ARTICLES

Psychrometric Chart Use

A psychrometric chart presents properties of air in a graphical format useful for troubleshooting greenhouse or livestock building environmental problems.

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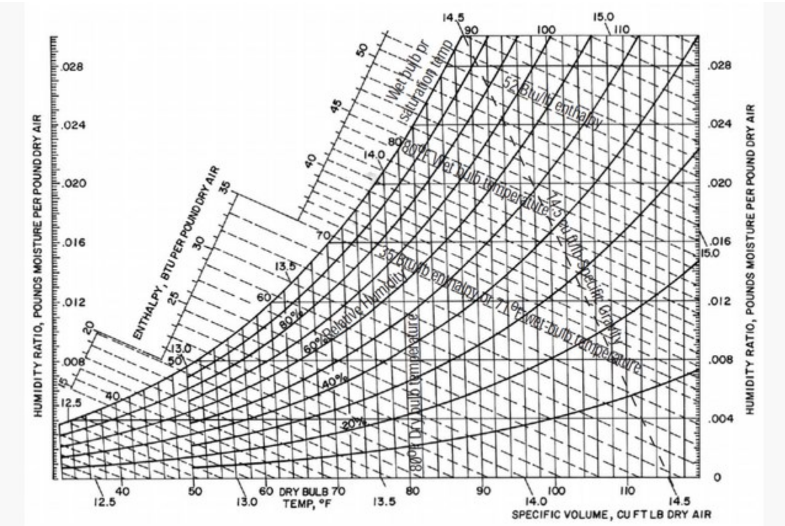
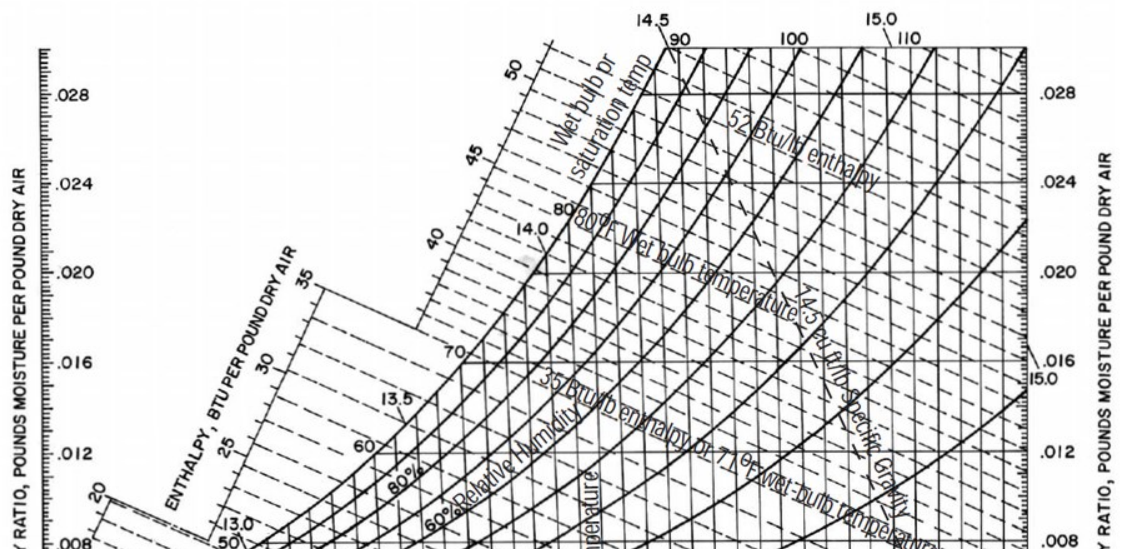


Psychrometric Chart and Air Characteristics

A psychrometric chart presents physical and thermal properties of moist air in a graphical form. It can be very helpful in troubleshooting and finding solutions to greenhouse or livestock building environmental problems. Understanding psychrometric charts can help you visualize environmental control concepts, such as why heated air can hold more moisture or, conversely, how allowing moist air to cool will result in condensation. This fact sheet explains how characteristics of moist air are used in a psychrometric chart. Three examples are used to illustrate typical chart use and interpretation. Properties of moist air are explained in the *Definitions Sidebar* for your reference during the following discussions.



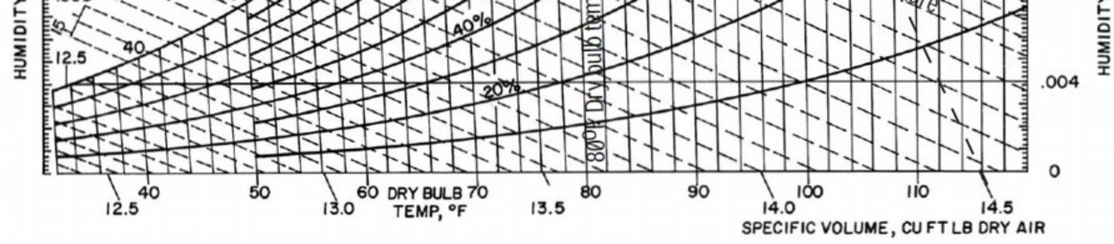


Figure 1. Psychrometric chart

Psychrometric charts are available in various pressure and temperature ranges. Figure 1, is for standard atmospheric pressure (14.7 psi) and temperatures of 30° to 120°F, which is adequate for most greenhouse or livestock housing applications. Psychrometric properties also are available as data tables, equations, and slide rulers.

A psychrometric chart packs a lot of information into an odd-shaped graph. If we consider the components piece by piece, the usefulness of the chart will be clearer. Boundaries of the psychrometric chart are a dry-bulb temperature scale on the horizontal axis, a humidity ratio (moisture content) scale on the vertical axis, and an upper curved boundary which represents saturated air or 100-percent moisture holding capacity. The chart shows other important moist air properties as diagrammed in Figure 2: wet-bulb temperature; enthalpy; dewpoint or saturation temperature; relative humidity; and specific volume. See the *Definitions Sidebar* for an explanation of these terms. Moist air can be described by finding the intersection of any two of these properties. This is called a "state point." From the state point all the other properties can be read. The key is to determine which interest. Some practice with examples will help. Use Figures 2 and 3 with the psychrometric chart in Figure 1 to verify whether you can find each air property.

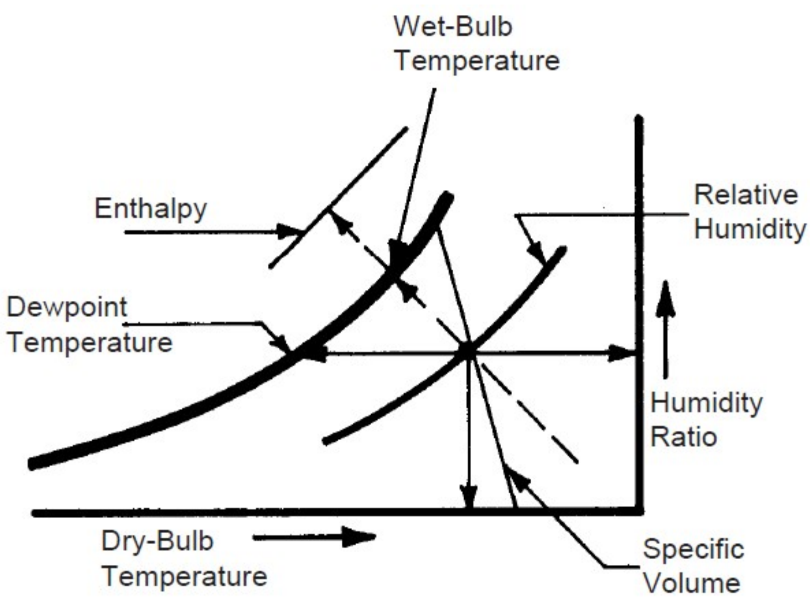


Figure 2. Properties of moist air on a psychrometric chart. Wet-bulb temperature and enthalpy use the same chart line but values are read off seperate scales.

An understanding of the shape and use of the psychrometric chart will help you diagnose air temperature and humidity problems. Note that cooler air (located along the lower, left region of the chart) will not hold as much moisture (as seen on the y-axis' humidity ratio) as warm air (located along right side of chart). A rule of thumb for inside typical greenhouses or animal buildings during winter conditions is that a 10°F rise in air temperature can decrease relative humidity 20 percent. Use of a psychrometric chart will show that this is roughly true. For example, to decrease relative humidity in a winter greenhouse during a critical time period, we could heat the air.

Use of Psychrometric Chart in Greenhouse and Barn

Example 1 Find air properties

A sling psychrometer* gives a dry-bulb temperature of 78°F and a wet-bulb temperature of 65°F. Determine other moist air properties from this information. Two useful air properties for environmental analysis in agricultural buildings would be relative humidity and dewpoint temperature. Relative humidity is an indicator of how much moisture is in the air compared to desirable moisture conditions, and dewpoint temperature indicates when condensation problems would occur should the (dry-bulb) temperature drop.

Find the intersection of the two known properties, dry-bulb and wet-bulb temperatures, on the psychrometric chart, Figure 1. The dry-bulb temperature is located along the bottom horizontal axis. Find the line for 78°F, which runs vertically through the chart. Wet-bulb temperature is located along diagonal dotted lines leading to scale readings at the upper, curved boundary marked "saturation temperature." The intersection of the vertical 78°F dry-bulb line and the diagonal 65°F wet-bulb line has now established a state point for the measured air. Now read relative humidity as 50 percent (curving line running from left to right up through the chart) and dewpoint temperature as 58°F (follow horizontal line, moving left, toward the curved upper boundary of saturation temperatures). This example is shown in Figure 3 so you may check your work.

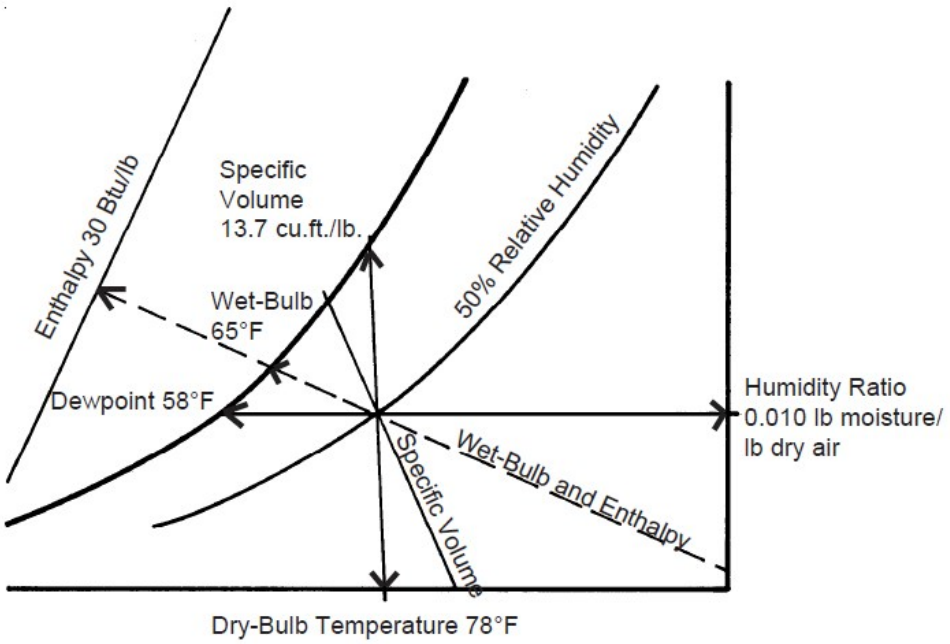


Figure 3. Diagram of Example 1. Verify these values on psychrometric chart (Figure 1)

What might we conclude from this information? The relative humidity of 50 percent is acceptable for most livestock and greenhouse applications. If we allowed the air temperature (dry-bulb) to decrease to 58°F (dewpoint) or below, the air would be 100 percent saturated with moisture and condensation would occur. The humidity ratio, as seen on the vertical, y-axis scale, is a reliable indicator of air moisture level since it reflects the pounds of moisture contained in a pound of dry air and does not fluctuate with dry-bulb temperature readings as does relative humidity. The humidity ratio for air in this example is about 0.0104 lb moisture/ lb dry air (move right horizontally from state point to humidity ratio scale).

Example 2 Winter ventilation

Often air is heated before it is introduced into greenhouse or young-livestock building environments. Consider an application where outdoor air at 40°F (dry-bulb) temperature and 80 percent relative humidity is heated to 65°F (dry-bulb) before it is distributed throughout the building.

Find the state point for the incoming cool air on the lower left portion of the psychrometric chart (point A in Figure 4). Note that other properties of the 40°F air include a wet-bulb temperature of 38°F, a dewpoint temperature of about 34°F and humidity ratio of 0.0042 lb moisture/ lb dry air. Heating air involves an increase in the dry-bulb temperature with no addition or reduction in the air's water content. The heating process moves horizontally to the right along a line of constant humidity ratio. See Figure 4 for this heating process between points A and B. Heating the air to 65°F (dry-bulb) has resulted in decreasing the relative humidity to about 32 percent. The heated air entering the building is dry enough to be useful in absorbing moisture from the plant or animal environment. (Verify that the heated air at point B continues to have a dewpoint of 34°F and humidity ratio of 0.0042 lb moisture/ lb dry air.) The heated air, with its lower relative humidity, can be mixed with moist, warm air already in the building. As fresh air moves through an animal environment, it will pick up additional moisture and heat before it reaches the ventilation system exhaust. We might measure the exhausted air conditions at 75°F (drybulb) and 70 percent relative humidity, represented by point C in Figure 4. Note that in this exhausted air, the humidity ratio has tripled to 0.013 lb moisture/ lb dry air. This means that much more water is ventilated out of the building in the warm, moist exhaust air than is brought in by the cold, high relative humidity incoming air. Removing moisture from the plant or animal environment is one of the major functions of a winter ventilation system.

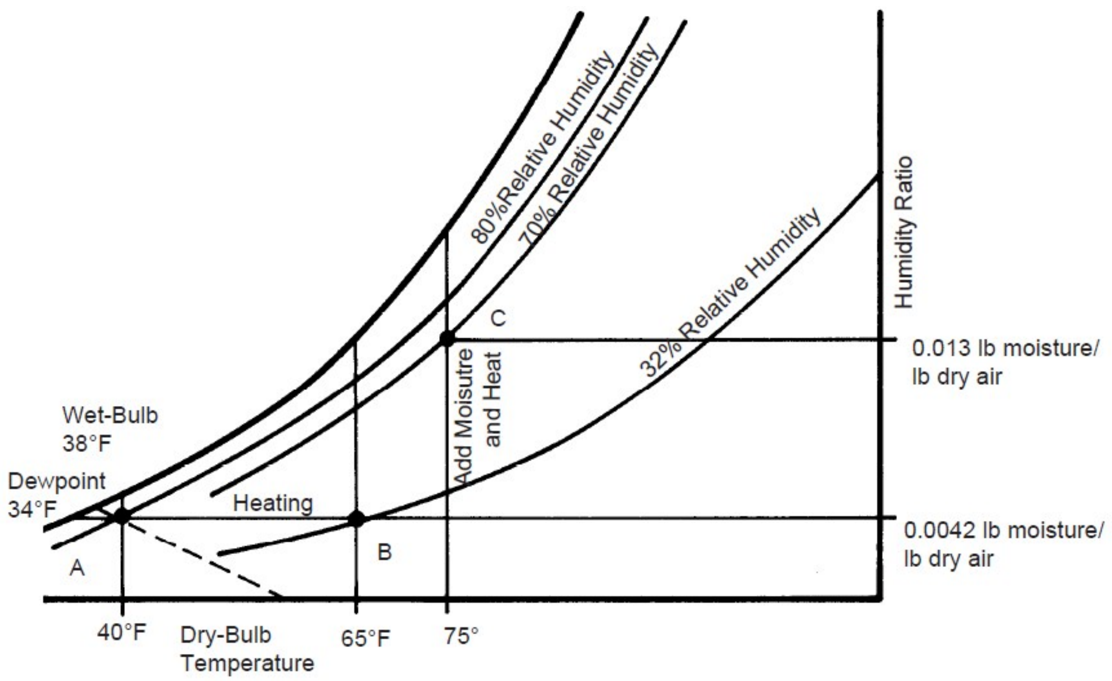


Figure 4. Diagram of Example 2. Outdoor air at 40°F, 80 percent relative humidity (point A is heated to 65°F (point B) for use in ventilation. Exhaust air (point C) at 75°F and 70% relative humidity contains three times the moisture of the fresh air (point A and B).

Definitions

The air surrounding us is a mixture of dry air and moisture and it contains a certain amount of heat. We are used to hearing about air temperature, relative humidity, and the dewpoint in discussions of weather conditions. All these properties and more are contained in a psychrometric chart. Chart shape and complexity take some getting used to. Refer to Figures 1 and 2. You will find that the upper curved boundary of the chart has one temperature scale, yet can represent three types of temperature: wet-bulb, dry-bulb, and dewpoint. This upper curved boundary also represents 100 percent relative humidity or saturated air.

Dry-bulb temperature

is the commonly measured temperature from a thermometer. It is called "dry-bulb" since the sensing tip of the thermometer is dry (see "wet bulb temperature" for comparison). Dry-bulb temperature is located on the horizontal, or x-axis, of the psychrometric chart and lines of constant temperature are represented by vertical chart lines. Since this temperature is so commonly used, assume that temperatures are dry-bulb temperatures unless otherwise designated.

Relative humidity

is a measure of the amount of water that air can hold at a certain temperature. It is "relative" to the amount of water that air, at that same temperature, can hold at 100 percent humidity, or saturation. Air temperature (dry-bulb) is important because warmer air can hold more moisture than cold air. Air at 60 percent relative humidity contains 60 percent of the water it could possibly hold (at that temperature). It could pick up 40 percent more water to reach saturation. Lines of constant relative humidity are represented by the curved lines running from the bottom left and sweeping up through to the top right of the chart. The line for 100 percent relative humidity, or saturation, is the upper, left boundary of the chart.

Humidity ratio

of moist air is the weight of the water contained in the air per unit of dry air. This is often expressed as pounds of moisture per pound of dry air. Since the humidity ratio of moist air is not dependent on temperature, as is relative humidity, it is easier to use in calculations. Humidity ratio is found on the vertical, y-axis with lines of constant humidity ratio running horizontally across the chart.

Dewpoint temperature

indicates the temperature at which water will begin to condense out of moist air. Given air at a certain dry-bulb temperature and relative humidity, if the temperature is allowed to decrease, the air can no longer hold as much moisture. When air is cooled, the relative humidity increases until saturation is reached and condensation occurs. Condensation occurs on surfaces which are at or below the dewpoint temperature. Dewpoint temperature is determined by moving from a state point horizontally to the left along lines of constant humidity ratio until the upper, curved, saturation temperature boundary is reached.

Enthalpy

is the heat energy content of moist air. It is expressed in Btu per pound of dry air and represents the heat energy due to temperature and moisture in the air. Enthalpy is useful in air heating and cooling applications. The enthalpy scale is located above the saturation, upper boundary of the chart. Lines of constant enthalpy run diagonally downward from left to right across the chart. Lines of constant enthalpy and constant wet-bulb are the same on this chart, but values are read from separate scales. More accurate psychrometric charts use slightly different lines for wet-bulb temperature and enthalpy.

Wet-bulb temperature

is determined when air is circulated past a wetted sensor tip. It represents the temperature at which water evaporates and brings the air to saturation. Inherent in this definition is an assumption that no heat is lost or gained by the air. This is different from dewpoint temperature, where a decrease in temperature, or heat loss, decreases the moisture holding capacity of the air, causing water to condense. Determination of wet-bulb temperature on this psychrometric chart follows lines of constant enthalpy, but values are read off the upper, curved, saturation temperature boundary.

Specific volume

indicates the space occupied by air. It is the inverse of density and is expressed as a volume per unit weight (density is weight per unit volume). Warm air is less dense than cool air, which causes warmed air to rise. This phenomena is known as thermal buoyancy. By similar reasoning, warmer air has greater specific volume and is hence lighter than cool air. On the psychrometric chart, lines of constant specific volume are almost vertical lines with scale values written below the dry-bulb temperature scale and above the upper boundary's saturation temperature scale. On this chart, values range from 12.5 to 15.0 cubic feet/ pound of dry air. Greater specific volume is associated with warmer temperatures (dry-bulb).

Example 3 Evaporative cooling

Evaporative cooling uses heat contained in the air to evaporate water. Air temperature (dry-bulb) drops while water content (humidity) rises to the saturation point. Evaporation is often used in hot weather to cool ventilation air. The process moves upward along the line of constant enthalpy or constant wet-bulb temperature, for example, from point D to point E in Figure 5. Notice that hot dry air (points D to E with a 24° F temperature drop) has more capacity for evaporative cooling than hot humid air (points F to G with only a 12° F temperature decrease).

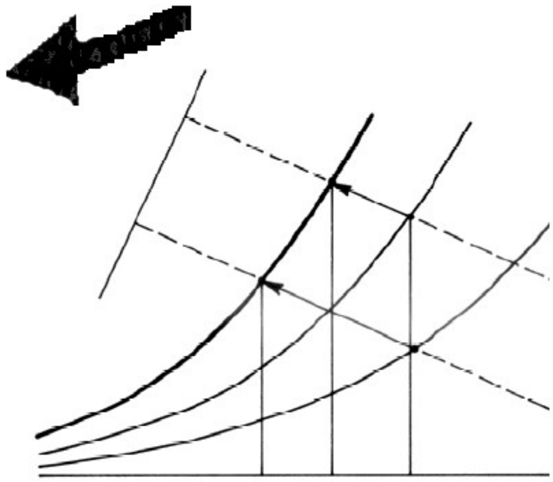


Figure 5. Diagram of Example 3. Evaporative cooling process with hot dry air from points D to E and with hot humid air from points F to G. Notice greater evaporative cooling capacity with dry air.

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*Sling psychrometer and other instruments are described in fact sheet G-81 Instruments for Measuring Air Quality, Evaluating Livestock Housing Environments.

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Expertise

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