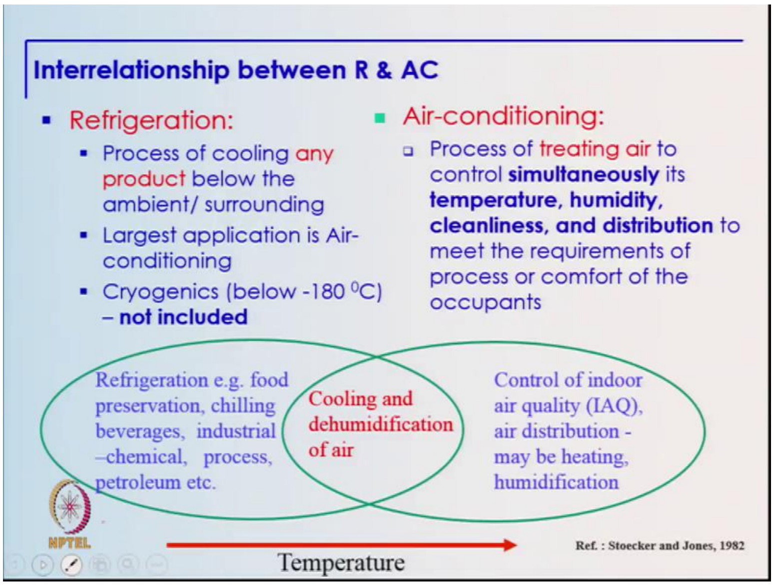
RAC Product Design
Prof. Sanjeev Jain & Bhupinder Godara
Department of Mechanical Engineering
Indian Institute of Technology, Delhi

Lecture - 03
Basic Concepts Psychrometry and Air- conditioning

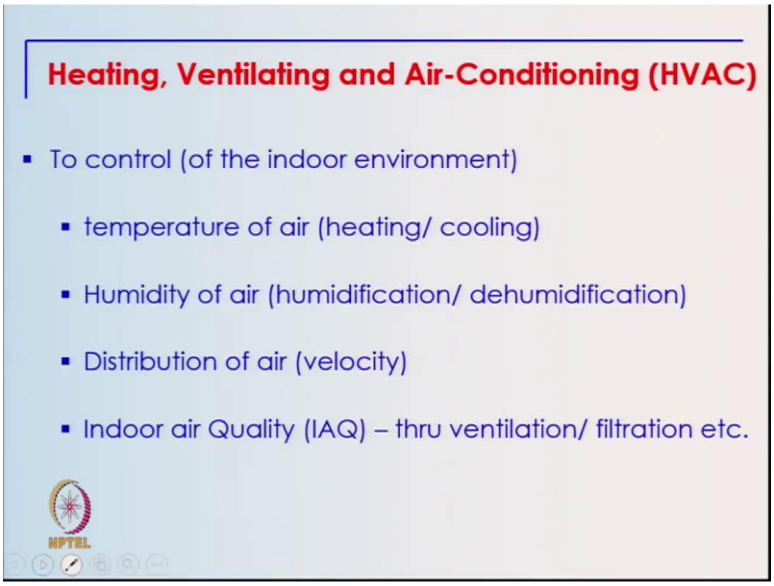
Welcome to this MOOC course, RAC Product Design. This course is been shared by me, I am Sanjeev Jain from IIT, Delhi and Mr. Bhupinder Godara. Mr. Godara has already given you an overview of the course and also introduced the basic concepts of refrigeration cycle. In this particular lecture I would be talking about the basic concepts related to air conditioning, particularly focusing on the psychrometry, so that you can appreciate this course much better.

Now, I would like to start with the basic difference between a refrigeration system and an air conditioning system. All of us are aware that a refrigeration system is any system which helps us to lower the temperature of any particular product below the ambient conditions. And the largest application of refrigeration systems is in air-conditioning, for air conditioning system designs and for air conditioning applications.



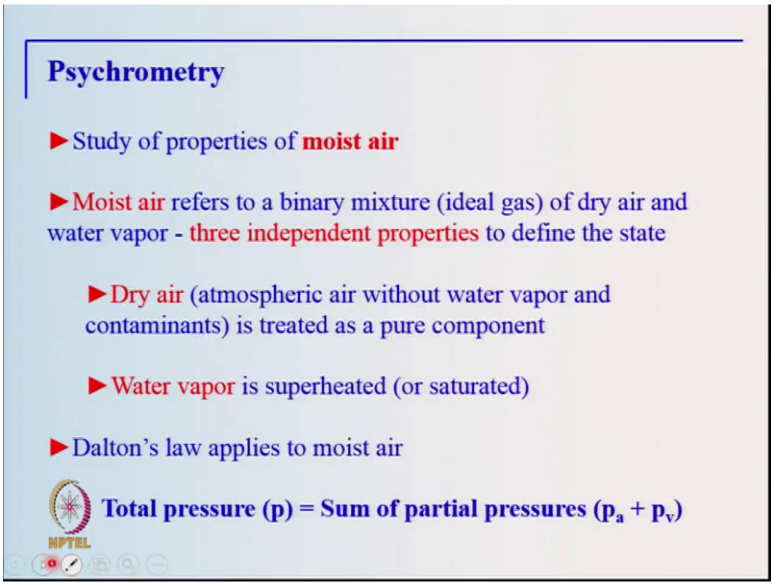
In this particular area cryogenics is not included because we deal with cryogenics when we are interested in liquefaction of gases and the temperatures are typically below minus 180 degree Celsius. So, refrigeration is a science or is refrigeration is a system which is used when we are interested in temperatures up to about minus 60, minus 70 degree Celsius. Refrigeration is extensively used in industry including chemical and process industries and also used for food preservation. One of the most common examples of refrigeration is in our domestic refrigerators where we store various kinds of fruits and vegetables for short term storages. It is also used for chilling beverages. In contrast to refrigeration, air conditioning encompasses variety of processes where we are interested in variety of conditions inside the conditioned space depending on the requirement.

So, in air conditioning the focus is on treatment of air. We are interested in controlling the temperature, the humidity, the quality and the distribution of air within the conditioned space depending on either the process requirements or the requirement of comforts for the occupants present in the condition space. So, we may have to heat the air or we may have to humidify the air as per the requirement in the case of air conditioning and also we may have to cool and de-humidify the air for which we use a refrigeration system. So, typically when we talk of refrigeration we are talking of much lower temperatures and when we are interested in air conditioning we may be dealing with much higher temperatures closer to the ambient conditions. There is another term which is used in industry extensively which is called Heating Ventilating and Air Conditioning, in short HVAC.



HVAC is basically used to control the temperature, humidity, distribution of air and the indoor air quality. So, it has the concept which we use in air conditioning. So, in HVAC we are again interested in controlling the temperature, humidity, distribution and quality of air and the additional focus is on heating of air which is typically not there in air conditioning and also on ventilation. Because in some applications even simple applications like basement parking we may be only doing ventilation and we would like to integrate it with the air conditioning system of the building and therefore, the focus here is also on ventilation.

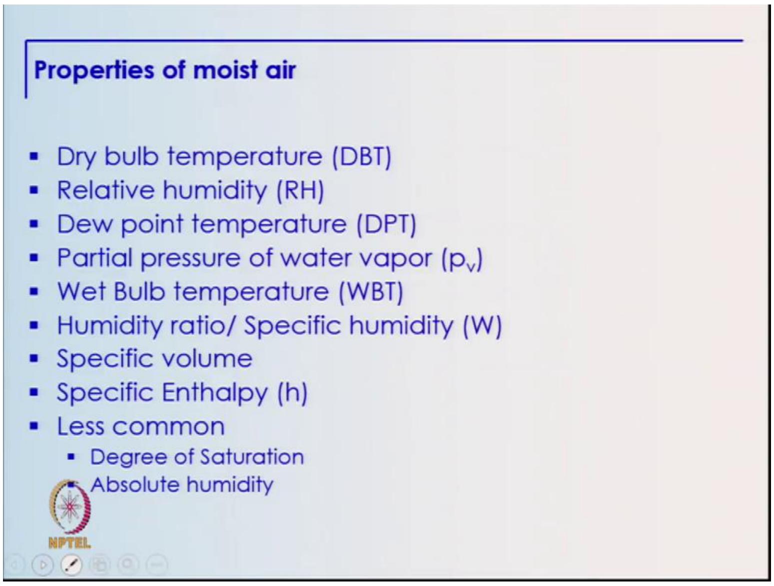
So, HVAC is a field which includes heating, ventilation and air conditioning of spaces or of buildings. So, with this brief introduction to air conditioning we would now like to go for understanding the properties of moist air because air conditioning deals with moist air, so that science is called pshychrometry.



So, in psychrometry we talk about moist air, we treat it as an ideal gas mixture of dry air and water vapor. So, it is a binary mixture and as you know from your basic thermodynamics that for any binary mixture, you require three independent properties to define its state. So that we have to keep in mind for appreciation of psychrometry. What we call as dry air is nothing but atmospheric air without the water vapor and without any contaminants.

So, all the gases which are present there are part of the dry air, but we still treat it as a pure substance. So that has to be kept in mind. We are not talking about nitrogen, oxygen and other gases present in atmospheric air as separate gases, all of that is included in dry air. Water vapor is typically super heated in air or it could even be saturated depending on the conditions of air.

For any binary mixture which is an ideal gas mixture, we can apply the Daltons law, and the Daltons law is also applicable for moist air and basically it states that the total pressure of moist air is equal to the sum of partial pressures of its components which is dry air and water vapor. For understanding the properties of moist air we deal with many different terms which are used in air conditioning practice. Some of these terms are listed here we would look at them more closely.



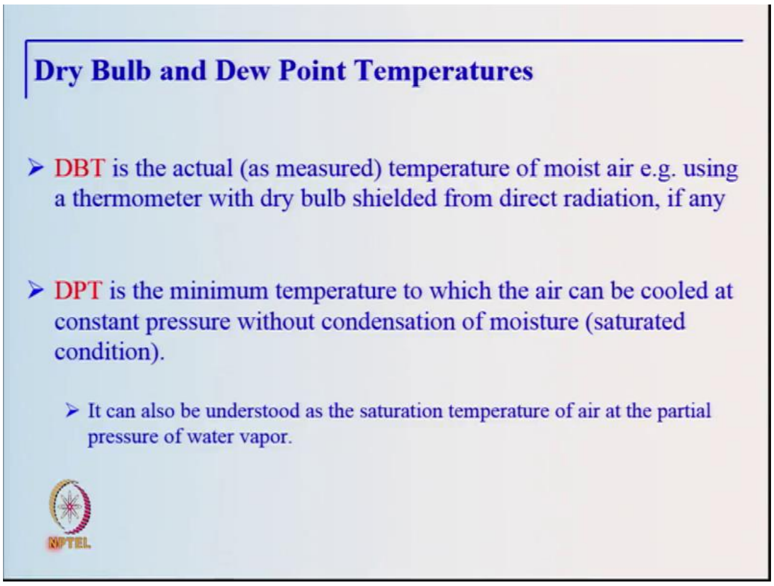
So, dry bulb temperature is the most commonly used term which we are aware of which is the actual temperature which is measured by a particular temperature measuring device, and there are several terms which are related to water vapor which is present in air. We would be looking at some of these terms in the next few slides.

So, before we go further, let us look at an overview of the different properties of moist air with the help of this psychrometric chart.

So, on this psychrometric chart on the x axis or on the horizontal axis, we have the dry bulb temperature and on the y axis or the vertical axis, we have the specific humidity or humidity ratio of air, and the various curves which are visible on this particular chart correspond to relative humidity varying from 0 to 100 percent. So, that top most curve corresponds to saturated air which is 100 percent relative humidity and then the next curve is 90 percent relative humidity and so on so forth. So, relative humidity decreases as we go towards the inside of the curve away from the top curve.

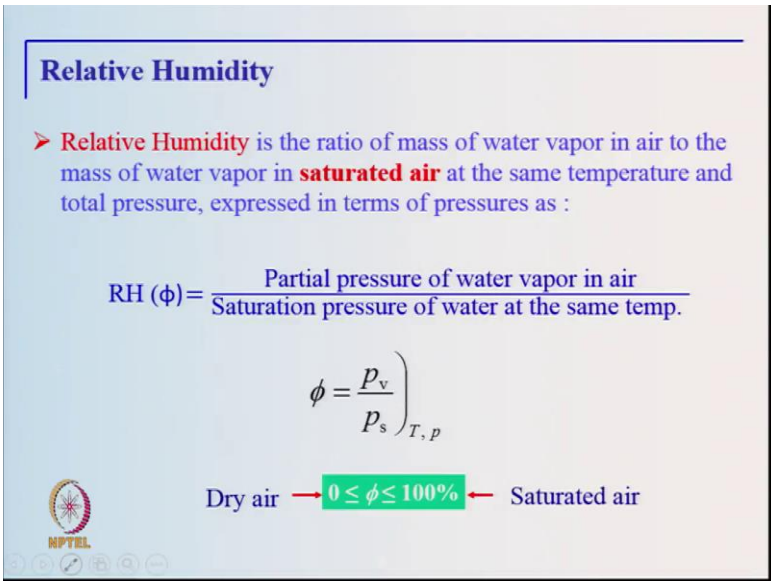
Then inclined lines which are shown here on this scale refer to the enthalpy of moist air which is basically the specific enthalpy of moist air which is defined per kg of dry air. And these lines which are shown within the chart, they correspond to the wet bulb temperature of air, and the lines which are steeper, these lines are the specific volume of moist air.

There are two other scales which we will discuss in detail in the rest of the lecture. This is one scale which is related to the sensible heat factor which is of interest in air conditioning calculations, and this semi circle on this side refers to again the sensible heat factor which may be of interest for varying outdoor ambient conditions. And on the outer of this scale we also have the enthalpy to the humidity ratio which is defined. And one should also keep in mind that this particular chart is drawn for one particular total pressure which is the atmospheric pressure which is 101325 Pascal.



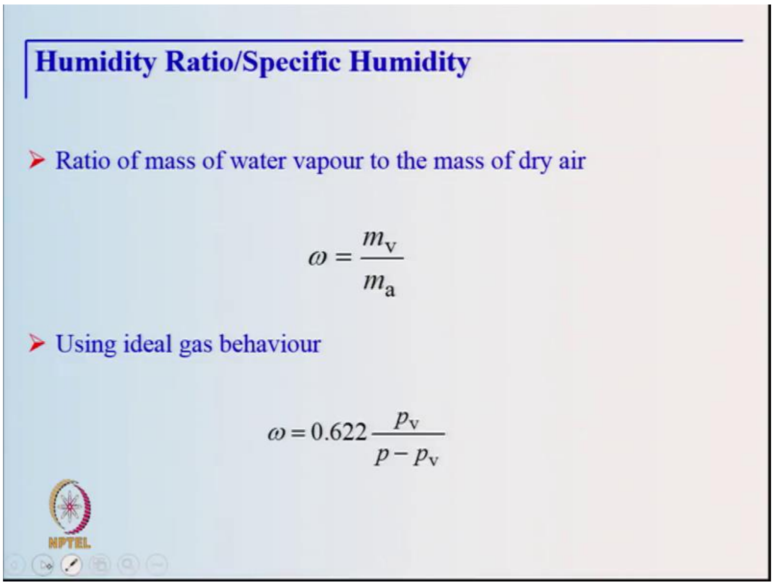
So, now, let us look at some of the terms little more in detail. So, what is dry bulb temperature? Obviously, we think we understand dry bulb temperature. So, it is the actual temperature which is measured by a thermometer which is dry but it should also be shielded from many direct radiations that have to be kept in mind because radiations can change the temperature being measured by the thermometer. The other temperature which is of interest is the dew point temperature, which we define as the minimum temperature to which the air can be cooled at constant pressure without any condensation.

So, it is like the saturated condition of air when we talk about we interpret in terms of the dew point temperature. It can also be understood as the saturation temperature of air at that particular partial pressure of water vapor which is present in the unsaturated air.

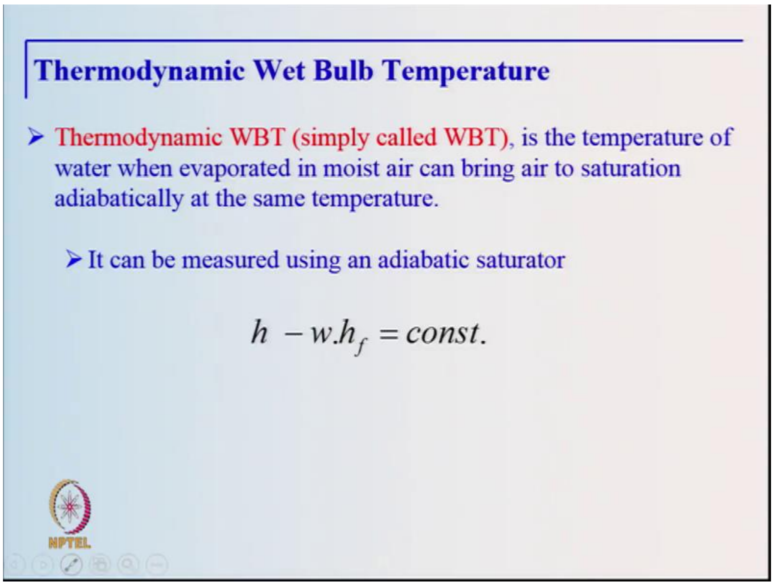


Next term which is of interest is relative humidity, which is the ratio of mass of water vapor which is actually present in air to the mass of water vapor which would be present in case the air is saturated at the same temperature and total pressure. It can also be interpreted in terms of partial pressures. So, we write relative humidity as the ratio of partial pressure of water vapor in air to the partial pressure of water vapor in saturated air at that particular temperature.

So, the relative humidity can vary from 0 percent to 100 percent. Zero percent refers to dry air with no water vapor being present and 100 percent refers to saturated air when you have maximum moisture air present in air.

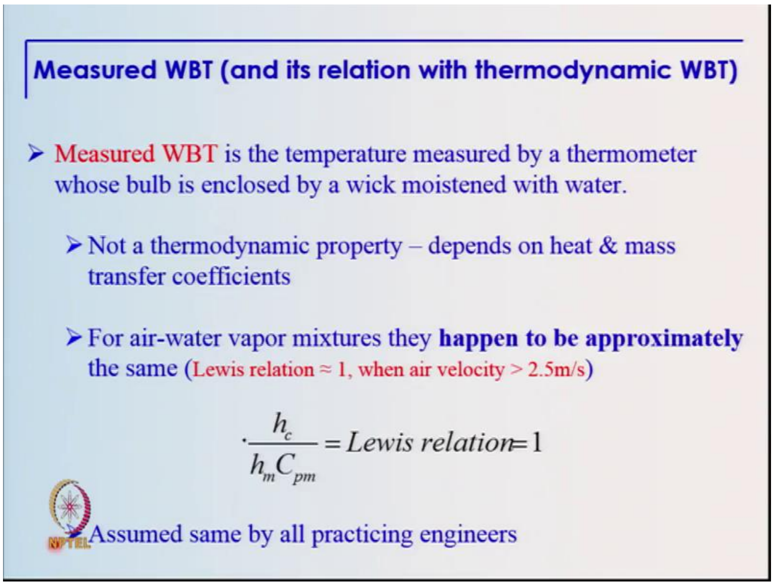


The next term which is of interest is the humidity ratio or specific humidity which is the ratio of mass of water vapor to the mass of dry air. And if we assume ideal gas behavior then we can easily prove in few steps that the specific humidity is given by this expression 0.622 times into the partial pressure of water vapor to the partial pressure of dry air which is the difference between the total pressure and the partial pressure of water vapor.



Another interesting term to understand and appreciate in depth is what we call as the wet bulb temperature. So, we have to understand that wet bulb temperature is a thermodynamic property and therefore, we also call it as thermodynamic wet bulb temperature. So, it is the temperature of water which is when evaporated in moist air can bring the air to saturated condition adiabatically at the same temperature. So, this is the exact definition of thermodynamic wet bulb temperature and it can be measured using an adiabatic saturator which is little more involved and complex device. Therefore, in practice we may not be actually measuring the thermodynamic wet bulb temperature using this device. We may just be measuring it with the help of a thermometer with the wet wick around it and that is called the measured wet bulb temperature which we will see in the next slide.

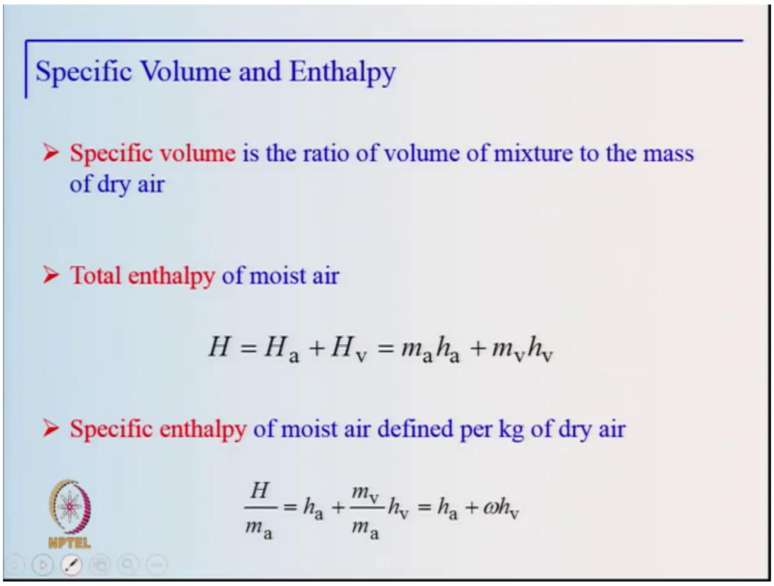
So, when the wet bulb temperature or the thermodynamic wet bulb temperature remains constant then enthalpy does not remain constant. It is this expression $(h\text{-}w.h_f)$ which remains constant. Where w- is the specific humidity of air and h_f -the enthalpy of water which is being sprayed in the air stream. The water is at the same temperature as the wet bulb temperature.



And it can easily be derived by writing the first law for an adiabatic saturator. As I mentioned in practice we measure wet bulb temperature by a simpler device which is basically a thermometer or a temperature measuring device with a, whose bulb is surrounded by a wet wick which is moistened by water. So, measured wet bulb temperature is the temperature which is measured by any temperature measuring device whose sensor is being surrounded by a wick which is wetted by water.

So, this measured wet bulb temperature is unfortunately not a thermodynamic property. It depends on the values of heat and mass transfer coefficients around the sensor and since it depends on the coefficients therefore, it cannot be a thermodynamic property. But it so happens that for air water vapor mixtures if the air is flowing at sufficiently high velocity of the order of 2.5 meters per second, the difference between measured wet bulb temperature and thermodynamic wet bulb temperature is quite negligible for all practical purposes. Therefore it is standard practice for engineers to use the measured wet bulb temperature as the thermodynamic wet bulb temperature.

Theoretically this is true when the Lewis relation is exactly equal to one. Lewis relation is defined as the ratio of the convective heat transfer coefficient to the convective mass transfer coefficient and also divided by the moist air specific heat. So, when this ratio is exactly 1, then the thermodynamic wet bulb temperature is equal to measured wet bulb temperature. For air, water, vapor mixture it comes out to be close to one and therefore, this approximation is used for all practical purposes.



The other term which is of interest is specific volume. Specific volume is the ratio of volume of mixture to the mass of dry air. And it should be kept in mind that most of the properties are defined per kg of dry air because dry air remains constant while the water vapor keeps on changing as the moist air undergoes different psychrometric processes. The total enthalpy of moist air consists of the enthalpy of the two components which are present in moist air which is dry air and water vapor. And specific enthalpy of moist air is defined per kg of dry air, and which is given by this expression which consists of the dry air enthalpy the enthalpy of the water vapor and the term which corresponds to the moisture content present in air.

Through the understanding of these terms, now we can look at the psychrometric chart again and appreciates some of the things.

So, the dry bulb temperature is in terms of degree Celsius which is the temperature of air, the constant wet bulb temperatures are these lines which are shown here. And they are again in degree Celsius. On the y axis or the vertical axis we have the moisture content which can vary from about 0 grams per kg to about 30 grams per kg and the psychrometric chart is typically drawn for the range of temperatures and humidities which are of interest in air conditioning calculations.

Then we have the enthalpy of moist air which is written in terms of kilo Joules per kg of dry air and these steeper lines correspond to the specific volume of moist air which is in meter cube of moist air per kg of dry air and the sensible heat factors do not have any dimensions. This psychrometric chart is very important from the point of view of understanding the psychrometric processes in air conditioning applications.

Let us assume that air is at this particular condition on the psychrometric chart. So, we can read most of the properties directly from the psychrometric chart, but for the dew point temperature we have to move horizontally up to the saturated line and then look for the temperature at that particular point, and that temperature there will give you the dew point temperature of the air which is unsaturated.

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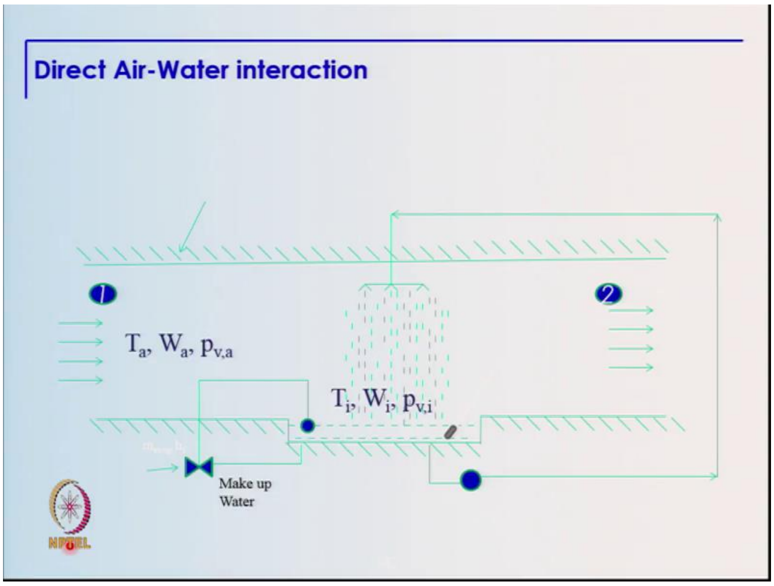

Keeping the basic psychrometry in mind, now let us look at some processes which are of interest in air conditioning practice. Let us first talk about direct air water interaction which we see extensively in cooling towers which are used in refrigeration systems which are used in power plants. And these type of interaction is also seen in air washers and the desert coolers which we use extensively at home.

So, a schematic is shown here where you have the air flowing in a duct and then we have a spray of water and this water evaporates and it either cools the air or it cools the water depending on the process which is of interest depending on the water temperature. So, for this process this direct air water interaction we have the sensible heat transfer and we also have the latent heat transfer.

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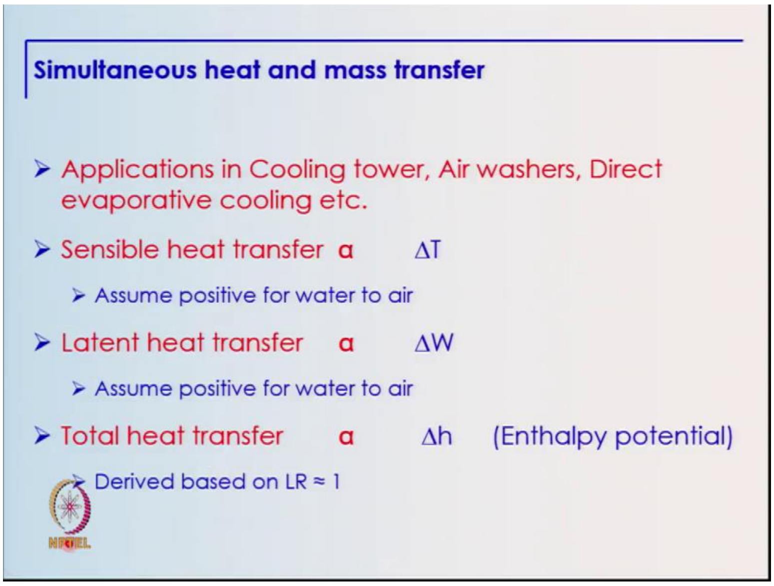

So, the sensible heat transfer between air and water is governed by the temperature difference between the two streams. So, for the purpose of analysis, let us assume that sensible heat transfer is positive when the temperature of water is higher than air. For this particular example this is the nomenclature this is the sign convention which we are assuming, and then we also have latent heat transfer because the water may evaporate in the air stream and transfer its moisture to the air stream.

Similarly, it is possible that the water vapor which is present in air may get condensed and loose its moisture to water. So, we define latent heat transfer which is basically proportional to either the difference in specific humidities of air which is unsaturated air and saturated air which is in contact with water at the water temperature. So, this has to be kept in mind we cannot define specific humidity of water, we only define the specific humidity of saturated air which is at the water temperature, so that is the difference. We can also define the latent heat transfer in terms of the partial pressure difference, the partial pressure of water vapor in moist air minus the partial pressure of water vapor in saturated air at the water temperature. So, here also we are assuming that the moisture transfer is from water to air and that we are treating as positive.

What is also interesting is suppose one of them is positive, and the other one is negative, how do we decide without doing the actual calculations what is the direction for total heat transfer. So, it can be proved through simple mathematics which is available in books. Total heat transfer can be, total heat transfer is proportional to the enthalpy difference and that concept is called the enthalpy potential. Again the difference in enthalpy is basically the difference in enthalpy of moist air minus the enthalpy of saturated air at the water temperature.

And this expression has being derived based on the assumption which we made earlier which is that Lewis relation is assumed to be one. Only then we can show that the total heat transfer is proportional to the difference in enthalpies and that concept is called the enthalpy potential. And we would like to now see how this potential helps us in better appreciation of the simultaneous heat and mass transfer between air stream and water.

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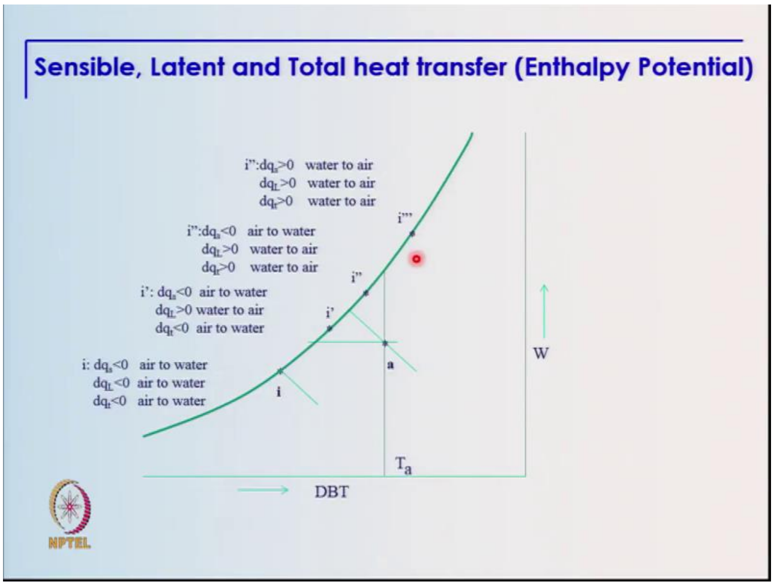


So, this is the basic psychrometric chart which I have drawn. So, let us try to locate the air condition on this particular chart. So, let us assume that air is at some point a, where it has a certain temperature dry bulb temperature T_a, it has a certain specific humidity which we can write as w_a, and then it has a certain enthalpy which is shown by the inclined line or a certain wet bulb temperature which is shown there.

It should be kept in mind that the constant wet bulb temperature lines and the constant enthalpy lines are not exactly the same, but the difference is generally small and therefore, on psychrometric chart we either show constant enthalpy lines or we show constant WBT lines.

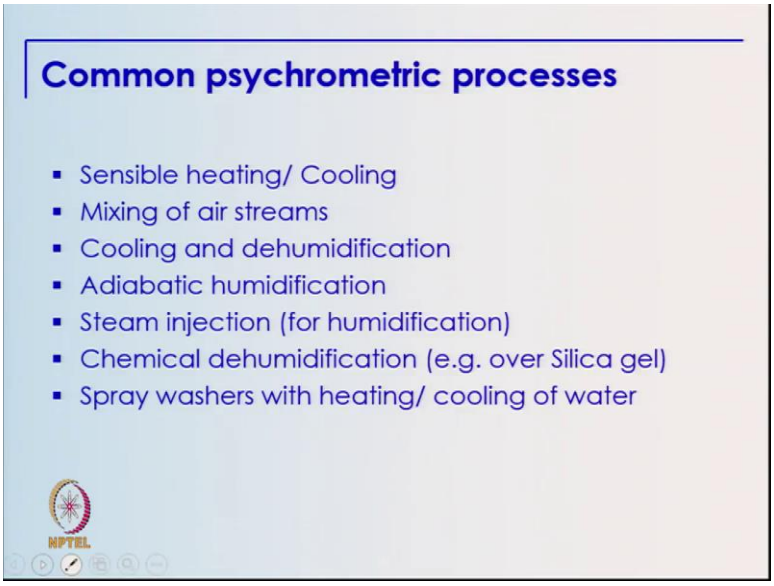
And one should be aware of what the lines represent in the chart which one is using. Assume that we have water at condition i in chart above, at this condition we can see that the temperature of air is higher than the temperature of water. So, the heat transfer will take place from air to water and therefore, the sensible heat transfer in this case is negative. And similarly the moisture transfer will take place from air to water again because the specific humidity of air is higher that the specific humidity corresponding to the saturated air at temperature of water at i. Therefore, the latent heat transfer is also going to be negative. The total heat transfer will be negative which means the total heat transfer will take place from air to water. It is interesting to note that even when air is in contact with water it can shed its moisture to water, and that happens when the water is chilled. It is at a much lower temperature as compared to the dew point temperature of air. So, this point here (horizontal line extended to meet the saturation curve) represents the dew point temperature of air.

Now, if we increase the temperature of water to a point such that it lies at this particular point i', again we see that the water temperature is lower than the air temperature therefore, the sensible heat transfer is negative. In this particular case the latent heat transfer is going to be from water to air, as we can see at the saturated condition the specific humidity of air is higher than the specific humidity of unsaturated air and therefore, the latent heat transfer is positive from water to air. And therefore, we cannot determine without looking at the actual numerical values the direction for the total heat transfer and we take help of the enthalpy potential and we see that the enthalpy of unsaturated air is higher than the enthalpy of saturated air. And therefore, we can say with confidence that the total heat transfer will take place from air to water.

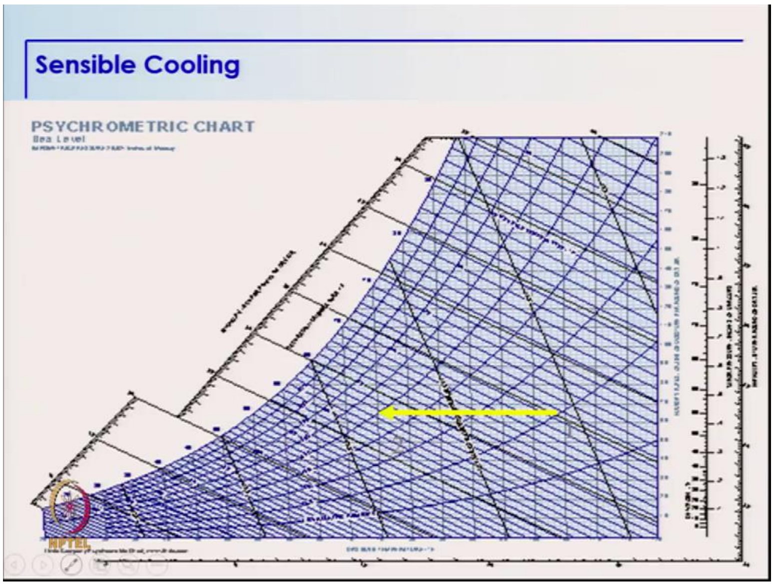
This basically means that water is picking up heat from the air stream and therefore, it is getting heated. Now, let us again increase the temperature of water to another value which is higher than the present value, and we see here again that the water temperature is lower than the air temperature. So, the direction of sensible heat transfer is negative and the direction of latent heat transfer is again positive here as in the previous case because the specific humidity of saturated air is higher than the specific humidity of unsaturated air, and in this particular case the direction for total heat transfer is from water to air because the enthalpy of saturated air in contact with water is higher than the enthalpy of unsaturated air.

This is an important concept which helps us to understand the direction of total heat transfer without going into the numerical evaluation of the two heat transfers. Finally, if we go to a temperature of water which is higher than the dry bulb temperature of air which is typically the case in the case of cooling towers, there we see that the sensible heat transfer is from water to air, the latent heat transfer is again from water to air, and therefore, the total heat transfer is from water to air which means that the water will get cooled in a cooling tower if it is at a condition which is somewhere there. But you have to also keep in mind that if in a cooling tower the water is at this particular condition water will still get cooled. So, any water temperature which is higher than this particular value will result in the cooling of water. So, this should be kept in mind and this is an important concept to understand, so that one can know the directions of the heat transfers, in the case of direct air interaction with water. Having understood the basic psychrometry,

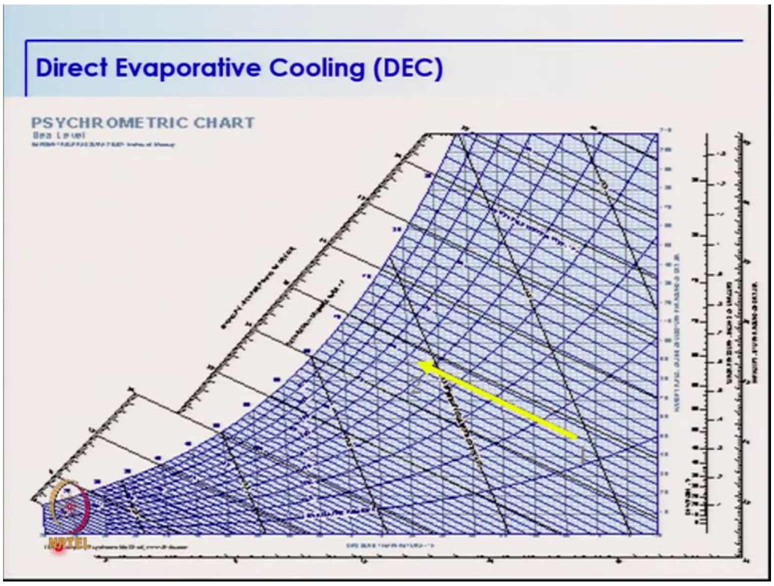
Now, let us try to look at various psychrometric processes which are of interest in air conditioning and going to the depth of air conditioning calculations, so that we are able to design the air conditioning system in an efficient manner. So, some of the psychrometric processes which are of interest are sensible heating and cooling.



The mixing of air streams, typically in an air conditioning system we have the mixing of fresh air with the return air. So, mixing of air streams is common in an air conditioning system. And depending on the outside conditions and the loads we may have the requirement for cooling and dehumidification or we may have to do some heating or we may have to increase the moisture of air for which we may be doing steam injection or we may be using adiabatic humidification. In some cases we are also interested in chemical dehumidification of air where we use materials which are called desiccants for the purpose of dehumidification of air. And sometimes in air conditioning we take the help of air washers by controlling the temperature of water we obtain different psychrometric processes as per the requirement.



Just to look at some of the processes on the psychrometric chart, we have sensible cooling of air which is shown on the psychrometric chart which is basically the reduction in dry bulb temperature of air without affecting its humidity, without affecting its specific humidity to be more precise because the relative humidity does change when you have sensible cooling.



The next process which is of interest to us, in India particularly is the process which happens in desert coolers the process is called direct evaporate cooling, and the wet bulb temperature of air remains constant in case of direct evaporative cooling. What has to be kept in mind is we are neither heating the water nor cooling the water. Water is at the ambient condition and it is being recirculated again and again and therefore, the process is shown here as a constant WBT process on the psychrometric chart.

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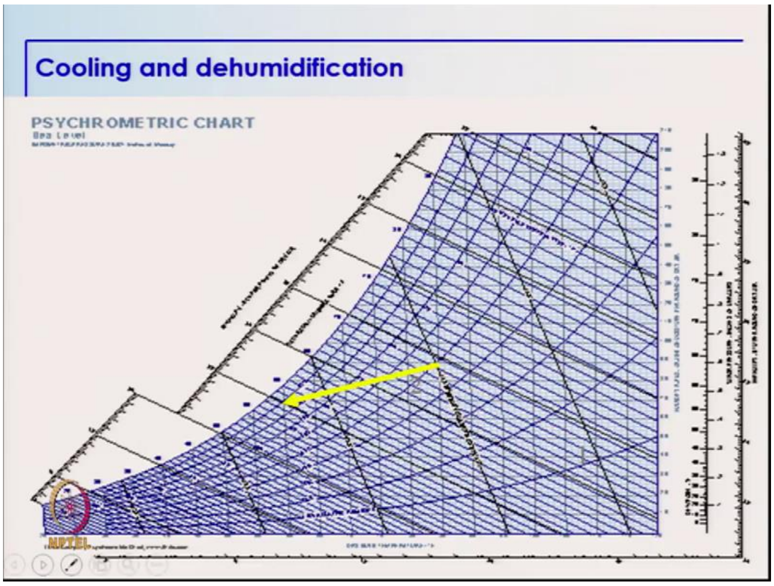
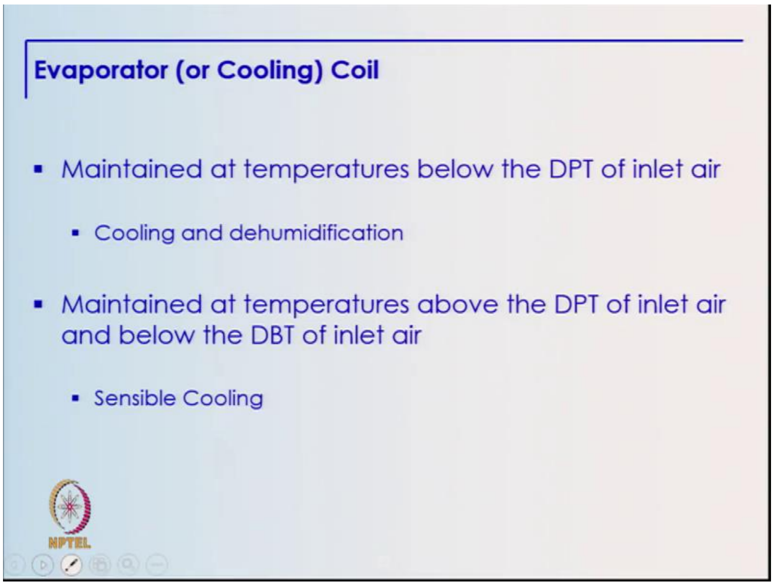
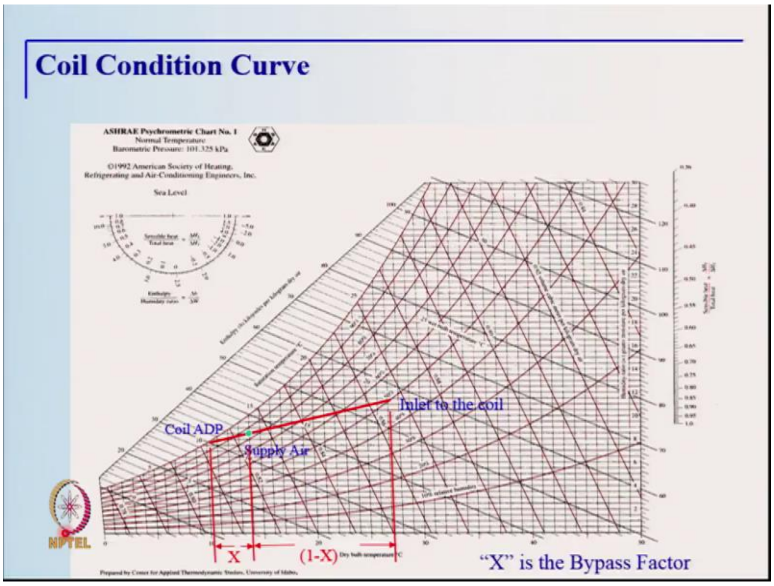


The next process which is of interest is cooling and dehumidification. The standard window and spilt air conditioners which we use in our homes have this process. During summers and monsoon we want both cooling and dehumidification. So, the air at any particular condition is both cooled and dehumidified simultaneously by maintaining the evaporator coil at a temperature which is lower than the dew point temperature of incoming air.



So, this is another process which is of interest. Now, in a room air conditioner or a split air conditioner or any particular air conditioning system we can maintain the coil which could be an evaporator coil or we can generate chilled water in a central plant and circulate chilled water through a coil. And this coil could be maintained at temperatures below the dew point temperature of the air. We will then achieve cooling and dehumidification of the air if the temperature is maintained below the dew point temperature of air.

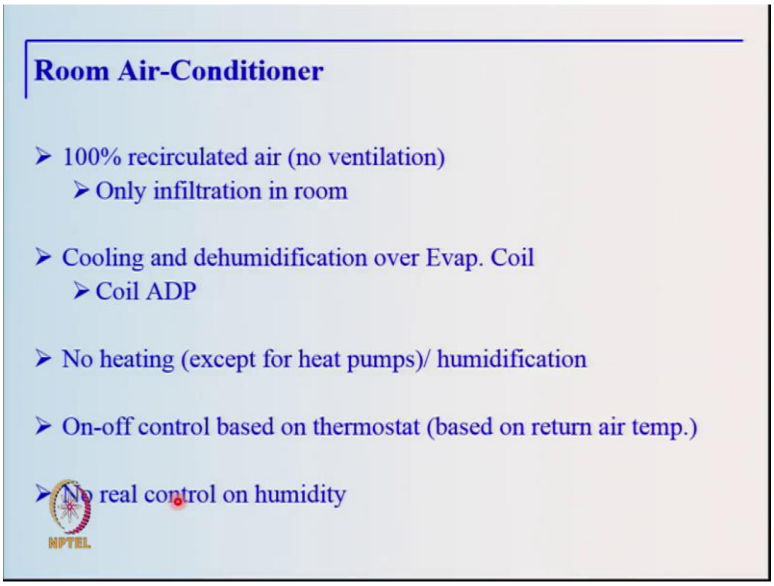
If the temperatures are maintained above the dew point temperature of air, but below the dry bulb temperature of air we would be able to achieve sensible cooling of air through these coils.



So, what happens over the coil is of interest therefore, we define the process when the air flows over a coil and that process is called coil condition curve. So, this is basically showing cooling and dehumidification which is happening over the coil, the air is entering at this particular point on the psychrometric chart, and then the air is being supplied at this particular condition which is shown here on the psychrometric chart. So, this is called the supply air condition.

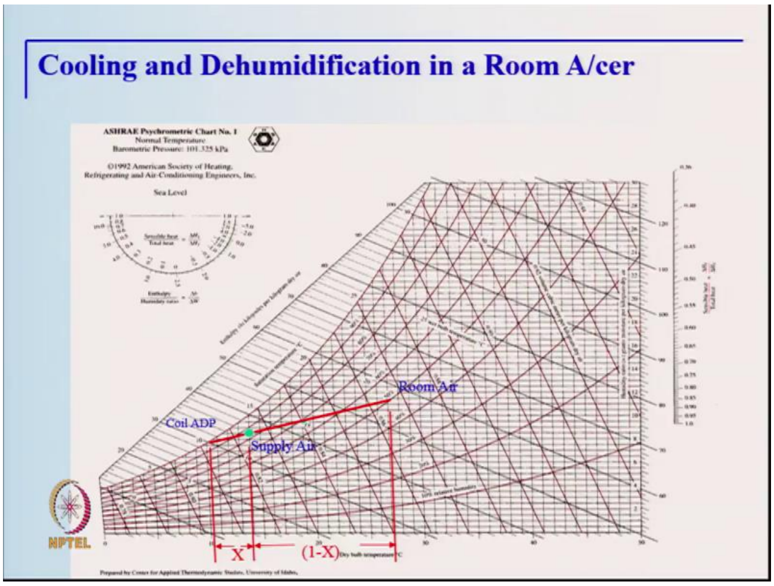
The path which the air follows is called the coil condition curve and this line when it hits the saturation line, that particular temperature is called the coil ADP or the coil apparatus dew point, which is the hypothetical temperature which is defined for the purpose of analysis of cooling coils. There is another term which is defined which is of interest which is called the bypass factor which is the ratio which is shown here on the diagram. So, the difference of temperatures or enthalpies between the coil ADP and the supply air to the difference between coil ADP and the inlet air, that ratio is called the bypass factor.

So, both these terms coil ADP and bypass factor taken together help us in the analysis of the air conditioning systems because then we do not have to go into the detailed design of cooling coil for air conditioning calculations.

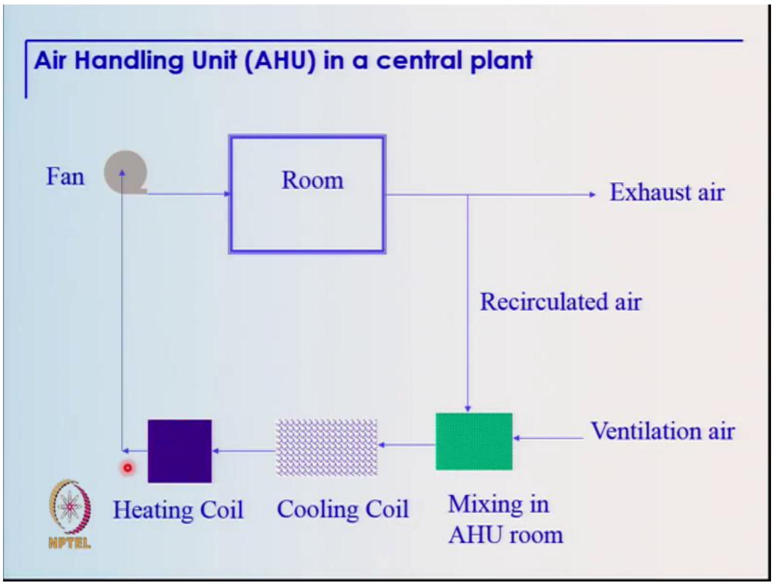


We will now, look at typical spilt and window air conditioners which are used in applications. So, in this particular case most of the time the air is simply recirculated and there is no provision for adding any fresh air, the only air which enters into the room is through the open doors and open windows. So, this is called infiltration which happens in conditioned spaces, and in typical room air conditioners we have the provisions for cooling and dehumidification which happens over the evaporator coil because the air comes in direct contact with the evaporator.

We have already understood the need for coil apparatus dew point in the previous slide. Typically there is no scope for any heating, except in some designs which are basically heat pumps, where we are able to heat the air and humidification is generally not possible in room air conditioners. The controls which are there in room air conditioners are just the on off controls which are based on thermostat, thermostat measures the temperature of the return air which enters the air conditioner and switches off the compressor as per the controls. And there is no real control over humidity in the case of room air conditioners.

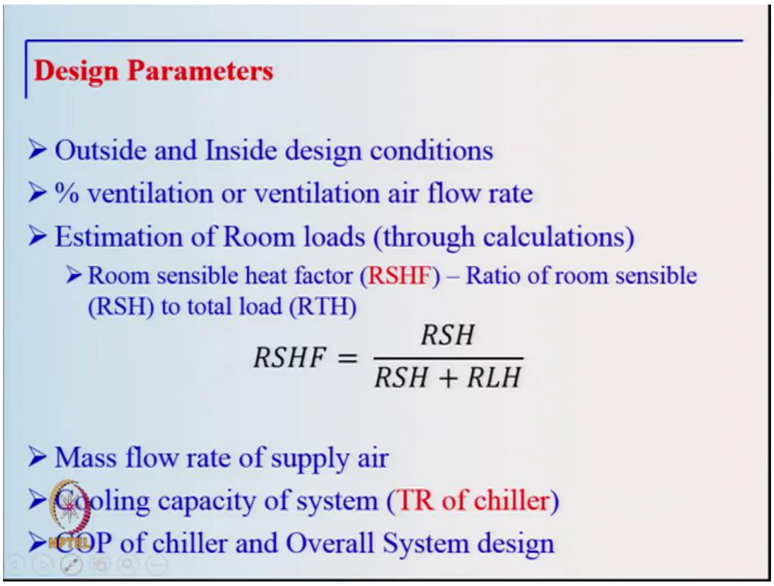


The process of cooling and dehumidification in a room air conditioner is similar to what we have just seen in the previous slide. So, we have the room air which is typically the 100 percent recirculated air which enters the coil and leaves at a certain temperature depending in the coil ADP which is being maintained by the room air conditioner. So, we have looked at all these things in the previous slide.



Now, let us look at a central plant. In a central plant chilled water is generated and then circulated in the cooling coils for the purpose of cooling and dehumidification. When there is a need for heating we have a heating coil through which we can circulate hot water, and we may be having a provision for humidification by spraying water or by injecting steam which is not shown on this particular slide.

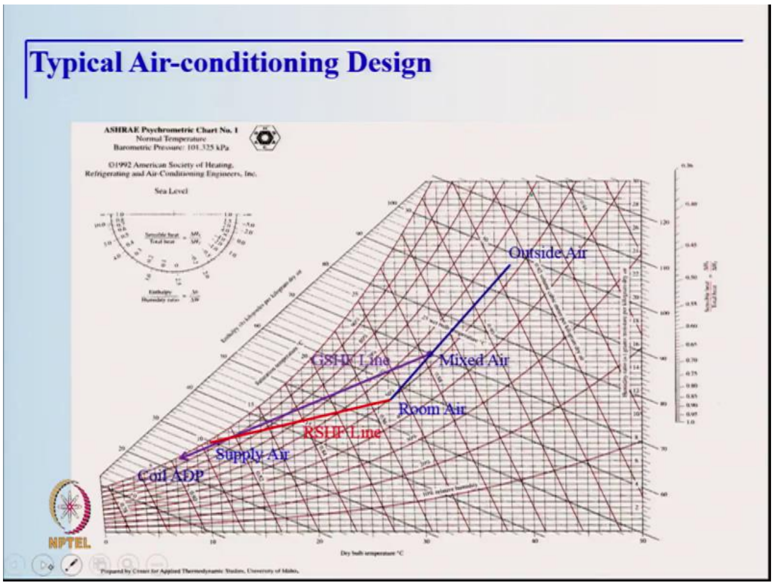
Typically the air which is coming out of the room; part of that air is exhausted and substantial amount of air is re-circulated, which is mixed with the fresh air which is introduced into the system in a chamber which is basically the air handling unit, and air handling unit also has a fan or a blower which circulates the air throughout the conditioned space.



The parameters which are of importance from the point of view of air conditioning system design are listed on this particular slide. They are: the outside design conditions which refer to the ventilation air, the inside design conditions, the conditions which we want to maintain within the conditioned space, the amount of air which we want to introduce either as a percentage of air circulation or the actual quantity of air which we want to introduce. Then one has to estimate the room loads through calculations based on the actual application and then design the system for that particular room load. So, room load will have two components, the sensible room load and the latent room load. And the ratio of the two, the ratio of the room sensible load to the room total load is an important parameter in the system design which is called the room sensible heat factor.

The other thing which is important from the point of view of air distribution is the flow rate of air which we are circulating through the conditioned space. That is to be understood from the basic psychrometry and a suitable value has to be selected for the same. Another parameter which is important from the design perspective is “What cooling capacity should I select for my system design?” which is typically the tonnage of the central plant which I am designing this the system for.

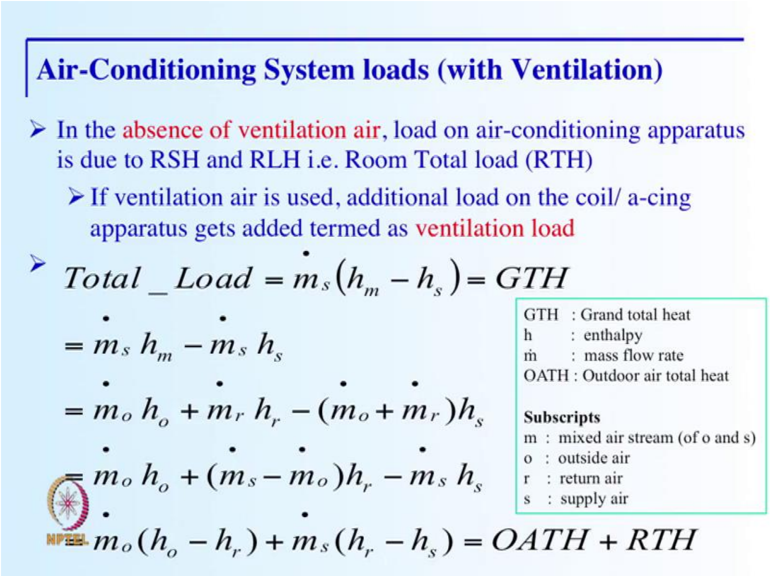
And then from the energy efficiency point of view we have to look at the coefficient of performance of the chiller and then the energy efficiency of the complete system.



Let us look at a typical air conditioning system design on a psychrometric chart. We have outside air which is being mixed with the room air, which is at the room air condition, which is passed over a cooling coil. So, you have the mixed air condition is shown there.

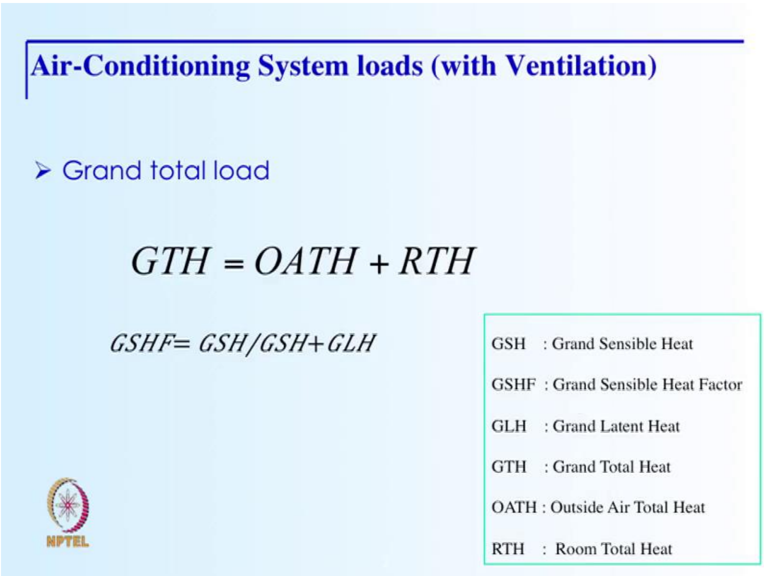
The red line shows the RSHF line i.e. the loads which are there in the room and this line corresponds to the sensible heat factor. The mixed air is passed over the coil and therefore, you have the coil condition curve being showed by the blue line and the intersection of two lines gives you the supply condition. It is important that these intersect within the psychrometric chart, so that you can get a supply air condition matching with the room loads and which is inclined with the chiller which is there in the plant.

So, this is the supply air condition. This line is also called the GSHF line or the grand sensible heat factor line, a term which we will discuss in subsequent slides.

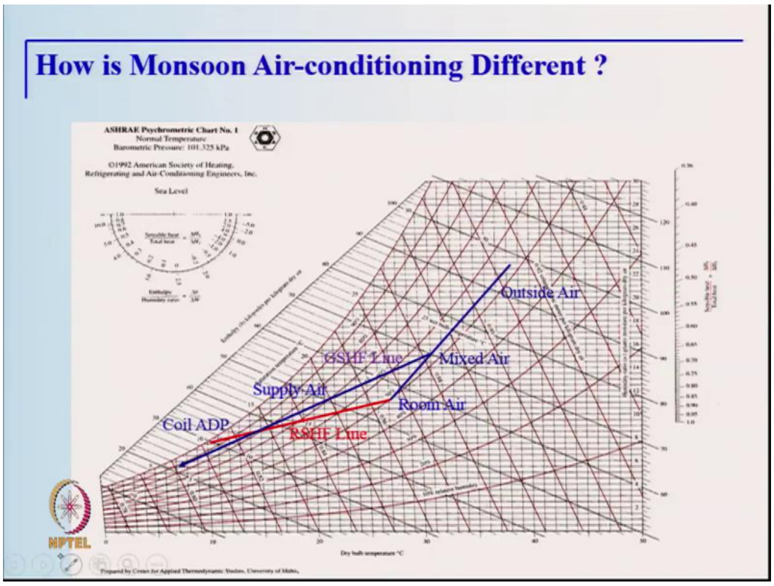


It also shows the coil ADP which we have already seen. For the case of room air conditioner as we have mentioned, we had no ventilation here and therefore, the line which was of interest for cooling and dehumidification was the RSHF line. But if we have the ventilation air also present then the load which comes on the coil is more than the room loads and that is due to the ventilation air which is being introduced.

So, the total load on the coil is a summation of the outdoor air load and the room load and the basic derivation is mentioned here which we will not discuss in great detail.

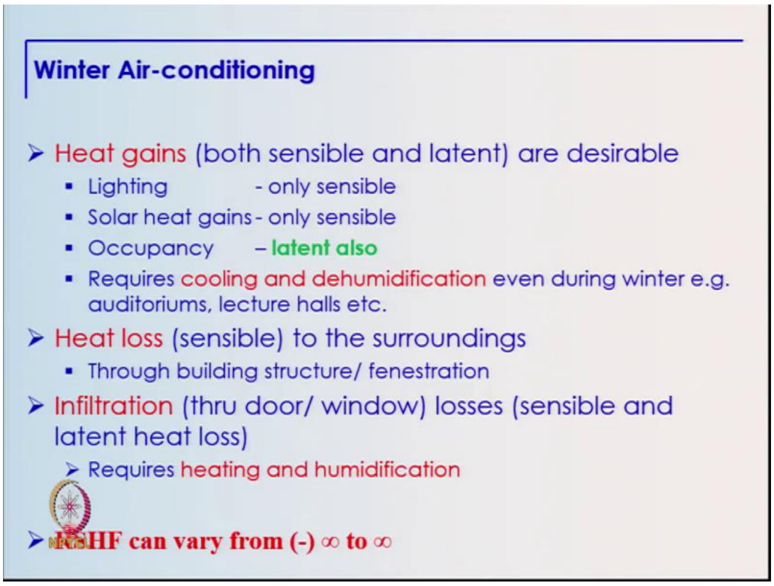


The grand total load is the summation of the outside air load and the room load. And we define a term which is called the grand sensible heat factor which is the ratio of the grand sensible heat to the grand total heat which is the summation of both sensible and latent heat.



What happens when we encounter the monsoon? During the monsoon the outdoor humidity increases substantially and its temperature decreases. First let us look at the summer air conditioning scenario where the temperatures are high, humidity is comparatively lower. So, we have the outside air, we have the room air, the mixed air, we have the room loads which follows the RSHF line and we have the coil condition curve from the mixed line and we have this condition which is showing the supply condition, the intersection of the two lines. When the weather shifts to monsoon conditions, the humidity increases; so, this we will see let us remove all these lines and look at the scenario where we have monsoon.

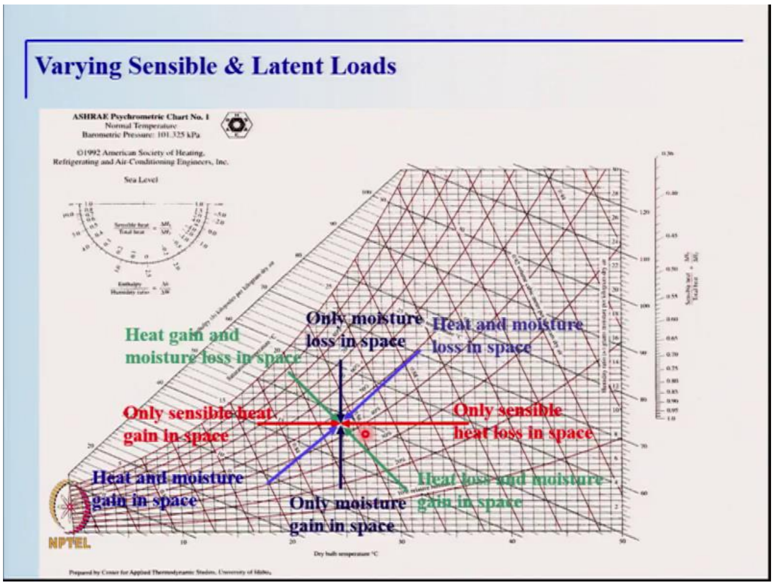
Now, you can see temperatures have slightly dropped and the humidity levels have gone up. And we have the RSHF line which is now, much lower which means lower RSHF basically means higher latent loads and the sensible loads have gone down in the room. And now, if we try to plot the coil condition curve we find that it will reduce the coil ADP to either a very low value or it may not intersect the saturation curve at all and therefore, in monsoon air conditioning we have to have proper design, so that we can handle the proper ratio of sensible and latent loads in the room. This is possible through various mechanisms. It is also possible with the help of dehumidification of outside air or by other means including heat pipe heat exchanges and other innovative technologies which can be used. Traditionally people used to do reheating of air for achieving the comfort conditions and achieving the desired humidity within the condition space.



The scenario is quite different in the case of winters. First thing we have to keep in mind although the outdoor is low in terms of temperature and humidity, but the heat gains are going to be beneficial from the point of view of air conditioning system design.

So, whether it is lighting which will add to the sensible heat load within the room or it is solar heat gains or it is occupancy, everything will help us in reducing the load on the system from the point of view of winter air conditioning, because in winter we would typically be interested in heating the air. So, if we have all these loads present of lighting solar heat gains and occupancy, occupancy also introduces the latent load, then we may have the requirement for cooling and dehumidification which is generally the case when we are dealing with the applications like auditoriums were the occupancies are very very high.

In applications where there is substantial heat loss to the surroundings either through the building structure or through the fenestration, we may have the requirement for heating of air in winters. In case the infiltration is substantial through the doors and windows then there will be substantial latent heat loss as well as sensible heat loss because of which we may have the requirement for heating and humidification in winter. So, in winters depending on the application there could be a requirement for cooling and dehumidification, there could be requirement for just sensible cooling or sensible heating or there could be requirement for both heating and humidification. And depending on the application the room sensible heat factor can vary from minus infinity to plus infinity. And this is an important thing to appreciate and keep in mind.



We will just look at it from the point of view of psychrometry on the psychrometric chart. Let us first see a case where we have sensible heating within the conditioned space. So, you have on this only sensible heat gain in this space. There is also a possibility of sensible heat loss in the space. So, this point here is showing the room condition and within the room the air is entering at this condition, it loses its heat to the surroundings and therefore, the room is being maintained at this particular condition.

The next process which could be of interest is where there is only latent heat gain in the room, you have just moisture being added in the room or you can have the moisture being lost in the room. Although these two processes may not be very practical, but from a theoretical understanding point of view we may have scenarios where we have primarily the moisture gain or loss. Then we have a process where we have both sensible and latent heat gain in the room which is typically also the case in the case of summer air conditioning or we may have both sensible and latent heat loss in the space which is shown by this line. The other scenario could be where we have the sensible heat loss, but there is moisture gain in the space. So, we follow this green line or we may have sensible heat gain and moisture loss in the space.

All these scenarios will result in different values of room sensible heat factors which can be read from this particular semi-circle as shown here. The horizontal lines correspond to the RSHF factor which is 1, the vertical line corresponds to an RSHF factor which is 0. And the other lines depending on whether the room sensible heat factor is positive or negative and the room total load whether it is positive or negative will have negative values for room sensible heat factor or positive values for room sensible value heat factor. So, this is an interesting scenario for winter air conditioning which has to be kept in mind for the appreciation of the course.

Thank you very much. So, we end this lecture with this particular note.