Electrical Tech Note — 386

Biosystems & Agricultural Engineering Department
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Psychrometric Chart

The psychrometric chart is a plot of the temperature of air verses the water content of the air. Temperature is the horizontal axis of the chart and water content is the vertical axis of the chart. An accurate method of finding the point on the chart for the air is to measure quantities called dry bulb temperature (standard temperature measurement) and the wet bulb temperature. The wet bulb temperature is determined by placing a wick over the sensing end of the thermometer and passing air over that wick for about two minutes. The sensing bulb will cool based upon the rate of evaporation of water from the wick. A device for measuring both the dry bulb temperature and the wet bulb temperature is called a psychrometer. A psychrometer using thermometers is shown in Figure 386.1.

This Tech Note explains how to use a psychrometric chart to determine quantities of air such as relative humidity, heat content (enthalpy), specific volume, and dew point. At a given temperature, air can hold only a certain amount of water in the vapor form. Saturation is the point where the air at a particular temperature is holding the maximum amount of water in the vapor form. If more water is added, it will form droplets. The water droplets may remain in suspension as fog, or they may form on surfaces of objects such as a window, or fall as rain. As the temperature of air rises, the ability to absorb water as a vapor increases. This is how air can be used for drying.

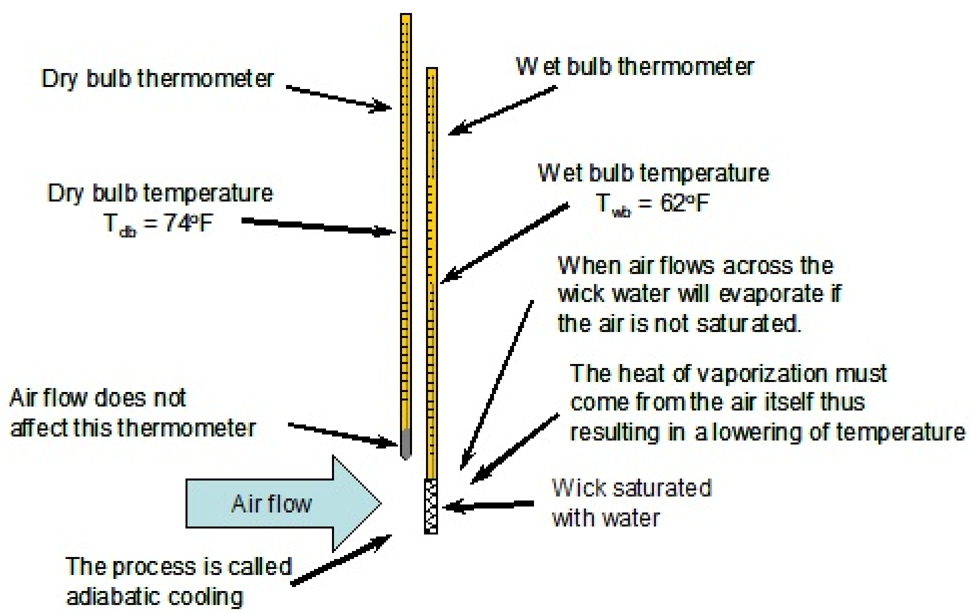

Figure 386.1 *A device called a psychrometer, in this case using two thermometers, measures the dry bulb temperature and the wet bulb temperature. With these two measurements the characteristics of air can be determined.*

Locating position on a Psychrometric Chart: In order to determine the characteristics of air two of the conditions of the psychrometric chart must be determined. Two conditions that are generally easy to determine are the dry bulb temperature and the wet bulb temperature. The dry bulb temperature is simply the temperature of the air as determined by some sensor such as a thermometer. This determines the horizontal position on the psychrometrc chart. In order to find the vertical position on the psychrometric chart some method must be used to determine the amount of water vapor that is in the air. A common method is to place a wick saturated with water over the sensing bulb of the thermometer and passing air over the wick. If the air is completely saturated with water, no water will evaporate from the wick. If the air is less than saturated, water will evaporate from the wick. As water changes state from a liquid to a vapor the water will absorb heat from the air. The heat that is absorbed from the air will lower the temperature of the thermometer. This is called the wet bulb temperature. It takes about two minutes of air flow for this thermometer to reach it’s lowest reading. These two measurements can be used to find a location on the psychrometric chart as shown in Figure 386.2.

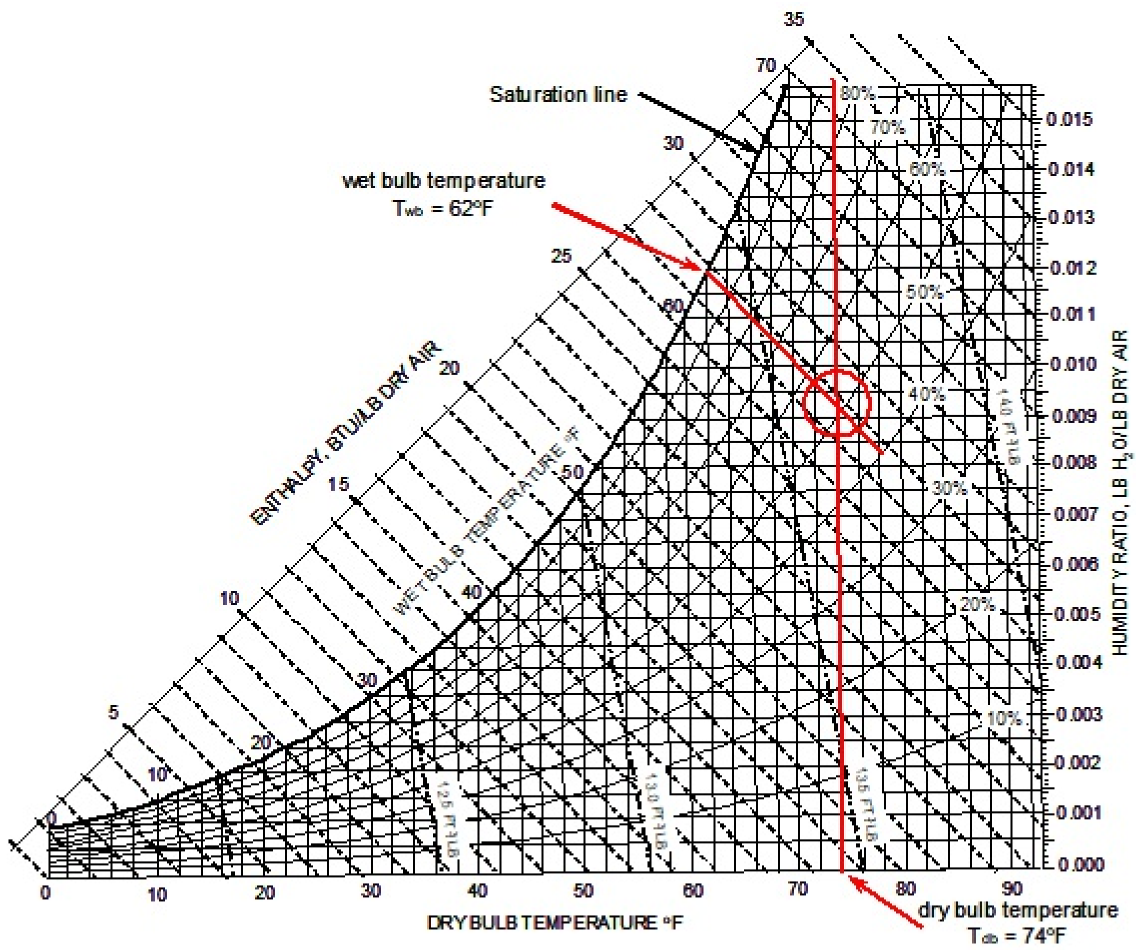

Figure 386.2 *The point that describes the air is found where the vertical line for the dry bulb temperature crosses the diagonal dashed constant enthalpy line that passes through the wet bulb temperature found on the saturation line.*

Here is how to locate the point that describes the conditions of the air in Figure 386.2. Use the dry bulb temperature of 74°F and the wet bulb temperature of 62°F indicated by the psychrometer in Figure 386.1. First find the dry bulb temperature and draw a line straight up the chart. Next find the wet bulb temperature on the curved saturation line. This may take a little practice. It may be easier to find the temperature on the horizontal line at the bottom of the chart and then follow that line up to the curved saturation line. Once the location of the wet bulb temperature has been found on the chart, move downward to the right on the chart parallel to the dashed enthalpy lines. This is illustrated in Figure 386.2. The point where this line crosses the vertical dry bulb temperature line is the point that describes the conditions of the air. All other important parameters of the air can be determined once this point on the chart has been located.

Humidity Ratio or Specific Humidity: The actual mass of water vapor in the air is called humidity ratio or sometimes specific humidity. Examine the psychrometric chart of Figure 386.3 and find the humidity ratio on the right hand side of the chart. Move horizontally to the right from the point that describes the conditions of the air and read the value. This psychrometric chart gives humidity ratio in pounds (lbs) of water per pound of dry air. For the conditions described in Figure 386.1 the humidity ratio is 0.0092 lb H_2O/lb dry air. Humidity ratio is needed for the inlet air and exhaust air from a confinement space in order to calculate the air flow rate necessary to remove moisture.

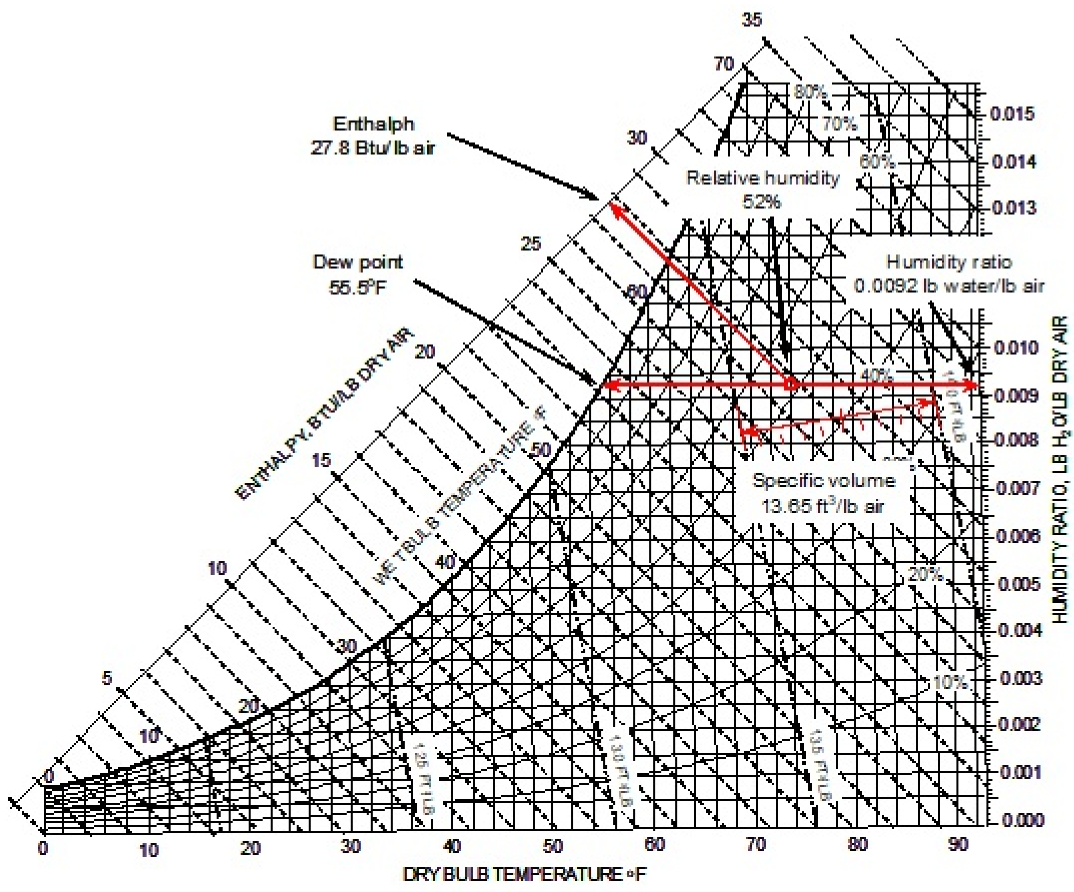

Figure 386.3 *The conditions described by the psychrometer of Figure 386.1 are shown on the chart with the characteristics of the air also shown for those conditions.*

Relative Humidity: At a particular dry bulb temperature air will become saturated with water and cannot accept any more water as vapor. Look for the saturation line on the psychrometric chart of Figure 386.2. Relative humidity is the percent to which the air is saturated. The curved lines represent relative humidity and are labeled in percent. For the conditions described in Figure 386.1, the relative humidity of the air is found as shown in Figure 386.3 and is about 52%.

Enthalpy: The enthalpy of the air is the heat content of the air. The scale is a straight line starting at the lower left of the chart of Figure 386.3 and drawn on a diagonal towards the upper right of the chart. The diagonal dashed lines extend downward to the right from the enthalpy scale are constant enthalpy lines. Moving parallel to these dashed lines is adiabatic heating or cooling. For the conditions described in Figure 386.1, the enthalpy of the air is about 27.8 Btu/lb dry air. Enthalpy is needed for the inlet and exhaust air for a confinement space in order to determine the amount of heat removed by the ventilation air and wether supplemental heat will be required at the designated ventilation rate.

Specific Volume: Specific volume lines on the chart of Figure 386.3 are almost vertical. A heat and moisture balance calculation for a confinement space will yield results in pounds of air that must be moved at the designated inlet and exhaust conditions. Ventilation fans are rated in air flow in cubic feet of air moved at a specific static pressure difference. (See Tech Note 387 for information on ventilation fan characteristic curves.) Specific volume is needed in order to convert air flow rate in pounds per minute to cubic feet per minute (cfm). The specific volume or the air described in Figure 386.1 has a value of approximately 13.65 ft^3/lb dry air.

Dew Point: The temperature at which water will condense on surfaces is called the dew point. If condensation forms on a window, then the surface of the window is at or below the dew point for the air in the space. To find the dew point, move horizontally to the left from the point that describes the air until the saturation line is reached. The temperature at that intersection is the dew point. For the conditions described in Figure 386.1, the dew point is shown on the chart of Figure 386.3 as approximately 55.5^{o}F. Condensation will form on any surface in that confined space that is at or below 55.5^{o}F. Condensation on inside building surfaces is an indication that insulation levels are inadequate, or that the ventilation rate needs to be increased.

Sensible heat and latent heat: When conditioning the air in a controlled space, air enters the space at one temperature and relative humidity and leaves at another temperature and relative humidity. Except in the case of adiabatic heating or cooling, the heat content of the air changes as the air is moved through the space. This change in heat content is called the *total heat*. The temperature of the air in the space can be changed without any change in the actual water content of the air (constant humidity ratio). This occurs when the temperature increases or decreases resulting in a horizontal movement on the psychrometric chart. As the air cools the relative humidity will increase, and as the air is heated the relative humidity will decrease. This process of heating or cooling is called *sensible heat* change. Sensible heat change is a horizontal movement across the psychrometric chart without any water being added or taken away from the air.

The heat content of the air in the confined space can also be changed without any change in temperature. This is done by evaporating water into the air to increase the heat content, or condensing water out of the air to lower the heat content. On the psychrometric chart this is a vertical movement from the original point that describes the air in the confined space. This is called *latent heat* and it is a change in heat content without any change in the temperature. Examine the psychrometric chart of Figure 386.4 which represents air entering a confined space at 40^{o}F and 80% relative humidity, and leaving the space at a temperature of 60^{o}F and 80% relative humidity. The enthalpy of the air entering the space is 14.1 Btu/lb dry air and leaves the space with an enthalpy of 23.8 Btu/lb dry air. The total heat change is the difference between these two enthalpy values which in this case is 9.7 Btu/lb dry air. Note the horizontal and vertical lines drawn on the chart between the points that represent the air entering and air leaving the space. The lines change from horizontal to vertical at a point with an enthalpy of 18.9 Btu/lb dry air. The horizontal line is the sensible heat change which in this case results in a temperature increase of 20^{o}F and the vertical line represents a latent heat change which results from an increase of 0.0046 lb H_2O/lb dry air (0.0087 - 0.0041).

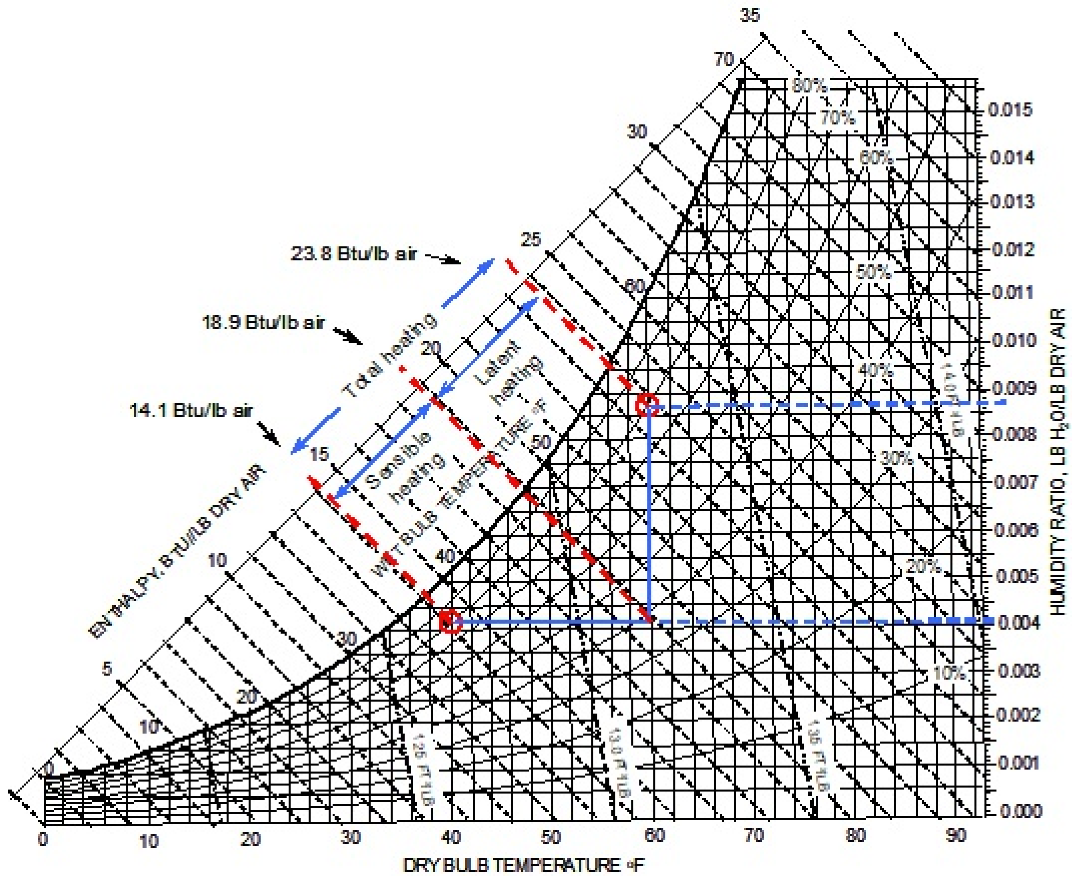

Figure 386.4 *The total heat content of the air leaving a confined space as compared to the air entering the confined space can be subdivided into sensible heat change resulting in a temperature change with no change in water content, and a latent heat change which results in a change in water content at a constant temperature.*

Psychrometric Charts: There are programs on the web that provide all of the environmental parameters for a point on the psychrometric chart. These programs can be accurate and convenient to use especially if the parameters for the air are needed in units different than described in this Tech Note. However, it is important to understand the meaning of the information found on the psychrometric chart and how that information is used for various applications such as human and animal space conditioning or product drying. Psychrometric charts can also be found on the web that cover different ranges of conditions than the following charts. Figure 386.5 and Figure 386.6 cover the temperature range from approximately 0^{o}F to 110^{o}F which is adequate for most human and animal space conditioning applications.

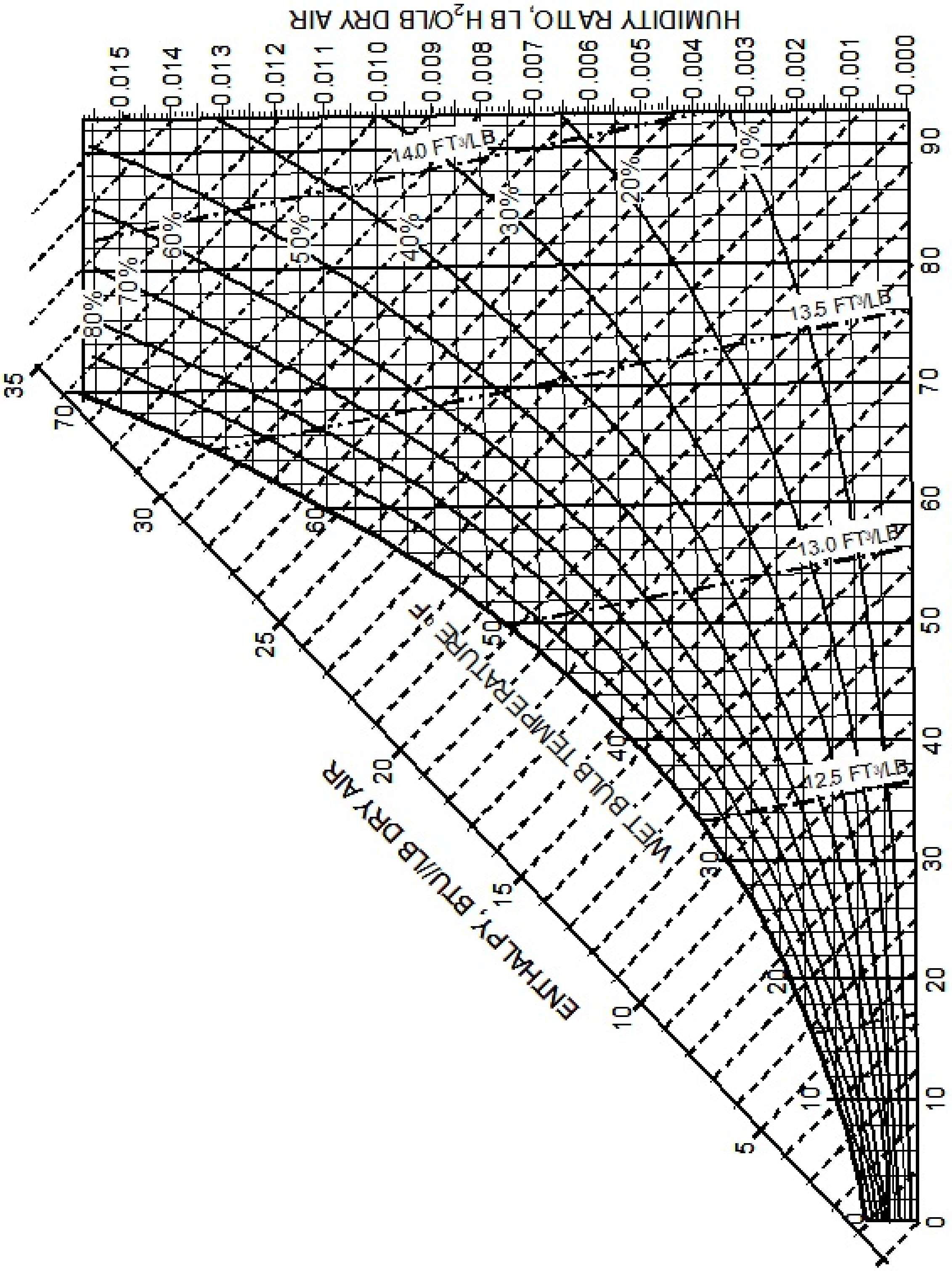

Figure 386.5 *Psychrometric chart ranging from approximately 0°F to 90°F.*

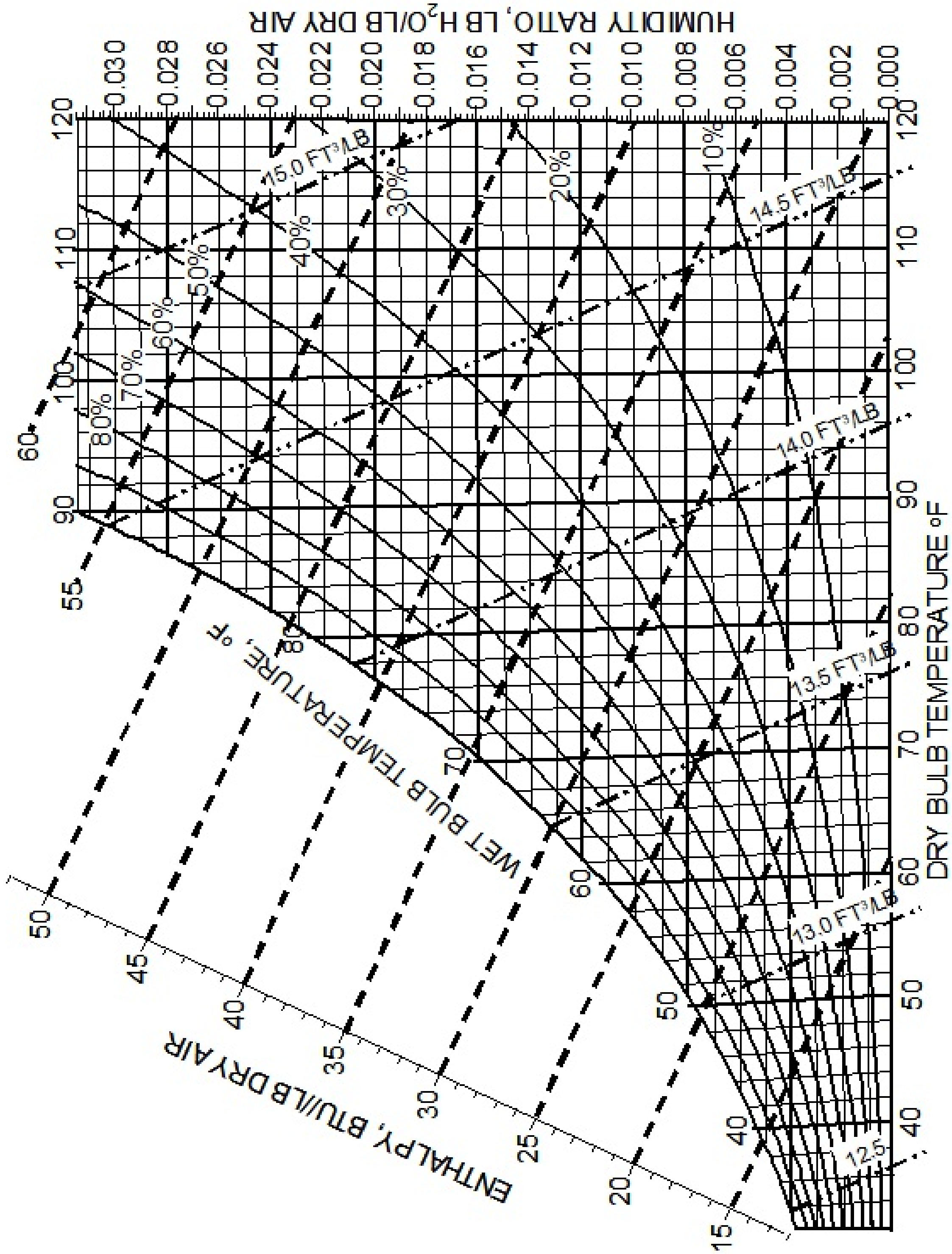

Figure 386.6 *Psychrometric chart ranging from approximately 40°F to 110°F.*