Building Services III

Lecture 1

Need for Air Conditioning in Buildings

Why do we do air conditioning on buildings? Let us ask this question to ourselves, why do we build buildings? Basically, buildings provide shelter for human beings to, work and live.

Earlier, people desired a certain minimum level of comfort, but would modify clothing or expectations as a function of weather. Meaning their lifestyle was based on the kind of climate they live in, the kind of house they live in, based on that they change their clothing etc and their expectations are also very less. But in the current context people expect to be held at a constant level of comfort, in spite of the weather or location in the world . So in today's context, in the globalized world, people want to maintain certain comfort temperatures wherever they are, irrespective of the climate, irrespective of the clothing they are wearing. So let us see, what is comfort for human beings.

The effects of climate on people - Major elements of climatic environment which affect human comfort are: Air Temperature, Radiation, Air movement (wind speed) and Humidity. Basically what is thermal comfort? Thermal comfort - is that condition of mind which expresses satisfaction with the thermal environment." Based on these parameters, people have a mental idea or perception that this comfortable for me and it always happens that it changes for different people in different regions of the world. This thermal comfort level is not the same for everyone and it also varies with age groups and culture.

Let us see, Bodily Heat Transfer**.** How the human body gains and loses heat? because basically comfort has to do a lot with bodily heat. So what are the ways for heat gain for the human body? It is through metabolism which is the energy produced by the conversion of food through activity and heat, absorption of Radiant Energy and Heat Conduction toward body

We have looked at how the human body responds to the environment respective of heat gain or loss. Now let us go into, shelter and the environment. Shelter is the main instrument for fulfilling the requirements of comfort. It modifies the natural environment to approach optimum conditions of livability.

So we are clear that shelter, can't do away with the natural environment. It is just a modification of optimum conditions of livability. Now comes the architect's problem, it is to produce an environment which will not place undue stress upon the body's heat-compensation mechanism.

So as architects we have the responsibility to design the shelter in such a way that, it does not play any stress upon the human mechanism. This heat compensation mechanism. Now let us look at, what are the different ways people adapt to heat. Before that, we talk about this thermal comfort. So, what is the right comfort level or in other words, the comfort zone for human beings. Scientists and many scholars and researchers, have undertaken several experiments and they have found out that,

The comfort zone refers to the range of temperature conditions of air movement, humidity and exposure to direct sunlight, under which a moderately clothed human feels, 'comfortable'. We should also think about how this comfort impacts the health and efficiency of human beings. Prolonged exposure to discomforting conditions can produce adverse effects on the human health and prolonged discomfort also causes loss of efficiency in work coupled with physical strain.

So once if you are not comfortable with environment you work in or live in, naturally it affects our health and it also affects our productivity or efficiency, in the work we do. So are the parameters of thermal comfort same for everyone? Not really. It basically depends upon two things; the biological limits and the Cultural perceptions. Biological limits are important, people can die if they get too hot or too cold. But, cultural perceptions of comfort vary widely. People of different cultures have reported being comfortable at temperatures ranging from 6 to 30 degrees centigrade.

So it very clear to us, that this comfort zone is not the same across the world, across age groups and across different cultures. But anyways, as I said earlier, we live in a globalized world where the same kind of environment is expected out of people, expected out of buildings, wherever they are put up and people want to work with the same kind of clothing, same kind of environment, irrespective of the weather conditions. So, how to identify the right comfort temperature? Let us go back to experiments;
This slide is just to show how people across cultures and across age groups, adapt to the heat, the thermal adaptation. The ideas of comfort has also changed over the years.

In this slide, you can see on the left you see the idea of an open air school in USA in 1900. However, a century later, you see the idea of an air conditioned office Which is completely enclosed on all four sides. It is much deeper and larger. So people, by experiments and research, were able to replicate the open air concept, the comfortable environment even in a closed space, by way of air-conditioning.

Here you can see, a person undergoing or is participating in an experiment, early experiments on human subjects to assess the physical responses to heat, stress and other parameters.

Through such experiments, people were able to identify the right comfort zone for human beings.

Ok, enough with experiments, what is the finding or what is the solution?
The findings of experiments built into technical guidelines for buildings; the temperature is to be held constant in the range of 21 to 23 degree Celsius. (this is based on the ASHRAE - American Society for Heating standard 55, and this has been accepted across the world) So once, we have identified this right comfort or temperature zone, it was easy for people to manufacture comfort. If someone asks the question, Can we manufacture comfort, some hundred years back, people would have laughed. But yes, it is possible, it has become a reality.
After knowing the right comfort level, it was easy to help achieve the right comfort level. There is this quote by Cooper which states, " When it was shown that no natural climate could consistently deliver perfect comfort conditions, air-conditioning broke free of its geographic limits. When no town could deliver an ideal climate, all towns became potential markets for air-conditioning."

Please take note of the phrase here, 'ideal climate;, people want to live in ideal climate. Thanks to air conditioning, this is possible today. Talking in an Indian context, a large segment of people in our country, can't afford air conditioning, unlike the people living in other developed countries. So I will give you just a short comparison of the comfort levels achieved when using a ceiling fan in relation to, when using an air conditioner. As seen in the earlier slide;

The environmental factors that affect personal comfort in the home are; Air temperature, relative humidity and air Movement. A ceiling fan has no effect on the first two factors. Only, the air conditioning can affect both the temperature and the humidity in the house. What does the ceiling fan do? The ceiling fan, on the other hand can increase the air movement in a room and thus, create a cooling effect that will help increase the comfort level. Air movement helps to keep you cool primarily by increasing the role of evaporation of moisture from your skin. That’s just what a ceiling fan does and our people are content with just that much. If you really want higher levels of comfort, there is no choice but to do air conditioning. Ceiling fans, can’t replace air conditioning because ceiling fans do not lower humidity. Now, we have seen why people require air conditioners.

Basic Refrigeration Principles
Let’s proceed to the basics of air conditioning, in other words, the basic refrigeration principles. What is refrigeration? Refrigeration is not associated with cold or cooling, it deals with transfer of heat or removal of heat in other words.

What is air conditioning, then? Air conditioning is defined as the process which cools (or heats), cleans, circulates, freshens air and control its moisture content simultaneously. So air conditioning, does all these things, that is why we feel comfortable when sitting in an air conditioned room. In order to understand how air conditioning or refrigeration works, we have to go through our high school physics a little bit and the second law of thermodynamics is very important to understand how an air conditioner works.

Let us get into that; What is thermodynamics? Thermodynamics is a branch of science that deals with the mechanical action of heat. There are three laws of thermodynamics, we will just see the first and second law. What does the first law state? Energy can neither be created or destroyed, but can be converted from one form to another and the second law; Energy always travels from a warm object to a colder one. The rate of heat travel is in direct proportion to the temperature difference between the two bodies.

You can see in the picture below, when ice cubes are placed on a plate, placed on top of a vessel with boiling water, it melts down. So, the heat travels from a warmer object to a cold one. However, if you practice the vise versa of this experiment, the water on a plate, over a vessel which is not boiling, the ice is not formed on the plate. Hence, the law that energy always travels from a warm object to a cold one and the vice versa is not possible.

Let us delve into the basic definitions of Heat, temperature and humidity before we go into the basics principles of Air conditioning. What is heat? This is a form of energy primarily created by the transformation of other types of energy into heat energy. Energy in transfer, never constant, moving from warm body to colder body. So now that we have defined heat, how to measure heat? There should be some scale or some measurement, so let us see how it is measured;

Heat Measurement - Heat is measured in Joules (J). The unit of heat, SI unit is Joules. Previously special units were in use for the measurement of heat.The British Thermal Unit (Btu) was defined as the amount of heat necessary to raise the temperature of 1lb of water by 1 deg F. They are no longer in use but we have to know how people calculate the BTU and kilocalories because while dealing with air conditioning, people still talk about heat load in terms of British Thermal unit. What is BTU apart from being a British thermal unit?

> The kilocalorie (kcal) was defined as the amount of heat necessary to raise the temperature of 1kg of water by 1 degC.
Btu was defined as the amount of heat necessary to raise the temperature of one pound of water by one degree fahrenheit and the Kilocalorie is defined to be the amount of heat

necessary to raise the temperature of 1kg of water by 1 degree Celsius. In order to convert, these two values into Joules, you can use these factors;
1 Btu = 1055.06 J
1 kcal = 4186.8 J

Temperature is the scale to measure the intensity of heat. All of us know, temperature is measured in Celsius and Fahrenheit.

To give you an understandable difference between Fahrenheit and Celsius, see the picture below; Water boils at 100 degree Celsius/ 212 degree Fahrenheit and water freezes at 0 degree Celsius/ 32 degree Fahrenheit. It is hence made very clear, the difference between the boiling point and freezing point; in Celsius scale it is divided into 100 equal increments, and in the fahrenheit scale it is divided into 180 equal increments. Once again, to understand the relationship between the two, you can use the formula given below;

Relation between Fahrenheit and Centigrade scale :

Fahrenheit = 9/5 Centigrade + 32 degree

Centigrade = 5/9 (Fahrenheit = 32 degree)

Humidity - Humidity is the amount of moisture in the air. In air conditioning we are concerned with the relative humidity of the air. *Relative Humidity* (rh) is the percent of moisture in the air as compared to 100 percent of the moisture that air at that temperature can hold. The amount of moisture that air can hold varies with the temperature. The warmer the air is, the more moisture it can hold. Generally people feel more comfortable in a range of 40 percent to 50 percent rh (relative humidity) So I hope you know how important humidity is, in achieving thermal comfort, because unless humidity is approached in the right manner, the right comfort cannot be achieved.

Once we have gone through the basic definitions of heat, temperature and humidity, now we can go a step further into the working principles of how heat is transferred from one object to another or through a medium.

Heat energy tends to distribute itself evenly until a perfectly diffused uniform thermal field is achieved. So as we saw in the second law of thermodynamics, heat is transferred from a warmer body to colder body and that they say, this is perfectly diffused until a perfectly diffused uniform is achieved. It tends to flow from the higher temperature to the lower temperature zones by any of the following ways. Through, conduction, convection and

radiation. As we saw This is a constant process. It tends to flow from high temperature to lower temperature zones, by any or all of the following ways;

Conduction is the flow of heat through a substance. A very classic example would be; when you put the ladle or spoon into boiling water, it gets heated up quickly. However, if you put a wooden ladle into the boiling water, it doesn't heat up quickly at all. Metal is a good conductor of head and wood is a bad conductor.

Convection is the flow of heat by means of a fluid medium, either gas or liquid, normally air or water. All of us have seen, how people bake cakes i.e through convection ovens. In this oven, the heat is transferred through a medium i.e air. The last is radiation, all of us human beings or any living objects on the earth, cannot live without the sun's radiation. Radiation is the transfer of heat by waves similar to light waves or radio waves. Once we have seen the ways of heat transfer, the next step higher is the change of state.

This principle, Change of state principle, play a very important key role in the air conditioning mechanism. Let us look at that. The picture graphic here is self explanatory. So normally, the most common substances exist in three different states - solid, liquid and gaseous state depending on the temperature and pressure to which they are exposed. When a solid changes to a liquid or a liquid changes to vapour, heat is absorbed even though no temperature change takes place. The same amount of heat is given off than vapour changes to a water, vapour changes to a liquid and when liquid turns into solid. Basically, heat is absorbed or given off in this change of state. But they say, that when this change takes place, there is no temperature change. Aren't you curious as to what happens during the change of state? Why is there no temperature change or basically what happens to the heat? Since heat is absorbed or given off, but there is no temperature change. Let us see what happens.

What happens to heat energy? The heat energy that was absorbed by the water became molecular energy, and as a result the molecules re-arranged themselves, changing ice into water and water into steam. When the steam condenses back into water, that same molecular energy is again converted into heat energy. So that is what happens during the process of change of state. But this is not enough, Here are two principles that help understand the process that are involved in this change of state i.e Sensible heat and Latent Heat.

Sensible heat is defined as the heat required to either increase or decrease the temperature of the matter without changing its state. For example, when you boil water and as it begins to boil, the water which is at room temperature, begins to boil due to heat. But when it boils at room temperature, it is still in the same state, doesn't change into vapor. In this period of increasing heat, you can see a temperature change i.e a difference in temperature without the

change of state. So that is what is, sensible heat, the heat that can be measured using a temperature measuring device. There is simply a difference in temperature without a change in state. This is what is sensible heat. The heat that can be measured via a temperature measuring device.

What is Latent heat? The quantity of heat which is absorbed or released by a substance during a change of state (fusion or vaporization) at constant temperature. The word "latent" is a latin word for "hidden". This latent heat is the key player in the change of state, it is hidden heat. So now that we know what is Sensible heat, what is latent heat, let us move on to, what are the different types of latent heat. Once again, this latent heat, has to be understood because this plays a very major role in air conditioning. What are the types of latent heat? Latent heat of fusion, latent of evaporation and latent heat of sublimation.

A change of substance from a solid to a liquid or from a liquid to a solid involves the latent heat of fusion. Also called as latent heat of melting or latent heat of freezing. So it very obvious, fusion is change from solid to liquid.

Latent heat of evaporation - A change of substance from a liquid or a vapour or from a vapour back to a liquid involves the latent heat of evaporation. Also called as latent heat of boiling/ vaporization or latent heat of condensation. So when you heat water, it evaporates, so it is evaporation. But when you change vapor to water, it is condensation; latent heat of Condensation.

Lastly, it is the Latent heat of sublimation; A change directly from a solid to a vapour without going through the liquid phase can occur in some substances. One very common example is camphor or naphthalene balls, when heated they never go to a liquid state, they directly change from a solid to gaseous or vapour state. Another example is the Use of "dry ice" or solid CO_2 for cooling. Another example, camphor balls or naphthalene balls, when heated, they never go to a liquid state, rather, they directly change to vapor state.

You can see here, the latent of vaporization for water and refrigerant. Refrigerant is a liquid used in air conditioning process to make the air cooler. Here you can see the distinct difference between the latent heat of water and the refrigerant. The latent of Vaporization for water is; 970 BTU/lb (pound), whereas for refrigerant, it can change state a much lower temperature. This only goes to show that a refrigerant change its state at a very low temperature.

Saturation Temperature

Let us see what is Saturation Temperature - The condition of temperature and pressure at which both liquid and vapor can exist simultaneously is termed saturation. A saturated liquid or

vapour is one at its boiling point. At higher pressures the saturation temperature increases and with a decrease in pressure, the saturation temperature decreases.

There is a very close relationship between temperature and pressure and by altering one of these two things, we can make liquid boil at a lower temperature or higher temperature, as we wish. So, we will see why do we need to understand saturation temperature, when we move on to the principles of refrigeration or when we learn about how does the mechanism work. There are two more terms called Superheated vapour and Subcooled liquid. A superheated vapour, once when liquid turns into vapour, any further heat to the vapour, rises its temperature so that the pressure remains constant. The term superheated vapour is used to describe a gas whose temperature is above its boiling or saturation point. Once a subcooled liquid reaches its vapor state, it passes on to a superheated vapor state, which is above the saturation of boiling point. But it still stays as a vapor.

Subcooled liquid is a liquid at a temperature lower than the saturation temperature at a given pressure. A subcooled liquid is a liquid where you lower the temperature with a constant pressure, where it still remains a liquid without changing state.

These are the qualities a refrigerant has to possess to function as a good refrigerant. As we saw in the previous slide, talking about saturation temperature, there is a very close relationship between temperature and pressure and it's very important for refrigerant liquids, especially.

At atmospheric pressure water boils at 100 degree celsius. If pressure is increased above atmospheric pressure, the boiling point is higher and if the pressure is decreased below atmospheric pressure the boiling point is lower. The refrigerants have the same properties like that of water except that the range of their boiling point is lower. For example, when you heat water in planes there is a certain atmospheric pressure which is normal by default, the water boils at 100 degree Celsius. The same water if you boil at a higher altitude, where the pressure is considered to be low, it boils quickly. So, once pressure decreases, the boiling point also lowers.

The refrigerants have the same properties like that of water except that the range of their boiling point is lower and that’s why it is used as a refrigerant. The temperature of the liquid depends upon the surrounding pressure also. The pressure plays a very important role in altering the boiling point as we like.