Ergonomics Research Techniques

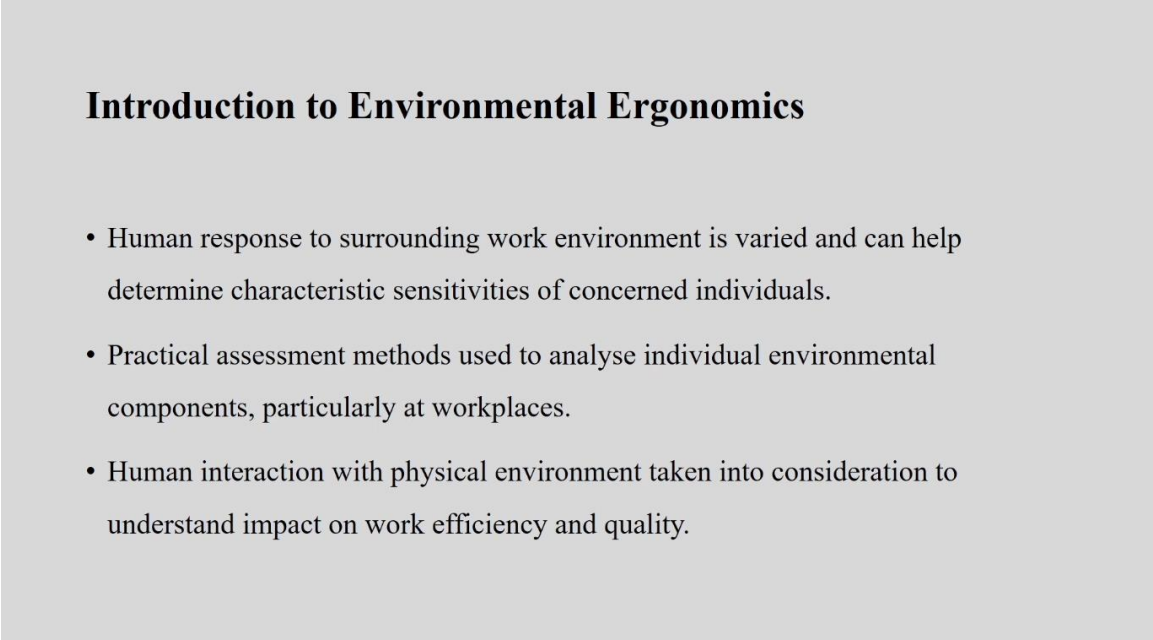
Dr. Urmi R Salve

Department of Design, Indian Institute of Technology Guwahati

Week 12: Lec 40- Assessment of environmental factors

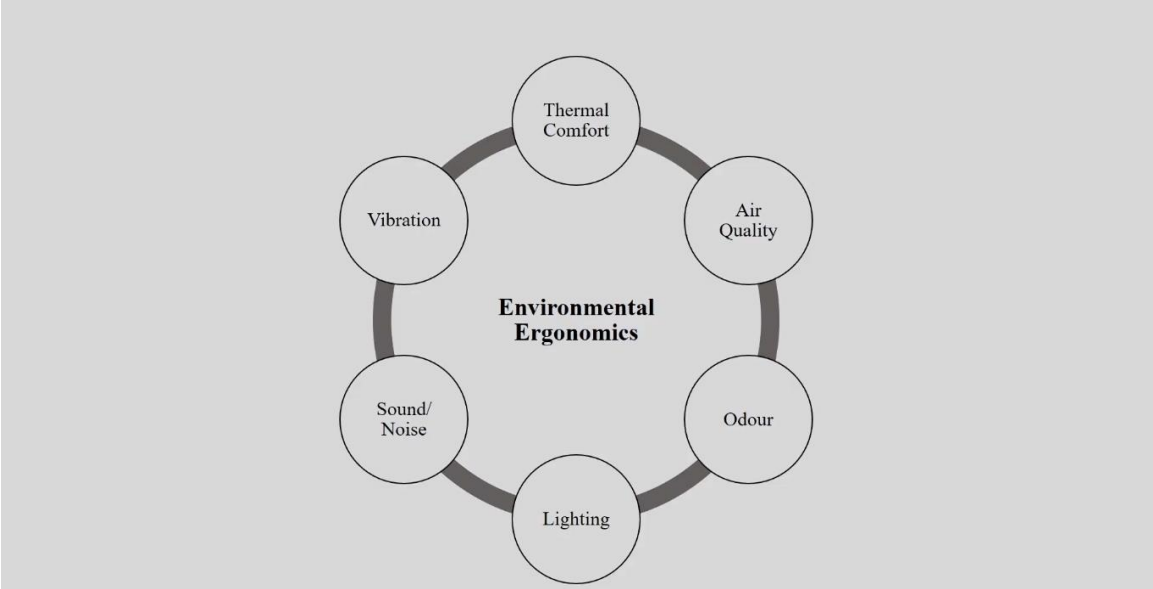
Measurement of thermal conditions at workplace

Welcome. Today, we will be discussing about the environmental ergonomics. So we will be taking from today onwards few weeks where we will be talking mainly about the different types of techniques and tools which are being used to analyze, assess and evaluate the environmental ergonomical factors, ok. So we will understand that what are those factors, what are the parameters or tools that we can measure and how do we measure. So slowly we will be taking towards the evaluation process and assessment process. So we will be discussing the methods and associated tools or instruments that are being used for this type of evaluation. So let us start about this particular topic that is the environmental ergonomics.



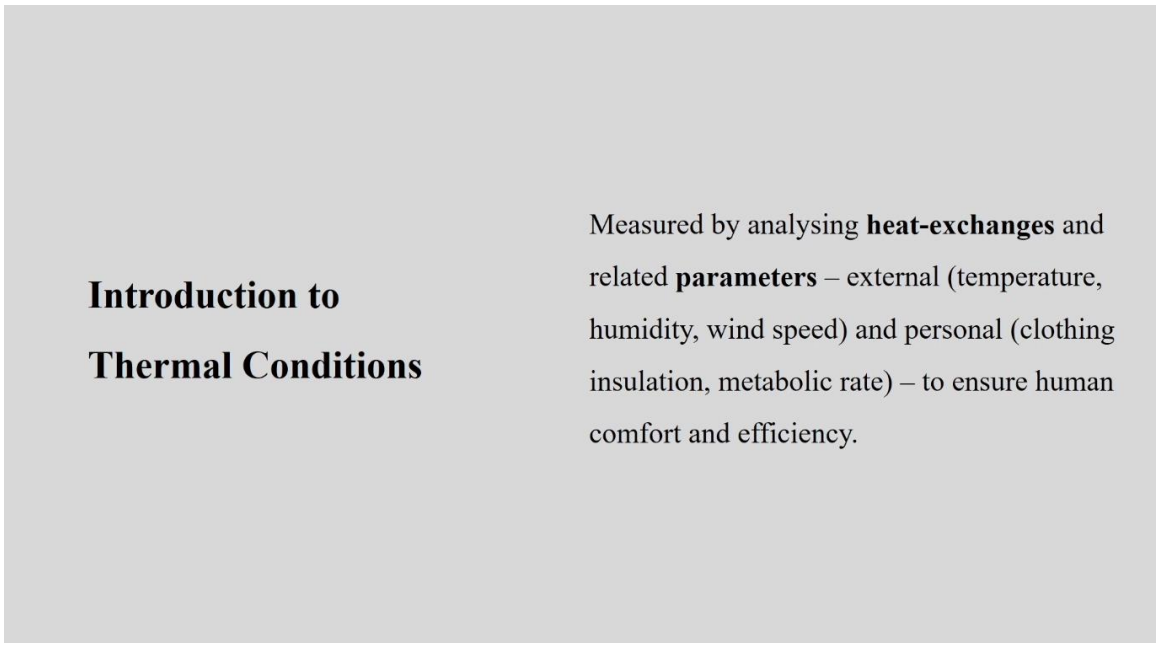
So all of us know that human always respond towards the surrounding environment. So these surrounding environments are varied in nature and definitely it can help in determining the characteristics, the sensitivities of concerned individuals, right. So how sensitive we are, how it is affecting the performance, everything is dependent on the individual to individual. Of course, the climatic condition also helps them to adapt the situation and then slowly they respond towards various factors or various environmental variables. So practical assessment methods which are being used to analyze the

environment, individual environmental components, particularly we can do it at the workplace, ok. So at any workplace we can use that. So, human interaction with physical environment taken into consideration to understand the impact of such environmental factors on the work efficiency, work quality, even the work quantity, ok. So these are some elements that we need to understand thoroughly. So it is very much connected to various physiological responses which are going to get impact based on the changes on the environmental parameter. Suppose thermal changes, if there are some thermal changes how the physiological changes are happening and how that is going to impact your performance or productivity of the whole system that we are going to understand in detail.



Elements of Environmental Ergonomics

So these are the major element which is going to be considered. First is thermal comfort, air quality, outdoor environment, illumination which we will be talking about from lighting perspective, sound and noise and vibration. So let us begin with the thermal condition.



So if we talk about thermal condition how do we measure it? Normally we measure the thermal condition by analyzing the heat exchanges and related parameters of heat exchanges are external and personal parameters. So under external parameters we try to understand the temperature, humidity, wind speed etc. From the personal we can go ahead with the clothing insulation, the personal metabolic rate and all those things. So how much heat is there in the environment and what is getting generated within body and then how the balancing is happening. What is the kind of heat exchange is happening? Is it from outside within the body or from inside of our body it is going outside? How this scenario is? Based on that we will get the you know physiological responses, we will understand how the this can be measured and based on the measurement we will be able to tell that what are the varieties of responses can be obtained and how that is going to affect the individual's performance at the workplace. So let us understand what heat exchange is.

Heat-Exchange Analysis

Heat Production = Heat Loss

- Assessed by **measuring climatic parameters** directly affecting human heat balance
- **State of comfort/ low thermal strain** achieved when heat balance is maintained close to equilibrium at relatively stable body temperature
- Expressed in **Wm^{-2}** as heat exchanged between skin and environment

So of course it is like kind of heat is being produced within the body and the kind of heat we are losing from our body. So if there is equilibrium we are in a peaceful situation, if there is no break in the equilibrium definitely there will be either heat stress or cold stress. So we can say this heat exchange can be assessed by measuring the climatic parameters directly affecting the human heat balance. So what are these climatic parameters? That we are going to learn in next slides. So state of comfort or low thermal strain can be achieved when heat balance is maintained close to the equilibrium. Of course if what is the amount of heat is generating and what is the amount of heat we are you know going out from our body if that is near to equal amount or equilibrium is maintained then of course you are in a comfort zone. So we can express this particular heat exchange in W by meter square as the heat exchange between the skin and the environment. This formula we can express it in this particular way. When we are talking about heat exchange we need to understand what the process of heat exchange is. It is typical physics methods that is the convection and the radiation. These are the two ways how heat is getting exchanged between the outdoor environments or to the environment and the human body. So let us understand what is or we will understand that what the convection is.

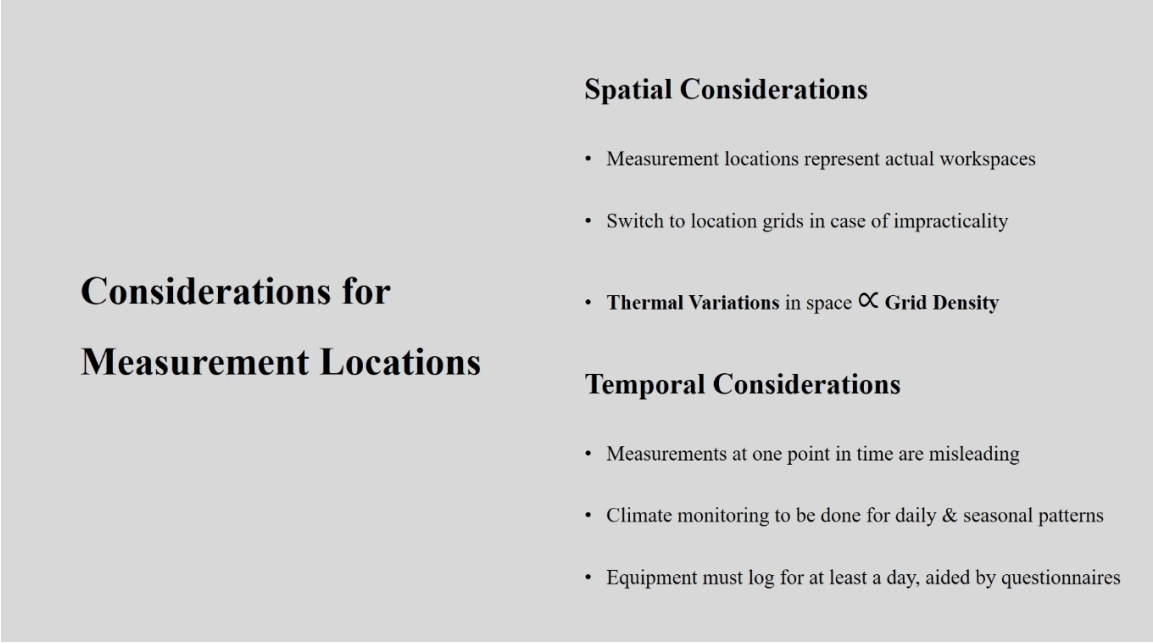
Methods of Heat Exchange

- **Convection** heat transfer – Cool air flows along skin surface and carries heat away from body
- **Radiation** heat transfer – Between body and environment without direct physical contact and separation in space

Body Comfort	Heat Stress	Heat Balance	Cold Stress
Thermal Equilibrium	Heat Loss > Heat Production	Heat Loss = Heat Production	Heat Production > Heat Loss
Mode of Heat Transfer	Evaporation	Convection	Convection Evaporation
Body Temperature	Increased	Comfortable	Decreased

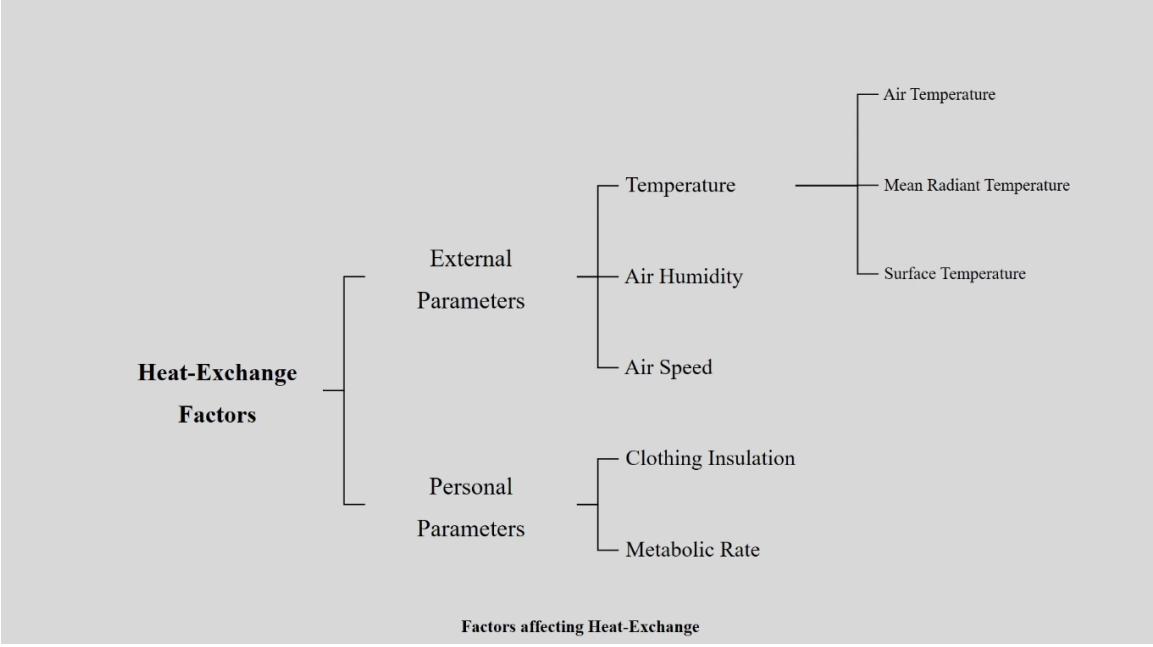
So convection it is the process of heat transfer. Cool air flows along the skin surface and carries the heat away from your body. So if there is some kind of cold air which is going which is present in the environment, once it touches our skin, it takes the heat away from our body. The second is the radiation through like through radiation we have heat transfer. So, between body and environment without any direct physical contact and separation in space ok. So these are the two major methods or way that heat exchange happens between the human body and the connected physical environment. So here you can see that I have mentioned what will be the heat stress and when it will be heat balance and when it will be cold stress. Because when we are talking about thermal stress, thermal stress can be heat stress and thermal stress can be cold stress. Both cases you are if you are not in a comfort zone, then it is stress. So in thermal equilibrium if we look at from the thermal equilibrium perspective, if heat loss is more than your heat production, heat loss is more than your heat production this is little wrong this is this will be this: heat production is more than your heat loss then definitely you are in heat stress ok. So mode of transport will be evaporation and body temperature will keep on increasing ok. So that cases it will be very difficult. Now if it is heat balance that means whatever the heat loss is happening the same amount of heat is getting produced ok within your body. So you are in a comfort zone. So what is the possible way of heat transfer? Again it is mainly the convection and you are in comfortable situation. Here also cold stress that whatever the heat production is happening, it is less than the heat loss. If we are losing heat in a more quantity as we are producing within our body. So our body is getting slowly cold direction right. So that is where it is cold stress and we can say that convection and evaporation both process happens when we are talking about the cold stress and your whole body temperature slowly specifically cold body

temperature slowly goes down and we feel cold. So then it is cold stress. Now how we can do the measurement location? So when we are talking about heat stress, cold stress or thermal comfort we need to understand how do we measure them right. So we should before we do the measurement, we should have the position where we are going to measure and the time when we are going to measure.



So measurement location needs to be present in at the actual workplace. So you suppose you are talking about heat stress or cold stress, you need to understand what is the kind of workplace they have. So suppose right now I am in this recording room if I have cold stress or heat stress, I need to understand what is the thermal environment of this particular recording room right. So the measurement location needs to be within this particular premise. So switch to the location grids in case of impractical activity. So if you find that it is very difficult to measure, so you just need to put it in a grid format and you check those grid location and you can do the measurement. So, thermal variation in space is quite equivalent to the grid density ok. Now coming to the temporal consideration. So measurements at one point in time are misleading. Suppose I am talking about point measurement. So I want to measure the thermal environment of this particular recording room when I am doing the recording. Now I just come and do the measurement once. That is not going to give you a correct fact of the thermal environment of this particular situation. So what we need to do? Suppose I am recording for a 2 hours period of time. So maybe we can do at the beginning of the work, then at the middle of the session and maybe at the end of the session or maybe depending on the kind of experiment or objective I have, I can measure within 10 minutes interval or 15 minutes interval like that ok. So only once measurement is not going to give you the actual result. So you based on the objective you need to decide what are the temporal

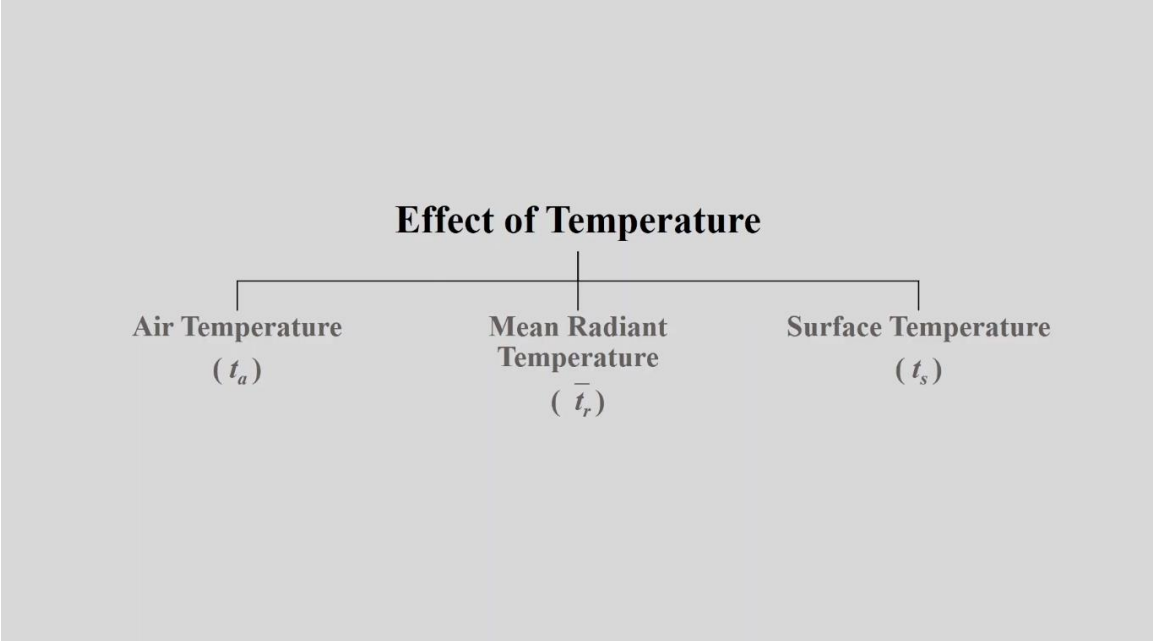
division you want for your data collection in terms of environmental thermal measurements. If we talk about climate, so climate monitoring to be done for daily and seasonal pattern. So here also same consideration. Suppose I am doing a recording at the summer season, I am doing the recording at winter season as well as in the rainy season. So thermal environment will not be similar in all these 3 seasons right. So when we are talking about thermal environment, we have to take a consideration of these climate ok. So suppose I am talking about thermal environment of India and thermal environment of any other country or a particular location. So then that case is also space is important, time is important, morning shift or evening shift, middle shift, when. So based on that the whole environmental parameter, thermal parameter will change. So whenever we are talking about thermal environment measurement, we need to take the consideration of the location, we need to take the consideration of the timing. So equipment must lock for at least a day aided by the questionnaire. So it is not only the actual measurement will help you to give an understanding of the thermal environment thermal comfort, it also needs some know added questionnaire which is going to be answered by the occupant of that particular position or particular location. So here if you would like to take a kind of understanding of the thermal environment of this particular recording room, then I should be responding towards the questionnaire once you do the physical measurement of the thermal parameters ok. So these are the considerations you need to take before you start any kind of thermal measurement of any workplace. So let us understand what are the factors need to be assessed for the heat exchange.



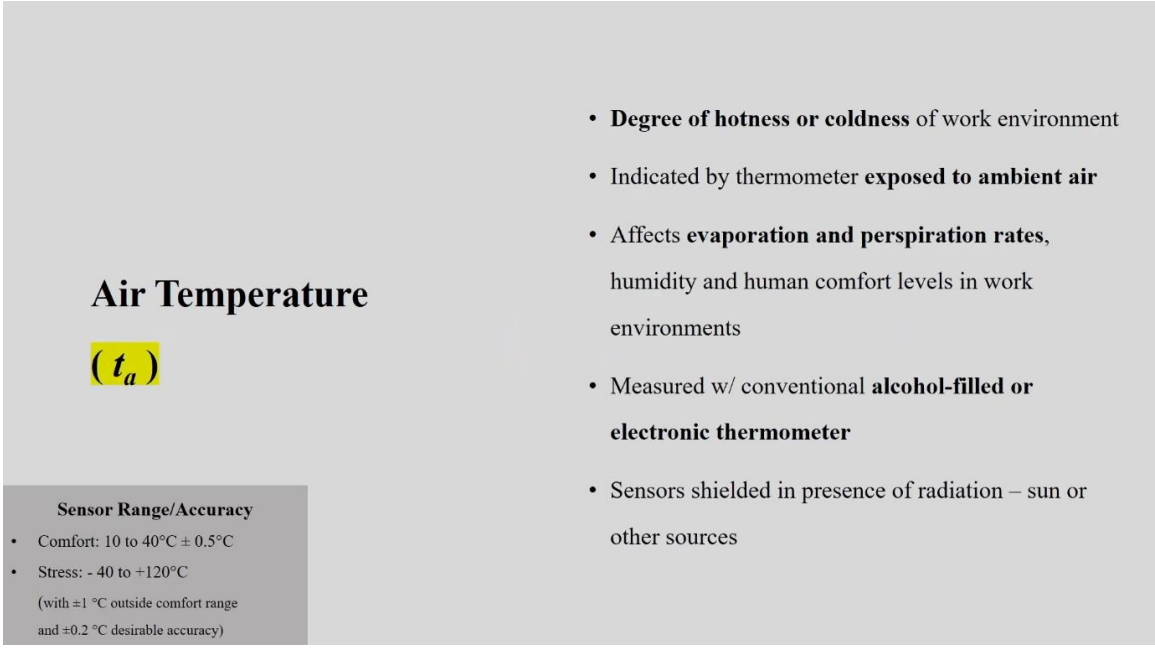
Factors affecting Heat-Exchange

So this is the kind of flow chart we can understand that factors which is going to affect the heat exchange. So external parameter and personal parameter. If we talk about external parameter, definitely the temperature, the air humidity and air speed ok. So

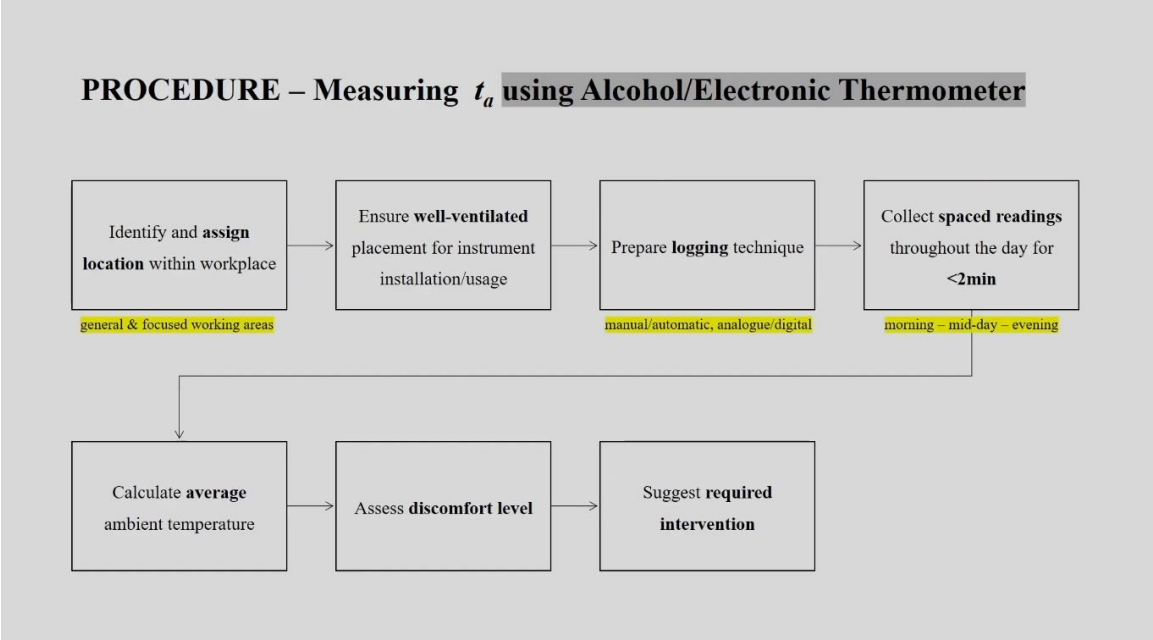
when we are talking about temperature, temperature of the air, of the environment which is surrounding. Second is air humidity because thermal comfort is very much connected with the kind of you know humidity we have in the air. With the same temperature maybe you know just take an example 37 degree Celsius ok. Where in one case humidity is less, in another case humidity is very high. You will find that with the same temperature where the humidity is very high, the person may find discomfort. Whereas where the humidity is under tolerant you know tolerable range, maybe they find more comfortable. So external when we are talking about that then humidity, temperature and the air speed. So if you have some kind of wind around definitely that gives more comfort to the person right. So these are the major external factor that is going to affect the heat exchange of the human being. Now coming to temperature you have air temperature, mean radiant temperature and surface temperature. All these three we are going to learn how to measure. Now coming to personal parameter first impacting factor is clothing that what is the kind of clothing you arehaving on that particular period of time and the metabolic rate. So if you are having you know you are wearing some clothing which is very much you know causing disturbance in the evaporation or maybe convection, then it will happen that heat is getting accumulated in your body, then you will feel more heat stress right. That is why during summer season we wear cotton clothes right. Now metabolic rate, so if your metabolic rate is very high that means heat is getting produced within the body right. So if metabolic rate is high then you will feel more heat in your body and that is going to affect the heat exchange of the whole system ok. If it is less then it is also going to affect in other way ok. So personal factors within that clothing is an important issue that you need to take care and the metabolic rate that also need to be measured to understand the heat exchange of the whole system of the human body.



So now if we talking about effect of temperature these are the three variable that we should measure. So, first one is air temperature we will denote it as t_a, mean radiant temperature that is t_r and surface temperature that is the t_s.



Now let us describe the air temperature. So degree of hotness or coldness at the work environment that we will be talking about air temperature. Indicated by the thermometer exposed to the ambient air. So you can use the thermometer and you can get an indication what is the temperature. It affects the evaporation and perspiration rate, humidity and human comfort level in the work environment. It can be measured with conventional alcohol filled or electronic thermometer and the sensor shielded in presence of radiation that is the sun or any other sources also can affect the air temperature. So here you can see I have given a range that is the where you will feel what. So you will feel comfort if it is 10 to 40 degree Celsius plus minus 0.5 whereas you can feel stress if it is minus 40 degree to plus 120 degree Celsius. So here you can feel heat stress, here you can feel cold stress right. So this is the kind of air temperature and we are going to measure it using the alcohol filled thermometer or any kind of electronic thermometer.



So what is the procedure of this particular method? So what we were going to do? We are going to identify and assign the location within the workplace. So suppose this is the recording room, I want to measure the air temperature over here. So we will try to understand that what are the position or location that we are going to measure for the air temperature. So maybe we can create the grid, normally if it is a small room, then we can have 9 point grid like 1, 2, 3, 1, 2, 3 and in between 1, 2, 3. So like that we can create 9 points and we can measure the grid. If it is bigger room, we can depending on the requirement, depending on the position, depending on the position of the fan, position of the AC, position of the window, we can definitely create a different grid system or specific location for our purpose and we can assign that these are the location where we are going to measure. So very first thing is you need to identify the location where you are going to measure the temperature. And what you need to do that ensure the well ventilated placements for instrument installation are being used. In the third stage you have to prepare the logging technique. Logging technique means how you are going to measure it. So maybe sometimes we do manual or automatic, sometimes we have analog or digital system. So how you are going to collect your data, so that you need to decide. It is absolutely based on the type of instrument you have. In the fourth stage you have to collect the spaced readings throughout the day maybe less than 2 minutes. So that way you can measure the reading. So it is always advised that you assess or record the reading for the whole shift. Here I have mentioned throughout the day that means 24 hours, but if it is not required suppose you want to do for 8 hour shift then you do for the 8 hour shift. If you want for 4 hour shift, you do it for that particular 4 hours shift. So you do the measurement. Once it is done then you calculate the average ambient temperature. So it is like you are just keep on recording and then you need to do the average then you will understand how it is being changed. Then assess the discomfort

level and once you understand if it is heat or cold whatever it is once you understand that what you have to do you have to suggest the required intervention.

Instruments Used

- Alcohol-filled Thermometer
- Electronic Thermometer

So what are the instrument used for this particular technique? First we can use the alcohol filled thermometer or if not you have electronic thermometer. All are available in the market. Any one of this based on your budget, based on your laboratory expenses you can access any one of it.

Alcohol-filled Thermometer

- **Direct measurement** of air temperature
- Thermometer filled with dyed alcohol

  (ethanol, toluene, kerosene)
- Temperature range measured between

  -112°C (low freezing point) & 78°C (high boiling point)

Red-Dyed Alcohol Thermometer

So direct measurement of the air can be done by the alcohol filled thermometer and thermometer filled with maybe dyed alcohol can be used then its readings are more clear maybe sometimes it is ethanol, maybe sometimes it is kerosene based on the brand you will get that. And temperature range measured between minus 112 degree centigrade. So below the freezing point and 78 degree centigrade. So here I have given an example of red dyed alcohol thermometer fine. So this way you can do the measurement. This will look like this. So this you can use for your ambient temperature measurement or air temperature measurement.

Electronic Thermometer

- **Direct measurement** of air temperature
- Temperature change detected by use of **thermosensitive devices** where electrical resistance changes in response to changing temperature

Predictive Measurement Mode

- Thermometer displays **predicted equilibrium temperature**
- Measurements taken over 15 to 30 seconds

Range: 31.6 °C to 42.2 °C

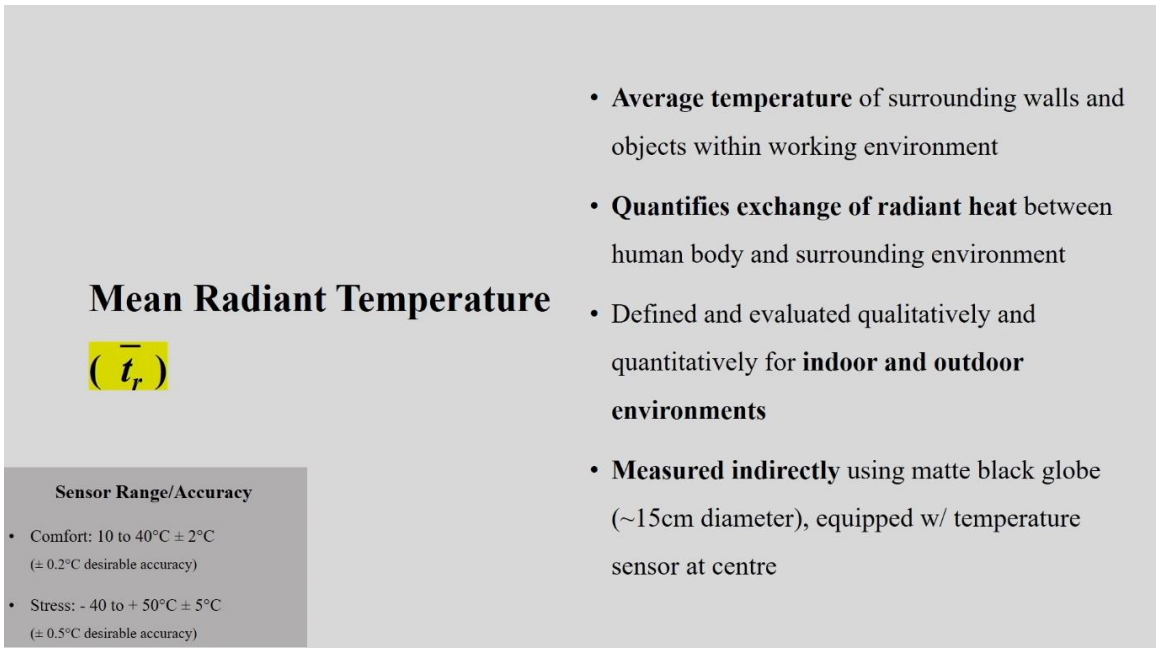
Continuous Measurement Mode

- Thermometer displays **actual equilibrium temperature**
- Achieved in less than 60 seconds

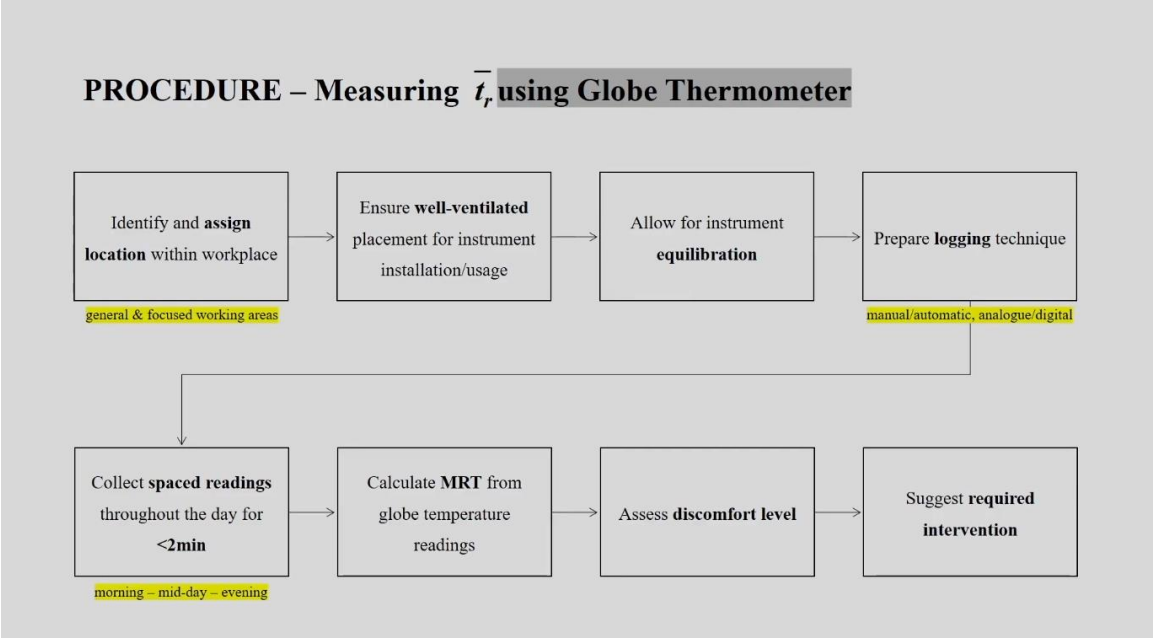
Range: 26.7 °C to 42.2 °C

Electronic (Digital) Thermometer & Hygrometer

Now electronic thermometer so that also is available. So you have sensors in that and then you can measure it. So again you can have the direct measurement and temperature change detected by use of thermo sensitive devices where electrical resistance changes in the response to changing the temperature happens and through that you can get the measurement. So it is predictive measurement method. So thermometer displays predictive equilibrium temperature and measurements taken over 15 to 30 seconds. So it is very quick ok and ranges are like this 31.6 degree Celsius to 42.2 degree Celsius. And under continuous measurement mode so if it is predictive then you can use this. If it is continuous then you can use thermometer display actual equilibrium temperature and achieved in less than 60 second ok. So that is possible. So electronic digital thermometer or an hygrometer. Now this was the air temperature or ambient temperature. Now we need to understand we had three right. So air temperature then next is mean radiant temperature.



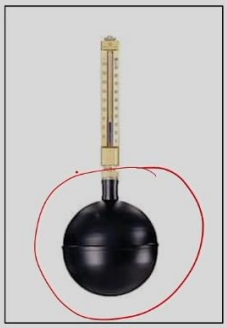
So mainly we are talking about radiant temperature which is connected with your radiant heat exchange right. So the average temperature of surrounding walls and the object within the work environment that you are going to measure. So quantifies the exchange of radiant heat between the human body and the surrounding environment. What is happening within the body and the surrounding environment? It is defined and evaluated qualitatively and quantitatively for indoor and outdoor. For both indoor and outdoor you can have this type of measurement. So it is measured direct indirectly using matte black globe. So you have a globe thermometer, we call it as globe thermometer. It is a globe within that we have a thermometer you know leaning within that and you place that thermometer it is a very dark matte globe ok. I will show you the picture if I have. So that you place in that particular location and you can understand what is the radiant temperature is there in that particular situation ok.



So how do we measure? Similarly we need to identify and assign the location as we did for the air temperature. You need to ensure that it is well ventilated, placement of the instrument and installations are properly done. So you need to confirm that. Then what you need to do? You have to allow the instrument equilibrium. You have to keep it for some time. So you need then prepare the logging technique. Collect the spaced reading throughout the day as we did for air temperature. Can calculate the mean radiant temperature from the globe temperature reading. So you have to calculate it and you need to assess the discomfort or comfort. If it is comfort you need not to go ahead for any kind of suggestion, but if there is some kind of discomfort what you have to do? That you have to suggest some intervention for that particular situation. So till here you have instrumentation. This is through your questionnaire and then you take this decision based on all these variable whatever all these data that you are going to get from the instrument ok.

Globe Thermometer

- **Indirect measurement** of mean radiant temperature (MRT)
- Matte-black metallic sphere (copper alloy with **high conductivity**) encasing a thermometer with sensor located at the centre
- **Predicts simultaneous effects** of air temperature, long-wave radiation and air movement on human heat stress levels
- MRT determined by **balance of heat transfers** – radiation (heat gain) and convection (heat loss) – between the globe and surrounding air
- Assessment of **room warmth** as per human comfort levels



Globe Thermometer

So what is the instrument we are going to use for this? The name of the instrument is globe thermometer. So it looks like this. This is a black matty globe. This is the thermometer. The center is placed in this particular location. So it cause the radiation heat and it assess that temperature and it you can see the reading over here ok. So indirect measurement, of course it is not the direct measurement. Indirect measurement of mean radiant temperature. So this matty, matte black metallic sphere you know. It is a copper alloy with very high conductivity. This material or this particular instrument is being manufactured with lot of understanding like you know this material itself is very important, important factor for this particular instrument. So it predicts the simultaneous effect of air temperature, long wave radiation and air movement on human heat stress level. So mean radiant temperature determined by balance of heat transfer that is related to the radiation that means heat gain and convection that is the heat loss between the globe and the surrounding environment. So if it is very hot at the outside and then you can have different reading. If it is not that then you will get different reading of it. So it is like you know you are trying to understand balance between the heat balance of the heat transfer, radiation and the convection. So how it is happening? So assessment of room warmth as per the human comfort level. So using this particular variable you can also have an understanding about the human comfort level.

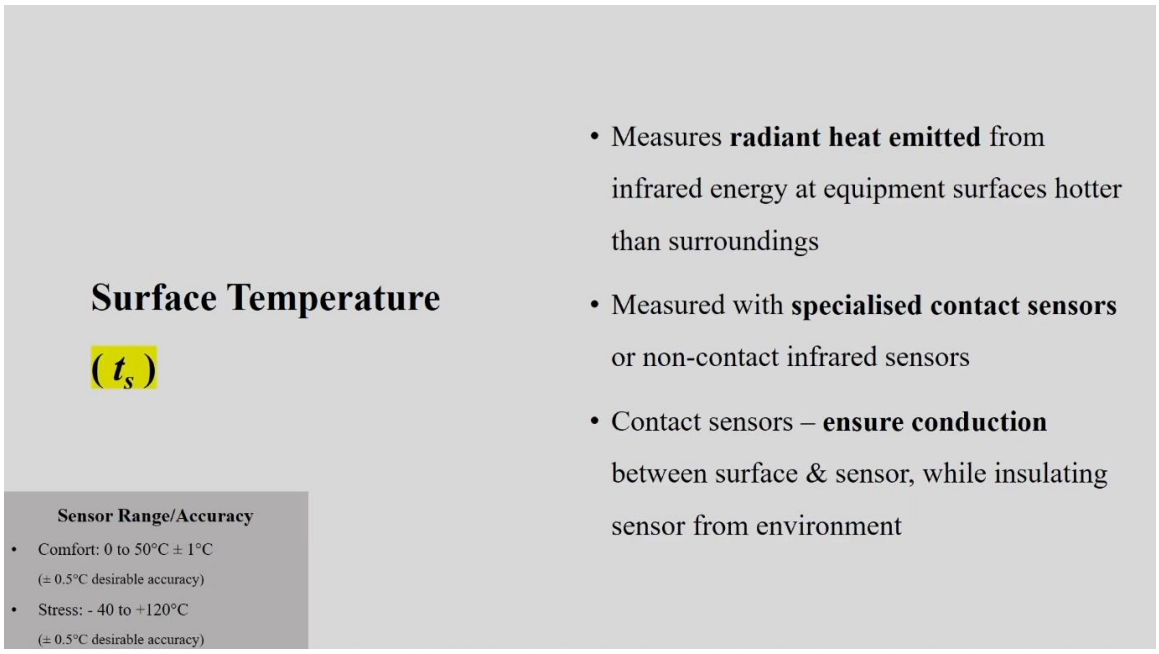
Calculating $\bar{t}_r$ using globe temperature

If $v_a > 0.15$ (air movement)

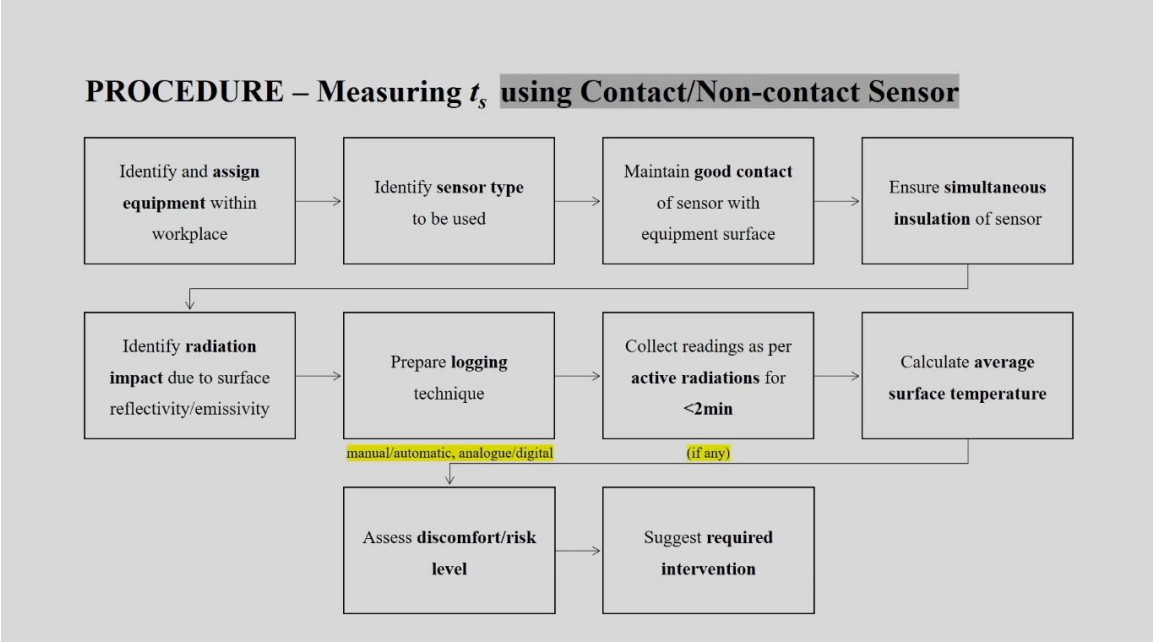
$$\bar{t}_r = \left[\left| (t_g + 273)^4 + \frac{1.1 \cdot 10^8 \cdot v_a^{0.6}}{e_g \cdot D^{0.4}} \cdot (t_g - ta) \right|^{0.25} - 273 \right]$$

where $\bar{t}_r$ - mean radiant temperature (°C)
t_g – globe temperature (°C)
t_a – ambient temperature (°C, shielded)
v_a – air speed (ms^{-1})
D – globe diameter (standard = 0.15m)
e_g – emission coefficient (for matte black paint = 0.95)

How do you calculate? So this is the formula that you can use where t_r this is the mean radiant temperature, t_g that you are going to get from your globe thermometer reading, t_g. t_a is your ambient temperature that you can get from your earlier that alcohol filled thermometer or electronic thermometer, v_a is your air speed that you can measure with another instrument, D is your globe thermometer diameter. This is standard 0.15 meter and e_g is the emission coefficient for black matte, see this particular matte black paint you have this particular value. So you have this formula to understand what is the mean radiant temperature. So nowadays you have different free softwares where you just give all these values t_g, t(a) and v_a automatically it gives you an value which talks about t_r that is the mean radiant temperature ok. So that is possible or simply you can use this particular formula to calculate it ok.



Last one is your surface temperature or $t(_s)$. So it can be like we can measure radiant heat emitted from infrared energy at equipment surface hotter than surrounding ok. Suppose you have a surface where you are working and that surface is hotter than the surrounding. In that case you need to understand that what is the kind of heat is radiating from that particular surface. So that radiant heat which is going to emit from that particular surface we are going to measure and we are going to call it as surface temperature. So it is measured with specialized contact sensor or non-contact infrared sensor and contact sensors ensure conduction between the surface and sensor while insulating sensor from the environment. So this is the kind of sensor range or accuracy you can consider during the surface temperature reading.



So what is the procedure? Quite similar but still there are small deviation. First is you have to identify and assign the equipment within that particular workplace. You have to identify what sensor type are you are going to be used for this. So it is based on the availability as well as the objective of your study. Then maintain the good contact of sensor within the equipment surface. So if the surface of that particular equipment and the instrument that you are going to measure is not creating the contact properly then your readings are going to be different or it is not going to give you the correct reading. So first you need to establish the contact is correct. So ensure simultaneous insulation of that particular sensor because if you are not ensuring then maybe the sensor is going to get damaged. So identify the radiation impact due to surface reflectivity or emissivity and then prepare the logging technique. Once you do that like you know you understand how you are going to collect your data then you collect your reading expert the active radiation for less than 2 minutes or if something specific you can go for that. Then calculate the average surface temperature because you are doing it for whole day right. So maybe you can do the average of it and then you assess the discomfort level. Once you assess the discomfort level or you assess the risk level then you go for the intervention as and what it is required. Very similar, only thing is you need to understand this how the sensor is going to work for your case. What is the surface? How you are going to create that contact that is based on the individual experiment to individual experiment. So you need to maintain that.

Ambient Temperature Sensor

- **Shuttered construction** of radiation shields ensures natural aspiration and accurate placement of sensor probe at ambient temperature
- Light-coloured shields **reflect solar radiation** projected on the device
- Sensor protected from other radiation and reflection sources of heat

Ambient Temperature Sensor (with radiation shields)

Next I am talking about this ambient temperature sensor. So it is you know shuttered construction of radiation shields which ensures the natural aspiration and accurate placement of sensor probe at the ambient temperature. So you can see how it is being exposed. So light colored shield reflects this solar radiation and projected on the device. So sensors are protected from other radiations and reflection sources of that particular area or of that particular heat. So it is connected like this and you will get the recording ok. Once these three parts are done then we can go ahead with the effect of air humidity.

Air Humidity

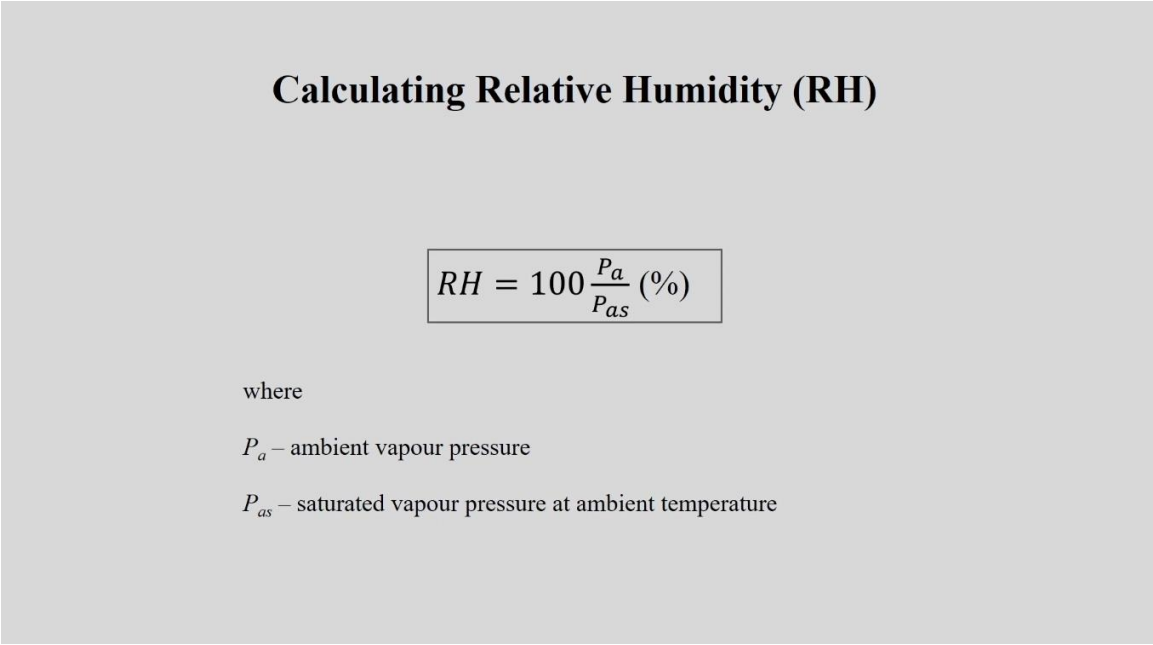
(RH)

- Expressed as **relative humidity**
- **Actual moisture content** in surroundings in comparison to maximum possible moisture content **at given temperature**
- Environmental moisture content **determines direction of vapour flow** between skin and surroundings

Sensor Range/Accuracy

- Comfort: 500 to 3000 Pa ± 150 Pa
- Stress: 500 to 6000 Pa ± 150 Pa

Effect of air humidity. So let us understand that air humidity. It is expressed as relative humidity that is why it is RH, relative humidity. So actual moisture content in surrounding in comparison to maximum possible moisture content at any given temperature. So what is there in actual and what is maximum is possible ok. So you are going to compare that. So suppose in a particular situation, in a particular air temperature, you understand right that if temperature goes on the higher direction, a capacity of humidity content is going to increase right. So in a particular temperature what is available in actual and what is possible to accommodate in maximum. So if you are going to compare that that we are going to call as relative humidity ok. So environmental moisture content determines the direction of vapor flow. If your the humidity relative humidity in the ambient air is very high, then there is less chance of evaporation from your body and if there is less chance of evaporation then what will happen the heat will accumulate in your body and there then you will find lot of heat stress. You will find lot of discomfort right. But if the content of the humidity is less in the environment, then what will happen there will be high chance of evaporation and then there will be heat loss from your body and you will feel comfort. So that is the method and that is the mechanism how it is going to affect your heat comfort or thermal comfort in a particular situation.



So relative humidity we can measure 100 multiplied by $P_{(a)}$ that is the ambient vapour pressure divided by $P_{(as)}$ that is the standard vapour pressure at the ambient temperature in percentage right. So relative humidity we measure using percentage.

Instruments Used

- Electronic Hygrometer
- Dew-Point Sensor
- Assman Psychrometer
- Sling/Whirling Psychrometer

So what are the instruments we need? We need electronic hygrometer, dew point sensor, Asman's psychometer, sling or wheeling psychrometer ok. These are the instrument can be used to understand the relative humidity.

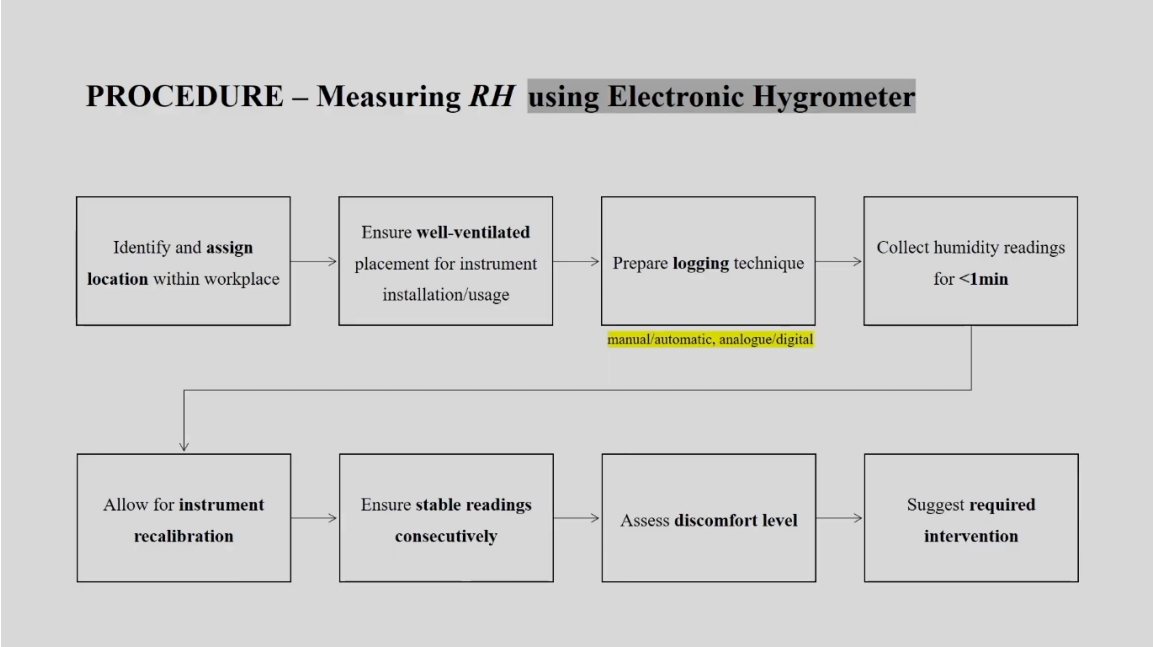
Electronic Hygrometer

- Equipped with a **temperature sensor** and a different sensor **(types – capacitance, resistance, gravity, optical)**
- Humidity measured in proportion to property change (capacitance or resistance) due to **changed air humidity**
- Instrument durability dependent upon **sensor type, manufacturer quality and operating environment**

Electronic Hygrometer

Let us understand one by one; electronic hygrometer. So this may look like this but it can be little different also depending on the brand that you are going to use. So equipped with a temperature sensor and a different sensor that is the capacitance, resistance, gravity and optical and humidity measured in proportion to property change due to the change in the air humidity. And durability dependent upon sensor type, what is the type

of sensor, manufacturer quality and the operating environment. Based on that it can be different ok, it can be different. So this is how electronic hygrometer look like. Every other thing has their own capacity, you can check individually from your own source. Now let us understand how we did for the air temperature and relative humidity or the surface temperature.



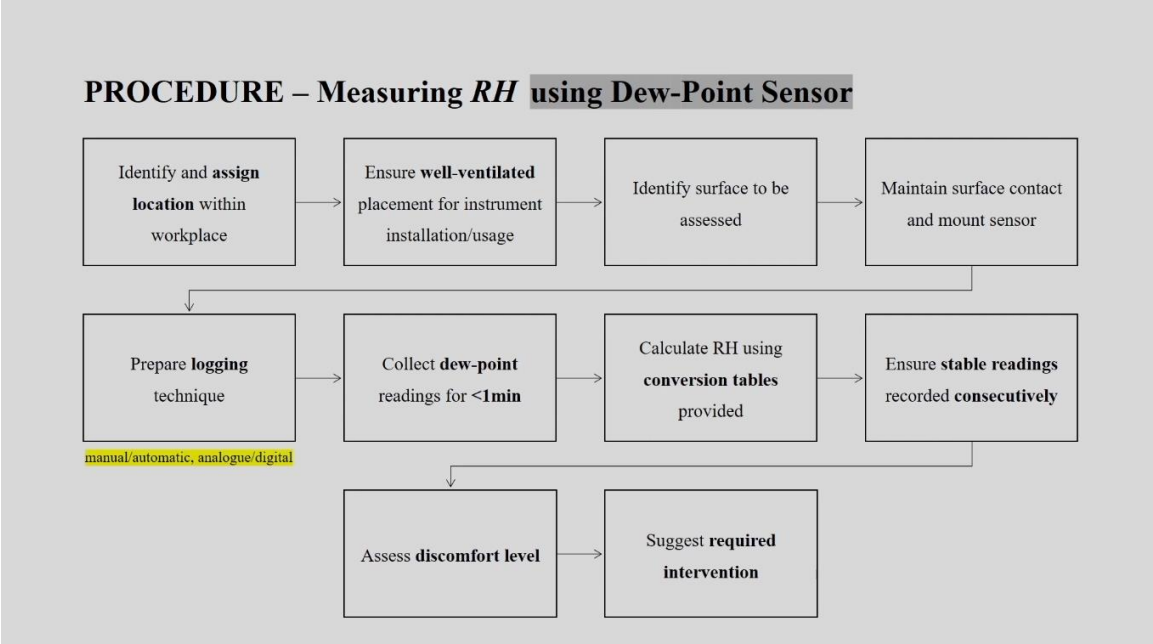
Let us understand how you are going to measure the relative humidity using the electronic hygrometer. So you have to again assign the identify and assign the location. Then ensure the well ventilated placement of the instrument, installation and uses. Then you need to prepare the logging technique. These are very common. Collect the humidity reading. Now here you have to do the reading within less than 1 minute ok. So allow the instrument for recalibration but for each case you need to do the recalibration, if you are using the electronic hygrometer. So you have to do the recalibration. Ensure the stable readings are consecutive readings are stable. So suppose you are taking a reading at 3 hours 45 minutes, then 3 hours 46 minutes and 3 hours 47 minutes. If these 3 readings consecutive readings are exactly same or very close, then you can consider it. If it is fluctuating then you have to keep on taking the reading. So assess the discomfort level and based on that you can do the you can suggest the required intervention for specifically taking a consideration from the relative humidity. Now if that instrument is there ok.

Dew-Point Sensor

- Monitoring device used in building technology assessments for **condensation forming risks**
- **Dew-Point**: Temperature at which moisture concentration of environment is equal to saturation vapour pressure causing condensation
- Commonly installed at **climate-controlled** ceilings, controlled pipelines and storage areas before resultant damage
- High-precision dew-point measurement predicts **early condensation** instances
- Industrial applications include protecting equipment, saving energy and preventing over-drying
- Highly accurate and reliable in use, but slightly expensive

Dew-Point Sensor (Hand-held)

Now if another instrument that is the Dew-Point sensor then also you can measure. So here I will give the instrument detail little bit, but it is not exactly specific for each instrument. There may be some operational changes from brand to brand ok. So you need to it is a monitoring device, used in building technology assessment for condensation forming risk. So how the Dew-Points are condensing to understand that we are going to use this particular instrument. So what is Dew-Point? Temperature at which moisture concentration of the environment is exactly equal to the saturation vapour pressure causing the condensation right. So that is the Dew-Point. So commonly installed at the climate controlled ceiling, controlled pipelines and the storage areas before if there is some kind of going to a damage before to prevent that, you are going to install such instrument so that you can get an alert. So high precision Dew-Point measurement predicts the early condensation instances ok. So it gives an alert system. It creates an alert system that here it is going to happen. So whatever the precautionary measures is possible to take you please take it ok. So that is the kind of uses of it. So industrial applications include protecting the equipment. So suppose there is an instrument which we should protect from the reaching to the Dew- Point. So what you can do? You can have this particular Dew-Point sensor and you can keep on monitoring continuously that when the temperature is going to change and if it is changing and it is reaching towards dew point then definitely we need to start the intervention. We need to do some kind of changes or operation need to be changed ok. It is highly accurate and reliable in use but it is expensive.



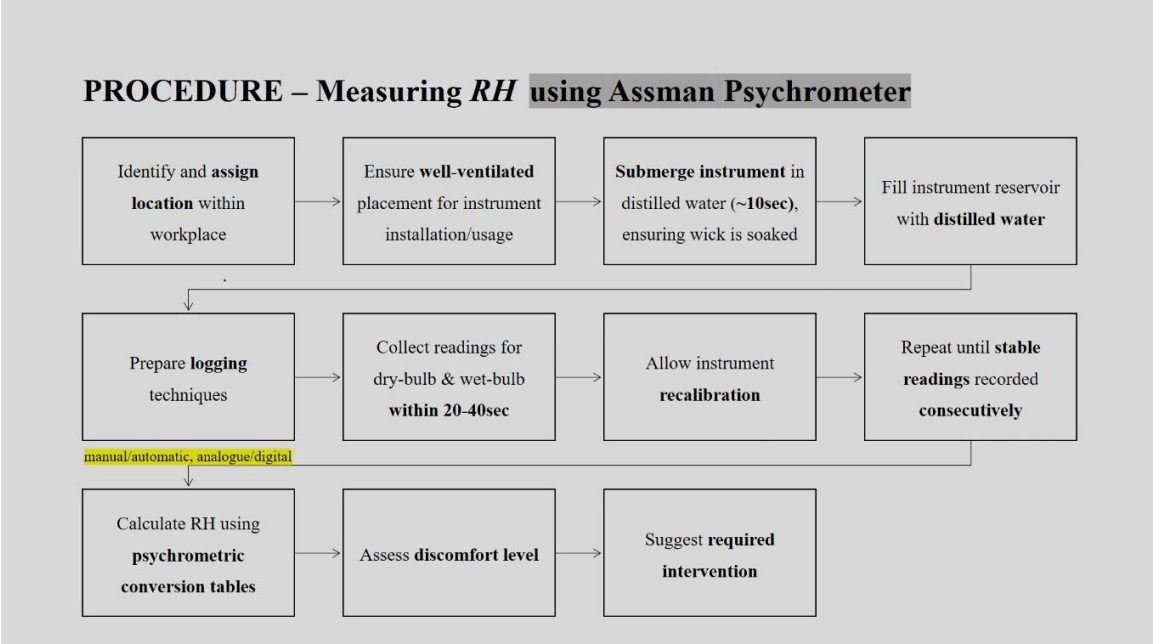
So what is the procedure? So you need to identify and assign the location same thing. Ensure that well ventilated, identify the surface to be assessed. So it is not that always you assess everywhere. So you need to identify that particular surface. Maintain the surface contact and mount sensor. This is very important as we did in the surface temperature right. We established the contact. We established that contact. If we are failed to establish that contact, we will not get the correct reading. You need to prepare the logging system. So collect the Dew-Point reading for less than 1 minute. Calculate the relative humidity. You have the conversion table. So which is being provided with the instrument. So you calculate that. Ensure that stable readings are recorded consecutively as I mentioned in the earlier case and then you assess the discomfort level and you give your suggestions or recommendation as per required ok. So this is how we are going to use the Dew-Point sensor. This is also not used for every cases. It is only used where it is required to understand that if Dew-Point reaches then there is going to be a trouble for the whole situation. So to do so this type of sensors or this type of instruments we are going to use. So everywhere every instrument is not required. Based on the objective that you are going to work on, you should choose which instrument you use for your experiment.

Assman Psychrometer

- Measurement of **temperature and humidity of ambient air**
- Consists of two thermometers – **dry-bulb** (ambient temperature sensor) and **wet-bulb** (temperature sensor wrapped in wet cotton wick)
- **Evaporation** from wet wick cools wet-bulb thermometer down, relatively lowering wet-bulb temperature to dry-bulb (air) temperature
- **Difference in temperatures** used to calculate relative humidity

Assman Psychrometer

Then this is a different type of psychrometer. We will measure the humidity and the of this ambient temperature and relative humidity from this using this particular instrument. It is very nice that it has a dry bulb. It has a wet bulb ok. So it has a dry bulb. It has a wet bulb. So from the wet bulb you can understand that what is the kind of evaporation is happening due to the content of water vapour in your environment ok. So evaporation from the wet wick cools the wet bulb thermometer ok. So that happens and so it takes down. So always dry bulb temperature is high. Low wet bulb temperature is in lower side. You can find the difference. So relatively lowering the wet bulb temperature to the dry bulb temperature and differences in temperature used to calculate the relative humidity ok. It is very similar for the wheeling hydrometer that we are going to discuss in the next.



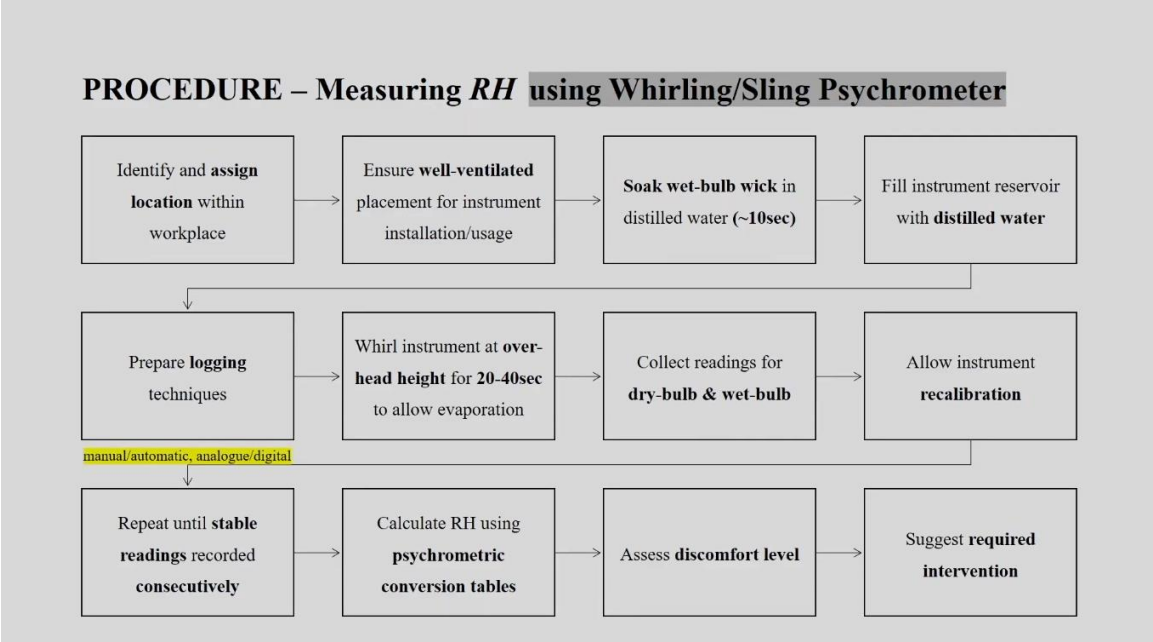
This is the procedure. Here all these varieties the initial phases are same. In third phase what you have to do you have to submerge the instrument in distilled water. Why? Because you are going to create that wet bulb right. So for less than a kind of 10 second ensuring this wick is you know soaked. So fill instrument reservoir with distilled water. Then you prepare the logging system. Collect the reading for dry bulb and wet bulb within 20 to 40 second. Allow the instrument for further recalibration and you repeat that particular procedure till your consecutive readings are not coming same ok. So you have to stable. I can say not same. I will say it is stable right. So consecutive reading need to be stable. Once it is done then there is no psychometric chart or table from that you do the conversion and you calculate the relative humidity. Once you calculate the relative humidity you assess the discomfort level and you go for your suggestions or modifications right. So this is how you are going to use this particular psychrometer. So you can see how this looks like ok based on the brand that you are using it can change.

Whirling Psychrometer

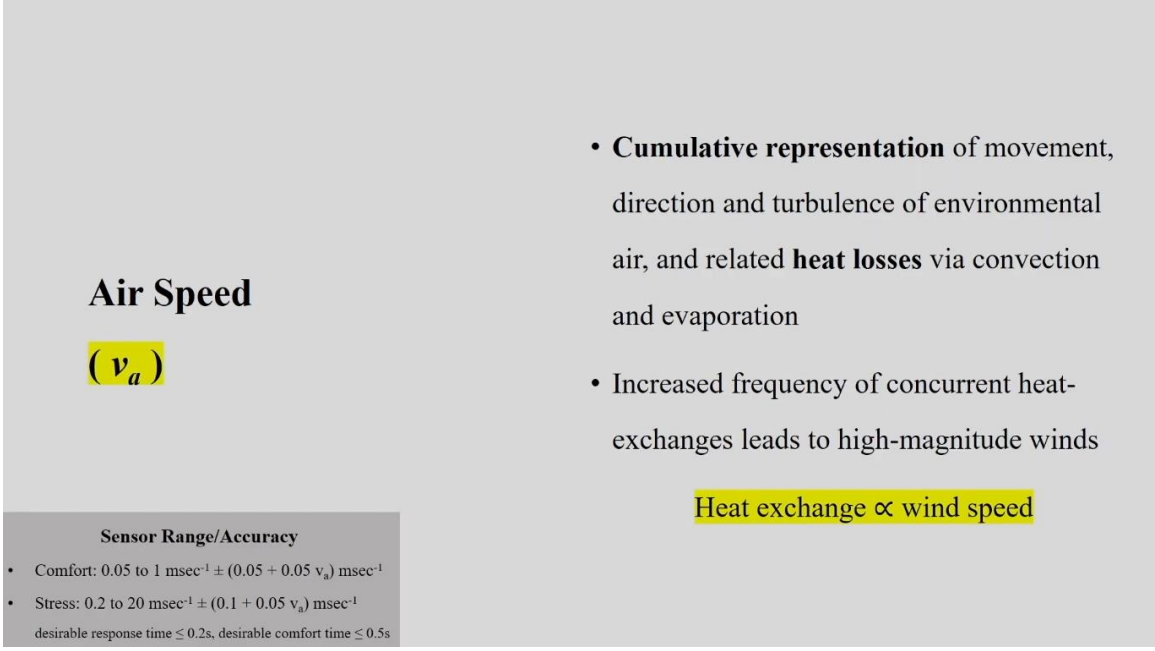
- Designed with two thermometers – **dry-bulb and wet-bulb** – encased within plastic housing
- Dry-bulb thermometer exposed to air temperature
- Wet-bulb thermometer with cotton wick covering the bulb, wick soaked in distilled water before using equipment
- **Pivoting handle rotates** psychrometer allowing water from wick to evaporate and lower wet-bulb temperature
- Drier air cools down wet-bulb thermometer to lower wet-bulb temperature, increasing difference and thus, higher relative humidity

Whirling/Sling Psychrometer

Next is whirling psychrometer. Probably this is very common instrument and most of our ergonomics lab will have this particular instrument. Function is quite similar. The principle is quite similar as we discussed in the earlier psychrometer. So again here we have a dry bulb and wet bulb you know in a cased situation. So you can see it is a one case and this is another case. So you have one wet bulb another is dry bulb. So dry bulb thermometer exposed to the air temperature. Wet bulb thermometer with cotton wick covering that particular bulb and the you know that particular wick is soaked in a distilled water. So you know same principle that if the water content in the air is high then evaporation will be less. If water content water vapor is less in the air, then evaporation will be more ok. So the same principle is being used. So pivoting handle, this is your pivoting handle ok. You can rotate this particular instrument. Dryer air cools down well bulb temperature or wet bulb thermometer to lower the wet bulb temperature and increasing the difference and thus the higher relative humidity. So if the this particular difference dry and wet bulb is more then relative humidity will also change.



This is the procedure. It is very similar as we did for the earlier psychrometer ok. So you need to recalibrate it ok and then you need to go for the further process. Relative humidity you have also here your psychometric conversion table and using that psychometric conversion table you can find that what is the relative humidity. Once we understood the effect of relative humidity, let us go ahead with the effect of air speed.



We will be terming it as v($_a$), velocity of air ok air speed. So cumulative representation of movement direction and the turbulence of environmental air and related heat loss via convection and evaporation. Very simple definition right. So when we are talking about

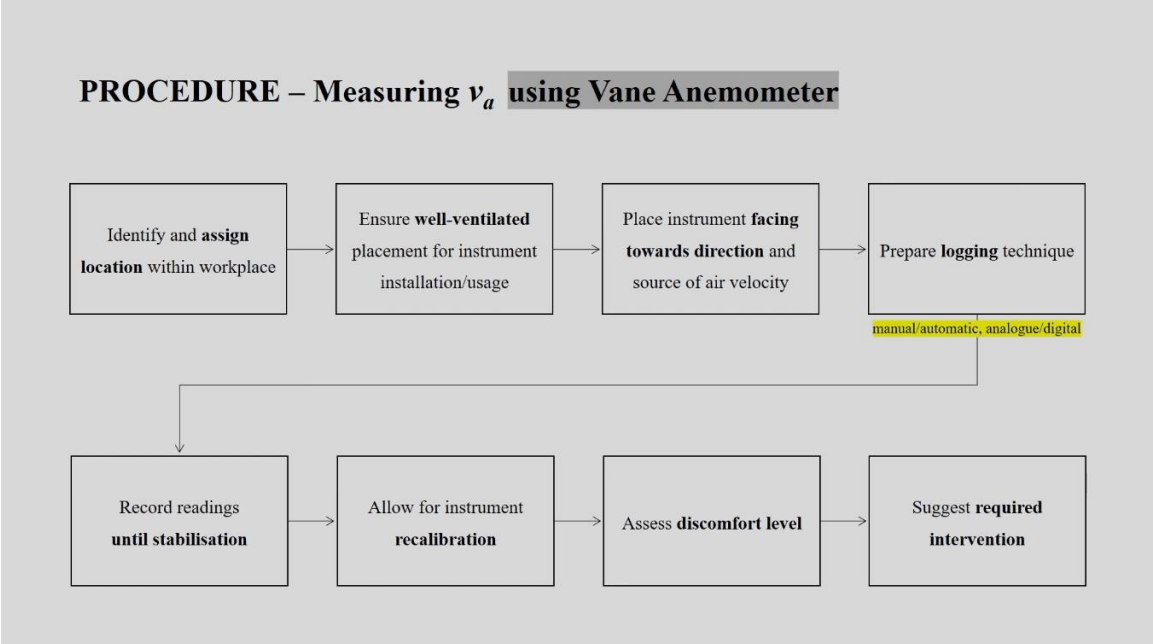
the movement, we are talking about the direction, we are talking about the turbulence of environmental air and which is going to cause the heat loss due to convection and the evaporation right. So increased frequency of concurrent heat exchanges leads to high magnitude winds right. So heat exchange is equivalent to the wind speed. If there is high amount of heat exchange, wind speed also will increase. So these are the kind of instrument, a Kata thermometer, very commonly used instrument. Also vane anemometer that is also commonly used instrument for measuring your air velocity. So let us understand one by one.

Vane Anemometer

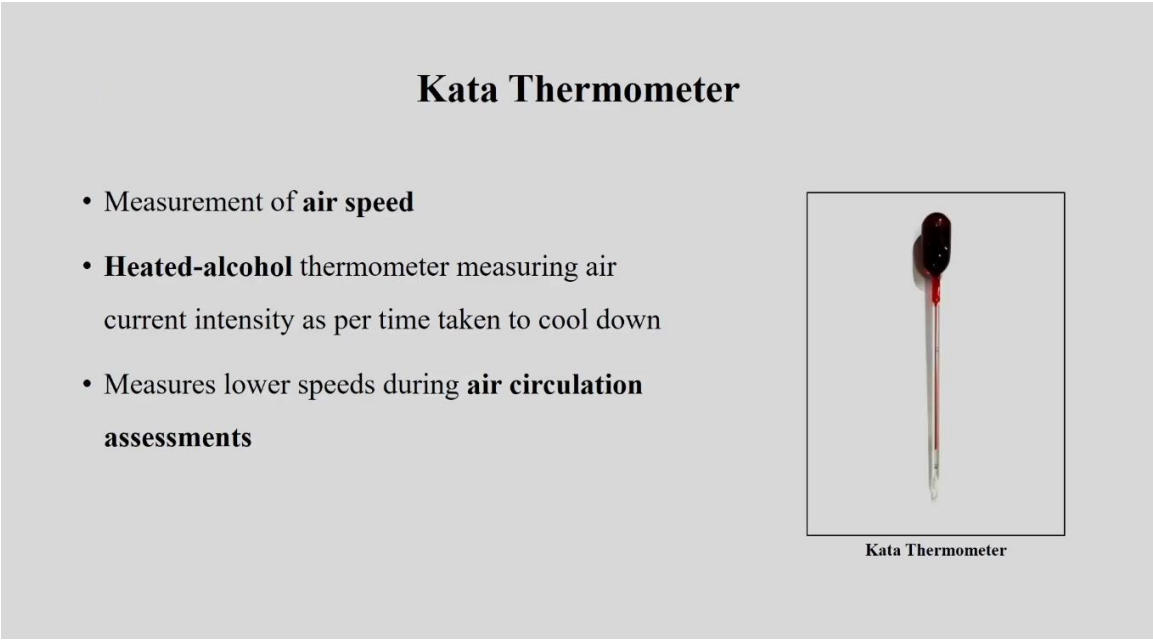
- Wind meter used to measure air velocity for **unidirectional air movement** with slow fluctuations
- Can be used for calculating **volumetric flow** of air
- Easy-to-use and portable types commonly used for monitoring HVAC systems, airflow equipment and exhaust systems

Vane Anemometer

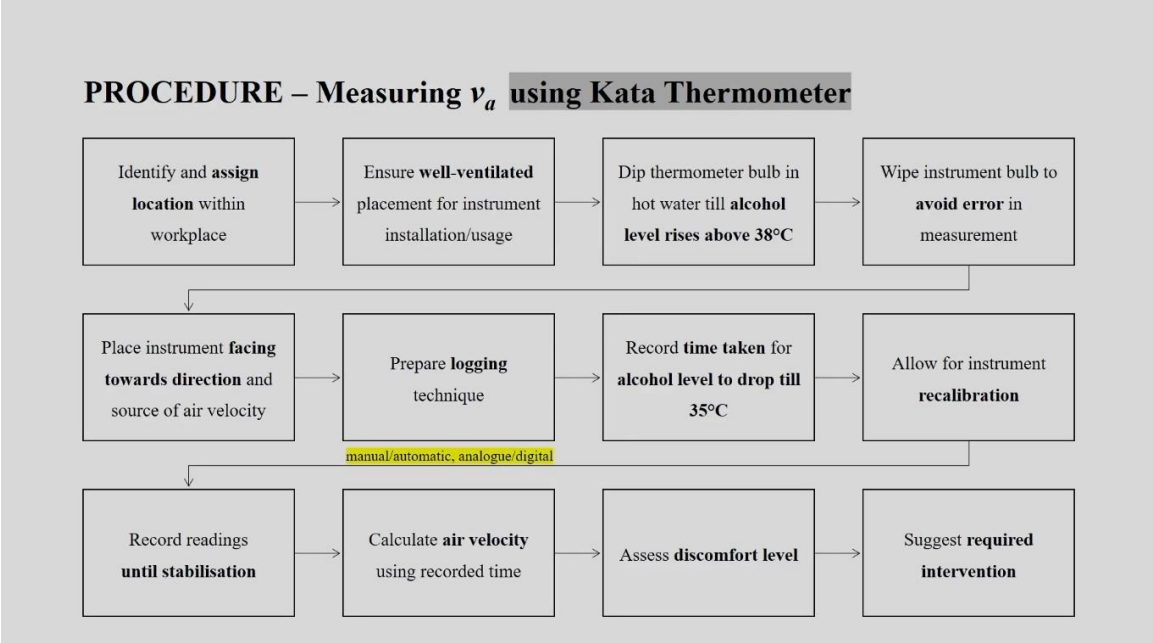
So this is how the vane anemometer looks like also here depending on the brand it will be different. So wind meter used to measure air velocity for unidirectional air movement with slow fluctuation. If the fluctuations are very high, it will not work. Can be used for calculating the volumetric flow of the air and easy to use and portable types commonly used for monitoring HVAC system, air flow equipment and exhaust system. Just for all these cases you can use this particular anemometer.



So again let us understand what is the procedure. You have to find out the location that you have to find out it is well ventilated. Place the instrument facing towards direction and the source of the air velocity. So you have to check that in which direction the air is flowing. Based on that you have to position it. So then you prepare the logging system. Record the reading until it is stabilized. So consecutive readings need to be stabilized. Allow the instrument for recalibration. You assess the discomfort and finally you give the suggestion or recommendation whatever is required. So using this particular instrument you can measure the air velocity in this way.

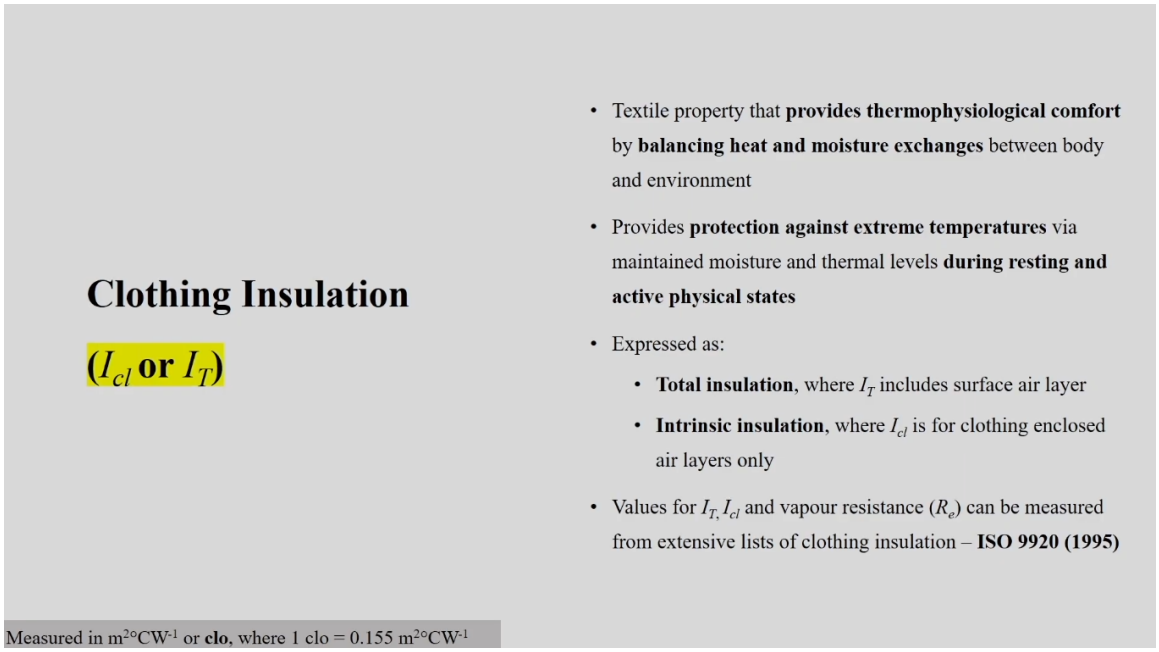


This is the instrument named as Kata thermometer. So measurement of air speed, heat alcohol thermometer measuring air current intensity as per time taken to cool down. So measures the lower speed during air circulation assessment. Using that Kata thermometer we can measure the air circulation assessment. So how it is circulating right within the environment.



So what is the procedure? First you need to identify those logging places like you know position, space, well ventilation that need to be maintained. The next is dip the thermometer bulb into hot water till alcohol level rises till 38 degree Celsius. You have to first create that. So in hot water you have to dip that Kata thermometer. Wipe the instrument bulb to avoid any error in the measurement that you need to follow the precaution. Then place the instrument facing towards the direction and source of air velocity. So where in which direction the air is flowing you have to place that thermometer in that particular location. You need to prepare the login. Record the time taken for alcohol level to drop till 35 degree Celsius. So you started with 38 degree, you stopped at 35 degree. Allow the instrument for recalibration and record the readings till it is stabilized. So you have to repeat it two times, three times, mainly minimum three times is required. Then you calculate the air velocity using the recorded time. So how long it took from 38 to 35. So based on that you can do the calculation. Then you do the discomfort level calculation, you assess that and you give your suggestion. So here you are going to finish your Kata thermometer reading and you can measure the air velocity. This is little you know you need lot of practice, you need lot of experience to do all this process. Whereas in case of this you get automatic reading. So this is little easy. Now once you do all those things, these all were for the outer environment. So how the outer environment is going to affect your heat exchange procedure. So everything we

discussed. Now we have something called personal factor. Under that we have clothing and we have metabolic rate. Let us discuss those two component further.



So effect of clothing insulation. So as I mentioned if you have lot of clothing it will prevent the person to lose the body heat towards the environment. So how it looks like. So clothing we can call it as $I_{(T)}$ or $I_{(CL)}$. So you know insulation due to clothing, insulation due to clothing. So or insulation due to textile basically so $I_{(T)}$. So textile property that provides thermo physiological comfort by balancing the heat and moisture exchange between the body and environment we will be calling it as clothing insulation. It provides protection against the extreme temperatures via maintained moisture and thermal level during resting and active physical stress states. It is expressed as total insulation and intrinsic insulation. Total insulation and intrinsic insulation. So when we are talking about total insulation where $I_{(t)}$ includes surface, air, layer. Intrinsic insulation where I(cl) is for clothing closed air layers only. So only for clothing. So values for $I_{(t)}$, $I_{(cl)}$ and vapor resistance can be measured from extensive list of clothing insulation which is being published in ISO 9920 in 1995. So they have all lists. Suppose you are wearing only a vest, okay, what is your clothing insulation? So we call it as clo value. Suppose you are wearing socks and then shoe, so what is your clothing insulation? So what is the clo value, okay? Also like that ISO listed this whole list, you know, whole set of possible set of clothing that is possible and what is the clo value for it that we can refer from this particular standard.

Calculating Vapour resistance (R_e) from Insulation

$$Re = \frac{I_t}{0.0165 \cdot im}$$

where Re – clothing vapour resistance ($m^2°CW^{-1}$)

I_t – clothing heat resistance ($m^2°CW^{-1}$)

im – clothing permeability index (n.d.)

0.0165 – Lewis constant ($m^2°CW^{-1}$)

Assumption: Head and hands are covered with caps and gloves, i.e. body is fully covered.

So how do we calculate the vapor resistance? $R_{(e)}$ is equal to $I_{(t)}$ divided by 0.0165 into im. So what are these things? $R_{(e)}$ is the clothing vapor resistance. $I_{(t)}$ is the clothing heat resistance. im is the clothing permeability index. So how the permeability is there for that particular textile, for that particular material and this is a Lewis constant. So assumption is head and hands are covered with the caps and gloves that is the body is fully covered. In that particular situation, this formula you can use and you can get the vapor resistance, okay? But it is always suggested you refer the clo value from ISO 9920.

Sample Values of Clothing Insulation for Workwear

Work Clothing Ensembles	(clo)	I_{cl} ($m^2°CW^{-1}$)	I_T ($m^2°CW^{-1}$)
Underpants, shirt, trousers, socks, shoes	0.75	0.115	0.196
Underwear with short sleeves and legs, shirt, trousers, jacket, socks, shoes	1	0.155	0.235
Underwear with short sleeves and legs, shirt, trousers, jacket, thermos jacket, socks, shoes	1.25	0.19	0.266
Underwear with short sleeves and legs, shirt, trousers, jacket, heavy quilted outer jacket and overalls, socks, shoes	1.85	0.285	0.352
Underwear with long sleeves and legs, thermos jacket and trousers, outer thermos jacket and trousers, socks, shoes	2.2	0.34	0.403

Source: (Stanton et. al., 2005)

So sample values for clothing insulation for the kind of wear or kind of the uniform people wear during the workplaces. So these are the values. Suppose I am talking about underpants, shirt, trousers, socks and shoe. If this is the whole combination, then your clo value is 0.75, okay? This is referred from ISO. Then I(cl) will be this and I(t) will be this. So this is measured. So always when we do clothing related things, we refer all these varieties of pre-computed table, okay? And if it is not exactly the description over here, you can calculate yourself using the individual clo value available in that particular list and then you calculate your R(e) separately, fine? So this is the reference from where I have taken this. So you can see if these things are increasing, your clo value is also increasing. So number of where you are increasing, the clo value is also increasing.

Sample Values of Clothing Insulation for Dailywear

Work Clothing Ensembles	(clo)	I_{cl} ($m^2{}^oCW^{-1}$)	I_T ($m^2{}^oCW^{-1}$)
Panties, T-shirt, shorts, light socks, sandals	0.3	0.05	0.145
Underwear, shirt, trousers, socks, shoes	0.7	0.11	0.196
Underwear, tracksuit, long socks, running shoes	0.75	0.115	0.200
Panties, shirt, trousers, jacket, socks, shoes	1	0.155	0.235
Underwear, singlet with short sleeves, shirt trousers, vest, jacket, socks, shoes	1.15	0.18	0.257

Source: (Stanton et. al., 2005)

So this is again some like only panties, t-shirts, shorts, light socks and sandals. So very informal, very comfort type of clothing. Then clo value is quite low. Whereas if you are wearing so many things, then your clo value is quite high, okay? So that way you can understand what is the kind of thermal comfort you have from the clothing perspective, okay? So what are the varieties of clothing you are wearing and how that clothing is affecting your comfort? So when we are talking about thermal comfort, it is not only the air temperature, air velocity or radiant heat, it is not only that, what we are wearing, okay? So if your body surface is covered with some, suppose you are wearing gloves, right? So you are minimizing the chance of water vapor evaporation from your body. Then what will happen? Your clo value will increase. If you remove that glove, definitely your clo value will decrease and you will go in the little comfort zone of thermal comfort, okay? Now next factor is metabolic rate. So cloth is one factor coming under personnel and then second is your metabolic rate that is going to affect your thermal comfort.

So we call it BMR, Basal Metabolic Rate or RMR, Resting Metabolic Rate. So minimal caloric count required by individuals for accomplishing everyday task at the workplace is the basal metabolic rate. So metabolic energy of human body released as heat, right? So we have lot metabolism, lot of metabolism is happening. So when it happens, it releases energy. The energy is released in terms of heat and that can cause your, that can actually affect your thermal comfort. So classified as per general work or job task description and used for predicting the inspection and intervention at work as required. This can be measured using indirect calorimetry or that is the measuring the oxygen uptake. Because when we are talking about energy generation within the body through metabolism, definitely it requires oxygen consumption. Through oxygen only the metabolism happen. So when we have the metabolism, we consume more oxygen, right? So using indirectly we measure the metabolic rate, using the amount of oxygen consumed by that particular person. So the data derived from extensive listing provided in this particular standard that is ISO 8996. It is published in 1990. However, there are some more revision.

Estimation Methods for Metabolic Heat Production

Level	Method	Accuracy	Workplace Inspection Status
I	**A:** Classification as per activity type	Rough information with higher error risks	Not necessary
	B: Classification as per occupation		Information on technical equipment and work organisation
II	**A:** Using tables of group assessment	Higher error risk with ± 15% accuracy	Time study necessary
	B: Using estimation tables for specific activities		
	C: Using heart rate under defined conditions		Not necessary
III	Measurement	Error risks within measurement accuracy and time study limits (± 15% accuracy)	Time study necessary

ISO 8996 (1990), Ergonomics: Determination of Metabolic Heat Production, ISO
Source: (Stanton et. al., 2005)

So estimation method for metabolic heat production, it has different category, you know level 1, level 2 and level 3. So this is the source that I have used to get this particular data. Now let us understand it. So classification as per activity type and classification as per the occupation. So this is you know, you can get a rough information with higher error risk, okay? That is possible and maybe sometimes at the workplace it is not necessary. However, here you may need little about some kind of technical equipment, okay? For these 3 cases, you have higher error risk plus minus 15 percent accuracy and it require time study because how long you are in that particular case, okay? So time study is important and for using the heart rate under specific defined condition, maybe it is not required for the inspection status at the workplace. Now if I am coming for the measurement, the error risk within the measurement accuracy and time study, it was again 15 percent accuracy and time study is very much important over here. So estimation of methods for metabolic heat production, we should follow this chart to get the understanding and it is being described at the ISO 8996 and I referred this particular table from Stanton which is being published in 2005, okay?

Metabolic Rate Classification for General Work Description

Class	Mean Metabolic Rate		Activity Examples
	W/m^{-2}	W	
0 (resting)	65	115	Resting
1 (low metabolic rate)	100	180	Writing, typing, sewing, inspection/assembly work, operating foot switch/pedal, drilling small parts
2 (moderate metabolic rate)	165	295	Nail hammering, forging, operating off-road construction equipment, intermittent handling of load
3 (high metabolic rate)	230	415	Carrying heavy material, hand mowing, digging, shovel/sledgehammer work, pushing/pulling heavy load
4 (very high metabolic rate)	290	520	Working w/ axe, climbing stairs/ramp/ladder, quick walking w/ steps

ISO 8996 (1990), Ergonomics: Determination of Metabolic Heat Production, ISO
Source: (Stanton et. al., 2005)

The next part that is the metabolic rate classification for general work description that if you are you know resting in condition, the mean metabolic rate will be W per meter square if that is the unit then it is 65, then low metabolic rate it will be 100, moderate 165, high 230 and very high in then it is 290. So if you can have an understanding what is the kind of metabolic rate they have in a particular point of time based on the activity schedule, okay? Activity description, you can understand where they can be. Suppose I am doing a carrying heavy material or hand moving or digging or shoveling, if I am doing such activity definitely my metabolic rate will be somewhere here, right? But if I am just sitting, I am not doing lot of work, I am maybe somewhere here, then my metabolic rate will be near to 65 or 75 or somewhere that so that I am in a resting condition and which will give me more thermal comfort than this particular case, okay? So if you are doing lot of physical activity, okay? Your muscle is acting, so your metabolic rate is increasing, the heat is getting generated within the body and that can cause thermal discomfort. So this is how you should measure the metabolic rate classification. You can use this particular classification table and again I would like to mention it is being referred from this particular book. You can see if you want you can check or cross check back from this particular book, okay? So everything we did, everything we measured, small, small categories, right? We measured the all effects which is from the external factor and the factors which is for the personnel. Now we should understand how we are going to assess the subjective. Now I will go back to two slides and I will see where this is applicable. Now here you can see everywhere we are talking about assessment of the discomfort level. How do we assess it? Similarly there is some procedure to it, right? So in this particular section when I am talking about the subjective assessment, we are going to understand that particular aspect. So let us go ahead.

Subjective Assessment – Category Segregation

Category	Question
Perceptual	*How are you feeling (at this precise moment)?*
Evaluation	*Do you find this…?*
Preference	*Would you prefer to be…?*
Acceptability	*Do you find this acceptable?*
Tolerance	*Is it tolerable?*

So here you have these 5 categories. One is perceptual, then you need to understand about the evaluation, then preference, acceptability and tolerance. So if you want to develop the questions or related information or you want to interview it then you should go ahead with this type of question. If you want to understand mainly about the perception, then how you are feeling about this particular environment, how you are feeling about the temperature, so this type of question. If it is evaluation, do you find it is comfortable? Do you find it is discomfort? Something like that question. If you are talking about preference, so these are the kind of variables you should have to assess the subjective response. And these are the varieties of questions you can derive based on the requirement.

Scale of Subjective Descriptions of Personal Thermal State in response to the question, *"How are you feeling right now?"*

Introductory phrase: ***"I'm feeling…/I am…"***		
Poles	**Degrees**	**Scaled terminology**
Hot	+4	very hot
	+3	hot
	+2	warm
	+1	slightly warm
Indifference	0	neutral
	-1	slightly cool
	-2	cool
	-3	cold
Cold	-4	very cold

So it is not only that no single question, maybe you need to understand the severity, you need to understand the intensity, so you can use the kind of scale. The scale of subjective description of personal thermal state in response to the question. Because I am talking about how are you feeling right now. So I told I am feeling hot. Now hot means at what extent? So you can use this 5 point scale. So you can use that or you can use this type of scale or the whole category you can club together and you can have a one scale or you can use visual analog scale, VAS. So any kind of scale you can use to give a value or give a gradient in that particular situation.

Scale of Subjective Descriptions of Personal Thermal State in response to the question, *"Did you find this…?"*

Introductory phrase: ***"I find it…"***		
Poles	**Degrees**	**Scaled terminology**
Comfort	0	comfortable
	1	slightly comfortable
	2	uncomfortable
	3	very uncomfortable
Discomfort	4	extremely uncomfortable

Now when I am talking about comfort, similarly we can use this type of scale 0, 1, 2, 3, 4, so 5 point scale or you can use this kind of point description. So comfortable, slight comfortable, uncomfortable, very uncomfortable and extremely uncomfortable. So here it is kind of middle point and this is on this direction, this is in another direction. So you can have this type of scale.

Scale of Subjective Descriptions of Personal Thermal State in response to the instruction, *"Please state how you would prefer to be now."*

Introductory phrase: ***"I would prefer to be…"***		
Poles	**Degrees**	**Scaled terminology**
Warmer	+3	much warmer
	+2	warmer
	+1	a little warmer
	0	neither warmer nor cooler
	-1	slightly cooler
	-2	cooler
Cooler	-3	much cooler

Similarly here you have warmer, you have cooler and again you have it is a 7 point scale and you have description along with that particular scale. So that way you can measure them.

Personal Acceptability Statement Form

Categories	(a) After the question, ***"How do you judge this environment on a personal level?"***	(b) Statement I or II after thee instruction, ***"Taking into account only your personal preference…"***	
	"On a personal level, this environment for me is…"	I: *"Would you accept this environment rather than reject it?"*	II: *"Would you reject this environment rather than accept it?"*
0	*"…acceptable rather than unacceptable."*	YES	NO
1	*"…unacceptable rather than acceptable."*	NO	YES

Then personal acceptability statement. Suppose I want to understand do you accept this thermal environment for your activity or not? So what type of questions you can ask? Here is the description. So acceptable rather than unacceptable, so you can go for either yes situation, so all these are binary, either yes or no. So you have gradation in earlier case, here you have gradation, here you have only binary data. So you can do the acceptability rating using this type of situation or this type of questions. So in this way once you have all these factors together, then you can say yes I have an understanding, appropriate understanding about the thermal situation or thermal condition of this whole scenario or of this whole workplace. So I have described that how the external factors can be assessed in different method, different tools and how do you assess your clothing and how do you assess your metabolic rate. Once you have all combination then you can assess the subjective understanding that how the person is reacting towards that particular thermal environment. Once you have full understanding about all these variables then definitely you can go ahead with your intervention or recommendation. Suppose for this particular situation if you talk about the clothing you can get a value how I am going to, how my skin is going to evaporate, how the metabolic rate, I am in a resting condition. So you can understand what is the kind of metabolic rate I have right now. You can measure the air temperature, air velocity, relative humidity, radiant heat using any kind of instrument that I described. Then you are going to ask me about my subjective feeling for this particular environment. So once you have all these variables ready with you then you can say that this particular thermal environment is conducive for this type of activity or not. If you find that this is not conducive or this is not comfortable then definitely you can go ahead with the intervention or recommendation. If it is comfortable then you continue the same thing further. So this is how we are going to use thermal comfort or thermal measurement to design the work environment in a particular situation. So that is all for today. You should do the practice of how to measure these variables. So you should have access to all these instruments. So every laboratory, basic ergonomics laboratory may have all these instruments. So wherever you are and you try to get, use them and get them and use them and check the variable that you can measure and based on that you can do your or plan your experiment. If you have any question you can put it in your discussion forum or you can discuss it in the open discussion session. That is all. Thank you.