same result as when we are testing the manual technique. So, we can see that this instrument can replace the tedious manual technique.

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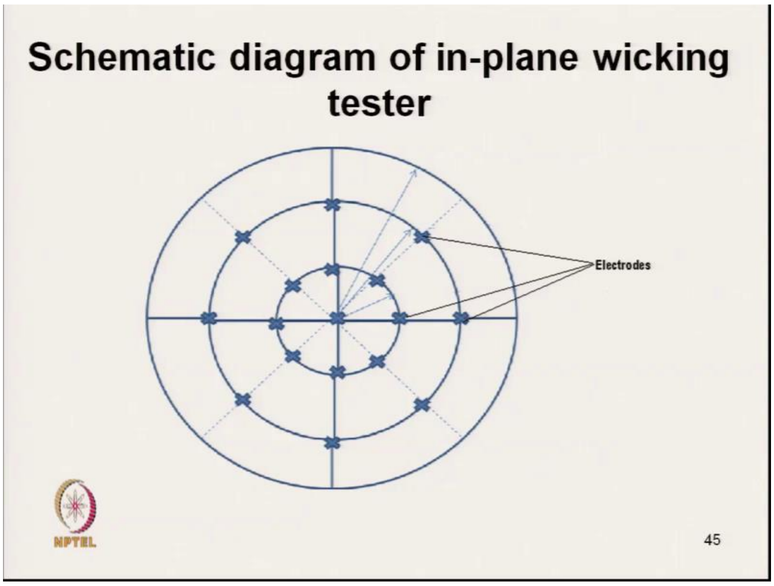

Next is that inplane wicking tester. So, using the same technique, here what we have used, we have used different electrodes placed in circular ring form. Now, at the centre, we have main electrode and other electrodes at different direction 1, 2, 3, 4, 5, 6, 7, 8, at 8 directions at least we can measure the flow direction. And at different distance from the centre, we have placed electrodes. Now, once this frame is ready, we can place the fabric on this frame, and water is being supplied at the centre. And depending on the movement of the water front, the circuit will get completed.

Suppose, the water is moving in vertical direction in north direction. So, then first this circuit will be completed, and the LED related to this point will glow which will show the direction of movement. But the limitation of the system is that this is the discrete system, and where we have to ensure that fabric is actually constantly in touch with this frame. And also this frame sometime interferes the free movement of liquid through the fabric.

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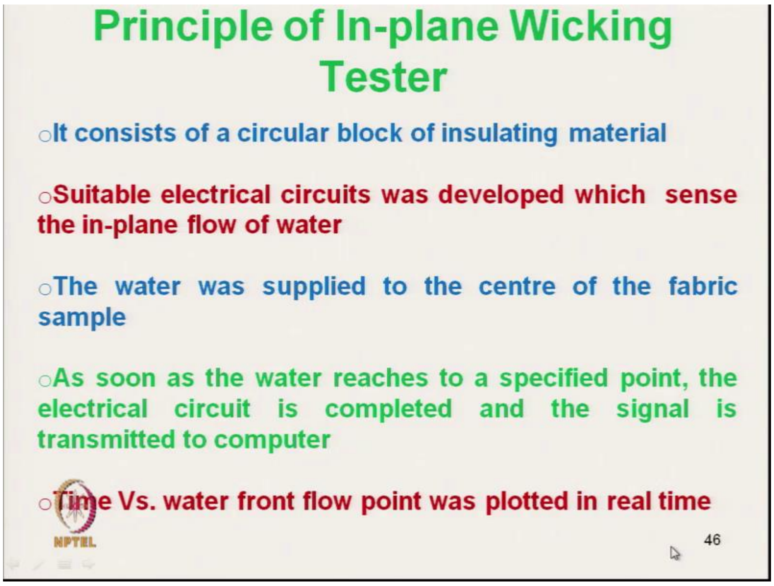

So, it consists of a circular block of insulating material. Suitable electrical circuits was developed which sense the in-plane flow of water. The water was supplied to the centre of the fabric sample. As soon as the water reaches to a specified point, the electrical circuit is completed and the signal is transmitted to the computer. So, accordingly we can actually come to know that which point what is the direction of the flow of liquid front. So, time versus water front flow point was plotted in real time.

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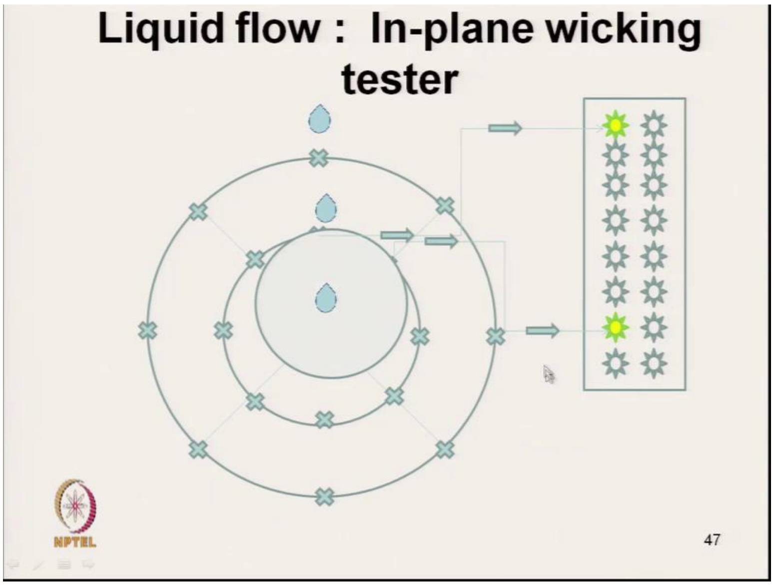

So, in this picture, the liquid is transmitted asymmetrically. So, here if you see this top one and this one, there circuit is completed; but in others other 1, 2, 3, 4, 5, 6 electrode, the circuit is not completed. So, these two are glowing so which is showing the direction. And these electrodes are in the first level and in second level we have other electrodes. So, in this instrument what we have done, we have used totally two levels. So, we can keep on increasing the levels, and also you can keep on increasing the number of electrodes in different direction. So, this is the basic principle we wanted to prove. And we found we can use this technique for measurement of in-plane wicking of liquid.

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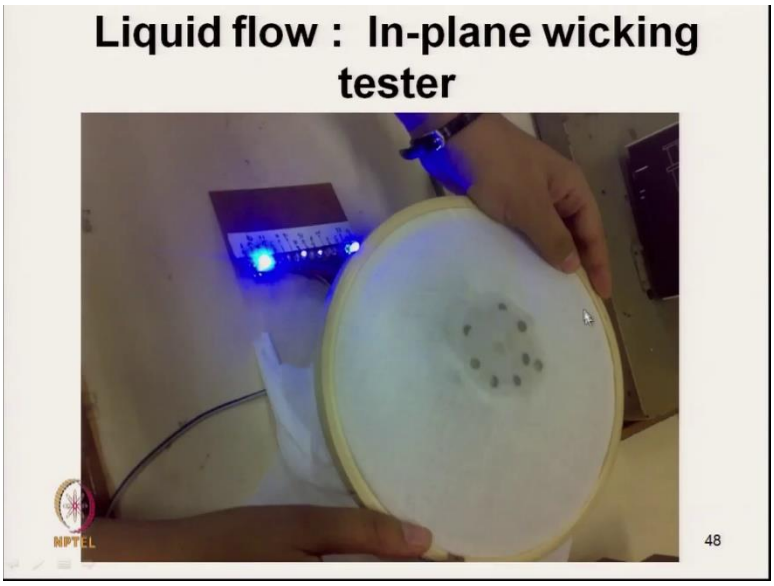

And here this picture demonstrate how the liquid is flowing, and the LED is glowing. So, we can develop the instrument commercial using this principle.

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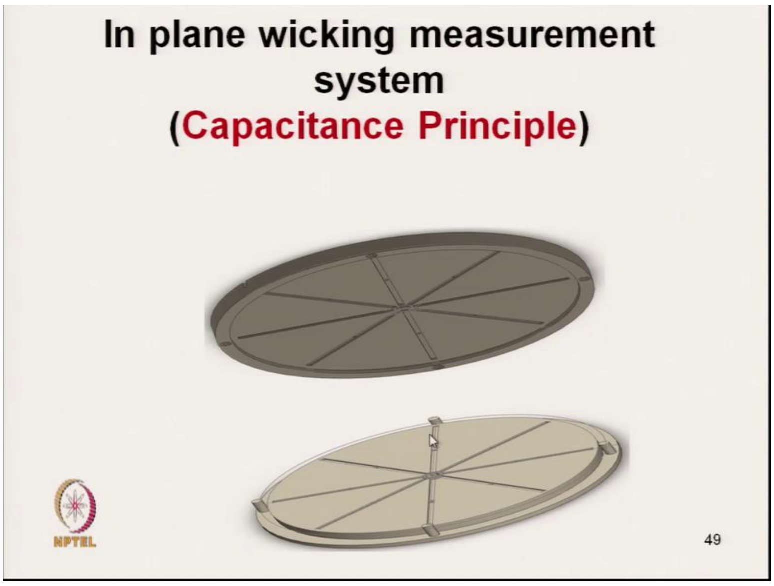

Next is that in plane wicking system using the capacitance principle. Till now what we have discussed it was resistance principle. Now, we will discuss one instrument which works in capacitance principle. These are the two plates insulating plates with slots. So, we have 1, 2, 3, 4 slots which makes actually 8 different directions, 1, 2, 3, 4, 5, 6, 7, 8 directions.

Similarly, this is a bottom plate, and we have exactly same top plates. And in bottom plate, these are the slots. This slots will be filled with the metallic plate, metallic plate will be the similarly with the top plate. And in between if we place the fabric and this plate will actually form parallel plate capacitor. So, using the parallel plate capacitance principle, we can measure the water transmission, waterfront transmission the distance transmitted during the in plane wicking at different directions.

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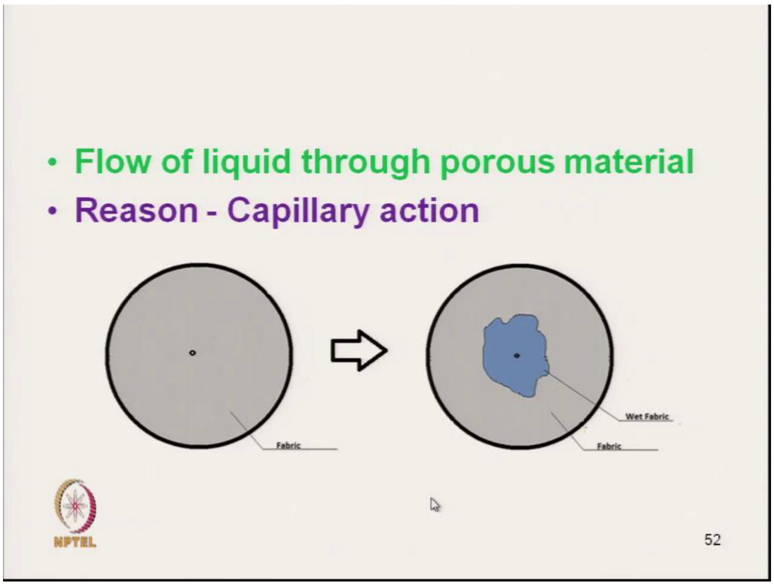

Flow of liquid through porous material we can measure, and it is by capillary action. So, this is the fabric sample, at the center once we actually supply liquid water once we supply at the centre, the liquid will get wicked through parallel plate parallel actually capacitance, we can measure this transmission. Gradually the liquid front is transmitting at different direction it is not circular. So, depending on the structure, the liquid will flow at different direction; using the parallel plate capacitor, we can measure the distance travelled at different direction. It is getting transmitted.

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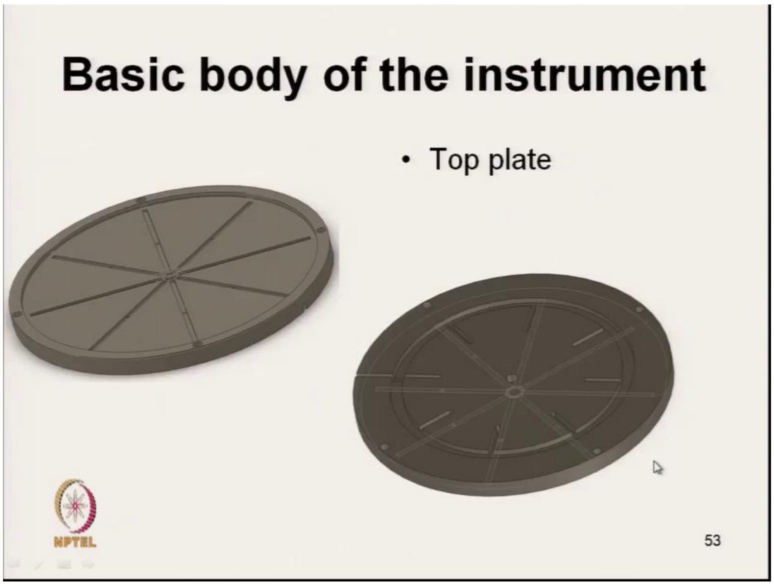

Now, this is the top plate, top plate inner side and this is outer side. Inner side we have slots.

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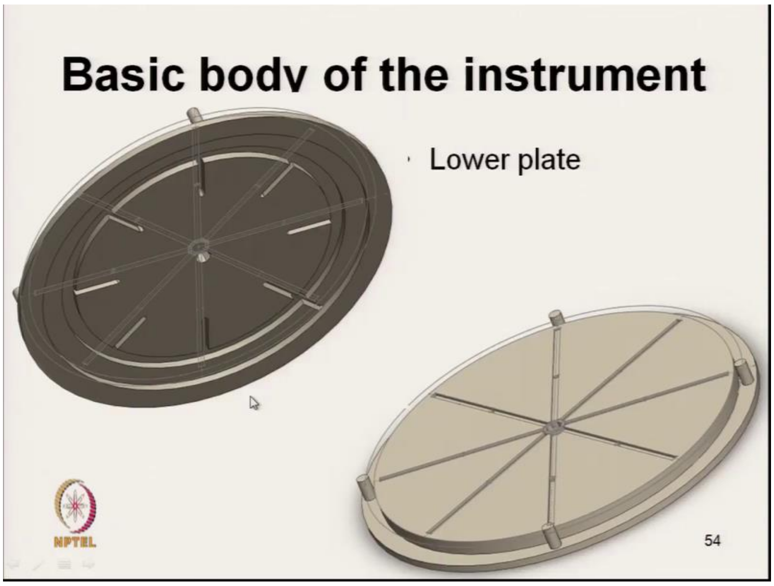

Similarly, bottom plate its inner side with the slot. It is the other side.

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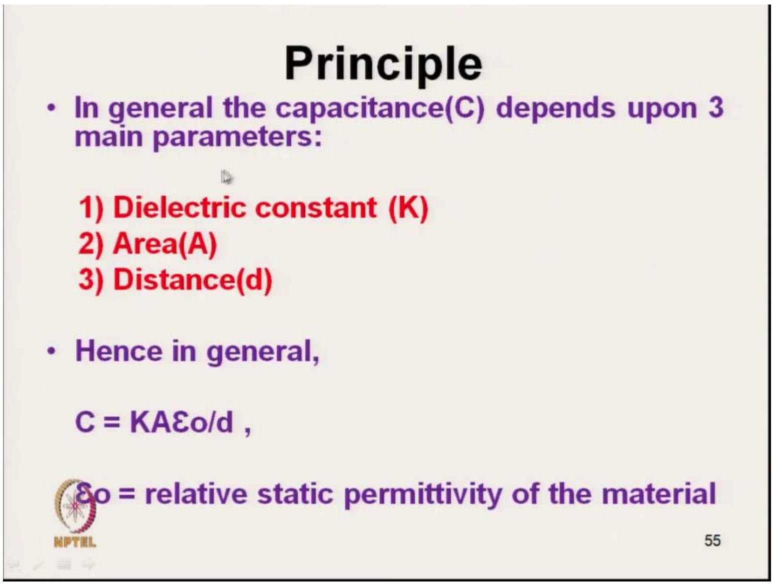

And in general the capacitance depends on 3 main parameters, one is dielectric constant K, second is area, and third is distance between. So, hence in general

C = KAƐo/d ,

Where, **Ɛo** is relative static permittivity of the material ok. So, from here from this equation, you can calculate the capacitance.

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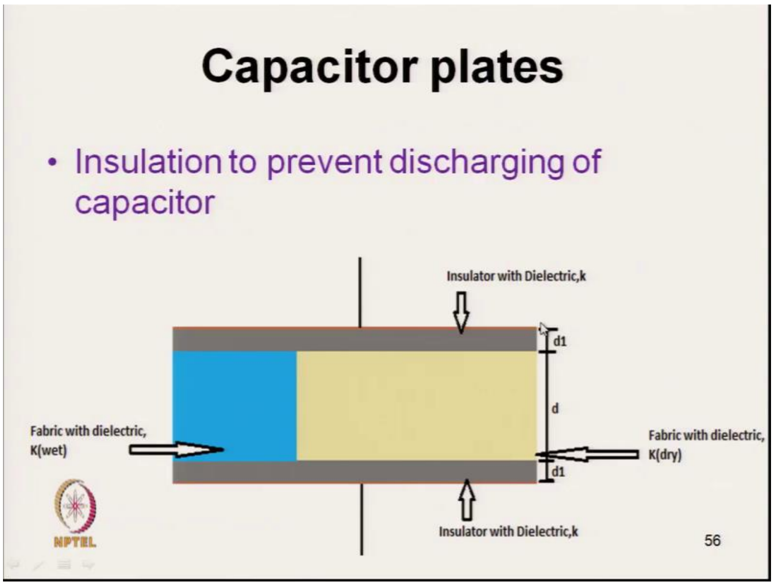

And insulation to prevent the discharge of the capacitance, we need to insulate. So, what you have done, we have used the material the plate which is insulating in nature, and the conducting plate, the metallic plate, is placed under slot. And here once it is flowing, the liquid is flowing, the liquid the water is actually replacing the air inside the fabric structure.

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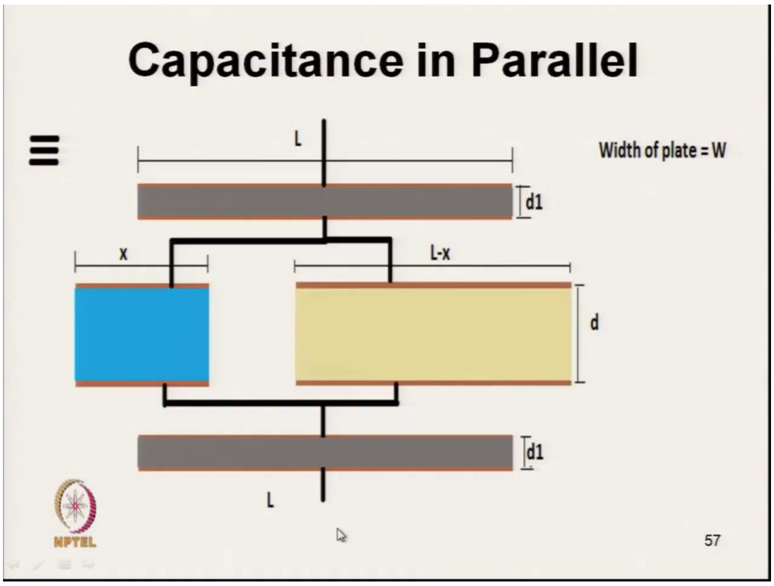

Thus the capacitance value changes and the change in capacitance we can record ok.

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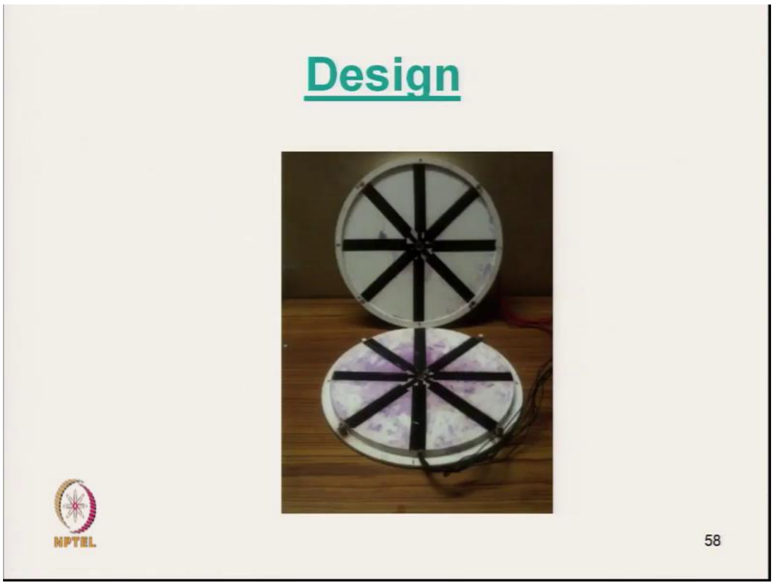

And this is the design of the instrument. So, this is here its inner side of the bottom plate inner side of the top plate. And the black tape is actually placed to prevent the parallel plate from wetting, because liquid will flow through this surface, and fabric is placed in between these plates.

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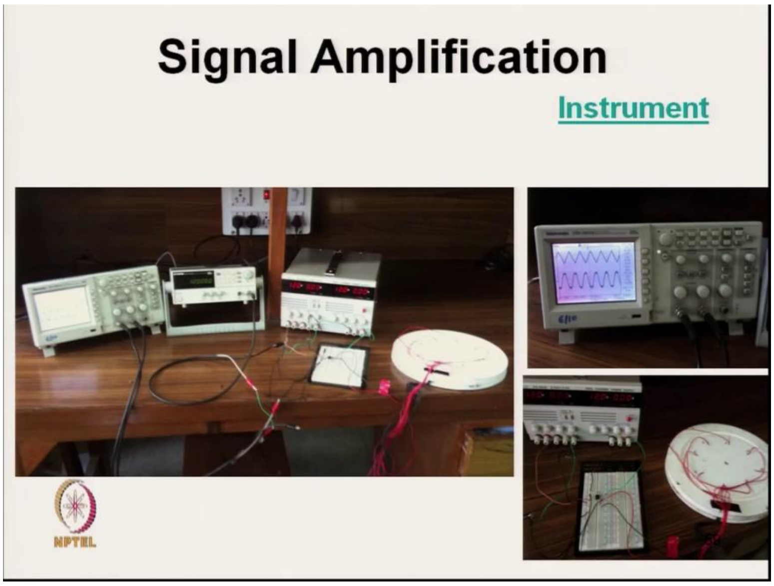

So, this is the instrument. And here this system, it is a top plate; and below that there will be bottom plate. And the electronic circuit, here it is actually recording the capacitance value change in capacitance value from 8 different parallel plate capacitors.

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Now, if we try to see the working of this instrument, they trying to measure the horizontal wicking, this is the bottom plate, this is top plate which can be removed and placed again. And these are the different parallel plate ok. We can place there is a slots, so that we can place exactly at the same position where parallel plates are formed. These are the two plates bottom and top. And total electrical signal the capacitance value is being recorded through this circuit. And at the centre, we have a hole through which we can actually supply liquid with the known controlled way, in the controlled way we can supply liquid through that.

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And I can little bit forward, and this is the fabric sample. Here we can use wide range of fabric starting from very thick fabric to very thin fabric ok. Here we are trying to use nonwoven fabric in a fabric is being placed in between the plates. Plates are placed top plate, is placed in its proper position. And now the fabric is kept in straight condition. And after that the water supply is being placed at the centre.

And as soon as the water supply is started, now we will start getting the waterfront. And waterfront is actually recorded through the computer. Now, water is being filled and then we will see that the waterfront is being recorded here. So, this is a technique where we can get the wicking behavior throughout the fabric surface of different direction using the capacitance principle. In another technique which measures the liquid transmission wicking which is known as the moisture management tester.

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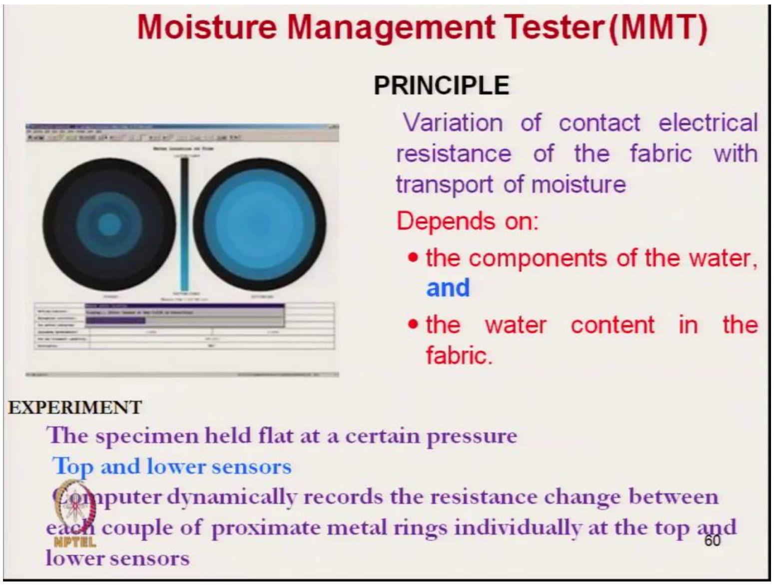

Here electrical resistance principle is being used. Variation of contact electrical resistance of the fabric which with transport of moisture that is measured. It depends on the components of the water, and the water content in the fabric. So, the fabric water content if it is changing, then it will change the electrical resistance. The specimen is actually held flat at a certain pressure, top and lower sensors ok, so that is actually placed between the top and lower sensor. Computer dynamically record the resistance change between each couple of proximity metal ring. So, there are proximity metal rings are there individually at the top and lower sensor.

So, for both top and lower sensor computer will automatically change the, that measure the change in the resistance. And from there, we can calculate the moisture transmission characteristics. Now, after moisture in liquid form, now we will see the moisture transmission in vapor form.

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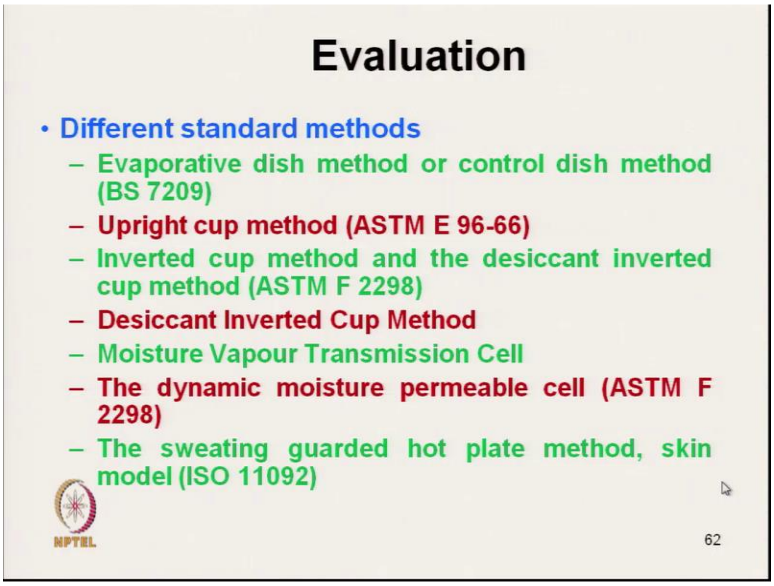

So, the evaluation is that different standard methods are there. So, this methods are, first is the evaporative dish method or control dish method which follows BS 7209. So, the methods of measurement, there are different methods one is evaporative dish method which is very commonly used for apparel textile, functional textiles. Next is that upright cup method which is similar to evaporative dish method, specification little bit different, but the method of measurement are exactly same. Upright cup method ASTM E 96-66 method ok.

Next is that inverted cup method and the desiccant inverted cup method. Inverted cup method is mainly used for say water proof type of functional clothing. Desiccant inverted cup method. Moisture vapour transmission cell. So, this is another method where we measure the moisture vapour transmission by measuring the change in relative humidity of within a cell with the time. So, that rate of change of relative humidity if we record there we can actually measure the moisture vapour transmission, we will discuss this method. And next is that the dynamic moisture permeable cell which follows the ASTM F 2298 method. Next method is sweating guarded hot plate method with the skin model.

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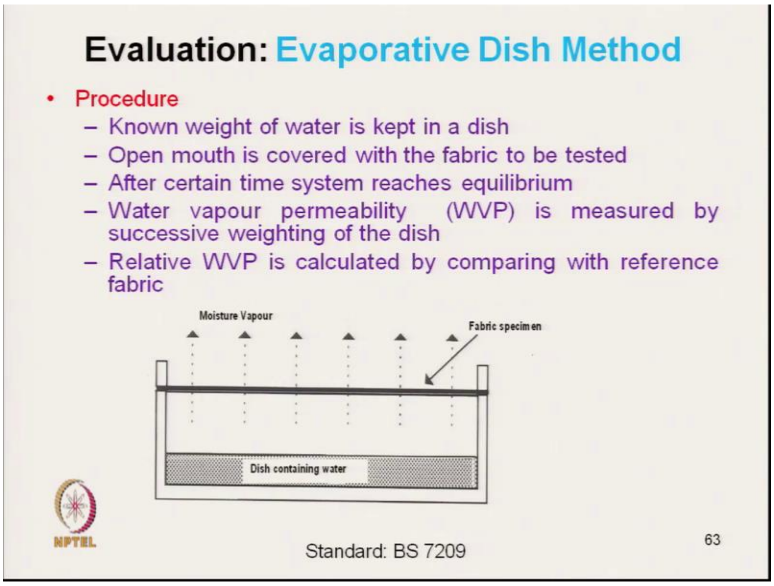

So, and in addition to that another method will discuss which is permetest. So, this method we will discuss one by one first is that evaporative dish method which is very commonly used. Here in this method there is a dish partially filled with water. So, known weight of water is kept in a dish. So, we can take that mass of the water, and open mouth of the dish is covered with the fabric specimen. So, this is the fabric specimen.

And what we measure simply with the time. The amount of moisture water vapor transmitted through the fabric that is recorded. After certain time, the system reaches its equilibrium, because initially there will be some transient stage, because the fabric is being placed the fabric the moisture vapor will get transmitted through the fabric structure, there will be some transient stage, but after certain time the equilibrium will reached. Once equilibrium is reached, then the water vapor will steadily move through the fabric ok.

The water vapor permeability is measured by successive weighing of the dish. So, after equilibrium, suppose we take the initial mass of the dish w1 and after certain times after say 1 hour or 2 hour we take the mass again say w2. And this difference in mass of this dish shows the transmission of moisture vapor through the fabric. Relative water vapor permeability is calculated by comparing with the reference fabric. So, once is water vapor permeability, but main problem with water vapor permeability is that it depends on the totally other factor.

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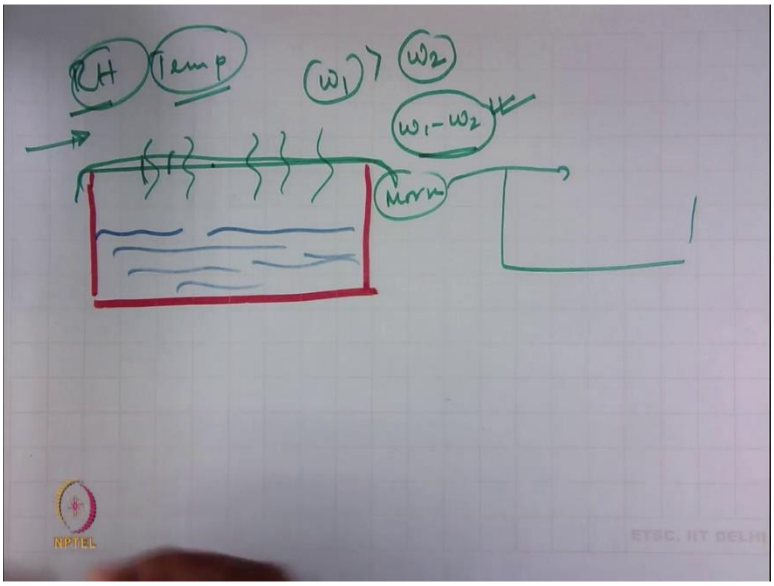

Now, let us see the water vapor permeability. Suppose, this is the reservoir, where we are having the liquid water, and the fabric is this is the fabric sample specimen. And if we are taking initial mass is w 1 after certain time the mass of this reservoir is w2. So, w1 is more than w2. So, w1- w2 is the liquid actually transmitted, it is a water vapor it is transmitted w1-w2. But this transmission depends on many other factors, not only the fabric transmission characteristics, but the RH, temperature, vapor pressure RH. So, all this factors.

So, for a particular fabric if the relative humidity or temperature changes little bit. So, once you are testing at the morning, and in the afternoon if we change test this same fabric, it will give entirely different result, so that will give us the wrong interpretation. So, water vapor permeability is if we try to measure it will give some wrong result so that is why if we use some standard reference fabric and measure the ratio that is the relative water vapor permeability that will give us the almost constant value.

Because whatever error is incorporated due to the change in relativity humidity or temperature or may be air movement so that this all these changes, will get affected by the fabric sample will be affected and also the reference fabric sample. So, the errors incorporated will be same for both reference and the test sample. So, if you take the ratio should be approximately same for both the cases so that is why relative water vapor permeability is used.

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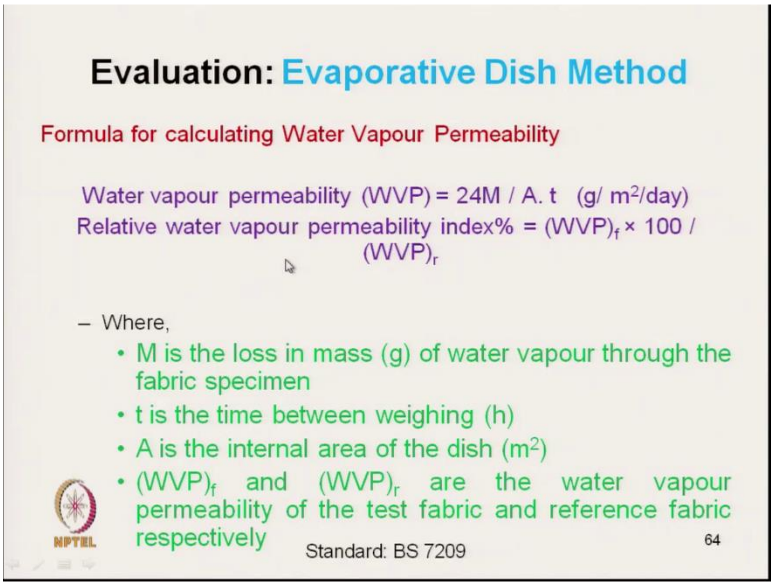

So, another method which is exactly same as that of earlier method that we will discuss, so evaporative dish method. The formula for calculating the water vapor permeability is

Water vapour permeability (WVP) = 24M / A. t (g/ m^2/day)

Now, what is that and relative water vapor permeability is expressed in terms of %

Relative water vapour permeability index% = $(WVP)_f \times 100 / (WVP)_r$

Where,

- M is the loss in mass (g) of water vapour through the fabric specimen
- t is the time between weighing (h)
- A is the internal area of the dish (m^2)
- $(WVP)_f$ and $(WVP)_r$ are the water vapour permeability of the test fabric and reference fabric respectively

So, this is the relative water vapor permeability which is approximately, which will remain same irrespective of the test condition.

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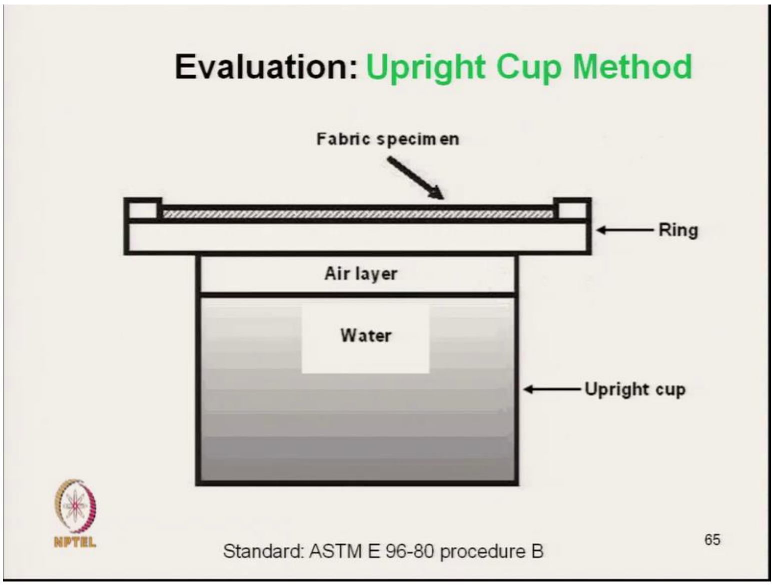

And the ASTM method which is the exactly same method exactly similar, which is called upright cup method. Similarly, upright cup is there earlier case it has a dish, it is air layer it is partially filled with water, and there will be fabric specimen.

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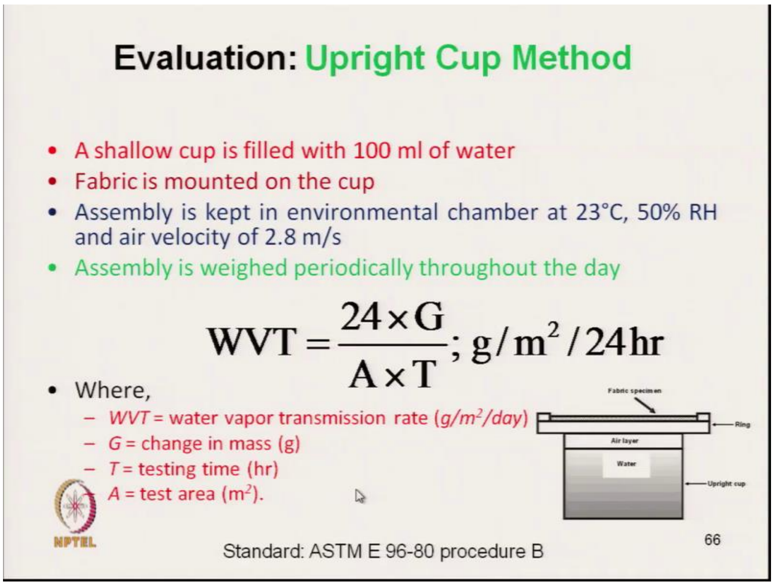

And in up right cup method, a shallow cup is filled with 100 ml of water. This is shallow cup it is filled with 100 ml of water. Fabric is mounted on the cup. Assembly is kept in environmental chamber at 23^0C. Here temperature and relativity humidity is specified,

23^0C and 50 % R.H, and the air velocity is 2.8 m/s. So, all these three parameters which affect the moisture vapour transmission are kept constant. It has been specified here.

Assembly is weighed periodically throughout the day as in case of earlier case. And water vapor transmission is measured; it is calculated exactly in the same way as its earlier case.

$$WVT = \frac{24 \times G}{A \times T};\ g/m^2/24\,hr$$

Where,

- WVT = water vapor transmission rate ($g/m^2/day$)
- G = change in mass (g)
- T = testing time (hr)
- A = test area (m^2).

So, from this method, we can measure the moisture vapor transmission through textile material. So, we will stop here. In next class, we will discuss few other methods.

Till then thank you.