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About the Psychrometric Chart

Application Note 96-02001-04

1 Introduction

The psychrometric chart shows graphically the parameters relating to water moisture in air. This application note describes the purpose and use of the psychrometric chart as it affects the HVAC engineer or technician.

Air comprises approximately 78% nitrogen, 21% oxygen, and 1% other gasses. But air is never dry, even in a desert. Two-thirds of the earth's surface is covered with water and this, along with other surface water and rain, maintain low pressure water vapor to be suspended in the air making up part of the 1% of other gasses. The psychrometric chart indicates the properties of this water vapor through the following parameters, each of which is explained in more detail below:

- dry bulb temperature
- wet bulb temperature (also known as saturation temperature)
- dew point temperature
- relative humidity
- moisture content (also known as humidity ratio)
- enthalpy (also known as total heat)
- specific volume (the inverse of density)

The final page of this document has a psychrometric chart you can print.

Any psychrometric chart is valid at a certain pressure of air. The pressure of air is related to the height above (or below) sea level. The chart provided by Power Knot is valid at sea level (760 mm of Hg). You must make corrections for different altitudes.

If you know any two of the parameters above, you can find the other five values from the chart.

The study of psychrometrics and therefore the usefulness of the chart are important in the HVAC industry because:

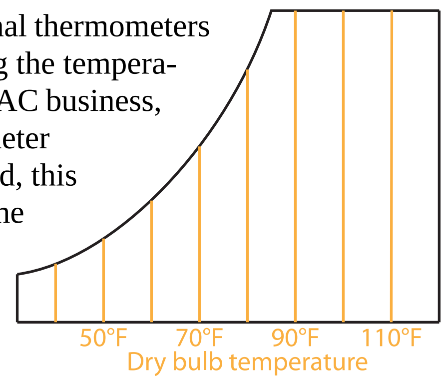
- people feel comfortable over a narrow range of temperature and humidity
- machines (especially electronic machines) operate over a specific range of temperature and humidity
- to calculate the amount of heating or cooling required for a certain space requires knowledge of the moisture content of the air

For an example on how the psychrometric chart is used in practice, please read Power Knot's application note on measuring enthalpy to evaluate the efficiency of an air conditioning system.

2 Properties on the Chart

2.1 Dry bulb (DB) temperature

We measure the temperature of the air with a thermometer. Traditional thermometers have a bulb that contains a liquid that expands, and a tube indicating the temperature on a scale. As the liquid expands, it rises up the scale. In the HVAC business, we use a thermocouple and electronic meter or an infrared thermometer because these are faster and more rugged. Whichever method is used, this measurement is called the dry bulb temperature because the end of the thermometer that is making the measurement has no moisture on it.

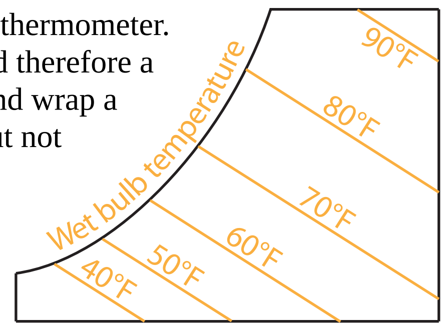


The temperature of the air is measured in °F in the USA and in °C everywhere else.

This temperature is shown as the horizontal axis of the chart.

2.2 Wet bulb (WB) temperature

The wet bulb temperature is measured by having the bulb of the thermometer moist. The moisture evaporates, lowering the temperature recorded by the thermometer. Less moisture in the air will result in a faster rate of evaporation and therefore a colder reading. In practice, we can use an electronic thermometer and wrap a paper tissue over the thermocouple. Make the paper tissue moist, but not too wet that water is dripping from it. Move air over the tissue (or move the thermocouple through the air) so the water evaporates.

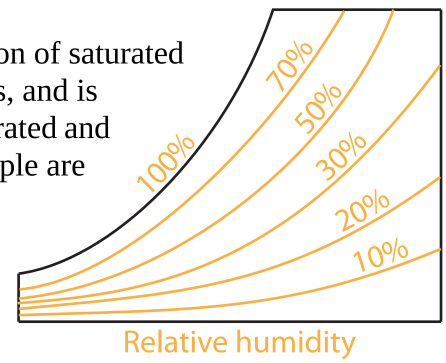


When the air sample is saturated with water (that is, it has 100% relative humidity), no water can evaporate from the moist tissue so the WB temperature will read the same as the DB temperature. This temperature is therefore also referred to as the saturation temperature.

This temperature is indicated by diagonal lines on the chart.

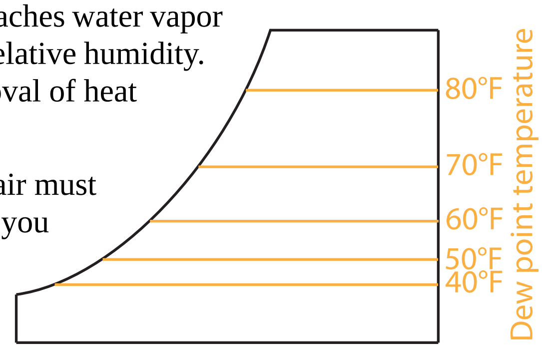
2.3 Relative humidity (RH)

This is the ratio of the fraction of water vapor in the air to the fraction of saturated moist air at the same temperature and pressure. RH is dimensionless, and is usually expressed as a percentage. 100% RH indicates the air is saturated and cannot hold any more moisture. Preferred values of comfort for people are between 35% and 60%.



Lines of constant relative humidity are shown as exponential lines on the psychrometric chart. The line at 100% is referred to as the saturation line.

2.4 Dew point (DP) temperature



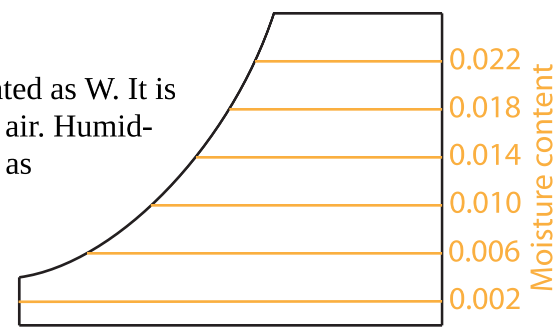
This is the temperature of the air at which a moist air sample reaches water vapor saturation. It is equivalent to a wet bulb temperature at 100% relative humidity. At this combination of temperature and humidity, further removal of heat results in water vapor condensing into liquid.

A practical view of the dew point is the temperature to which air must be cooled before condensation will begin. An example is when you take a bottle of beer out of the refrigerator. Water condenses on the outside of the bottle only if the original temperature of the bottle was below the dew point. The instantaneous temperature of the water is the dew point temperature.

As a sample of air is cooled, its RH climbs until it reaches 100% RH (saturated air). This is the dew point temperature. At saturation, the dew point temperature equals the wet bulb temperature, which also equals the dry bulb temperature, and the RH is 100%.

This temperature is shown as horizontal lines on the chart.

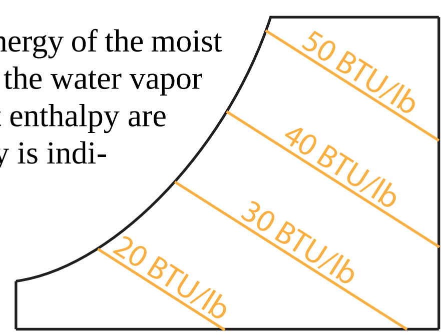
2.5 Moisture content



This is also known as the humidity ratio and is usually designated as W. It is the proportion of the mass of water vapor per unit mass of dry air. Humidity ratio is dimensionless, but in the US it is usually expressed as pounds of moisture per pound of dry air; elsewhere it may be expressed as grams of water per kilogram of dry air or as a percentage.[1]

The moisture content is the vertical axis of the chart.

2.6 Enthalpy (total heat)



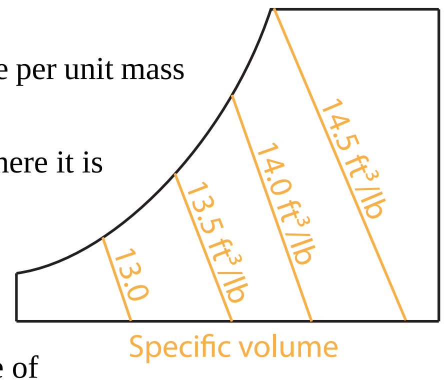
Enthalpy (heat content)

Enthalpy (usually designated as h) is the total amount of heat energy of the moist air and therefore includes the amount of heat of the dry air and the water vapor in the air. In the approximation of ideal gases, lines of constant enthalpy are parallel to lines of constant WB temperature. Thus the enthalpy is indicated by diagonal lines on the chart.[2]

In the US, enthalpy is measured in BTU per pound of dry air; elsewhere it is measured in Joules per kilogram of air.

1. In the US, it may also be expressed as grains of water per pound of air where 7000 grains equal 1 pound.
2. In practice there is a very slight difference between the lines of constant WB temperature and lines of constant enthalpy that can usually be ignored.

2.7 Specific volume

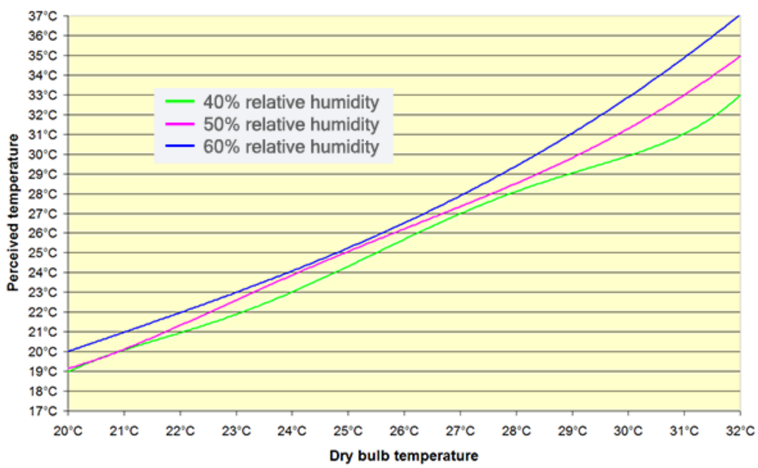


This is the inverse of density. Specific volume is therefore the volume per unit mass of the air sample. This is shown as diagonal lines on the chart.

In the US, this is measured by cubic feet per pound of dry air; elsewhere it is measured by cubic meters per kilogram of dry air.

2.8 Comfort zones

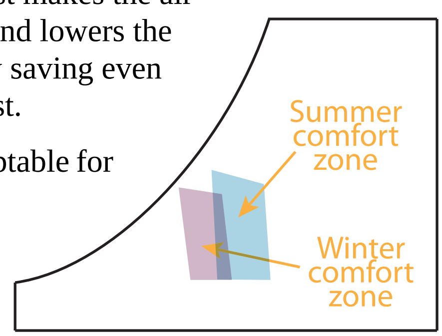
People feel comfortable within a small range of temperatures and humidities. The ranges vary based on where you live and on the time of year. In the northern hemisphere, people typically wear more clothes in winter than in summer. Therefore, rooms are maintained at cooler temperatures in winter than in summer.



People are sensitive to humidity because water evaporates from the skin and this evaporation cools the body. At a high humidity, water evaporates from the skin slowly, so we feel warmer. At a low humidity, water evaporates faster and we feel colder. The effect of perceived increase in temperature with increase in humidity is referred to as the Heat Index and is shown graphically in the figure.[1]

This also explains why some people increase the temperature of a room after treating an air conditioner with the Synthetic Refrigeration Catalyst. The treatment with the Synthetic Refrigeration Catalyst makes the air colder. This colder air condenses more water moisture from the air and lowers the humidity. People compensate by raising the temperature and thereby saving even more money after treatment with the Synthetic Refrigeration Catalyst.

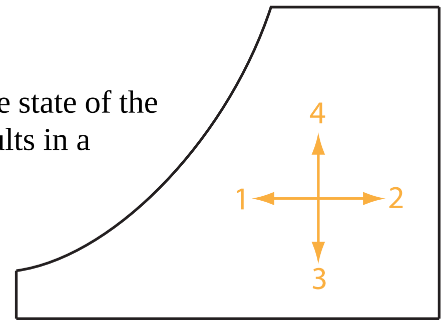
The psychrometric chart shows the two comfort zones typically acceptable for US citizens.



1. This is taken from the Journal of Applied Meteorology, published by the American Meteorological Society, July 1979. “The Assessment of Sultriness” by Steadman, R. G. The findings in the paper are given in degrees Celsius.

3 Plotting on the psychrometric chart

3.1 Sensible and latent heating and cooling

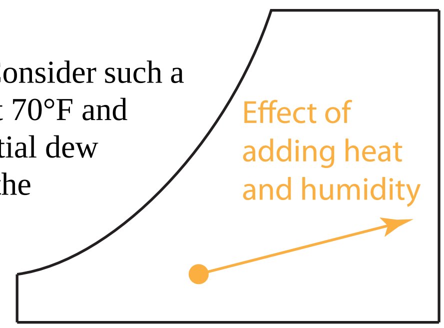


Sensible heat is heat that is added or subtracted without a change in the state of the substance. Latent heat is where the addition or subtraction of heat results in a change of state of the substance.

Therefore, looking at the chart to the right, we see that when there is a heating or cooling of the air, movement on the chart takes place as follows:

1. sensible heat is removed (no moisture condenses)
2. sensible heat is added (the humidity ratio and dew point are constant)
3. latent heat is removed (moisture is removed from the air)
4. latent heat is added (moisture is added to the air, but the dry bulb temperature is constant)

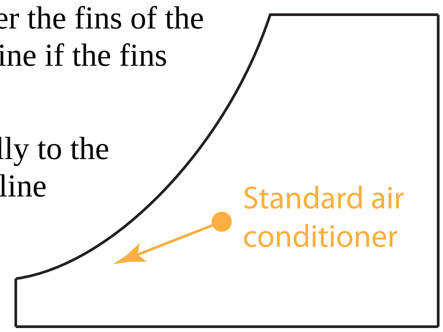
3.2 Standard heater and humidifier



Most winter heaters also add humidity to maintain the comfort level. Consider such a heater that heats and adds humidity to the space air. The return air is at 70°F and 30% RH and the output of the heater is at 115°F and 13% RH. The initial dew point is 37°F; the ending dew point is 52°F. Therefore, the change on the chart is up and to the right.

3.3 Standard air conditioner

With a standard air conditioner, water moisture in the air condenses when it touches the evaporator coil of the air conditioning system. Suppose the air in the room is at 75°F and 50% RH. This point falls within the summer comfort zone. Looking at the psychrometric chart, we see the dew point is 55°F. The coil of the air conditioner is at 45°F so the system will condense water from the air. If the supply air leaving the system is at 55°F dry bulb and 53°F wet bulb, we see from the chart that the dew point is 51.5°F. Therefore the change on the chart is down and to the right.



We see from this description that the dew point of the air passing over the fins of the evaporator coil and the surface temperature of those fins that determine if the fins will be wet or dry.

Theoretically, the process takes place by moving the point horizontally to the left until the dew point is reached, and then following the saturation line (wet bulb line) to the end point. In practice, the process is a curved line moving down and left. This is because of the mixing of those parts of the air stream that have reached the dew point with those parts that are still being sensibly cooled.

4 Example uses of the psychrometric chart

4.1 Finding relative humidity

Question Given the ambient temperature is 70°F measured by a dry bulb thermometer and 60°F measured by a wet bulb thermometer, what is the relative humidity?

Answer Look at horizontal axis to find 70°F. Move a pencil up this line to meet the intersection with the diagonal line for 60°F. Identify that this point falls just over half way between the lines of relative humidly for 50% and 60%. The answer is 56% relative humidity.

Question Is this point an acceptable temperature and humidity for personal comfort all year for people in the USA?

Answer No. this point falls into the “winter comfort zone” but not the “summer comfort zone.”

4.2 Dew point

Question An air conditioning system is not working well. The temperature of the evaporator coil is 53°F. The air in the room is at 76°F and 40% relative humidity. Will the air conditioner remove moisture from this air?

Answer Look at the horizontal axis to find 76°F. Move a pencil up this line to meet the intersection with the exponential line for 40% relative humidity. Move the pencil to the right to read the dew point. This is 50°F. The evaporator coil is warmer than the dew point so it will not condense water from the air.

4.3 Cooling a house

Question A house is 4500 ft^2 and has 12 ft ceilings. For comfort, the home owner specifies 0.3 changes of air per hour. The outside air temperature is 90°F dry bulb and 73.5° wet bulb. The air indoors is 75°F dry bulb 50% relative humidity. What is the amount of cooling required to provide the fresh air?

Answer The total volume of the house is 4500 x 12 = 54,000 ft^3. We need to change 54,000 x 0.3 = 16,200 ft^3/hour (which equates to 270 ft^3/minute, or cfm). From the psychrometric chart, the enthalpy of the incoming air is 37.0 BTU/lb and the specific volume is 14.2 ft^3/lb. Therefore the energy of the incoming air is 16,200 x 37 / 14.2 = 42,211 BTU/hour. Similarly, the enthalpy of the air indoors is 16,200 x 28.1 / 13.7 = 33,228 BTU/hour. The heat difference is 8,984 BTU/h, or about 0.75 tons.

Psychrometric chart at sea level (760 mm Hg)
US measurement units

power knot

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