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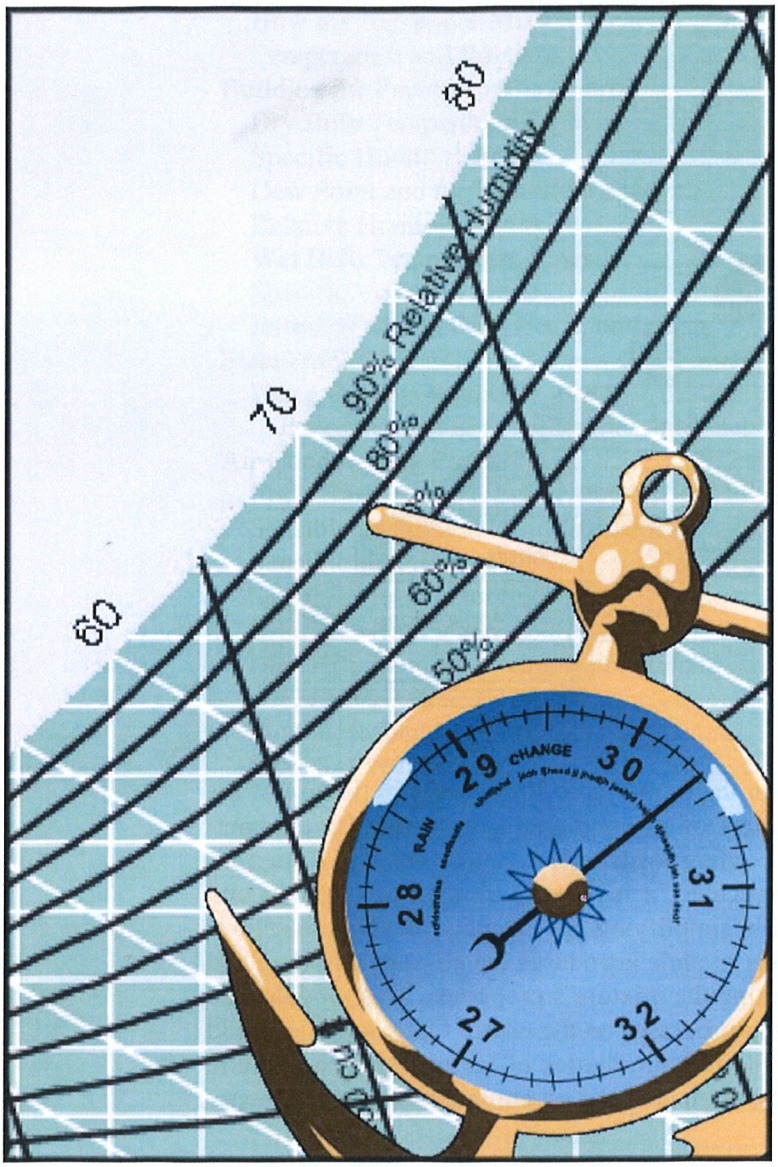
PSYCHROMETRICS



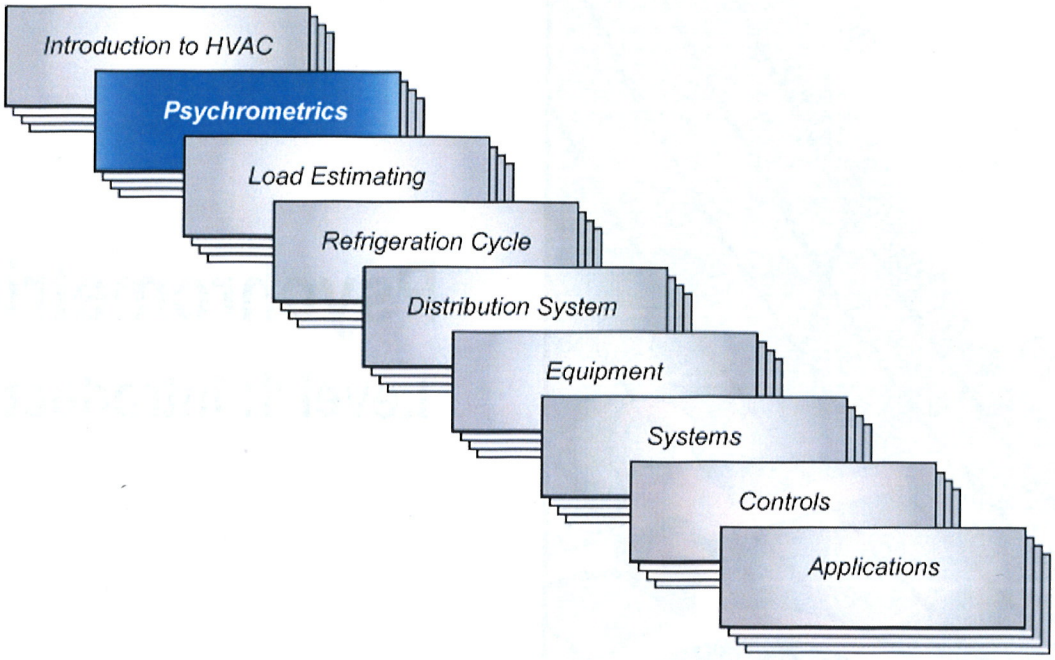
Psychrometrics

Level 1: Introduction

Technical Development Program

Technical Development Programs (TDP) are modules of technical training on HVAC theory, system design, equipment selection and application topics. They are targeted at engineers and designers who wish to develop their knowledge in this field to effectively design, specify, sell or apply HVAC equipment in commercial applications.

Although TDP topics have been developed as stand-alone modules, there are logical groupings of topics. The modules within each group begin at an introductory level and progress to advanced levels. The breadth of this offering allows for customization into a complete HVAC curriculum – from a complete HVAC design course at an introductory-level or to an advanced-level design course. Advanced-level modules assume prerequisite knowledge and do not review basic concepts.



Psychrometrics is the study of the air and water vapor mixture. Proficiency in the use of the psychrometric chart is an important tool for designers of air conditioning systems. Psychrometrics is required to properly calculate heating and cooling loads, select equipment, and design air distribution systems. While the topic is not complicated, it involves a number of formulas and their application; the psychrometric chart is useful in simplifying the calculations. This module is the first of four on the topic of psychrometrics. This module introduces the air-vapor mixture and how the psychrometric chart can be used to determine the mixture's properties. This module also explains how to plot the eight basic air conditioning processes on the chart. Other modules build on the information from this module to explain the psychrometrics of various air conditioning systems, analysis of part load and control methods, computerized psychrometrics, and the theory used to develop the chart.

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Introduction

Why does an air-conditioning design course begin with psychrometrics? In the computer-aided design world of today, is psychrometrics a necessary and practical topic to understand? The answer is that the principles of psychrometrics provide the key to understanding why the air conditioning industry exists and will help explain many of the processes and steps used in system design. It is so important, we have four TDP modules devoted to psychrometrics. This first module has four sections: properties of air and vapor, building the psychrometric chart, state points, and air conditioning processes. Other modules describe using psychrometrics to analyze processes and determine loads or airflows, using psychrometrics to evaluate performance of compound systems with the psychrometric chart or computer tools, and psychrometric formula and the theory used to construct the chart.

Many of the terms and concepts are used in daily conversation, yet we may not recognize them as psychrometrics. What does ***relative humidity*** really mean? How does a cooling coil remove water vapor? What causes air conditioning ducts to sweat? The answers to questions such as these depend upon the properties of air and water vapor and how they act together. Being able to analyze air conditioning systems with an understanding of these properties means better operating systems and lower costs.

The history of psychrometrics started on a foggy evening in 1902 on a train platform in Pittsburgh. A young engineer for Buffalo Forge Company was working on an air conditioning design problem involving a Brooklyn printer who was having a problem with color registration between printing press runs. Color printing was done at that time by running the paper through the presses for each primary color. The concentration of the various color dots gave the pictures their color. Since paper changes dimensionally with changes in the humidity, on some days, the colors were not lining up, leading to poor quality and wasted materials. On this foggy night, the young engineer observed the fog condensing on cold surfaces and determined that there was a relationship between temperature and humidity. As temperature dropped, the air could hold less moisture. It followed that a temperature could be reached where the air could hold no more moisture and a concept called ***dew point*** control was born. This understanding of dew point allowed him to solve the printer's problem. The young engineer, Willis Carrier, went on to mathematically describe the phenomena he observed that night and the science of psychrometrics was born.

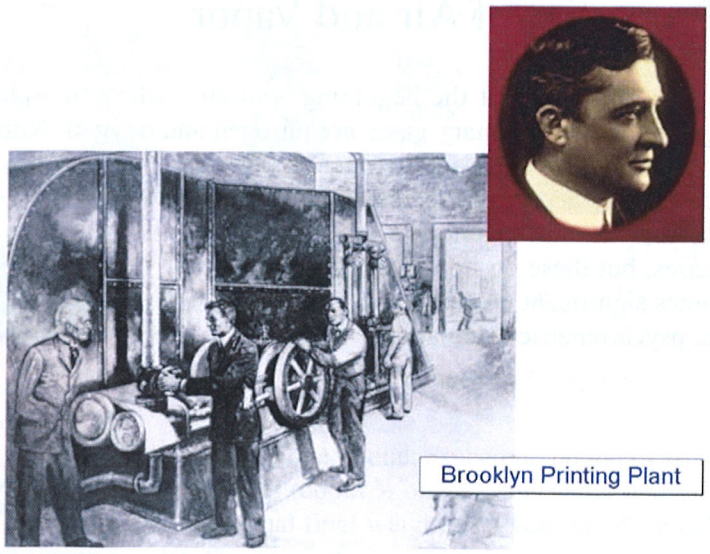


Figure 1

Dr. Carrier and the Brooklyn Printing Plant

The formulas that were developed were plotted on a chart that is the psychrometric chart. This chart is one of the most useful tools a system designer has to describe air conditioning processes.

What is Psychrometrics?

Psychrometrics is the study of the thermodynamic properties of moist air. In other words, if the air is to be conditioned, how can the amount of heat that must be added or removed and the amount of moisture that must be added or removed be determined? This is what we can learn from our study of psychrometrics.

Five uses for psychrometrics:

Determine the temperature at which condensation will occur in walls or on a duct.

Find all the properties of moist air by knowing any two conditions.

Calculate the required airflow to the space and the equipment to satisfy the loads.

Determine the sensible and total cooling load the unit needs to provide

Determine the coil depth and temperature to meet the design load conditions.

Properties of Air and Vapor

We will start at the beginning with air itself. Atmospheric air is a mixture of a number of gases. The two primary gases are nitrogen and oxygen. Nitrogen accounts for 77 percent of air's weight by volume and oxygen accounts 21 percent. The remaining 1 percent is trace amounts of other gases, but these do not appear in volumes significant enough to be a factor in psychrometric calculations.

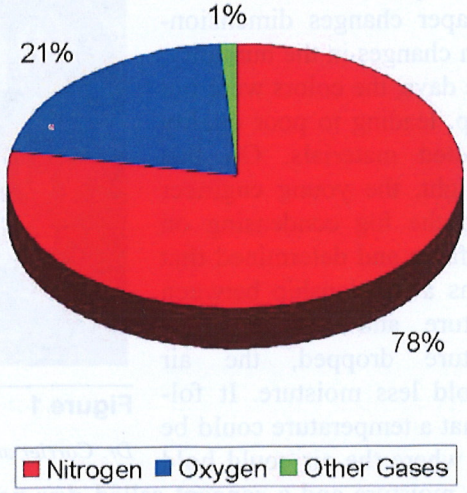


Figure 2

Composition of Dry Atmospheric Air

Atmospheric air has one other element in this mixture of gases commonly called air: water vapor. Water vapor is not present in large quantities in the atmosphere; however, it is a significant factor to those concerned with the field of psychrometrics and air conditioning.

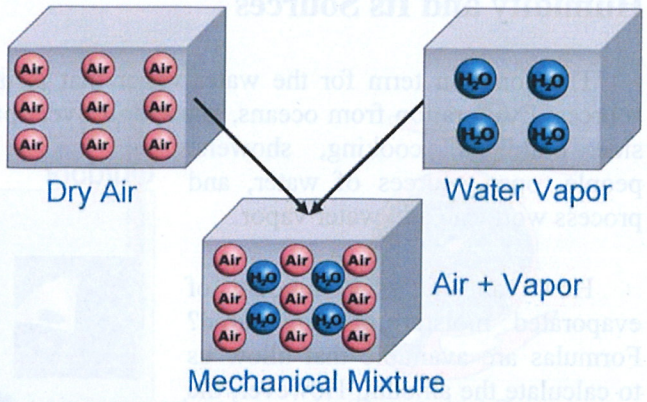


Figure 3

Atmospheric air is a mixture of dry air and water vapor.

How Air and Water Vapor are Measured

Air conditioning is the simultaneous control of temperature, humidity, cleanliness, and distribution. So, the first order of business in order to control temperature and humidity, is how they can be measured. Once temperature and humidity are determined, then the amount of each to be removed or added can be calculated.

Convention for the industry is to base calculations of air properties on pounds. Since air is a mixture, and not a compound, the amount of moisture in the mixture can change. Therefore, to have a common measuring point, ***moisture content*** is defined by comparing the moisture content at any point to dry air.

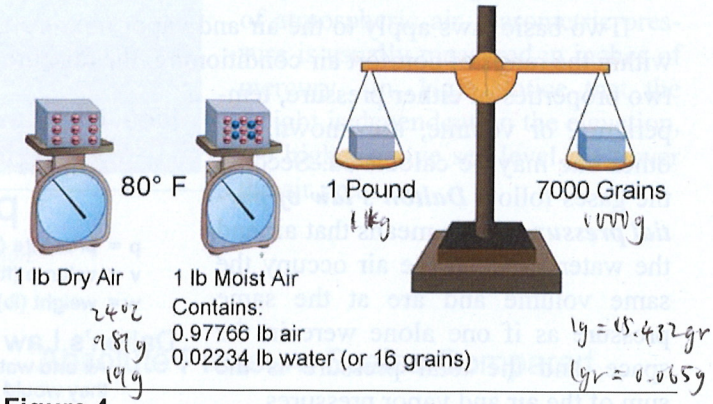


Figure 4

Psychrometric calculations are based on a pound of dry air.

The amount of actual water vapor present in a quantity of air is so small that it is measured in grains. It takes 7000 grains to make up one pound. Since one pound of air at 100° F, with all the water it can hold, contains 302.45 grains (about ½ ounce), this water does not have much bearing on the actual weight of the air. The actual final weight of a volume of air will be the sum of the air's dry weight and the weight of the water vapor it contains.

The unit of measurement

for moisture content is pounds of moisture per pound of dry air (lb / lb_{da}). Note: to convert from pounds of moisture per pound of dry air to grains is:

lb / lb_{da} * 7000 = Grains

Humidity and Its Sources

The common term for the water vapor that is in the air is humidity. Humidity has many sources. Evaporation from oceans, lakes, and rivers puts water into the air and forms clouds. Inside buildings, cooking, showers, people, open sources of water, and process work can add water vapor.

How can the exact amount of evaporated moisture be measured? Formulas are available that allow us to calculate the amount. However, the psychrometric chart makes it easy and provides a good way to visualize the process.

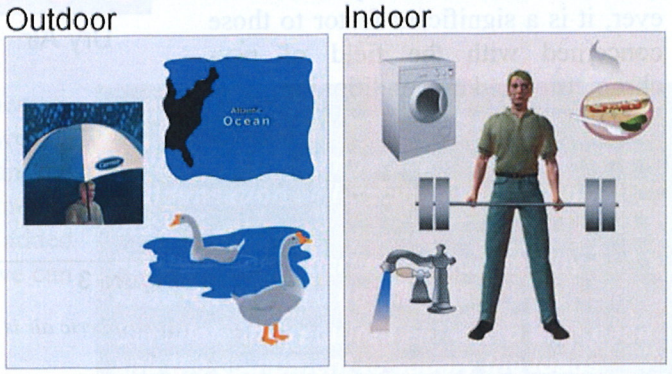


Figure 5

Water vapor in the air comes from many sources.

How the Air-Vapor Mixture Reacts

Two basic laws apply to the air and vapor mixture that make our calculations possible. First, within the range of comfort air conditioning, the mixture follows the ideal gas laws. Put simply, if two properties of either pressure, temperature, or volume, are known, the other one may be calculated. Second, the gases follow ***Dalton's law of partial pressures***. This means that air and the water vapor in the air occupy the same volume and are at the same pressure as if one alone were in the space, and the total pressure is the sum of the air and vapor pressures.

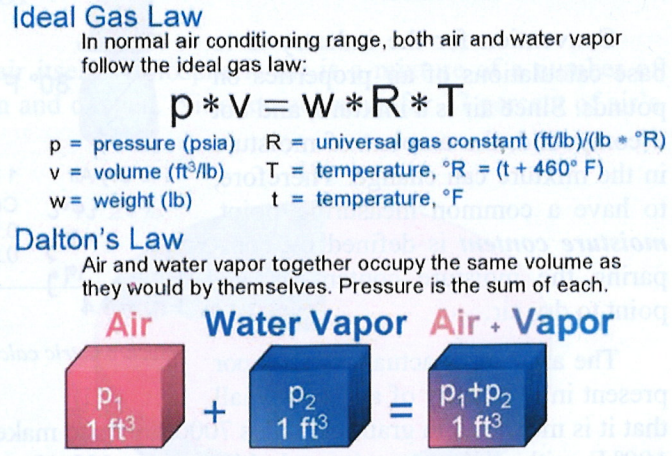


Figure 6

The ideal gas law and Dalton's Law control psychrometric calculations.

Temperature and Pressure

Our first air property, air temperature, can be easily determined with a standard thermometer. What about the second, pressure? What is air pressure?

Air pressure is often called barometric pressure.

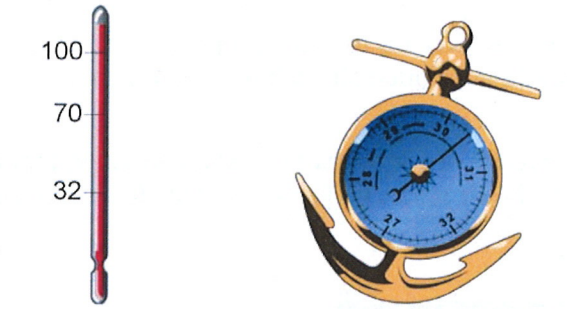


Figure 7

Air Temperature and Pressure

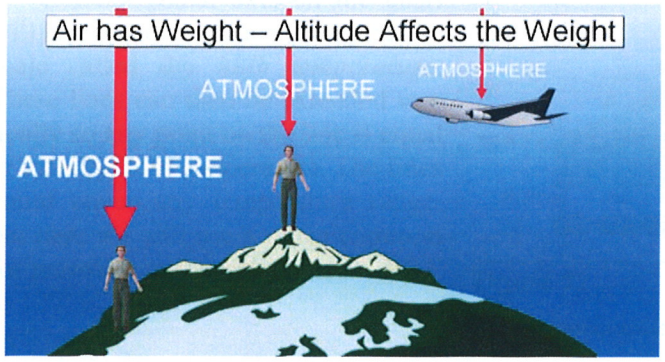


Figure 8

The weight of atmospheric air varies with elevation.

The daily weather report gives the barometric pressure. Air has weight, even though we may not recognize it as such. The barometer is a measure of the weight of the column of atmospheric air. Barometric pressure is usually measured in inches of mercury, (in. Hg). Notice that the weight is dependent on the elevation, the higher above sea level the lower the air pressure.

The air in a space where conditions are being calculated is dependent on barometric pressure. To account for the weight of atmospheric air, calculations use the absolute pressure. This is referred to as pressure in pounds per square inch absolute, written psia. At sea level, this is 29.921 in. Hg and converts to 14.696 psia; in Denver at 5000 feet elevation the pressure is 12.23 psia. Since the two laws depend on pressure, the charts also depend on pressure. To account for this, psychrometric charts are published for different elevations, sea

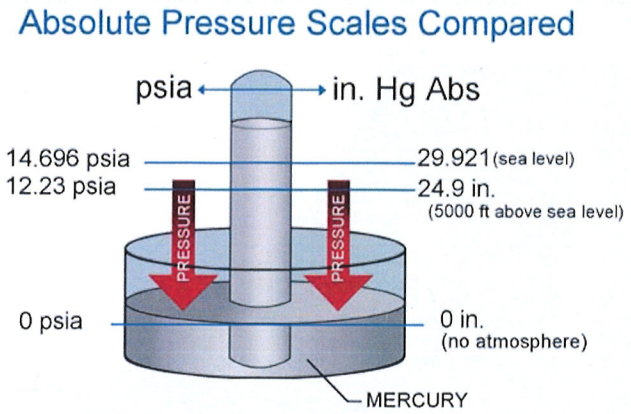


Figure 9

Absolute pressure is used in psychrometric calculations.

Building the Psychrometric Chart

A psychrometric chart is a convenient way to determine properties of air and describe air conditioning processes. To create the chart, it is necessary to base the calculations on elevation; sea level is used for this discussion.

Since the behavior of temperature and humidity are predictable at atmospheric pressure and temperatures, different characteristic properties can be plotted on a graph. To start the chart it is necessary to define our vertical and horizontal axis.

Dry Bulb Temperature Scale

Our horizontal axis on the chart will represent an ordinary temperature scale called ***dry bulb temperature***. These lines can then be extended vertically so any point on the line is equal to that dry bulb temperature. The lines could cover any temperature range, but here we will use a range common for normal comfort calculations, 30° F to 120° F.

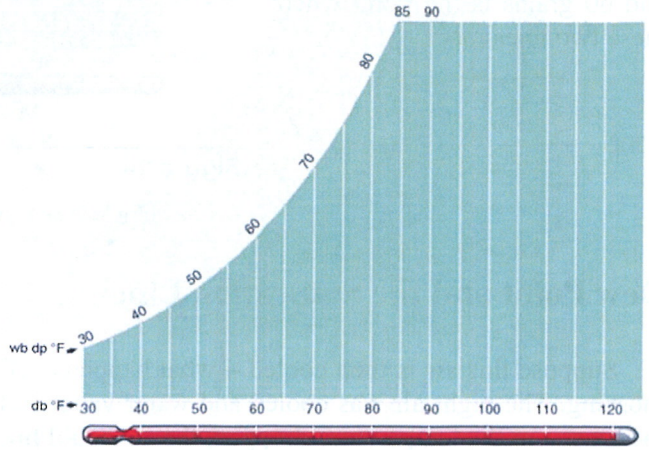


Figure 12

The horizontal scale is dry bulb temperature.

Specific Humidity Scale

Next, the vertical scale is made according to the amount of water vapor mixed with each pound of dry air. Since the amount of water vapor is small, the scale is plotted in grains of water vapor per pound of dry air at standard atmospheric pressure. Some charts plot water vapor in pounds of water per pound of dry air rather than grains. The vertical axis is called the specific humidity scale.

Not always grains

Some charts will plot specific humidity in pounds of water vapor per pound of dry air, lb/lb$_{da}$. Some charts have both scales.

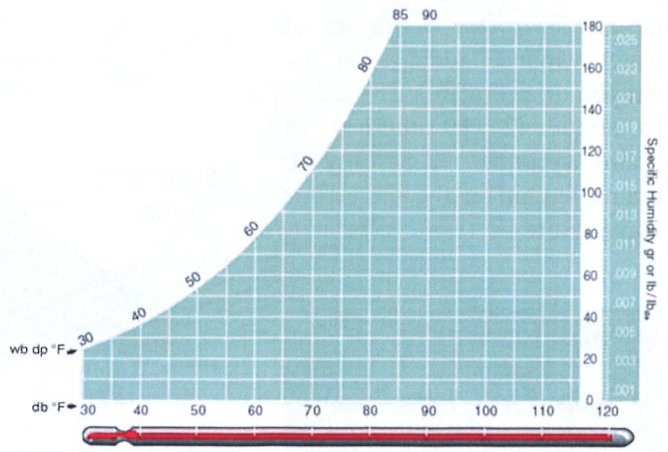


Figure 13

The vertical scale is specific humidity, a measure of the amount of water vapor in the air.

Now it is easy to locate many air and water vapor mixtures by using the chart. For example, air at 75° F dry bulb temperature is anywhere on the vertical line above 75° F, regardless of the humidity. Air with 60 grains of water vapor per pound of dry air is anywhere on the horizontal line at 60 grains. The air at 75° F and 60 grains is the point where these two lines meet.

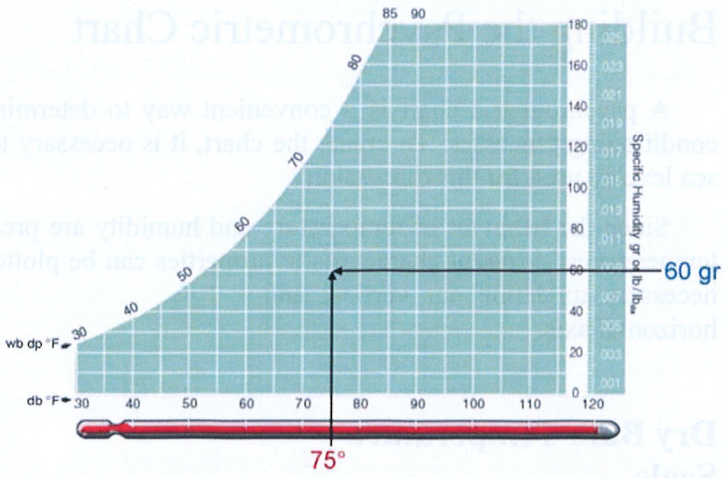


Figure 14

Locate a dry bulb and specific humidity point.

Dew Point and the Saturation Line

Suppose this air is then cooled – what happens? Observe the dew on the grass on a summer morning. The night air was cooled and water vapor in the air from the day before condensed on the grass. As the temperature dropped, the air could hold no more water vapor and so water condensed out of the air. This highlights the fact that the amount of water vapor that the air can hold is related to the air temperature.

As the air at 75° F and 60 grains has the temperature reduced, no water vapor is removed until the air reaches its point of maximum humidity. For this example, when the temperature is 53° F, any further cooling will now cause some water vapor to condense, because at 53° F the air can hold only 60 grains per pound of air. The temperature at which the moisture content or relative humidity has reached 100 percent is called the dew point. If the temperature drops below the dew point, say to 48° F, only 50 grains of water vapor remain in the air. Therefore, 10 grains of water vapor condenses. If the temperature drops still further to about 42° F, another 10 grains is condensed as only 40 grains remain in the air at this temperature.

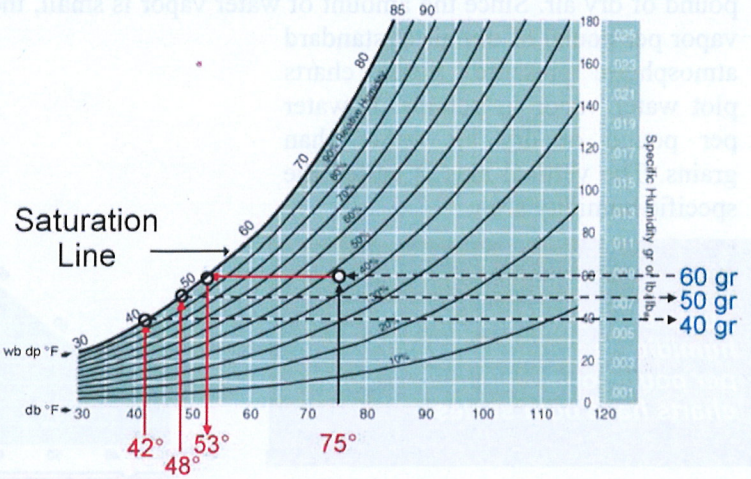


Figure 15

Saturation Line

Water vapor

in the air at the dew point has a relative humidity of 100 percent and is said to be saturated.

A line that connects these and other 100 percent saturation points is known as the saturation line, which is the same as the 100 percent relative humidity line. This line gives the dew point temperatures and is called the saturation curve or saturation line. The dew point temperature for air depends upon the amount of water vapor present and is found on the psychrometric chart by moving horizontally over to the saturation curve and reading the temperature there.

To illustrate the use of dew point, we will check to see whether sweating occurs on a 55° F uninsulated supply air duct that runs through an unconditioned space. At a space temperature of 95° F dry bulb and 100 grains of water vapor, the dew point is 67° F. That means the 55° F duct cools the surrounding unconditioned air below the 67° F dew point, therefore, water vapor condenses. Moisture condenses not only on the duct, but also on any surface with a temperature below the dew point of the air. If water dripping is likely to cause damage, the duct should be wrapped with insulation then with a vapor barrier. Enough insulation should be used to prevent the outside surface temperature from dropping below the dew point of the surrounding air.

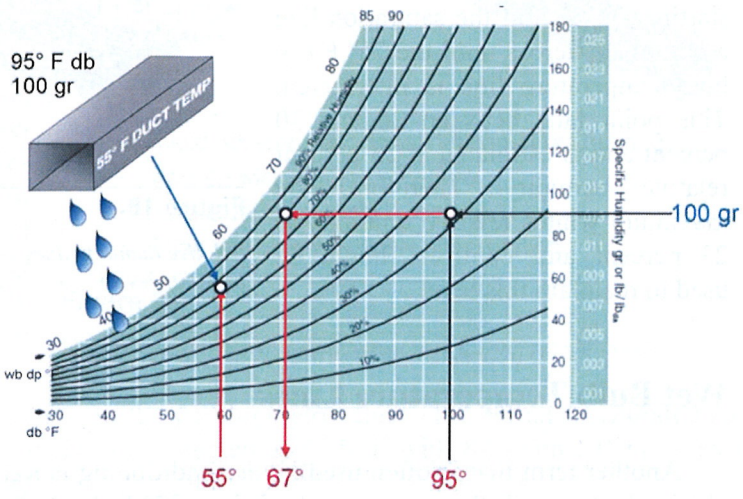


Figure 16

Determine dew point with conditions of a duct in an unconditioned space.

Relative Humidity Lines

The saturation curve indicates the 100 percent relative humidity line. Lines for partly saturated air look very much like the saturation line on the chart. These lines normally appear in increments of 10 percent and indicate the degree of saturation.

Relative humidity is defined as the amount of moisture in the air compared to the maximum amount that could be present at the same temperature. For example, air at 75° F dry bulb with 60 grains shows a relative humidity between the 40 and 50 percent lines on the chart.

Check this by following the 75° F dry bulb temperature line up to the saturation line could be used to check this. Here, air has 132 grains of water vapor. The relative humidity is approximately equal to 60 divided by 132, or 45 percent.

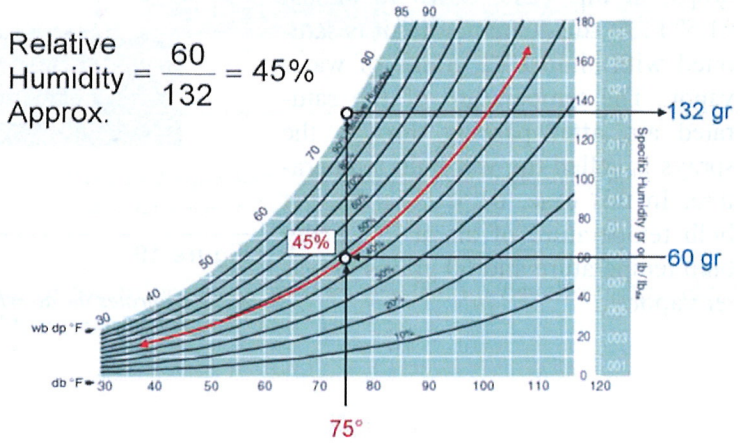


Figure 17

Relative humidity lines resemble the saturation curve.

One use for relative humidity lines is to determine the maximum allowable relative humidity permitted inside a house in winter without having moisture condense on the windows. If the window surface temperature is 35° F and the room temperature is 75° F, the maximum relative humidity can be found by starting at 35° F at the saturation line and moving across until the 75° F dry bulb temperature line is intersected. This point falls between 20 and 30 percent and is estimated at 23 percent relative humidity. Therefore, the maximum winter relative humidity is 23 percent and controls should be used to maintain this level.

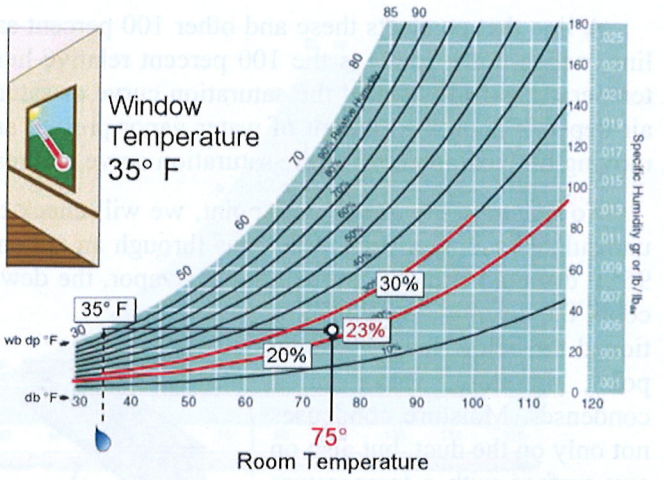


Figure 18

Relative humidity lines can be used to determine maximum winter humidity levels.

Wet Bulb Temperature Lines

Another term that is often used in air conditioning is ***wet bulb temperature***. To see how it is obtained, start with the same pound of air at 75° F dry bulb temperature and 60 grains of water vapor. Pass this air through a series of water sprays that use the same water repeatedly, except for the small amount that may evaporate. This device is called a saturator. As the air goes through the water spray, the temperature of the air drops because heat is absorbed to evaporate the atomized water. If the sprays are well designed, the air temperature drops, in this case, down to almost 61.5° F. At this temperature, it is saturated with almost 82 grains of water vapor. The temperature of the saturated air, after passing through the sprays is called the wet bulb temperature. In this case, 61.5° F is the wet bulb temperature of air at 75° F dry bulb temperature and 60 grains of water vapor.

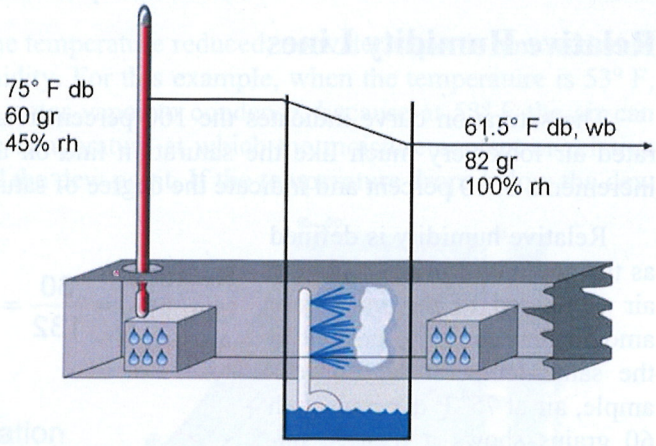


Figure 19

Water saturates the air when passed through a water spray saturator.

This experiment would be difficult to perform every time the wet bulb temperature was needed. Instead, a device called a sling psychrometer can be used more conveniently and gives quite accurate results. The sling psychrometer consists of two thermometers mounted in a frame and attached to a handle by means of a swivel. One thermometer has a wetted cotton wick wrapped around its mercury bulb. When the apparatus is whirled around, air is moved across the wick and some of the water is evaporated. This evaporation absorbs heat and causes the thermometer to register the wet bulb temperature. A dry bulb thermometer is usually mounted on the sling psychrometer so that a wet bulb/dry bulb comparison can be instantly taken. This piece of equipment provides a convenient way of determining the humidity condition in the air, since measuring the specific humidity or dew point directly is difficult to do.



Figure 20

Wet bulb temperature is determined with a sling psychrometer.

This wet bulb process is also shown on the psychrometric chart. The initial unsaturated air started at 75° F with 60 grains and ended up saturated at 61.5° F with 82 grains. If these two points are connected, they form the 61.5° F wet bulb temperature line. In a similar manner, the wet bulb lines run diagonally from the lower right up to the saturation curve. All wet bulb temperatures are read at the saturation line.

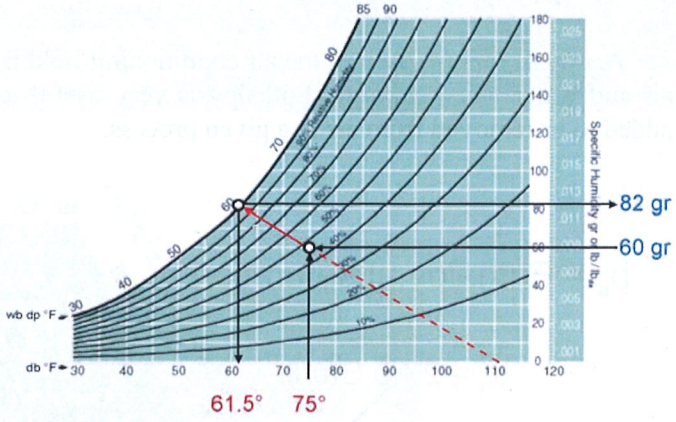


Figure 21

Wet bulb temperature lines run diagonally, intersecting the saturation curve at the wet bulb temperature.

To round out our understanding of the information we can get from a psychrometric chart, two other properties of the air need to be explained.

Specific Volume Lines

The first property is specific volume. Specific volume is defined as the number of cubic feet occupied by one pound of air at any given temperature and pressure. For example, one pound of air at 75° F dry bulb displaces a volume of 13½ cubic feet at sea level. If the air is heated to 95° F, it expands and takes up 14 cubic feet. Air, being a gas, will decrease in density as its temperature rises. If the air is cooled to 55° F, it occupies only 13 cubic feet, because the air is denser at lower temperatures. The lines for these specific volumes are shown on the psychrometric chart as almost vertical lines, which slant to the left. Specific volume is used primarily for checking fan performance and determining fan motor sizes for low and high temperature applications.

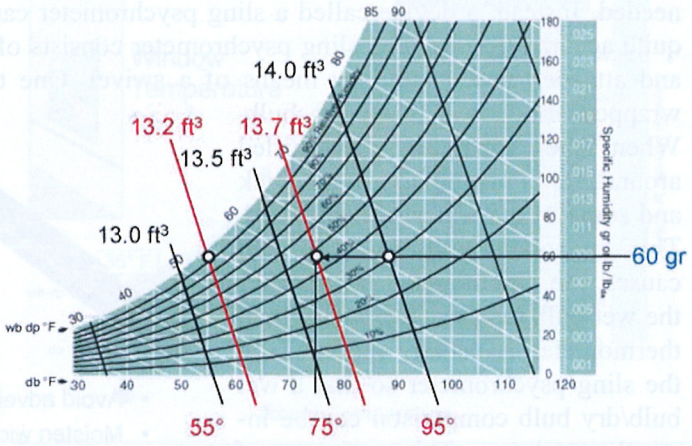


Figure 22

Specific Volume Lines

Enthalpy Scale (Total Heat Content)

Another property used in the air conditioning field is ***enthalpy***, or the total heat content of the air and water vapor mixture. Enthalpy is very useful in determining the amount of heat that is added to or removed from air in a given process.

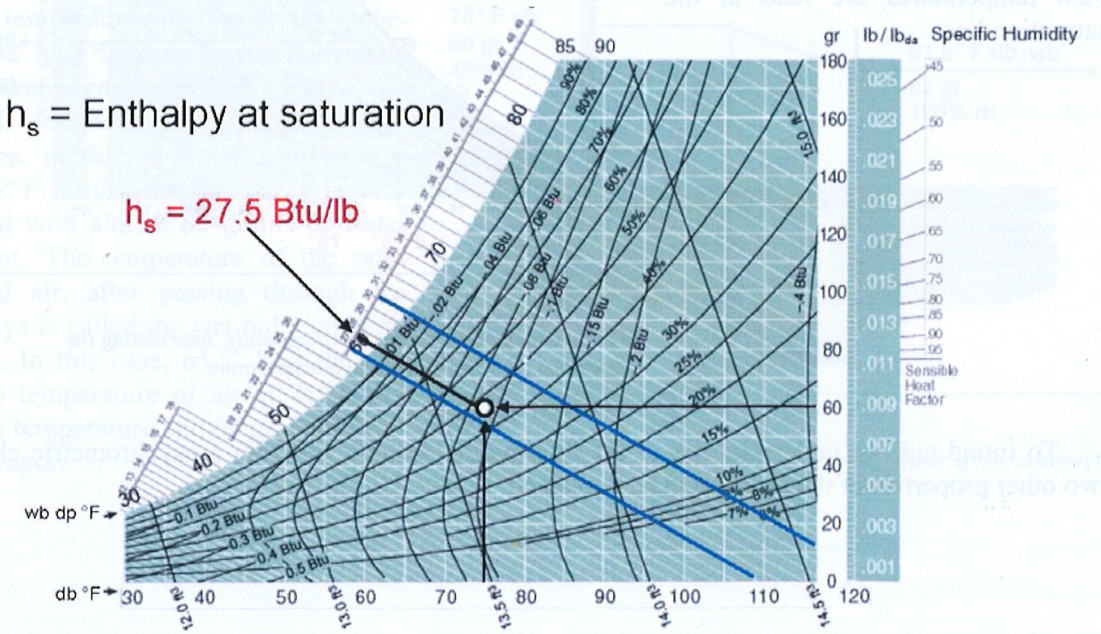


Figure 23

The enthalpy scale is an extension of the wet bulb lines.

It is found on the psychrometric chart by following along a wet bulb temperature line, past the saturation line, and out to the enthalpy scale. For example, air at 75° F dry bulb temperature and 60 grains of water vapor has an enthalpy of 27.50 Btu per pound of air. The enthalpy scale is shown at the extension of the wet bulb temperature lines and is read directly where the extended wet bulb line intersects the scale.

The enthalpy actually changes as the air becomes less saturated. This is shown on some charts with a deviation correction and by sloped enthalpy lines on other charts. For most comfort air conditioning calculations, the saturated enthalpy can be used without correction.

State Point

If all the lines that have been discussed are combined in one chart, it will look like the diagram. The chart now shows dry bulb temperature, specific humidity, dew point temperature, relative humidity, wet bulb temperature, specific volume and, enthalpy. When any two of these values are known, the exact condition of the air can be located on the chart and all other properties can be found from this one point. Such a point is sometimes referred to as a state point.

State Points

Intersection of any two values that define all other air properties:

Dry bulb temperature (db)
Wet bulb temperature (wb)
Dew point temperature (dp)
Specific humidity (gr or lb/lb$_{da}$)
Relative humidity % (rh)
Specific volume (ft^3)
Enthalpy (h) Btu/lb

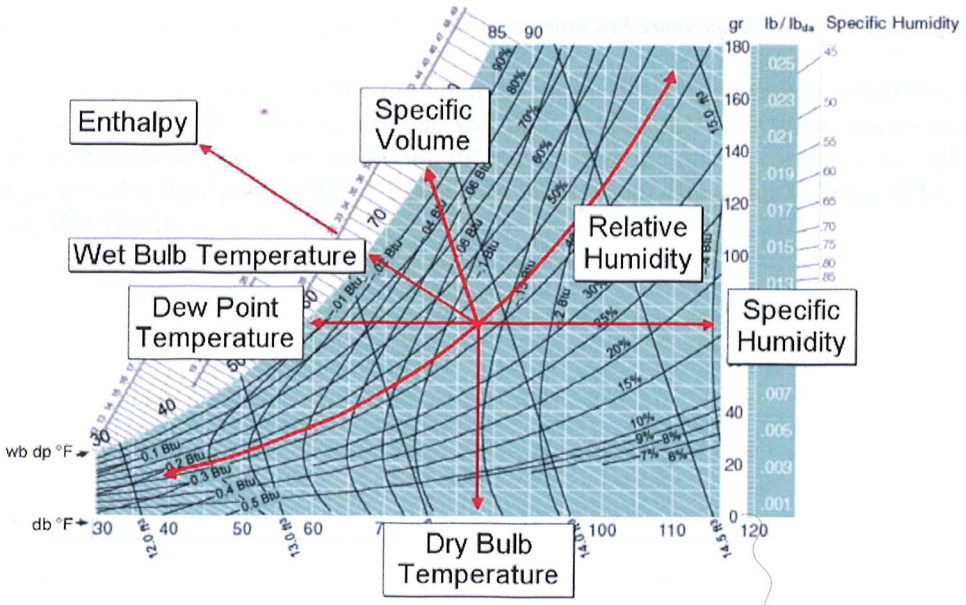


Figure 24

Seven properties can be found on the psychrometric chart.

Using the Psychrometric Chart

All the properties pertinent to most air conditioning calculations have now been defined using the psychrometric chart. The state point, or locating the properties using the two properties, now gives us a useful tool to evaluate conditions of the air at any point in the air conditioning process. Let's find the properties at four points common in an air conditioning system; room air, outdoor air, mixed return and outdoor air, and air leaving a cooling coil.

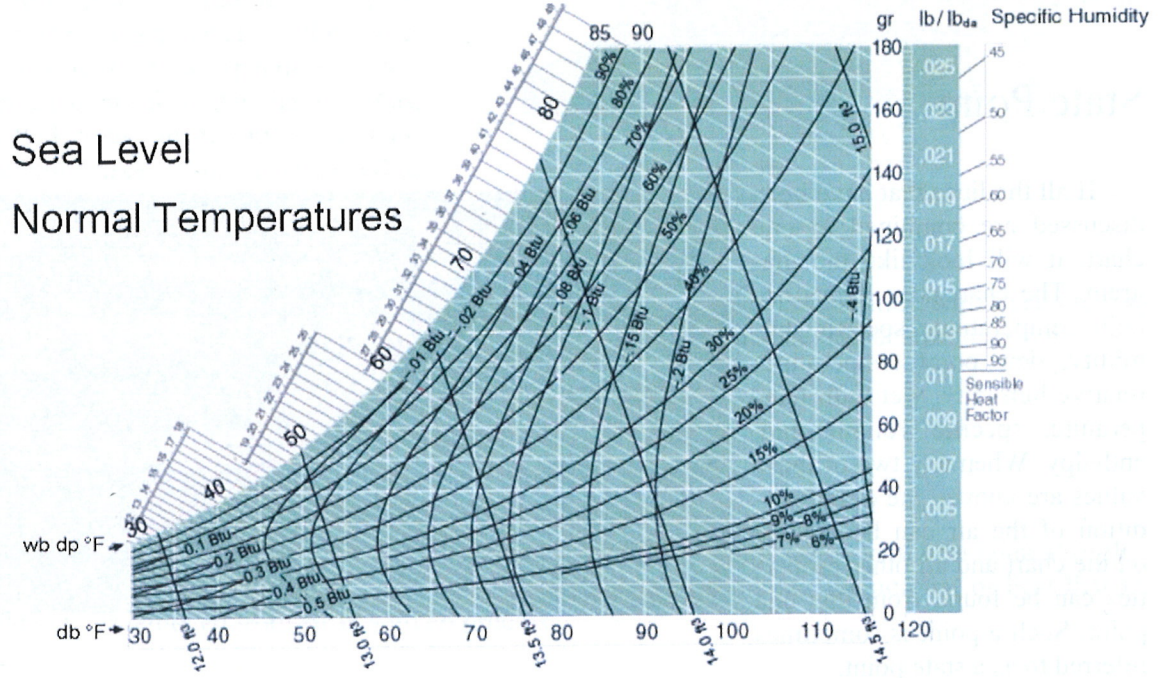


Figure 25

Complete Sea Level, Normal Temperature Psychrometric Chart

Examples Using State Points

First, room air conditions are normally given as a dry bulb temperature and a percent relative humidity, typically 75° F and 50 percent. To find the state point on the chart, we locate 75° F and follow the line vertically until it intersects the 50 percent relative humidity line. The other five air properties can then be read from this state point: wet bulb of 62.5° F, dew point of 55° F, specific humidity of 65 gr, air volume of 13.7 ft^3, and enthalpy of 28.1 Btu/lb.

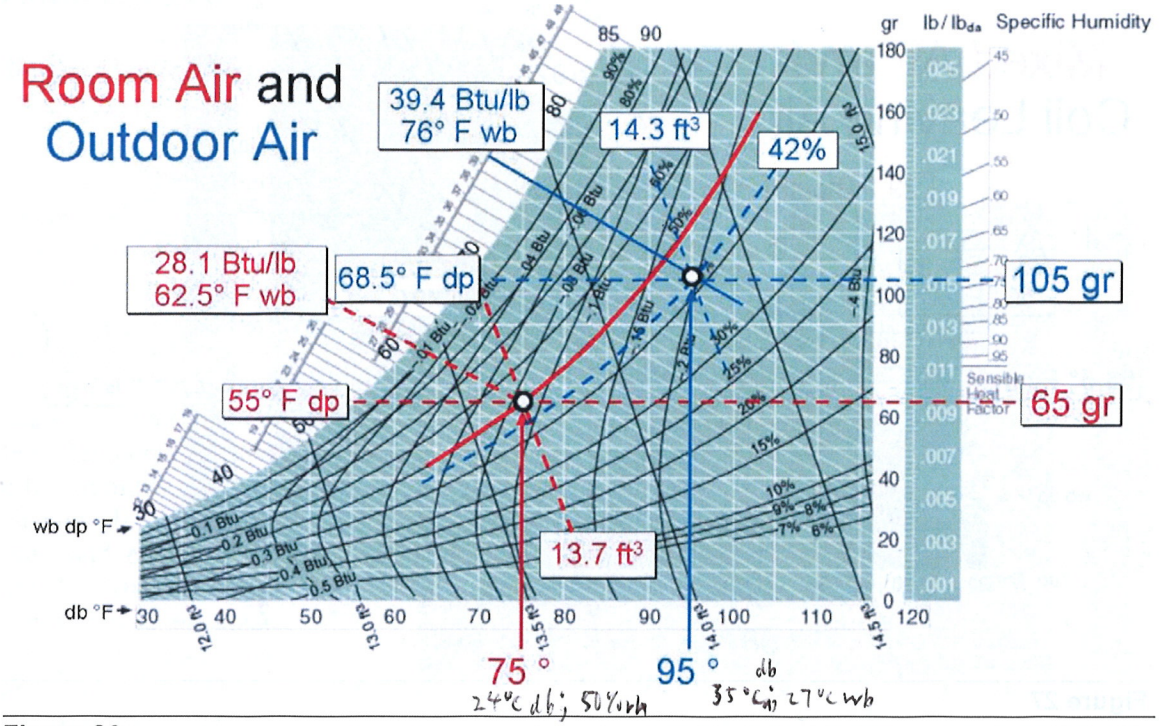


Figure 26

State Point Examples for Room Air and Outdoor Air

In a similar way, we can determine the other air properties at the outdoor condition, which is normally given as a dry bulb temperature and wet bulb temperature. For this example assume the state point conditions are 95° F dry bulb and 76° F wet bulb, the other properties are: relative humidity of 42 percent, dew point of 68.5° F, specific humidity of 105gr, air volume of 14.3 ft^3, and enthalpy of 39.4 Btu/lb.

Common air conditioning practice is to return air from the space to the unit and to mix that air with a portion of outdoor air. Using the last two examples, if 10 percent of the air is outdoor air and 90 percent of the room air are mixed the resulting mixed air state point conditions will be 78° F dry bulb and 64.7° F wet bulb. We explain how this is calculated in the next section of this module. Again, the properties can be determined by finding the state point and reading the other properties, which in this instance are: relative humidity of 50 percent, dew point of 57° F, specific

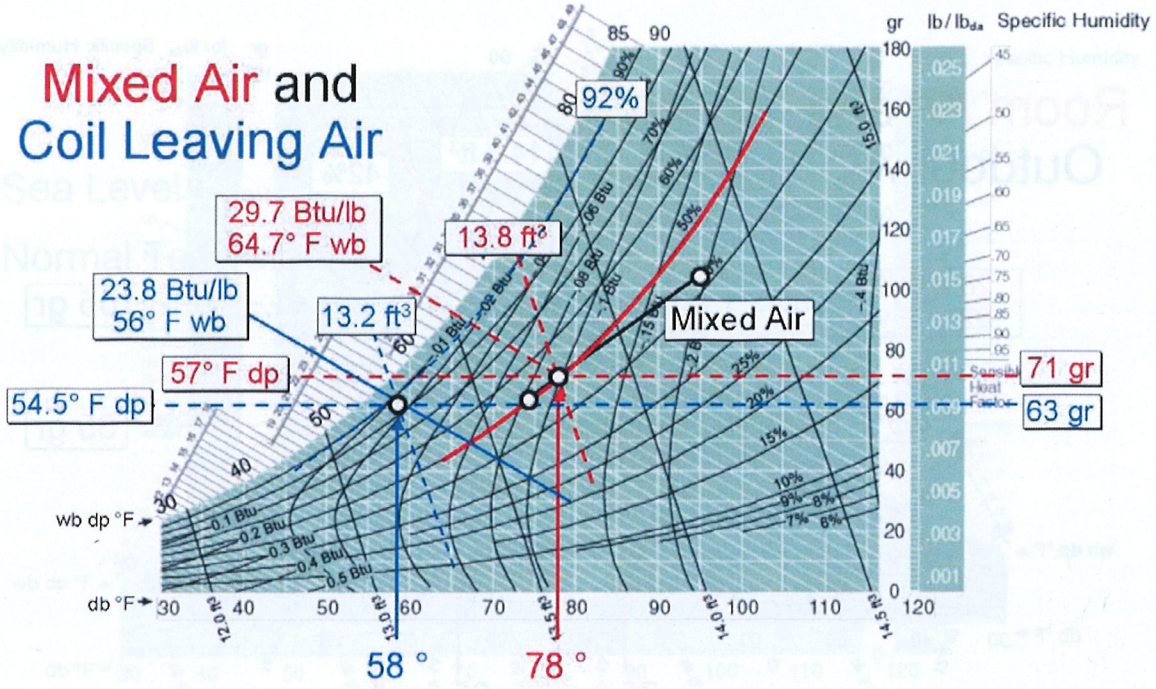


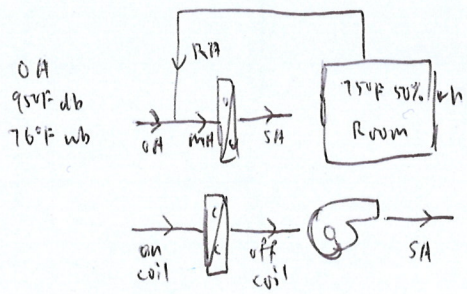
Figure 27

State point examples for mixed and coil leaving air

humidity of 71gr, air volume of 13.8 ft^3, and enthalpy of 29.7 Btu/lb.

Finally, the typical air conditions leaving the cooling coil can be found. Typical conditions are 58° F dry bulb and 56° F wet bulb. Finding this state point on the psychrometric chart, the other properties can be read: relative humidity of 90 percent, dew point of 54.5° F, specific humidity of 63 gr., air volume of 13.2 ft^3, and enthalpy of 23.8 Btu/lb.

We have now developed the psychrometric chart and learned how we can determine air properties using it. This is a good time to practice using the chart, Work Session 1 in the back of the book covers the skills covered so far.



Air Conditioning Processes

Air conditioning design is the application of a number of different psychrometric processes. For our purposes, a process could be defined as moving from one state point to another. To do this heat and moisture must be added or removed. In this section, we will discuss the eight basic air conditioning processes and how the chart is used to determine the heat and moisture added or removed.

Eight Basic Process Types

Starting at a condition on the chart, directional arrows show a change in a given direction. These represent the basic processes. Notice that as the condition changes either the dry bulb temperature, specific humidity, or both change. If the beginning and ending point are known, the chart can be used to determine how much heat and moisture change. Air mixing is also a typical air conditioning process and is included in this section as well.

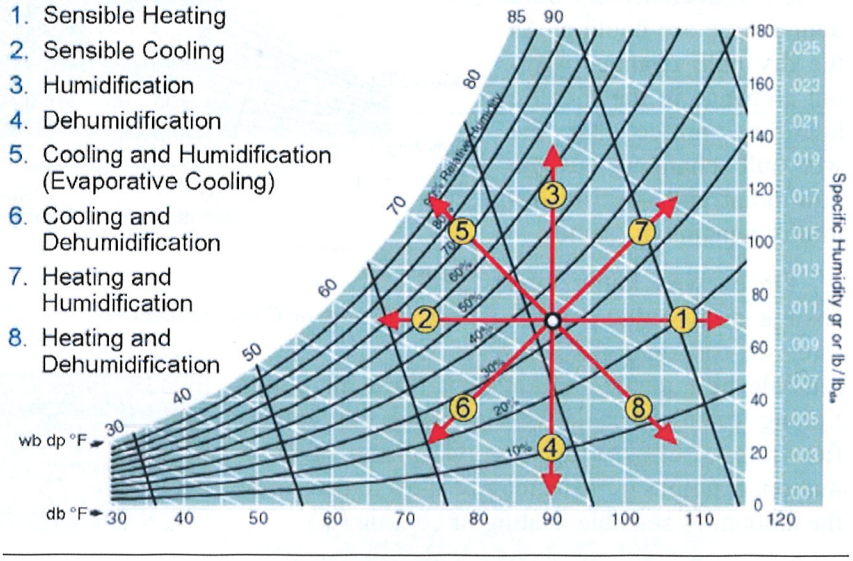


Figure 28

The Eight Basic Air Conditioning Processes

Each of the eight processes is familiar though we may not always recognize them by the process definition. The eight processes and a typical example are:

Sensible Heating – Residential gas furnace

Sensible Cooling – Cooling coil above the air dew point

Humidification – Steam humidifier in an air handler

Dehumidification – Dehumidifier

Evaporative Cooling or Cooling and Humidification – Swamp cooler

Cooling and Dehumidification – Cooling coil below the air dew point

Heating with Humidification – Winter heating with humidifier

Heating with Dehumidification – Chemical dehumidification wheels

Pure humidification and dehumidification are rare as some heating or cooling normally occurs in the process as well.

Sensible and Latent Heat Changes

The change in dry bulb temperature and specific humidity are referred to in air conditioning processes as sensible and latent heat changes.

Sensible heat changes result in a change in temperature and are indicated by a horizontal line on the psychrometric chart. Processes that increase dry bulb temperature are heating and those that decrease dry bulb temperature are cooling. As the dry bulb changes without a change in the specific humidity, notice that the wet bulb changes, but the dew point and specific humidity remains the same.

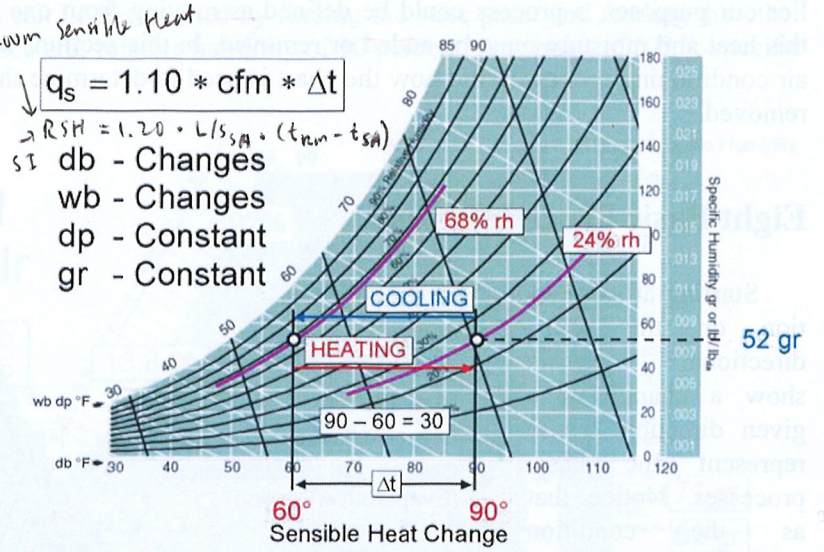


Figure 29

Sensible Heating or Cooling Processes

Once we know the change in dry bulb temperature, we can determine the sensible heat added or removed. Most air conditioning calculations are done using the volume flow rate, or cfm. With these two pieces of information, a simple formula may be used to determine the amount of sensible heating or cooling (q_s).

Sensible Heat Formula

q_s = 1.10 * cfm * Δ temperature

1.10 is a constant that adjusts for units

A latent heat change occurs when water is evaporated or condensed and the dry bulb temperature does not change. This shows up as a vertical line on the chart. Processes that increase specific humidity are ***humidification*** and those that decrease specific humidity are ***dehumidification***. As the specific humidity changes without a change in the dry bulb temperature, notice that the wet bulb, specific humidity and dew point change but the dry bulb remains the same.

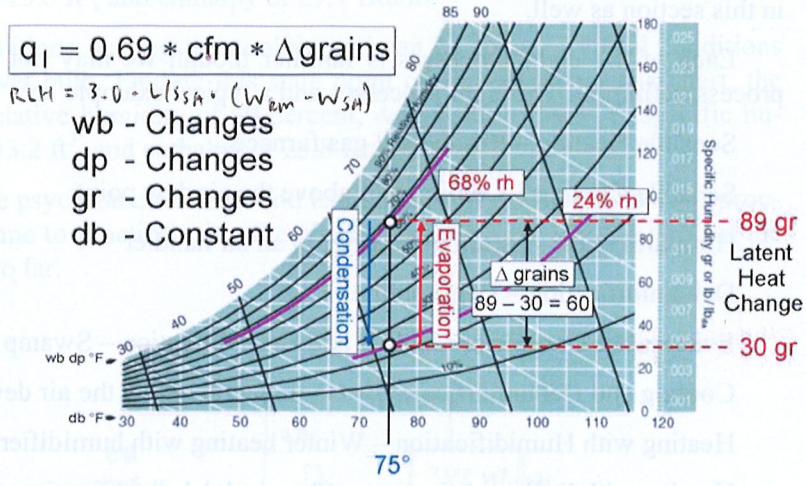


Figure 30

Latent Heating and Cooling Processes

Latent Heat Formula

q_l = 0.69 * cfm * Δ grains

0.69 is a constant that adjusts for units

Many air conditioning processes are a combination of both sensible and latent heat changes. The total heat is the sum of the sensible heat and the latent heat.

$$q_t = q_s + q_l$$

Enthalpy can be used to determine the total heat removed from a volume of air. Reading the scale between the two wet bulb lines does this. For example, air at 75° F dry bulb and 61.5° F wet bulb has an enthalpy of 27.5 Btu/lb. If this air is cooled and dehumidified to 55° F dry bulb and 51° F wet bulb, the enthalpy leaving the cooling coil is found to be 20.8 Btu/lb, Therefore, a total of 6.7 Btu is removed from each pound of air.

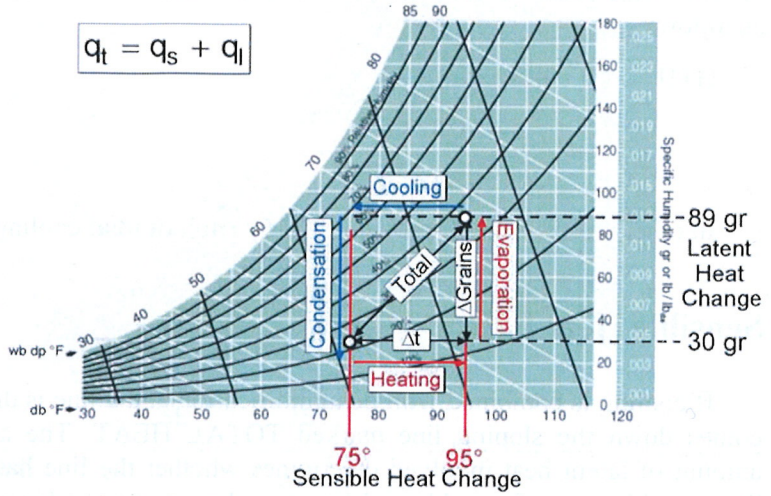


Figure 31

Total heat is sensible plus latent heat

If a triangle is drawn as shown, the vertical distance represents the amount of moisture removed - that is, latent heat. The horizontal distance represents the sensible cooling of the air. The enthalpy at the intersection of the vertical and horizontal lines is 25.8 Btu per pound. Therefore, the amount of latent heat removed is the difference between 27.5 and 25.8 or 1.7 Btu per pound. The sensible heat removed is the difference between 25.8 and 20.8, which equals 5 Btu per pound.

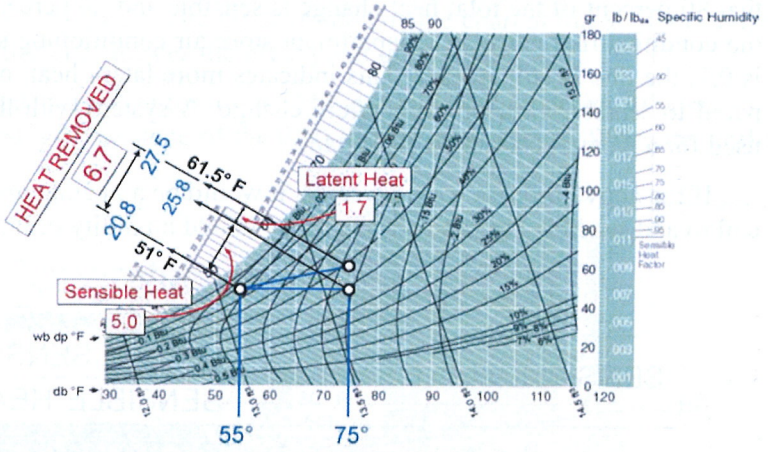


Figure 32

Enthalpy can be used to determine the total heat removed.,

When the enthalpy difference is used, we can use one additional formula to calculate the total capacity. The total capacity, sometimes called grand total heat is found by multiplying the airflow by a constant, 4.5, and the enthalpy difference.

By this using a simple formula:

$$GTH = 4.5 * cfm * \Delta h$$

$RTH = 1.09 \cdot L(SA) \cdot (h_{RM} - h_{SA})$

The difference in enthalpy (Δh) between the time it enters and leaves a space or a coil can be used to determine the grand total heat (GTH) gained or lost, in Btuh.

For our example, the difference in enthalpy is 6.7 Btu/lb. If 1000 cfm of air is circulated over the coil, which removes this heat, then 30,150 Btuh is removed, as follows:

GTH = 4.5 * cfm * Δh

= 4.5 * 1000 * 6.7

= 30,150 Btuh

Total heat formula

Q_t = 4.5 * cfm * Δenthalpy

4.5 is a constant that adjusts for units

In other words, the coil provides 30,150 Btuh of total cooling capacity.

Sensible Heat Factor

If cooling is combined with dehumidification and a line is drawn showing the process, the air comes down the sloping line marked TOTAL HEAT. The amount of sensible heat and the amount of latent heat involved determines whether the line has a gentle slope or a steep slope. This combination of sensible and latent cooling occurs so frequently in air conditioning that the slope of this line has been named the sensible heat factor.

The mathematical definition of the sensible heat factor (SHF) is shown in Figure 33. If no latent heat change occurs, then the sensible heat factor is 1.0 and the line is horizontal - a pure sensible heat change process. If the sensible heat factor is 0.8, the line starts to slope. This means that 80 percent of the total heat change is sensible and 20 percent is latent. That is approximately the condition that exists in a department store air conditioning system. If the sensible heat factor is 0.7, the line is still steeper. This indicates more latent heat, or more water vapor change compared to sensible heat or temperature change. A system with this sensible heat factor would be used for a theater, church, or restaurant.

If the above process were reversed, it would be a heating and humidifying process. A heating coil to add sensible heat and a water spray to add humidity or latent heat could accomplish this.

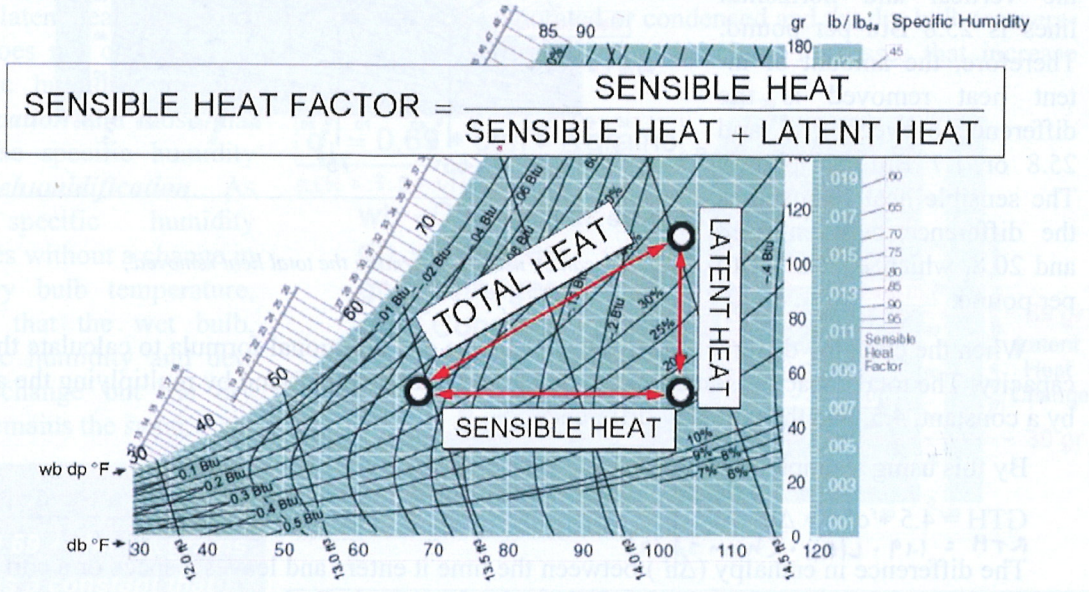


Figure 33

Sensible Heat Factor

For example, using the enthalpy calculated before, the total heat change is 6.7 Btu/lb, the sensible difference is 5 Btu/lb, and the latent difference is 1.7 Btu/lb. The SHF is then calculated by dividing the sensible heat difference by the total heat difference, which, in this example, is 0.75.

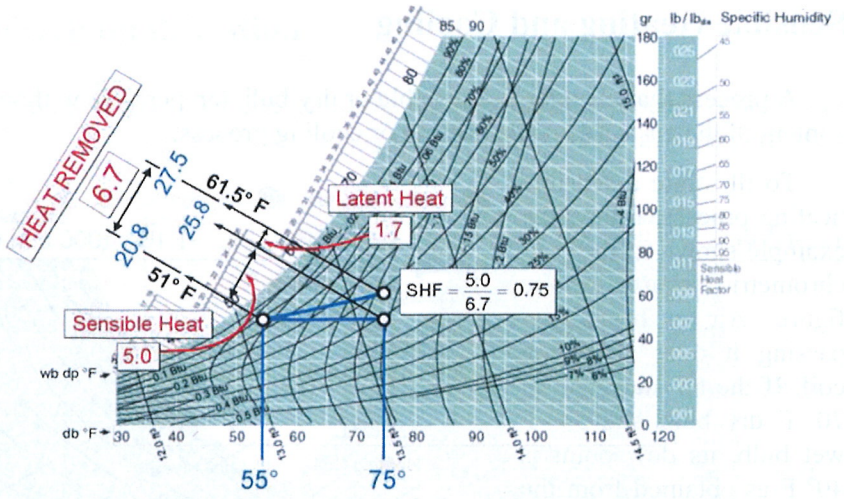


Figure 34

Example of Sensible Heat Factor Calculation

Sensible Heat Factor Scale

A convenient method for finding sensible heat can be found on the psychrometric chart. It is called the sensible heat factor scale. A small white circle printed on the chart at the 80° F dry bulb and the 50 percent relative humidity lines locates the pivot point of the scale.

To show the 0.90 sensible heat factor line for air at 75° F dry bulb and 60 grains of water vapor, take the following steps. First, get the slope of the 0.90 line by connecting 0.90 on the scale to the white circle. Draw a line parallel to this one passing through the air at 75° F and 60 grains. When the air is to be cooled and dehumidified, the apparatus dew point is found at the intersection of the sensible heat factor line and the saturation curve. In this case, it is 51° F. If the sensible heat factor is 0.80, the apparatus dew point, found by the same procedure, is 48° F.

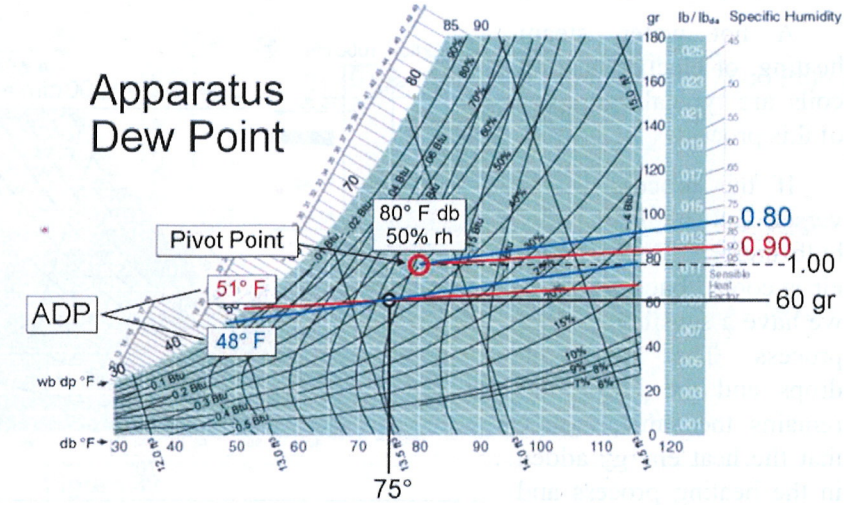


Figure 35

Use the sensible heat factor scale to find apparatus dew point.

The sensible heat factor is a very useful tool when making equipment selections. In combination with the psychrometric chart, it tells you the temperature at which the cooling coil must operate to handle the sensible and latent heat removal.

Sensible Heating and Cooling

A process that changes the sensible or dry bulb temperature without a change in the moisture content of the air is a sensible heating or cooling process.

To illustrate a sensible heating process, follow the example shown in the psychrometric chart in the figure. Air is heated by passing it over a heating coil. If the air starts out at 70° F dry bulb and 54° F wet bulb, its dew point is 40° F as obtained from the chart. After sensible heating to 100° F dry bulb, the dew point remains the same, because no water vapor has been added or condensed. The wet bulb temperature, however, has increased to 65° F. Also, notice that the relative humidity has decreased. This explains why relative humidity is high during early morning hours but decreases as the day gets warmer.

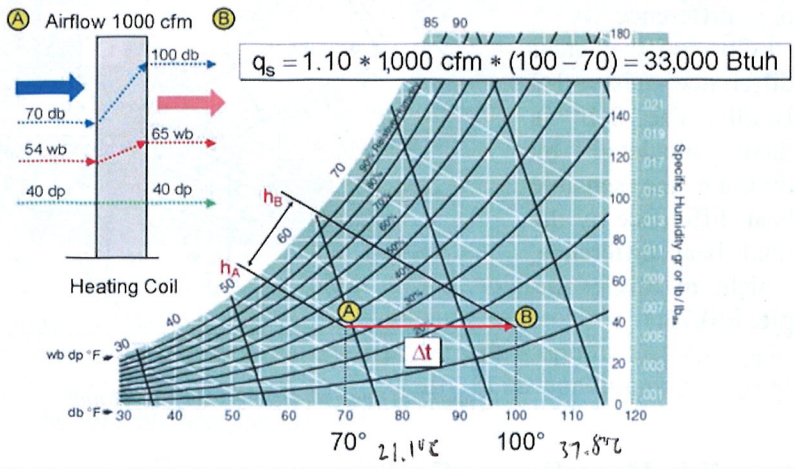


Figure 36

Sensible Heating Process

If the process airflow is 1000 cfm, the sensible heat equation can be used to determine the amount of heat that needs to be added to heat the air from 70° F to 100° F. In this example 33,000 Btuh of heat energy are required.

A hot water, steam heating, or electric heating coils are typical examples of this process.

If the process is reversed and the 100° F dry bulb and 40° F dew point air is cooled back to 70° F, we have a sensible cooling process. The wet bulb drops and the dew point remains the same. Notice that the heat energy added in the heating process and the heat energy subtracted cooling process are the same.

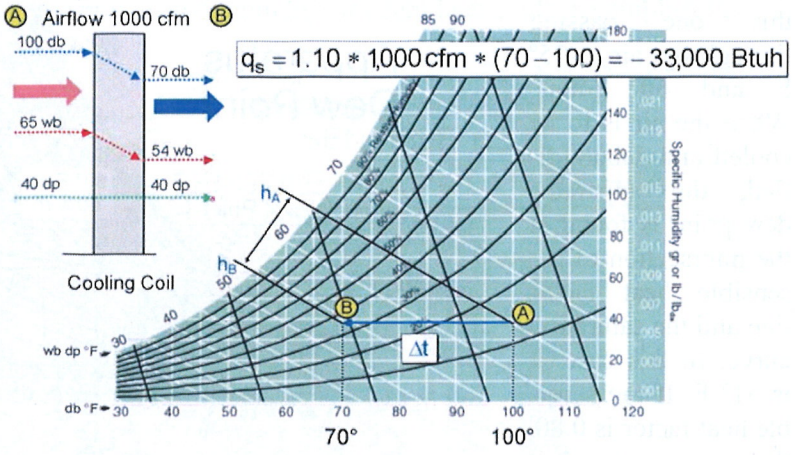


Figure 37

Sensible Cooling Process

The sensible cooling process often occurs when the surface temperature of a cooling coil is above the dew point.

Humidification and Dehumidification

When only moisture is removed with no change in the temperature, the process is dehumidification. In this example, 80° F air is entering and leaving the coil; the coil surface temperature is below the dew point of the air and moisture is removed. The dry bulb temperature remains the same and the wet bulb and dew point temperatures both decrease. The latent heat equation can be used with this example. It requires 27,600 Btuh of heat energy be removed to condense the 40 grains of moisture from the 1000 cfm of air.

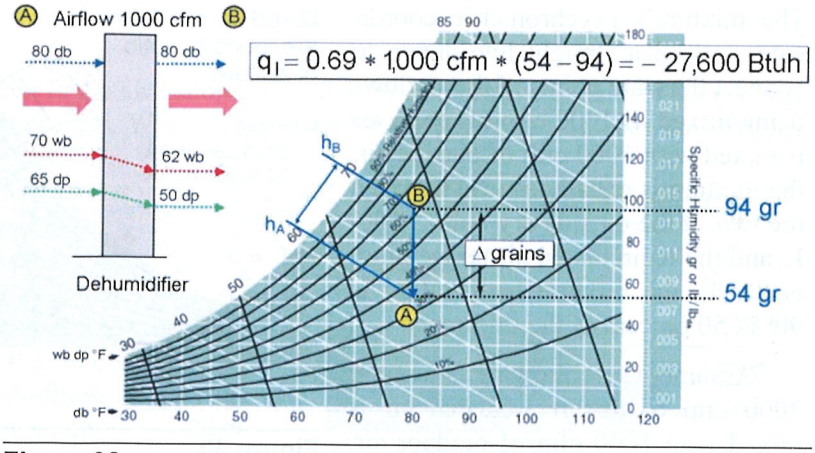


Figure 38

Dehumidification Process

This process is typical of what occurs with a dehumidifier some people use in a damp basement, during the summer. Removal of moisture only is not a common occurrence since most removal processes also tend to cool or heat the air as well.

If this process is reversed it is a humidification process. Sprays atomize water into the airstream to add moisture without affecting the dry bulb temperature. The latent heat equation can be used to determine how much heat energy must be added to convert the liquid water into water vapor without changing the temperature.

The humidification process is a typical air conditioning process, however, it is difficult to humidify without either cooling or heating the air as well.

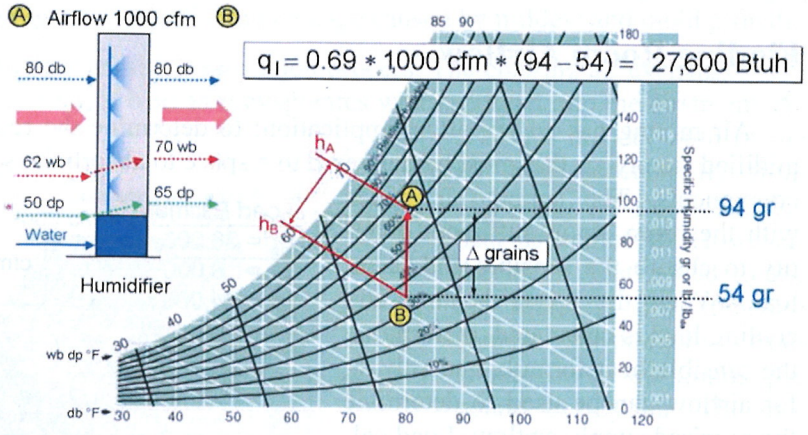


Figure 39

Humidification Process

Air Mixing

What happens when air at two different conditions is mixed? When recirculated room air is mixed with outdoor air, the mixture condition depends upon the conditions of the airstreams as they start out and the amount of each. The mixture's psychrometric coordinates fall on a straight line drawn to connect the state points of the airflows being mixed. If 1000 cfm of return air is mixed with 1000 cfm of outside air, the mixture is equally spaced between the two. If the outside dry bulb is 100° F, and the recirculated air temperature is 80° F, the mixture temperature is 90° F, 50 percent of the difference.

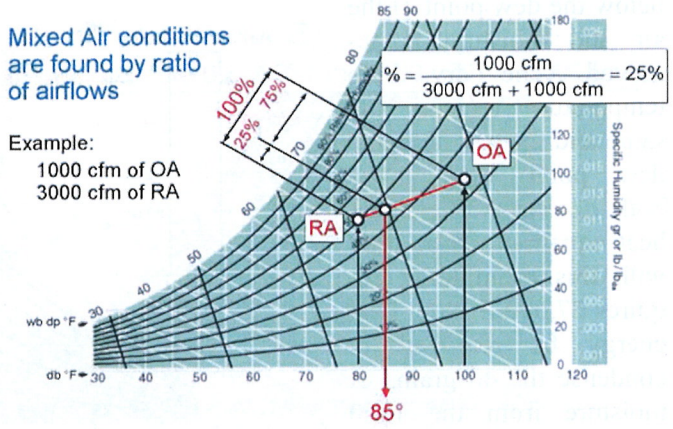


Figure 40

Mixing Return and Outdoor Air

Assume the following situation: 3000 cfm of this recirculated air is mixed with 1000 cfm of outdoor air. The mixture point ends up closer to the recirculated air's point because of the greater amount of recirculated air. Since, for all practical purposes the outdoor air represents 1/4 of the total volume of air, the mixture ends up at 1/4 the linear distance from the recirculated air's state point to the outdoor air's state point. The final temperature works out to be 85° F. Relative humidity, wet bulb temperature, grains of water vapor, and the mixture's dew point all can be found at the state point where 85° F meets the line connecting the return air and the outside air state points.

Finding Room Airflow

Air mixing has an important application: to determine the required quantity of cool, dehumidified supply air that must be delivered to a space to absorb the sensible and latent cooling load components. The supply air mixes with the room air in sufficient quantity to absorb the sensible and latent load. When the space heating and cooling load is calculated, rearranging the sensible heat formula and solving for airflow can be used to determine the required supply airflow. Load calculation programs yield three numbers: the sensible, latent, and total load requirements. The sensible load is used for determining the required room airflow. As long as the dew point is low enough the latent requirements will be met using the sensible load airflow.

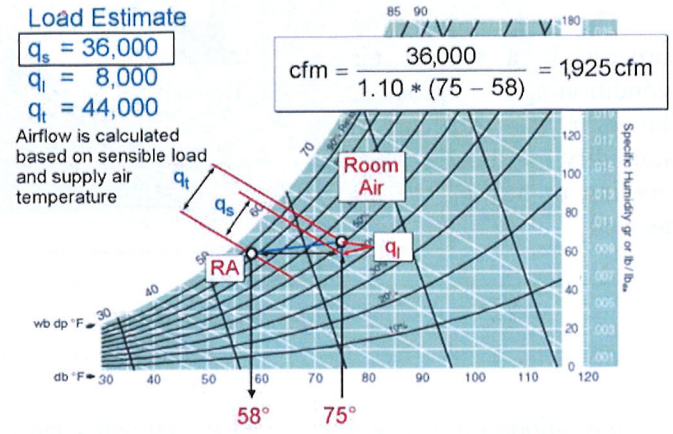


Figure 41

Calculating Room Airflow

An assumption needs to be made as to what the dry bulb temperature of the supply air will be in order to determine the supply airflow. In the example, a 58° F supply air temperature is assumed, which results in a required airflow of 1925 cfm.

Evaporative Cooling

Another process that is used in the air conditioning field is evaporative cooling. This is essentially the same as the wet bulb process. When the air goes through the spray, it loses sensible heat and picks up latent heat, thereby decreasing in dry bulb temperature and increasing in specific humidity. When no heat is added to or removed from the recirculated water, an ***adiabatic process*** is established, which is one where no heat enters or leaves the system. Therefore, the air condition moves up the wet bulb line at a constant enthalpy.

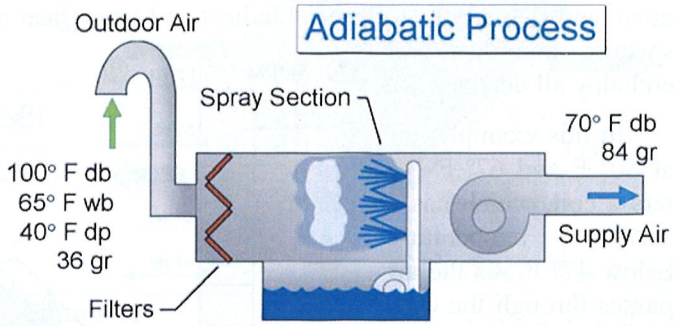


Figure 42

Evaporative Cooling with the Adiabatic Saturation Process

An example of evaporative cooling is the swamp cooler. It provides a crude but low-cost and simple means of using evaporative cooling to condition a space. The swamp cooler works best for arid climates, where substantial moisture can be added to the indoor air without creating excessive inside relative humidity. In addition, some applications require cooling with high humidity, such as the production areas of a textile mill. Overall, the swamp cooler has had limited success in residences because of the high humidity it produces, with the accompanying odor and building damage caused by mildew and mold growth.

The example shown follows the adiabatic saturation process. The entering air exchanges sensible heat for an equal amount of latent heat as it evaporates water sprayed into the airstream. As a result, the dry bulb of the air drops substantially, from 100° F to 70° F, as sensible heat is removed. However, the latent heat added to the air increases the moisture content substantially, from about 37 to 84 grains per pound of dry air. The distance the swamp cooler takes the entering air up the wet bulb line depends on the saturation efficiency of the spray section. In the example shown, it is 85.7 percent [(100° F - 70° F) / (100° F - 65° F)]. The greater the saturation efficiency, the lower

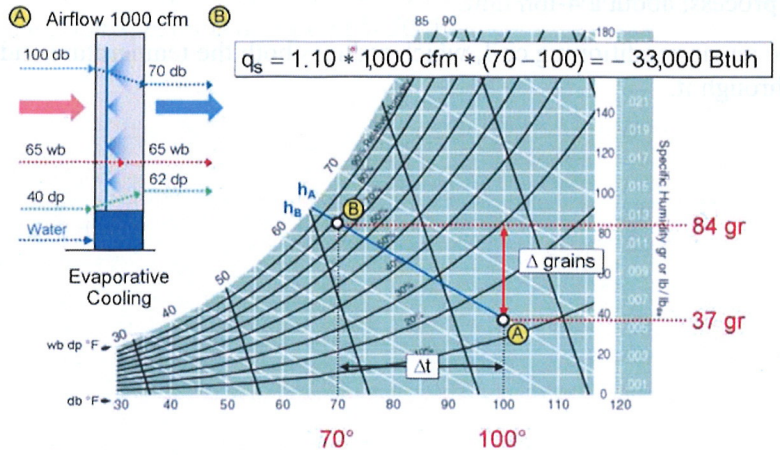


Figure 43

Evaporative Cooling Process

the leaving air dry bulb temperature, increasing sensible cooling capacity. Greater saturation efficiency also raises the leaving air specific humidity, increasing the latent cooling load added to the space. Since no heat is added or subtracted in the total process, the sensible heat loss is equal to the latent heat gain.

Cooling with Dehumidification

The sensible cooling process combined with the dehumidification is the process normally associated with air conditioning. This process is represented by diagonal movement on the chart, down and to the left. Both sensible heat and latent heat decrease. Dry bulb, wet bulb, dew point, specific humidity and enthalpy all decrease.

In this example, air at 80° F and 67° F enters a coil, which has a surface temperature below 47° F. As the air passes through the coil, the cold surface decreases the dry bulb temperature to 55° F. As the air reaches 100 percent saturation, the water vapor in the air condenses. The leaving air is at 51° F wet bulb and at 47° F dew point.

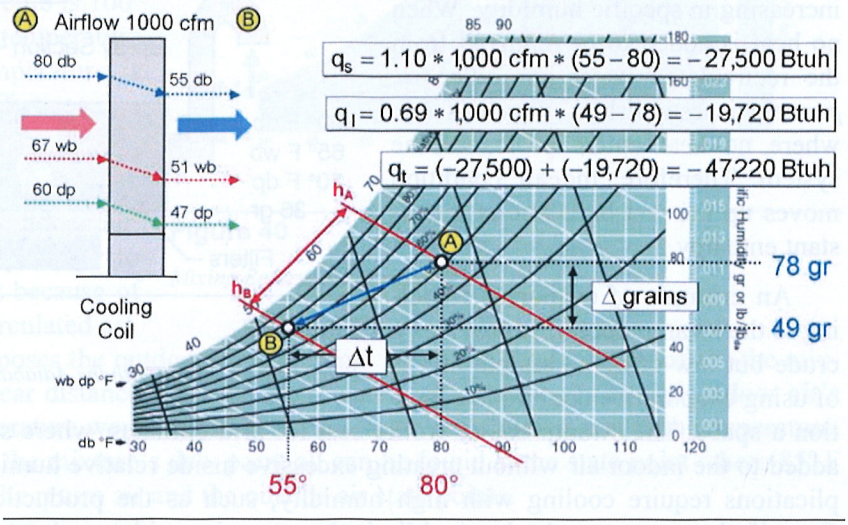


Figure 44

Cooling and Dehumidification Process

Both sensible and latent heat energy need to be removed. The sensible and latent heat formulas can be used to compute the total heat removal necessary. In this example, it required 47,220 Btuh of heat removal by the cooling coil for this cooling process, about a 4-ton unit.

An example of this would be an air conditioning coil, which reduces both the temperature and the moisture of the air passing through it.

Cooling Coils and the Bypass Factor

In order to understand the process of cooling and dehumidification it is necessary to understand cooling coils. Air cooling coils are multiple rows of copper tubes passing through either aluminum or copper fins. Performance is dependent on characteristics of the coil and the air passing through it. One important characteristic is the face area, which is the finned area length multiplied by height through which air flows. The coil face velocity is then the airflow through the coil divided by the face area. The other characteristics of the coil that influence performance are the number of rows of tubes in the airflow direction, the number of fins (fins/in.), and the temperature of the cooling fluid in the coil.

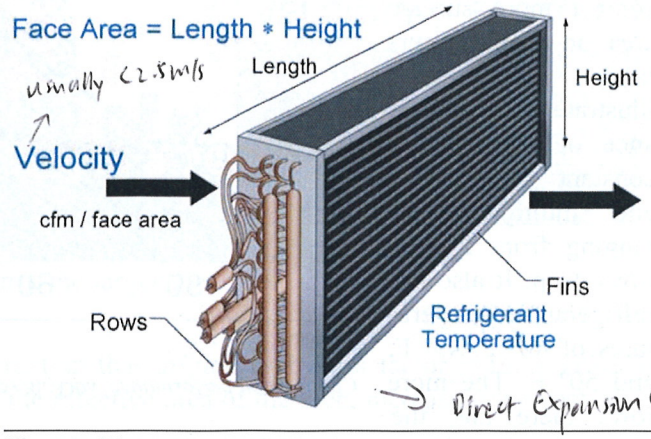


Figure 45

Characteristics of Cooling Coils

The mixing idea can be used to show how a cooling coil works. The figure illustrates one type of coil used for cooling and dehumidifying. Some of the air hits the tubes and some of it goes right through without hitting anything. The part that goes through freely is referred to as the bypass air, the remainder is the contact air. Let us assume that air enters the coil at 80° F dry bulb and 67° F wet bulb and that the coil surface temperature is 50° F. The air that hits the surface of the coil ends up saturated at a temperature of 50° F. The bypassed air is the same as when it started. After passing through the first row of tubes, the airstream is a mixture of bypassed and saturated conditions. If the bypass factor is 2/3 from this one-row coil, then the mixture is at 70° F, which is 2/3 the distance from the 50° F point to the 80° F point. If another row of cooling tubes is added, then less air bypasses the coil tubes. The bypass factor for the two-row coil might be close to 1/2. Air leaving the coil in this situation will be about 65° F. If a condition closer to saturation is required, more rows of tubes can be added. The name used for the coil's final average surface temperature is apparatus dew point. In the above case, the apparatus dew point is 50° F.

It is apparent that the number of rows and the temperature of the coil will change the coil performance by allowing the air to contact more surface area or a colder surface. The figure illustrates performance of a coil with constant air velocity and multiple rows ranging from 2 to 6 rows deep. It also has refrigerant temperatures of 40° F, 45° F, and 50° F. The more rows there are, the closer the coil comes to the saturation line, and the colder the refrigerant temperature the closer to saturation and with a lower leaving dew point temperature.

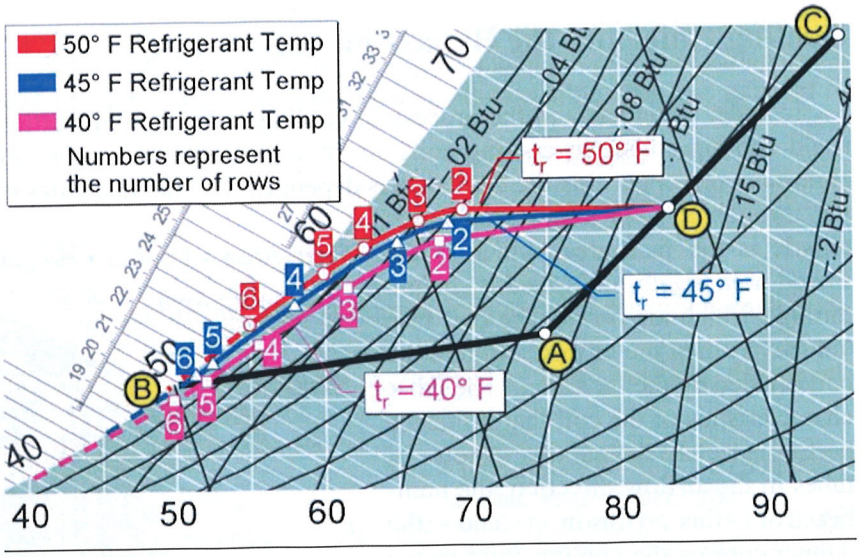


Figure 47

Cooling coil performance, varying rows and refrigerant temperature

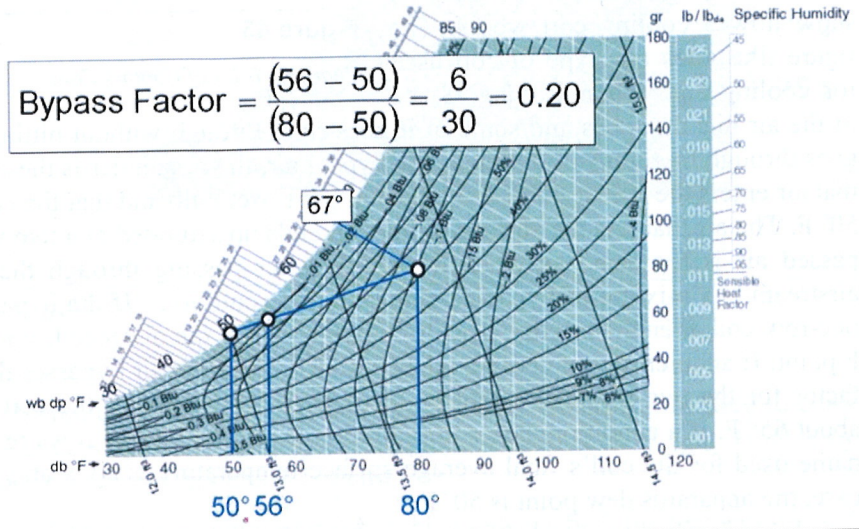


Figure 46

The bypass factor indicates coil performance.

The overall bypass factor for the complete cooling coil can be determined from the entering air conditions, leaving air conditions and the average surface temperature. In the example shown in the figure, the leaving air has a dry bulb temperature of 56° F. The overall bypass factor works out to be 0.20. The bypass factor for any coil depends upon the coil construction: that is, the number of tubes, size (face area), number of fins, and the tube and fin spacing.

One particular type of cooling coil shows the bypass values tabulated. Notice that each row added makes a smaller and smaller change in the bypass factor. Economically, it means that the sixth row of tubes in the coil is not as valuable as the second, third, or even fifth row.

ROWS	BYPASS FACTOR
2	0.31
3	0.18
4	0.10
5	0.06
6	0.03

Figure 48

Rows of Tubes and Bypass Factor

To lower the bypass factor:

Increase the number of rows of tubes
Increase the number of fins
Decrease the refrigerant temperature
Decrease the velocity

Another condition, affecting the bypass factor is the velocity of the air through the coil. This is shown in the table by some typical bypass factors for various velocities. It can be seen that if smaller quantities of air are used with any one coil, the velocity and consequently the bypass factor is reduced. So, for a given airflow (cfm), the larger the coil, the lower the bypass factor.

AIR VELOCITY	BYPASS FACTOR
300 fpm	0.11
400 fpm	0.14
500 fpm	0.18
600 fpm	0.20

Figure 49

Air Velocity and Bypass Factor

The final characteristic of coil construction that influences bypass factor is the number of fins. Fin surface on a tube act to increase the effective area of the tube, increasing the heat transfer effectiveness. In comfort cooling coils typical fin spacing ranges from 8 to 14 fins per inch of tube. As shown in the table the greater the fins per inch, the lower the bypass factor. Since cooling coils are a wetted surface, water is condensing on and running over the fin surface, the coil fin spacing above 14 fins results in poor water drainage and possible water blowing off the fin surface and into the ductwork.

FINS PER INCH	BYPASS FACTOR
8	0.31
12	0.18
14	0.03

LOWER BYPASS FACTORS RESULT FROM:

- **Larger number of rows**
- **Lower air velocity**
- **More fins**

Figure 50

Fin Spacing and Bypass Factor

Different types of equipment have different bypass factors. In some equipment the system designer has choices as to the rows, fins, or face area and in others, the designer of the equipment has made the decision. If the rows, fins and face area are locked in for a piece of equipment the only options left for the system designer are to change the refrigerant temperature or the velocity (airflow). The figure illustrates typical ranges of bypass factor (BF) for typical air conditioning products.

- Packaged Units to 20 Tons
  - Rows 2 to 4
  - BF 0.18 to 0.07
- Packaged Units over 20 Tons
  - Rows 3 to 6
  - BF 0.32 to 0.03
- Packaged Air Handlers
  - Rows 3 or 4
  - BF 0.12 to 0.03
- Air Handlers
  - Rows 3 to 10
  - BF 0.12 to 0.002

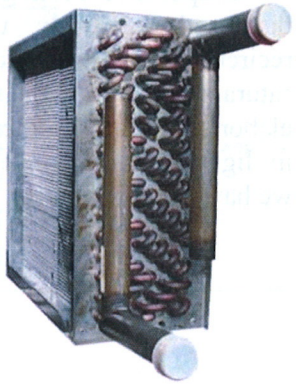


Figure 51

Typical Equipment Bypass Factors

How important is the bypass factor? Should it be high or low? There is no easy answer. Remember that a low coil bypass factor means a low air temperature leaving the coil.

The figure shows the impact of lower temperature supply air going to the room to pick up heat and water vapor, very much as a conveyor belt would do. For a 75° F room temperature, compare the heat absorbing capacity of the supply air at 55° F with air at 50° F.

The sensible heat pick up depends on the temperature difference, so the 50° F air with a 25° F difference can do a greater job than the 55° F air with only a 20° F difference. This is actually 25 percent greater, which means that it would take about 25 percent less air at 50° F to do the same job. Of course, this lower temperature obtained with a lower bypass factor would be desirable, for it would mean the possibility of smaller ducts to carry the air and a smaller fan and fan motor. Each would reduce the cost. However, there are some disadvantages too. To obtain the lower supply conditions may require the use of a larger cooling coil that would increase the initial cost. In addition, it may not be feasible to supply air at 50° F into a small room or office without causing discomfort. The limit of supply conditions depends upon how the air is brought in and the proximity of people to the outlets. For the most common applications of comfort air conditioning, on packaged products, cooling coils are three or four-row coils with bypass factors of 0.12 to 0.07.

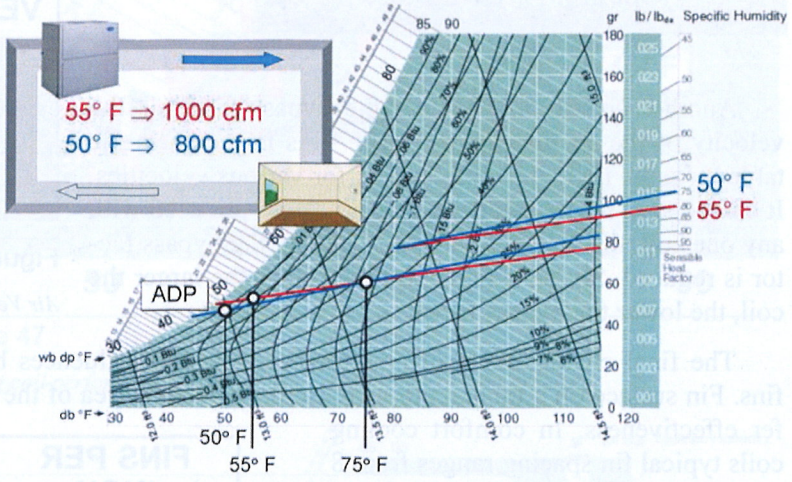


Figure 52

Example of Lower Supply Temperatures

Evaporative Cooling and Humidity Control

Evaporative cooling, as discussed previously, uses recirculating water sprays to saturate the air. We will elaborate on this principle in light of the knowledge we have acquired so far.

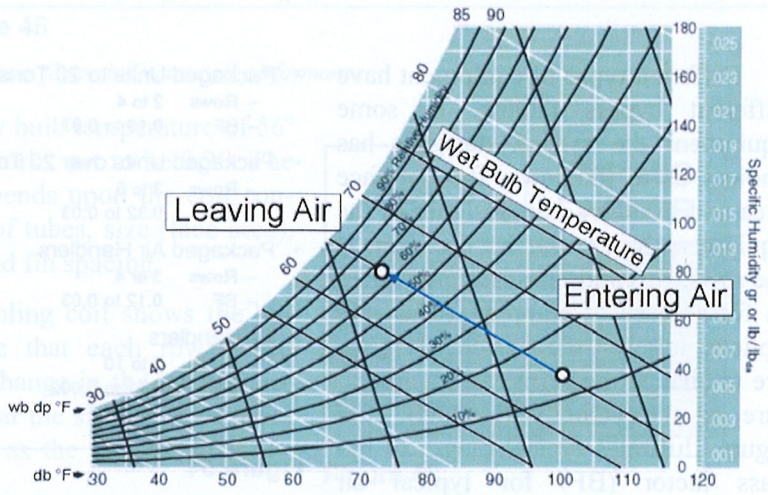


Figure 53

Evaporative Cooling Process

Assume that the temperature of the spray water and the leaving air is the same as the wet bulb temperature of the entering air. The air is cooled and humidified and becomes saturated at a temperature equal to the entering wet bulb. Figure 53 shows the way evaporative cooling appears on the psychrometric chart. The process takes place along the wet bulb line of the entering air and approaches the saturation line. The sensible heat given up is exactly equal to the latent heat required to saturate the air with moisture. If a continuous supply of spray water is available at a temperature below the dew point of the entering air, the air is cooled and dehumidified by the spray water. One way the spray water might be cooled below the dew point is by using a water chiller in a refrigeration system. Another method uses a cooling coil with recirculating water sprays. The water sprays improve the performance of the cooling coil during summer operation and provide close control of humidity as well as temperature. This process can be reversed in winter when it is desirable to heat and humidify the air. In this case, heat is added to the spray water to keep the wet bulb temperature of the leaving air above that of the entering air. The heated spray water is cooled, releasing heat and humidifying simultaneously.

A cooling tower acts as an evaporative cooler when the compression equipment is cycled off and there is no heat added to the condenser water loop by the condenser. Then the condenser water temperature entering and leaving the cooling tower will equalize, as shown here at 85° F. The tower will cool and saturate the air flowing through it just like the swamp cooler. In fact, under these zero-load conditions, with the condenser pump running, the psychrometric plot looks just the same as the swamp cooler.

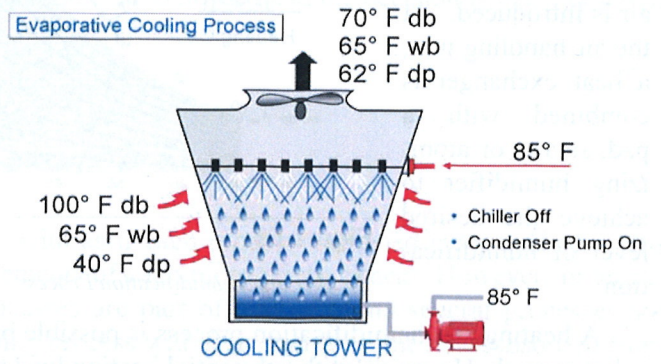


Figure 54

Cooling Tower – No Load

When operating with the compression equipment running, the cooling tower functions similar to an evaporative cooler with heat added to the spray water. The heat is added by the mechanical refrigeration system via the condenser. For example, when the outside air temperature is 100° F db and 65°F wb and the condenser water enters the tower at 95° F, a reasonable leaving air condition is 89° F db and 85° F wb. To accomplish this, the air passing through the tower has been greatly humidified, increasing in absolute humidity from 36 to 178 grains per pound of dry air. The outdoor air has also been slightly cooled, from 100° F to 89° F. At less than peak cooling conditions, as outside air dry bulb temperature drops, the outdoor air may increase somewhat in temperature rather than decreasing.

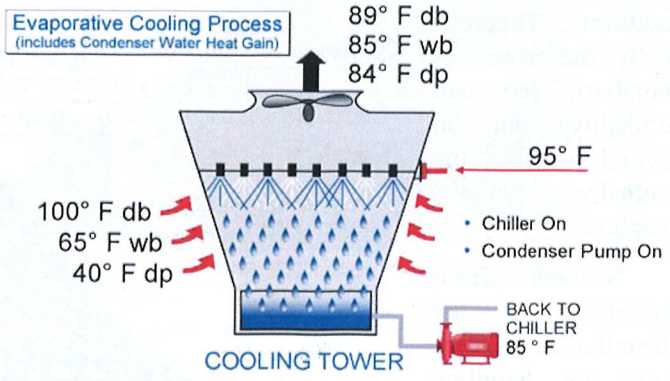


Figure 55

Cooling Tower – Peak Load

Heating and Humidification

The heating and humidification process is represented on the psychrometric chart as a diagonal line, moving up and to the right. Both the sensible heat and latent heat are increased. Dry bulb, wet bulb, dew point, specific humidity, and enthalpy all increase. Relative humidity may hold steady, decrease, or increase, depending on the amount of humidity added.

Heating and humidification is commonly practiced in comfort applications located in cold winter climates, particularly where outdoor ventilation air is introduced. At the air handling unit, a heat exchanger is combined with a pad, steam, or atomizing humidifier to achieve the desired level of humidification.

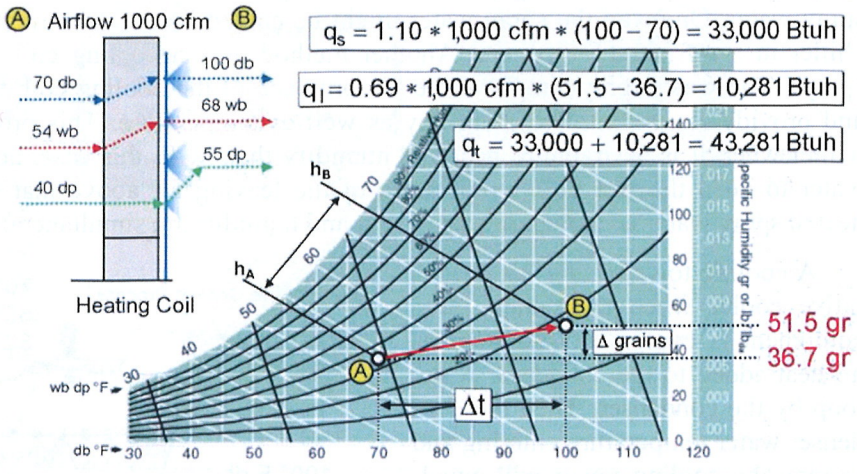


Figure 56

Heating and Humidification Process

A heating and humidification process is possible by use of hot water spray alone, if the water is hot enough. However, with substantial heating load this usually proves impractical.

Heating and Dehumidification

Heating and dehumidification, or sorbent dehumidification, is represented by diagonal movement on the chart, down and to the right. Latent heat is removed in exchange for a sensible heat addition. Theoretically, the process is adiabatic (constant enthalpy) but, in actual practice, the enthalpy climbs slightly.

Sorbent dehumidifiers are installed in the central air handling unit, and contain either a liquid absorbent, or a solid adsorbent, which is

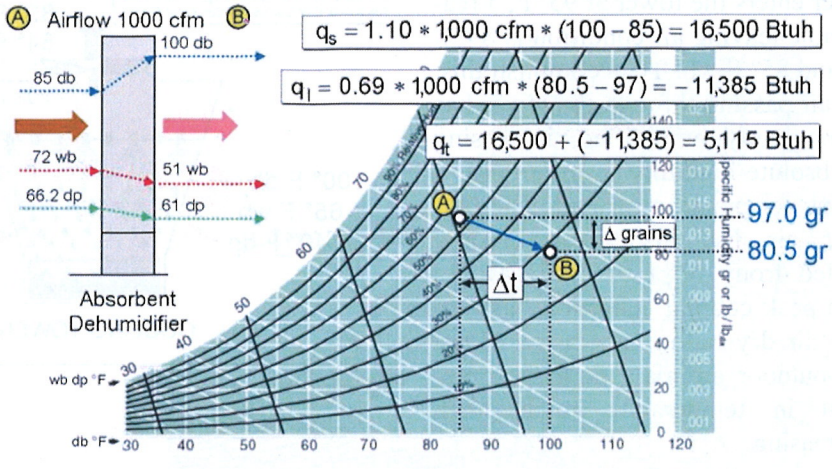


Figure 57

Heating and Dehumidification Process

exposed to the airstream. As the sorption process proceeds, the moisture in the air combines with the absorbent or adsorbent, condensing water from the air. As water is condensed, the latent heat of condensation is liberated, increasing the temperature of the airstream and the sorbent material.

The principles and processes discussed in the preceding two sections have identified how to find the properties of air and how the heat and moisture content change during air conditioning processes. These processes are all applied in products and applications regularly used in comfort air conditioning.

The principles of psychrometrics can be applied in another way. Temperature differences can be used when deciding whether to insulate ducts or whether to use more supply air. If 1000 cubic feet of air per minute at 55° F dry bulb temperature is needed to keep a room at 75° F, how much air is needed if the air temperature goes up to 57° F in an uninsulated duct before reaching the room?

The air has lost 2° F of the original 20° F temperature difference required to handle the sensible heat. This would indicate that 10 percent more air is needed and the decision is whether to use 1100 cfm or to insulate the duct.

Process Chart

Until now, processes have been dealt with as if each process happened independently. This concept is useful in evaluating the requirements of each piece of equipment. However, in an actual air conditioning application, the processes are part of a system and several processes are combined. In fact, the entire air conditioning process within a room from the heat Absorbed from the space, to the air delivered to the room, returned to the air conditioner, and then supplied back to the space is a system process.

It may be helpful to think of the process chart as following a molecule of air on its journey through the system. The process chart tracks the changes in state point conditions that occur in the air molecule as it undergoes each of the processes in the air conditioning system.

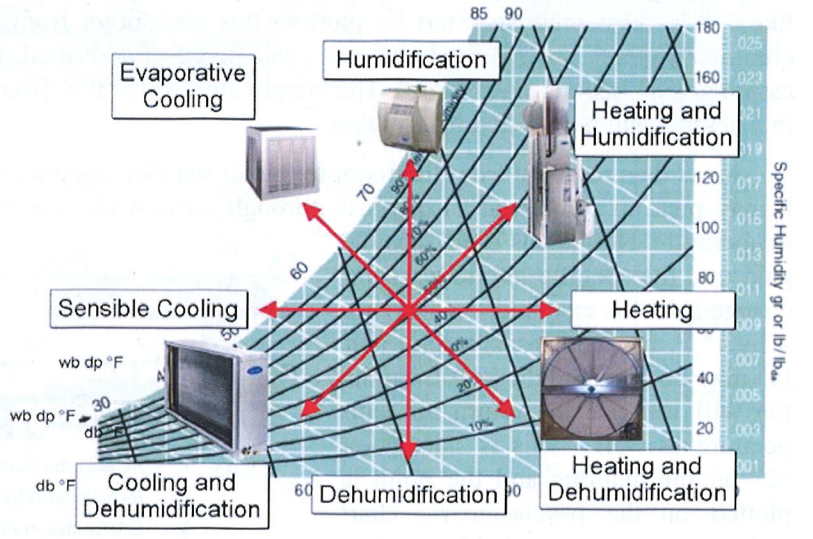


Figure 58

Process lines represent typical types of equipment.

It is advantageous to visualize this entire system of processes with a schematic diagram of the system and a system plot on a psychrometric chart. This diagram is sometimes referred to as an "H" diagram. This diagram, in conjunction with a system plot on the psychrometric chart, will be used in the next two modules to evaluate system performance.

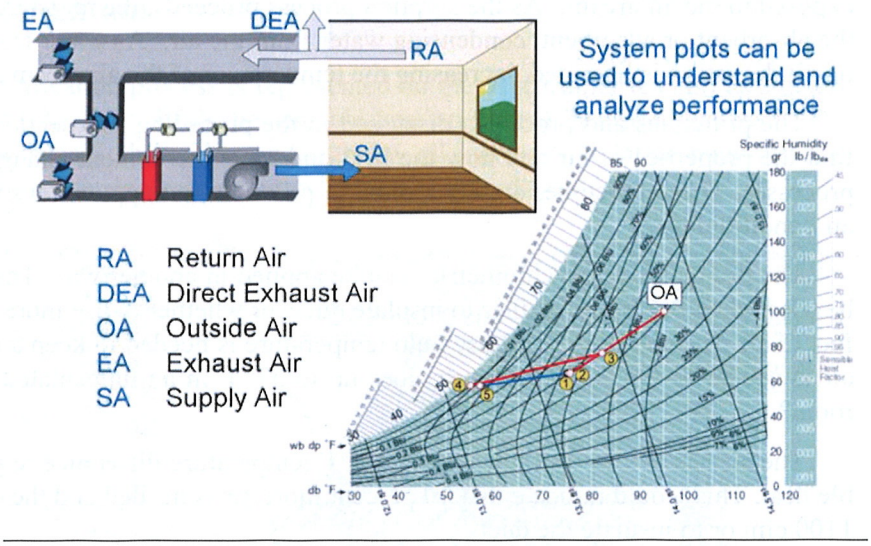


Figure 59

Visualize systems with an "H" diagram and a psychometric chart.

To see how processes work as a system, let's evaluate the basic room conditioning process. The air cycle of most commercial air conditioning systems has five process steps.

Starting in the room, a room control condition is generally assumed – normally something like 75° F, 50 percent rh. Start by plotting this state point from the diagram, "1," on the psychrometric chart. The required airflow is calculated as described, from the load estimate and the assumed supplied air temperature. The supply air absorbs the space sensible and latent heat loads in a heating and humidification process.

Air is then returned from the room to the air handler. As the air passes through the ductwork, it may pick up some heat as it passes through areas where the temperature is above return air temperature. Notice this is all-sensible gain and the specific humidity is unchanged. In this example, we increase it by 1° F. In some cases, a return air fan may be used and the heat from the fan will increase the return air temperature as well. This is state point "2" on the diagram and the point is plotted on the psychrometric chart and a process line, sensible heating, connects point "1" to point "2."

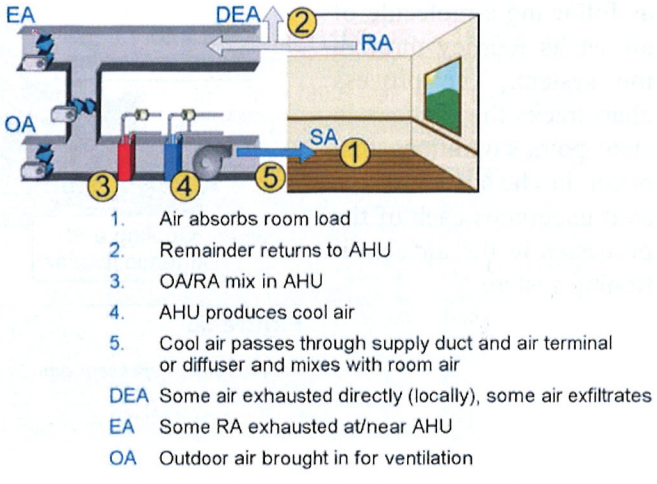


Figure 60

The complete air cycle is shown on an H diagram.

Outdoor air is required for ventilation of the space and it is common practice in air conditioning systems to mix the return air and outdoor air as they enter the air handler. A portion of the return air is exhausted so that the return air and ventilation air equal 100 percent of the required airflow. In this case, we have 20 percent of the airflow that must be outdoor air to provide ventilation. The outdoor air condition can be plotted, state point "OA."

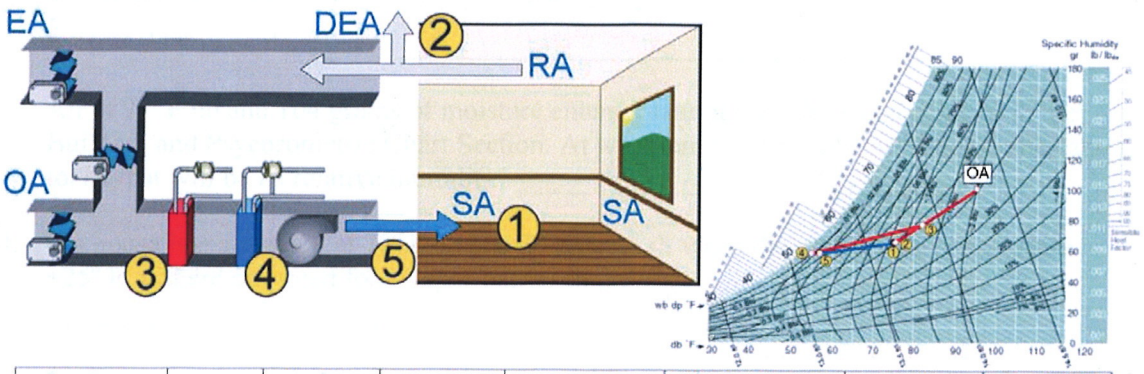
For this example, the outside air condition is 95° F dry bulb and 76° F wet bulb. Using the mixing equations, we can determine the condition of the mixed air, state point "3." This process results in heating and humidification of the return airstream.

Next, a cooling coil cools the air. If the ADP and bypass factor of the equipment are assumed the condition of the air leaving the coiling coil is determined. This is the cooling and dehumidification process. This occurs at state point "4" on our system plot.

Air then passes through a fan, at state point "5," and the heat from the fan increases the temperature, once again, this is a sensible heating process.

The air is again supplied to the space and it absorbs the heat and moisture that are added to the air by people, lights, process, and solar and transmission gains.

The resulting conditions are back at the room condition state point "1."



Dry Bulb (°F)	Airflow	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Humidity (%)	Humidity Ratio (gr/lb)	Enthalpy (Btu/lb)	Dew Point (°F)
Outdoor Air	600	90.4	72.8	43.3	93.35	36.38	65.1
Room Air	2658	75.0	62.5	50.0	64.92	28.15	55.1
Return Air	2058	78.3	63.7	44.8	64.92	28.95	55.1
Mixed Air	2658	81.0	65.9	45.0	71.34	30.63	57.7
Coil	2658	57.3	56.1	93.0	65.37	23.90	55.3
Supply	2658	58.0	56.4	90.7	65.37	24.07	55.3
Room	2658	75.0	62.5	50.0	64.92	28.15	55.1

Figure 61

Complete System Plot

This combination of an H diagram and a psychrometric chart system plot can be a powerful tool to evaluate system performance. As is evident from this discussion many assumptions about conditions at state points in the system are made based on the system configuration and capability. In the next modules, we use this approach to describe how changes in these characteristics will influence the system operation and conditions.

Summary

This module explained how atmospheric air is a mixture of gases, most importantly a compound mixture of dry air and water vapor, and how a graph, the psychrometric chart, can be used to determine the properties of the mixture. The module also described how psychrometrics is used to determine the air properties, load, and flow requirements of eight basic air conditioning processes. This information is a good start to understanding psychrometric calculations used in load estimating and equipment selection.

The next module develops further how to apply processes together into systems. If you wish to delve deeper into the development of the formula and the psychrometric chart, refer to the fourth module, Psychometrics, Level 4: Theory.

The principles discussed in this TDP module have many practical applications in the air conditioning industry. Review the five practical applications of psychrometrics presented previously, you should now be able to apply psychrometrics to all these situations. The second work session that follows is a good test of your grasp of the introductory concepts of psychrometrics. Psychrometrics is the backbone of air conditioning, and a thorough knowledge of the psychrometric chart is useful for efficient and economical air conditioning design.

Work Session 1

2. Using your psychrometric chart, find the proper values needed to fill in the blank spaces.

	db	wb	% rh	dp	W
A	75	65			
B	75		40		
C	75				80
D		65		55	
E		65	30		
F			30	55	

W = specific humidity, lb/lb of dry air

2. An air duct having a surface temperature of 60° F passes through a space at 90° F db and 75 wb.

   a. Will the duct sweat? Yes _____ No _____

   b. How do you explain this? _____

3. Air at 95° F db and 104 grains of moisture enters a saturator as shown on page 10 in the Building and Psychrometric Chart Section. At what temperature will the air leave the saturator? What will be its relative humidity? _____

4. If a house is maintained at 70° F db and 30 percent rh when the outdoor air temperature is +25° F, is there any need for a vapor barrier in the wall?

   _____

5. On a summer day at 7 a.m. the conditions outside are 70° F db and 80 percent rh. In mid-afternoon the outdoor temperature is 90° F db. If there has been no rain, what is the relative humidity when the db is 90° F? _____

6. The statement is made that the amount of water vapor needed to saturate a pound of air increases with the temperature of the air. How could you demonstrate this with the psychrometric chart?

   _____

   _____

   _____

7. The vapor in an air vapor mixture is saturated and there is 78 grains of moisture present.

   What is the db temperature? _____ ° F

   What is the wb temperature? _____ ° F

   What is the dp temperature? _____ ° F

Work Session 2

1. Air at 30° F db and 80 percent rh is sensibly heated to 75° F db by passing it over a heating coil. Show the process on a psychrometric chart and fill in the blank spaces below:

	db	wb	% rh	dp
Air at	30		80	
Heated to	75			

2. Air at 95° F db and 75° F wb is sensibly cooled to 80° F db by passing it over a cooling coil. Show the process on a psychrometric chart and fill in the blank spaces in the table below:

	db	wb	% rh	dp
Air at	95	75		
Cooled to	80			

3. Air at 80° F db and 50 percent rh is cooled and dehumidified to 50° F and 100 percent rh. How much sensible heat and latent heat is removed from 1000 cfm of this air?

   Sensible Heat Removed =1.10 *cfm * temperature change

   Latent Heat Removed =0.69 * cfm * grains of moisture removed

4. If 500 cfm of outdoor air at 96° F db and 76° F wb is mixed with 1500 cfm of return air at 80° F db and 50 percent rh, find the following properties of the mixture:

   a. Dry bulb _____ ° F
   b. Wet bulb _____ ° F
   c. Dew point _____ ° F
   d. Specific humidity _____ grains/lb.

5. Should the humidifier for a warm air furnace be located in the return air duct or in the warm air plenum or supply duct?

   Return Duct_____

   Supply Duct_____

   Explain why.

   _____

   _____

6. Air at 80° F db and 50 percent rh passes through a coil that has a bypass factor of 0.25 and is operating at 56° F apparatus dew point temperature. What will be the db and wb temperature of the air leaving the coil?

   db = _____ ° F wb = _____ ° F

7. What is the volume of one pound of dry air plus water vapor if its conditions are 95° F db and 75° F wb?

   v = _____ ft^3/lb dry air

8. Find the enthalpy of air whose dry bulb temperature is 76° F with 60 grains of moisture.
   _____ Btu/lb dry air

9. A room is maintained at 75° F db and 50 percent rh by air supplied from a cooling and dehumidifying coil whose leaving air temperature is 55° F db and 53° F wb. Find the sensible heat factor line along which the supply air is warming up. What percentage of the room load is sensible heat and what percentage is latent heat?

   SHF = _____
   % Sensible Heat = _____
   % Latent Heat = _____

Appendix

List of Symbols and Abbreviations

Symbols

cfm_{ba}	cfm of bypassed air, ft^3/m
cfm_{da}	cfm of dehumidified air, ft^3/m
cfm_{oa}	cfm of outdoor air, ft^3/m
cfm_{ra}	cfm of return air, ft^3/m
cfm_{sa}	cfm of supply air, ft^3/m
c_p	specific heat at constant pressure, Btu/lb * °F
c_{pa}	specific heat at constant pressure, air Btu/lb * °F
c_{pg}	specific heat at constant pressure, water Btu/lb * ° F
d	enthalpy deviation, Btu/lb
ρ	density, lb/ft^3
h_a	enthalpy of air, Btu/lb
h_{ADP}	enthalpy at ADP, Btu/lb
h_{ea}	entering air enthalpy, Btu/lb
h_{es}	enthalpy at effective surface temperature, Btu/lb
h_f	enthalpy of saturated liquid, Btu/lb
h_{fg}	enthalpy of evaporation or condensation, Btu/lb
h_g	enthalpy of saturated water vapor, Btu/lb
h_{la}	leaving air enthalpy, Btu/lb
h_{ma}	mixed air enthalpy, Btu/lb
h_{oa}	outdoor air enthalpy, Btu/lb
h_{rm}	room air enthalpy, Btu/lb
h_s	enthalpy of saturated air at dry bulb temperature, t″, Btu/lb
h_s'	enthalpy of saturated air at wet bulb temperature, t′, Btu/lb
h_{sa}	supply air enthalpy, Btu/lb
p	barometric pressure, psia, psfa, in. Hg
p_a	pressure of dry air, and partial pressure of dry air, psia
p_g	partial pressure of water vapor corresponding to the dry bulb temperature, t, psia
p_g'	partial pressure of water vapor corresponding to the dew point temperature, t′, psia
p_g''	partial pressure of water vapor corresponding to the wet bulb temperature, t″, psia
q	heat added or removed, Btuh
q_l	latent heat added or removed, Btuh
q_s	sensible heat added or removed, Btuh
q_t	total heat added or removed, Btuh
R	universal gas constant, 1545.32 $(lb_f/ft^2) * ft^3/(lb_{mole} * °R)$
R_a	gas constant for dry air
θ	relative humidity, %
R_w	gas constant for water vapor
s	entropy, $Btu/lb_{da} * °F$
T	absolute temperature ° R (t + 460° F)
t	dry bulb temperature, °F
t′	wet bulb temperature, °F
t″	dew point temperature, °F
t_{ADP}	temperature ADP, °F
t_{edb}	temperature entering dry bulb, °F
t_{es}	temperature effective surface, °F
t_{ew}	temperature entering water, °F
t_{ewb}	temperature entering wet bulb, °F
t_{ldb}	temperature leaving dry bulb, °F
t_{lw}	temperature leaving water, °F
t_{lwb}	temperature leaving wet bulb, °F
t_{ma}	temperature mixed outdoor and return air dry bulb, °F
t_{oa}	temperature outdoor air dry bulb, °F
t_{rm}	temperature room air dry bulb, °F
t_{sa}	temperature supply air, °F
v_a	specific volume of air ft^3/lb
v_g	specific volume of air, water vapor, ft^3/lb
v_w	specific volume of water, ft^3/lb

W	specific humidity, moisture content, lb/lb_{da} or gr
w	weight (mass), lb
W_{ADP}	specific humidity at ADP, moisture content, lb/lb_{da} or gr
W_{ea}	specific humidity of entering air, moisture content, lb/lb_{da} or gr
W_{es}	specific humidity at effective surface temperature, moisture content, lb/lb_{da} or gr
W_{la}	specific humidity of leaving air, moisture content, lb/lb_{da} or gr
W_{ma}	specific humidity of mixed air, moisture content, lb/lb_{da} or gr
W_{oa}	specific humidity of outdoor air, moisture content, lb/lb_{da} or gr
W_{rm}	specific humidity of room air, moisture content, lb/lb_{da} or gr
W_s	moisture content saturated at the wet bulb temperature, t, lb/lb_{da} or gr
W_s'	moisture content saturated at the dry bulb temperature, t′, lb/lb_{da} or gr
W_{sa}	specific humidity of supply air, moisture content, lb/lb_{da} or gr
Δgr	moisture content difference, gr
Δh	enthalpy difference, Btu/lb
Δt	temperature difference, °F

Superscripts

( )′	values corresponding to the wet bulb temperature, t′
( )″	values corresponding to the dew point temperature, t″

Subscripts

a	dry air
ba	bypassed air conditions
da	dehumidified air conditions
ea	entering air conditions
es	effective surface
f	liquid water
fg	vaporization
g	saturated water
l	latent heat (used with q)
la	leaving air conditions
ma	mixed air conditions
oa	outdoor air conditions
p	constant pressure
r	room conditions
ra	return air conditions
s	saturated (used with h, p, t, W
s	sensible heat (used with q)
sa	supply air conditions
t	total heat (used with q)

Units

Btu	British thermal units
Btuh	British thermal units per hour
cfh	cubic feet per hour
cfm	cubic feet per minute
fpm	feet per minute
gpm	gallons per minute
gr	grains of moisture per pound of dry air
in. Hg	inches of mercury
lb	pounds
lb/lb_{da}	pounds of moisture per pound of dry air
psfa	pounds per square foot absolute
psia	pounds per square inch absolute

Abbreviations

ADP	apparatus dewpoint
BF	bypass factor
CF	contact factor
db	dry bulb
dp	dew point
ERLH	effective room latent heat, includes bypassed air latent
ERSH	effective room sensible heat, includes bypassed air sensible
ERTH	effective room total heat, included bypassed air sensible and latent
ESHF	effective room sensible heat factor
F	Fahrenheit degrees
R	Rankine degrees
rh	relative humidity
RLH	room latent heat
RSH	room sensible heat
RSHF	room sensible heat factor
RTH	room total heat
Sat. Eff.	saturation efficiency
SHF	sensible heat factor
wb	wet bulb

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
-80	0.000116	0.000236	0.01732	1953234	1953234	-193.50	1219.19	1025.69	-0.4067	3.2112	2.8045	-80
-79	0.000125	0.000254	0.01732	1814052	1814052	-193.11	1219.24	1026.13	-0.4056	3.2028	2.7972	-79
-78	0.000135	0.000275	0.01732	1685445	1685445	-192.71	1219.28	1026.57	-0.4046	3.1946	2.7900	-78
-77	0.000145	0.000296	0.01732	1566663	1566663	-192.31	1219.33	1027.02	-0.4036	3.1864	2.7828	-77
-76	0.000157	0.000319	0.01732	1456752	1456752	-191.92	1219.38	1027.46	-0.4025	3.1782	2.7757	-76
-75	0.000169	0.000344	0.01733	1355059	1355059	-191.52	1219.42	1027.90	-0.4015	3.1700	2.7685	-75
-74	0.000182	0.000371	0.01733	1260977	1260977	-191.12	1219.46	1028.34	-0.4005	3.1620	2.7615	-74
-73	0.000196	0.000399	0.01733	1173848	1173848	-190.72	1219.51	1028.79	-0.3994	3.1538	2.7544	-73
-72	0.000211	0.000430	0.01733	1093149	1093149	-190.32	1219.55	1029.23	-0.3984	3.1459	2.7475	-72
-71	0.000227	0.000463	0.01733	1018381	1018381	-189.92	1219.59	1029.67	-0.3974	3.1379	2.7405	-71
-70	0.000245	0.000498	0.01733	949067	949067	-189.52	1219.63	1030.11	-0.3963	3.1299	2.7336	-70
-69	0.000263	0.000536	0.01733	884803	884803	-189.11	1219.66	1030.55	-0.3953	3.1220	2.7267	-69
-68	0.000283	0.000576	0.01733	825187	825187	-188.71	1219.71	1031.00	-0.3943	3.1142	2.7199	-68
-67	0.000304	0.000619	0.01734	769864	769864	-188.30	1219.74	1031.44	-0.3932	3.1063	2.7131	-67
-66	0.000326	0.000664	0.01734	718508	718508	-187.90	1219.78	1031.88	-0.3922	3.0985	2.7063	-66
-65	0.000350	0.000714	0.01734	670800	670800	-187.49	1219.81	1032.32	-0.3912	3.0908	2.6996	-65
-64	0.000376	0.000766	0.01734	626503	626503	-187.08	1219.85	1032.77	-0.3901	3.0830	2.6929	-64
-63	0.000404	0.000822	0.01734	585316	585316	-186.67	1219.88	1033.21	-0.3891	3.0753	2.6862	-63
-62	0.000433	0.000882	0.01734	547041	547041	-186.26	1219.91	1033.65	-0.3881	3.0677	2.6796	-62
-61	0.000464	0.000945	0.01734	511446	511446	-185.85	1219.94	1034.09	-0.3870	3.0600	2.6730	-61
-60	0.000498	0.001013	0.01734	478317	478317	-185.44	1219.98	1034.54	-0.3860	3.0525	2.6665	-60
-59	0.000533	0.001086	0.01735	447495	447495	-185.03	1220.01	1034.98	-0.3850	3.0450	2.6600	-59
-58	0.000571	0.001163	0.01735	418803	418803	-184.61	1220.03	1035.42	-0.3839	3.0374	2.6535	-58
-57	0.000612	0.001246	0.01735	392068	392068	-184.20	1220.06	1035.86	-0.3829	3.0299	2.6470	-57
-56	0.000655	0.001333	0.01735	367172	367172	-183.78	1220.08	1036.30	-0.3819	3.0225	2.6406	-56
-55	0.000701	0.001427	0.01735	343970	343970	-183.37	1220.12	1036.75	-0.3808	3.0150	2.6342	-55
-54	0.000750	0.001526	0.01735	322336	322336	-182.95	1220.14	1037.19	-0.3798	3.0077	2.6279	-54
-53	0.000802	0.001632	0.01735	302157	302157	-182.53	1220.16	1037.63	-0.3788	3.0004	2.6216	-53
-52	0.000857	0.001745	0.01735	283335	283335	-182.11	1220.18	1038.07	-0.3778	2.9931	2.6153	-52
-51	0.000916	0.001865	0.01736	265773	265773	-181.69	1220.21	1038.52	-0.3767	2.9858	2.6091	-51
-50	0.000979	0.001992	0.01736	249381	249381	-181.27	1220.23	1038.96	-0.3757	2.9786	2.6029	-50
-49	0.001045	0.002128	0.01736	234067	234067	-180.85	1220.25	1039.40	-0.3747	2.9714	2.5967	-49
-48	0.001116	0.002272	0.01736	219766	219766	-180.42	1220.26	1039.84	-0.3736	2.9642	2.5906	-48
-47	0.001191	0.002425	0.01736	206398	206398	-180.00	1220.28	1040.28	-0.3726	2.9570	2.5844	-47
-46	0.001271	0.002587	0.01736	193909	193909	-179.57	1220.30	1040.73	-0.3716	2.9500	2.5784	-46
-45	0.001355	0.002760	0.01736	182231	182231	-179.14	1220.31	1041.17	-0.3705	2.9428	2.5723	-45
-44	0.001445	0.002943	0.01736	171304	171304	-178.72	1220.33	1041.61	-0.3695	2.9358	2.5663	-44
-43	0.001541	0.003137	0.01737	161084	161084	-178.29	1220.34	1042.05	-0.3685	2.9288	2.5603	-43
-42	0.001642	0.003343	0.01737	151518	151518	-177.86	1220.36	1042.50	-0.3675	2.9219	2.5544	-42
-41	0.001749	0.003562	0.01737	142566	142566	-177.43	1220.37	1042.94	-0.3664	2.9149	2.5485	-41
-40	0.001863	0.003793	0.01737	134176	134176	-177.00	1220.38	1043.38	-0.3654	2.9080	2.5426	-40
-39	0.001984	0.004039	0.01737	126322	126322	-176.57	1220.39	1043.82	-0.3644	2.9011	2.5367	-39
-38	0.002111	0.004299	0.01737	118959	118959	-176.13	1220.40	1044.27	-0.3633	2.8942	2.5309	-38
-37	0.002247	0.004575	0.01737	112058	112058	-175.70	1220.41	1044.71	-0.3623	2.8874	2.5251	-37
-36	0.002390	0.004866	0.01738	105592	105592	-175.26	1220.41	1045.15	-0.3613	2.8806	2.5193	-36

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
-35	0.002542	0.005175	0.01738	99522	99522	-174.83	1220.42	1045.59	-0.3603	2.8739	2.5136	-35
-34	0.002702	0.005502	0.01738	93828	93828	-174.39	1220.42	1046.03	-0.3592	2.8670	2.5078	-34
-33	0.002872	0.005848	0.01738	88489	88489	-173.95	1220.43	1046.48	-0.3582	2.8604	2.5022	-33
-32	0.003052	0.006213	0.01738	83474	83474	-173.51	1220.43	1046.92	-0.3572	2.8537	2.4965	-32
-31	0.003242	0.006600	0.01738	78763	78763	-173.07	1220.43	1047.36	-0.3561	2.8470	2.4909	-31
-30	0.003443	0.007009	0.01738	74341	74341	-172.63	1220.43	1047.80	-0.3551	2.8404	2.4853	-30
-29	0.003655	0.007441	0.01738	70187	70187	-172.19	1220.44	1048.25	-0.3541	2.8338	2.4797	-29
-28	0.003879	0.007898	0.01739	66282	66282	-171.74	1220.43	1048.69	-0.3531	2.8273	2.4742	-28
-27	0.004116	0.008380	0.01739	62613	62613	-171.30	1220.43	1049.13	-0.3520	2.8207	2.4687	-27
-26	0.004366	0.008890	0.01739	59161	59161	-170.86	1220.43	1049.57	-0.3510	2.8142	2.4632	-26
-25	0.004630	0.009428	0.01739	55915	55915	-170.41	1220.42	1050.01	-0.3500	2.8077	2.4577	-25
-24	0.004909	0.009995	0.01739	52861	52861	-169.96	1220.42	1050.46	-0.3489	2.8012	2.4523	-24
-23	0.005203	0.010594	0.01739	49986	49986	-169.51	1220.41	1050.90	-0.3479	2.7948	2.4469	-23
-22	0.005514	0.011226	0.01739	47281	47281	-169.07	1220.41	1051.34	-0.3469	2.7884	2.4415	-22
-21	0.005841	0.011892	0.01740	44733	44733	-168.62	1220.40	1051.78	-0.3459	2.7821	2.4362	-21
-20	0.006186	0.012595	0.01740	42333	42333	-168.16	1220.38	1052.22	-0.3448	2.7757	2.4309	-20
-19	0.006550	0.013336	0.01740	40073	40073	-167.71	1220.38	1052.67	-0.3438	2.7694	2.4256	-19
-18	0.006933	0.014117	0.01740	37943	37943	-167.26	1220.37	1053.11	-0.3428	2.7631	2.4203	-18
-17	0.007337	0.014939	0.01740	35934	35934	-166.81	1220.36	1053.55	-0.3418	2.7569	2.4151	-17
-16	0.007763	0.015806	0.01740	34041	34041	-166.35	1220.34	1053.99	-0.3407	2.7505	2.4098	-16
-15	0.008211	0.016718	0.01740	32256	32256	-165.90	1220.33	1054.43	-0.3397	2.7443	2.4046	-15
-14	0.008683	0.017678	0.01741	30572	30572	-165.44	1220.31	1054.87	-0.3387	2.7382	2.3995	-14
-13	0.009179	0.018689	0.01741	28983	28983	-164.98	1220.30	1055.32	-0.3377	2.7320	2.3943	-13
-12	0.009702	0.019753	0.01741	27483	27483	-164.52	1220.28	1055.76	-0.3366	2.7258	2.3892	-12
-11	0.010252	0.020873	0.01741	26067	26067	-164.06	1220.26	1056.20	-0.3356	2.7197	2.3841	-11
-10	0.010830	0.022050	0.01741	24730	24730	-163.60	1220.24	1056.64	-0.3346	2.7137	2.3791	-10
-9	0.011438	0.023288	0.01741	23467	23467	-163.14	1220.22	1057.08	-0.3335	2.7075	2.3740	-9
-8	0.012077	0.024590	0.01741	22274	22274	-162.68	1220.21	1057.53	-0.3325	2.7015	2.3690	-8
-7	0.012750	0.025958	0.01742	21147	21147	-162.21	1220.18	1057.97	-0.3315	2.6955	2.3640	-7
-6	0.013456	0.027396	0.01742	20081	20081	-161.75	1220.16	1058.41	-0.3305	2.6896	2.3591	-6
-5	0.014197	0.028906	0.01742	19074	19074	-161.28	1220.13	1058.85	-0.3294	2.6835	2.3541	-5
-4	0.014977	0.030493	0.01742	18121	18121	-160.82	1220.11	1059.29	-0.3284	2.6776	2.3492	-4
-3	0.015795	0.032159	0.01742	17220	17220	-160.35	1220.08	1059.73	-0.3274	2.6717	2.3443	-3
-2	0.016654	0.033908	0.01742	16367	16367	-159.88	1220.05	1060.17	-0.3264	2.6658	2.3394	-2
-1	0.017556	0.035744	0.01742	15561	15561	-159.41	1220.03	1060.62	-0.3253	2.6599	2.3346	-1
0	0.018502	0.037671	0.01743	14797	14797	-158.94	1220.00	1061.06	-0.3243	2.6541	2.3298	0
1	0.019495	0.039693	0.01743	14073	14073	-158.47	1219.97	1061.50	-0.3233	2.6482	2.3249	1
2	0.020537	0.041813	0.01743	13388	13388	-157.99	1219.93	1061.94	-0.3223	2.6425	2.3202	2
3	0.021629	0.044037	0.01743	12740	12740	-157.52	1219.90	1062.38	-0.3212	2.6366	2.3154	3
4	0.022774	0.046369	0.01743	12125	12125	-157.05	1219.87	1062.82	-0.3202	2.6309	2.3107	4
5	0.023975	0.048813	0.01743	11543	11543	-156.57	1219.83	1063.26	-0.3192	2.6252	2.3060	5
6	0.025233	0.051375	0.01743	10991	10991	-156.09	1219.79	1063.70	-0.3182	2.6195	2.3013	6
7	0.026552	0.054059	0.01744	10468	10468	-155.62	1219.76	1064.14	-0.3171	2.6137	2.2966	7
8	0.027933	0.056872	0.01744	9971	9971	-155.14	1219.72	1064.58	-0.3161	2.6081	2.2920	8
9	0.029379	0.059817	0.01744	9500	9500	-154.66	1219.69	1065.03	-0.3151	2.6024	2.2873	9
10	0.030894	0.062901	0.01744	9054	9054	-154.18	1219.65	1065.47	-0.3141	2.5968	2.2827	10
11	0.032480	0.066131	0.01744	8630	8630	-153.70	1219.61	1065.91	-0.3130	2.5912	2.2782	11
12	0.034140	0.069511	0.01744	8228	8228	-153.21	1219.56	1066.35	-0.3120	2.5856	2.2736	12
13	0.035878	0.073047	0.01745	7846	7846	-152.73	1219.52	1066.79	-0.3110	2.5801	2.2691	13
14	0.037696	0.076748	0.01745	7483	7483	-152.24	1219.47	1067.23	-0.3100	2.5745	2.2645	14

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
15	0.039597	0.080621	0.01745	7139	7139	-151.76	1219.43	1067.67	-0.3089	2.5689	2.2600	15
16	0.041587	0.084671	0.01745	6811	6811	-151.27	1219.38	1068.11	-0.3079	2.5635	2.2556	16
17	0.043666	0.088905	0.01745	6501	6501	-150.78	1219.33	1068.55	-0.3069	2.5580	2.2511	17
18	0.045841	0.093332	0.01745	6205	6205	-150.30	1219.29	1068.99	-0.3059	2.5526	2.2467	18
19	0.048113	0.097960	0.01745	5924	5924	-149.81	1219.24	1069.43	-0.3049	2.5472	2.2423	19
20	0.050489	0.102796	0.01746	5657	5657	-149.32	1219.19	1069.87	-0.3038	2.5417	2.2379	20
21	0.052970	0.107849	0.01746	5404	5404	-148.82	1219.13	1070.31	-0.3028	2.5363	2.2335	21
22	0.055563	0.113128	0.01746	5162	5162	-148.33	1219.08	1070.75	-0.3018	2.5310	2.2292	22
23	0.058271	0.118641	0.01746	4932	4932	-147.84	1219.03	1071.19	-0.3008	2.5256	2.2248	23
24	0.061099	0.124398	0.01746	4714	4714	-147.34	1218.97	1071.63	-0.2997	2.5202	2.2205	24
25	0.064051	0.130408	0.01746	4506	4506	-146.85	1218.92	1072.07	-0.2987	2.5149	2.2162	25
26	0.067133	0.136684	0.01747	4308	4308	-146.35	1218.85	1072.50	-0.2977	2.5096	2.2119	26
27	0.070349	0.143233	0.01747	4119	4119	-145.85	1218.79	1072.94	-0.2967	2.5044	2.2077	27
28	0.073706	0.150066	0.01747	3940	3940	-145.35	1218.73	1073.38	-0.2956	2.4991	2.2035	28
29	0.077207	0.157195	0.01747	3769	3769	-144.85	1218.67	1073.82	-0.2946	2.4938	2.1992	29
30	0.080860	0.164632	0.01747	3606	3606	-144.35	1218.61	1074.26	-0.2936	2.4887	2.1951	30
31	0.084669	0.172387	0.01747	3450	3450	-143.85	1218.55	1074.70	-0.2926	2.4835	2.1909	31
32	0.088640	0.180474	0.01747	3302	3302	-143.35	1218.49	1075.14	-0.2915	2.4782	2.1867	32
32	0.08865	0.18049	0.01602	3302.07	3302.09	-0.02	1075.16	1075.14	0.0000	2.1867	2.1867	32
33	0.09229	0.18791	0.01602	3178.14	3178.16	0.99	1074.59	1075.58	0.0020	2.1812	2.1832	33
34	0.09607	0.19559	0.01602	3059.47	3059.49	2.00	1074.01	1076.01	0.0041	2.1755	2.1796	34
35	0.09998	0.20355	0.01602	2945.66	2945.68	3.00	1073.45	1076.45	0.0061	2.1700	2.1761	35
36	0.10403	0.21180	0.01602	2836.59	2836.61	4.01	1072.88	1076.89	0.0081	2.1645	2.1726	36
37	0.10822	0.22035	0.01602	2732.13	2732.15	5.02	1072.31	1077.33	0.0102	2.1590	2.1692	37
38	0.11257	0.22919	0.01602	2631.87	2631.89	6.02	1071.75	1077.77	0.0122	2.1535	2.1657	38
39	0.11707	0.23835	0.01602	2535.86	2535.88	7.03	1071.18	1078.21	0.0142	2.1481	2.1623	39
40	0.12172	0.24783	0.01602	2443.67	2443.69	8.03	1070.62	1078.65	0.0162	2.1427	2.1589	40
41	0.12654	0.25765	0.01602	2355.22	2355.24	9.04	1070.05	1079.09	0.0182	2.1372	2.1554	41
42	0.13153	0.26780	0.01602	2270.41	2270.43	10.04	1069.48	1079.52	0.0202	2.1319	2.1521	42
43	0.13669	0.27831	0.01602	2189.02	2189.04	11.04	1068.92	1079.96	0.0222	2.1265	2.1487	43
44	0.14203	0.28918	0.01602	2110.92	2110.94	12.05	1068.35	1080.40	0.0242	2.1212	2.1454	44
45	0.14755	0.30042	0.01602	2035.90	2035.92	13.05	1067.79	1080.84	0.0262	2.0978	2.1240	45
46	0.15326	0.31205	0.01602	1963.85	1963.87	14.05	1067.23	1081.28	0.0282	2.1105	2.1387	46
47	0.15917	0.32407	0.01602	1894.71	1894.73	15.06	1066.65	1081.71	0.0302	2.1052	2.1354	47
48	0.16527	0.33650	0.01602	1828.28	1828.30	16.06	1066.09	1082.15	0.0321	2.1000	2.1321	48
49	0.17158	0.34935	0.01602	1764.44	1764.46	17.06	1065.53	1082.59	0.0341	2.0947	2.1288	49
50	0.17811	0.36263	0.01602	1703.18	1703.20	18.06	1064.97	1083.03	0.0361	2.0895	2.1256	50
51	0.18484	0.37635	0.01602	1644.24	1644.26	19.06	1064.40	1083.46	0.0381	2.0843	2.1224	51
52	0.19181	0.39053	0.01603	1587.63	1587.65	20.07	1063.83	1083.90	0.0400	2.0791	2.1191	52
53	0.19900	0.40516	0.01603	1533.22	1533.24	21.07	1063.27	1084.34	0.0420	2.0739	2.1159	53
54	0.20643	0.42029	0.01603	1480.89	1480.91	22.07	1062.70	1084.77	0.0439	2.0689	2.1128	54
55	0.21410	0.43591	0.01603	1430.60	1430.62	23.07	1062.14	1085.21	0.0459	2.0637	2.1096	55
56	0.22202	0.45204	0.01603	1382.19	1382.21	24.07	1061.58	1085.65	0.0478	2.0586	2.1064	56
57	0.23020	0.46869	0.01603	1335.65	1335.67	25.07	1061.01	1086.08	0.0497	2.0536	2.1033	57
58	0.23864	0.48588	0.01603	1290.85	1290.87	26.07	1060.45	1086.52	0.0517	2.0485	2.1002	58
59	0.24735	0.50362	0.01603	1247.76	1247.78	27.07	1059.89	1086.96	0.0536	2.0435	2.0971	59
60	0.25635	0.52192	0.01604	1206.30	1206.32	28.07	1059.32	1087.39	0.0555	2.0385	2.0940	60
61	0.26562	0.54081	0.01604	1166.38	1166.40	29.07	1058.76	1087.83	0.0575	2.0334	2.0909	61
62	0.27519	0.56029	0.01604	1127.93	1127.95	30.07	1058.20	1088.27	0.0594	2.0284	2.0878	62
63	0.28506	0.58039	0.01604	1090.94	1090.96	31.07	1057.63	1088.70	0.0613	2.0235	2.0848	63
64	0.29524	0.60112	0.01604	1055.31	1055.33	32.07	1057.07	1089.14	0.0632	2.0186	2.0818	64

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
65	0.30574	0.62249	0.01604	1020.98	1021.00	33.07	1056.50	1089.57	0.0651	2.0136	2.0787	65
66	0.31656	0.64452	0.01604	987.95	987.97	34.07	1055.94	1090.01	0.0670	2.0088	2.0758	66
67	0.32772	0.66724	0.01605	956.10	956.12	35.07	1055.37	1090.44	0.0689	2.0039	2.0728	67
68	0.33921	0.69065	0.01605	925.43	925.45	36.07	1054.81	1090.88	0.0708	1.9990	2.0698	68
69	0.35107	0.71478	0.01605	895.85	895.87	37.07	1054.24	1091.31	0.0727	1.9941	2.0668	69
70	0.36328	0.73964	0.01605	867.34	867.36	38.07	1053.68	1091.75	0.0746	1.9893	2.0639	70
71	0.37586	0.76526	0.01605	839.86	839.88	39.07	1053.11	1092.18	0.0765	1.9845	2.0610	71
72	0.38882	0.79164	0.01606	813.37	813.39	40.07	1052.54	1092.61	0.0783	1.9797	2.0580	72
73	0.40217	0.81883	0.01606	787.85	787.87	41.07	1051.98	1093.05	0.0802	1.9750	2.0552	73
74	0.41592	0.84682	0.01606	763.19	763.21	42.06	1051.42	1093.48	0.0821	1.9702	2.0523	74
75	0.43008	0.87564	0.01606	739.42	739.44	43.06	1050.86	1093.92	0.0840	1.9654	2.0494	75
76	0.44465	0.90532	0.01606	716.51	716.53	44.06	1050.29	1094.35	0.0858	1.9607	2.0465	76
77	0.45966	0.93587	0.01607	694.38	694.40	45.06	1049.72	1094.78	0.0877	1.9560	2.0437	77
78	0.47510	0.96732	0.01607	673.04	673.06	46.06	1049.16	1095.22	0.0896	1.9513	2.0409	78
79	0.49100	0.99968	0.01607	652.44	652.46	47.06	1048.59	1095.65	0.0914	1.9466	2.0380	79
80	0.50736	1.03298	0.01607	632.54	632.56	48.06	1048.02	1096.08	0.0933	1.9419	2.0352	80
81	0.52419	1.06725	0.01608	613.35	613.37	49.06	1047.45	1096.51	0.0951	1.9373	2.0324	81
82	0.54150	1.10250	0.01608	594.82	594.84	50.05	1019.90	1069.95	0.0970	1.9327	2.0297	82
83	0.55931	1.13877	0.01608	576.90	576.92	51.05	1046.33	1097.38	0.0988	1.9281	2.0269	83
84	0.57763	1.17606	0.01608	559.63	559.65	52.05	1045.76	1097.81	0.1006	1.9236	2.0242	84
85	0.59647	1.21442	0.01609	542.92	542.94	53.05	1045.19	1098.24	0.1025	1.9189	2.0214	85
86	0.61584	1.25385	0.01609	526.79	526.81	54.05	1044.62	1098.67	0.1043	1.9144	2.0187	86
87	0.63575	1.29440	0.01609	511.20	511.22	55.05	1044.06	1099.11	0.1061	1.9099	2.0160	87
88	0.65622	1.33608	0.01609	496.13	496.15	56.05	1043.49	1099.54	0.1080	1.9053	2.0133	88
89	0.67726	1.37892	0.01610	481.59	481.61	57.04	1042.93	1099.97	0.1098	1.9008	2.0106	89
90	0.69889	1.42295	0.01610	467.51	467.53	58.04	1042.36	1100.40	0.1116	1.8963	2.0079	90
91	0.72111	1.46820	0.01610	453.91	453.93	59.04	1041.79	1100.83	0.1134	1.8919	2.0053	91
92	0.74394	1.51468	0.01611	440.76	440.78	60.04	1041.22	1101.26	0.1152	1.8874	2.0026	92
93	0.76740	1.56244	0.01611	428.04	428.06	61.04	1040.65	1101.69	0.1170	1.8830	2.0000	93
94	0.79150	1.61151	0.01611	415.74	415.76	62.04	1040.08	1102.12	0.1188	1.8785	1.9973	94
95	0.81625	1.66189	0.01612	403.84	403.86	63.03	1039.52	1102.55	0.1206	1.8741	1.9947	95
96	0.84166	1.71364	0.01612	392.32	392.34	64.03	1038.95	1102.98	0.1224	1.8697	1.9921	96
97	0.86776	1.76678	0.01612	381.19	381.21	65.03	1038.38	1103.41	0.1242	1.8653	1.9895	97
98	0.89456	1.82134	0.01612	370.42	370.44	66.03	1037.81	1103.84	0.1260	1.8610	1.9870	98
99	0.92207	1.87736	0.01613	359.99	360.01	67.03	1037.23	1104.26	0.1278	1.8566	1.9844	99
100	0.95031	1.93485	0.01613	349.90	349.92	68.03	1036.66	1104.69	0.1296	1.8523	1.9819	100
101	0.97930	1.99387	0.01613	340.13	340.15	69.02	1036.10	1105.12	0.1314	1.8479	1.9793	101
102	1.00904	2.05443	0.01614	330.69	330.71	70.02	1035.53	1105.55	0.1332	1.8436	1.9768	102
103	1.03956	2.11667	0.01614	321.53	321.55	71.02	1034.96	1105.98	0.1349	1.8394	1.9743	103
104	1.07088	2.18034	0.01614	312.67	312.69	72.02	1034.38	1106.40	0.1367	1.8351	1.9718	104
105	1.10301	2.24575	0.01615	304.08	304.10	73.02	1033.81	1106.83	0.1385	1.8308	1.9693	105
106	1.13597	2.31285	0.01615	295.75	295.77	74.02	1033.24	1107.26	0.1402	1.8266	1.9668	106
107	1.16977	2.38168	0.01616	287.71	287.73	75.01	1032.67	1107.68	0.1420	1.8223	1.9643	107
108	1.20444	2.45226	0.01616	279.90	279.92	76.01	1032.10	1108.11	0.1438	1.8181	1.9619	108
109	1.23999	2.52464	0.01616	272.34	272.36	77.01	1031.53	1108.54	0.1455	1.8139	1.9594	109
110	1.27644	2.59885	0.01617	265.01	265.03	78.01	1030.95	1108.96	0.1473	1.8097	1.9570	110
111	1.31381	2.67494	0.01617	257.91	257.93	79.01	1030.38	1109.39	0.1490	1.8056	1.9546	111
112	1.35212	2.75293	0.01617	251.02	251.04	80.01	1029.80	1109.81	0.1508	1.8013	1.9521	112
113	1.39138	2.83288	0.01618	244.36	244.38	81.01	1029.23	1110.24	0.1525	1.7972	1.9497	113
114	1.43162	2.91481	0.01618	237.88	237.90	82.00	1028.66	1110.66	0.1543	1.7931	1.9474	114

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
115	1.47286	2.99878	0.01619	231.61	231.63	83.00	1028.09	1111.09	0.1560	1.7890	1.9450	115
116	1.51512	3.08481	0.01619	225.53	225.55	84.00	1027.51	1111.51	0.1577	1.7849	1.9426	116
117	1.55842	3.17296	0.01619	219.63	219.65	85.00	1026.93	1111.93	0.1595	1.7807	1.9402	117
118	1.60277	3.26327	0.01620	213.91	213.93	86.00	1026.36	1112.36	0.1612	1.7767	1.9379	118
119	1.64820	3.35577	0.01620	208.35	208.37	87.00	1025.78	1112.78	0.1629	1.7727	1.9356	119
120	1.69474	3.45052	0.01620	202.97	202.99	88.00	1025.20	1113.20	0.1647	1.7685	1.9332	120
121	1.74240	3.54755	0.01621	197.74	197.76	89.00	1024.62	1113.62	0.1664	1.7645	1.9309	121
122	1.79117	3.64691	0.01621	192.67	192.69	90.00	1024.05	1114.05	0.1681	1.7605	1.9286	122
123	1.84117	3.74863	0.01622	187.76	187.78	90.99	1023.48	1114.47	0.1698	1.7565	1.9263	123
124	1.89233	3.85282	0.01622	182.97	182.99	91.99	1022.90	1114.89	0.1715	1.7525	1.9240	124
125	1.94470	3.95945	0.01623	178.34	178.36	92.99	1022.32	1115.31	0.1732	1.7485	1.9217	125
126	1.99831	4.06860	0.01623	173.84	173.86	93.99	1021.74	1115.73	0.1749	1.7446	1.9195	126
127	2.05318	4.18032	0.01623	169.47	169.49	94.99	1021.16	1116.15	0.1766	1.7406	1.9172	127
128	2.10934	4.29465	0.01624	165.23	165.25	95.99	1020.58	1116.57	0.1783	1.7367	1.9150	128
129	2.16680	4.41165	0.01624	161.10	161.12	96.99	1020.00	1116.99	0.1800	1.7327	1.9127	129
130	2.22560	4.53136	0.01625	157.10	157.12	97.99	1019.42	1117.41	0.1817	1.7288	1.9105	130
131	2.28576	4.65384	0.01625	153.21	153.23	98.99	1018.84	1117.83	0.1834	1.7249	1.9083	131
132	2.34730	4.77914	0.01626	149.44	149.46	99.99	1018.26	1118.25	0.1851	1.7210	1.9061	132
133	2.41025	4.90730	0.01626	145.76	145.78	100.99	1017.68	1118.67	0.1868	1.7171	1.9039	133
134	2.47463	5.03839	0.01627	142.21	142.23	101.99	1017.09	1119.08	0.1885	1.7132	1.9017	134
135	2.54048	5.17246	0.01627	138.74	138.76	102.99	1016.51	1119.50	0.1902	1.7093	1.8995	135
136	2.60782	5.30956	0.01627	135.37	135.39	103.98	1015.94	1119.92	0.1919	1.7055	1.8974	136
137	2.67667	5.44975	0.01628	132.10	132.12	104.98	1015.36	1120.34	0.1935	1.7017	1.8952	137
138	2.74707	5.59308	0.01628	128.92	128.94	105.98	1014.77	1120.75	0.1952	1.6978	1.8930	138
139	2.81903	5.73961	0.01629	125.83	125.85	106.98	1014.19	1121.17	0.1969	1.6940	1.8909	139
140	2.89260	5.88939	0.01629	122.82	122.84	107.98	1013.60	1121.58	0.1985	1.6903	1.8888	140
141	2.96780	6.04250	0.01630	119.90	119.92	108.98	1013.02	1122.00	0.2002	1.6865	1.8867	141
142	3.04465	6.19897	0.01630	117.05	117.07	109.98	1012.43	1122.41	0.2019	1.6826	1.8845	142
143	3.12320	6.35888	0.01631	114.29	114.31	110.98	1011.85	1122.83	0.2035	1.6789	1.8824	143
144	3.20345	6.52229	0.01631	111.60	111.62	111.98	1011.26	1123.24	0.2052	1.6751	1.8803	144
145	3.28546	6.68926	0.01632	108.98	109.00	112.98	1010.68	1123.66	0.2068	1.6715	1.8783	145
146	3.36924	6.85984	0.01632	106.43	106.45	113.98	1010.09	1124.07	0.2085	1.6677	1.8762	146
147	3.45483	7.03410	0.01633	103.96	103.98	114.98	1009.50	1124.48	0.2101	1.6640	1.8741	147
148	3.54226	7.21211	0.01633	101.55	101.57	115.98	1008.91	1124.89	0.2118	1.6603	1.8721	148
149	3.63156	7.39393	0.01634	99.20	99.22	116.98	1008.33	1125.31	0.2134	1.6566	1.8700	149
150	3.72277	7.57962	0.01634	96.92	96.94	117.98	1007.74	1125.72	0.2151	1.6529	1.8680	150
151	3.81591	7.76925	0.01635	94.70	94.72	118.99	1007.14	1126.13	0.2167	1.6492	1.8659	151
152	3.91101	7.96289	0.01635	92.54	92.56	119.99	1006.55	1126.54	0.2184	1.6455	1.8639	152
153	4.00812	8.16061	0.01636	90.44	90.46	120.99	1005.96	1126.95	0.2200	1.6419	1.8619	153
154	4.10727	8.36247	0.01636	88.39	88.41	121.99	1005.37	1127.36	0.2216	1.6383	1.8599	154
155	4.20848	8.56854	0.01637	86.39	86.41	122.99	1004.78	1127.77	0.2233	1.6346	1.8579	155
156	4.31180	8.77890	0.01637	84.45	84.47	123.99	1004.19	1128.18	0.2249	1.6310	1.8559	156
157	4.41725	8.99360	0.01638	82.56	82.58	124.99	1003.60	1128.59	0.2265	1.6274	1.8539	157
158	4.52488	9.21274	0.01638	80.71	80.73	125.99	1003.00	1128.99	0.2281	1.6238	1.8519	158
159	4.63472	9.43637	0.01639	78.92	78.94	126.99	1002.41	1129.40	0.2297	1.6203	1.8500	159
160	4.74680	9.66460	0.01639	77.176	77.192	127.99	1001.82	1129.81	0.2314	1.6166	1.8480	160
161	4.86120	9.89740	0.01640	75.472	75.488	128.99	1001.23	1130.22	0.2330	1.6131	1.8461	161
162	4.97780	10.13500	0.01640	73.813	73.829	130.00	1000.62	1130.62	0.2346	1.6095	1.8441	162
163	5.09690	10.37740	0.01641	72.197	72.213	131.00	1000.03	1131.03	0.2362	1.6060	1.8422	163
164	5.21830	10.62460	0.01642	70.620	70.636	132.00	999.43	1131.43	0.2378	1.6025	1.8403	164

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
165	5.34220	10.87680	0.01642	69.085	69.101	133.00	998.84	1131.84	0.2394	1.5989	1.8383	165
166	5.46850	11.13400	0.01643	67.588	67.604	134.00	998.24	1132.24	0.2410	1.5954	1.8364	166
167	5.59740	11.39630	0.01643	66.130	66.146	135.00	997.64	1132.64	0.2426	1.5919	1.8345	167
168	5.72870	11.66380	0.01644	64.707	64.723	136.01	997.04	1133.05	0.2442	1.5884	1.8326	168
169	5.86270	11.93660	0.01644	63.320	63.336	137.01	996.44	1133.45	0.2458	1.5850	1.8308	169
170	5.99930	12.21480	0.01645	61.970	61.986	138.01	995.84	1133.85	0.2474	1.5815	1.8289	170
171	6.13860	12.49830	0.01646	60.650	60.666	139.01	995.24	1134.25	0.2490	1.5780	1.8270	171
172	6.28060	12.78740	0.01646	59.364	59.380	140.01	994.65	1134.66	0.2506	1.5745	1.8251	172
173	6.42530	13.08210	0.01647	58.112	58.128	141.02	994.04	1135.06	0.2521	1.5712	1.8233	173
174	6.57290	13.38250	0.01647	56.888	56.904	142.02	993.44	1135.46	0.2537	1.5677	1.8214	174
175	6.72320	13.68860	0.01648	55.695	55.711	143.02	992.84	1135.86	0.2553	1.5643	1.8196	175
176	6.87650	14.00060	0.01648	54.533	54.549	144.02	992.24	1136.26	0.2569	1.5609	1.8178	176
177	7.03270	14.31860	0.01649	53.398	53.414	145.03	991.62	1136.65	0.2585	1.5574	1.8159	177
178	7.19180	14.64260	0.01650	52.291	52.307	146.03	991.02	1137.05	0.2600	1.5541	1.8141	178
179	7.35390	14.97270	0.01650	51.210	51.226	147.03	990.42	1137.45	0.2616	1.5507	1.8123	179
180	7.51910	15.30910	0.01651	50.154	50.171	148.04	989.81	1137.85	0.2632	1.5473	1.8105	180
181	7.68740	15.65180	0.01651	49.126	49.143	149.04	989.20	1138.24	0.2647	1.5440	1.8087	181
182	7.85890	16.00080	0.01652	48.121	48.138	150.04	988.60	1138.64	0.2663	1.5406	1.8069	182
183	8.03350	16.35640	0.01653	47.141	47.158	151.05	987.98	1139.03	0.2679	1.5372	1.8051	183
184	8.21140	16.71850	0.01653	46.185	46.202	152.05	987.38	1139.43	0.2694	1.5340	1.8034	184
185	8.39260	17.08740	0.01654	45.250	45.267	153.05	986.77	1139.82	0.2710	1.5306	1.8016	185
186	8.57700	17.46300	0.01654	44.339	44.356	154.06	986.16	1140.22	0.2725	1.5273	1.7998	186
187	8.76490	17.84550	0.01655	43.448	43.465	155.06	985.55	1140.61	0.2741	1.5240	1.7981	187
188	8.95620	18.23500	0.01656	42.578	42.595	156.07	984.93	1141.00	0.2756	1.5207	1.7963	188
189	9.15100	18.63160	0.01656	41.729	41.746	157.07	984.32	1141.39	0.2772	1.5174	1.7946	189
190	9.34930	19.03530	0.01657	40.901	40.918	158.07	983.71	1141.78	0.2787	1.5142	1.7929	190
191	9.55120	19.44640	0.01658	40.091	40.108	159.08	983.10	1142.18	0.2803	1.5108	1.7911	191
192	9.75670	19.86480	0.01658	39.300	39.317	160.08	982.49	1142.57	0.2818	1.5076	1.7894	192
193	9.96590	20.29070	0.01659	38.527	38.544	161.09	981.86	1142.95	0.2834	1.5043	1.7877	193
194	10.17880	20.72420	0.01659	37.773	37.790	162.09	981.25	1143.34	0.2849	1.5011	1.7860	194
195	10.39550	21.16530	0.01660	37.035	37.052	163.10	980.63	1143.73	0.2864	1.4979	1.7843	195
196	10.61600	21.61430	0.01661	36.314	36.331	164.10	980.02	1144.12	0.2880	1.4946	1.7826	196
197	10.84040	22.07120	0.01661	35.611	35.628	165.11	979.40	1144.51	0.2895	1.4914	1.7809	197
198	11.06870	22.53610	0.01662	34.923	34.940	166.11	978.78	1144.89	0.2910	1.4882	1.7792	198
199	11.30100	23.00910	0.01663	34.251	34.268	167.12	978.16	1145.28	0.2926	1.4850	1.7776	199
200	11.53740	23.49040	0.01663	33.593	33.610	168.13	977.53	1145.66	0.2941	1.4818	1.7759	200
201	11.77790	23.98000	0.01664	32.951	32.968	169.13	976.92	1146.05	0.2956	1.4786	1.7742	201
202	12.02250	24.47800	0.01665	32.323	32.340	170.14	976.29	1146.43	0.2971	1.4755	1.7726	202
203	12.27130	24.98470	0.01665	31.709	31.726	171.14	975.67	1146.81	0.2986	1.4723	1.7709	203
204	12.52440	25.50000	0.01666	31.110	31.127	172.15	975.05	1147.20	0.3002	1.4691	1.7693	204
205	12.78190	26.02410	0.01667	30.523	30.540	173.16	974.42	1147.58	0.3017	1.4660	1.7677	205
206	13.04360	26.55710	0.01667	29.948	29.965	174.16	973.80	1147.96	0.3032	1.4628	1.7660	206
207	13.30990	27.09910	0.01668	29.387	29.404	175.17	973.17	1148.34	0.3047	1.4597	1.7644	207
208	13.58060	27.65030	0.01669	28.839	28.856	176.18	972.54	1148.72	0.3062	1.4566	1.7628	208
209	13.85580	28.21080	0.01669	28.302	28.319	177.18	971.92	1149.10	0.3077	1.4535	1.7612	209
210	14.13570	28.78060	0.01670	27.778	27.795	178.19	971.29	1149.48	0.3092	1.4504	1.7596	210
211	14.42265	29.36475	0.01671	27.271	27.288	179.20	970.66	1149.86	0.3107	1.4473	1.7580	211
212	14.70960	29.94890	0.01671	26.763	26.780	180.20	970.03	1150.23	0.3122	1.4442	1.7564	212
213	15.00605	30.55260	0.01672	26.277	26.294	181.21	969.40	1150.61	0.3137	1.4411	1.7548	213
214	15.30250	31.15630	0.01673	25.790	25.807	182.22	968.76	1150.98	0.3152	1.4380	1.7532	214

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
215	15.60885	31.77995	0.01674	25.326	25.343	183.23	968.13	1151.36	0.3167	1.4350	1.7517	215
216	15.91520	32.40360	0.01674	24.861	24.878	184.24	967.49	1151.73	0.3182	1.4319	1.7501	216
217	16.23155	33.04775	0.01675	24.416	24.433	185.25	966.86	1152.11	0.3197	1.4288	1.7485	217
218	16.54790	33.69190	0.01676	23.970	23.987	186.25	966.23	1152.48	0.3212	1.4257	1.7469	218
219	16.87460	34.35685	0.01677	23.544	23.561	187.26	965.59	1152.85	0.3227	1.4227	1.7454	219
220	17.20130	35.02180	0.01677	23.117	23.134	188.27	964.95	1153.22	0.3241	1.4197	1.7438	220
221	17.53860	35.70870	0.01678	22.708	22.725	189.28	964.31	1153.59	0.3256	1.4167	1.7423	221
222	17.87590	36.39560	0.01679	22.299	22.316	190.29	963.67	1153.96	0.3271	1.4136	1.7407	222
223	18.22400	37.10435	0.01680	21.908	21.925	191.30	963.03	1154.33	0.3286	1.4106	1.7392	223
224	18.57210	37.81310	0.01680	21.516	21.533	192.31	962.39	1154.70	0.3301	1.4076	1.7377	224
225	18.93130	38.54445	0.01681	21.141	21.158	193.32	961.75	1155.07	0.3316	1.4031	1.7362	225
226	19.29050	39.27580	0.01682	20.765	20.782	194.33	961.10	1155.43	0.3330	1.3986	1.7347	226
227	19.66105	40.03030	0.01683	20.405	20.422	195.34	960.46	1155.80	0.3345	1.3972	1.7332	227
228	20.03160	40.78480	0.01683	20.045	20.062	196.35	959.81	1156.16	0.3359	1.3957	1.7316	228
229	20.41385	41.56300	0.01684	19.700	19.717	197.36	959.17	1156.53	0.3374	1.3913	1.7302	229
230	20.79610	42.34120	0.01684	19.355	19.372	198.37	958.52	1156.89	0.3389	1.3868	1.7287	230
231	21.19020	43.14365	0.01685	19.024	19.041	199.38	957.88	1157.26	0.3404	1.3839	1.7272	231
232	21.58430	43.94610	0.01686	18.692	18.709	200.39	957.23	1157.62	0.3418	1.3809	1.7257	232
233	21.99065	44.77335	0.01687	18.374	18.391	201.40	956.58	1157.98	0.3433	1.3780	1.7242	233
234	22.39700	45.60060	0.01688	18.056	18.073	202.41	955.93	1158.34	0.3447	1.3751	1.7227	234
235	22.81575	46.45330	0.01689	17.751	17.768	203.43	955.28	1158.70	0.3462	1.3722	1.7213	235
236	23.23450	47.30600	0.01689	17.446	17.463	204.44	954.62	1159.06	0.3476	1.3693	1.7198	236
237	23.66610	48.18465	0.01690	17.153	17.170	205.45	953.97	1159.42	0.3491	1.3679	1.7184	237
238	24.09770	49.06330	0.01691	16.860	16.877	206.46	953.31	1159.77	0.3505	1.3664	1.7169	238
239	24.54230	49.96855	0.01692	16.579	16.596	207.48	952.65	1160.13	0.3520	1.3621	1.7155	239
240	24.98690	50.87380	0.01692	16.297	16.314	208.49	951.99	1160.48	0.3534	1.3577	1.7140	240
241	25.44485	51.80620	0.01693	16.027	16.044	209.50	951.34	1160.84	0.3549	1.3549	1.7126	241
242	25.90280	52.73860	0.01694	15.757	15.774	210.51	950.68	1161.19	0.3563	1.3520	1.7111	242
243	26.37445	53.69885	0.01695	15.498	15.515	211.53	950.02	1161.55	0.3578	1.3492	1.7097	243
244	26.84610	54.65910	0.01695	15.238	15.255	212.54	949.36	1161.90	0.3592	1.3463	1.7083	244
245	27.33165	55.64775	0.01696	14.989	15.006	213.56	948.70	1162.25	0.3607	1.3434	1.7069	245
246	27.81720	56.63640	0.01697	14.739	14.756	214.57	948.03	1162.60	0.3621	1.3405	1.7055	246
247	28.31705	57.65405	0.01698	14.499	14.516	215.59	947.36	1162.95	0.3635	1.3391	1.7041	247
248	28.81690	58.67170	0.01698	14.259	14.276	216.60	946.69	1163.29	0.3649	1.3377	1.7026	248
249	29.33130	59.71905	0.01699	14.029	14.046	217.62	946.03	1163.64	0.3664	1.3335	1.7012	249
250	29.84570	60.76640	0.01700	13.798	13.815	218.63	945.36	1163.99	0.3678	1.3293	1.6998	250
251	30.37500	61.84410	0.01701	13.576	13.594	219.65	944.69	1164.34	0.3692	1.3265	1.6985	251
252	30.90430	62.92180	0.01702	13.355	13.372	220.66	944.02	1164.68	0.3706	1.3237	1.6971	252
253	31.44885	64.03045	0.01703	13.141	13.159	221.68	943.35	1165.03	0.3721	1.3209	1.6957	253
254	31.99340	65.13910	0.01703	12.928	12.945	222.69	942.68	1165.37	0.3735	1.3181	1.6943	254
255	32.55345	66.27940	0.01704	12.714	12.732	223.71	942.01	1165.71	0.3749	1.3154	1.6930	255
256	33.11350	67.41970	0.01705	12.501	12.518	224.72	941.33	1166.05	0.3763	1.3126	1.6916	256
257	33.68940	68.59230	0.01706	12.312	12.329	225.74	940.65	1166.39	0.3778	1.3112	1.6903	257
258	34.26530	69.76490	0.01707	12.123	12.140	226.76	939.97	1166.73	0.3792	1.3097	1.6889	258
259	34.35745	70.97045	0.01708	11.932	11.950	227.78	939.29	1167.07	0.3806	1.3056	1.6876	259
260	34.44960	72.17600	0.01708	11.742	11.759	228.79	938.61	1167.40	0.3820	1.3015	1.6862	260
261	35.55825	73.41525	0.01709	11.559	11.576	229.81	937.93	1167.74	0.3834	1.2988	1.6849	261
262	36.66690	74.65450	0.01710	11.376	11.393	230.83	937.25	1168.08	0.3848	1.2960	1.6835	262
263	37.29245	75.92810	0.01711	11.200	11.217	231.85	936.56	1168.41	0.3862	1.2933	1.6822	263
264	37.91800	77.20170	0.01712	11.024	11.041	232.87	935.87	1168.74	0.3876	1.2905	1.6808	264

Thermodynamic Properties of Water At Saturation: U.S. Units

TEMP °F	ABSOLUTE PRESSURE psi	ABSOLUTE PRESSURE in. Hg	SPECIFIC VOLUME (ft^3/lb) Sat. Liquid v_f	SPECIFIC VOLUME (ft^3/lb) Evap. v_{fg}	SPECIFIC VOLUME (ft^3/lb) Sat. Vapor v_g	ENTHALPY (Btu/lb) Sat. Liquid h_f	ENTHALPY (Btu/lb) Evap. h_{fg}	ENTHALPY (Btu/lb) Sat. Vapor h_g	ENTROPY (Btu/lba/°F) Sat. Liquid s_f	ENTROPY (Btu/lba/°F) Evap. s_{fg}	ENTROPY (Btu/lba/°F) Sat. Vapor s_g	TEMP °F
265	38.56075	78.51035	0.01713	10.854	10.871	233.89	935.19	1169.08	0.3890	1.2878	1.6795	265
266	39.20350	79.81900	0.01714	10.684	10.701	234.90	934.51	1169.41	0.3904	1.2851	1.6781	266
267	39.86380	81.16340	0.01715	10.520	10.538	235.92	933.82	1169.74	0.3918	1.2837	1.6768	267
268	40.52410	82.50780	0.01715	10.357	10.374	236.94	933.13	1170.07	0.3932	1.2823	1.6755	268
269	41.20235	83.88875	0.01716	10.199	10.217	237.96	932.44	1170.40	0.3946	1.2783	1.6742	269
270	41.88060	85.26970	0.01717	10.042	10.059	238.98	931.74	1170.72	0.3960	1.2743	1.6729	270
271	42.57710	86.68780	0.01718	9.890	9.907	240.01	931.05	1171.05	0.3974	1.2716	1.6716	271
272	43.27360	88.10590	0.01719	9.738	9.755	241.03	930.35	1171.38	0.3988	1.2689	1.6703	272
273	43.98880	89.56200	0.01720	9.591	9.609	242.05	929.65	1171.70	0.4002	1.2662	1.6690	273
274	44.70400	91.01810	0.01721	9.445	9.462	243.07	928.95	1172.02	0.4016	1.2635	1.6677	274
275	45.43815	92.51285	0.01722	9.303	9.321	244.09	928.26	1172.35	0.4030	1.2609	1.6664	275
276	46.17230	94.00760	0.01722	9.162	9.179	245.11	927.56	1172.67	0.4044	1.2582	1.6651	276
277	46.92585	95.54185	0.01723	9.026	9.043	246.14	926.86	1172.99	0.4058	1.2569	1.6639	277
278	47.67940	97.07610	0.01724	8.890	8.907	247.16	926.15	1173.31	0.4071	1.2555	1.6626	278
279	48.45270	98.65055	0.01725	8.758	8.776	248.18	925.45	1173.63	0.4085	1.2516	1.6613	279
280	49.22600	100.22500	0.01726	8.627	8.644	249.20	924.74	1173.94	0.4099	1.2476	1.6600	280
281	50.01940	101.84040	0.01727	8.500	8.517	250.23	924.03	1174.26	0.4113	1.2450	1.6588	281
282	50.81280	103.45580	0.01728	8.373	8.390	251.25	923.32	1174.57	0.4127	1.2423	1.6575	282
283	51.62670	105.11295	0.01729	8.251	8.268	252.28	922.61	1174.89	0.4141	1.2397	1.6563	283
284	52.44060	106.77010	0.01730	8.129	8.146	253.30	921.90	1175.20	0.4154	1.2371	1.6550	284
285	53.27545	108.46980	0.01731	8.011	8.028	254.33	921.19	1175.51	0.4168	1.2345	1.6538	285
286	54.11030	110.16950	0.01731	7.893	7.910	255.35	920.47	1175.82	0.4182	1.2318	1.6525	286
287	54.96640	111.91255	0.01732	7.778	7.796	256.38	919.76	1176.13	0.4196	1.2305	1.6513	287
288	55.82250	113.65560	0.01733	7.664	7.681	257.40	919.04	1176.44	0.4209	1.2291	1.6500	288
289	56.70025	115.44275	0.01734	7.554	7.571	258.43	918.32	1176.75	0.4223	1.2253	1.6488	289
290	57.57800	117.22990	0.01735	7.444	7.461	259.45	917.60	1177.05	0.4236	1.2215	1.6476	290
291	58.47785	119.06200	0.01736	7.337	7.355	260.48	916.88	1177.36	0.4250	1.2189	1.6464	291
292	59.37770	120.89410	0.01737	7.231	7.248	261.51	916.15	1177.66	0.4264	1.2163	1.6451	292
293	60.30005	122.77195	0.01738	7.128	7.146	262.54	915.43	1177.96	0.4278	1.2137	1.6439	293
294	61.22240	124.64980	0.01739	7.026	7.043	263.56	914.70	1178.26	0.4291	1.2111	1.6427	294
295	62.16760	126.57425	0.01740	6.926	6.944	264.59	913.97	1178.56	0.4305	1.2086	1.6415	295
296	63.11280	128.49870	0.01741	6.827	6.844	265.62	913.24	1178.86	0.4318	1.2060	1.6402	296
297	64.08130	130.47060	0.01742	6.731	6.748	266.65	912.51	1179.16	0.4332	1.2035	1.6390	297
298	65.04980	132.44250	0.01743	6.635	6.652	267.68	911.77	1179.45	0.4345	1.2009	1.6378	298
299	66.04195	134.46260	0.01744	6.542	6.560	268.71	911.04	1179.75	0.4359	1.1996	1.6366	299
300	67.03410	136.48270	0.01745	6.450	6.467	269.74	910.30	1180.04	0.4372	1.1982	1.6354	300

Thermodynamic Properties of Moist Air: U.S. Units
(STANDARD ATMOSPHERIC PRESSURE, 29.921 in. Hg)

TEMP °F	w_s lbw/lba	VOLUME (ft^3/lb) Sat. Liquid v_a	Evap. v_{as}	Sat. Vapor v_s	ENTHALPY (Btu/lb) Sat. Liquid h_a	Evap. h_{as}	Sat. Vapor h_s	ENTROPY (Btu/lb_{da}/°F) Sat. Liquid s_a	Evap. s_{as}	Sat. Vapor s_s	CONDENSED WATER HW Btu/lb	Sw Btu/lb/°F	VAPOR PRESS. p_s in. Hg	TEMP °F
-80	0.0000049	9.553	0.000	9.553	-19.221	0.006	-19.215	-0.04594	0.00002	-0.04592	-193.45	-0.4067	0.000236	-80
-79	0.0000053	9.579	0.000	9.579	-18.980	0.005	-18.975	-0.04531	0.00002	-0.04529	-193.06	-0.4056	0.000255	-79
-78	0.0000057	9.604	0.000	9.604	-18.740	0.006	-18.734	-0.04468	0.00002	-0.04466	-192.66	-0.4046	0.000275	-78
-77	0.0000062	9.629	0.000	9.629	-18.500	0.007	-18.493	-0.04405	0.00002	-0.04403	-192.27	-0.4036	0.000296	-77
-76	0.0000067	9.655	0.000	9.655	-18.259	0.007	-18.252	-0.04342	0.00002	-0.04340	-191.87	-0.4025	0.000319	-76
-75	0.0000072	9.680	0.000	9.680	-18.019	0.008	-18.011	-0.04279	0.00002	-0.04277	-191.47	-0.4015	0.000344	-75
-74	0.0000078	9.705	0.000	9.705	-17.778	0.008	-17.770	-0.04217	0.00002	-0.04215	-191.07	-0.4005	0.000371	-74
-73	0.0000084	9.731	0.000	9.731	-17.538	0.009	-17.529	-0.04155	0.00003	-0.04152	-190.68	-0.3994	0.000400	-73
-72	0.0000090	9.756	0.000	9.756	-17.298	0.010	-17.288	-0.04093	0.00003	-0.04090	-190.27	-0.3984	0.000430	-72
-71	0.0000097	9.781	0.001	9.782	-17.057	0.010	-17.047	-0.04031	0.00003	-0.04028	-189.87	-0.3974	0.000463	-71
-70	0.0000104	9.807	0.000	9.807	-16.817	0.011	-16.806	-0.03969	0.00003	-0.03966	-189.47	-0.3963	0.000498	-70
-69	0.0000112	9.832	0.000	9.832	-16.577	0.012	-16.565	-0.03907	0.00003	-0.03904	-189.07	-0.3953	0.000536	-69
-68	0.0000120	9.857	0.001	9.858	-16.336	0.012	-16.324	-0.03846	0.00003	-0.03843	-188.66	-0.3943	0.000576	-68
-67	0.0000129	9.883	0.000	9.883	-16.096	0.013	-16.083	-0.03785	0.00004	-0.03781	-188.26	-0.3932	0.000619	-67
-66	0.0000139	9.908	0.000	9.908	-15.856	0.015	-15.841	-0.03724	0.00004	-0.03720	-187.85	-0.3922	0.000665	-66
-65	0.0000149	9.933	0.001	9.934	-15.616	0.016	-15.600	-0.03663	0.00004	-0.03659	-187.44	-0.3912	0.000714	-65
-64	0.0000160	9.959	0.000	9.959	-15.375	0.016	-15.359	-0.03602	0.00005	-0.03597	-187.04	-0.3901	0.000766	-64
-63	0.0000172	9.984	0.000	9.984	-15.135	0.018	-15.117	-0.03541	0.00005	-0.03536	-186.63	-0.3891	0.000822	-63
-62	0.0000184	10.009	0.001	10.010	-14.895	0.019	-14.876	-0.03481	0.00005	-0.03476	-186.22	-0.3881	0.000882	-62
-61	0.0000198	10.035	0.000	10.035	-14.654	0.020	-14.634	-0.03420	0.00005	-0.03415	-185.81	-0.3870	0.000945	-61
-60	0.0000212	10.060	0.000	10.060	-14.414	0.022	-14.392	-0.03360	0.00006	-0.03354	-185.39	-0.3860	0.001013	-60
-59	0.0000227	10.085	0.001	10.086	-14.174	0.024	-14.150	-0.03300	0.00006	-0.03294	-184.98	-0.3850	0.001086	-59
-58	0.0000243	10.111	0.000	10.111	-13.933	0.025	-13.908	-0.03240	0.00007	-0.03233	-184.57	-0.3839	0.001163	-58
-57	0.0000260	10.136	0.001	10.137	-13.693	0.027	-13.666	-0.03180	0.00007	-0.03173	-184.15	-0.3829	0.001246	-57
-56	0.0000279	10.161	0.001	10.162	-13.453	0.029	-13.424	-0.03121	0.00008	-0.03113	-183.74	-0.3819	0.001333	-56
-55	0.0000298	10.187	0.000	10.187	-13.213	0.031	-13.182	-0.03061	0.00008	-0.03053	-183.32	-0.3808	0.001427	-55
-54	0.0000319	10.212	0.001	10.213	-12.972	0.033	-12.939	-0.03002	0.00009	-0.02993	-182.90	-0.3798	0.001526	-54
-53	0.0000341	10.237	0.001	10.238	-12.732	0.035	-12.697	-0.02943	0.00009	-0.02934	-182.48	-0.3788	0.001632	-53
-52	0.0000365	10.263	0.000	10.263	-12.492	0.038	-12.454	-0.02884	0.00010	-0.02874	-182.06	-0.3778	0.001745	-52
-51	0.0000390	10.288	0.001	10.289	-12.251	0.040	-12.211	-0.02825	0.00011	-0.02814	-181.64	-0.3767	0.001865	-51
-50	0.0000416	10.313	0.001	10.314	-12.011	0.043	-11.968	-0.02766	0.00011	-0.02755	-181.22	-0.3757	0.001992	-50
-49	0.0000445	10.339	0.001	10.340	-11.771	0.046	-11.725	-0.02708	0.00012	-0.02696	-180.80	-0.3747	0.002128	-49
-48	0.0000475	10.364	0.001	10.365	-11.531	0.050	-11.481	-0.02649	0.00013	-0.02636	-180.37	-0.3736	0.002272	-48
-47	0.0000507	10.389	0.001	10.390	-11.290	0.053	-11.237	-0.02591	0.00014	-0.02577	-179.95	-0.3726	0.002425	-47
-46	0.0000541	10.415	0.001	10.416	-11.050	0.056	-10.994	-0.02533	0.00015	-0.02518	-179.52	-0.3716	0.002587	-46
-45	0.0000577	10.440	0.001	10.441	-10.810	0.060	-10.750	-0.02475	0.00016	-0.02459	-179.10	-0.3705	0.002760	-45
-44	0.0000615	10.465	0.001	10.466	-10.570	0.065	-10.505	-0.02417	0.00017	-0.02400	-178.67	-0.3695	0.002943	-44
-43	0.0000656	10.491	0.001	10.492	-10.329	0.068	-10.261	-0.02359	0.00017	-0.02342	-178.24	-0.3685	0.003137	-43
-42	0.0000699	10.516	0.001	10.517	-10.089	0.073	-10.016	-0.02302	0.00019	-0.02283	-177.81	-0.3675	0.003343	-42
-41	0.0000744	10.541	0.002	10.543	-9.849	0.078	-9.771	-0.02244	0.00020	-0.02224	-177.38	-0.3664	0.003562	-41
-40	0.0000793	10.567	0.001	10.568	-9.609	0.083	-9.526	-0.02187	0.00021	-0.02166	-176.95	-0.3654	0.003793	-40
-39	0.0000844	10.592	0.001	10.593	-9.368	0.088	-9.280	-0.02130	0.00023	-0.02107	-176.52	-0.3644	0.004039	-39
-38	0.0000898	10.617	0.002	10.619	-9.128	0.094	-9.034	-0.02073	0.00024	-0.02049	-176.08	-0.3633	0.004299	-38
-37	0.0000956	10.643	0.001	10.644	-8.888	0.100	-8.788	-0.02016	0.00025	-0.01991	-175.65	-0.3623	0.004575	-37
-36	0.0001017	10.668	0.002	10.670	-8.648	0.107	-8.541	-0.01959	0.00027	-0.01932	-175.21	-0.3613	0.004866	-36
-35	0.0001081	10.693	0.002	10.695	-8.407	0.113	-8.294	-0.01902	0.00028	-0.01874	-174.78	-0.3603	0.005175	-35
-34	0.0001150	10.719	0.002	10.721	-8.167	0.120	-8.047	-0.01846	0.00030	-0.01816	-174.34	-0.3592	0.005502	-34
-33	0.0001222	10.744	0.002	10.746	-7.927	0.128	-7.799	-0.01790	0.00032	-0.01758	-173.90	-0.3582	0.005848	-33
-32	0.0001298	10.769	0.003	10.772	-7.687	0.136	-7.551	-0.01733	0.00034	-0.01699	-173.46	-0.3572	0.006214	-32
-31	0.0001379	10.795	0.002	10.797	-7.447	0.145	-7.302	-0.01677	0.00036	-0.01641	-173.02	-0.3561	0.006601	-31

Thermodynamic Properties of Moist Air: U.S. Units

(STANDARD ATMOSPHERIC PRESSURE, 29.921 in. Hg)

		VOLUME (ft^3/lb)			ENTHALPY (Btu/lb)			ENTROPY (Btu/lb_{da}/°F)			CONDENSED WATER		VAPOR PRESS.	
TEMP °F	w_s lbw/lba	Sat. Liquid v_a	Evap. v_{as}	Sat. Vapor v_s	Sat. Liquid h_a	Evap. h_{as}	Sat. Vapor h_s	Sat. Liquid s_a	Evap. s_{as}	Sat. Vapor s_s	HW Btu/lb	S_w Btu/lb/°F	p_s in. Hg	TEMP °F
-30	0.0001465	10.820	0.002	10.822	-7.206	0.153	-7.053	-0.01621	0.00038	-0.01583	-172.58	-0.3551	0.007009	**-30**
-29	0.0001555	10.845	0.003	10.848	-6.966	0.163	-6.803	-0.01565	0.00040	-0.01525	-172.14	-0.3541	0.007442	**-29**
-28	0.0001650	10.871	0.002	10.873	-6.726	0.173	-6.553	-0.01510	0.00043	-0.01467	-171.70	-0.3531	0.007898	**-28**
-27	0.0001751	10.896	0.003	10.899	-6.486	0.184	-6.302	-0.01454	0.00045	-0.01409	-171.25	-0.3520	0.008381	**-27**
-26	0.0001858	10.921	0.003	10.924	-6.245	0.194	-6.051	-0.01399	0.00048	-0.01351	-170.81	-0.3510	0.008890	**-26**
-25	0.0001970	10.947	0.003	10.950	-6.005	0.207	-5.798	-0.01343	0.00050	-0.01293	-170.36	-0.3500	0.009428	**-25**
-24	0.0002088	10.972	0.004	10.976	-5.765	0.220	-5.545	-0.01288	0.00053	-0.01235	-169.92	-0.3489	0.009995	**-24**
-23	0.0002214	10.997	0.004	11.001	-5.525	0.233	-5.292	-0.01233	0.00057	-0.01176	-169.47	-0.3479	0.010594	**-23**
-22	0.0002346	11.022	0.005	11.027	-5.284	0.246	-5.038	-0.01178	0.00060	-0.01118	-169.02	-0.3469	0.011226	**-22**
-21	0.0002485	11.048	0.004	11.052	-5.044	0.261	-4.783	-0.01123	0.00063	-0.01060	-168.57	-0.3459	0.011893	**-21**
-20	0.0002632	11.073	0.005	11.078	-4.804	0.277	-4.527	-0.01069	0.00067	-0.01002	-168.12	-0.3448	0.012595	**-20**
-19	0.0002786	11.098	0.005	11.103	-4.564	0.293	-4.271	-0.01014	0.00071	-0.00943	-167.67	-0.3438	0.013336	**-19**
-18	0.0002950	11.124	0.005	11.129	-4.324	0.311	-4.013	-0.00960	0.00075	-0.00885	-167.21	-0.3428	0.014117	**-18**
-17	0.0003121	11.149	0.006	11.155	-4.084	0.330	-3.754	-0.00905	0.00079	-0.00826	-166.76	-0.3418	0.014939	**-17**
-16	0.0003303	11.174	0.006	11.180	-3.843	0.348	-3.495	-0.00851	0.00083	-0.00768	-166.30	-0.3407	0.015806	**-16**
-15	0.0003493	11.200	0.006	11.206	-3.603	0.368	-3.235	-0.00797	0.00088	-0.00709	-165.85	-0.3397	0.016718	**-15**
-14	0.0003694	11.225	0.007	11.232	-3.363	0.390	-2.973	-0.00743	0.00093	-0.00650	-165.39	-0.3387	0.017679	**-14**
-13	0.0003905	11.250	0.007	11.257	-3.123	0.413	-2.710	-0.00689	0.00098	-0.00591	-164.93	-0.3377	0.018690	**-13**
-12	0.0004128	11.276	0.007	11.283	-2.882	0.435	-2.447	-0.00635	0.00103	-0.00532	-164.47	-0.3366	0.019754	**-12**
-11	0.0004362	11.301	0.008	11.309	-2.642	0.460	-2.182	-0.00582	0.00109	-0.00473	-164.01	-0.3356	0.020873	**-11**
-10	0.0004608	11.326	0.009	11.335	-2.402	0.487	-1.915	-0.00528	0.00114	-0.00414	-163.55	-0.3346	0.022050	**-10**
-9	0.0004867	11.351	0.009	11.360	-2.162	0.515	-1.647	-0.00475	0.00121	-0.00354	-163.09	-0.3335	0.023289	**-9**
-8	0.0005139	11.377	0.009	11.386	-1.922	0.544	-1.378	-0.00422	0.00128	-0.00294	-162.63	-0.3325	0.024591	**-8**
-7	0.0005425	11.402	0.010	11.412	-1.681	0.573	-1.108	-0.00369	0.00135	-0.00234	-162.17	-0.3315	0.025959	**-7**
-6	0.0005726	11.427	0.011	11.438	-1.441	0.606	-0.835	-0.00316	0.00142	-0.00174	-161.70	-0.3305	0.027397	**-6**
-5	0.0006041	11.453	0.011	11.464	-1.201	0.640	-0.561	-0.00263	0.00149	-0.00114	-161.23	-0.3294	0.028907	**-5**
-4	0.0006373	11.478	0.012	11.490	-0.961	0.675	-0.286	-0.00210	0.00157	-0.00053	-160.77	-0.3284	0.030494	**-4**
-3	0.0006722	11.503	0.013	11.516	-0.721	0.713	-0.008	-0.00157	0.00165	0.00008	-160.30	-0.3274	0.032160	**-3**
-2	0.0007088	11.529	0.013	11.542	-0.480	0.751	0.271	-0.00105	0.00174	0.00069	-159.83	-0.3264	0.033909	**-2**
-1	0.0007472	11.554	0.014	11.568	-0.240	0.792	0.552	-0.00052	0.00182	0.00130	-159.36	-0.3253	0.035744	**-1**
0	0.0007875	11.579	0.015	11.594	0.000	0.835	0.835	0.00000	0.00192	0.00192	-158.89	-0.3243	0.037671	**0**
1	0.0008298	11.604	0.016	11.620	0.240	0.881	1.121	0.00052	0.00202	0.00254	-158.42	-0.3233	0.039694	**1**
2	0.0008742	11.630	0.016	11.646	0.480	0.928	1.408	0.00104	0.00213	0.00317	-157.95	-0.3223	0.041814	**2**
3	0.0009207	11.655	0.017	11.672	0.721	0.978	1.699	0.00156	0.00224	0.00380	-157.47	-0.3212	0.044037	**3**
4	0.0009695	11.680	0.019	11.699	0.961	1.030	1.991	0.00208	0.00235	0.00443	-157.00	-0.3202	0.046370	**4**
5	0.0010207	11.706	0.019	11.725	1.201	1.085	2.286	0.00260	0.00246	0.00506	-156.52	-0.3192	0.048814	**5**
6	0.0010743	11.731	0.020	11.751	1.441	1.143	2.584	0.00311	0.00259	0.00570	-156.05	-0.3182	0.051375	**6**
7	0.0011306	11.756	0.022	11.778	1.681	1.203	2.884	0.00363	0.00272	0.00635	-155.57	-0.3171	0.054060	**7**
8	0.0011895	11.782	0.022	11.804	1.922	1.266	3.188	0.00414	0.00286	0.00700	-155.09	-0.3161	0.056872	**8**
9	0.0012512	11.807	0.024	11.831	2.162	1.332	3.494	0.00466	0.00300	0.00766	-154.61	-0.3151	0.059819	**9**
10	0.0013158	11.832	0.025	11.857	2.402	1.402	3.804	0.00517	0.00315	0.00832	-154.13	-0.3141	0.062901	**10**
11	0.0013835	11.857	0.027	11.884	2.642	1.475	4.117	0.00568	0.00330	0.00898	-153.65	-0.3130	0.066131	**11**
12	0.0014544	11.883	0.027	11.910	2.882	1.551	4.433	0.00619	0.00347	0.00966	-153.17	-0.3120	0.069511	**12**
13	0.0015286	11.908	0.029	11.937	3.123	1.630	4.753	0.00670	0.00363	0.01033	-152.68	-0.3110	0.073049	**13**
14	0.0016062	11.933	0.031	11.964	3.363	1.714	5.077	0.00721	0.00381	0.01102	-152.20	-0.3100	0.076751	**14**

Thermodynamic Properties of Moist Air: U.S. Units

(STANDARD ATMOSPHERIC PRESSURE, 29.921 in. Hg)

TEMP °F	w_s lbw/lba	VOLUME (ft^3/lb) Sat. Liquid v_a	Evap. v_{as}	Sat. Vapor v_s	ENTHALPY (Btu/lb) Sat. Liquid h_a	Evap. h_{as}	Sat. Vapor h_s	ENTROPY (Btu/lb_{da}/°F) Sat. Liquid s_a	Evap. s_{as}	Sat. Vapor s_s	CONDENSED WATER HW Btu/lb	Sw Btu/lb/°F	VAPOR PRESS. p_s in. Hg	TEMP °F
15	0.0016874	11.959	0.032	11.991	3.603	1.801	5.404	0.00771	0.00400	0.01171	-151.71	-0.3089	0.080623	15
16	0.0017724	11.984	0.034	12.018	3.843	1.893	5.736	0.00822	0.00419	0.01241	-151.22	-0.3079	0.084673	16
17	0.0018613	12.009	0.036	12.045	4.084	1.988	6.072	0.00872	0.00440	0.01312	-150.74	-0.3069	0.088907	17
18	0.0019543	12.035	0.037	12.072	4.324	2.088	6.412	0.00923	0.00460	0.01383	-150.25	-0.3059	0.093334	18
19	0.0020515	12.060	0.039	12.099	4.564	2.193	6.757	0.00973	0.00482	0.01455	-149.76	-0.3049	0.097962	19
20	0.0021531	12.085	0.042	12.127	4.804	2.303	7.107	0.01023	0.00505	0.01528	-149.27	-0.3038	0.102798	20
21	0.0022592	12.110	0.044	12.154	5.044	2.418	7.462	0.01073	0.00529	0.01602	-148.78	-0.3028	0.107849	21
22	0.0023703	12.136	0.046	12.182	5.285	2.537	7.822	0.01123	0.00554	0.01677	-148.28	-0.3018	0.113130	22
23	0.0024863	12.161	0.048	12.209	5.525	2.662	8.187	0.01173	0.00580	0.01753	-147.79	-0.3008	0.118645	23
24	0.0026073	12.186	0.051	12.237	5.765	2.793	8.558	0.01223	0.00607	0.01830	-147.30	-0.2997	0.124396	24
25	0.0027339	12.212	0.053	12.265	6.005	2.930	8.935	0.01272	0.00636	0.01908	-146.80	-0.2987	0.130413	25
26	0.0028660	12.237	0.056	12.293	6.246	3.072	9.318	0.01322	0.00665	0.01987	-146.30	-0.2977	0.136684	26
27	0.0030039	12.262	0.059	12.321	6.486	3.222	9.708	0.01371	0.00696	0.02067	-145.81	-0.2967	0.143233	27
28	0.0031480	12.287	0.062	12.349	6.726	3.378	10.104	0.01420	0.00728	0.02148	-145.31	-0.2956	0.150066	28
29	0.0032984	12.313	0.065	12.378	6.966	3.541	10.507	0.01470	0.00761	0.02231	-144.81	-0.2946	0.157198	29
30	0.0034552	12.338	0.068	12.406	7.206	3.711	10.917	0.01519	0.00796	0.02315	-144.31	-0.2936	0.164631	30
31	0.0036190	12.363	0.072	12.435	7.447	3.888	11.335	0.01568	0.00832	0.02400	-143.80	-0.2926	0.172390	31
32	0.0037895	12.389	0.075	12.464	7.687	4.073	11.760	0.01617	0.00870	0.02487	-143.30	-0.2915	0.180479	32
32*	0.003790	12.389	0.075	12.464	7.687	4.073	11.760	0.01617	0.00870	0.02487	0.02	0.0000	0.18050	32
33	0.003947	12.414	0.078	12.492	7.927	4.243	12.170	0.01665	0.00905	0.02570	1.03	0.0020	0.18791	33
34	0.004109	12.439	0.082	12.521	8.167	4.420	12.587	0.01714	0.00941	0.02655	2.04	0.0041	0.19559	34
35	0.004277	12.464	0.086	12.550	8.408	4.602	13.010	0.01763	0.00977	0.02740	3.05	0.0061	0.20356	35
36	0.004452	12.490	0.089	12.579	8.648	4.793	13.441	0.01811	0.01016	0.02827	4.05	0.0081	0.21181	36
37	0.004633	12.515	0.093	12.608	8.888	4.990	13.878	0.01860	0.01055	0.02915	5.06	0.0102	0.22035	37
38	0.004820	12.540	0.097	12.637	9.128	5.194	14.322	0.01908	0.01096	0.03004	6.06	0.0122	0.22920	38
39	0.005014	12.566	0.101	12.667	9.369	5.404	14.773	0.01956	0.01139	0.03095	7.07	0.0142	0.23835	39
40	0.005216	12.591	0.105	12.696	9.609	5.624	15.233	0.02004	0.01183	0.03187	8.07	0.0162	0.24784	40
41	0.005424	12.616	0.110	12.726	9.849	5.851	15.700	0.02052	0.01229	0.03281	9.08	0.0182	0.25765	41
42	0.005640	12.641	0.115	12.756	10.089	6.086	16.175	0.02100	0.01275	0.03375	10.08	0.0202	0.26781	42
43	0.005863	12.667	0.119	12.786	10.330	6.330	16.660	0.02148	0.01324	0.03472	11.09	0.0222	0.27831	43
44	0.006094	12.692	0.124	12.816	10.570	6.582	17.152	0.02196	0.01374	0.03570	12.09	0.0242	0.28918	44
45	0.006334	12.717	0.129	12.846	10.810	6.843	17.653	0.02244	0.01425	0.03669	13.09	0.0262	0.30042	45
46	0.006581	12.743	0.134	12.877	11.050	7.114	18.164	0.02291	0.01479	0.03770	14.10	0.0282	0.31206	46
47	0.006838	12.768	0.140	12.908	11.291	7.394	18.685	0.02339	0.01534	0.03873	15.10	0.0302	0.32408	47
48	0.007103	12.793	0.146	12.939	11.531	7.684	19.215	0.02386	0.01592	0.03978	16.10	0.0321	0.33651	48
49	0.007378	12.818	0.152	12.970	11.771	7.985	19.756	0.02433	0.01651	0.04084	17.10	0.0341	0.34937	49
50	0.007661	12.844	0.157	13.001	12.012	8.294	20.306	0.02480	0.01712	0.04192	18.11	0.0361	0.36264	50
51	0.007955	12.869	0.164	13.033	12.252	8.616	20.868	0.02528	0.01774	0.04302	19.11	0.0381	0.37636	51
52	0.008259	12.894	0.171	13.065	12.492	8.949	21.441	0.02575	0.01840	0.04415	20.11	0.0400	0.39054	52
53	0.008573	12.920	0.177	13.097	12.732	9.293	22.025	0.02622	0.01907	0.04529	21.11	0.0420	0.40518	53
54	0.008897	12.945	0.184	13.129	12.973	9.648	22.621	0.02668	0.01977	0.04645	22.11	0.0439	0.42030	54
55	0.009233	12.970	0.192	13.162	13.213	10.016	23.229	0.02715	0.02048	0.04763	23.11	0.0459	0.43592	55
56	0.009580	12.995	0.200	13.195	13.453	10.397	23.850	0.02762	0.02122	0.04884	24.11	0.0478	0.45205	56
57	0.009938	13.021	0.207	13.228	13.694	10.790	24.484	0.02808	0.02198	0.05006	25.11	0.0497	0.46870	57
58	0.010309	13.046	0.216	13.262	13.934	11.197	25.131	0.02855	0.02277	0.05132	26.11	0.0517	0.48589	58
59	0.010692	13.071	0.224	13.295	14.174	11.618	25.792	0.02901	0.02358	0.05259	27.11	0.0536	0.50363	59

Thermodynamic Properties of Moist Air: U.S. Units

(STANDARD ATMOSPHERIC PRESSURE, 29.921 in. Hg)

		VOLUME (ft^3/lb)			ENTHALPY (Btu/lb)			ENTROPY (Btu/lb_{da}/°F)			CONDENSED WATER		VAPOR PRESS.	
TEMP °F	w_s lbw/lba	Sat. Liquid v_a	Evap. v_{as}	Sat. Vapor v_s	Sat. Liquid h_a	Evap. h_{as}	Sat. Vapor h_s	Sat. Liquid s_a	Evap. s_{as}	Sat. Vapor s_s	HW Btu/lb	S_w Btu/lb/°F	p_s in. Hg	TEMP °F
60	0.011087	13.096	0.233	13.329	14.415	12.052	26.467	0.02947	0.02442	0.05389	28.11	0.0555	0.52193	**60**
61	0.011496	13.122	0.242	13.364	14.655	12.502	27.157	0.02994	0.02528	0.05522	29.12	0.0575	0.54082	**61**
62	0.011919	13.147	0.251	13.398	14.895	12.967	27.862	0.03040	0.02617	0.05657	30.11	0.0594	0.56032	**62**
63	0.012355	13.172	0.261	13.433	15.135	13.447	28.582	0.03086	0.02709	0.05795	31.11	0.0613	0.58041	**63**
64	0.012805	13.198	0.270	13.468	15.376	13.942	29.318	0.03132	0.02804	0.05936	32.11	0.0632	0.60113	**64**
65	0.013270	13.223	0.281	13.504	15.616	14.455	30.071	0.03178	0.02902	0.06080	33.11	0.0651	0.62252	**65**
66	0.013750	13.248	0.292	13.540	15.856	14.984	30.840	0.03223	0.03003	0.06226	34.11	0.0670	0.64454	**66**
67	0.014246	13.273	0.304	13.577	16.097	15.529	31.626	0.03269	0.03107	0.06376	35.11	0.0689	0.66725	**67**
68	0.014758	13.299	0.314	13.613	16.337	16.094	32.431	0.03315	0.03214	0.06529	36.11	0.0708	0.69065	**68**
69	0.015286	13.324	0.326	13.650	16.577	16.677	33.254	0.03360	0.03325	0.06685	37.11	0.0727	0.71479	**69**
70	0.015832	13.349	0.339	13.688	16.818	17.279	34.097	0.03406	0.03438	0.06844	38.11	0.0746	0.73966	**70**
71	0.016395	13.375	0.351	13.726	17.058	17.901	34.959	0.03451	0.03556	0.07007	39.11	0.0765	0.76528	**71**
72	0.016976	13.400	0.364	13.764	17.299	18.542	35.841	0.03496	0.03677	0.07173	40.11	0.0783	0.79167	**72**
73	0.017575	13.425	0.378	13.803	17.539	19.204	36.743	0.03541	0.03802	0.07343	41.11	0.0802	0.81882	**73**
74	0.018194	13.450	0.393	13.843	17.779	19.889	37.668	0.03586	0.03930	0.07516	42.11	0.0821	0.84684	**74**
75	0.018833	13.476	0.406	13.882	18.020	20.595	38.615	0.03631	0.04063	0.07694	43.11	0.0840	0.87567	**75**
76	0.019491	13.501	0.422	13.923	18.260	21.323	39.583	0.03676	0.04199	0.07875	44.10	0.0858	0.90533	**76**
77	0.020170	13.526	0.437	13.963	18.500	22.076	40.576	0.03721	0.04339	0.08060	45.10	0.0877	0.93589	**77**
78	0.020871	13.551	0.454	14.005	18.741	22.851	41.592	0.03766	0.04484	0.08250	46.10	0.0896	0.96733	**78**
79	0.021594	13.577	0.469	14.046	18.981	23.652	42.633	0.03811	0.04633	0.08444	47.10	0.0914	0.99970	**79**
80	0.022340	13.602	0.487	14.089	19.222	24.479	43.701	0.03855	0.04787	0.08642	48.10	0.0933	1.03302	**80**
81	0.023109	13.627	0.505	14.132	19.462	25.332	44.794	0.03900	0.04944	0.08844	49.10	0.0951	1.06728	**81**
82	0.023902	13.653	0.522	14.175	19.702	26.211	45.913	0.03944	0.05108	0.09052	50.10	0.0970	1.10252	**82**
83	0.024720	13.678	0.542	14.220	19.943	27.119	47.062	0.03986	0.05278	0.09264	51.09	0.0988	1.13882	**83**
84	0.025563	13.703	0.561	14.264	20.183	28.055	48.238	0.04033	0.05448	0.09481	52.09	0.1006	1.17608	**84**
85	0.026433	13.728	0.582	14.310	20.424	29.021	49.445	0.04077	0.05626	0.09703	53.09	0.1025	1.21445	**85**
86	0.027329	13.754	0.602	14.356	20.664	30.017	50.681	0.04121	0.05809	0.09930	54.09	0.1043	1.25388	**86**
87	0.028254	13.779	0.624	14.403	20.905	31.044	51.949	0.04165	0.05998	0.10163	55.09	0.1061	1.29443	**87**
88	0.029208	13.804	0.646	14.450	21.145	32.105	53.250	0.04209	0.06192	0.10401	56.09	0.1080	1.33613	**88**
89	0.030189	13.829	0.669	14.498	21.385	33.197	54.582	0.04253	0.06392	0.10645	57.09	0.1098	1.37893	**89**
90	0.031203	13.855	0.692	14.547	21.626	34.325	55.951	0.04297	0.06598	0.10895	58.08	0.1116	1.42298	**90**
91	0.032247	13.880	0.717	14.597	21.866	35.489	57.355	0.04340	0.06810	0.11150	59.08	0.1134	1.46824	**91**
92	0.033323	13.905	0.742	14.647	22.107	36.687	58.794	0.04384	0.07028	0.11412	60.08	0.1152	1.51471	**92**
93	0.034433	13.930	0.769	14.699	22.347	37.924	60.271	0.04427	0.07253	0.11680	61.08	0.1170	1.56248	**93**
94	0.035577	13.956	0.795	14.751	22.588	39.199	61.787	0.04471	0.07484	0.11955	62.08	0.1188	1.61154	**94**
95	0.036757	13.981	0.823	14.804	22.828	40.515	63.343	0.04514	0.07723	0.12237	63.08	0.1206	1.66196	**95**
96	0.037972	14.006	0.852	14.858	23.069	41.871	64.940	0.04558	0.07967	0.12525	64.07	0.1224	1.71372	**96**
97	0.039225	14.032	0.881	14.913	23.309	43.269	66.578	0.04601	0.08220	0.12821	65.07	0.1242	1.76685	**97**
98	0.040516	14.057	0.912	14.969	23.550	44.710	68.260	0.04644	0.08480	0.13124	66.07	0.1260	1.82141	**98**
99	0.041848	14.082	0.944	15.026	23.790	46.198	69.988	0.04687	0.08747	0.13434	67.07	0.1278	1.87745	**99**
100	0.043219	14.107	0.977	15.084	24.031	47.730	71.761	0.04730	0.09022	0.13752	68.07	0.1296	1.93492	**100**
101	0.044634	14.133	1.010	15.143	24.271	49.312	73.583	0.04773	0.09306	0.14079	69.07	0.1314	1.99396	**101**
102	0.046090	14.158	1.045	15.203	24.512	50.940	75.452	0.04816	0.09597	0.14413	70.06	0.1332	2.05447	**102**
103	0.047592	14.183	1.081	15.264	24.752	52.621	77.373	0.04859	0.09897	0.14756	71.06	0.1349	2.11661	**103**
104	0.049140	14.208	1.118	15.326	24.993	54.353	79.346	0.04901	0.10207	0.15108	72.06	0.1367	2.18037	**104**

Thermodynamic Properties of Moist Air: U.S. Units

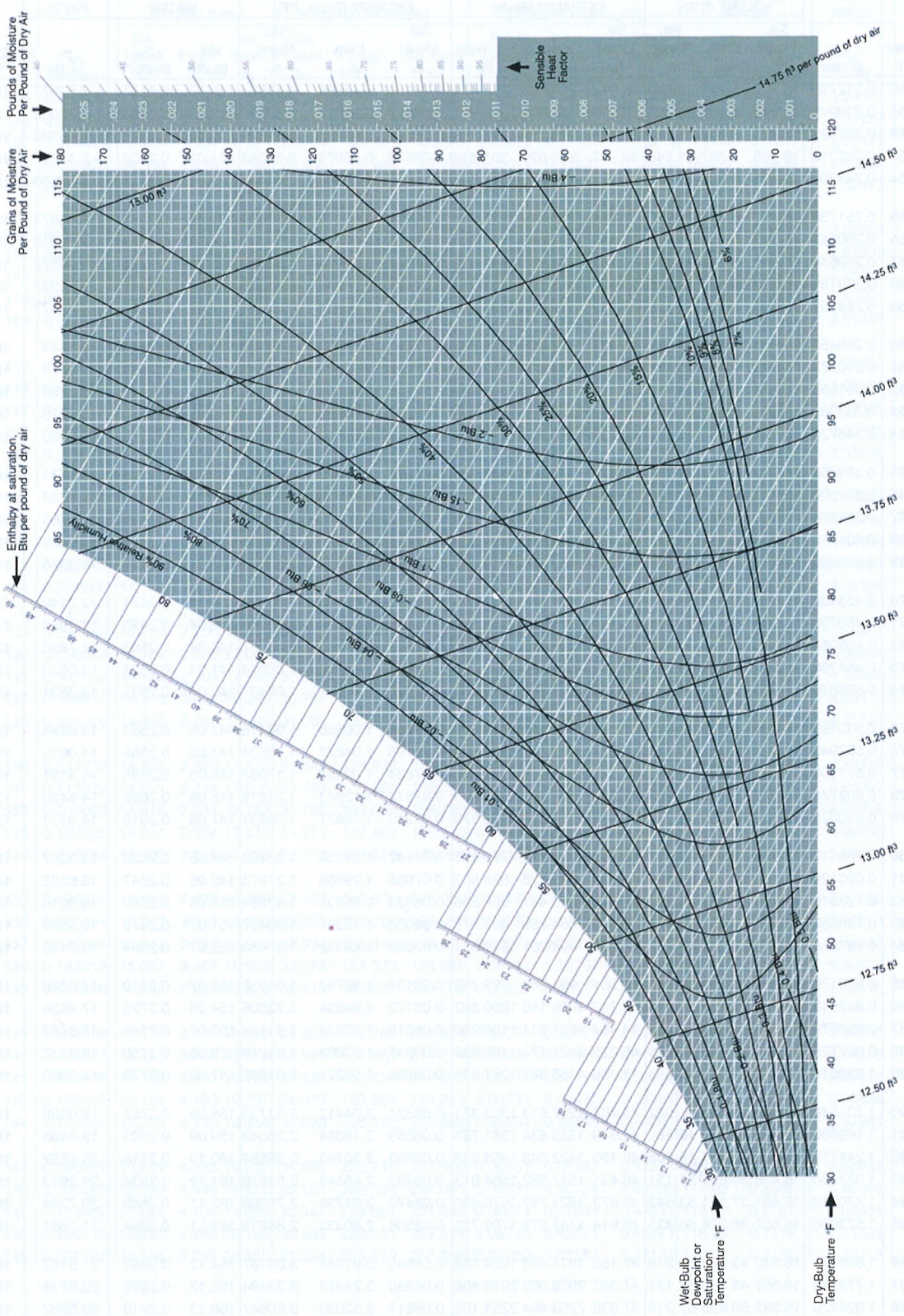
(STANDARD ATMOSPHERIC PRESSURE, 29.921 in. Hg)

TEMP °F	w_s lbw/lba	VOLUME (ft^3/lb) Sat. Liquid v_a	Evap. v_{as}	Sat. Vapor v_s	ENTHALPY (Btu/lb) Sat. Liquid h_a	Evap. h_{as}	Sat. Vapor h_s	ENTROPY (Btu/lb_{da}/°F) Sat. Liquid s_a	Evap. s_{as}	Sat. Vapor s_s	CONDENSED WATER HW Btu/lb	Sw Btu/lb/°F	VAPOR PRESS. p_s in. Hg	TEMP °F
105	0.050737	14.234	1.156	15.390	25.233	56.142	81.375	0.04944	0.10525	0.15469	73.06	0.1385	2.24581	**105**
106	0.052383	14.259	1.196	15.455	25.474	57.986	83.460	0.04987	0.10852	0.15839	74.06	0.1402	2.31297	**106**
107	0.054077	14.284	1.237	15.521	25.714	59.885	85.599	0.05029	0.11189	0.16218	75.06	0.1420	2.38173	**107**
108	0.055826	14.309	1.279	15.588	25.955	61.844	87.799	0.05071	0.11537	0.16608	76.05	0.1438	2.45232	**108**
109	0.057628	14.335	1.322	15.657	26.195	63.866	90.061	0.05114	0.11894	0.17008	77.05	0.1455	2.52473	**109**
110	0.059486	14.360	1.367	15.727	26.436	65.950	92.386	0.05156	0.12262	0.17418	78.05	0.1473	2.59891	**110**
111	0.061401	14.385	1.414	15.799	26.677	68.099	94.776	0.05198	0.12641	0.17839	79.05	0.1490	2.67500	**111**
112	0.063378	14.411	1.461	15.872	26.917	70.320	97.237	0.05240	0.13032	0.18272	80.05	0.1508	2.75310	**112**
113	0.065411	14.436	1.511	15.947	27.158	72.602	99.760	0.05282	0.13434	0.18716	81.05	0.1525	2.83291	**113**
114	0.067512	14.461	1.562	16.023	27.398	74.964	102.362	0.05324	0.13848	0.19172	82.04	0.1543	2.91491	**114**
115	0.069676	14.486	1.615	16.101	27.639	77.396	105.035	0.05366	0.14274	0.19640	83.04	0.1560	2.99883	**115**
116	0.071908	14.512	1.669	16.181	27.879	79.907	107.786	0.05408	0.14713	0.20121	84.04	0.1577	3.08488	**116**
117	0.074211	14.537	1.726	16.263	28.120	82.497	110.617	0.05450	0.15165	0.20615	85.04	0.1595	3.17305	**117**
118	0.076586	14.562	1.784	16.346	28.361	85.169	113.530	0.05492	0.15630	0.21122	86.04	0.1612	3.26335	**118**
119	0.079036	14.587	1.845	16.432	28.601	87.927	116.528	0.05533	0.16111	0.21644	87.04	0.1629	3.35586	**119**
120	0.081560	14.613	1.906	16.519	28.842	90.770	119.612	0.05575	0.16605	0.22180	88.04	0.1647	3.45052	**120**
121	0.084169	14.638	1.971	16.609	29.083	93.709	122.792	0.05616	0.17115	0.22731	89.04	0.1664	3.54764	**121**
122	0.086860	14.663	2.037	16.700	29.323	96.742	126.065	0.05658	0.17640	0.23298	90.03	0.1681	3.64704	**122**
123	0.089633	14.688	2.106	16.794	29.564	99.868	129.432	0.05699	0.18181	0.23880	91.03	0.1698	3.74871	**123**
124	0.092500	14.714	2.176	16.890	29.805	103.102	132.907	0.05740	0.18740	0.24480	92.03	0.1715	3.85298	**124**
125	0.095456	14.739	2.250	16.989	30.045	106.437	136.482	0.05781	0.19315	0.25096	93.03	0.1732	3.95961	**125**
126	0.098504	14.764	2.326	17.090	30.286	109.877	140.163	0.05823	0.19906	0.25729	94.03	0.1749	4.06863	**126**
127	0.101657	14.789	2.404	17.193	30.527	113.438	143.965	0.05864	0.20518	0.26382	95.03	0.1766	4.18046	**127**
128	0.104910	14.815	2.484	17.299	30.767	117.111	147.878	0.05905	0.21149	0.27054	96.03	0.1783	4.29477	**128**
129	0.108270	14.840	2.569	17.409	31.008	120.908	151.916	0.05946	0.21799	0.27745	97.03	0.1800	4.41181	**129**
130	0.111738	14.865	2.655	17.520	31.249	124.827	156.076	0.05986	0.22471	0.28457	98.03	0.1817	4.53148	**130**
131	0.115322	14.891	2.744	17.635	31.489	128.881	160.370	0.06027	0.23163	0.29190	99.02	0.1834	4.65397	**131**
132	0.119023	14.916	2.837	17.753	31.730	133.066	164.796	0.06068	0.23876	0.29944	100.02	0.1851	4.77919	**132**
133	0.122855	14.941	2.934	17.875	31.971	137.403	169.374	0.06109	0.24614	0.30723	101.02	0.1868	4.90755	**133**
134	0.126804	14.966	3.033	17.999	32.212	141.872	174.084	0.06149	0.25375	0.31524	102.02	0.1885	5.03844	**134**
135	0.130895	14.992	3.135	18.127	32.452	146.505	178.957	0.06190	0.26161	0.32351	103.02	0.1902	5.17258	**135**
136	0.135124	15.017	3.242	18.259	32.693	151.294	183.987	0.06230	0.26973	0.33203	104.02	0.1919	5.30973	**136**
137	0.139494	15.042	3.352	18.394	32.934	156.245	189.179	0.06271	0.27811	0.34082	105.02	0.1935	5.44985	**137**
138	0.144019	15.067	3.467	18.534	33.175	161.373	194.548	0.06311	0.28707	0.35018	106.02	0.1952	5.59324	**138**
139	0.148696	15.093	3.585	18.678	33.415	166.677	200.092	0.06351	0.29573	0.35924	107.02	0.1969	5.73970	**139**
140	0.153538	15.118	3.707	18.825	33.656	172.168	205.824	0.06391	0.30499	0.36890	108.02	0.1985	5.88945	**140**
141	0.158643	15.143	3.835	18.978	33.897	177.857	211.754	0.06431	0.31456	0.37887	109.02	0.2002	6.04256	**141**
142	0.163748	15.168	3.967	19.135	34.138	183.754	217.892	0.06471	0.32447	0.38918	110.02	0.2019	6.19918	**142**
143	0.169122	15.194	4.103	19.297	34.379	189.854	224.233	0.06511	0.33470	0.39981	111.02	0.2035	6.35898	**143**
144	0.174694	15.219	4.245	19.464	34.620	196.182	230.802	0.06551	0.34490	0.41081	112.02	0.2052	6.52241	**144**
145	0.180467	15.244	4.393	19.637	34.860	202.740	237.600	0.06591	0.35587	0.42218	113.02	0.2068	6.68932	**145**
146	0.186460	15.269	4.546	19.815	35.101	209.550	244.651	0.06631	0.36724	0.43395	114.02	0.2085	6.86009	**146**
147	0.192668	15.295	4.704	19.999	35.342	216.607	251.949	0.06671	0.37861	0.44611	115.02	0.2101	7.03435	**147**
148	0.199110	15.320	4.869	20.189	35.583	223.931	259.514	0.06710	0.45871	0.45871	116.02	0.2118	7.21239	**148**
149	0.205792	15.345	5.040	20.385	35.824	231.532	267.356	0.06750	0.40384	0.47174	117.02	0.2134	7.39413	**149**

Thermodynamic Properties of Moist Air: U.S. Units

(STANDARD ATMOSPHERIC PRESSURE, 29.921 in. Hg)

		VOLUME (ft^3/lb)			ENTHALPY (Btu/lb)			ENTROPY (Btu/lb_{da}/°F)			CONDENSED WATER		VAPOR PRESS.	
TEMP °F	w_s lbw/lba	Sat. Liquid v_a	Evap. v_{as}	Sat. Vapor v_s	Sat. Liquid h_a	Evap. h_{as}	Sat. Vapor h_s	Sat. Liquid s_a	Evap. s_{as}	Sat. Vapor s_s	HW Btu/lb	S_w Btu/lb/°F	p_s in. Hg	TEMP °F
150	0.212730	15.370	5.219	20.589	36.064	239.426	275.490	0.06790	0.41656	0.48524	118.02	0.2151	7.57977	150
151	0.219945	15.396	5.403	20.799	36.305	247.638	283.943	0.06829	0.43017	0.49925	119.02	0.2167	7.76958	151
152	0.227429	15.421	5.596	21.017	36.546	256.159	292.705	0.06868	0.44507	0.51375	120.02	0.2184	7.96306	152
153	0.235218	15.446	5.797	21.243	36.787	265.029	301.816	0.06908	0.45973	0.52881	121.02	0.2200	8.16087	153
154	0.243309	15.471	6.006	21.477	37.028	274.245	311.273	0.06947	0.47494	0.54441	122.02	0.2216	8.36256	154
155	0.251738	15.497	6.223	21.720	37.269	283.849	321.118	0.06986	0.49078	0.56064	123.02	0.2233	8.56871	155
156	0.260512	15.522	6.450	21.972	37.510	293.849	331.359	0.07025	0.50724	0.57749	124.02	0.2249	8.77915	156
157	0.269644	15.547	6.686	22.233	37.751	304.261	342.012	0.07065	0.52434	0.59499	125.02	0.2265	8.99378	157
158	0.279166	15.572	6.933	22.505	37.992	315.120	353.112	0.07104	0.54216	0.61320	126.02	0.2281	9.21297	158
159	0.289101	15.598	7.190	22.788	38.233	326.452	364.685	0.07143	0.56073	0.63216	127.02	0.2297	9.43677	159
160	0.299450	15.623	7.459	23.082	38.474	338.263	376.737	0.07181	0.58007	0.65188	128.02	0.2314	9.6648	160
161	0.310270	15.648	7.740	23.388	38.715	350.610	389.325	0.07220	0.60025	0.67245	129.02	0.2330	9.8978	161
162	0.321560	15.673	8.034	23.707	38.956	363.501	402.457	0.07259	0.62129	0.69388	130.03	0.2346	10.1353	162
163	0.333360	15.699	8.341	24.040	39.197	376.978	416.175	0.07298	0.64325	0.71623	131.03	0.2362	10.3776	163
164	0.345720	15.724	8.664	24.388	39.438	391.095	430.533	0.07337	0.66622	0.73959	132.03	0.2378	10.6250	164
165	0.358650	15.749	9.001	24.750	39.679	405.865	445.544	0.07375	0.69022	0.76397	133.03	0.2394	10.8771	165
166	0.372200	15.774	9.355	25.129	39.920	421.351	461.271	0.07414	0.71535	0.78949	134.03	0.2410	11.1343	166
167	0.386390	15.800	9.726	25.526	40.161	437.578	477.739	0.07452	0.74165	0.81617	135.03	0.2426	11.3965	167
168	0.401310	15.825	10.117	25.942	40.402	454.630	495.032	0.07491	0.76924	0.84415	136.03	0.2442	11.6641	168
169	0.416980	15.850	10.527	26.377	40.643	472.554	513.197	0.07529	0.79821	0.87350	137.04	0.2458	11.9370	169
170	0.433430	15.875	10.959	26.834	40.884	491.372	532.256	0.07567	0.82858	0.90425	138.04	0.2474	12.2149	170
171	0.450790	15.901	11.414	27.315	41.125	511.231	552.356	0.07606	0.86058	0.93664	139.04	0.2490	12.4988	171
172	0.469050	15.926	11.894	27.820	41.366	532.138	573.504	0.07644	0.89423	0.97067	140.04	0.2506	12.7880	172
173	0.488290	15.951	12.401	28.352	41.607	554.160	595.767	0.07682	0.92962	1.00644	141.04	0.2521	13.0823	173
174	0.508670	15.976	12.937	28.913	41.848	577.489	619.337	0.07720	0.96707	1.04427	142.04	0.2537	13.3831	174
175	0.530190	16.002	13.503	29.505	42.089	602.140	644.229	0.07758	1.00658	1.08416	143.05	0.2553	13.6894	175
176	0.552940	16.027	14.103	30.130	42.331	628.197	670.528	0.07796	1.04828	1.12624	144.05	0.2569	14.0010	176
177	0.577100	16.052	14.741	30.793	42.572	655.876	698.448	0.07834	1.09253	1.17087	145.05	0.2585	14.3191	177
178	0.602740	16.078	15.418	31.496	42.813	685.260	728.073	0.07872	1.13943	1.21815	146.05	0.2600	14.6430	178
179	0.630020	16.103	16.139	32.242	43.054	716.525	759.579	0.07910	1.18927	1.26837	147.06	0.2616	14.9731	179
180	0.659110	16.128	16.909	33.037	43.295	749.871	793.166	0.07947	1.24236	1.32183	148.06	0.2632	15.3097	180
181	0.690120	16.153	17.730	33.883	43.536	785.426	828.962	0.07985	1.29888	1.37873	149.06	0.2647	15.6522	181
182	0.723310	16.178	18.609	34.787	43.778	823.487	867.265	0.08023	1.35931	1.43954	150.06	0.2663	16.0014	182
183	0.758850	16.204	19.551	35.755	44.019	864.259	908.278	0.08060	1.42397	1.50457	151.07	0.2679	16.3569	183
184	0.797030	16.229	20.564	36.793	44.260	908.061	952.321	0.08098	1.49332	1.57430	152.07	0.2694	16.7190	184
185	0.838170	16.254	21.656	37.910	44.501	955.262	999.763	0.08135	1.56797	1.64932	153.07	0.2710	17.0880	185
186	0.882510	16.280	22.833	39.113	44.742	1006.150	1050.892	0.08172	1.64834	1.73006	154.08	0.2725	17.4634	186
187	0.930570	16.305	24.111	40.416	44.984	1061.314	1106.298	0.08210	1.73534	1.81744	155.08	0.2741	17.8462	187
188	0.982720	16.330	25.498	41.828	45.225	1121.174	1166.399	0.08247	1.82963	1.91210	156.08	0.2756	18.2357	188
189	1.039510	16.355	27.010	43.365	45.466	1186.382	1231.848	0.08284	1.93221	2.01505	157.09	0.2772	18.6323	189
190	1.101540	16.381	28.661	45.042	45.707	1257.614	1303.321	0.08321	2.04412	2.12733	158.09	0.2787	19.0358	190
191	1.169650	16.406	30.476	46.882	45.949	1335.834	1381.783	0.08359	2.16684	2.25043	159.09	0.2803	19.4468	191
192	1.244710	16.431	32.477	48.908	46.190	1422.048	1468.238	0.08396	2.30193	2.38589	160.10	0.2818	19.8652	192
193	1.327880	16.456	34.695	51.151	46.431	1517.582	1564.013	0.08433	2.45143	2.53576	161.10	0.2834	20.2913	193
194	1.420290	16.481	37.161	53.642	46.673	1623.757	1670.430	0.08470	2.61738	2.70208	162.11	0.2849	20.7244	194
195	1.523960	16.507	39.928	56.435	46.914	1742.879	1789.793	0.08506	2.80332	2.88838	163.11	0.2864	21.1661	195
196	1.640700	16.532	43.046	59.578	47.155	1877.033	1924.188	0.08543	3.01244	3.09787	164.12	0.2880	21.6152	196
197	1.772990	16.557	46.580	63.137	47.397	2029.069	2076.466	0.08580	3.24914	3.33494	165.12	0.2895	22.0714	197
198	1.924720	16.583	50.635	67.218	47.638	2203.464	2251.102	0.08617	3.52030	3.60647	166.13	0.2910	22.5367	198
199	2.099750	16.608	55.315	71.923	47.879	2404.668	2452.547	0.08653	3.83276	3.91929	167.13	0.2926	23.0092	199
200	2.304540	16.633	60.793	77.426	48.121	2640.084	2688.205	0.08690	4.19787	4.28477	168.13	0.2941	23.4906	200



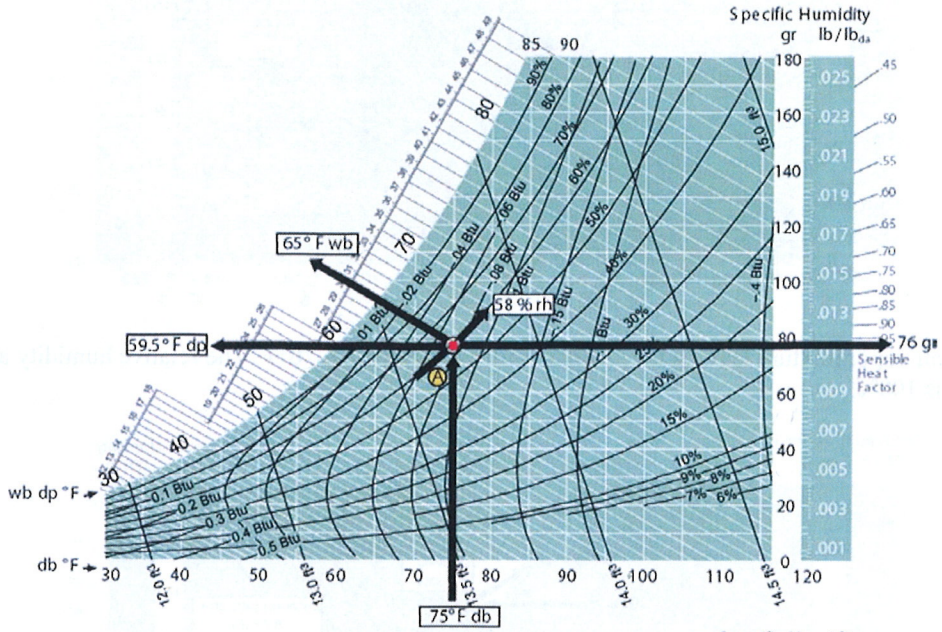
Psychrometric Chart, Normal Temperature, Sea Level

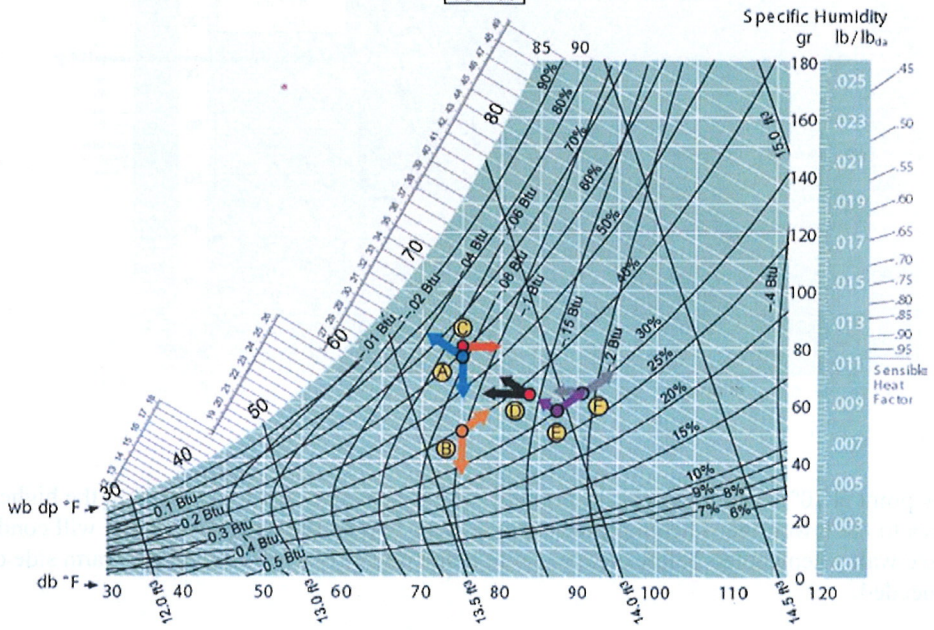
Work Session 1 Answers

1.

	db	wb	% rh	dp	W
A	75	65	**58**	**59.5**	**76**
B	75	**59.8**	40	**49.5**	**52.5**
C	75	**65.7**	**61**	**61.8**	80
D	**82.5**	65	**38**	55	**64.5**
E	**86.7**	65	30	**51.5**	**57**
F	**90.5**	**67.5**	30	55	**64.5**

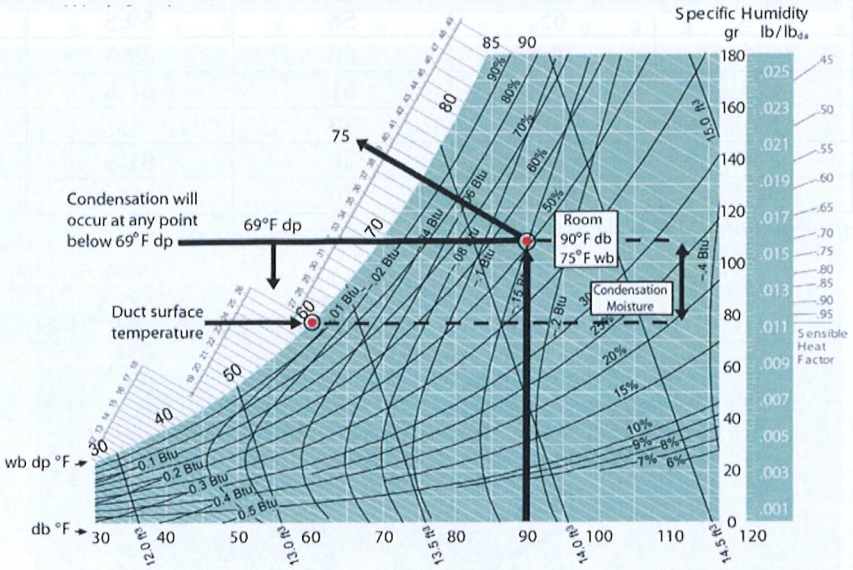
W= specific humidity lb/lb dry air



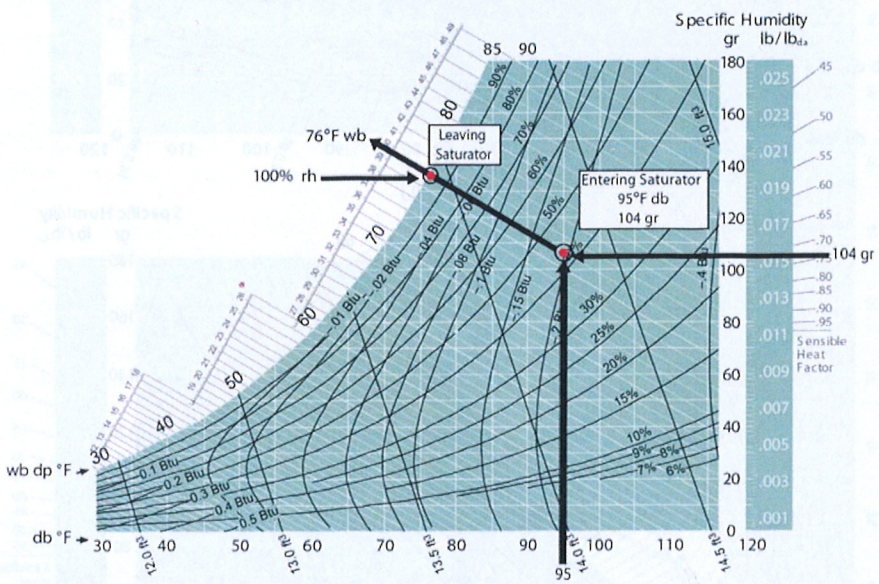


2. a. Yes

   b. Air at 90° F db and 75° F wb has a dew point of approximately 69° F. Any object in the space with a temperature of less than 69° F will cool the moisture below its saturation temperature and condensation will occur.

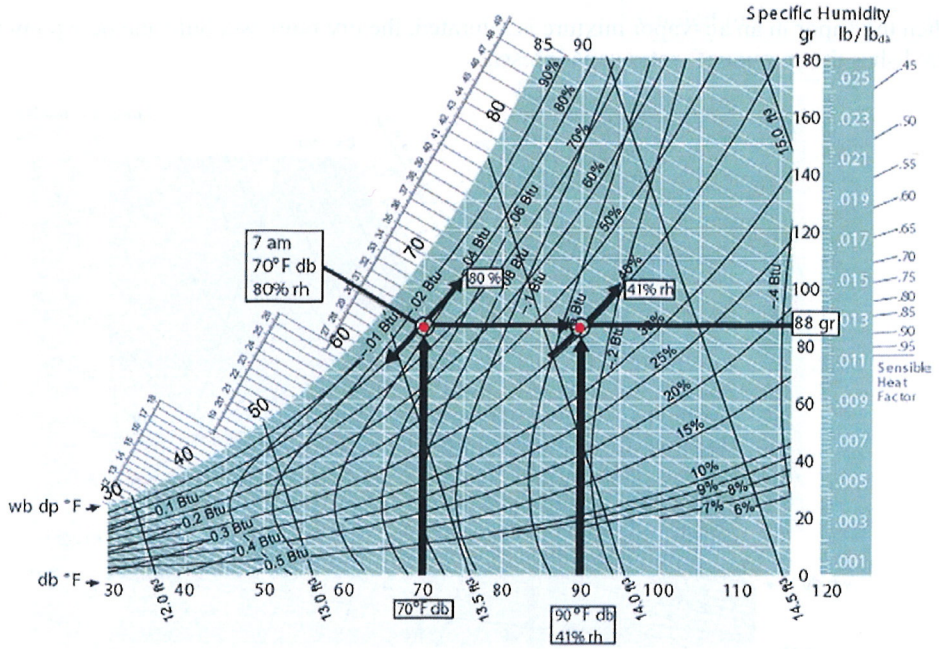


3. The air vapor mixture leaving the saturator will be saturated at 76° F. The relative humidity at saturation is 100%.

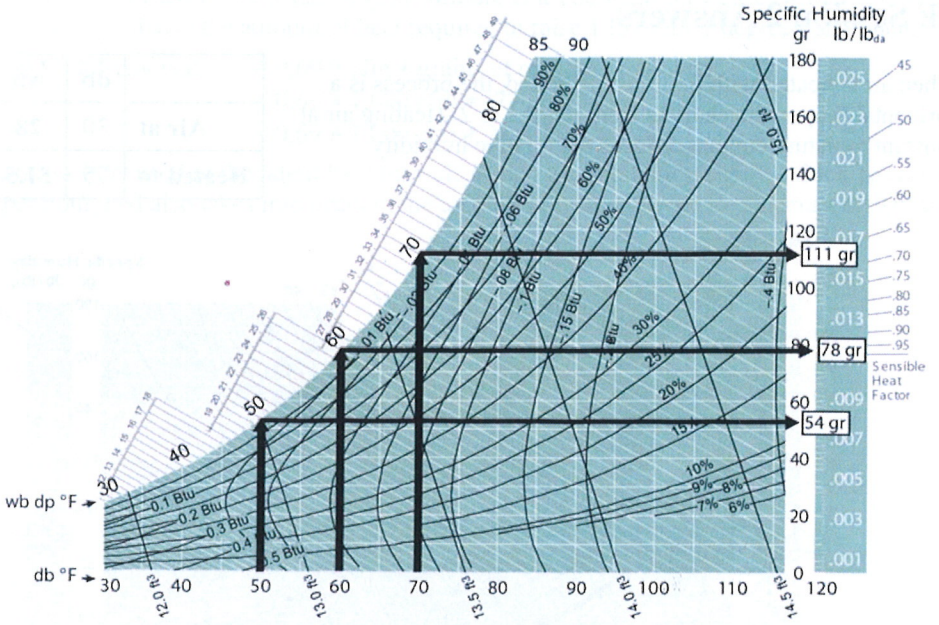


4. The dew point at 70° F and 30% relative humidity is 37° F. Water vapor will go from the higher dew point area to the lower one. Therefore, the vapor will try to pass through the wall and will condense within the wall when cooled below the dew point temperature. A vapor seal on the warm side of the wall is needed.

5. When the temperature is 90° F, the relative humidity is 41%. If there is no precipitation, the specific humidity, remains constant through out the day. The relative humidity will vary during the day with the dry bulb.

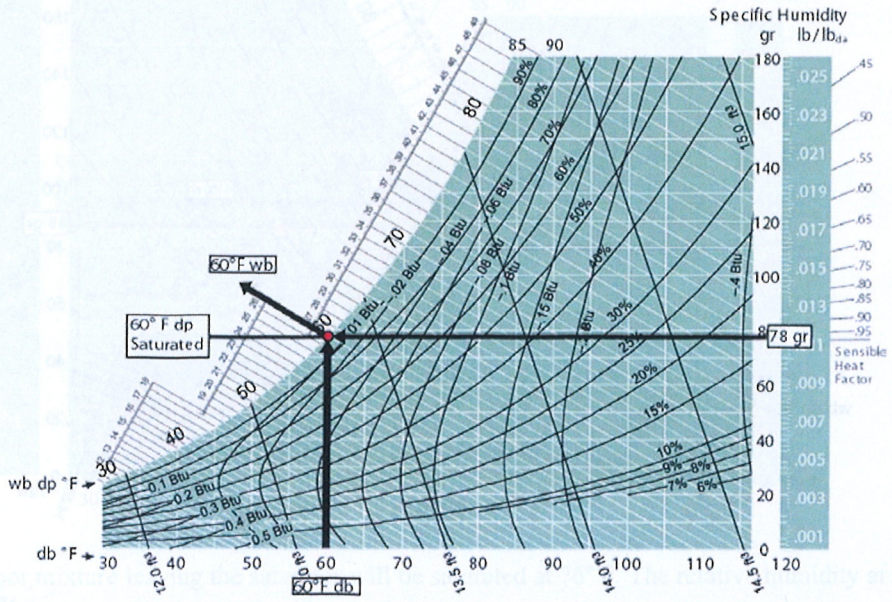


6.



7. What is the db temperature? 60° F
   What is the wb temperature? 60° F
   What is the dp temperature? 60° F

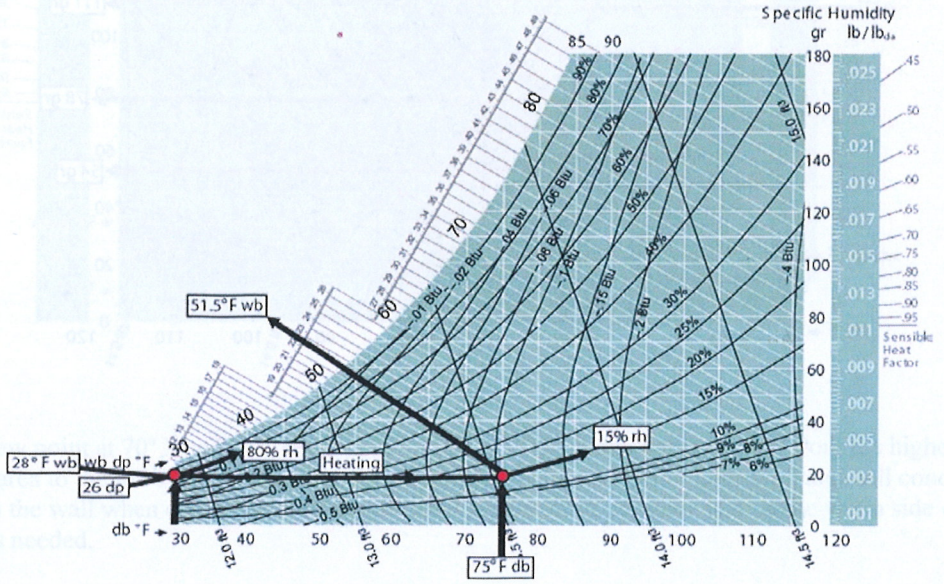
   When the vapor in an air-vapor mixture is saturated, the dry bulb, wet bulb and dew point temperature establishes the amount of water vapor present.



Work Session 2 Answers

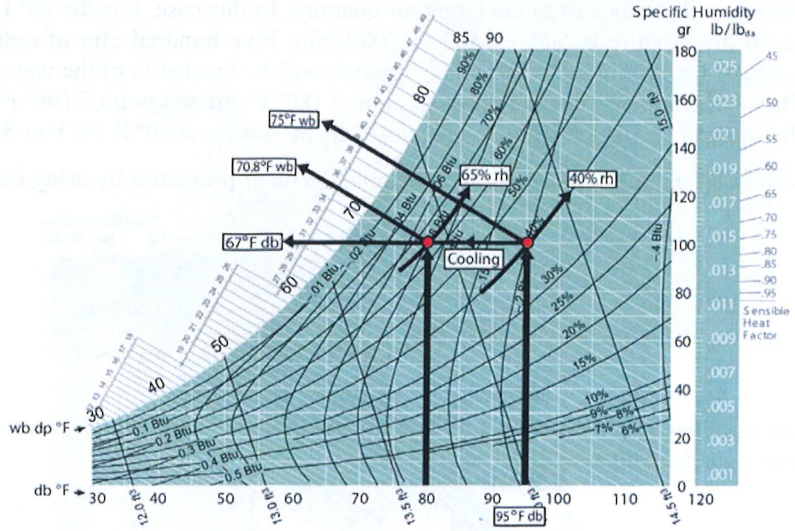
1. When air is heated with no moisture added, the process is a horizontal line on the chart as from point 1 to 2. Heating air at constant moisture content reduces the relative humidity.

	db	wb	% rh	dp
Air at	30	**28**	80	**26**
Heated to	75	**51.5**	**15**	**26**



2. When air is cooled without condensing moisture, the process is a horizontal line on the chart as from point 1 to 2. Cooling air at constant moisture content increases the relative humidity.

	db	wb	% rh	dp
Air at	95	75	**40**	**67**
Cooled to	80	**70.8**	**65**	**67**

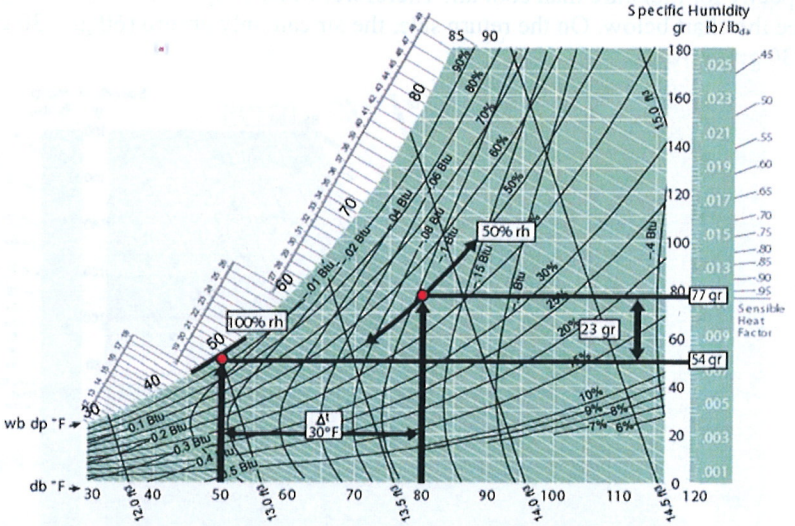


3. Sensible Heat Removed = 1.10 * cfm * temperature change
= 1.10 * 1,000 cfm * (80° F-50° F)
= 1.10 * 1,000 cfm * 30 = 33,000 Btuh

The factor 1.10 used in the sensible heat formula is a combination figure, which converts cfm to lbs per hour, and also the amount of heat required to raise 1 lb of air 1 degree Fahrenheit.

Latent Heat Removed = 0.69 * cfm * grains of moisture removed
= 0.69 * 1,000 cfm * (77 gr – 54 gr)
= 0.69 * 1,000 cfm * 23 = 15,870 Btuh

The factor 0.69 used in the latent heat formula is also a combination figure, which converts cfm to lbs per hour, and also takes into account the amount of heat removed to condense moisture.

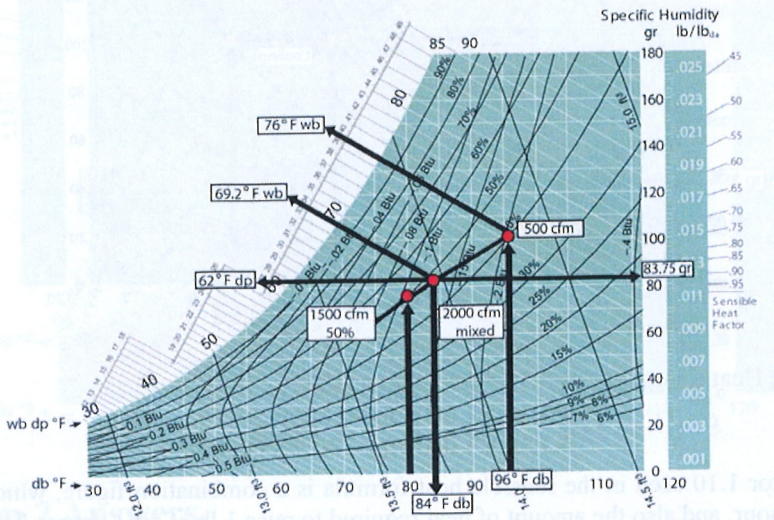


4.

a. Dry bulb 84° F
b. Wet bulb 69.2° F
c. Dew point 62° F
d. Specific humidity 83.75 gr/lb

The mixture will be closest to the larger air quantity. In this case, it is the 80° F db condition. The total cfm is in the mixture is 500 + 1500 or 2000 cfm. Five hundred cfm of outdoor air represents 500/2000 or ¼ of the mixture. Therefore, the mixture will be located ¼ of the way up from point 1 on line 1-2. The temperature difference between point 1 (80° F db) and point 2 (96° F db) is 96-80 or 16 degrees. One-quarter of 16 is 4 degrees. Therefore, the mixture is at 80° F +4° F or 84° F db or point 3.

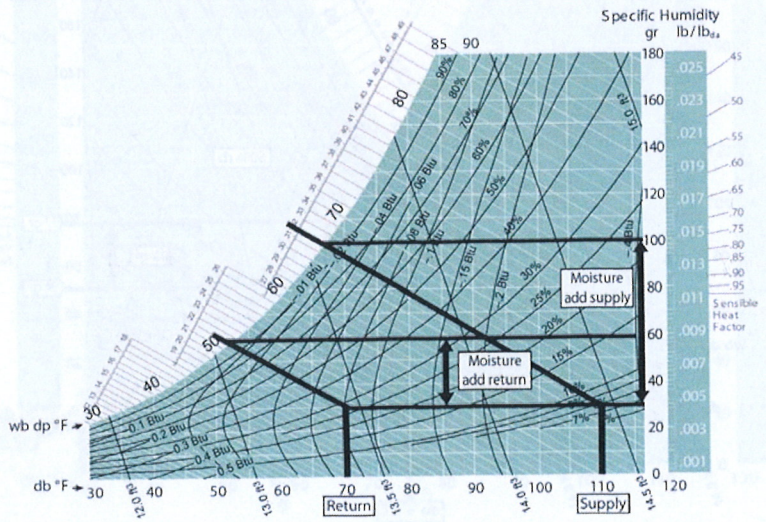
By locating 84° F on line 1-2, we can determine the other properties by using the chart.



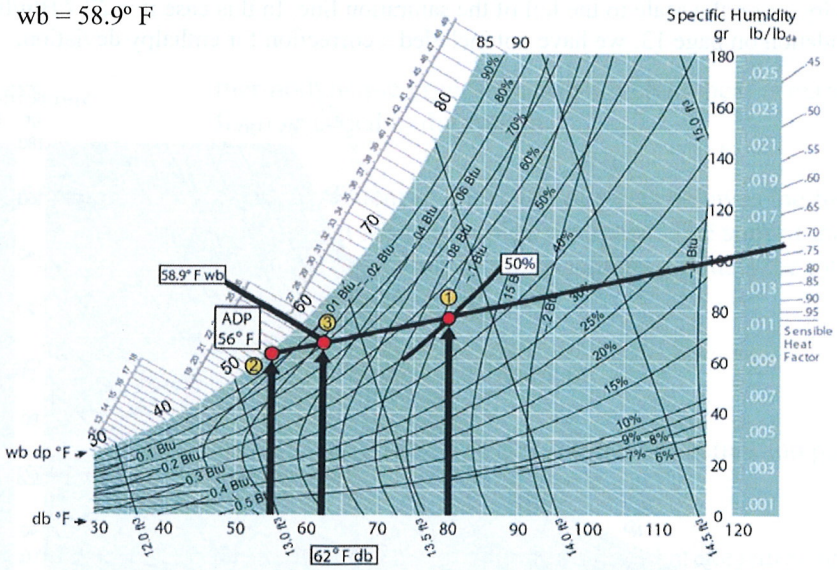
Note: The temperature of the mixture can also be determined by calculation as follows:

$$t_m = \frac{(cfm_1 \times t_1) + (cfm_2 \times t_2)}{cfm_1 + cfm_2} = \frac{(1500 \times 80) + (500 \times 96)}{1500 + 500} = \frac{120{,}000 + 48{,}000}{2000} = \frac{168}{2} = 84°F$$

5. The humidifier should be located on the supply side in the warm air from the furnace. Warm air has a greater capacity for moisture than cool air. Therefore, water evaporates more readily in the warm air stream. See the chart below. On the return side, the air can only absorb (60 gr – 30 gr) on the supply (100 gr – 30 gr) or 70 gr.



6. db = 62° F wb = 58.9° F



The bypass factor of 0.25 means that 75% of the 80° F db and 50% rh will contact the coil and be cooled to 56° F saturation (point 2), 25% of the air at point 1 will pass through the coil unchanged. The air leaving the coil will be a mixture of air at these two conditions.

db leaving the coil = 56° F +1/4(80° F+56° F)
= 56 + 6 = 62° F (point 3)

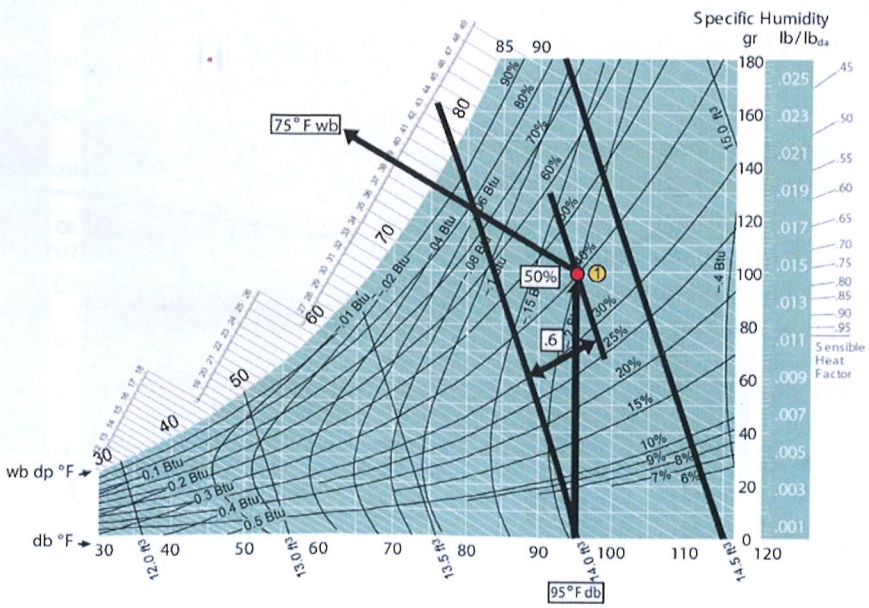
From the chart, the wb leaving the coil is 58.9° F.

This could also be checked by using the mixing equation: $t_m = \frac{(0.75 * 56) + (0.25 * 80)}{1.0}$

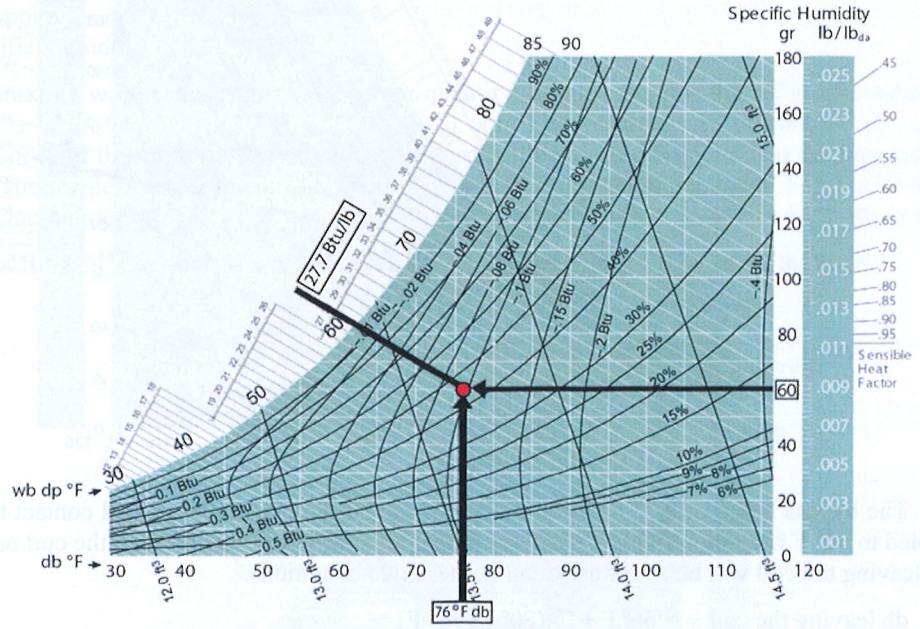
$t_m = 42 + 20 = 62$

7. Air at 95° F db and 75° F wb falls between the 14 and 14.5 cu ft/lb volume lines. Point 1 is estimated to be 0.6 of the distance to the left of the 14.0 cu ft line.

Volume at point 1 = 14 + 0.6 x (14.5-14) = 14.3 cu ft/lb



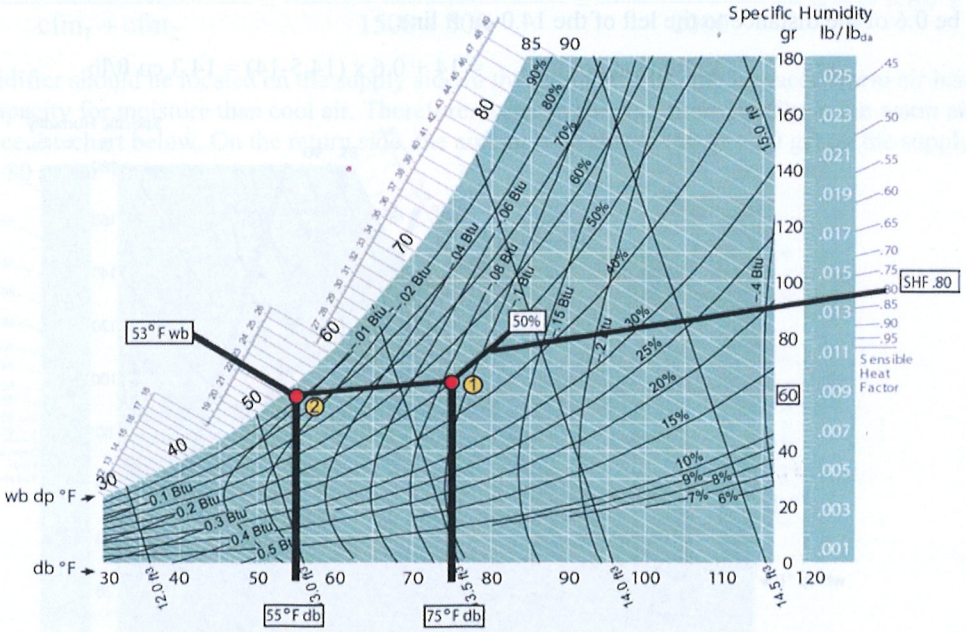
8. To determine enthalpy of air at condition 1, follow from point 1 parallel to a wb line and read enthalpy Btu/lb dry air on the scale to the left of the saturation line. In this case it is 27.7 Btu/lb_{da}. Per the recommendation on page 13, we have not included a correction for enthalpy deviation.



9. Draw a line connecting points 1 and 2. Then draw a line parallel to line 1-2 through the pivot point dot at 80° F db and 50% rh to the sensible heat factor scale. Read 0.8.

   Room sensible heat is 80% of the room total heat.

   Room latent is 100% -80% or 20% of the room total heat.



Glossary

adiabatic process	thermodynamic process during which no heat is extracted from or added to the system
Dalton's Law of Partial Pressure	each constituent of a mixture of gases behaves thermodynamically as if it alone occupied the space. The sum of the individual pressures of the constituents equals the total pressure of the mixture.
dehumidification	removal of water vapor from air.
dew point	5emperature at which water reaches the saturation point (100% relative humidity)
dry bulb temperature	temperature of air on a thermometer that measures sensible heat energy
enthalpy	thermodynamic quantity equal to the sum of the internal energy of a system plus the product of the pressure-volume work done on the system. h = E + pv, where h = enthalpy or total heat content, E = internal energy of the system, p = pressure, and v = volume.
humidification	the process of adding water vapor to the air
moisture content	the weight of water vapor, expressed in pounds or grains, associated with one pound of dry air. One pound of dry air is equal to 7000 grains
relative humidity	the ratio of the amount of vapor contained in the air to the greatest amount the air could hold at that temperature. Normally expressed as percentage.
superheat	extra heat in a vapor when at a temperature higher than the saturation temperature corresponding to its pressure.
wet bulb temperature	temperature indicated by a psychrometer when the bulb of one thermometer is covered with a water-saturated wick over which air is caused to flow at approximately 900 ft/min (4.5 m/s) to reach an equilibrium temperature of water evaporating into air, when the heat of vaporization is supplied by the sensible heat of the air.

Notes

Prerequisites:

This module assumes the participant has an understanding of industry terminology, basic concepts of the air conditioning, and the mechanical refrigeration process. The following TDPs are good reference for this material:

Form No.	Book Cat. No.	Instructor CD Cat. No.	Title
TDP-102	796-026	797-026	ABCs of Air Conditioning

Learning Objectives:

After completing this module, participants will be able to:

- Understand the properties of air and water vapor mixtures.
- Build the psychrometric chart.
- Use the psychrometric chart to determine the properties of an air/water vapor mixture.
- Use the psychrometric chart to understand the basic air conditioning processes.
- Understand how the processes can be combined into a system using a system plot diagram and psychrometric chart.

Supplemental Material:

Form No.	Book Cat. No.	Instructor CD Cat. No.	Title
TDP-202	796-031	797-031	Psychrometrics, Level 2: Process
TDP-203	796-032	797-032	Psychrometrics, Level 3: Application
TDP-204	796-033	797-033	Psychrometrics, Level 4: Theory
	796-018		Normal Temperature, Vinyl 11" x 17" Chart
	796-013		SHF Alignment Ruler
	796-016		Pad of 25 Paper Normal Temp 11" x 17" Charts

Instructor Information:

Each TDP topic is supported with a number of different items to meet the specific needs of the user. Instructor materials consist of a CD-ROM disk that includes a PowerPoint™ presentation with convenient links to all required support materials required for the topic. This always includes: slides, presenter notes, text file including work sessions and work session solutions, quiz and quiz answers. Depending upon the topic, the instructor CD may also include sound, video, spreadsheets, forms, or other material required to present a complete class. Self-study or student material consists of a text including work sessions and work session answers, and may also include forms, worksheets, calculators, etc.



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Supersedes Form No. TDP-3

Cat. No. 796-030
Supersedes Cat. No. 791-409