Science of Clothing Comfort

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Lecture – 26
Clothing Comfort Related to Thermal Transmission (contd…)

Hello everyone. We will now continue with the Clothing Comfort Related to Thermal Transmission. In earlier segment we have discussed the different parameters related to human thermophysiological comfort. And also we have discussed the instruments for thermal transmission measurement of thermal transmission like Tog meter, guarded hot plate and instruments for measuring the thermal transmission at the flame at flame condition and radiative heat conditions. And also we have discussed various factors which affect the thermal comfort.

Now, we will start the thermal transmission parameters. So, for any comfort or any thermal transmission related measurement, we need to know some practical parameters because the instruments always give the parameters, which are related to heat transmission directly, but those parameters may not be always used in practical situation. So, for comparison of practical thermal related thermal insulation related characteristics, we need to know few practical parameters.

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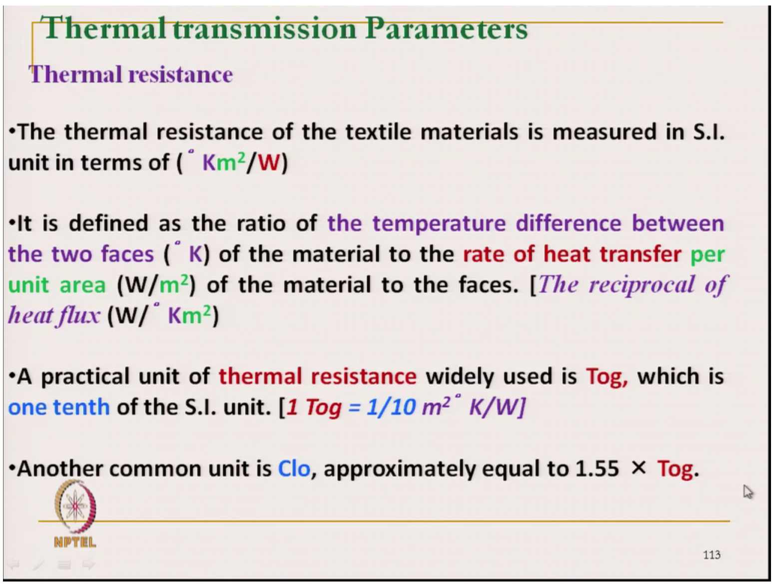

So, this basically what we have learnt till now, this we have studied that the thermal resistance of textile material is measured in S I unit it is in degree Kelvin meter square by watt. So, it is just reciprocal of thermal transmittance. So, what is this resistance as we know it is a defined as the ratio between the temperature difference between 2 faces of material. If in case in our case it is a textile material. So, in degree Kelvin and this with the rate of heat transfer per unit area that is watt per square meter.

So, if we take the ratio of this. So, we will get the thermal resistance. Basically it is a reciprocal of heat flux. The heat flux is expressed in terms of watt per degree Kelvin meter square. So, the thermal resistance measurement that we can we have seen we can measure in the different instruments like in from Tog meter we can measure or by using sweating guarded hot plate. So, a practical unit is used for thermal resistance measurement. It is a called Tog which is one-tenth of S I unit that is 1 Tog is equal to one-tenth of meter square degree Kelvin per watt ok and another very practical unit, which is used for measurement of or expression of thermal resistance of clothing.

So, Clo this term comes from the clothing. So, if we in other instruments like S I unit or Tog, we normally measure the thermal resistance in terms of a fabric form ok in flat sheet form. But if we talk about the overall clothing the thermal transmission about or thermal insulation of overall clothing then we use the term Clo. And Clo there is an approximate relationship it is 1.55 multiplied by Tog is equal to 1 Clo.

So, this derivation will try to see we will do this derivation relationship we will try to derive this relationship.

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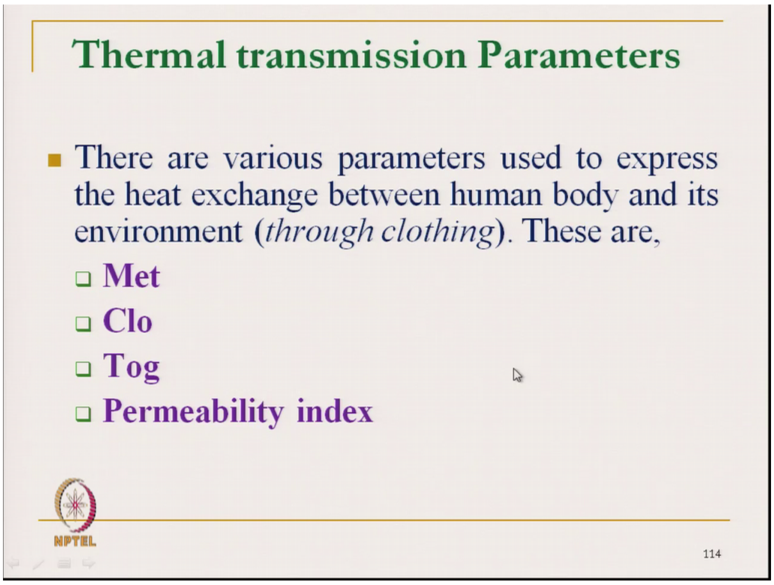

So, there are various parameters which we can express for measuring the actual thermal comfort of through fabric thermal transmission through fabric. So, this are basically one is Met. Met term is widely used in human thermal comfort. Met this term this comes from the term metabolic heat this is the metabolic heat. Clo; Clo is another term for expressing the thermal comfort of total clothing. It is not the fabric as we have mentioned another term is tog. So, these 3 terms Met Clo and Tog they are related with the thermal transmission along with that permeability index which is used for measuring the thermal transmission characteristics along with the moisture vapor transmission. So, all these 4 characteristics all these 4 parameters we will try to measure a Met.

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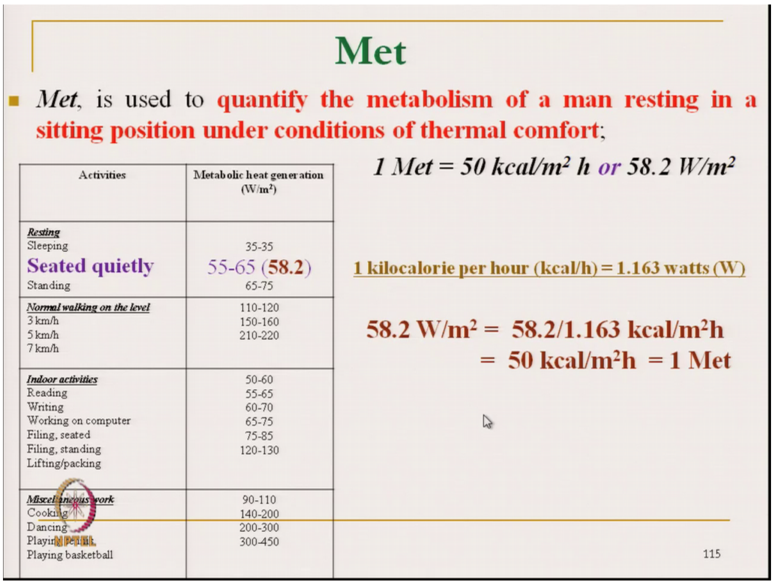

So, what is Met? It is just used to quantify the metabolic heat. So, metabolic metabolism of man when he is resting and sitting under air conditioned of that condition of thermal comfort. So, a person when is sitting and resting position comfortably So, at that situation whatever metabolic heat is producing it is called met. So, typically the value of 1 Met is 50 kilocalorie per square meter hour. So, if we convert it to watt per square meter it comes out to be 58.2 watts per square meter.

So, this value. So, if we see the table here in the table if we see for a sleeping person it is a 35 around 35 watt per square meter. So, that is a 32 to 35 square meter watt per square meter and sitting quietly a person it is around 55 to 65. So, that it is coming within that range. So, it comes out to be 58.2 that is the specific value it is given. So, 1 Met is equal to 50 kilocalorie per square meter or 58 watt per square meter.

So, Met has nothing to do with the clothing it is only it is a metabolic heat it shows, but why do we need to know about met for clothing comfort for a thermal insulation of clothing, because the this particular heat has to be balanced by clothing that whatever this heat is generated. So, this heat has to come out has to be transmitted through the clothing. So, that is how the clothing comfort clothing thermal insulation is related with Met.

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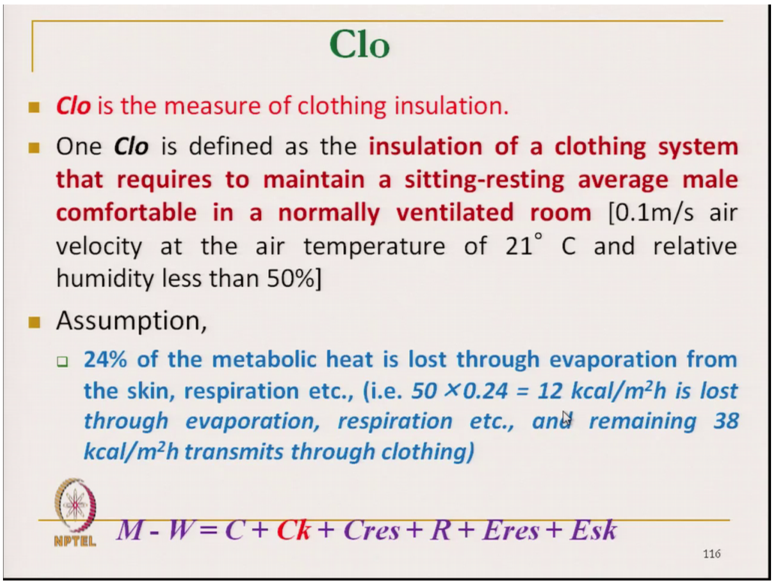

Now, try to see what is Clo. So, Clo as we have mentioned it is a thermal insulation of to overall clothing. It is not only one particular garment it is Clo is actually it is a totality a total garment including tops bottoms innerwear everything. So, one Clo is defined as the insulation of clothing system. Clothing system means it is a total clothing including even socks gloves everything.

So, total clothing system that requires to maintain a sitting resting average male comfortable in a normally ventilated room. What is ventilated room? It is defined the air velocity has to be 0.1 meter per second and the temperature will be around 21 degree Celsius and relative humidity will be less than 50 percent. So, that means, at that condition when a person actually generates 1 Met, that to balance that heat the whatever thermal insulation is required that is 1 Clo of clothing.

So, for clothing Clo and Met is directly related. So, this value of Clo then can be derived from the value of met. So, let us see the assumption is that it is assumed that 24 percent of metabolic heat is lost through other process other than fabric. So, this is maybe a through skin which is not covered by the clothing and the respiration. So, respiration and respiration through the skin respiration that evaporative heat lost through respiration, these are not actually taken into account, but other than this.

So, this is actually assume that 24 percent of the total heat metabolic heat is transmitted through this all these processes. And that means, it is a 50 multiplied by 0.25 it is coming out to be 12 kilocalorie per square meter hour is lost through evaporation respiration etcetera. And remaining 38 kilocalorie per square meter hour the thus this heat will be transmitted through the clothing; that means, our clothing has to take care of this 38 kilocalorie heat. So, that heat the transmission that is for that it requires 1 Clo.

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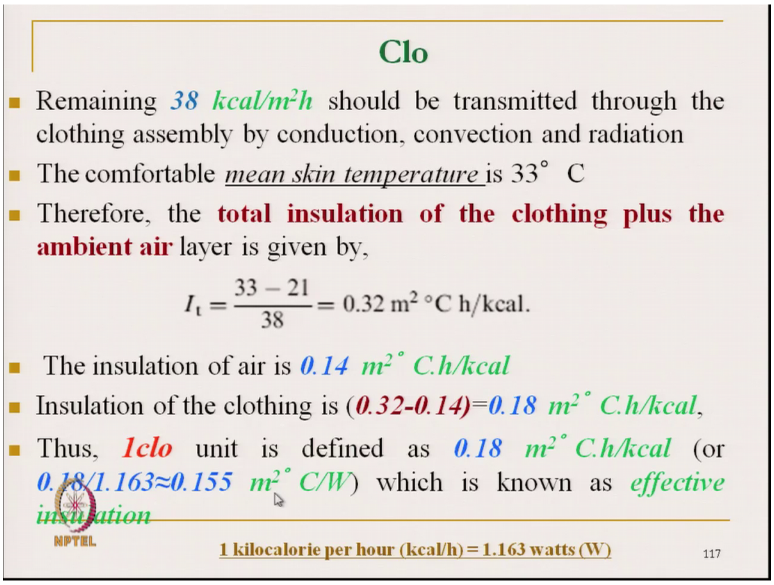

So, 38 kilocalorie. So, that the comfortable men the mean skin of a person is around 33 degree Celsius. So; that means, that a person when he is sitting at the room of 21 degree Celsius, that air conditioned room the mean skin temperature is 33 degree Celsius. So, that is the comfortable skin temperature. So, that temperature and the room temperature is 21 degree Celsius that is assumed. So, that let us see the total heat transmission. So, total heat transmission through that it is a 33 that the total insulation required by the clothing is 33 minus 21 divided by this 38. So, that is the total insulation required by the total system clothing system.

And clothing system it is including the insulation of air. So, that 0.32 is the insulation of the clothing system, which includes the air insulation. So, let us see the insulation of air insulation of air is 0.14. So, that is the standard and standard room the insulation is 0.14 which means we require the clothing insulation 0.32 minus 0.14. So, that is the insulation of clothing required. So, 0.18 meter square degree Celsius hour per kilocalorie. So, that insulation is required for clothing and this is the basically equivalent to 1 Clo.

So, this actually you have seen this 1 Clo value it comes from the Met value. So, it is related to. So, 1 Clo is equal to 0.18 square meter degree Celsius hour per kilocalorie that is the 1 clo ok. So, 1 clo if we convert into watt kilocalorie to watt. So, it is come out to comes out to be 0.155 meter square degree Celsius watt. So, that is the effective insulation of clothing. So, the 1 clo is equal to 0.155.

Now, let us see. So, the relations this is the SI unit. S I unit and relationship between S I unit and Tog we have seen it is one tenth.

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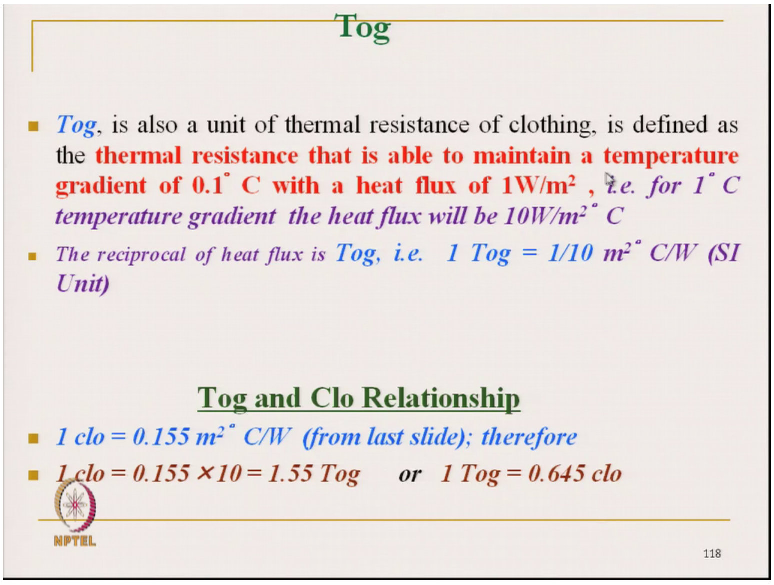

So, if we convert it is a one tenth. So, Tog is also a unit of thermal insulation as we have discussed is defined as the thermal resistance that is able to maintain a temperature gradient of 0.1 degree Celsius with a heat flux of 1 watt per square meter so; that means, it is one-tenth of a S I unit finally, we the relationship between clo and Tog it comes out to be 1 Clo is equal to 1.55 tog.

So, that is the relationship. So, with this practical unit we can now totally we can evaluate the insulation of clothing. And there are standard values available for insulation.

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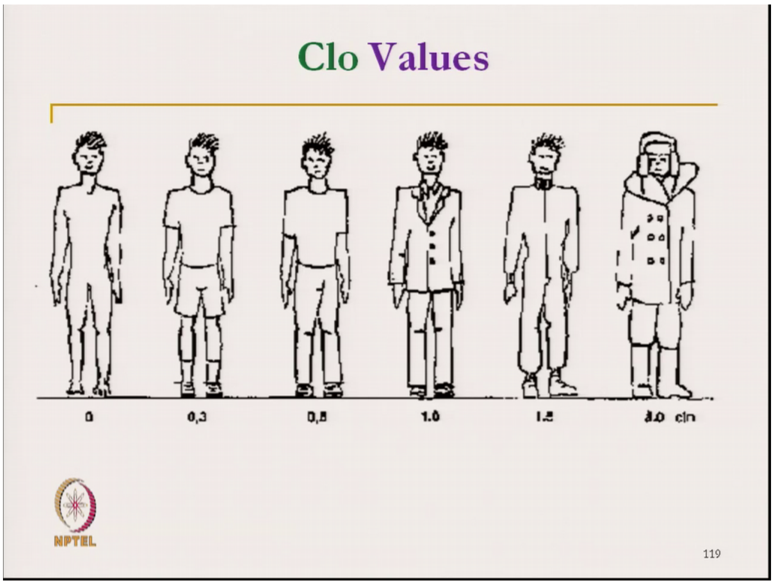

So, if you see the clo value. So, Clo value here it is a typical example of clo value. So, person without any cloth; that means, he does not have any cloth so that means, the clothing insulation is 0. So, here the Clo value is equal is 0. A person with a short and a t shirt like t shirt it is total Clo value is around 0.3 these are the typical values.

So, person with a this type of full trouser and the t shirt it is come out comes out to be 0.5. So, this it is 1 clo. So, it is a 1.8 clo and this is a 3 around 3 clo. So, this way the total Clo value increases. So, here what does it mean? 1 clo or what does it mean 0.5 clo so; that means, this fabric it is it actually provides a insulation of 0.5 clo. So, if a person is producing the one met, one met. So, that he means if he is sitting idle in well ventilated air conditioned room, this person will be little bit he will feel little bit cooler.

So, if it is one met 1 clo; that means he will balance with the 1 Met. So, that is how we can derive the insulation of clothing. And we can use this value Clo value to propose to select fabric or clothing ensemble for particular application. Now let us see how to use this Clo value for actually Clo value it is a insulation; that means, this type of Clo value will be used for clo cold temperature. And this Clo value is used for developing the clothing for extreme cold climate clothing.

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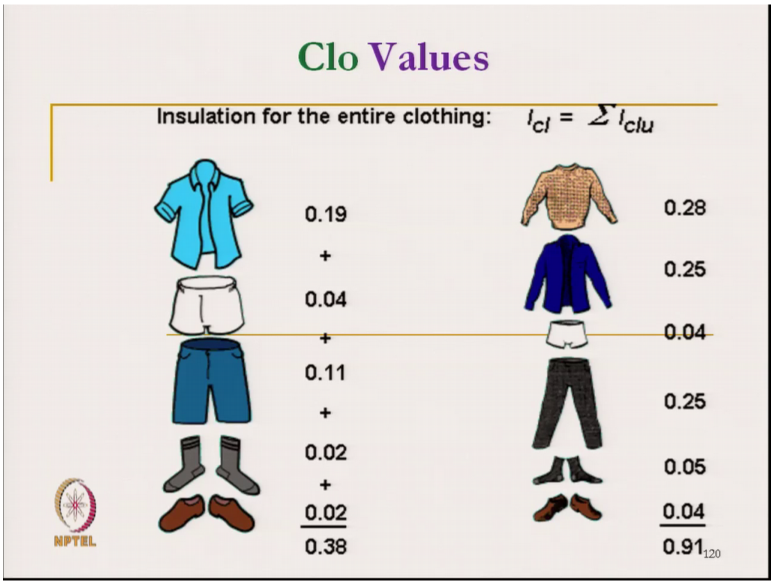

Now, try to see how the Clo value is actually added. So, normally these Clo values of individual component individual garments are known. So, if it is known so; that means, that we can if simply add this all this Clo value we will get the total Clo value of the clothing system. If we see here a shirt it is a 0.19 this 0.04 0.11 and socks is 0.2. So, if we add it comes out to be 0.38.

So, this will give as a total Clo value of 0.38 and this is 0.1991. So, this value this will be actual a make a this total segment total combination will make a person comfortable when he is generating 1 Met.

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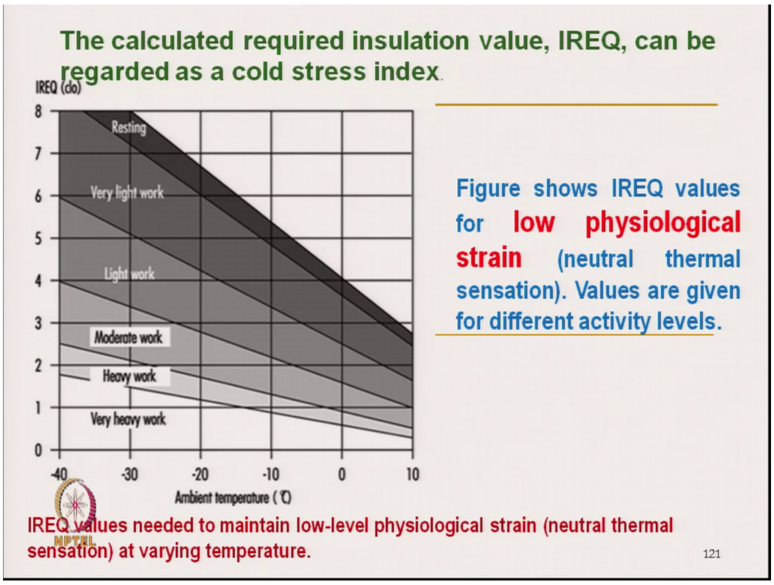

So, this is a typical curve which is known as that IREQ; that means, is required insulation curve. So, this is this typical curve will guide as to select the clothing Clo value total insulation required to for a total clothing ok.

So, for at different condition different at different temperature level, sub 0 temperature level and at different physical condition. So, let us try to see. So, this figure IREQ values these are the IREQ value in y axis it for low physiological strain; that means, a per to keep a person comfortable. So, we need a clothing of this type of Clo value so; that means, neutral thermal sensation that means, no he is actual thermally comfortable.

So, these values are given for different activities. Now try to see so far at a temperature environment temperature say at 20 degree Celsius. So, the minus 20 degree Celsius at sub 0 temperature, if a person is actually working he is actually resting. If he is resting at that, temperature minus 20 degree Celsius temperature. So, he needs a clothing of a Clo value around 7 or 8. So, around 6 to 7 this is the type of Clo value he needs. So; that means, it is a minimum Clo value here so; that means, he needs minimum 6 Clo value for to make him little bit comfortable you can survive, but at least she he needs an for to making very highly comfortable, he needs 7 around 6.5 or 6.7 clo value.

So, that which means that if at person sitting idle. So, he needs at sub 0 temperature he needs a clothing of very thick in nature with high insulation, but at that temperature if person start little work. So, in that case he may need a clothing of little bit lower clo. So, that insulation if he has a clothing of lower insulation that can also be sufficient, that will be sufficient at that temperature minus 20 degree Celsius temperature but if we works very hard.

So, he may need a fabric of 1 clo at 1 clo fabric which is sufficient for normal ventilated room or air conditioned room, but if with that clothing he will be comfortable thermally at even a 20 minus 20 degree Celsius if he works hard. So, that way we can at different temperature this curve gives indication about the clothing requirement insulation requirement. So, from this curve one can easily design the or propose different types of clothing for person at extreme cold climate.

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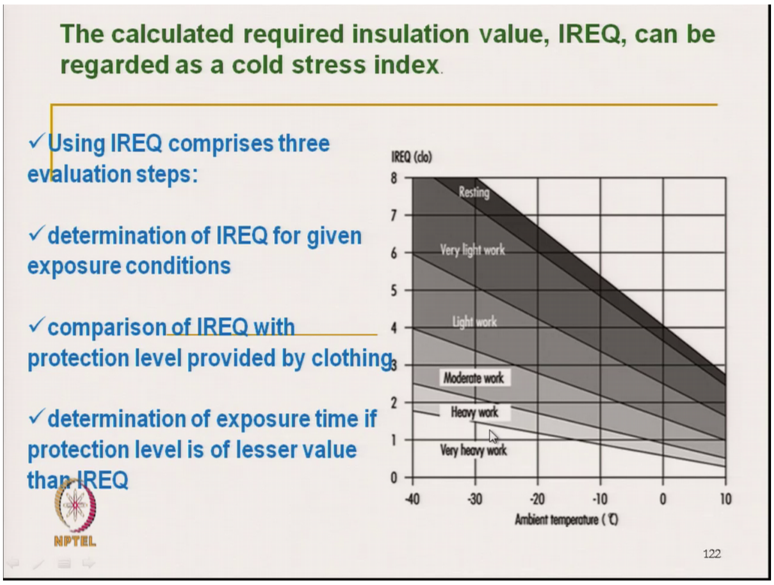

So, let us see how to calculate the calculated required insulation that is IREQ can be regarded as the cold stress index. So, that value at that temperature at particular what is the cold stress for a particular person and how he will be comfortable for a particular with a particular type of clothing. So, and using the IREQ comprises 3 evaluation steps.

So, to use. So, we have to have 3 steps of evolution first is the determination of IREQ for a given exposure condition. So, if we know the exposure condition, and if we know the physical activity of a person. So, we can determine the IREQ level. Suppose a person needs to work little or a needs to sleep at minus 30 degree Celsius temperature. So, from this curve we can actually evaluate what will be the thermal stress. So, at that say suppose he is working little work he is doing little work. So, this is the point. So, 6 IREQ is the cold stress of the person.

So, if we know the cold stress and if we then we have to select the clothing, which will give us say 6 clo value. So, then we have to compare this IREQ value with the protective level of clothing, that is Clo value of clothing total clothing. So, then we can select. And if suppose this value this value is we are not able to get suppose 6 Clo value is required. So, if 6 Clo value is required, if we do not have this clothing with 6 clo then we can definitely try to use, but in that case we have to know the what is the exposure time. So, he cannot actually be comfortable at that condition for longer time.

So, we have to determine the exposure time if the protection level is of lesser value than IREQ. So, we can use suppose we can use if we want if we need say 6 clo we have a clothing of say 2 clo; that means, we have to decide, what will be the exposure time. If he wants to go for some time for a few seconds then he may go he may be alone, but if it is a longer exposure time then it will be difficult.

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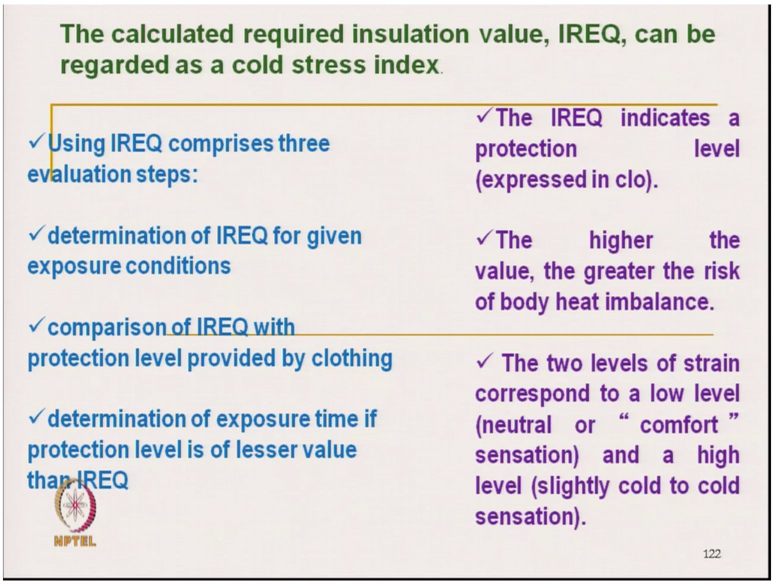

So, the IREQ indicates the protection level as we have discussed the higher the value the greater the risk of the body heat imbalance.

So, that value should be within at a within a limit it should not be high. If higher IREQ value; that means, we should be actually careful that it may we actually it may harm the body heat imbalance. And the 2 levels of strain that is the 2 there are 2 levels one is the lower level where he is actually neutral or comfortable and higher level; that means, she is feeling slightly cooler.

So, that within that range it works. So, that how we actually decide which cloth has to be used and which combination we can select. So, there are various standard combinations available one can see. So, these are the different types of combinations.

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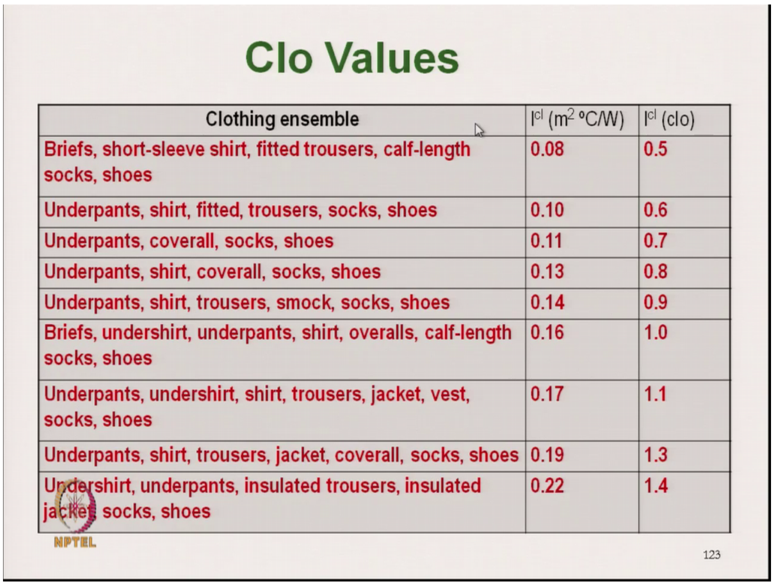

Clo Values

Clothing ensemble	I^{cl} (m^2 °C/W)	I^{cl} (clo)
Briefs, short-sleeve shirt, fitted trousers, calf-length socks, shoes	0.08	0.5
Underpants, shirt, fitted, trousers, socks, shoes	0.10	0.6
Underpants, coverall, socks, shoes	0.11	0.7
Underpants, shirt, coverall, socks, shoes	0.13	0.8
Underpants, shirt, trousers, smock, socks, shoes	0.14	0.9
Briefs, undershirt, underpants, shirt, overalls, calf-length socks, shoes	0.16	1.0
Underpants, undershirt, shirt, trousers, jacket, vest, socks, shoes	0.17	1.1
Underpants, shirt, trousers, jacket, coverall, socks, shoes	0.19	1.3
Undershirt, underpants, insulated trousers, insulated jacket, socks, shoes	0.22	1.4

And their total clo values are given. So, depending on the Clo value suppose we need a Clo value of 1.4. Then we may like to select this combination one undershirt underpant, insulated, trouser, insulated jacket, socks, shoe.

So, if we take this combination; that means, we will get a Clo value of 1.4. So, accordingly we can select for a particular application.

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Clo Values

Clothing ensemble	I^{cl} (m^2 °C/W)	I^{cl} (clo)
Briefs, T-shirt, shirt, fitted trousers, insulated coveralls, calf-length socks, shoes	0.23	1.5
Underpants, undershirt, shirt, trousers, jacket, overjacket, hat, gloves, socks, shoes	0.25	1.6
Underpants, undershirt, shirt, trousers, jacket, overjacket, overtrousers, socks, shoes	0.29	1.9
Underpants, undershirt, shirt, trousers, jacket, overjacket, overtrousers, socks, shoes, hat, gloves	0.31	2.0
Undershirt, underpants, insulated trousers, insulated jacket, overtrousers, overjacket, socks, shoes	0.34	2.2

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So, these are some few more combinations.

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Clo Values

Clothing ensemble	I^{cl} (m^2 °C/W)	I^{cl} (clo)
Undershirt, underpants, insulated trousers, insulated jacket, overtrousers, overjacket, socks, shoes	0.34	2.2
Undershirt, underpants, insulated trousers, insulated jacket, overtrousers, socks, shoes, hat, gloves	0.40	2.6
Undershirt, underpants, insulated trousers, insulated jacket, overtrousers and parka with lining, socks, shoes, hat, mittens	0.40–0.52	2.6–3.4
Arctic clothing systems	0.46–0.70	3–4.5
Sleeping bags	0.46–1.1	3–8

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So, sleeping bag. It can keep Clo value of up to 8. So, accordingly we can select. So, sleeping bag is we need very high Clo value because at that time the there is no physical work. So, IREQ requirement will be very high.

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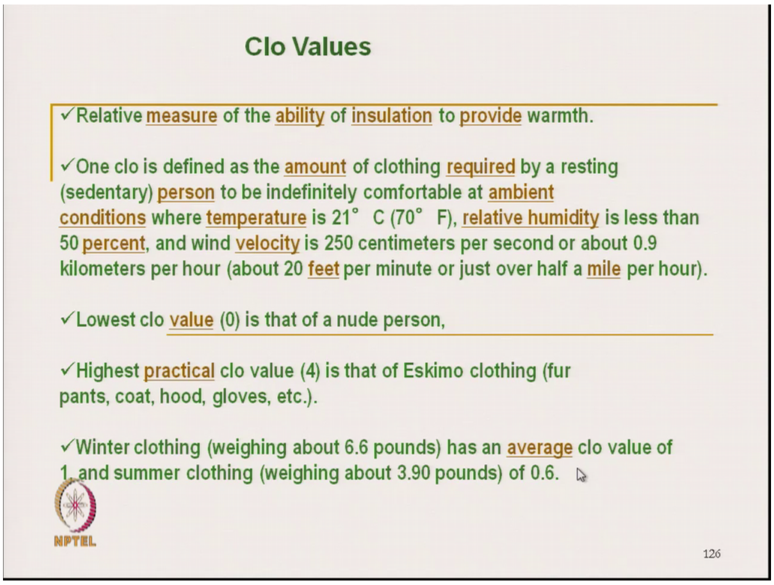

Now, as we have mentioned relative measure of the ability of insulation to provide warmth. That is the clo value. And Clo value is the it is a basically it is a person when he is sitting and resting position at certain temperature that air conditioned temper room and the level of insulation requirement is the of a clothing is a clo and lowest value of clo is 0; that means, when a person is unclothed, a nude person has a Clo value of 0, because he does not have any clo cloth. And the highest practical Clo value is a for any garment it is a 4 for eskimo clothing. So, that type of clothing is available.

And winter clothing has average Clo value of 1 and summer clothing average Clo value of 0.6. So, this Clo value we can always increase, but Clo value is related with the total weight of the clothing. So, that we have to take care for other comfortnes of thermal comfort or heaviness. We should not feel heaviness. So, that way we should be we should be able to develop clothing of higher Clo value with lower mass.

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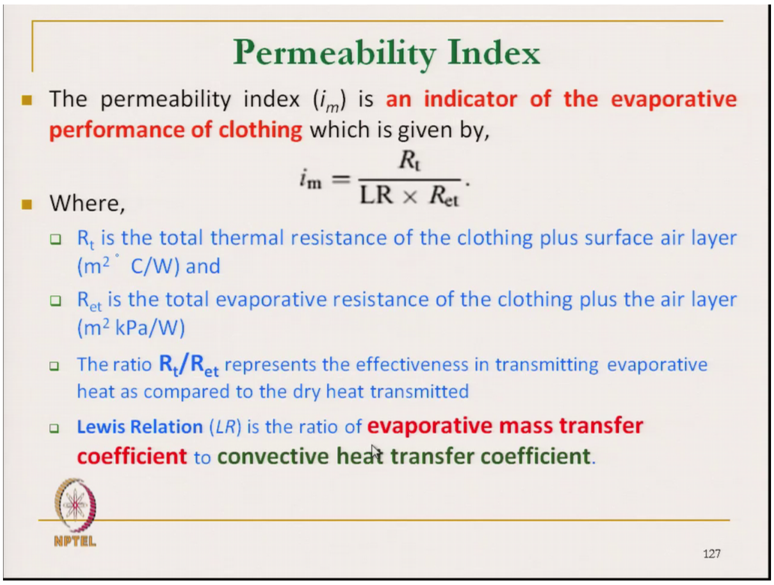

And another parameter which is practical parameter which is known as the permeability index; this is the combination of the dry heat transmission and moisture vapor transmission. This permeability index is an indicator of the evaporative performance of clothing ok. So, that where Rt is the total thermal resistance of the clothing plus surface layer of air. So, this is the Rt and Ret is the total evaporative resistance of clothing plus air layer. So, if we take if we combine this ratio Rt by Ret represent the effectiveness in transmission of evaporative heat as compared to dry heat.

So, this ratio if we can calculate this ratio, that is the for it is a it shows the effectiveness of the evaporative transmission. And this is the Lewis ratio Lewis; Lewis relation is the ratio of evaporative mass transmission coefficient and convective heat transmission coefficient. So, it indicates that how much mass transmission will take place along with the evaporative heat transmission.

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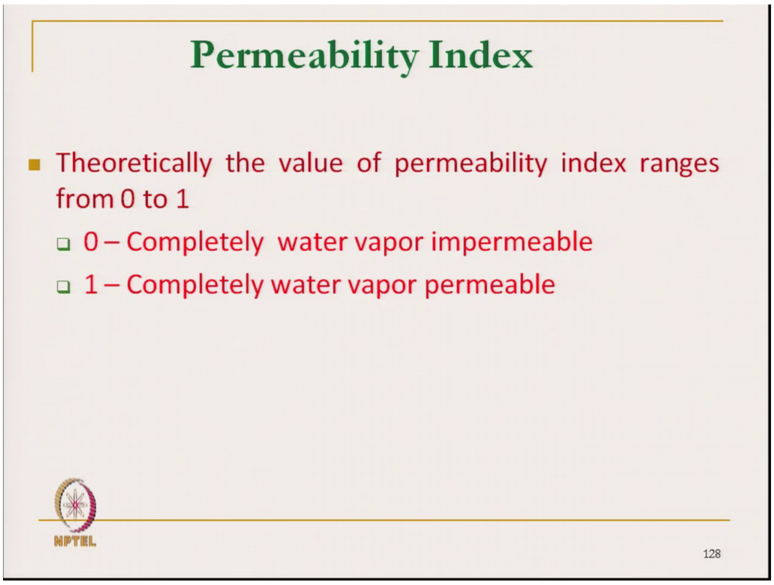

And the permeability index it is a value it is ranging from 0 to 1.

So, if the fabric is totally impermeable, that no water vapor transmission is there it will give a value 0. And a completely water vapor transmission if it is there it is a 1 values, it varies from 0 to 1 value. It gives indication of whatever what is the water vapor permeability now we will discussed the thermal transmission characteristics of clothing various factors which affect the thermal transmission of clothing.

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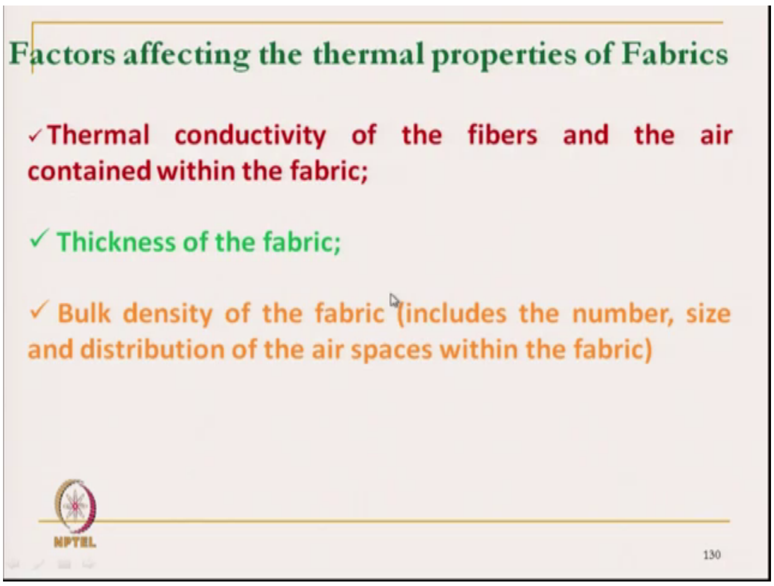

The factors which affect the thermal transmission properties of fabrics are first is the thermal conductivity of fiber and air contained within the fabric. So, total thermal conductivity of fiber material and air.

So, that actually affect the thermal transmission characteristics. It is basically conductive heat transmission. So, that is basically thickness of the fabric is directly related affect the thermal property, thermal transmission property ok; that means, higher thickness means higher air entrapment are also higher thickness means sometime it is a thicker material means higher quantity of fiber present.

So, thickness of fabric is actually directly related with the thermal transmission characteristics. Then bulk density of the fabric, which means that whatever the pores present in the fabric and the number of pores size of individual pores and distribution of pore, that affect the thermal transmission characteristics. So, this bulk characteristics or thickness they are related with the manufacturing technique and type of twist type of fiber. So, all these parameters we will discuss one by one.

So, one is thickness of fabric bulk density of fabric.

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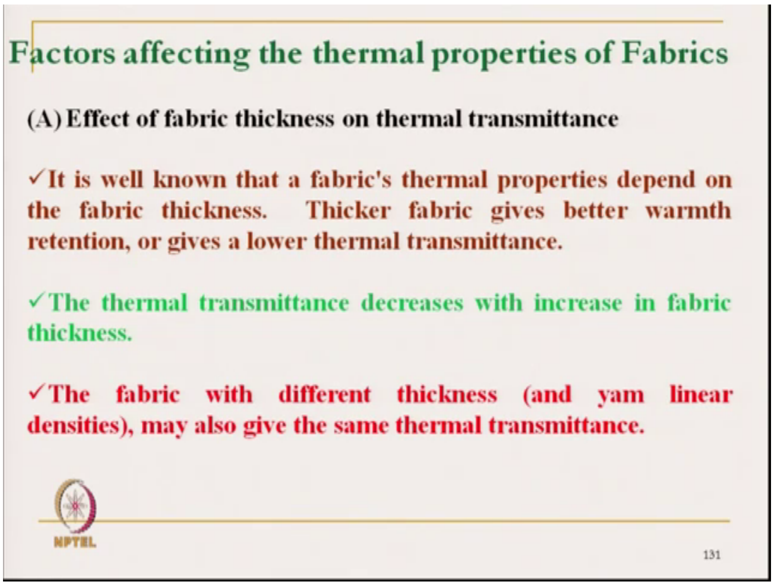

So, these are related with these are actually dependent on the various factors. First let us see the fabric thickness what are the affects of thickness of fabric on thermal transmission characteristics. So, it is well known that the thicker the fabric, higher will be the thermal resistance because thicker fabric gives better warmth due to lower thermal transmission.

So, thicker fabric has got 2 components. Either it will have more number of blockage more number of fibers another is higher entrapment of steal layer that this overall the thicker fabric will give higher thermal resistance. The thermal transmittance decreases with the increase in fabric thickness. The fabric with different thickness also may give same thermal transmittance or fabric with same thickness may give the different thermal transmittance; that means, thickness is not the only criteria for to measure the thermal transmission characteristics.

So, other than the thickness, there may be some other thermal transmission parameters. So, thickness is just not the only parameter determining the thermal transmission of fabric.

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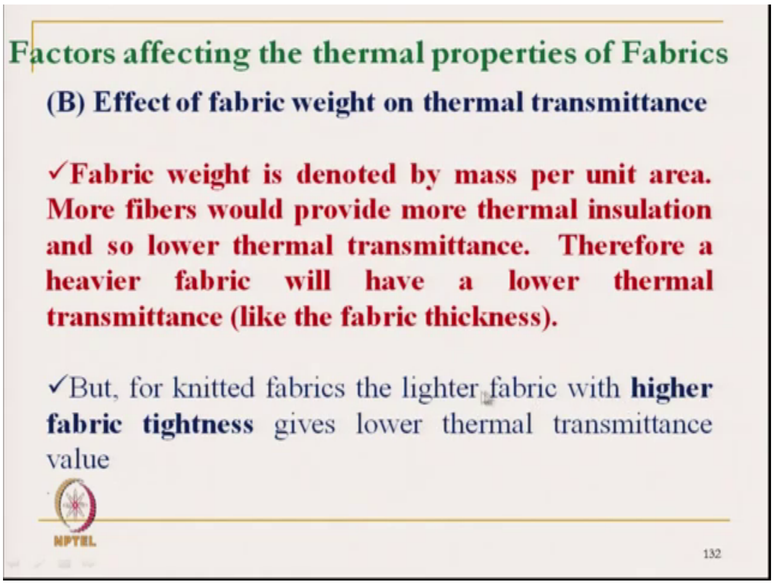

So, another parameter is the mass of fabric weight of fabric. So, fabric weight is denoted by the mass per unit area. Normally as the mass per unit area increases it provides more material. So, higher mass per unit area it is normally it gives the higher fabric insulation. So, lower thermal transmittance it same as the fabric thickness.

But there are other aspects also; that means a knitted fabric with the lighter fabric with higher tightness factor; that means, if we have a lighter fabric with higher tightness factor or heavier fabric with lower tightness factor. So, lighter fabric with higher tightness factor gives the lower thermal transmittance value; that means, here again the fabric weight is not the only criteria we have to see the compactness of the structure. So, that higher tightness factor gives lower thermal transmittance means, it is a basically it blocks the convective heat and radiative heat.

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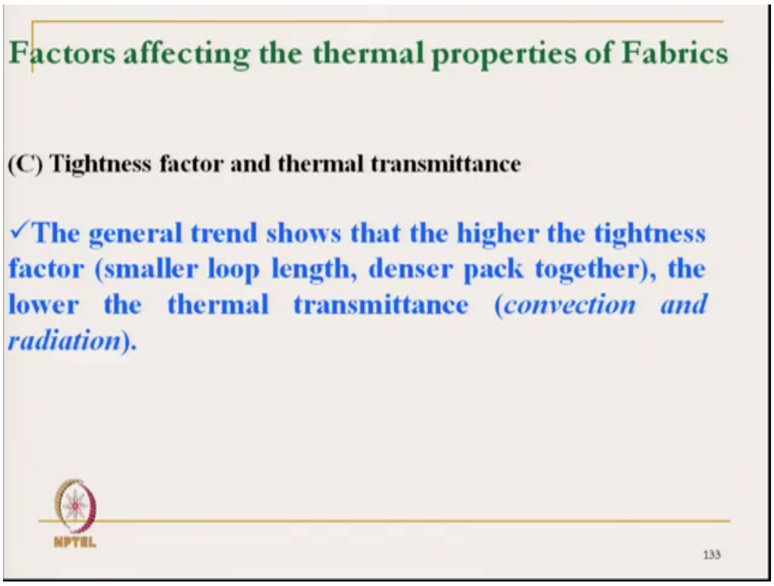

So, irrespective of the mass per unit area and thickness of the fabric if the fabric structure is open if the tightness is less that also give the higher thermal transmittance. So, higher thermal. So, higher tightness factor gives the lower thermal transmittance this is due to blocking of the convictive heat and radiative heat. On the other hand, if we see the tighter fabric and the thermal tighter fabric also sometime gives the lower thermal higher thermal transmission. It gives lower thermal resistance. How because a tighter fabric if it is in jammed condition it does not have any air pocket.

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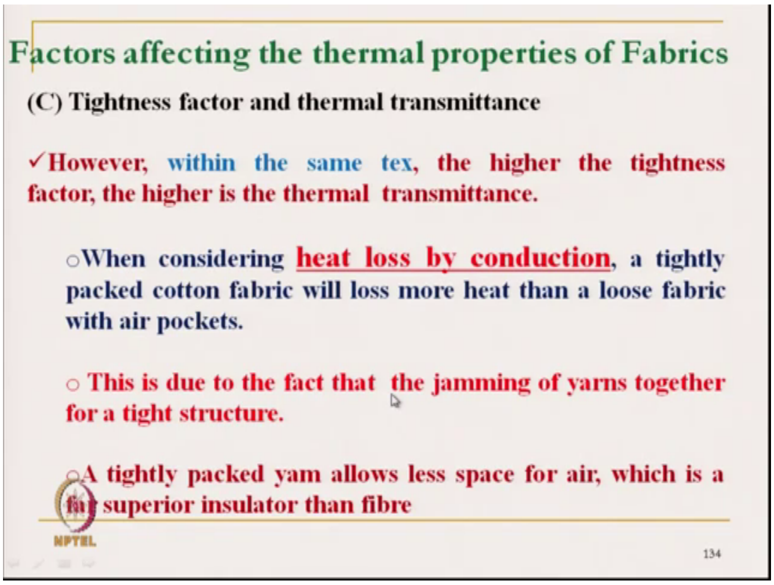

So, that insulation due to that heat when considering heat loss by conduction that; that means, if the tight fabric is there; that means, there is no air pocket. So, heat transmission through conduction will be high the tighter tightly packed cotton fabric will lose more heat than loose open fabric ok. So, conduction, for conductive heat transmission higher conductive heat transmission we need tighter fabric with and for higher radiative and convective heat we need open fabric structure.

So, this is due to the fact that jamming of yarn together with the tightness of structure will give the better thermal transmission due to conduction. Also if we see the twist, if we increase the twist level, so; that means, the air pocket inside the yarn structure is reduced. So, it also gives the higher conductivity due to the conductive heat loss.

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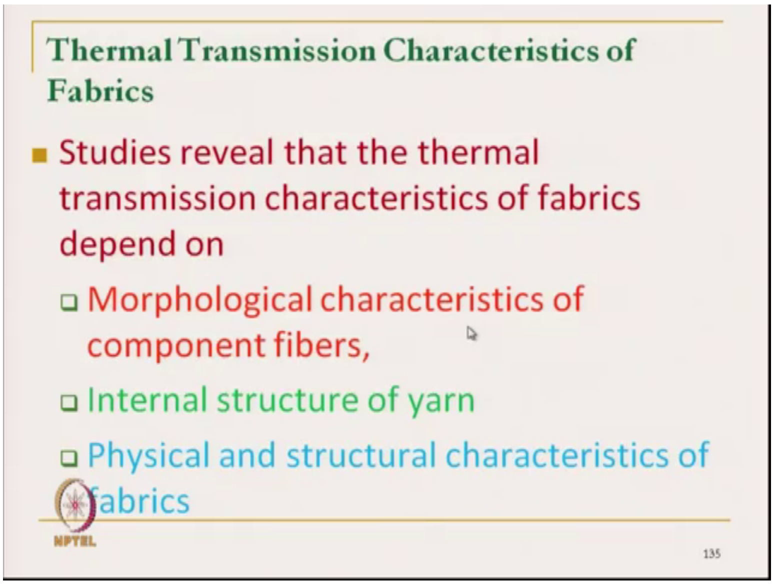

And there are studies, which reveals that the transmission characteristics of fabric depend on one is the morphological characteristics of morphological characteristics of fiber. So, fiber morphology we change, fiber structure internal structure of fiber. If we change the thermal transmission characteristics will change it is dependent on the yarn structure. So, if we can incorporate the bulk in the yarn that will affect the transmission characteristics of fabric and also physical and structural characteristics of fabric.

So, it depends on the fiber characteristics, depend on the yarn characteristics and also the fabric characteristics. Now let us see one by one.

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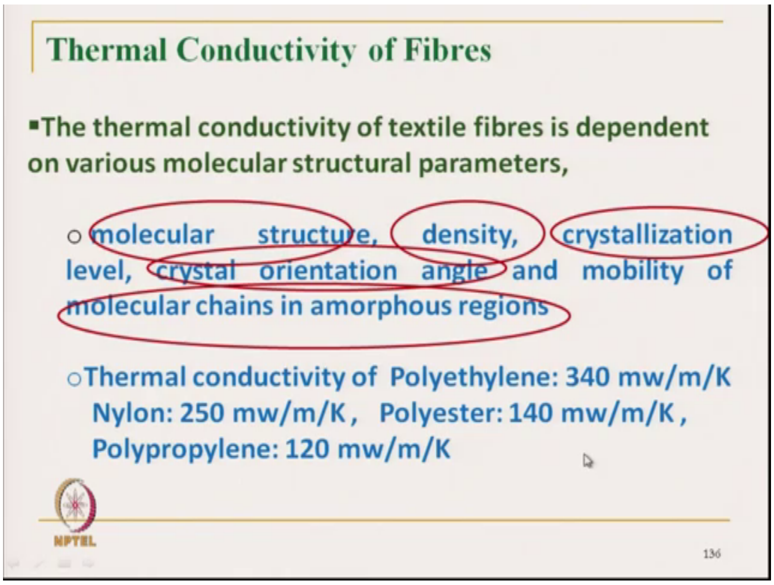

The fiber characteristics it is basically conductivity of fiber it dependent on the molecular structure of fiber. So, it is a molecular structure. It is density crystallinity crystalline orientation and mobility of molecular change in amorphous region. So, these are the factors, which actually controls the thermal conductivity of particular fiber.

Let us see the typical values of few fibers polypropylene 340 nylon 250 polyester 140 and polyethylene 120. So, these are due to the molecular structure density and all these parameters and also for the same molecule.

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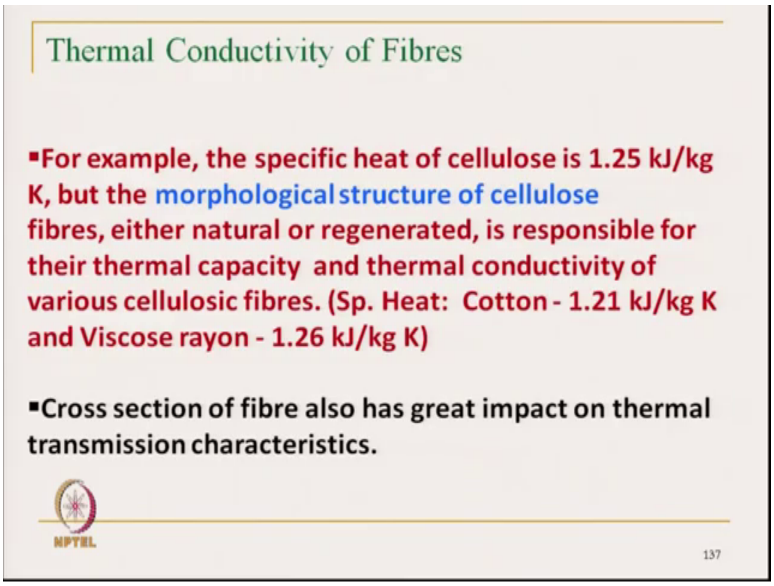

Like cellulose has got specific heat is 1.25. So, due to the difference in morphological structure of natural cellulose that is cotton or regenerated cellulose the thermal transmission characteristics changes.

So, this if we some for a particular polymer, if we change the morphological structure we can change the thermal characteristics. Even cross sectional shape of fiber that changes the thermal transmission characteristics. Not only the thermal transmission characteristics with the cross sectional shape, it is air permeability moisture vapor permeability or also the moisture in liquid form that is weeking characteristics also changes. So, we will discuss in the next segment when the effect of fiber cross section.

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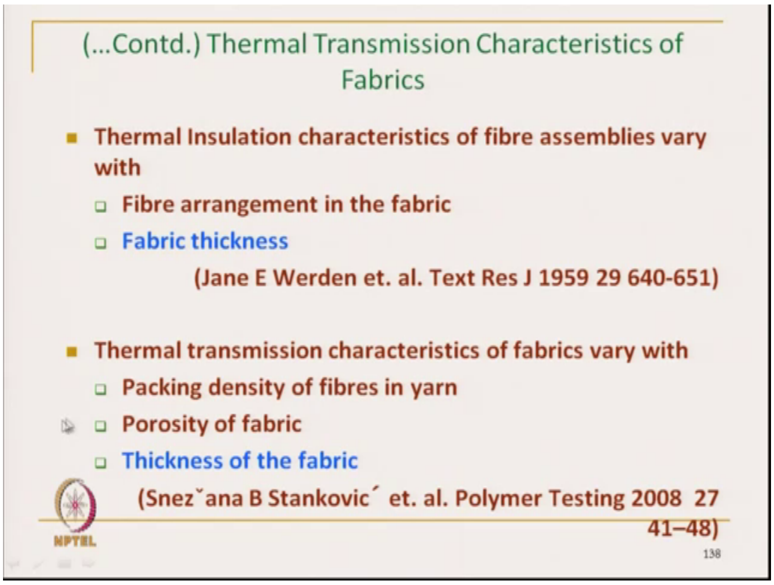

Now, let us see few other studies the thermal insulation characteristics of fiber assembly varying with the fiber arrangement in the fabric. So, if the fiber arrangements are parallel to the length wise direction or if it is a random. So, it affects the thermal transmission characteristics. This are due to the orientation this are due to the a pore structure opening structure. So, that this affect the thermal transmission characteristics and also we know that fabric thickness; obviously, higher fabric thickness higher entrapment of air pocket. So, lower will be the thermal higher will be the thermal insulation.

Another study it shows that thermal transmission characteristics depend on the packing density of fiber in yarn. So, if we can pack the yarn fiber dense, that will affect the thermal transmission characteristics. This will see in detail if we can distort if we can make the bulk in the yarn we will see ultimately it affects the thermal transmission characteristics of clothing porosity of fabric. So, fabric with higher pore will give better thermal insulation that also will see how the pores inside the yarn will give a better thermal insulation and obviously, thickness of fabric thermal.

So, as we know the fabric thickness is a major part in deciding the thermal transmission of a particular fabric. A same fabric a different level of thickness will give different thermal transmission characteristics. So, let us see a thermal resistance of fabric under different compression level.

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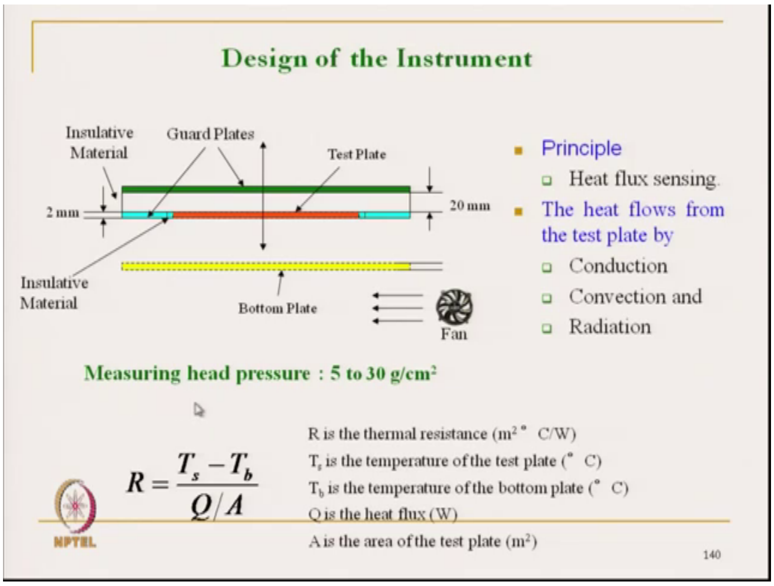

For that one instrument has been designed and developed. This instrument works is just a reverse it is a average state of guarded hot plate. So, this is a similar guarded hot plate has been developed where the red, this red colour plate it is a test plate.

And this sky colour these are the guard plates ok. Side guard plates guard ring and this is earlier in guarded hot plate or. So, bottom plate. So, this 3 plates were there and this is one this is the base plate with the perforation. So, this total system this top this total system is actually placed on a cross head of tensile tester. This is a placed and this total system moves up and down. And this bottom plate which is perforated over which fabric is placed.

Now, as this is moving downward, the fabric will get compressed. So, that length the thickness of the fabric can be measured here and also compressional load can be measured. And at different air velocity; that means, to know the convective heat loss at different compressive load that has been developed. So, this study shows that if we these are the different parts of the fabric, the instruments and this is actually the heat transmits in conduction convection and radiative mode. And with this formula we can measure the measuring the measuring head pressure is 5 to 30 gram per square centimeter we can vary the pressure.

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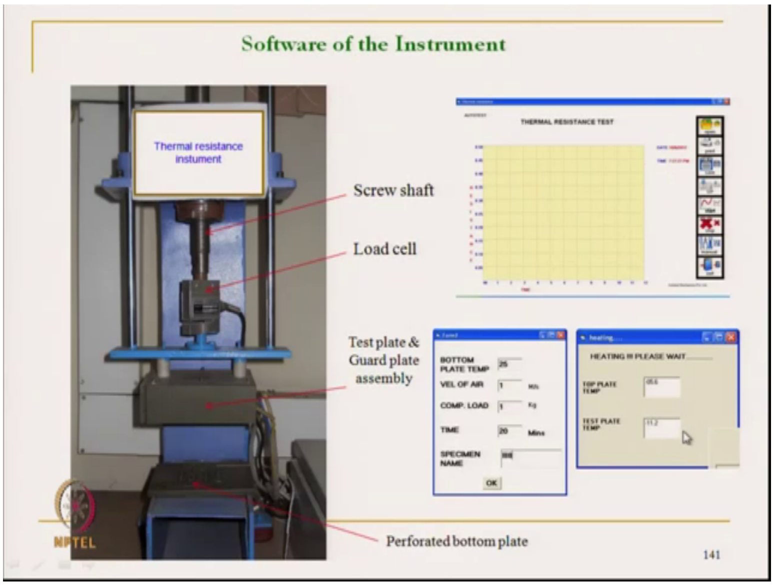

This is the instrument ok. Where this is the load cell and fabric is placed here the perforated bottom plate. And here the fabric is placed and total guarded plate assembly is kept here. So, as it is going down. So, we can plot the thickness versus displacement curve, the time versus thickness curve.

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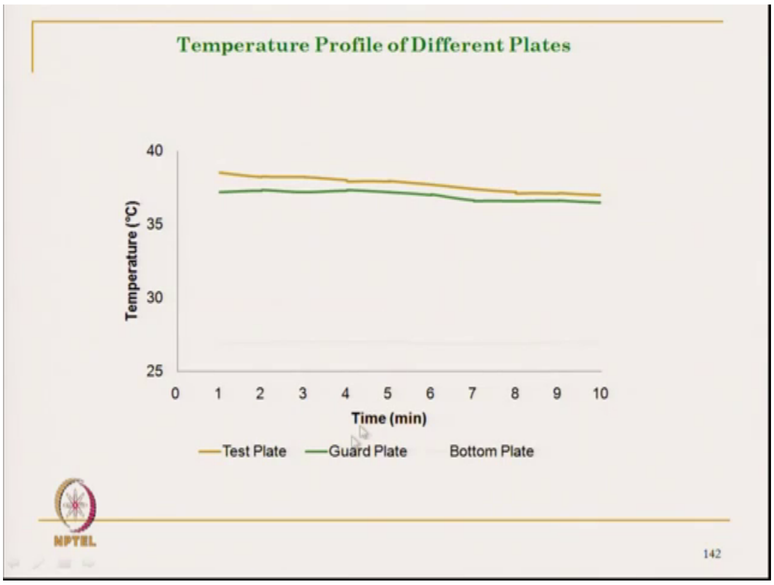

So, what we have observed that we have we wanted to measure the consistency of the temperature. So, the temperature for longer time it gives almost constant there is no significant change in temperature.

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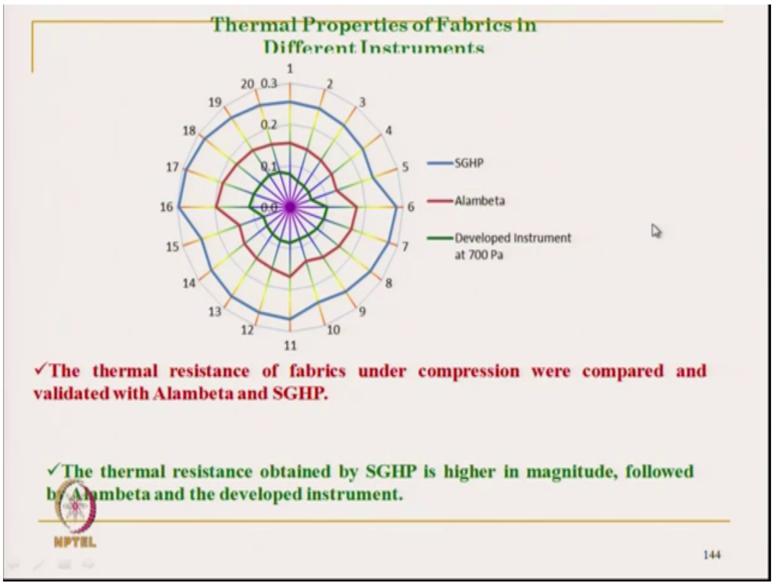

And now let us see, we have compared different types of a 20 different fabrics sample we have taken. And those samples the thermal transmission characteristics were measured using 3 different techniques. This outer curve it is measured by sweating guarded hot plate. So, that guarded hot plate standard measurement technique we have used for the same fabric next red one is the used by the alambeta and inner curve is for the developed instrument.

So, what does it show? So, the fabric the same fabric keeps 3 different insulation level the value which we are getting the 3 different values for a same fabric; that means, the sweating guarded hot plate gives higher insulation value. The alambeta gives little bit lower insulation and the designed develop instrument gives the lowest insulation value; that means, that and another thing it is to be noted the nature of the curve shape of the curve is exactly same; that means, the sweating guarded hot plate the level of pressure used in sweating guarded hot plate is less; that means, effective thickness of the fabric is high or same fabric, it is a higher thickness, that is why it is giving higher insulation.

Whereas in case of alambeta the pressure exerted it is higher than the sweating guarded hot plate. That is why the fabric gets compressed little bit. So, air pocket is reduced. So, we get lower thermal insulation. And the developed instrument where we need to measure the thickness. So, we need to know the thickness at minimum pressure. So, here the minimum pressure is used which is 700 pascal. So, 0.7 kilo pascal is the minimum pressure we can use here. So, that is why here the fabric compressed a little bit more and that is why we get the lower thermal insulation but for comparison purpose for evaluation purpose.

So, we cannot compare this value this exact value with the sweating guarded hot plate or alambeta, but the nature of the curve. So, same nature of the curve which indicates this value which is given giving which is actually we are getting from this instrument are consistent value.

So, using this instrument, we have tested the thermal insulation characteristics at different pressure level.

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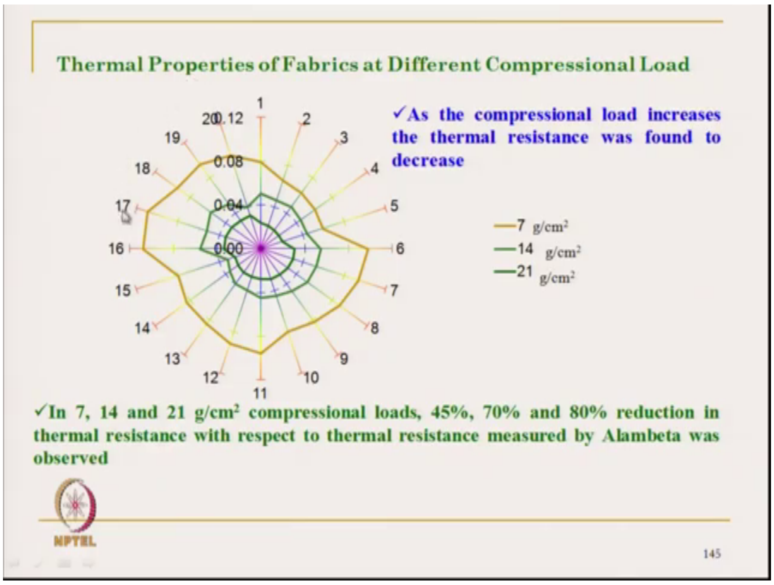

So, this is the value the same 20 fabrics were being used. Here minimum pressure is 7 gram per square centimeter. And then we have increased the pressure to 14 gram per square centimeter and then 21 gram per square centimeter. So, from this graph we can see that with the increase in pressure, this thermal insulation fabric gradually is losing the thermal insulation characteristics.

So, this is this gives a good indication that a fabric which we have to develop, that fabric should not get compressed easily, but if we at all gets compressed it should come out it should have good resilience characteristics. So, that is how. So, one of fabric when it is a new bulky condition the fabric may give warmth, but after several use after several laundering or pressing, the same fabric may lose it is warmth due to loss in thickness. So, we will stop here. So, we will continue with the various factors in our next class.

Thank you.