Science of Clothing Comfort
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Lecture – 04
Understanding Clothing & Clothing Comfort (contd…)

Hello everyone, now we will continue with the fundamentals of human thermal physiology.

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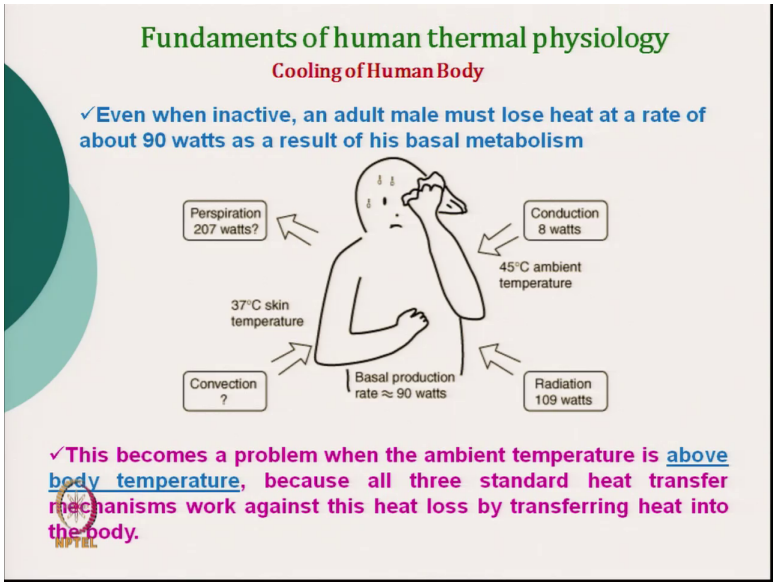

So, earlier lecture we have discussed the condition where the environmental temperature is lower than our body temperature and the temperature was actually 23 degree Celsius. Now we will discuss one situation which is just reverse opposite, where environmental temperature is more than the body temperature.

Now, so, this model it shows that environmental temperature is 45 degree Celsius and at 45 degree Celsius the skin temperature is considered to be around 37 degree Celsius. It is not 34 degree the lower temperature skin temperature is there, when the environmental temperature is lower than the body temperature. But when temperature rises above the core temperature like 37 degree Celsius, always our human our physiology tries to keep the temperature at 37 degree Celsius equal to core temperature.

So, here the skin temperature is 37 degree Celsius and even the temperature increases or body physiology always tries to a control the temperature, maintain that temperature by different physiological activities like sweating and all. So, 37 degree Celsius is considered to be the skin temperature at that 45 degree Celsius environmental temperature.

Now, here we can see that the all the common thermal transmission processes, like conduction, conve ction and radiation all this activity all this processes actually transmits heat from environment to the body and our body also generates extra heat of 90 watt, that is basal production of heat.

So, even when we are inactive so that also that time we produce 90 watt heat metabolic heat this becomes a problem, because we are actually receiving heat from all the directions.

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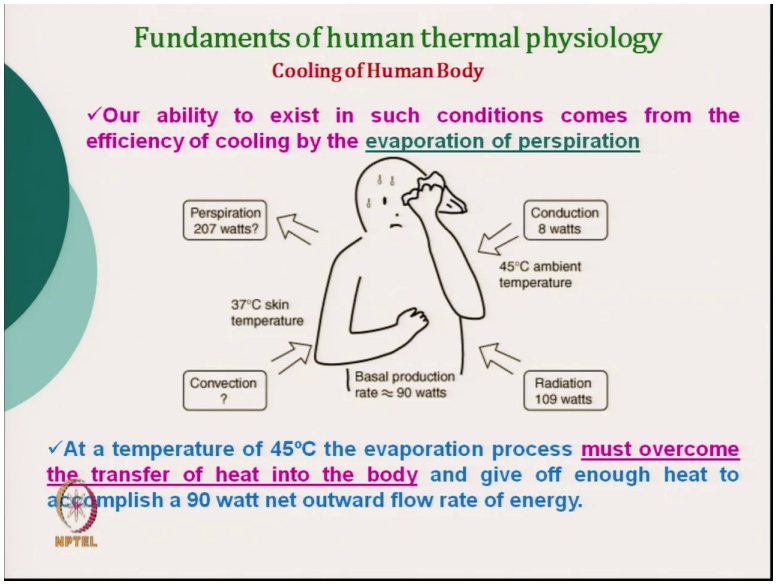

So, basic we have to now release heat we have to balance the heat, so our ability to exist in such a condition is only by the cooling through evaporative perspiration. So, that is the only activity through which our body can be cooled down. So, at a temperature of 45 degree Celsius the evaporative evaporation process must overcome all this heat which we are receiving.

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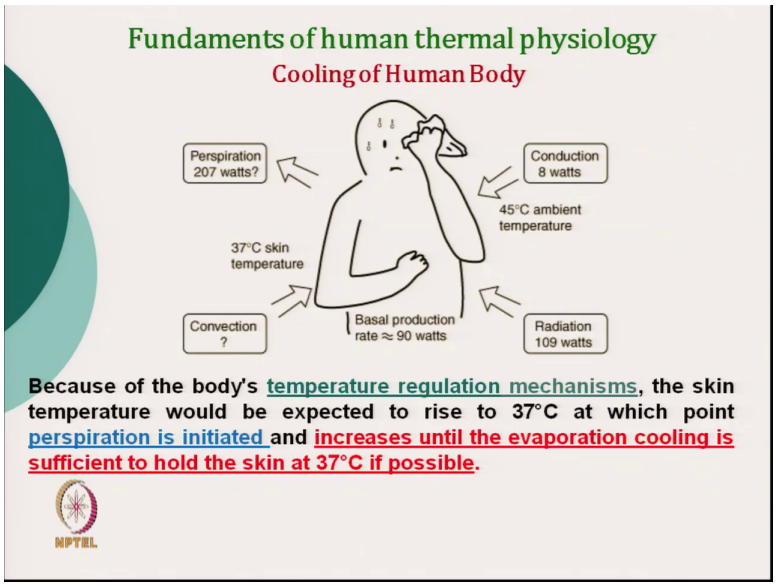

So, our body temperature is as I have we have discussed that is skin temperature is 37 degree Celsius, the skin temperature would be expected to rise to 37 degree Celsius at which point our perspiration will initiate. It will get initiated at 37 degree Celsius and the as we have discussed that as the temperature goes on increasing, the perspiration will also increase and to maintain the skin temperature at 37 degree Celsius. If possible if it is not possible then we have to see the alternate way we have to see some this is the physiological process which will always try to keep the temperature maximum temperature 37 degree Celsius.

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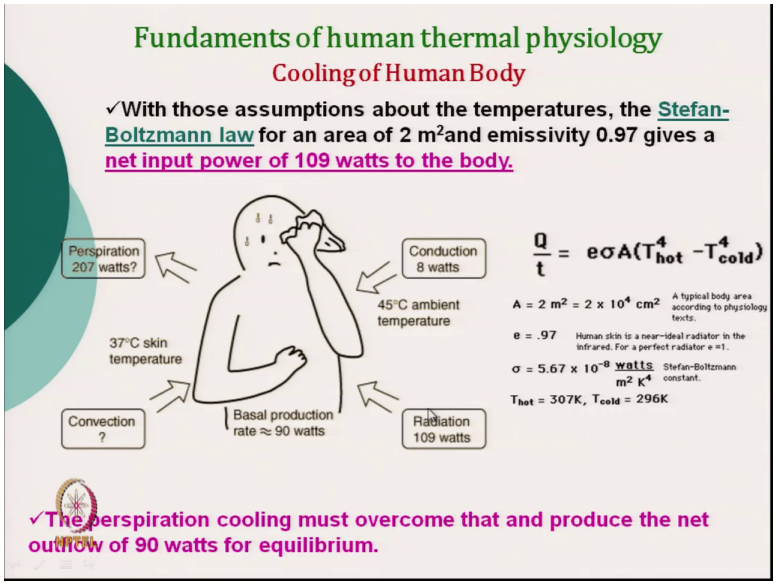

So, now as we have already seen in case of cooling condition, the similar assumptions will keep here like our body area total body area is 2 square meter and emissivity is 0.97 and if we use the same equation this equation. So, we will get the overall net input of heat by radiation which will come to be 109 watt.

So, here the here T hot means here what is the T hot; T hot means environmental temperature which is 45 degree Celsius; that means, 273 because this has to be in temperature has to be in Kelvin scale. So, 273 plus 45 this will become T hot will become 318 degree Kelvin and T cold that means, 37 plus 273 it will become 310.

Now, using all this parameters plus T hot as a 318 and T cold as 310, if we see we will get the value approximately 109, now here you can also see. So, if it becomes 50 what will be the heat radiative heated, so that way you will see the it is a radiative heat transmission through our to our body or from our body, it is always measure among.

Now, in suppose we are in front of fire. So, their heat temperature may be more than 100 degree Celsius more may be 150, 200 degree Celsius. In that case you can imagine the level of radiative heat. So, there we it is very difficult to survive without any clothing, in that case we have to use some special clothing that we will discuss later. So, after radiative heat so then it comes the main activity which is cooling by perspiration.

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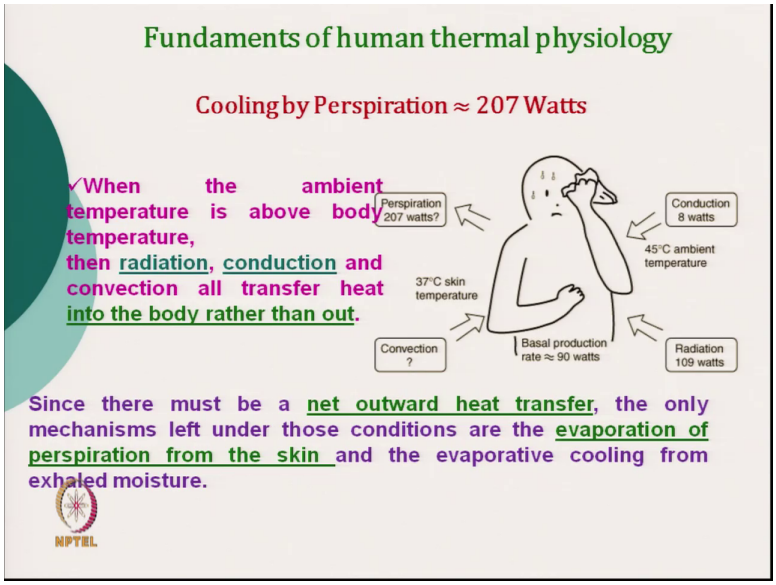

So, here in earlier case at the room temperature when room temperature is 23 degree Celsius, we have assumed that we have seen that in sensible perspiration is around 600 gram per day. But when temperature becomes say 45 degree Celsius that it people we will start sweating, that in that case the total liquid total fluid or total moisture transmission will be approximately 7.5 liters per day 7.5 that is there is an it make assumption this may be more or a little bit less than that.

So, when the ambient temperature is above the body temperature, then the radiation, conduction and convection all 3 common mechanism transfers heat transfer heat to our body ok. Since there must be net outward flow because, net outward flow means 90 what we produce that heat has to be flown out. So, the only mechanism is the perspiration, so perspiration has to be very high so that you can get the cooling effect.

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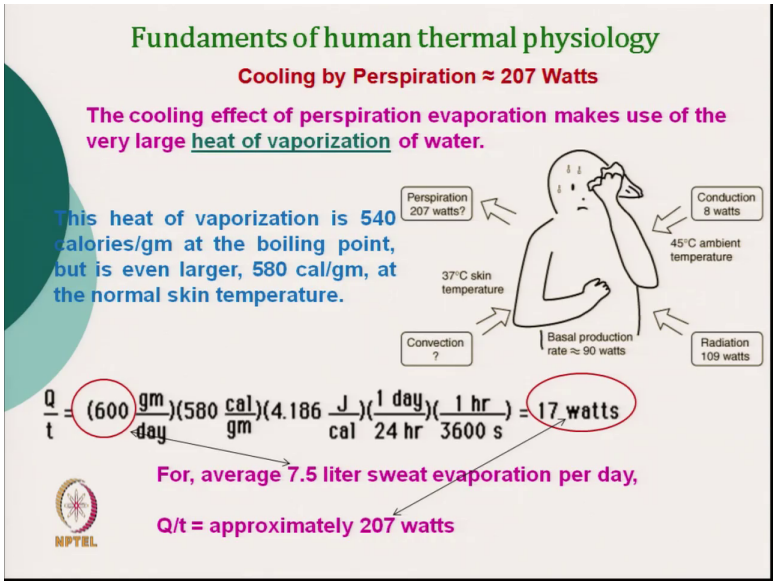

So, if you see that total perspiration here

$$\frac{Q}{t} = (7.5)Liter\left(580\frac{cal}{gm}\right)\left(4.186\frac{J}{cal}\right)\left(\frac{1}{24}\frac{day}{hr}\right)\left(\frac{1hr}{3600\,s}\right) = 207watts$$

Now consider, we are we do not prosper we stop perspiration due to something; that means our body core temperature will start increasing then we cannot survive. At the same time suppose we have we are we have used wrong clothing, which is not allowing our body to that sweat to get evaporated in that case we will not feel comfortable.

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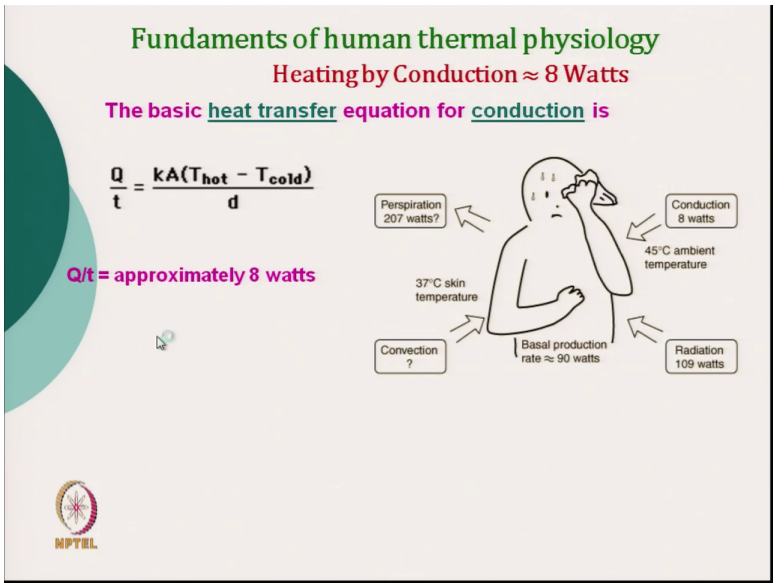

So, then comes the conduction, conduction is all always a earlier also you have seen it is always it is a insignificance 8 watt conduction and this you can we can get from the earlier value T hot becomes that your 318, this is 310 and the similar equation we can get 8 watt. So, Q by T approximately it is 8, earlier it was we have seen I think it is a 11.

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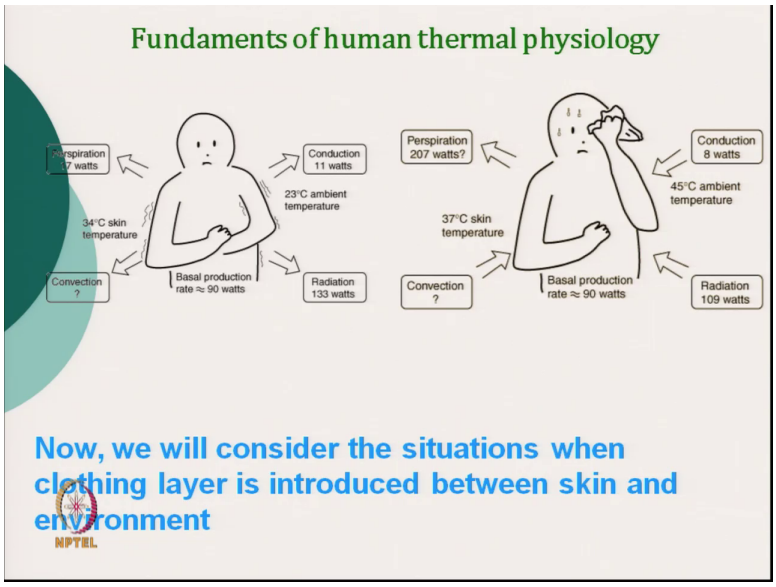

Now, what we have seen here till now unclothed person in cold condition when room temperature is 23 degree Celsius and also in warm condition when room the environmental temperature is 45 degree Celsius. This we have seen the heat flow how to calculate the heat flow and how to balance the heat flow how the heat gets balanced.

Now, this is not the actual situation, actual situation is that we have to use some clothing and then that we have seen now we will consider the situation when clothing layer is introduced between skin and environment. Till now what we have discussed the skin is directly interacting with the environment, now clothing layer has come into picture and we have to be comfortable.

Now the situation now comes this is the situation where we have used we are using one cloth layer and this is the skin and from skin earlier you have seen directly the vapor gets transmitted to the environment no issues and if it receives it is receiving directly.

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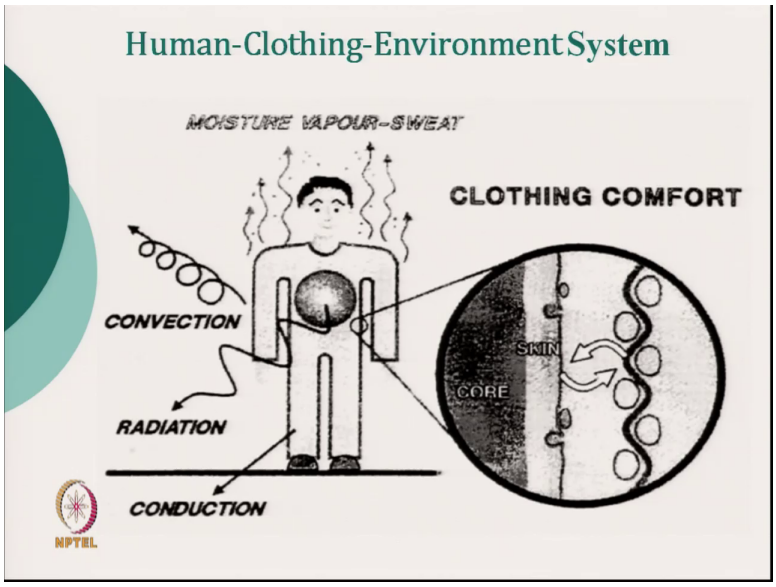

Now, our clothing has to do has to perform its duty, now the thing is that if it is we are talking about the moisture transmission moisture vapor transmission. This is suppose it is a vapor transmission now the there is no free transmission of moisture vapor, this clothing has to be such that that it is not restricting the moisture free moisture flow in the vapor form.

So, there are mechanisms that we will discuss that through clothing how the moisture in vapor form gets transmitted, even if it is a liquid form then it has to transmit from inner layer this is the inner layer; inner layer to outer layer. It has to transmit from the inner layer to outer layer minerals and from there it gets evaporated. If it is heat then clothing layer has to transit heat from the inner layer to outer layer. Now it is talking it is about the temperature when the environmental temperature is lower than our body temperature.

Now, in higher temperature like 45 degree Celsius or 50 degree Celsius, we have seen that the radiative heat is actually it is a entering towards our heat. Now clothing is not there we cannot do anything it directly enters into our body skin through the skin, now here clothing's function has to be there it has to actually reflect back the radiative heat. So, radiative heat it has to stop at the same time the to make to keep our body cool, it has to transmit the liquid moisture or perspiration or vapor it has to transmit out the moisture to keep our body cool.

So, here the main environment is this is the in between skin and the clothing that portion it is known as the micro climate. So, it is not the environmental temperature which is effective, which is actually giving us comfort feeling it is the microclimate which is important. So, the microclimate temperature and humidity which is directly actually interacting with our body.

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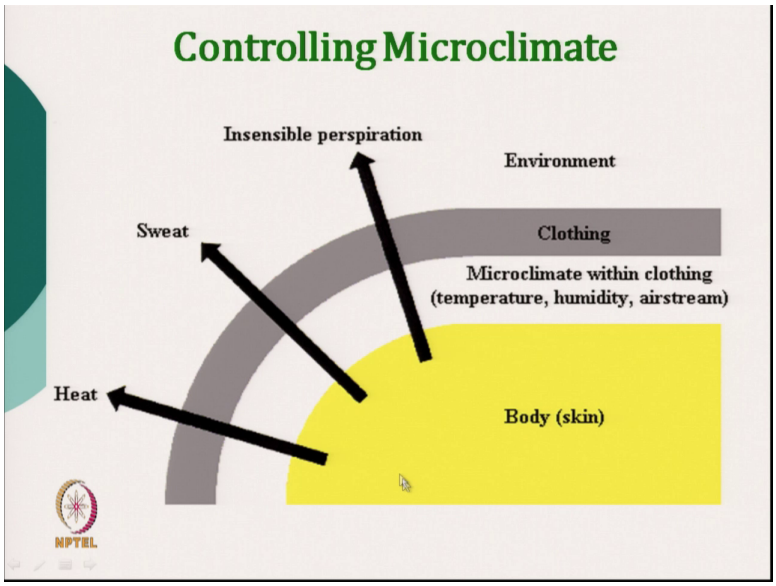

So, this is the picture we can show this is ours body and this one is skin and here is the clothing and through this clothing we transmits the heat, sweat and insensible perspiration and the microclimate which is the temperature of microclimate, humidity and air stream which actually gives our comfort feeling. That is important that controlling the micro climate is important and it is controlled by the proper selection of clothing. Now, if we see what our target is, what should be our target? Our target at microclimate should be 32 plus minus 1 degree Celsius that is the temperature we should keep our microclimate temperature time.

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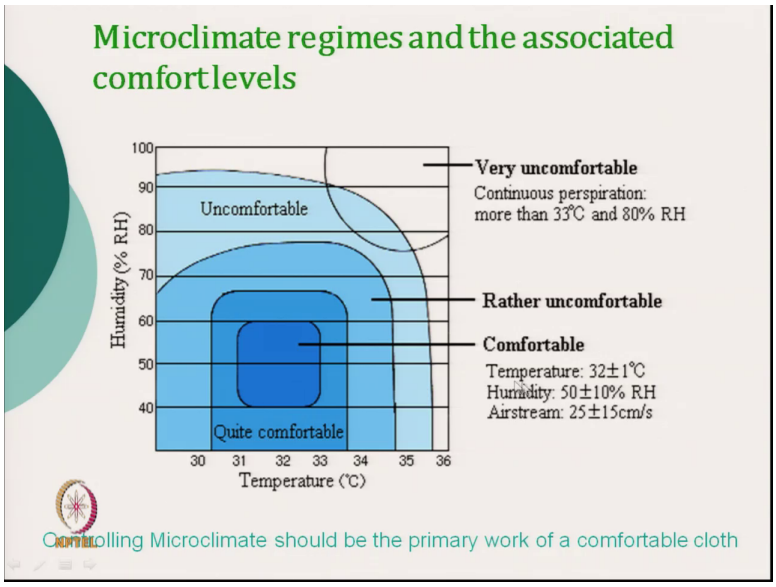

As we have discussed like our environmental temperature if it is a 25 degree Celsius, we have feel comfortable, but at that temperature environmental temperature if it is 25 degree Celsius if you see the microclimate temperature is around 32 33 degree. So, this is the zone where micro climate temperature is most very comfortable zone. So, that is our and our humidity of the micro climate we should always try to keep 50 plus minus 10, that is 40 to 60 degree.

Where 60 percent relative humidity that we have to always try to keep, that is the most comfortable zone and if we cannot, so this is acceptable zone. This is the ne is acceptable zone and then but a very uncomfortable we will see it is a high humidity if and the temperature high temperature. This is the most uncomfortable zone, but here if you see at 36 degree Celsius, at 36 degree Celsius if your humidity at that temperature even at lower humidity you will feel uncomfortable.

Similarly, at say 30 degree Celsius temperature if your humidity is very high we will feel uncomfortable. So, that this we have already experienced, but our clothing has to be such that we can control our microclimate humidity and temperature as per our requirement that is to keep our self comfortable at least thermo physiologically comfort.

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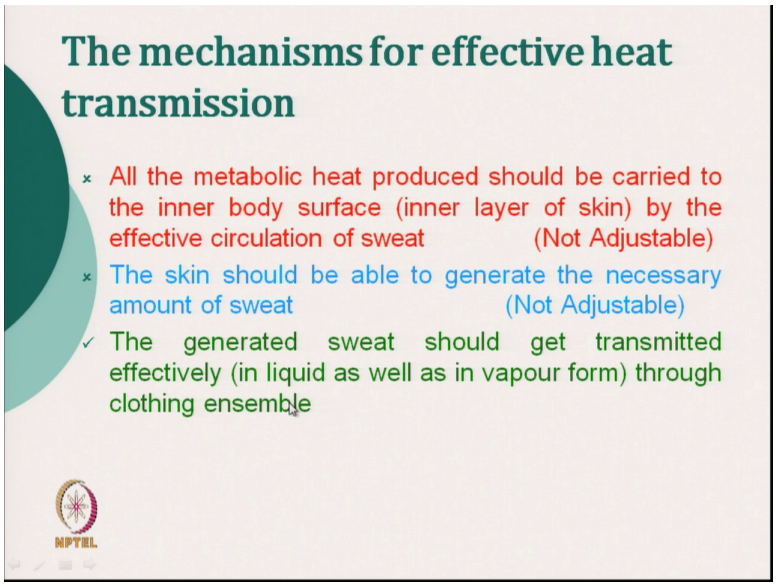

Now, the mechanism of heat transmission that is our body generates heat through metabolic activity and through skin it has to come out and which is we cannot adjust this is there in the body physiology we cannot control. Similarly skin should be able to generate necessary amount of sweat that also we cannot adjust, but the thing which we can address adjust our clothing structure.

Depending on the requirement we can adjust our the generated sweat, should get transmitted through our clothing ensemble in the form of liquid or in the form vapor and our cloth that clothing should be able to transmit all this vapor and liquid to keep our self comfortable. To keep the microclimate with the required zone required range this can be controlled by proper clothing.

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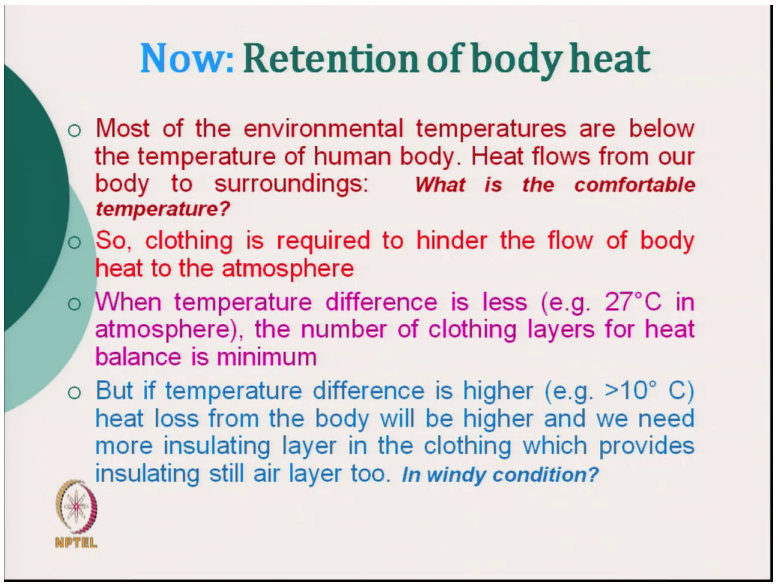

Now, earlier we have to we have discussed that body heat that clothing is actually acts as a barrier thermal barrier ok, it hinders the heat flow. But most of the cases will see it has to retain the body heat because, most of the temperature or environmental temperature is the lower than our body temperature. In those cases the clothings performance is to retain the body heat, it is hindering the body heat flow it is good because, it should retain the body heat.

So, the clothing is required to hinder the flow of the body. Sometime you will feel that the hindrance of the heat flow it is not comfortable in activity, but it depends on the environmental temperature. When the temperature difference is say low say 10 degree the 10 degree means atmospheric temperature is 27 degree, in that case the heat flow rate will be slower.

So, that we can have proper clothing with that with the normal clothing, but the if the heat flow is at very high rate, means the environmental temperature is low say 0 degree Celsius in that case heat flow rate will be very fast. So, in that case retention of body heat is very important and clothing can do that and in case of windy condition it is more severe, windy condition the heat flow rate will be because they are convective heat is very convective heat flow is very high. So, that way so in that case you need to protect to will discuss somewhere, so that how to control the convective heat flow..

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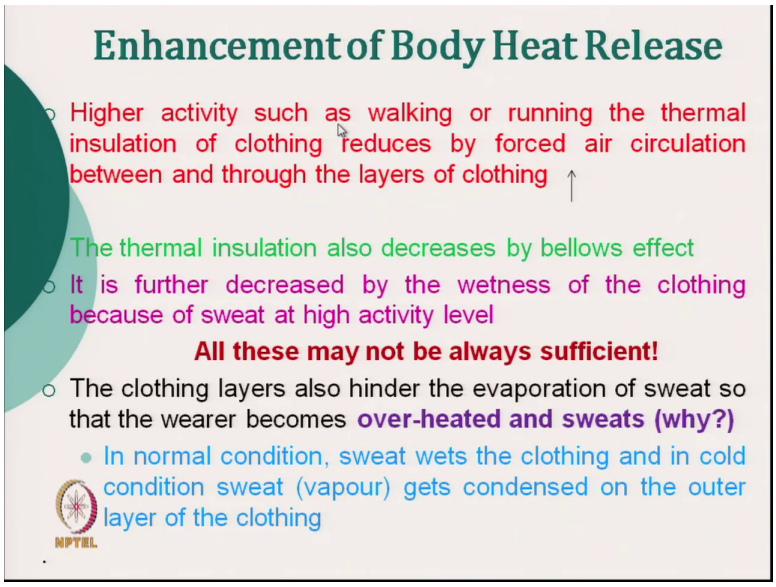

So, enhancement how to enhance the body heat release ok, body heat release it is a basically high activity at higher activity such as walking and running the thermal insulation of clothing reduces by forced air circulation. So, it so initially the body activity higher it increases the heat generation and then it releases it reduces by human activity which is forced circulation, then thermal insulation also decreases by bellow effect that was also already you have discussed it is a pumps the fresh air and that hot air its comes out from different openings and it is further decreased by wetness of the clothing.

So, if when the cloth gets wet, so it is thermal transmission it is a thermal transmission is very high. So, it is thermal resistance become low, so it releases heat at very high rate. So, that is the body heat release is in the all this may not be always sufficient because, see the clothing layer also hinders the evaporation of sweat.

So, heat transmission is ok these are the activities we have seen, this 3 activities by which we can deduce increase the body heat release. But sometime that clothing layer it hinders the free evaporation of the sweat. So, that also creates the body increase the body heat because, in normal condition sweat wets the clothing and clothing and the in cold condition it gets condensed. So, that it gets condensed and, but all this in either cases the sweat removal removes less heat from the body than it does when it is able to evaporate from the skin bare skin that we have discuss basically.

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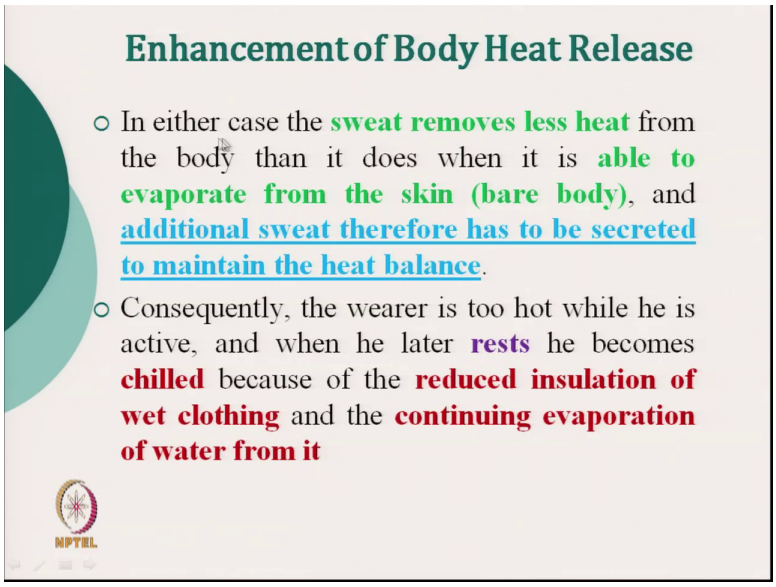

So, with the bare skin whatever sweat is removed, it is not we cannot expect that if the same sweat will level of sweat will be removed when it is clothing. So, it is the sweat releases always less. So, we have to enhance by designing the clothing and additional sweat therefore has to be secreted to maintain the heat balance. So, means we are sweating, but we are not that the sweat is not getting removed that means, body is not getting cooled. So, what happened to keep our body by physiology we start releasing the more sweat, so we start sweating again.

So, consequently the wearer is too hot while he is in active, so this phenomena we have observed in sports. Normally in when the where sports person is in active condition he is very he is although it is a he is sweating he is actually he is sweating and when he later raised. Suddenly when it is coming out he becomes it is chilled effect because his cloth is wet and his activity is reduced he is stopped his activity; that means, he will start releasing the heat very high rate. So, what happened?

So, he will immediately he will start feeling chilled, that is why when he high; after high activity to eliminate any shock thermal shock, normally players have been rapped with some cloth because. So, that sudden actually it gives the buffering effect, so that it is sudden shock is not there because if body is warm it suddenly started releasing the heat.

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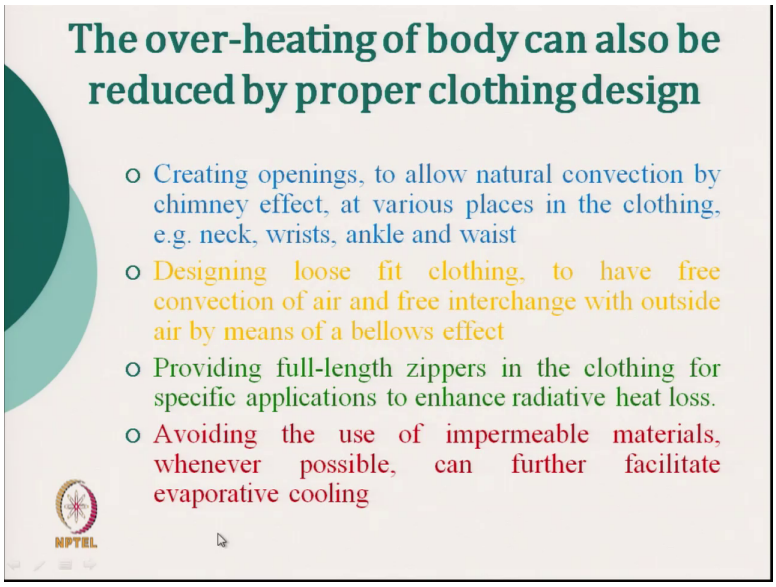

So, the overheating of body can also be reduced, but proper designing of clothing. So, that we can do by proper designing what is that creating opening. So, we can create different opening like in a wrist, neck, ankle, waist we have seen in the sports clothing design, there are different portion where the different openings have been created, to enhance the body heat release.

So, if we suppose in a neck portion or some portion you will see it is not design basically, all though it seems it is designed, but some openings have been created like your knitted openings. But these are created due to enhance the body heat release. Like designing loose fit clothing ok.

Loose fit clothing and in during activity during activity we have seen, the in high active clothing like soccer or in a tennis the clothings are not a tight fit it is a loose fit clothing and if you see it is a with a short duration like sprinting and all this there it is tight fit long duration activity. It is a loose fit because see this lose fit clothing to have free convection of air and free interchange with the outer air.

So, that free convection takes place, that is why it is a; it enhances the body heat release providing full zip. So, if you are extremely hot just remove , so that you can cool down quickly and avoiding the use of impermeable material wherever possible can further. So, you do not used we should not use the impermeable material. So, that it hinders the flow free of flow of liquid moisture or moisture in vapor form.

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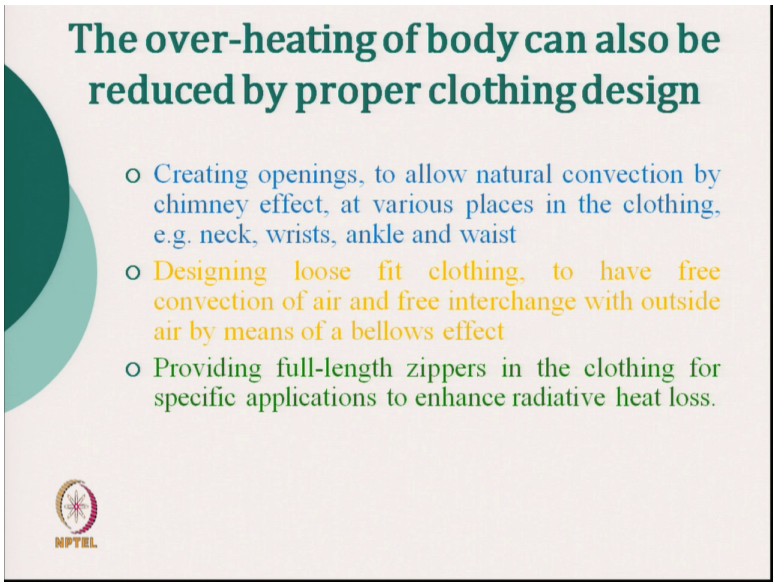

So, if we take care of all these steps, then we can actually enhance further body heat release ok. But for our protective clothing for special protective clothing when we use we cannot use the single layer we have to use a multi layer.

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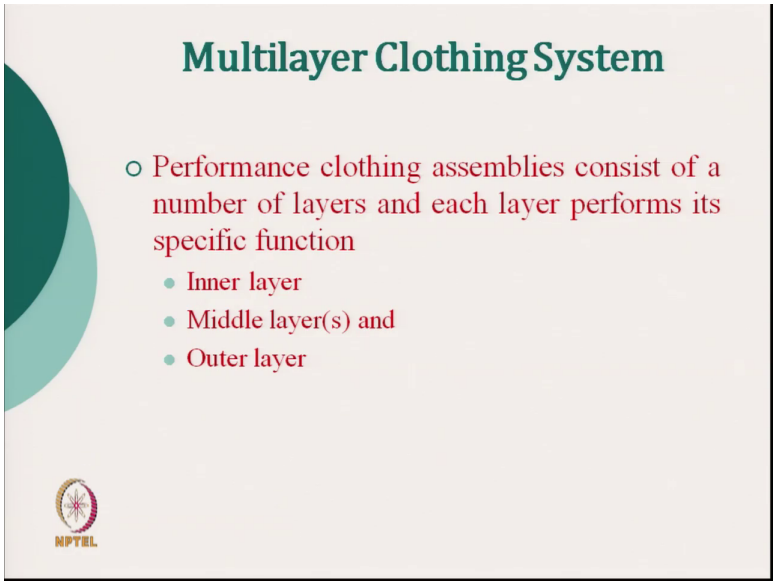

Multi layer clothing and multi layer clothing they have their different activity they different function.

So, here the performance clothing assembly consist of a number of layers, the performance clothing it has to perform specific activity ok and then at the same time we

have to keep our body comfortable. So, there are typically 3 layers is outer layer, middle layer and inner layer.

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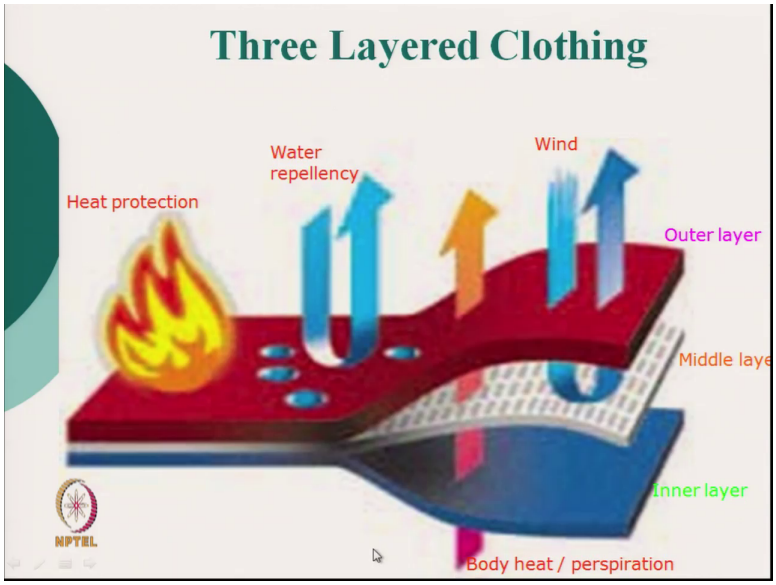

So, this is the inner layer as a typically and this is outer layer, suppose we are using this as a fire protecting clothing. So, air outer layer will perform the heat protection like or a 1 is the it should be fire proof, it should be reflective coating you must have seen that there are some aluminized coated fabric layer is given which is an outside, because that will reflect outwards a radiative heat so outer layer.

If it is say water proof we can have water repellent finish. So, there are different this actually this is actually functional layer, then middle layer is there and inner layer inner layer actually it is a tactile sensation we which is in contact with our body.

So, that has to be soft and it has to be touch has to be very comfortable and you will see that the body heat and perspiration should actually flow through all these 3 layer, otherwise we will not feel comfortable. So, these are the different layers and we will see different research studies later where we will see that the different layer they have their functions.

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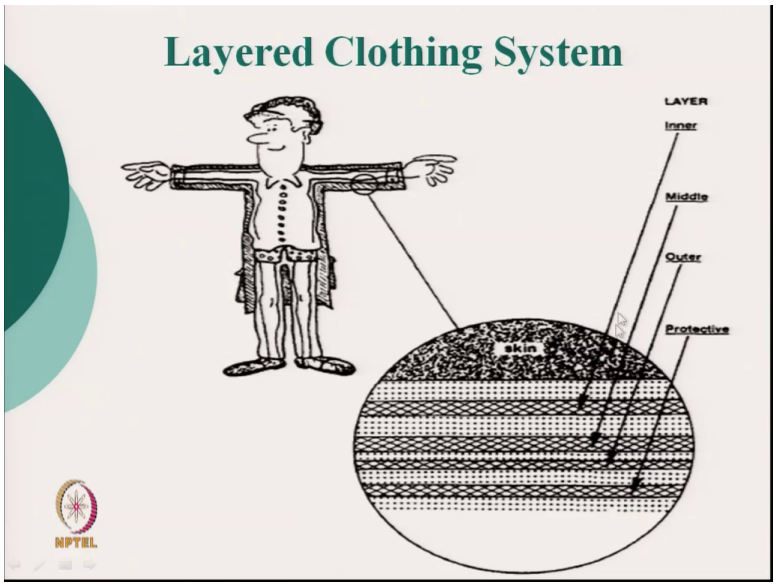

Now, this is another layer it is an inner layer, this is skin inner layer middle layer outer layer and protective layer, some time even after that we use some protective layer. Like your hazardous environment and all these thing and in between this layer we have seen these are the stilll air layer, so we can create that layer.

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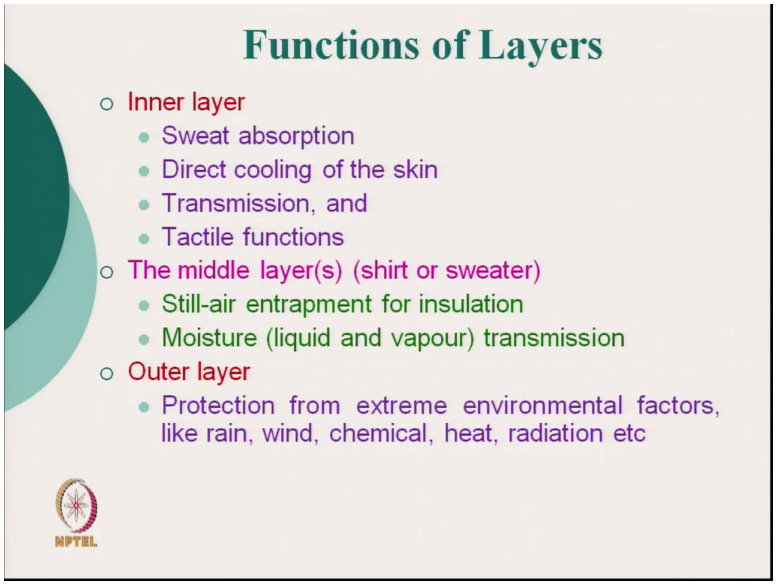

So, inner layer has got its function it is main function is to sweat absorption from the skin to keep our self comfortable, direct cooling of the skin transmission of heat and moisture and tactile function so touch. If it is not comfortable suppose we there is a prickle sensation some itching sensation, some harsh feeling, then it will not (Refer Time: 29:34). So, that inner layer has to be all this characteristics, then middle layer it is

basically it is insulating layer 1 is insulation it provides insulation; insulation from say for extreme cold climate. The body heat should not go out for extreme hot climate body the outside heat should not come inside.

So, this layer is very important it creates insulation by actually having steel air entrapment and then moisture transmission layer. So, it is a liquid and moisture vapor form it has to transmitted, so this function of this the middle layer is extremely important we have to select this middle layer very carefully depending on the situation and outer layer is basically basic functional layer.

If it is protection from environmental facts like rain, wind, chemical, heat, radiation whatever may be. So, this outer layer some coating has to be there which will protect us from different this environmental threat.

Now, so now we will we have reached to the last segment of this a session, it is a now step to understand the clothing comfort. So, we have understood the requirement of clothing and we know we have now discussed about the different aspects of comfort and now what are the steps. So, to understand the step, so first we have to know the as we have discussed the customer need the wearers need we have to, so trend analysis we have to do.

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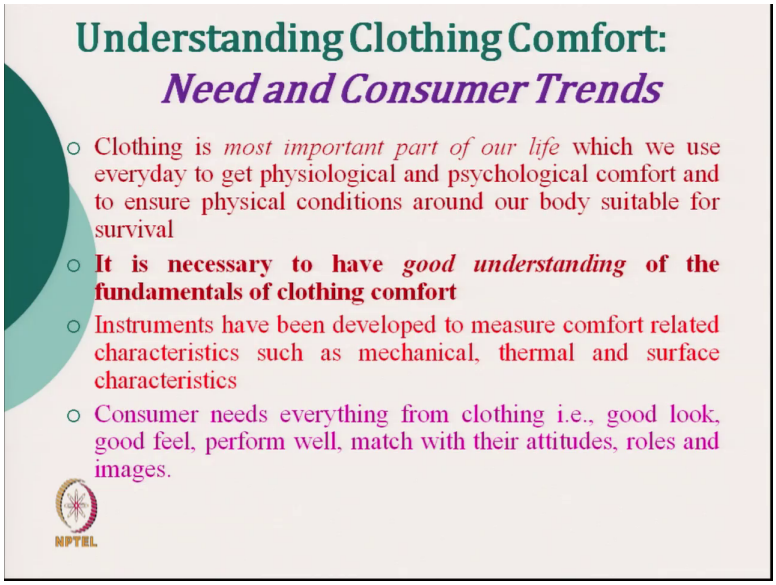

So, it is required to understand their need. So, customer need is now it has become very stringent, it is a good look, good feel, it should perform well ok. So, it should match with the attitude, so though this are the different activities.

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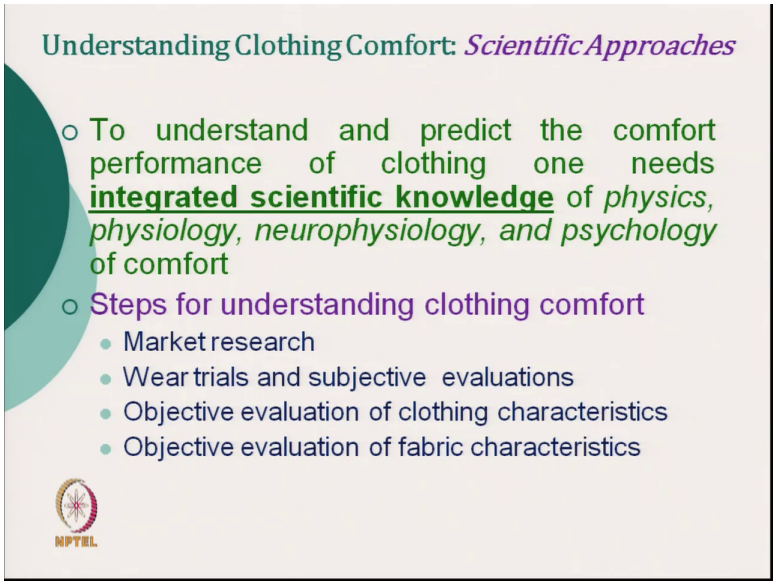

So, for this we should have integrated knowledge. So, physics, physiology, neurophysiology, psychology; so all this we should have integrated knowledge on this. So, the steps of to study understand the clothing comfort is the first is the market research, it goes backward first it is a market research. Then after doing market research you developed clothing and then to it evaluate it by the wear trial technique or subjective technique. Subjective technique means by touch by actually by questionnaire and all this.

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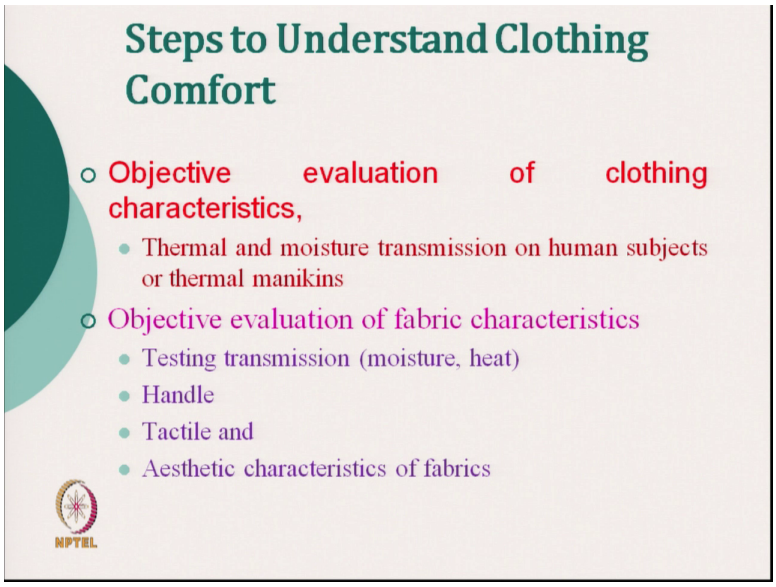

So, this is the wear trial technique then objective evaluation of clothing. So, clothing as a whole we can measure objectively, so with the by using some instruments like manikin thermal manikin. So, you can get the total thermal transmission behavior by thermal manikin and objective evaluation of the fabric characteristics.

So, that all this things we have to do to study to know the clothing comfort. So, what is market research as we have discussed earlier also identification of target group personal interview and consumers survey to gather market information on the particular pure product.

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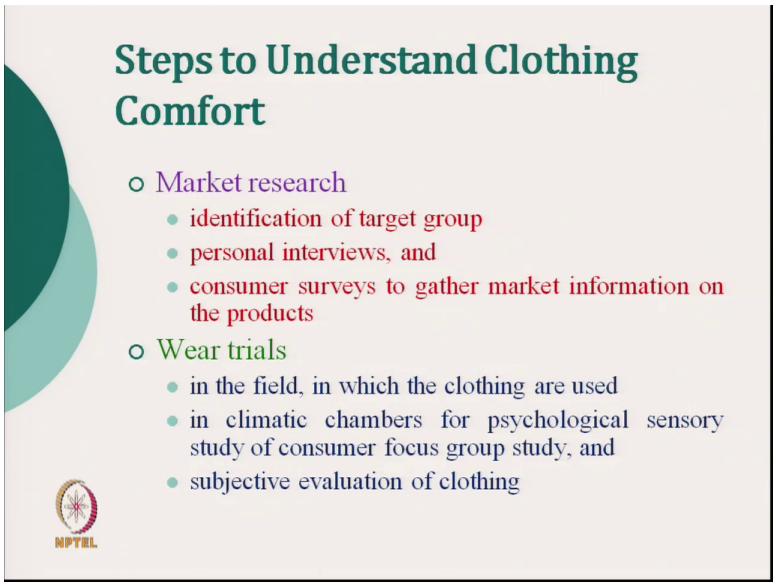

Then wear trials technique wear trial, what is wear triall? It is in the field in which the clothing are used. So, that you have to create the situation like fire fighter clothing we have we have to develop. So, we have developed in the lab we have tested, but it is not it does not help, someone has to wear the cloth he has to go in front of fire exact situation close to that situation then only you can say this is the comfortable one this will work this is called wear trial technique.

You have to stimulate that situation that climate then objective evaluation of clothing, so that clothing has to be objectively evaluated.

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So, after wear trial technique that you got information, then you test it by thermal manikin. So, it is a you prepare clothing the use say that clothing because, the wear trial means you will give you some you will give that the wearer will give us some information this is perfect this is this is gives the proper comfort and other.

But you will not be able to give us the exact value, what is the thermal transmission, what is the moisture transmission that we have to do objectively in the laboratory. So, in clothing thermal manikin we can get the total information about the heat flow; heat flow characteristics and next is the objective evaluation of fabric.

So, objective evaluation of fabric you we can do moisture testing or moisture transmission heat transmission testing ok, fabric handle test we can do and tactile testing we can do aesthetic testing we can do. So, all these things objective testing we can do in the laboratory and we have to integrate all this information.

So, a market research and then your wear trial technique objective evolution of clothing and objective evaluation of fabric characteristics, all these things are linked. If we have we if we can interlink these things then we can actually tell this is the fabric which is comfortable which is comfortable for a particular situation.

So, a fabric if we tell we are we cannot have a, which will be comfortable for all the situation it is not possible. A fabric will be comfortable for a particular in environmental

condition particular person and all these. That is it is a if you say that give me a comfortable clothing it is not possible, the comfortable clothing for at what condition what is the situation what is the environmental condition.

So, this thing this all this interlinking should be there and I think this is the end of this session.

Thank you.