Ergonomics Workplace Analysis
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Lecture - 12
Assessment of Thermal Environment

Hello, all; welcome back to the session. Today we will be talking about the Assessment of Thermal Environment. We are talking about the evaluation of the workplace, so ergonomic workplace evaluation. So, when we are talking about Ergonomic Workplace in Evaluation, the physical environment is a very important component in terms of performance, productivity, or the kind of design we have around.

Suppose we understand some concepts of thermal environment, how we can measure them how the impact is there of the thermal environment on us. And what are the varieties of you know comfort, expressions or sensitivities are there, then it will be very easy when we are talking about the physical environment in ergonomic workplace evaluation. So, today's topic is how we can do the assessment for the thermal environment, so let us first understand what it is.

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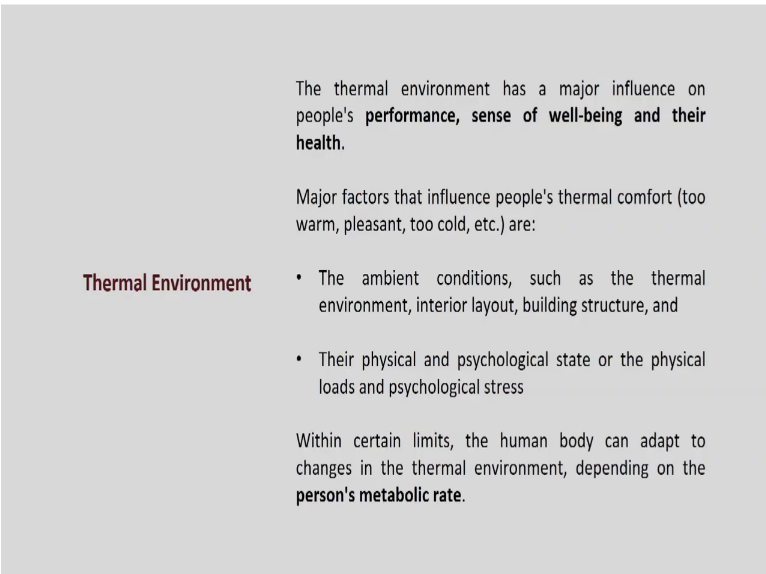

The thermal environment has a major influence, as I mentioned earlier, on the performance, so you can easily understand this one from your own experience. If the environment is not conducive or not comfortable in terms of heat, then we feel discomfort, and discomfort definitely affects your performance. Sense of well-being right, when you do not feel good. So when we are talking about health, like, suppose we are working or as this whole topic is on the occupational health like ergonomics workplace, so workplace depends, when we are working. When we are working in a particular kind of extreme environment, definitely that has an affects on the physiology, as we discussed in earlier days.

So, on the physiology, if it is affecting then the whole physiological system maybe digestive system, maybe respiratory system, they will have an effect, so that it will affect the health. So, major factors that influence people's thermal comfort that is if the environment is too hot or too cold, then there will be a problem.

The ambient conditions such as thermal environment, interior layout, building structure, it always has an effect on the total experience. The first what we talk that the ambient condition, environment, interior layout; these are the physical factors present in the workplace. But, something which is personal like your own physical fitness, your own psychological status of that current situation on that particular situation that also has an impact or has a relation with the thermal environment or thermal comfort.

So, within certain limits, the human body can adopt the changes in thermal environment depending on the person's metabolic rate. So, what is the metabolic rate that we will be talking later.

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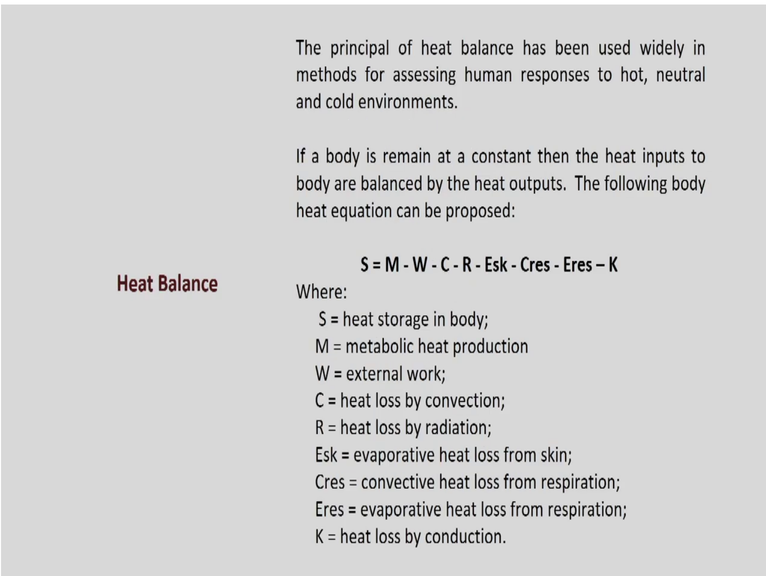

When we are talking about thermal environments, like heat and how it is getting balanced, we need to really understand what is the heat balance we maintain in a particular workplace or in the surrounding. So, it's very simple that S, what we call at this heat storage of the body, is equal to M that is means metabolic heat production, like heat generates within our body, so that is the source of energy, source of heat.

So, from that different subtraction of sources like W that is the external work minus C that is the heat loss by convection, minus R that is the heat loss by radiation Esk that is the evaporation heat loss from your skin. So, many times it happens when we are working; we discuss this on during our physiological fundamentals or physiology that some perspiration continuously happens from our skin that we do not understand and something is the so it absorption, so that also separate. So, that is one, then Cres convective heat loss from your respiration, Eres evaporation heat loss from respiration, and K that the heat loss by conduction. So, this is the basic heat balance mechanism or heat balance formula that our body follows. It is very important when we understand the thermal comfort and the available heat within the surrounding.

So, when we are talking about the thermal environment or thermal physical environment, thermal indices is a very important nomenclature or very important aspect that we always measure and compare. So, what are these? This is a very useful tool for describing, designing, and assigning thermal environments in the thermal index.

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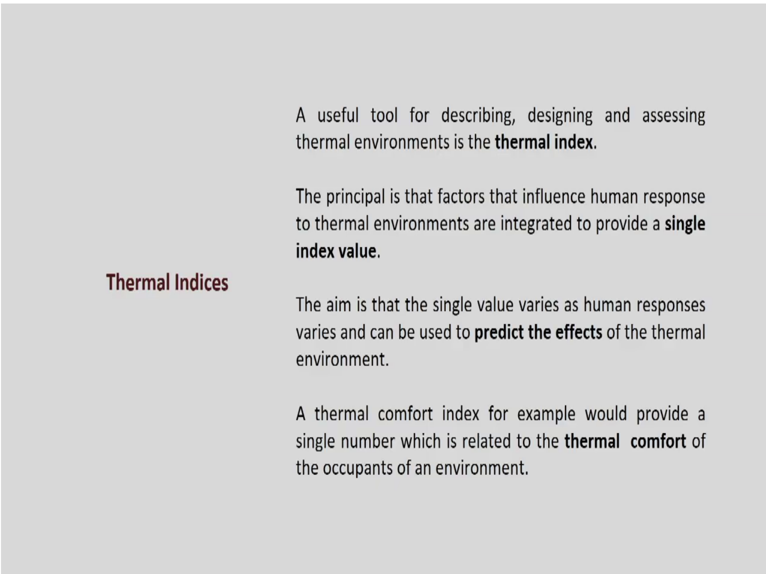

So, the principle is that factors that influence human response to thermal environments are integrated to provide a single index value. Whatever the components are there within the environment as per as thermal is concerned we are translating them into a single index value which is very easy then to compare or to use further.

The aim is that the single value varies as human responses varies like; if the indices is on the higher side, or on the lower side, my responses towards the thermal environment will also change accordingly, and this can be used as to predict the effects. Because suppose some index says that if the index value is lower than this particular point then we are, a prediction is the human being in the normal condition we will feel comfortable.

So, if we understand that index value or if we measure the index value, we can predict the person who is working in that particular location or particular work environment, we will feel comfort and the performance or productivity will be as expected. If there is a change or there is some difference in that phenomena, maybe we need to look into or look back what is the problem. So, indices really help to understand those criteria or critical points where ergonomic evaluation needs to start.

A thermal comfort index, for example, would provide a single number which is related to the thermal comfort of that particular occupation of a particular environment. Suppose a person working in a maybe we can take an example like fish processing industry, so a lot of cold temperatures and the surrounding temperature is very-cold. So, what if we understand the index, a particular thermal index over there, then we can find that how long the person is comfortable to do their job in that particular index. So, based on that, maybe we can decide on the work-rest cycle, or maybe we can decide on what kind of clothing we should give so that comfort level can come back. These are the decision-making point we choose when we are talking about the thermal indices.

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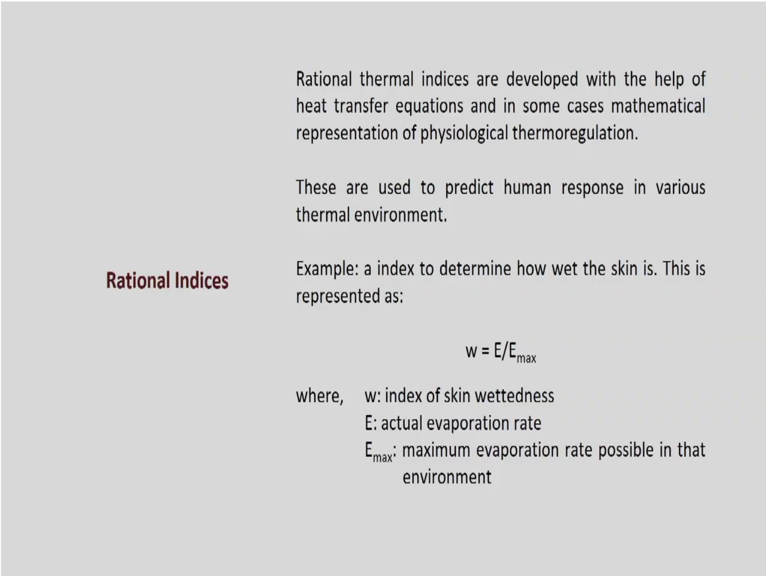

So, let me tell the rational of these indices; so, rational thermal indices are developed with the help of heat transfer equation what we discussed earlier that heat balance and heat transport equation and in some cases, mathematical representation of physiological thermoregulation. So, physiological thermoregulation we discussed that how it happens? It happens through our hypothalamus, and all these physiological phenomena like ATP transfers to; translate to ADP. And then heat generates there has metabolism happening through that heat generates all these calculations. These are used to predict human responses in various thermal environments.

Let us take an example index to determine how wet the skin is; maybe the index we can call "w"; w is equal to E divided by E max. What is w? "w" is the index of skin wettedness, how wet my skin is, how we can calculate that? E divided by E max, E means actual evaporation rate.

So, what currently is happening divided by E max, means how the maximum evaporation rate can be. So, based on that, so if it is the actual one is tending to the maximum, then I will understand my skin is going to dry if it is not happening it is less, then maybe there is some accumulation of humidity on my skin so that I will feel little wettedness right.

So, these are some indices that can help us to understand the comfort as well as it will help us to understand. It will not give direct measurement, but it will help us to get an idea how the performance or productivity is getting affected or is there any scope of design intervention to improve the situation or not.

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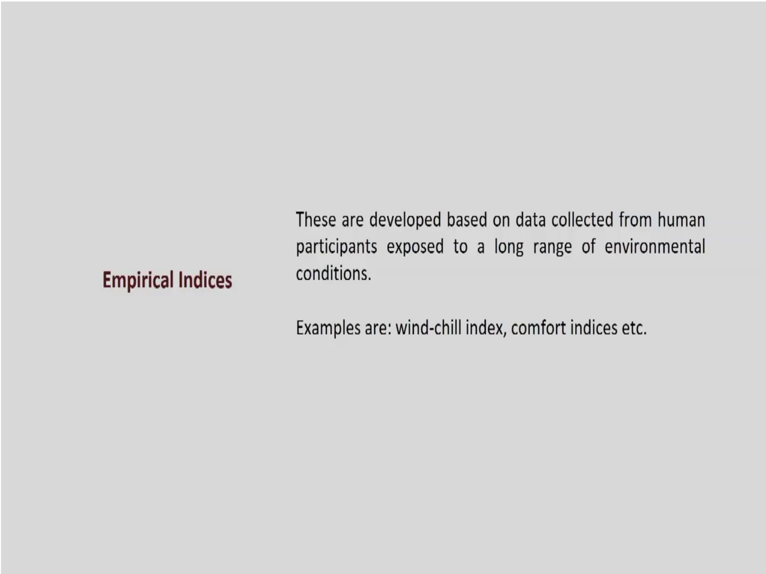

So, when we are talking about empirical indices, these are developed based on the data collected from human participants exposed to a long range of environmental conditions. So, it is not that all of us sudden we someone can develop that it needs real long exposure and lot of other calculation; some examples are, windshield index, some are comfort index and there are many others we will be discussing few of them. When we are talking about thermal index or thermal indices, one very important index is WBGT (Wet Bulb Globe Temperature) index.

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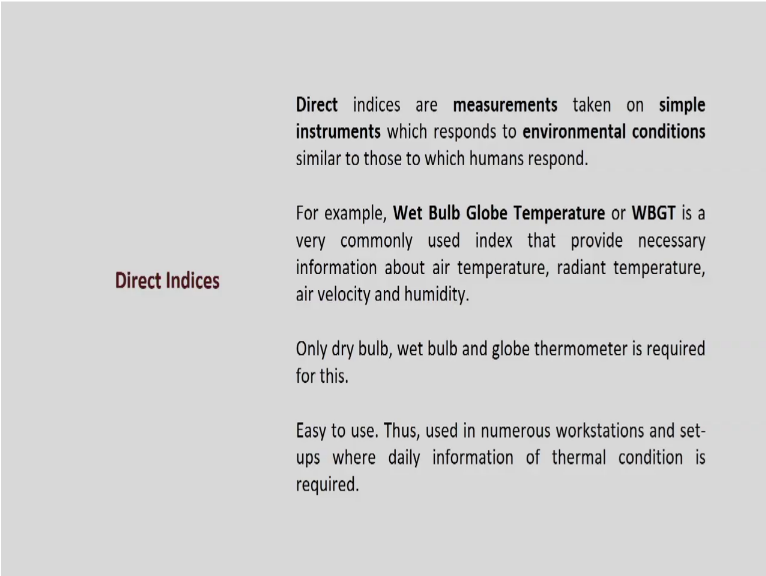

So, what it is? It comes under the direct indices. So, what are direct indices? Direct indices are measurements taken on the simple instrument; it is very important criterion that is the simple instrument. So, we may not have the facility to measure a lot of critical components or critical variables, but if we have some simple instruments that we will name them. So, if we have that, maybe we can have a good idea about the thermal impact or thermal environmental impact on the human body; so, one of them is the WBGT index. So, for measuring the WBGT index, we only need dry bulb, wet bulb and globe thermometer, which is very easily, commonly available. And every workplace, we can use these three instruments to identify or to measure the WBGT index.

It has a specific formula. I would request you to look into the books and find out and measure your own WBGT index wherever you are working. You can do some evaluation based on your idea or your understanding, your surrounding physical environment, and find out the WBGT index of that particular location. One more critical component is effective temperature; it is also a handy and commonly used index. So, what it is, it says, is often used as an estimate of a body's surface temperature.

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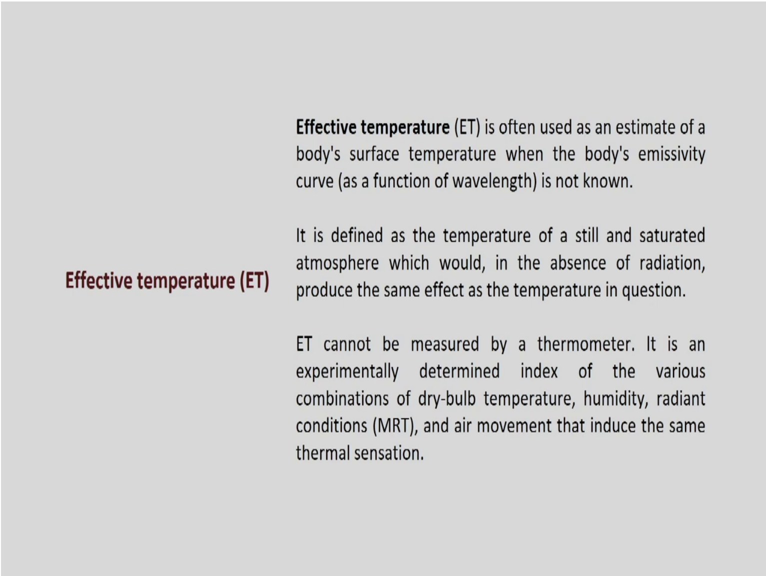

It gives an estimation of the surface temperature when bodies emissive curve is not known. So, what it does? It is defined as the temperature of a still and saturated atmosphere which would, in the absence of radiation, produced the same effect as the temperature in question. This particular temperature, we can test in a different situation.

Effective temperature cannot be measured by a thermometer, it is an experimentally determined index of the various combinations of dry bulb temperature, humidity, radiant condition and air movement that include the same thermal sensation. So, it is not only a measurement of some physical environment; it includes the sensation as well, that's why it is effective temperature, and it talks about the surface of the skin.

So, very much important when we are talking about thermal comfort, performance, productivity, and all those relevant topic. So, the effective temperature is the very useful index in industry, and we practice it to understand and measure when we are talking about thermal comfort. So, as we are talking about indices or thermal indices, let us speak about thermal comfort; because physical environment; physical thermal environment has a direct impact on the sensation, so the sensation or our perception is only the thermal comfort.

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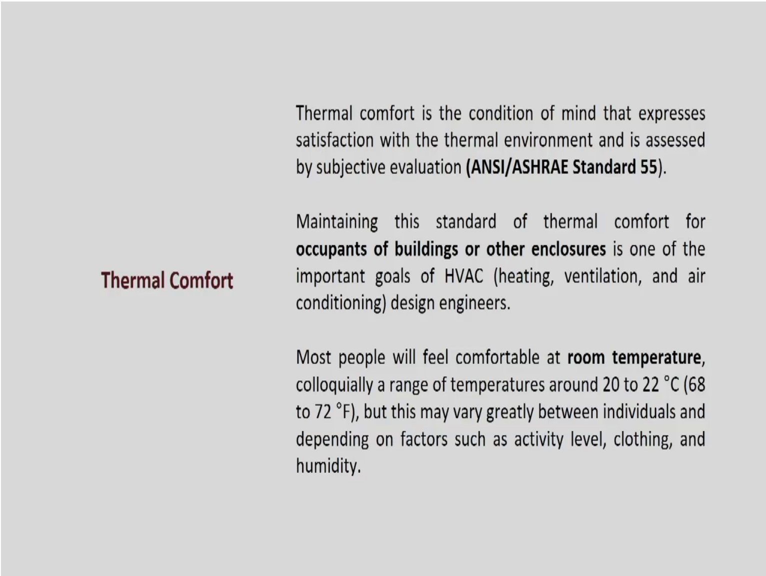

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation. So, it is not a measurement; it is a subjective evaluation; it is defined by different standards, especially ANSI or ASHRAE. Maintaining this standard of thermal comfort for occupants of the building or other enclosure, so when we are within us surrounding is one of the important goals of HVAC, it design engineers.

So, what they does, they try to achieve that all the occupants of that particular room or enclosure should feel comfort to understand that they need to understand what the thermal comforts talks about. Thermal comfort depends on the different indices of components like; air velocity, air temperature, humidity, and all those things.

Most people will feel comfortable at room temperature, which normally ranges from 20 to 22 degrees centigrade, but this may vary greatly between individuals and depending on the factors such as activity level, clothing, humidity, etc. Take an example, if the temperature of that particular room is some degree centigrade, suppose 20 degrees.

And someone who is wearing a very thin cloth and someone is wearing a woolen sweater or something; definitely, the comfort level will change, the comfort level will vary from one person to another person. Therefore, thermal sensation or perceived comfort is very important to understand when we are designing the interior. Why this is important, of course, we are talking the same thing.

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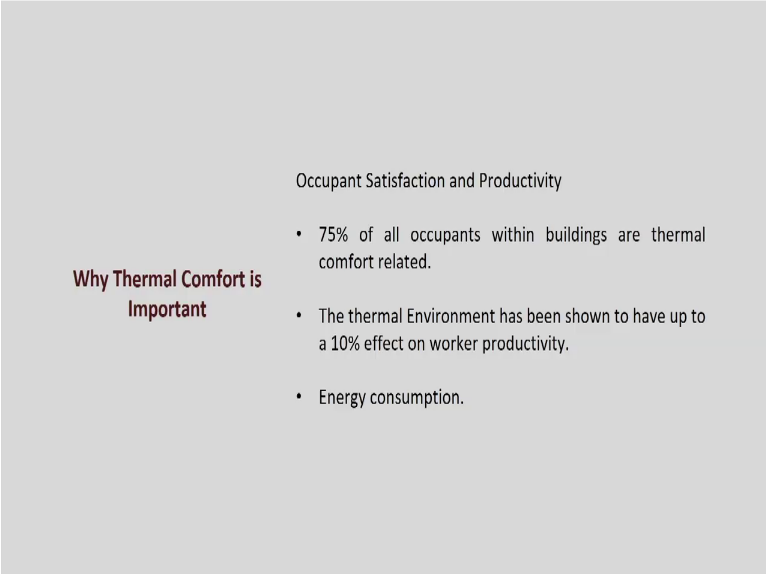

So, we say that if 75 percent of all occupants within the building are telling that it is thermally comfort, then it becomes very easy to say the environment is good. The thermal environment has been shown to have up to a 10 percent effect on the worker's productivity. We are not very sure, or it is not very easy to directly measure that, what is the percentage of impact, but still, it has been identified that it is almost 10 percent or it can go up to 10 percent, and of course, it depends on the energy consumption.

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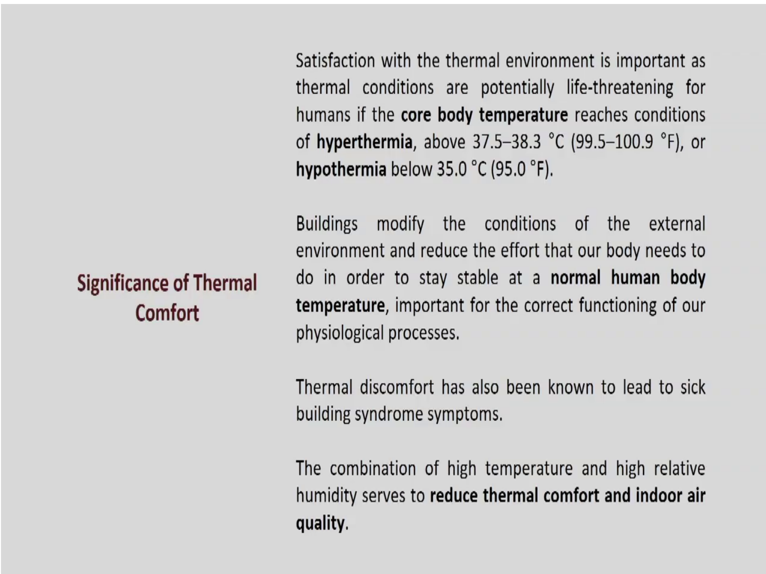

Satisfaction with the thermal environment is very important as thermal conditions are potentially life-threatening for humans if the core temperature reaches the condition of hypothermia or hyperthermia. So, what is hypothermia? Hypothermia says that when your core body temperature goes down to 35 degrees centigrade. Hypothermia, when it crosses 37 or 38 degrees centigrade, then there may be a case of different physiological malfunction may be the fatal case.

If you do not understand thermal comfort, it becomes very difficult to make a decision in case of hypothermia and hyperthermia. So, buildings modify the conditions of the external environment and reduce the comfort that our body needs to do in order to stay stable at a normal human body temperature; that is the designer's role.

So, important for the correct functioning of our physiological processes, why we need that core body temperature on a constant position? Because it helps us to function that physiological functions run in a smooth way, so that needs to be done. Thermal comfort has also been known to lead to sick building syndrome symptoms; it is a very common phrase, but determining that is very difficult. Therefore, the combination of high temperature and high relative humidity serves to reduce thermal comfort and indoor air quality.

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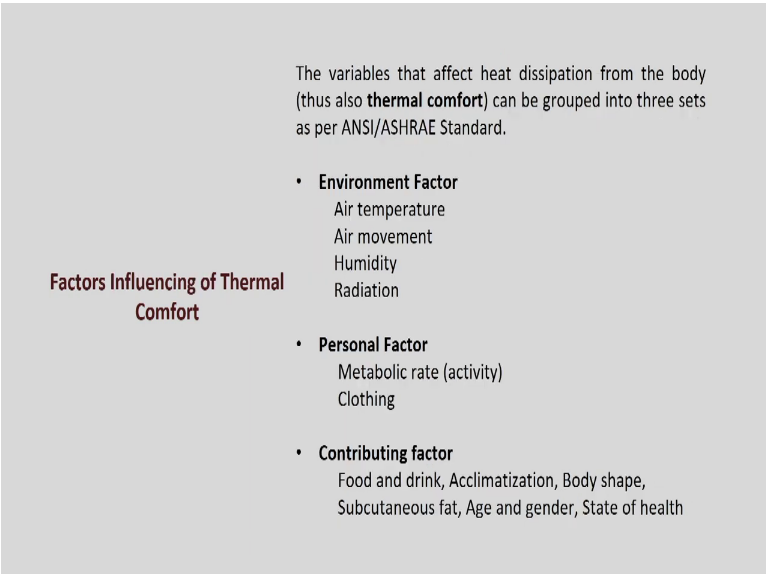

When we are talking about thermal comfort, we understood the thermal indices, but definitely, thermal comfort has is the causal factor of many other things. So, we should know the, what are the influencing factors available which actually affect thermal comfort. Thus, there are three major factors one is an environmental factor, personnel factor, and contributing factor.

Now, these divisions are made by the ANSI and ASHRAE standards; there are maybe some changes in the terminology by different other researchers. So, environmental factors like; air temperature, air movement, humidity, and radiation will be considered as per the ANSI standard. Personnel factors; metabolic rate and clothing, contributing factors; food and drink, acclimatization, body shape, subcutaneous fat, age, gender, and state of health; these are being defined by the ANSI and ASHRAE. So, let us understand what these are.

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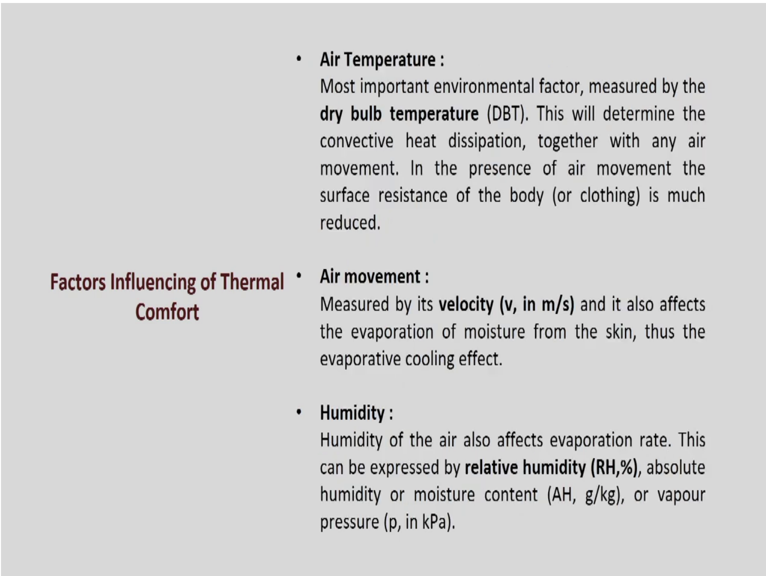

Air temperature; air temperature is the most vital environmental factor measured by the dry bulb. So, when we are talking about air temperature, we will be talking about the measurement of the dry bulb. This will determine the convective heat dissipation, together with any air movement. In the presence of air movement, the surface resistance of the body is much reduced, which we need to understand. Because if you have clothing there, then perceptions or comfort will be different. The next parameter or variable is air movement.

Based on the air movement, your perception or your comfort level changes and how we measure it? We measure in terms of velocity, so meter per second normally we can translate it according to our requirement as well. Now, comes under humidity; what it is? It absolutely depends on how much water content we have within the environment, so usually, we calculate this one as the relative humidity, then one more important factor is radiation.

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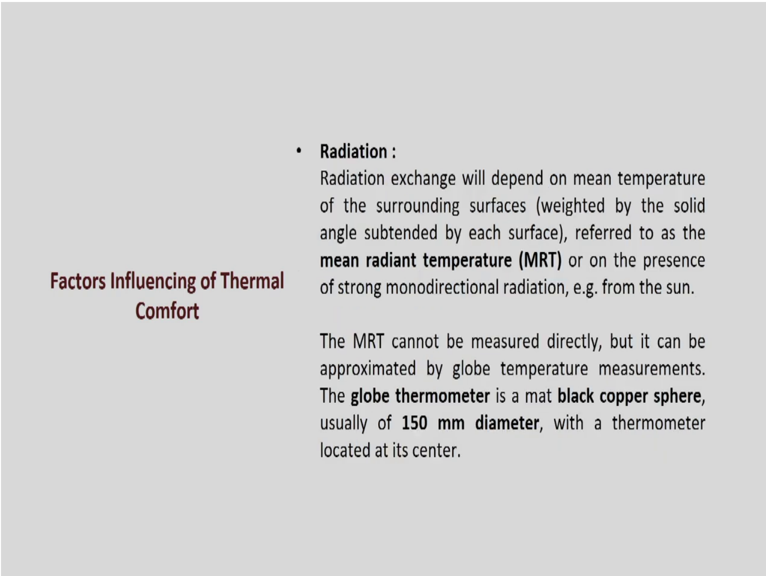

Radiation exchange will depend on the mean temperature of the surrounding surface, referred to as the Mean Radiant Temperature (MRT). This particular variable is an important measurement when we are talking about the thermal environment. The MRT cannot be measured directly, but it can be approximated by globe temperature measurement.

The globe temperature is measured with the help of a globe thermometer. This globe thermometer is a black copper sphere and usually of 150-millimeter diameter we preferred, which is located exactly at the center.

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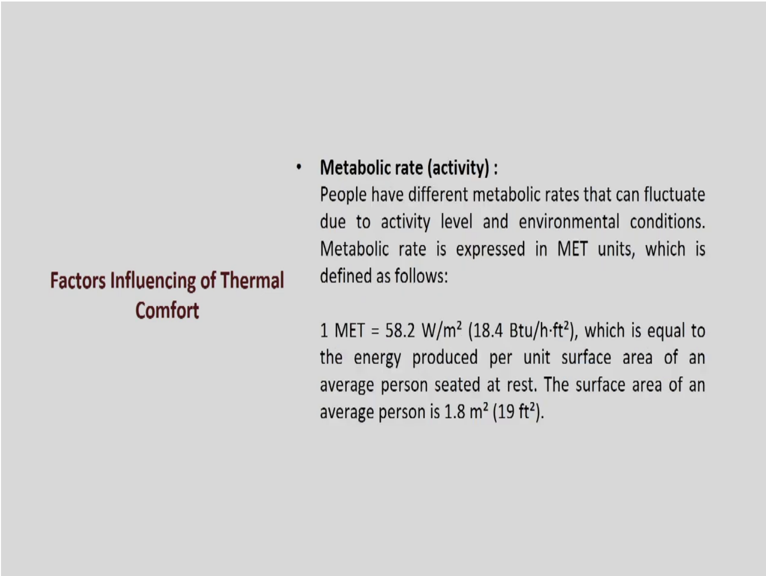

When we are talking about other contributing factors, the major is metabolic rate, which is the source of the heat within the body. People have different metabolic rates that can fluctuate due to activity level because if you run definitely heat production within in your body will be different. But, if you are in a sedentary job, the production rate will be different, so environmental conditions also.

If you are in a cold room, that metabolic rate will change. Metabolic rate is expressed in MET unit, which can be defined as one MET equal to 58.2 Watt per meter square. So, these are the calculation that you need to do when you are specifically calculating the thermal discomfort, thermal comfort, and presents of heat within the environment and how the human being is interacting or reacting on that particular aspect.

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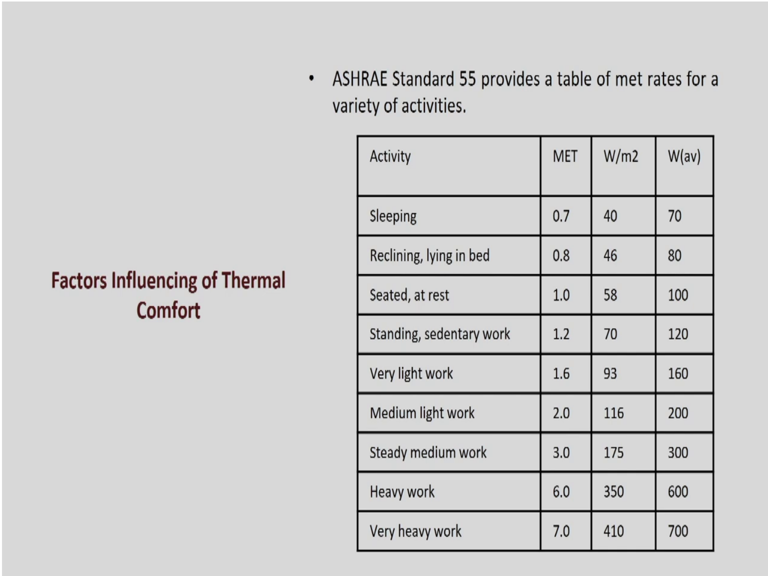

Activity	MET	W/m2	W(av)
Sleeping	0.7	40	70
Reclining, lying in bed	0.8	46	80
Seated, at rest	1.0	58	100
Standing, sedentary work	1.2	70	120
Very light work	1.6	93	160
Medium light work	2.0	116	200
Steady medium work	3.0	175	300
Heavy work	6.0	350	600
Very heavy work	7.0	410	700

In the ASHRAE standard, some of the activities are being already calculated and mentioned by them. So, you can refer above table directly or, based on the requirement, you may calculate as well. When we are talking about thermal comfort, we already spoke about what kind of heat we have within the environment. Now, thermal comfort very much dependent on the clothing pattern.

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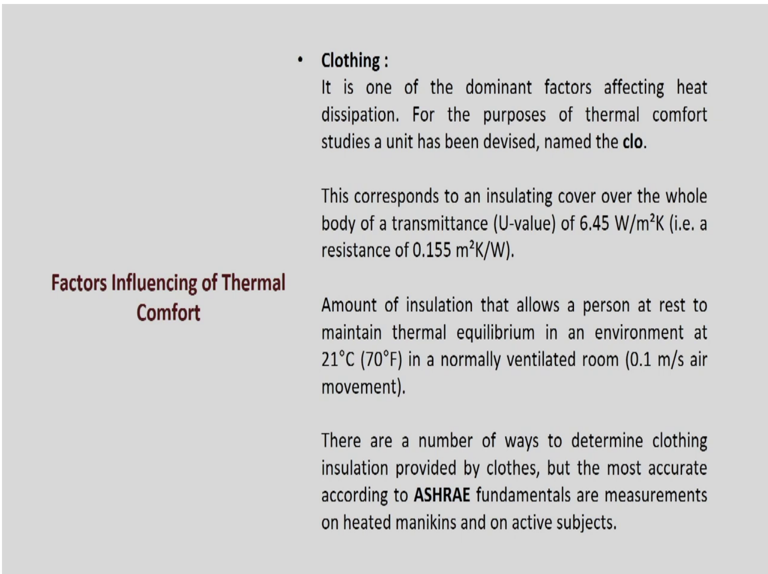

It is a dominant factor that affects heat dissipation; the heat will go out from the body. So, how the insulation is; very important, and it is always presented this particular clothing factor as “clo” values. It has vary every fabric has their own “clo” value based on that we can decide what kind of insulation we have within our body. So, this corresponds to an insulating cover of the whole body of transmittance of 6.45 Watt per meter square K.

Amount of insulation that allows a person at rest to maintain thermal equilibrium in an environment at 21 degrees centigrade in the normally ventilated room we consider as one “clo”. There are several ways to determine clothing insulation provided by clothes, but the most accurate, according to ASHRAE fundamentals, are measurements on heated manikins and on the active subjects. So definitely, we can get these measurements done.

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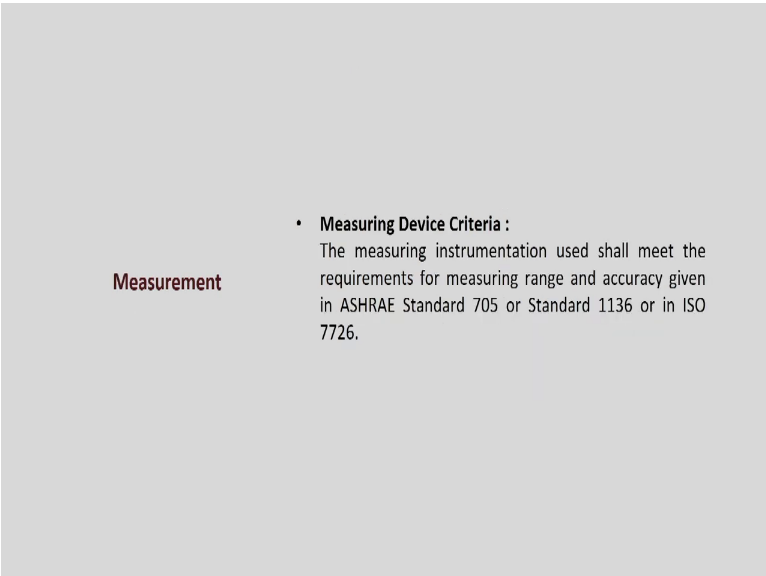

Let us understand some of the measurements, so what are the measurement device criteria; the measuring instrumentation that is defined by ASHRAE that needs to be used shall meet the requirements of the measurement range. So, what is the whole range can be possible it should measure that and accuracy given in ASHRAE standard 705 or standard 1136 or in ISO 7726, these are the standards you can follow, and you can get the measurement device criteria.

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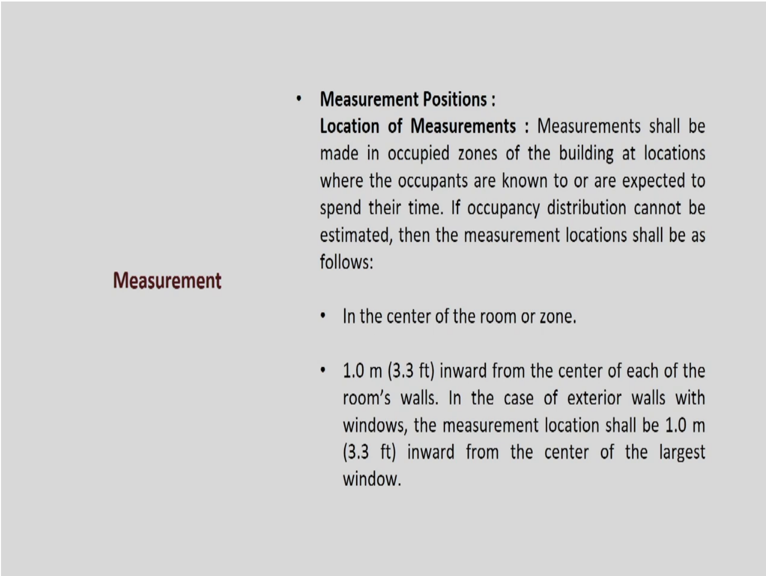

When we are talking about measurement, let us understand where we should measure it, so measurement location, position. So, measurement shall be made in the occupied zone of the building at locations where the occupants are known to or are expected to spend their time. So, it is not that the whole room is occupied by one person and in the long room other corners, no one is there.

So, where do you measure? You will be measured only the location where the occupant is; if that is not being defined or you cannot find that, then what you should do, you should make measure it at the center of the room or the center of that particular zone. One meter inward from the center of each of the room's walls. In the case of exterior walls with windows, the measurement location shall be one meter inward from the center of the largest window.

Because these are the sources of difference in the environmental heat, wind a position can change the wind speed. Then window position will change the wind speed also; it may give some other external heat within the room. So, these are the things we should maintain when we are talking about the measurement location, at which level we should measure like height.

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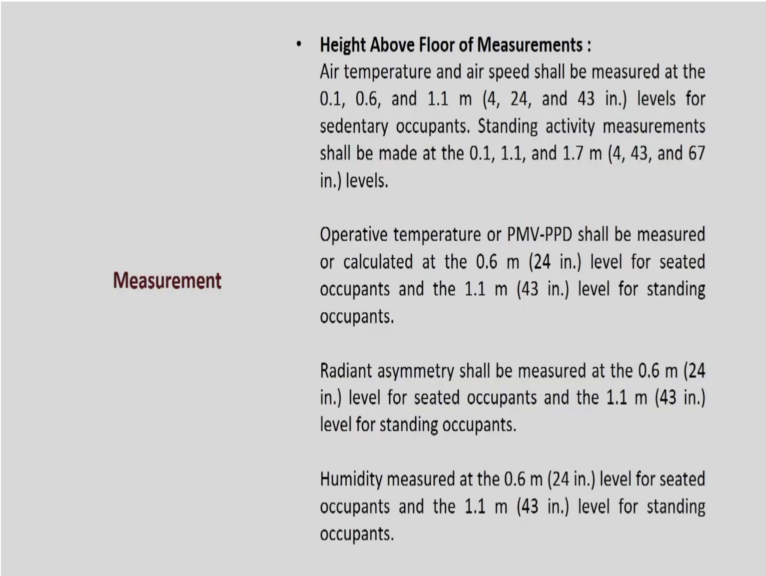

Air temperature or air speed shall be measured at the 0.1, 0.6, or 1.1 meter levels for sedentary occupation if the person is in seated condition. Same thing will vary if the person is standing, so that will be 0.1 1.1 or 1.7 meters. Operative temperature or PMV-PPD shall be measured or calculated at the 0.6 meter level for seated occupants; if it is standing, then 1.1-meter level. Radiant asymmetry always we need to measure at the 0.6 meters it seated, if standing then 1.1-meter. Humidity also follows the same position.

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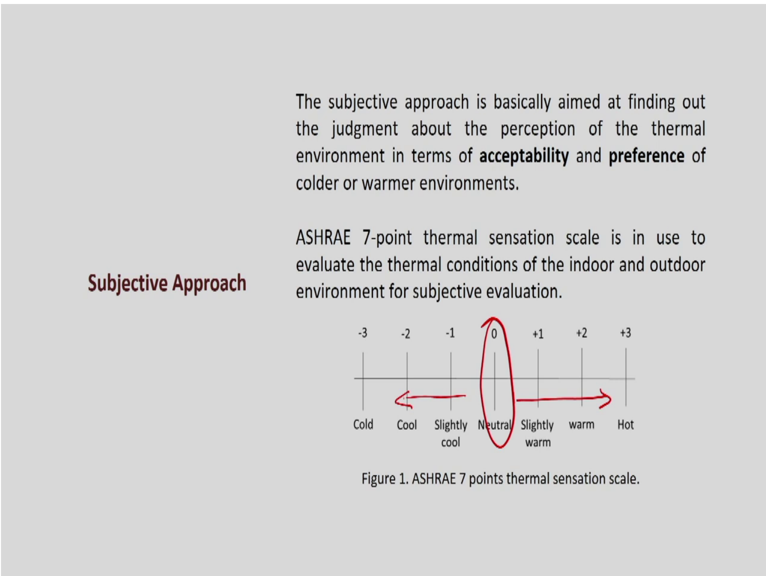

When we are talking about measurement, we talked about thermal comfort; very important is how we should gather data as per thermal comfort is concerned. So, definitely, it is a subjective approach; what is it? So, the subjective approach is basically aimed at finding out the judgment about the perception of the thermal environment in terms of acceptability or preference of colder or warmer environments.

So, we have one very standard used scale that is the ASHRAE 7-point thermal sensation scale which I mentioned. The neutral point we call it as 0, once we go on the site like on the left-hand side, it keeps on getting like cool sensation, or cold sensation, other side it is heat sensation. So, a significant frequently used scale is this ASHRAE 7-point thermal sensation scale.

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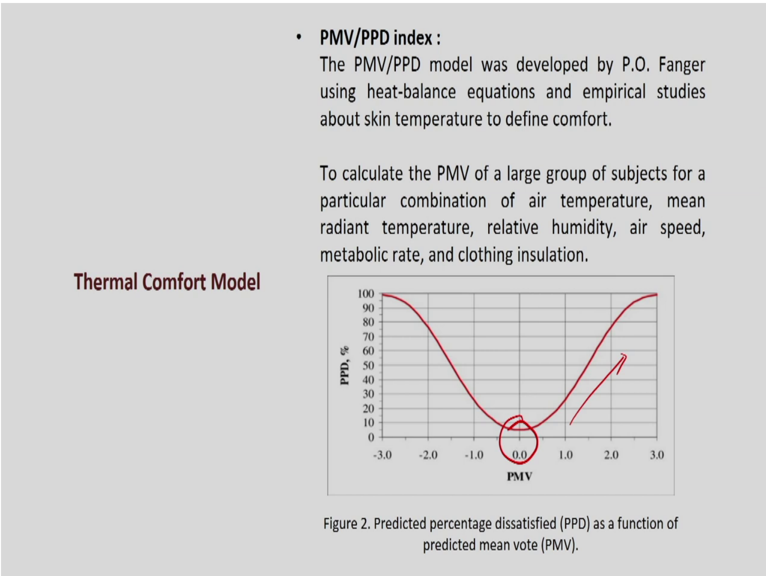

Now, I am not going to elaborate, but if required, you can go into detail. So, the PMV-PPD index is an important aspect; we call it a thermal comfort model and see where this PMV is located. So, the PMV value like “0.0” is fundamental, how the PPD percentage is increasing on the other side. The thermal comfort standard requires the PPD to be less than 10% to correspond to a PMV of between slightly cool sensation and slightly warm sensation according to ISO 7730 and ASHRAE 55.

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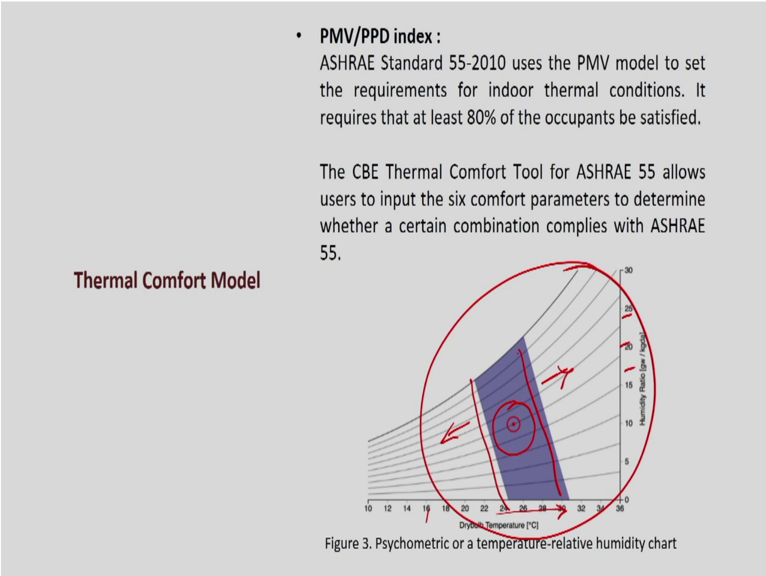

When we are talking about PMV and PPD index, you see one above figure, which is very important, that whole zone we call the comfort zone. So, psychometric or temperature relative humidity chart, so again it is a by ASHRAE 55. So, what it says that if your comfort level lies within the zone, then you are safe; if it is outside, you are not in the comfort zone.

The concern is that this whole particular phenomenon is globally valid, but the temperature ranges are not always true for all contexts. Based on the context, the temperature zone changes, and it may shift on both sides.

So, based on your understanding, your requirement, you need to establish this particular zone, and you have to find out where your comfort zone is. Because comfortability again depends on the adaptation capacity or habitual activities, so those are an essential aspect.

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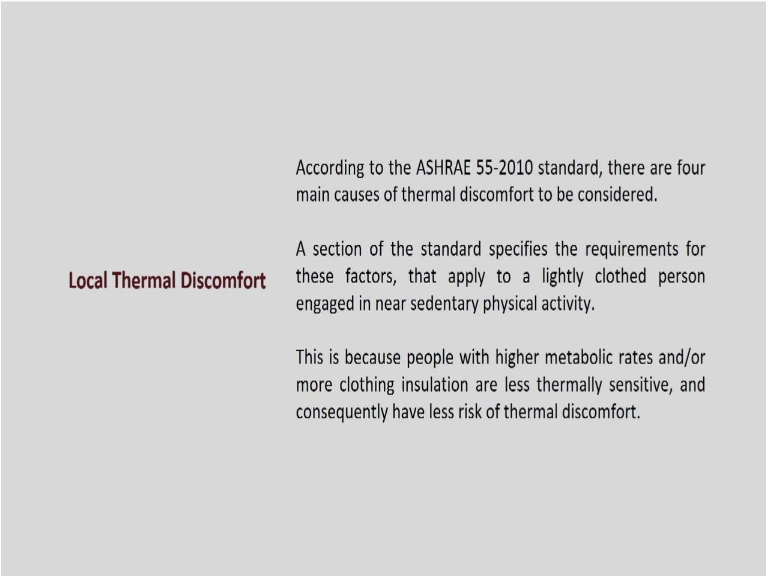

Now, the critical discussion is local thermal discomfort; according to ASHRAE 55-2010 standard, there are four main causes of thermal discomfort. A section of the standards specifies the requirements for these factors applied to the lightly clothed person engaged in near sedentary physical activity.

So, this is because people with higher metabolic rates and more clothing insulation are less thermally sensitive. Because they are not in touch with the direct environment and consequently have less risk of thermal discomfort, this phenomenon will definitely change based on the context.

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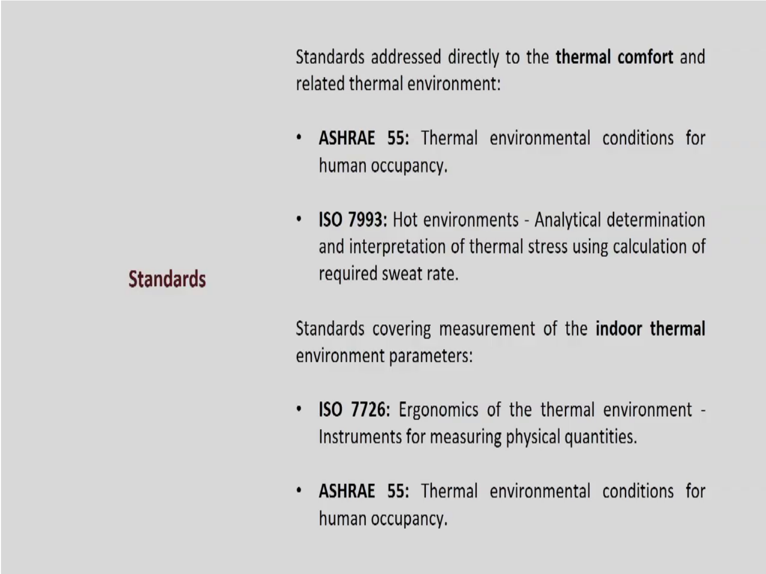

Now, let me talk a bit about these standards; we have varieties of standards. So, ASHRAE 55, it says about the thermal environmental conditions for human occupancy. ISO 7993, it talks about hot environment, analytical determination and interpretation of thermal stress using calculation of required sweat rate. So these are mainly on thermal comfort.

We have something for the indoor thermal environment that is ISO 7726; it talks about the ergonomics of the thermal environment, instruments for measuring physical quantities, and ASHRAE 55 that also talks about the thermal environmental conditions for human occupancy.

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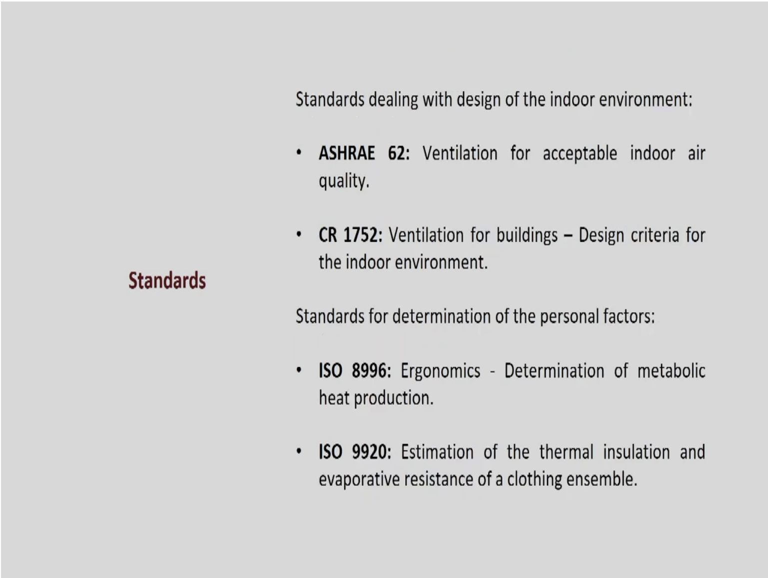

Now, some standards deal with the design of the indoor environment, like ASHRAE 62, ventilation for acceptable indoor air quality, and CR 1752 ventilation for buildings design, criteria for the indoor environment. Standards for determination of the personal factors like ISO 8996 that talks about the ergonomics determination of metabolic heat production, and ISO 9920 that is the estimation of the thermal insulation and evaporative resistance of the clothing and ensemble.

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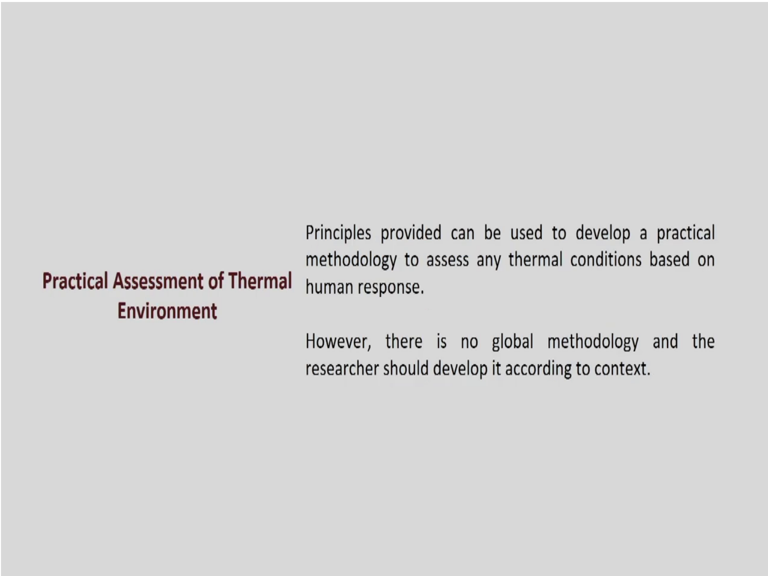

When we talk about all these aspects like thermal discomfort, thermal comfort, thermal temperature, indices measurement, and all those things, a practical assessment of the thermal environment is very important. So, this particular principle, whatever we are following for the practical assessment, can be used to develop a practical methodology to assess any thermal conditions based on the human responses, what you can do yourself.

However, if you see through the literature, there is no globally acceptable applicability for all contexts; that kind of methodology is not being established till now. So, based on your context, you need to develop your own methodology, and you have to work on it.

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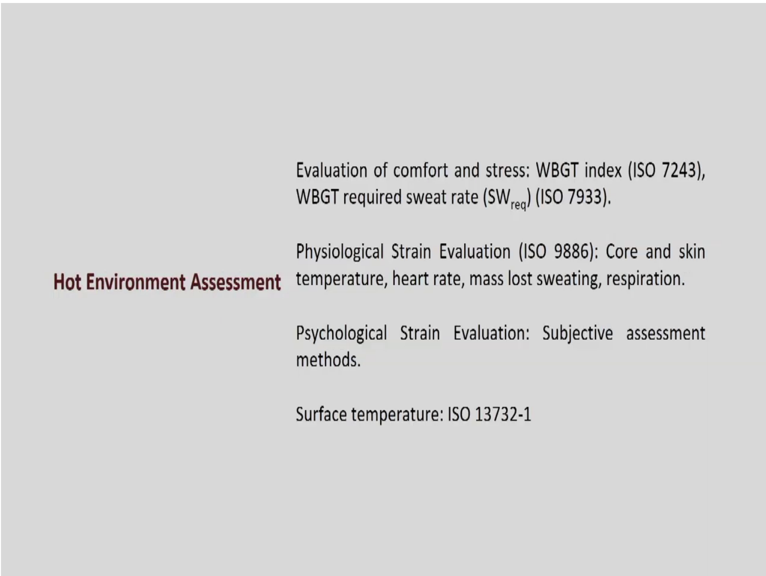

When we are talking about measurement or assessment, we can have three variety hot, moderate and cold, so for hot environment measurement assessment. So, evaluation of comfort and stress, we can go for WBGT index, which is being mentioned in ISO 7243, and WBGT required sweat rate; this is again some modification in 7933 that is also ISO. Physiological strain evaluation; what it is, mainly the core and skin temperature, heart rate, mass lost sweating, and respiration. Psychological strain evaluation; subjective assessment method. And the surface temperature is being mentioned in ISO 13732-1. So, you can have understood when we are talking about the hot environment assessment. Now, if we are talking about moderate environment assessment, predicted mean vote, and predicted percentage dissatisfied.

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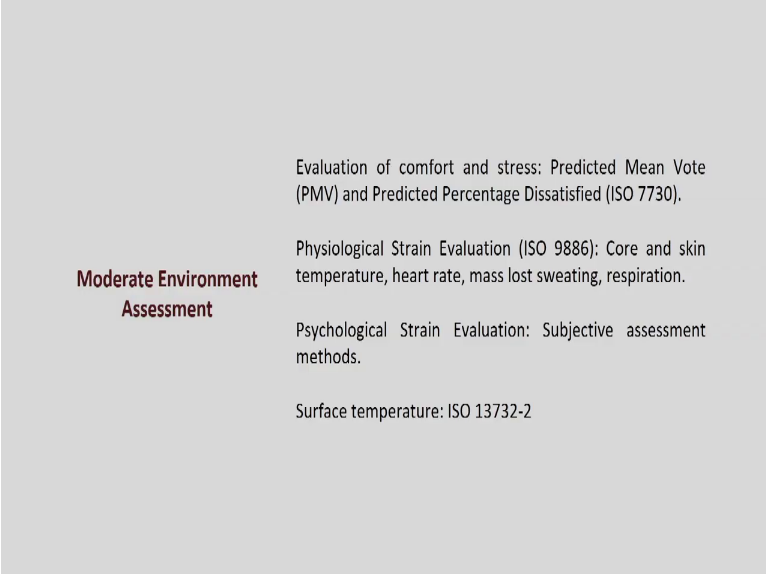

So, which we already spoke about, that model that is being presented very in detail ISO 7730. Physiological strain evaluation again the same core and skin temperature, heart rate, mass lost sweating, and respiration, subjective assessment method, and surface temperature.

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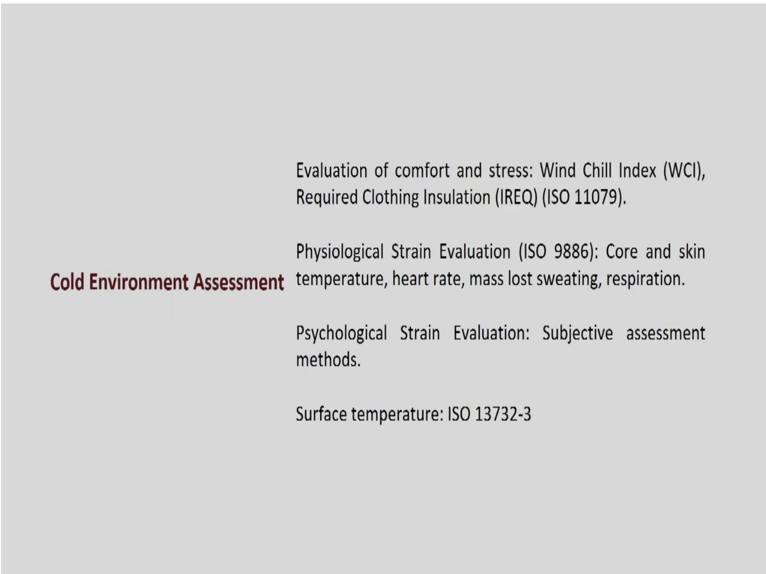

And cold environment same Wind Chill Index what I mentioned in the very first, then physiological same again core and skin temperature, heart rate, mass lost of sweating, respiration. And subjective assessment method, and surface temperature which is depicted in ISO-13732 part 3, so the previous one is part 2, the first one is part 1, and the third one is part 3, so this way you can access.

All these whole courses, we will be talking about different applications and the assessment criteria. So, detailing is impossible, but of course, when you are talking about all these assessment measurements, you can practice yourself and generate your own methodology.

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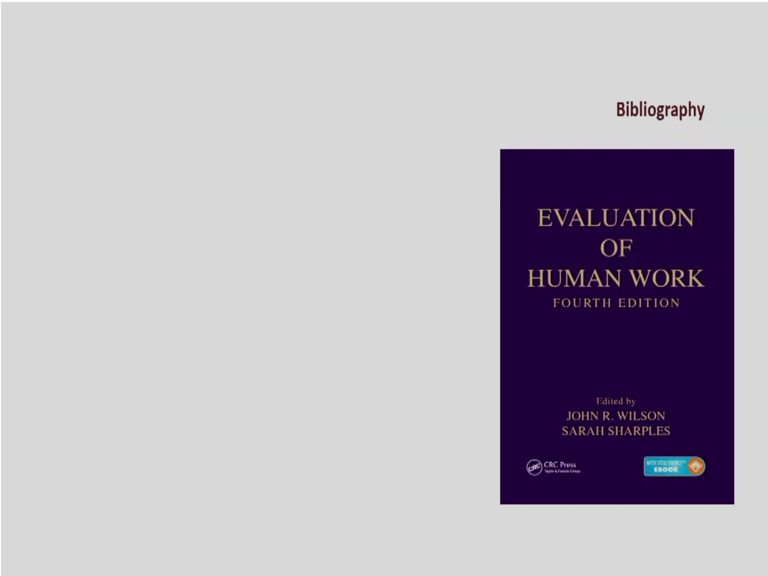

This is one of the books that I ask you to refer; if you want to know more, also there are varieties of literature available that will help you to understand and explore more about the impact of the thermal environment on performance and productivity. And how it is relevant or is it related to the ergonomic workplace evaluation, and how we can take those key points to design or design modification or the thermal environment changes.

So, what will be the instruction for you is whatever we discussed; please take each point, practice it at home, and find out the varieties or possibilities in your research area.

Thank you.