Science of Clothing Comfort
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Lecture – 32
Moisture Transmission & Clothing Comfort (contd.)

Hello everyone.

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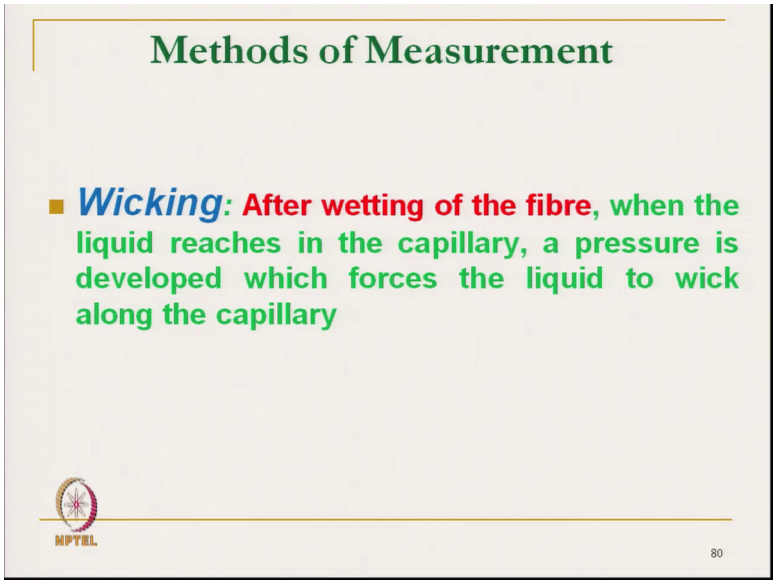

We are discussing the methods of measurement of liquid water transmission through textile material. So, in last segment we have discussed about the wetting phenomena, measurement of wetting phenomena of textile material; now we will be discussing the wicking. So, after wetting of fibre when the liquid reaches in the capillary, a pressure is developed and that actually that force capillary force which helps in transporting the material through the capillary; the liquid through the capillary.

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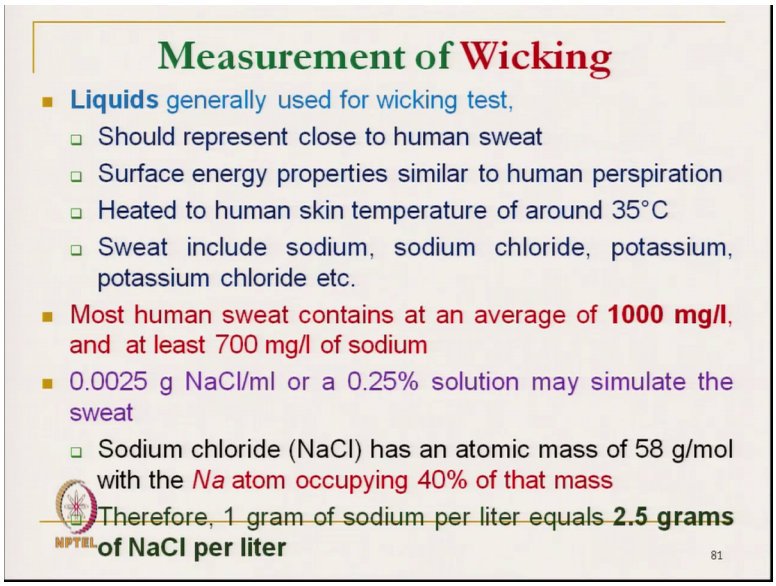

And the wicking as we have already discussed for measurement of wicking, we need a particular fluid to simulate the human sweat. You cannot directly use the water, plain water or distilled water.

So, the liquid actually the water when it is mixed with 2.5 gram NaCl per litre of water; that actually closely simulate the human sweat as far as the wicking trance performance is concerned. And also the temperature of the system should be kept around 35 degree Celsius which is close to human skin temperature.

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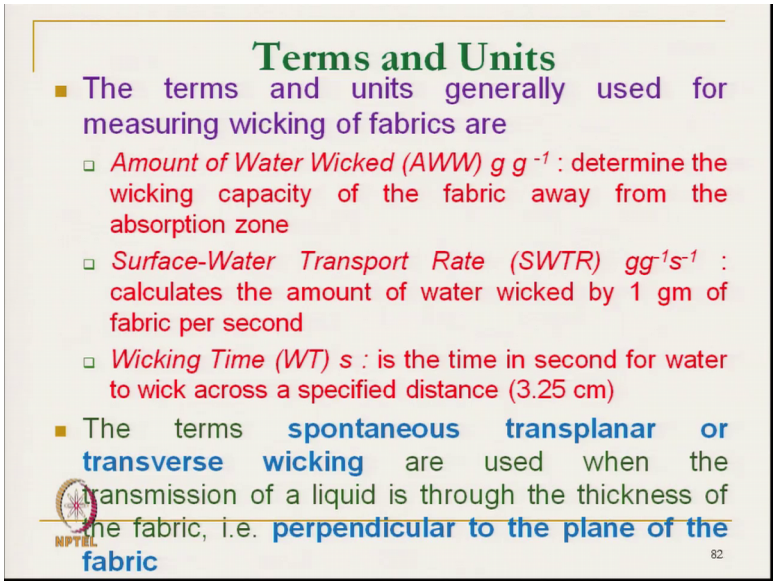

So, like wetting the wicking also has got specific terms to express. So, there are different terms which is used for wicking; so, Amount of Water Wicked; AWW wicked it is a gram per gram of fabric; determines the wicking capacity of fabric away from the absorption zone.

So, that is how it is transporting the liquid from one zone to another zone; it is in terms of the gram of liquid transported by gram of fabric. Surface Water Transport Rate; SWTR it is a gram per gram per second calculated based on the amount of water wicked by 1 gram for fabric per second. So, 1 gram of fabric how much water is wicked per second it is expressed in terms of SWTR, Surface Water Transport Rate. And wicking time it is the time in second for water to wick across a specified distance, the distance here is a 3.25 centimetre; it is a fixed distance, for that distance what is the time required for a particular fabric so that is in second.

So, for comparison one can take any of this one; so, the term spontaneous transplanar or transverse wicking are used when the transmission of liquid through the thickness of the fabric, which is very important it is a perpendicular to the plane of the. So, there are basically 3 types of wicking are there; so, one is vertical wicking which is against the gravity it is the liquid wicks vertically. Another is in plane wicking which is along the plane, another is the transplanner which is across the plane; so, across the thickness of the fabric. So, all 3 wicking types are important; so transplanner is basically important for the fabric clothing because the water needs to get transmitted from inner layer to outer layer; one surface of the fabric to another surface of the fabric.

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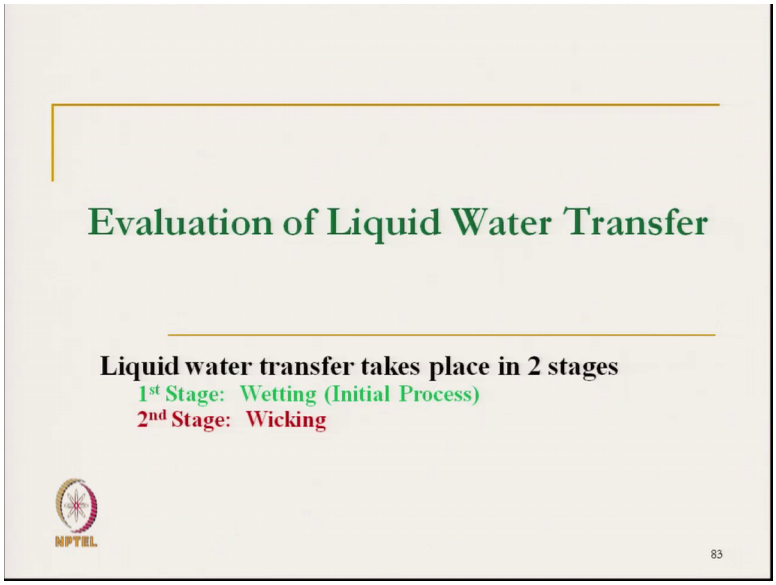

So, evaluation of liquid transfer transmission is basically it in 2 terms, 2 types it is in 2 stages we have discussed already. First stage; is a wetting it is initial process that we have already discussed, the method of manufacturing method of testing we have discussed and second stage it is wicking. So, now, we will discuss the evaluation methods for wicking.

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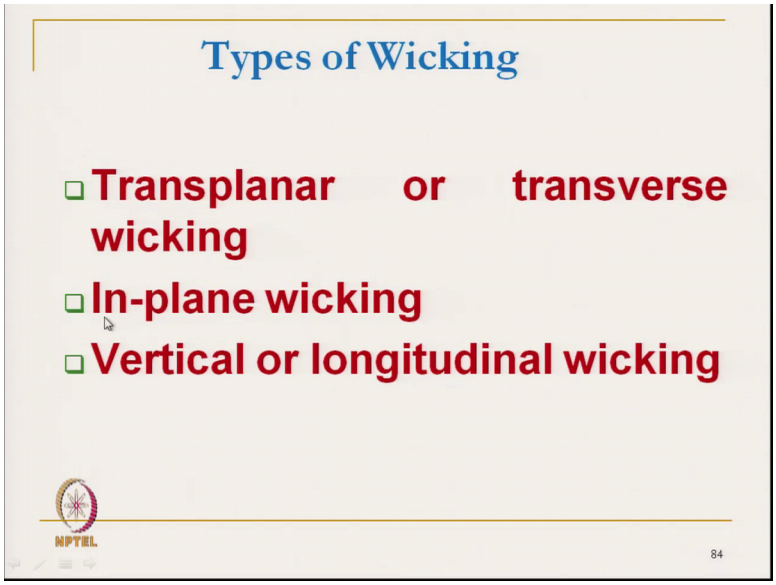

So, there are 3 types of wicking; so that we have discussed transplanar or transverse wicking, in plane wicking along the surface along the plane of the fabric and vertical or longitudinal wicking. So, in plane wicking is always also termed as horizontal wicking.

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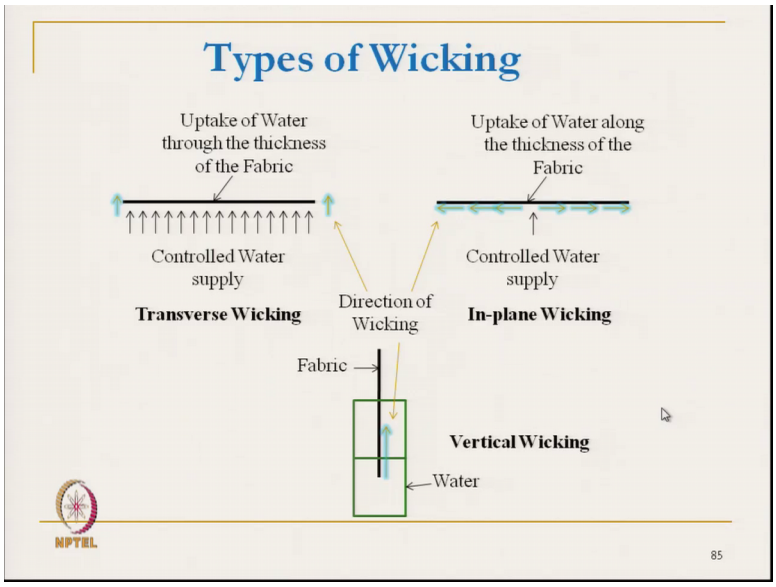

So, this wicking there are 3 types of wicking are shown here. So, here this is the fabric; it is shown and the water is supplied from the bottom of the fabric and here the water gets transmitted from bottom surface to top surface; so, across the thickness it is transmitted.

Whereas, in in-plane wicking water is supplied from the bottom, but at a particular point; in transverse wicking water is supplied at total throughout the surface, throughout the area cross section of the fabric and it is; it gets transmitted to the other surface. But here our idea is not to that not that water to transmit in the other surface its idea is that water to transmit horizontally.

So, water is supplied from the centre point and vertical wicking is basically it is this is the fabric sample and here the water reservoir. And when fabric is in actually when it is a fabric is in touch with the water gets wicked through the capillary channel vertically; so, that is why it is called vertical wicking. So, the in transfers wicking up take of water across the thickness, here the along the thickness, here along the surface here also along the surface, but the direction is here in vertical direction. So, this 3 measurement techniques we will try to see how to measure.

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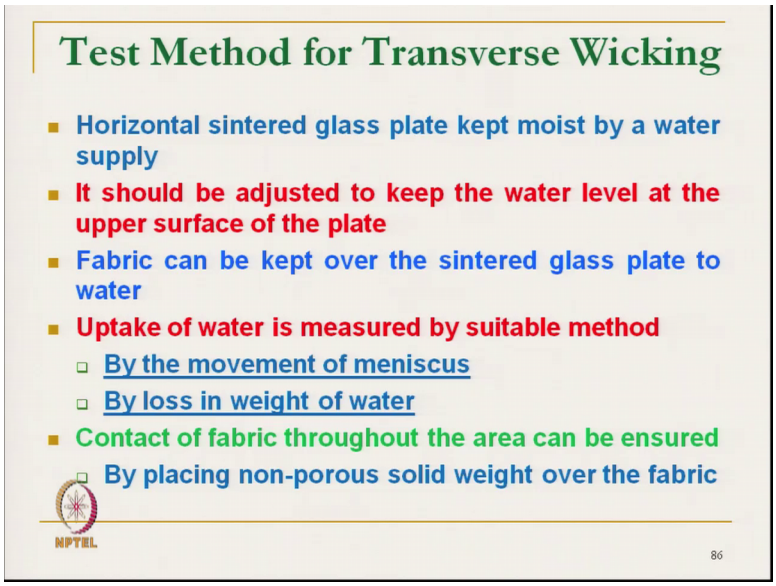

So, first we will see the transverse wicking technique. So, horizontal sintered glass plate is kept moist by water supply. So, one sintered plate with a perforation it is kept horizontally; it should be adjusted to keep the water level at the upper surface of the plate. So, water level has to be kept in such a fashion that it should reach at least at the upper surface of the plate so, that when the fabric is placed on the sintered plate; sintered plate means there are holes there.

So, water comes in terms of droplet form which stimulates the sweating it is skin. So, as when we place the fabric it is in touch with the fabric surface in bottom surface is in touch with the sintered plate; which is moist and water is getting transmitted through throughout the thickness. Fabric can be kept over the sintered plate to the water; so, uptake of water is measured by suitable method.

So, as soon as we keep the fabric on the sintered plate; which is moist. So, as soon and it will fabric will try to wick the water, water will be taken. So, the methods which normally is used one is the movement of meniscus, another is the loss of weight of water that is in the from the reservoir what is the loss of weight that can be measured or movement of meniscus; if we know the cross section of the tube that we will discuss now.

Contact of the fabric throughout the area can be insured so that the fabric when is it is placed; the fabric should be in touch with the sintered plate throughout the cross section;

otherwise the bubble will be created it will interfere the wicking characteristics. So, what we have to do? After placing the fabric over the sintered plate; we can place a plate non porous solid weight to you have to solid plate we can place over the fabric so, that there is proper contact at the bottom surface of the fabric.

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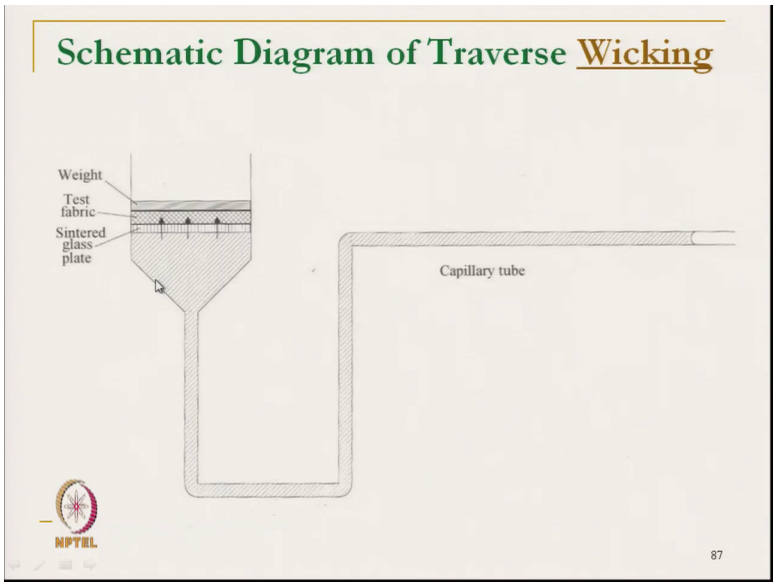

Now if you see the diagram; here this is the diagram. Here it is a constant supply of water constant supply of water and after that this water, there is a sintered plate. This height of this water supply water is that can be adjusted so, that the water level is just above the sintered plate.

So, top of the sintered plate is always in moist condition. So, that we have to adjust this height; so we can or you can raise this height and this is flexible tube. After that our test fabric is placed; when test fabric is placed the water above the sintered plate is actually will be wicked through the cross section, whole cross section. And this weight that is plate not it should not be very heavy; light plate is placed above same cross section is placed over the sintered plate, over the fabric sample; so, that there is a constant its contact is maintained. Now, let us see the animation of this instrument.

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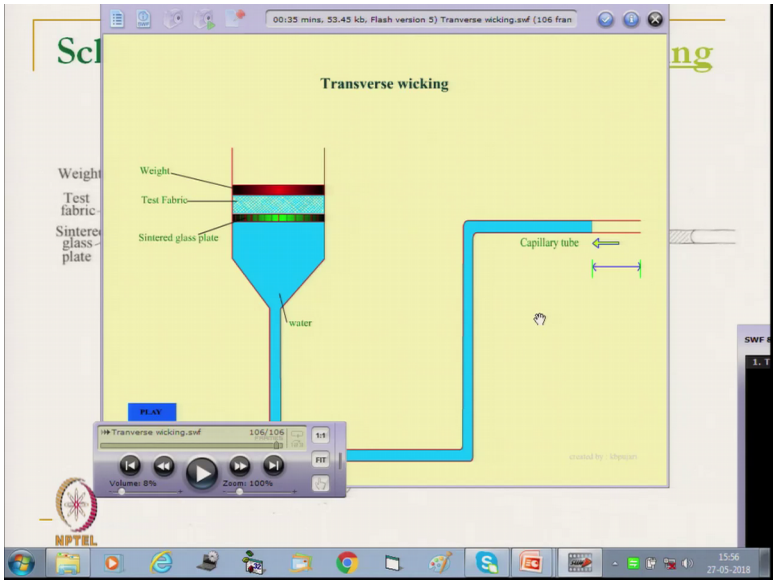

This is the situation; this is the water blue colour it is and this green colour it shows the sintered plate.

So, height is adjusted so that the top of the sintered plate is moist; water is supplied. Now after that you can see the fabric sample is placed on this is the fabric sample is placed on the sintered plate, then the light weight the same area it is placed so, that it helps in proper contact. Now; now the wicking start across the plane thickness and as it is wicked this meniscus will; will be actually that is absorbing, so meniscus will move. So, this movement of meniscus with the time can be noted down; so, this is the way measurement of the transplanar or transverse wicking.

Now, in place of this meniscus we can have another arrangement which will actually siphon out the water and that reduction in mass can be noted down; this is that.

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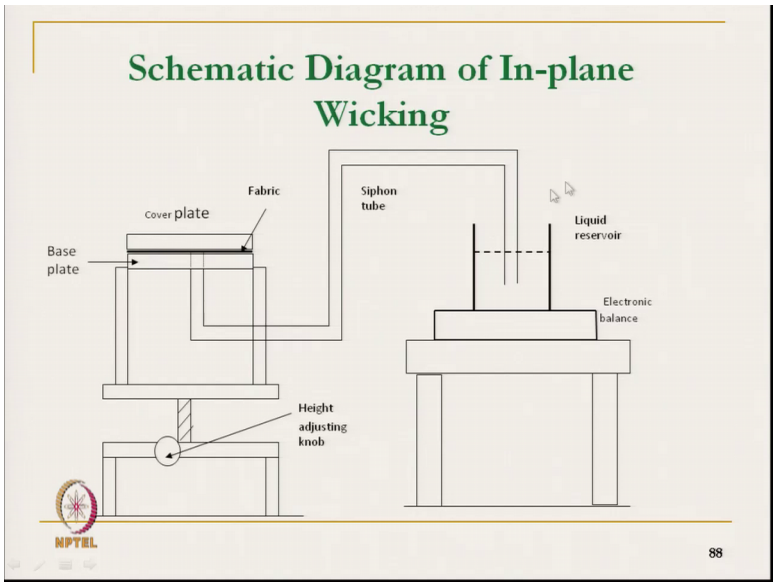

So, here although this is the in plane wicking system, but here the same this portion earlier this here it was a meniscus. So, this portion has been replaced by this here, the water is placed here and this is the microbalance; electronic balance is there and as the water is wicked the mass of the water is reduced. So, that can be noted down at this connected with the computer; so, with the time on can get the transverse wicking.

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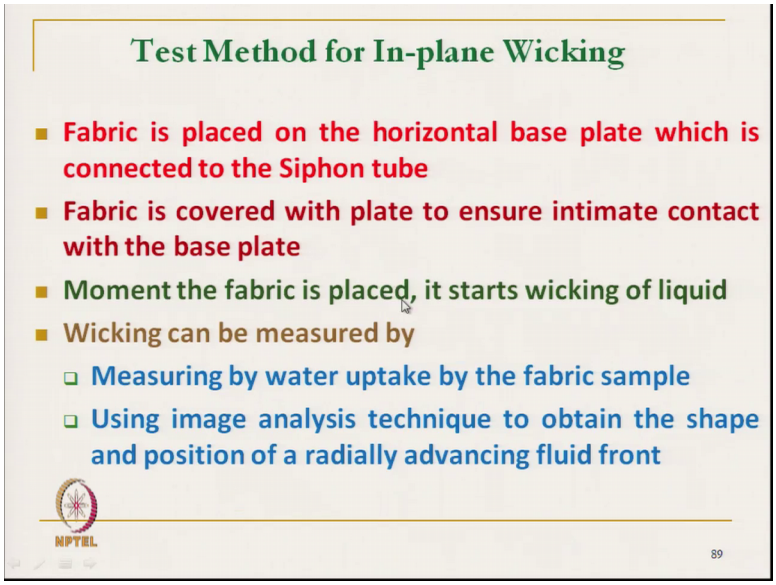

Now, in-plane wicking, the fabric is in plane wicking; here this is the in-plane wicking set up. Here the fabric is place no sintered plate over plate up at the centre there is a hole.

So, the fabric is placed on horizontal base plate which is connected to a siphon tube; this is the siphon tube on with which this plate is connected.

Now fabric is covered with plate to ensure intimate contact with the base plate. So, that similarly the another plate will be there cover plate which will cover the fabric so, that proper contact is there with the base plate. Moment of fabric is placed; it starts wicking, so that is and the movement of water is measured that is a transmission of water along the plane is measured by this electronic balance.

So, moment the fabric is placed it starts wicking of liquid; wicking can be measured by measuring the uptake of water by fabric sample, that is how much water is it is taking or by image processing technique; that is the that area of water it is that is area of water can be actually measured by taking the images. And in that case one can use the some coloured water; so, that it can be image can be taken. And the proper shape of water transmission front can be measured; that is called radially advancing fluid front can be measured by image processing.

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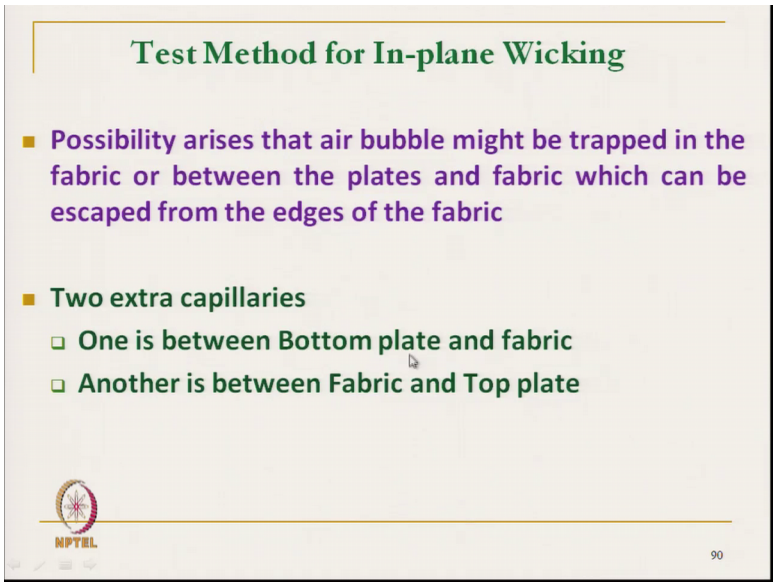

So, here the problem is that problem here there maybe error due to the one extra layer of air. So, the problem is a possibility of arising air bubble which might be trapped in the fabric or between the plate and the fabric. So, when the 2 plates are placed between 2 plates of fabrics are placed; so, between bottom plate and fabric and also fabric and top plate there may be air gap created; also there may be air bubble inside the fabric. So, 2

extra capillaries may be created; one is between bottom plate and fabric, another is between top plate and fabric.

Along with that extra air bubble inside the fabric may interfere the flow of liquid which may create the error, which may generate error. So, that this we have to take care of this phenomena this is a schematic diagram here. So, water is being supplied through the siphon tube and as the water gets transmitted; so, this height we can adjust here as the water gets transmitted, the mass of this liquid changes reduces that is actually measured.

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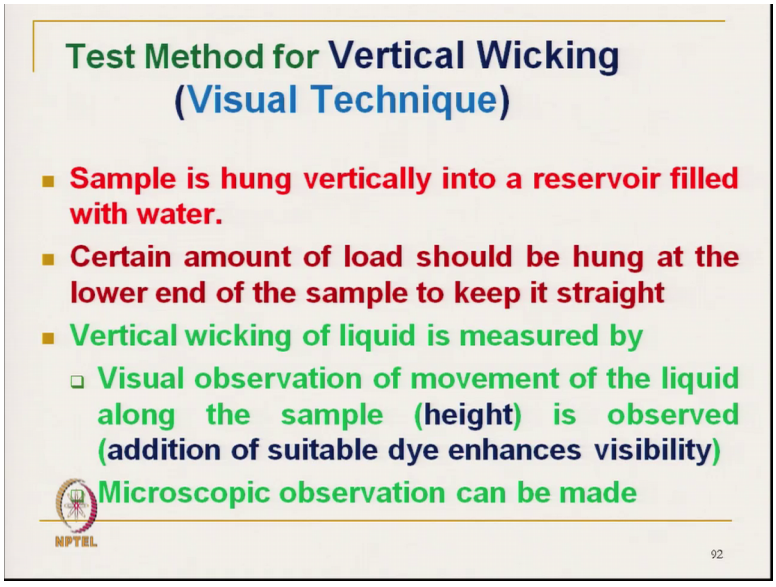

Vertical wicking as that it is a simple technique, it is a by visual method we can measure. The sample is hung vertically into the reservoir filled with water; certain amount of load is kept actually it should hung at the lower end so that the fabric is kept in the straight condition, otherwise there will be some wrinkle.

Vertical wicking of liquid is measured by visual observation of movement of liquid along the sample; that is the height which what is the height it is reaching by the visual observation. Sometime it may happen that the colour is it is not visible in that in clearly; so that some dye may be added to enhance the visibility. And also microscopic observation can be made so to get some accurate result.

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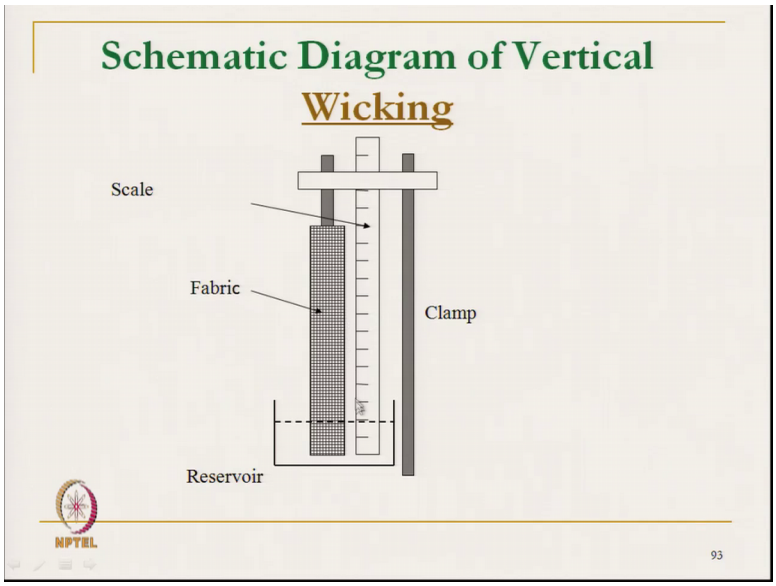

This is the vertical wicking set up here it is a reservoir; the fabric state some weight can be an hung be here and this is the scale.

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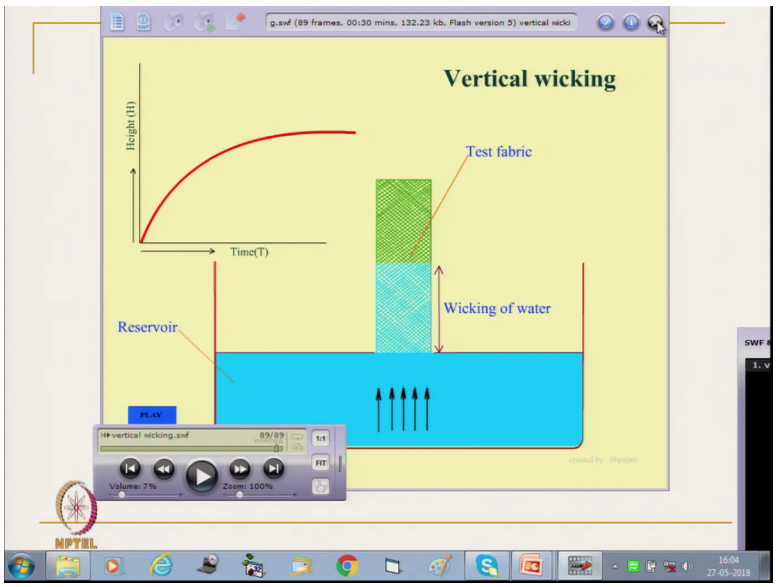

Now, try to see now here this fabric is its putting the fabric in the reservoir as soon as the fabric is in contact with the water; so, water will start wicking. So, one can get plot the time versus wicking height by visual observation; so, this is the technique or microscopic technique can be used.

Main problem with this measurement technique is that it is a visual that manually in nature; manual error can be there. Another problem is that in case of very thick fabrics like non woven when the liquid is not flowing evenly throughout the thickness cross section; so, if the liquid flow is through the inside of the thickness in a particular, it is not coming in the surface; then measurement technique that this type of visual technique is not useful. In that case we have to use some other techniques this technique is useful mainly for very thin fabric.

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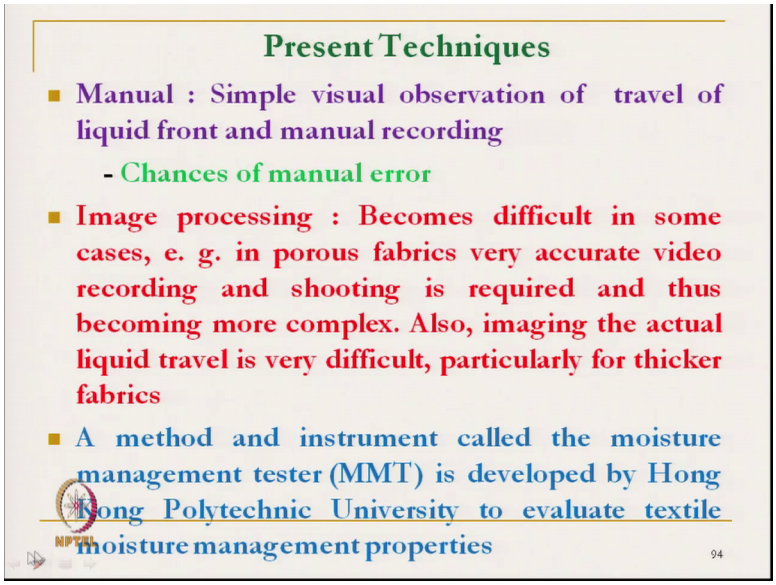

So, this manual measurement is simple visual observation of travel of liquid front and manual recording chances of manual error is there. So, image processing also difficult particularly for porous material like thick material. So, we cannot see the actual travel of liquid front; so, based on the looking at all these problem a method has been developed by in Hong Kong Polytechnic University that is a Moisture Management Tester, which actually evaluates the moisture management property by that resistance principle.

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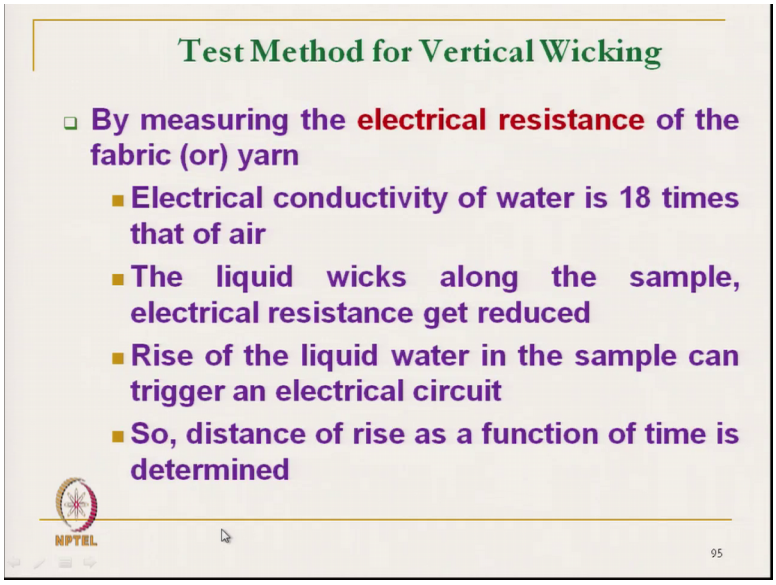

By measuring the electrical resistance of fabric or yarn; so, as the as we know the dry fabric has got higher resistance than the wet fabric; liquid has got very low resistivity. So, that using this principle the electrical resistance measurement technique is being used to measure the wicking characteristics.

So, when the fabric is there is no liquid water is there; so we can measure the resistance and as the water a fabric is filled with water. So, the resistance becomes very low; so depending on that one can measure the wicking characteristics. So, electrical conductivity of water is 18 times that of air; the liquid wicks along the sample electrical resistance gets reduced; rise in liquid water in the sample can be triggered an electrical circuit.

So, as soon as the water is rising through the fabric, electrical circuit gets completed and it will actually be indicated by glowing LED lamp; that will show that particular that price of a particular that liquid at that particular height. So, distance of rise as a function of time is determined.

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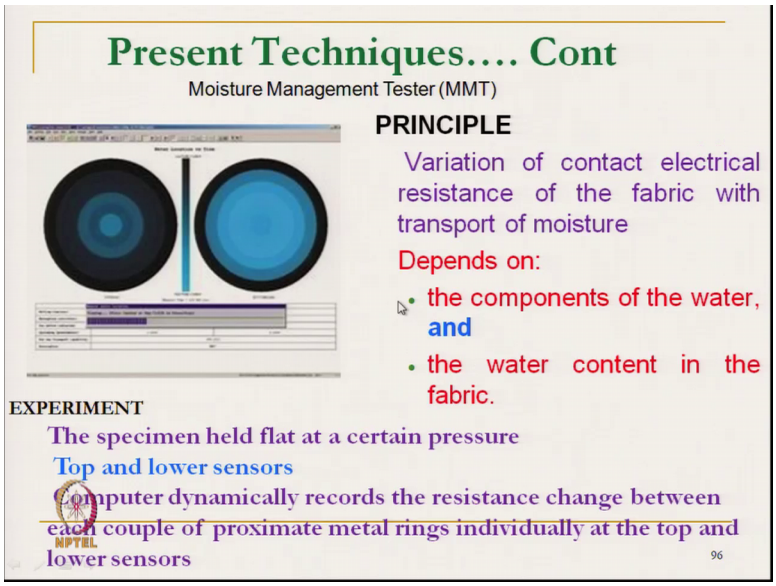

So, with the time one can determine the function distance. So, here in Moisture Management Tester; the principle is variation of contact electrical resistance of the fabric with transport of moisture. So, depends on the component of the water and water content in the fabric so, that the resistance will change. The specimen held flat at certain pressure top and bottom sensors are there; computer dynamically record the resistance change.

So, as when water is supplied; so automatically computer change the dynamically the change in resistance between each couple of proximity metal ring. So, there are number of metal rings are there; so, these are the different proximity metal rings between top and bottom layer. So, that will add ring individually at top and bottom sensor; so, it measures the change in resistance and the water flow it can measure. So, there are some other instruments available which actually measure the wicking characteristics based on resistance and capacitance principle.

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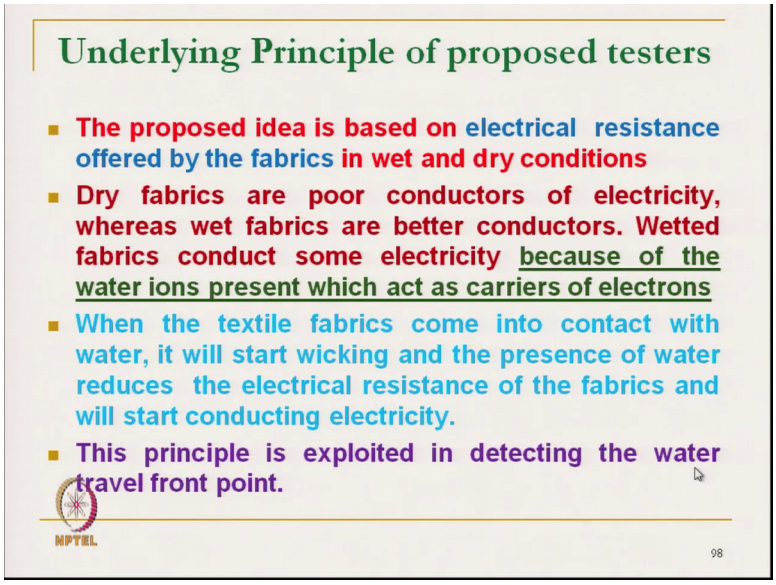

So, the principle is that first method is that the proposed idea is based on electrical resistance offered by fabric in wet and dry condition. Dry fabrics are poor conductor of electricity, whereas wet fabrics are good conductor. Wetted fabrics conduct some electricity because of the water ions present which acts as carrier of electrons. So, what due to presence of water ion; so electricity flows through that wet fabric.

So, when the textile fabric comes into contact with water it will start wicking. So, wicking will be started and the presence of water reduces the electrical resistance of the fabric and will start conducting the electricity and circuit will get completed. The principle is exploited in detecting the water travel front point; so, that at certain time what is the water travel front that can be measured.

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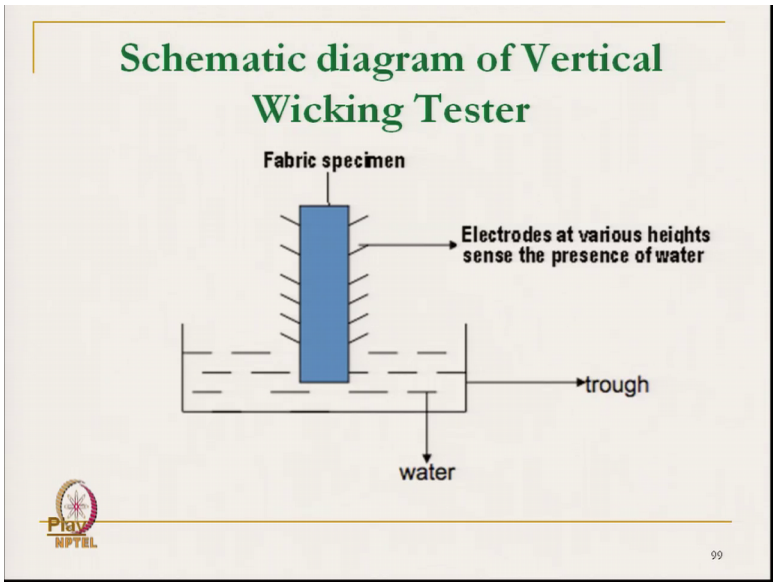

The schematic diagram, this is the schematic diagram here. So, here what happened here number of electrons; so, electrodes at various known heights are been created here. And these electrodes are connected with the circuit basically supply; as soon as suppose the water is reached here, this electrode at this height will get the current. And it will send signal by glowing the particular LED light at that showing that it has reached at that particular height. So, this can be connected with the computers computer also to get the automatic result.

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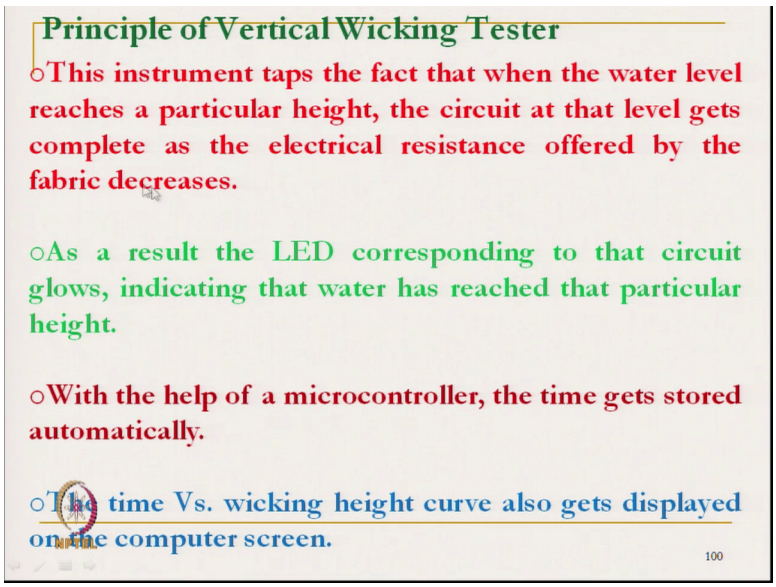

So, as a result; so, as soon as it reaches the LED corresponding to that circuit glows. So, there are there are different circuits are there; so, the LED at that particular as soon as it reaches that at that height; that particular LED will glow. And indicating that water has reached to that particular height; with the help of microcontroller the time gets stored automatically. So, at what time what is the time to reach to that particular height. So, time versus wicking height can be displayed.

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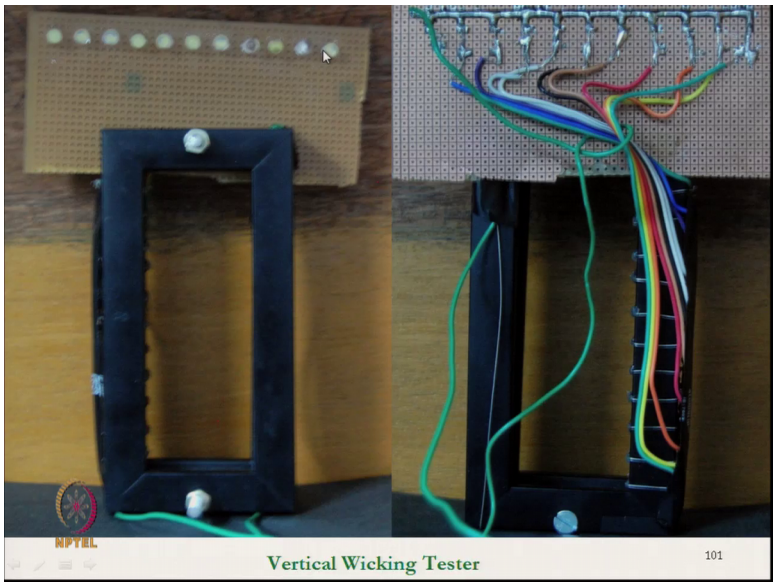

This is the circuit diagram here these are the LEDs to show that the one particular LED is corresponding to particular height.

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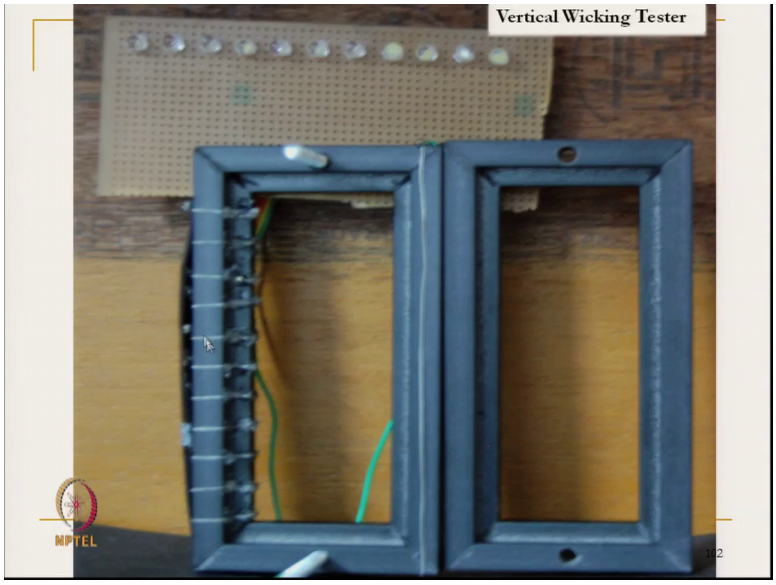

If you see on the other side; this is the side here these are the different at different height when water reaches the particular height. Then through the fabric this particular suppose it is reaching here; this circuit will get completed and immediately the LED will glow here it will show that it is the particular height it has reached. So, automatically it can be measured using the principle of resistance.

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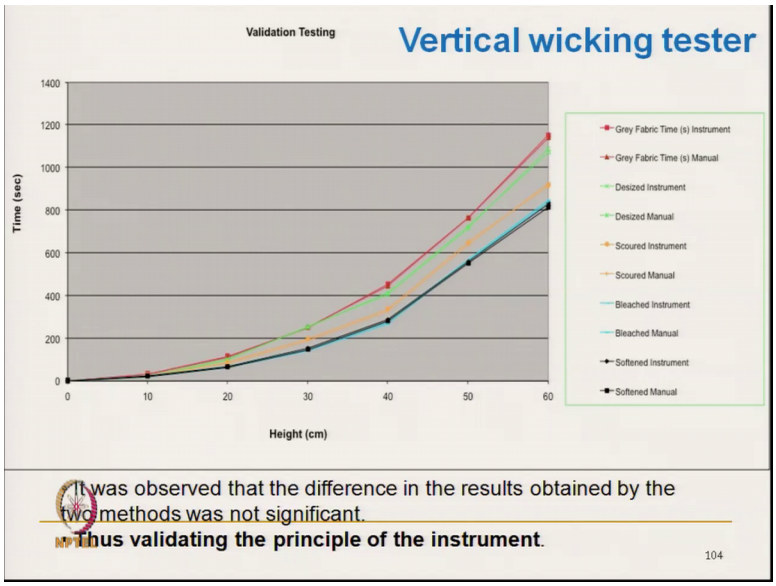

So, this instrument has been validated, the repeatability of test consistency of testing. So, at different time it has been repeated and it has been observed the instrument is giving a correct result. So, it is at different height and time; so it is measuring and the same sample has been tested repeatedly.

So, it gives repeatability and also this is the difference fabrics has been; it has observed that the difference in result obtained by the 2 methods was not significant. So, that at difference methods like visual method has been tested. So, the same fabric has been tested visual principle and using this method of that resistance method same fabrics. So, it has been observed that both the methods are giving exactly same result very close, there is no significant difference; so we can say that this instrument is working perfectly.

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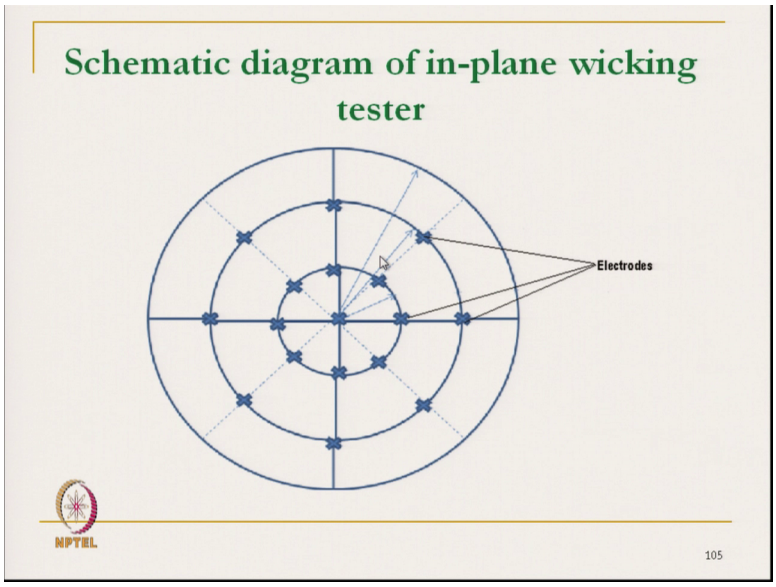

And the same principle was used to measure the in-plane wicking also. So, here again similar techniques are used, but at the centre point; there is an electrode is there from where the liquid is being transported, liquid is being supplied at the centre. This is the at the bottom plate and over that the fabric is placed and these are the electrodes. So, 1 2 3 4; so 8 electrodes are placed at a particular distance.

So, along the in a concentric circle; one can place a large number of electrons their electrodes depending on the requirement, but in this instrument 8 electrodes were placed so that at least at 8 direction; different direction of liquid flow one can measure. So, liquid is being supplied at the centre and as it gets transmitted; suppose the liquid is transmitting it is not say it is symmetrically, it gets transmitted asymmetrically. So, this is if it is say in lengthwise direction; if it is say transmitting lengthwise direction it at faster rate; so, it will reach at this point first before this it is reaching water.

So, if as soon as it is reaching here; the this will show that this is the at this angle particular say 0 degree angle or say 90 degree angle. So, this at this angle the when the circuit is completed one can show the direction of the liquid flow.

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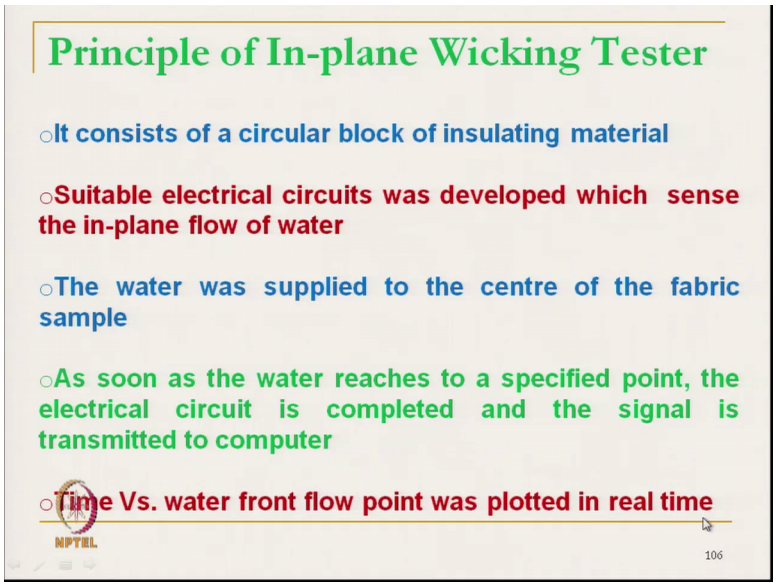

So, it consists of a circular block of insulating material; suitable electrical circuit was developed which says the in plane flow of water. The water was supplied to the centre of the fabric sample as soon as the water reaches to a specified point; the electrical circuit is completed and the signal is transmitted to the computer.

So, at different direction; so this instrument gave the asymmetric direction flow at the rate of flow at different direction it gives. So, it shows it gives the lengthwise direction; it cannot keep the mass of water transmitted, but it is the length of water transmitted it looks that time versus water front point was plotted in real time; so, that.

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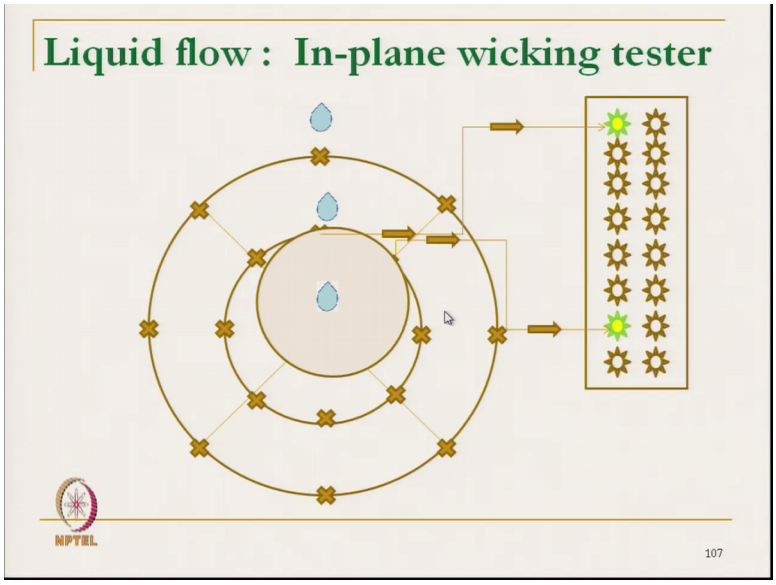

So, one can see as soon as suppose it is transmitted. So, here waterfront is in this fashion; so, in this fashion if it is there, so that the electrode here and at this point will glow. So, this is the this electrode it is glowing this; so, one can see the direction of waterfront flow in plane wicking tester.

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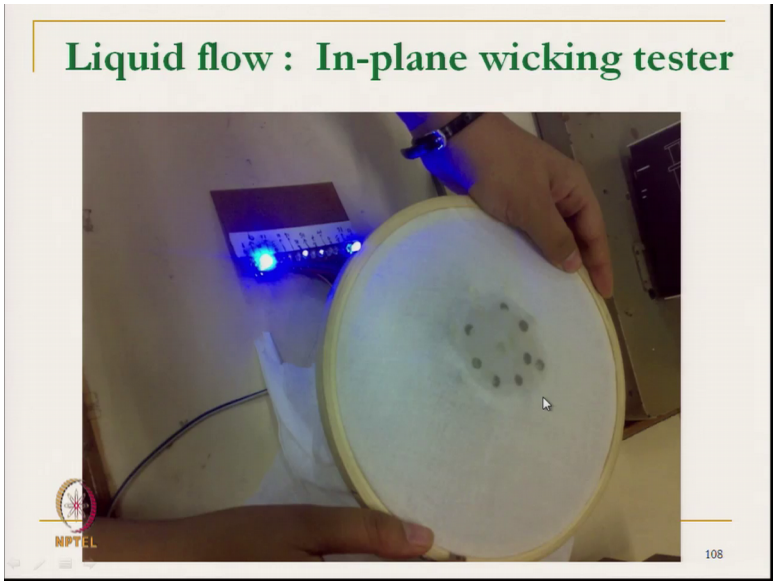

So, if you see this is the type of; so, here at the bottom we have the, this electrodes as soon as it is touching; so, at the centre there is a electrode. So, immediately this LED will glow and also this data can be stored in computer.

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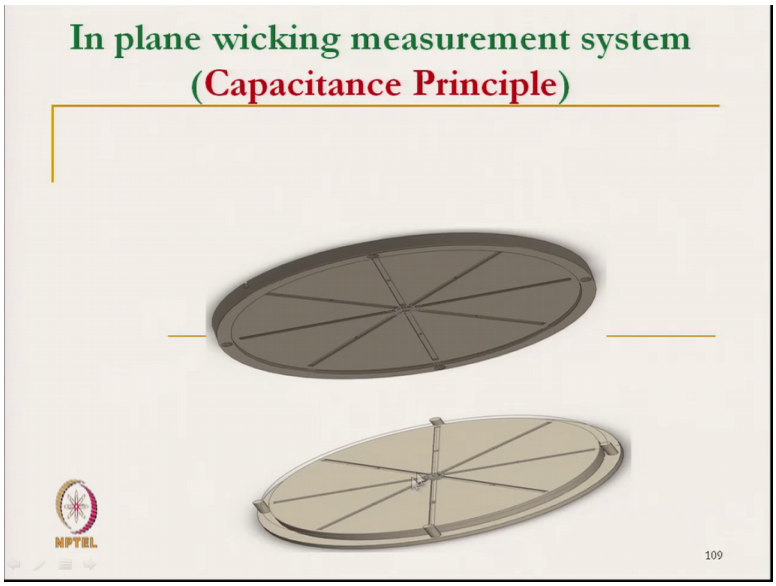

So, next instrument is based on the capacitance principle. Here this is say top plate and this one is it say it is a bottom plate; here it is a top plate. So there are 8 different capacitance plate capacitor; so, these are the capacitor plate parallel plate capacitors are being created.

So, this plates are they are similarly one the other side there are 2 symmetrical plates. So, and in between the fabric is placed; so, this these are the plates 1, 2, 3, 4, 5, 6, 7, 8; 8 direction is it can also measure. So, once the fabric is placed in between this plate this these are the insulating material and only the plates are this strip; metal strips are there one can place. So, once the fabric is placed in between; so, fabric and this plates there will be 8 different parallel plate capacitors will be created.

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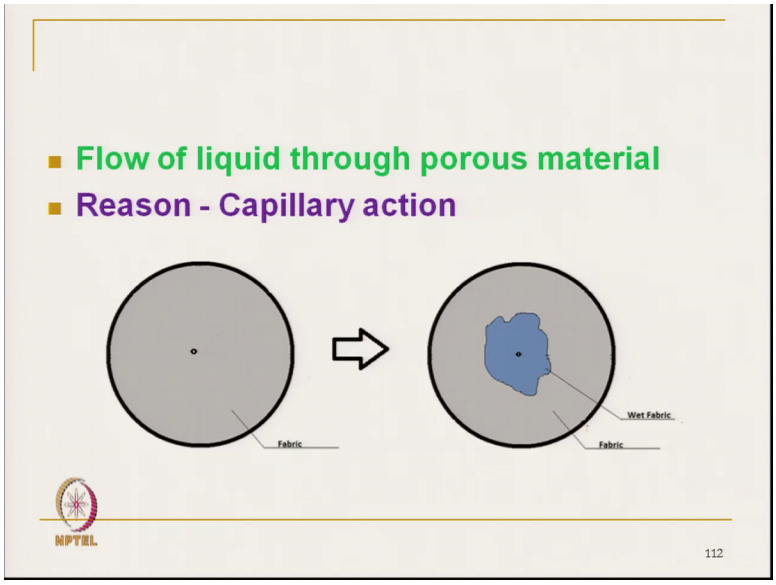

So, flow of liquid through porous material; capacitance due to the capillary action it will lay. So, this is the way the water gets transmitted; so, as soon as it starts the water is this is a waterfront, gradually this waterfront will increase this is waterfront is increasing like this; waterfront, so, we can we want to measure the waterfront travel.

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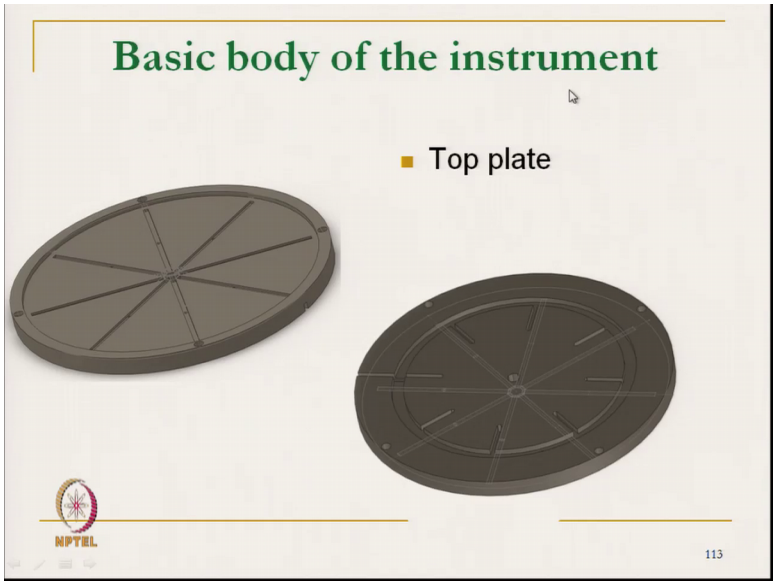

So, this is a top plate this is inner view this is outer view of the top plate in the inner view the top plate. So, this is the inner view; so, here the plates that is stripes or metal strips are placed and this basic material of the top plate is a insulating material.

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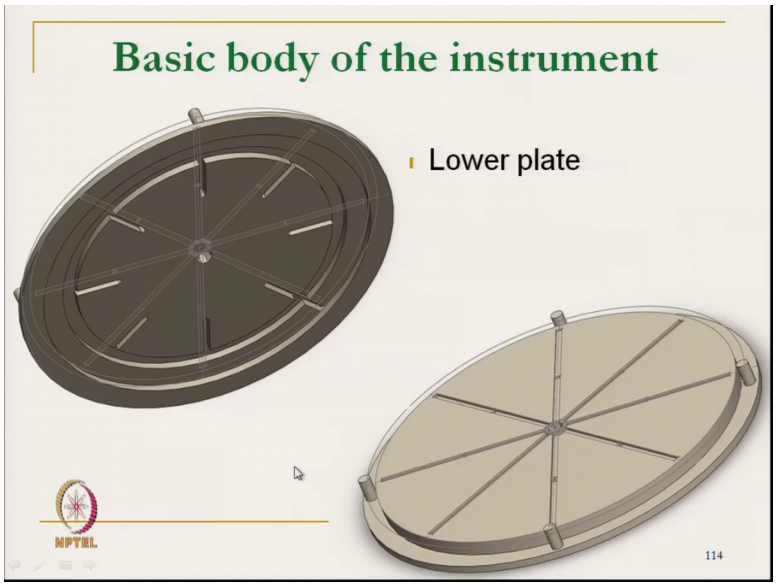

Similarly, the lower plate at the lower place the same it is a basically at the same it is a size and shape, it is placed. And here again the same metal strips are placed here and the difference between top plate and bottom plate is that; here in the top plate there is a there are slots here present here at different plates slots are present; here the projections are at 4 different point.

So, when the and at the top plate another point is that at the centre there is a hole; so, that water gets actually we have to supply the water here. So, as soon as the on the top plate, on the bottom plate the fabric is placed; then the top plate is placed and so that to ensure that proper the parallel plate is actually created. So, we have to that this top plate is placed actually at the exactly at the hole; so that the proper parallel plate is created, so 1 2 3 4 5 6 7 8 parallel plates will be created.

And then after placing the water is being supplied through the centre and as the water flow flows throughout the this plane; the capacitance of the plates capacitor plate capacitance of they will form a parallel plate capacitors. So, 8 parallel plate capacitors will be there created and as the water flows through that the capacitance of this capacitor will get changed. Initially there were dry plate, dry fabric; so, as the water flows. So, that depending on the amount of water travelled or length of water travelled; the capacitance will get changed.

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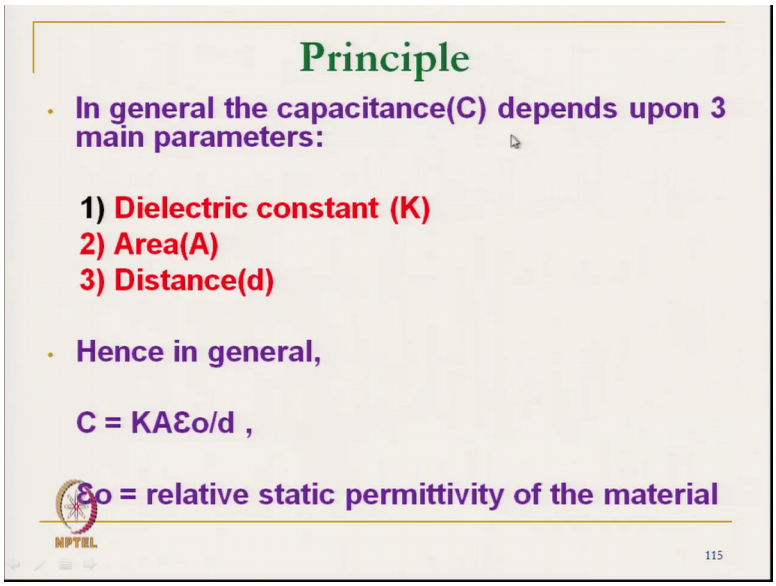

So, this; so the capacitance depend upon the 3 main parameters, dielectric constant of the material, the area of the material and distance. So, hence in general capacitance equal to K multiplied by A multiplied by the static permittivity of the material, divided by the distance of the material that is the thickness of the material. So, that if we know all this parameter and we can measure the capacitance.

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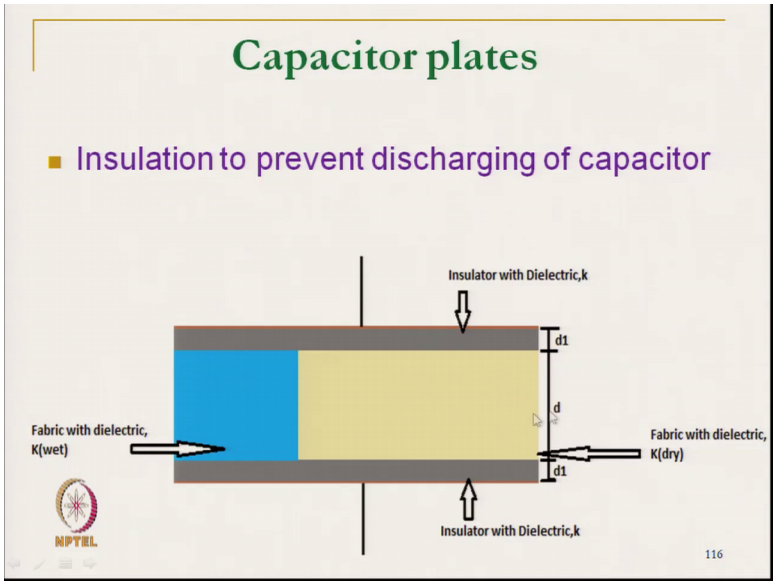

So, this is the basic principle underline principle is that; initially suppose this is the plate this one is the dry material and d 1 and d 2 are the thicknesses of the plates top plate and bottom plate and d is the thickness of the material.

So, total thickness we can measure and at the dry condition without any water content; we can measure the reference capacitance of the material that has to be measured. And another system is required in this principle calibration; we have to actually measure the capacitance of the completely weight fabric.

So, completely weight fabric that is one value the capacitance of weight and capacitance of dry, 100 percent dry material. And depending these 2 reference value as soon as the water flows through the fabric; the change in capacitance value can be recorded and with the some equation one can measure what is the distance travelled by the water.

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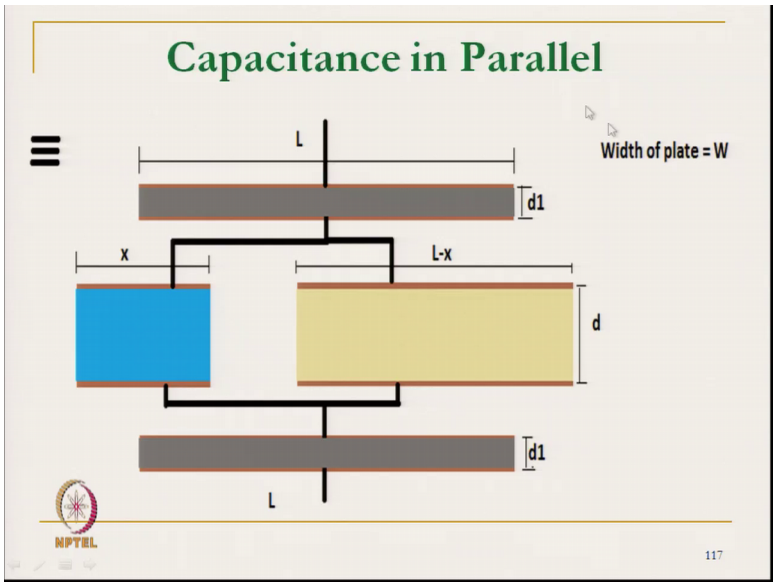

So, this is the basic principle, x is the distance travelled by the water and L is the total distance. So, remaining distance dry fabric is the L minus x, d 1 and d 2 are the thickness of the plates, d is the thickness of the material fabric; W is the width.

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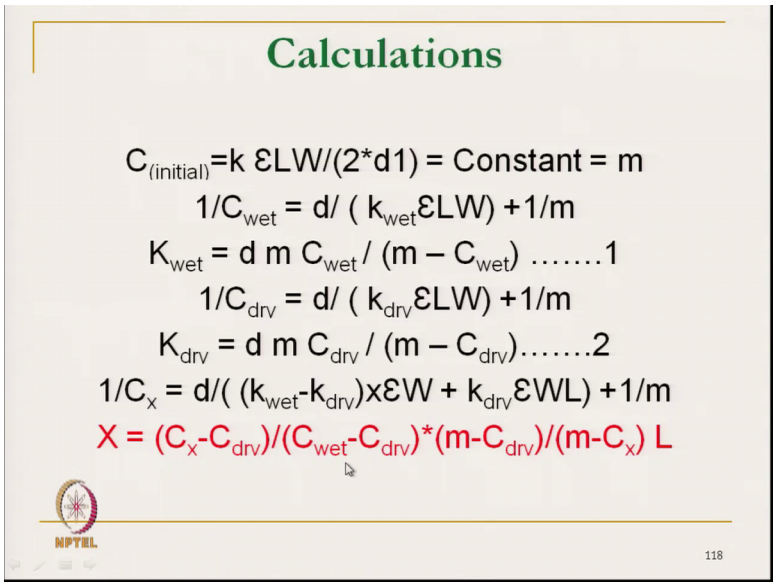

So, using all these data; one can calculate the initial thickness. So initial capacitance with the dry material which is m; so one can and similarly; so, if you see the wet, it is completely wet if you want to measure capacitance; 1 by capacitance of wet using this is the standard form a and m is the it is a constant, constant for that particular system without any material.

So, d 2 d 1; so without any fabric; so if we do not use any fabric this is d 1 bottom plate this is top plate of the capacitance capacitor. So, 2 d 1 is used as a when there is no fabric no water nothing. So, this is the constant, m is a constant for the particular system; so, to eliminate that function. So, this is wet when it is completely wet we can measure the capacitance value.

And K value we can measure; similarly for measuring the reference, another reference which is it dry. So, K dry we can measure and using these 2 values capacitance wet and dry and actual capacitance value what we are getting that from there we can measure the length travelled. So, by using this equation that X value we can measure; X is the length travel in the waterfront; so, for at we have at present in this instrument we have 8 different parallel plate capacitance.

So, we can get different X value for different capacitance capacitor plate. So, it will we can get the complete plot online; at real time we can plot this online that is real time plot of capacitance that is waterfront through the fabric and the motion. Advantage of this

instrument is that we can measure the total flow at any thickness irrespective of the thickness we can measure the capacitance.

So, from very thin fabric to even very thick non woven fabric we can measure and this also the x value it gives the what is the amount of what is the length of the water travelled that can be measured.

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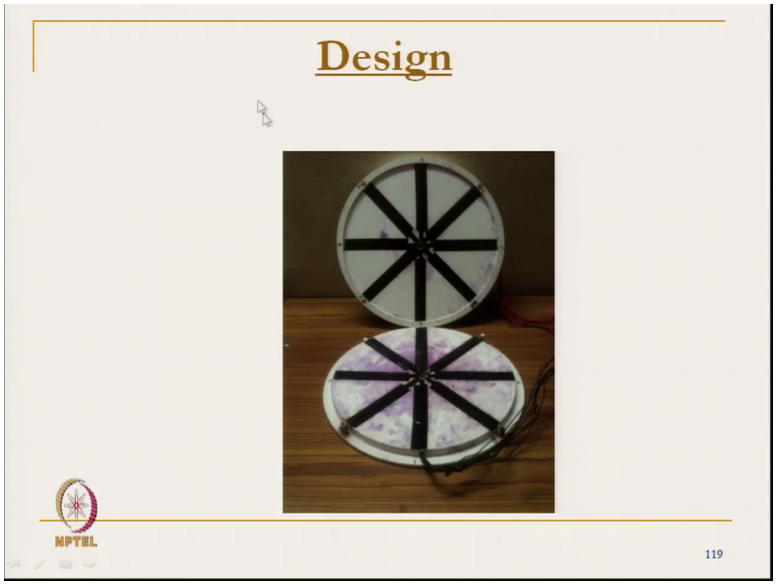

So, this is the instrument here; so this one is the bottom plate and this is the top plate and in between we can place the fabric. Let us see the one video clipping this is the prototype which has been developed in the laboratory.

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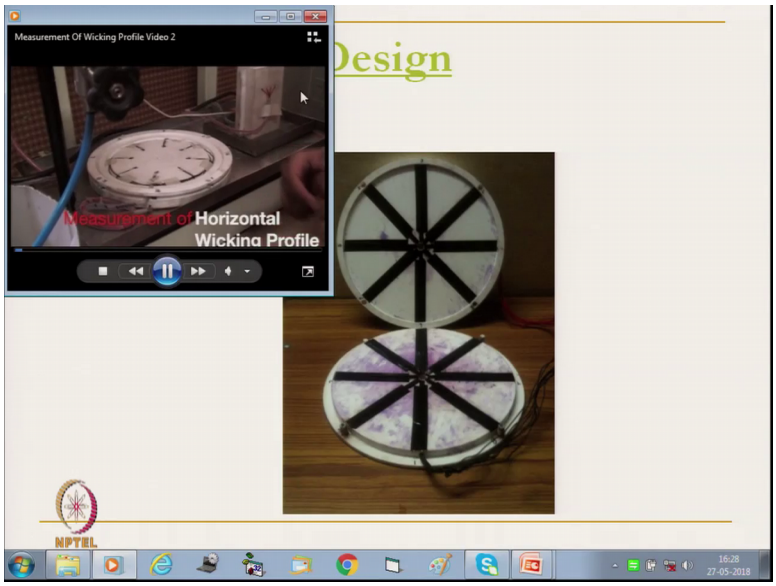

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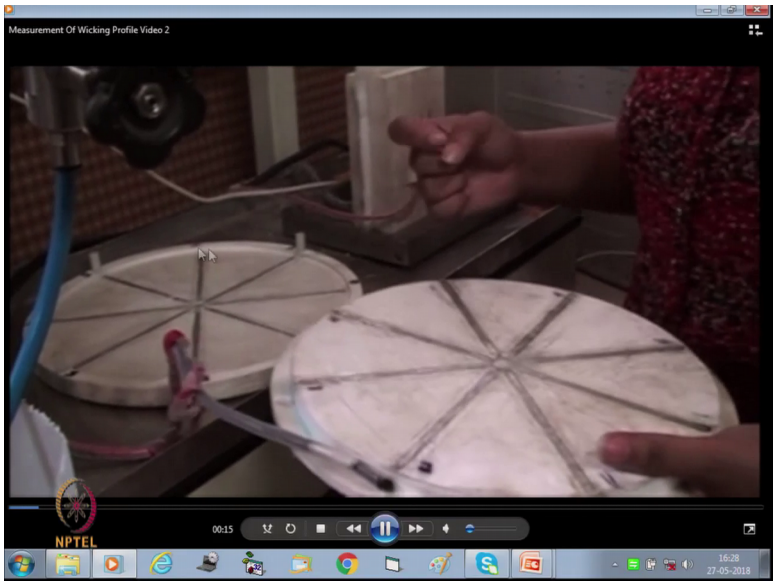

So, this is the top plate, this one is the bottom plate.

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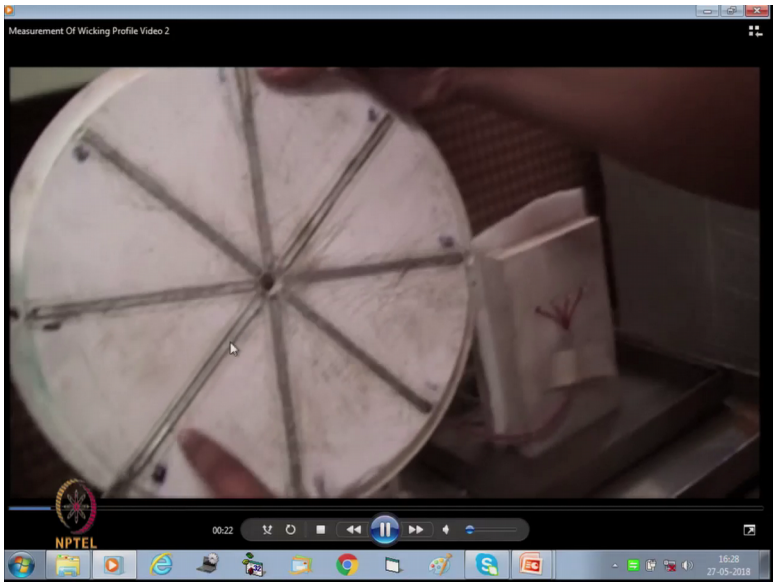

And with this slots; one can these are the capacitance plate similarly at the bottom these are the capacitance plate and with this slot one can place. So, that proper there is no shifting of the capacitance plate proper capacitance have that capacitors are formed.

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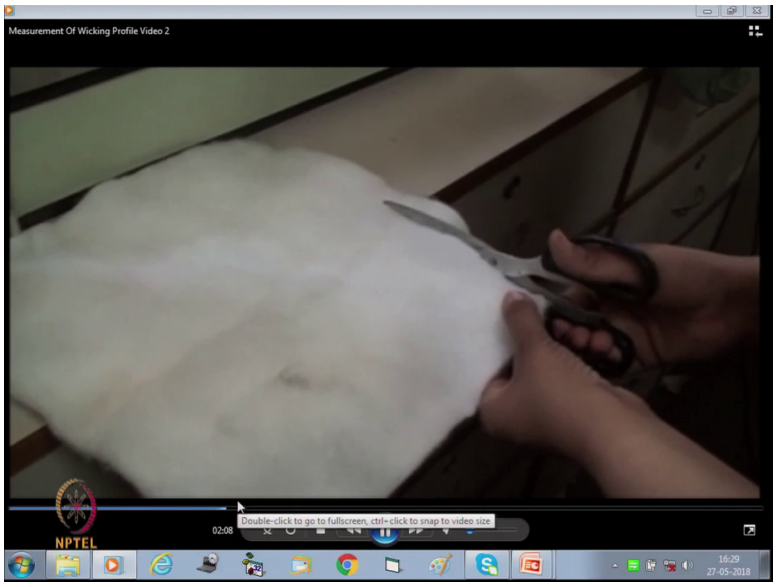

Now this is the way and now, the fabric samples; fabric samples any fabric samples can be used here it is showing the thick non woven fabric and another advantage it need not be the exactly the same. So, one even without cutting the fabric we can use. So, it is a

non destructive type testing is there; so, we have to place the fabric on the bottom plate and then top plate has to be we can use.

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So, this is the bottom plate and top plate is placed on that.

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And after only and we can use some load also to eliminate any; what any air bubble and any space extra space, now this is the water supply.

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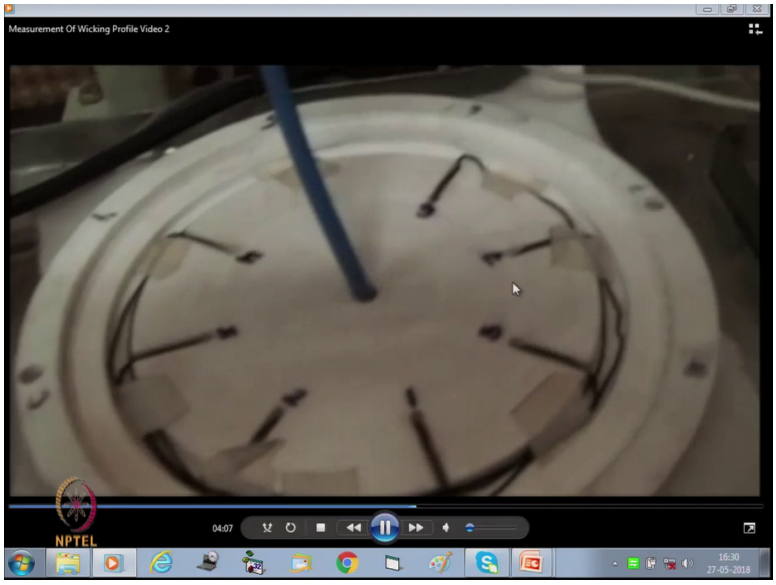

So, we can control the water supply depending on the requirement; the controller is there.

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And as soon as the water supply starts; the computer screen will show the water fault; the water controller is there.

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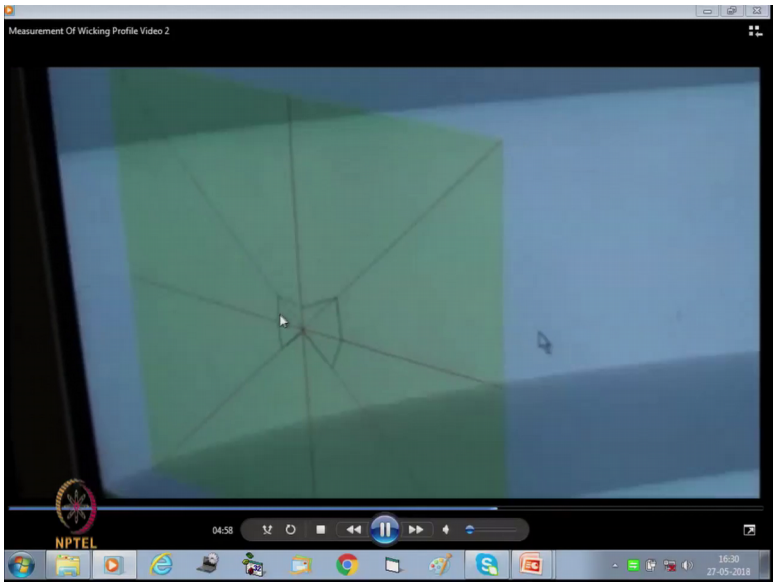

Now, this is the water travel point.

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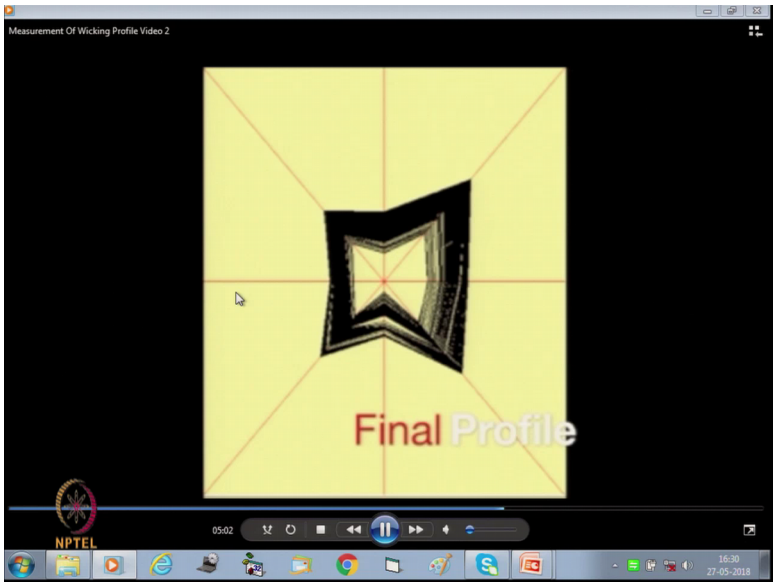

So, at different time, with the time at different direction how the water is flowing that can be measured.

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This is the instrument which is and after every test we have to basically wipe out the excess water and then so, to keep it to eliminate any air.

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Similarly, the same principle is being used to measure the vertical wiki where the capacitance plates are in vertical direction.

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Principal is exactly; so, then signal amplification circuit is there.

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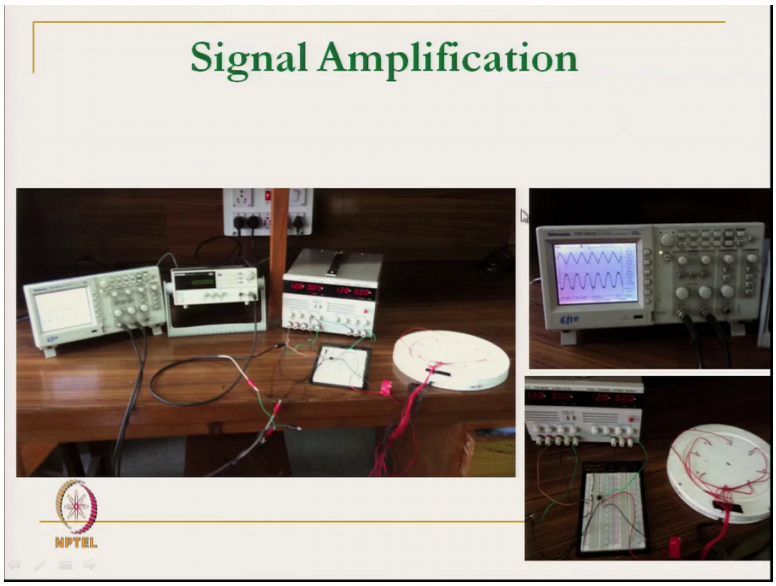

So, to get the exact value of the waterfront; so, now, we have completed the liquid flow through the fabric. In next class we will start the moisture vapour transmission related phenomena and how the moisture vapour gets transmitted through textile material till then.

Thank you.