

UNDERSTANDING SUPERHEAT (AND SUBCOOLING)

Properly calculating these measurements will greatly help to determine the efficiency—or inefficiency—of an HVACR system.

BY ANDY SCHOEN, CM

[Editor's Note: For more information on test instruments that can be utilized to properly calculate superheat, see "What in the Truck Do HVACR Techs Carry" on pg. 8. Readers also can use the information shown in the images to determine superheat and subcooling measurements for R-134a and R-401A systems—the answers for which can be found on pg. 36.]

When it comes to explaining the subject of superheat, it is useful to begin with the most abundant fluid on our planet, refrigerant R-718—otherwise known as water. The illustration in Image 1 shows that water boils at 212°F (100°C); which is a principle that plays into the definition of **saturation temperature**—the temperature at which a fluid boils.

A fluid at its saturation temperature can exist in two phases: as a liquid or vapor; or as a mixture of both. Liquid and vapor at its saturation temperature is referred to, respectively, as saturated liquid and saturated vapor. In the case of water, it exists at 212°F as liquid water; as a mixture of liquid and vapor (steam); or as a vapor.

HEATING UP

A tea kettle provides an excellent example of what happens when water is heated to its boiling temperature. As water boils it converts to steam; the temperature of the steam leaving the kettle will not exceed its saturation temperature.

However, if heat is added to the saturated steam (shown in Image 2), the steam's temperature rises—and in the case



Image 1 This illustration is a basic example of the definition of saturation temperature—the temperature at which fluid boils.

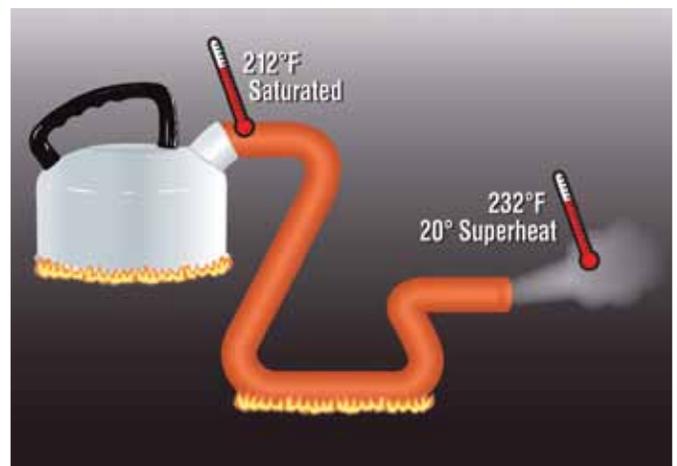


Image 2 The addition of heat to saturated steam (as illustrated above) superheats the steam's temperature.

of this illustration, superheats the temperature of the steam from 212°F to 232°F.

The amount of superheat in a vapor is determined by subtracting the saturation temperature from the actual vapor temperature. For example, at a temperature of 232°F, the

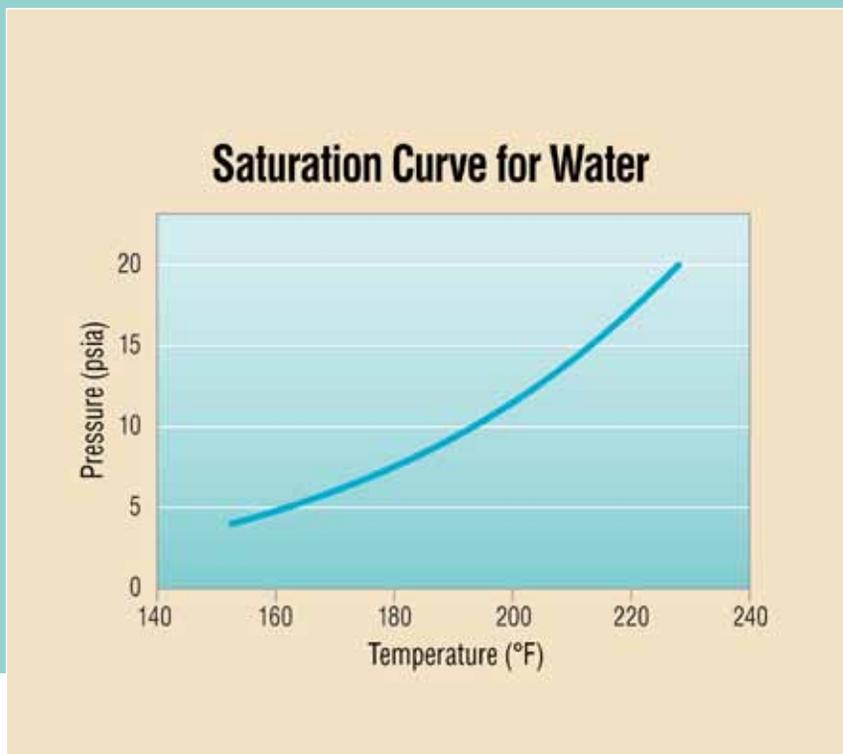


Image 3 Pressure applied toward a fluid will affect its saturation temperature—a factor that can complicate determining superheat. The saturation curve above shows how pressure impacts the boiling temperature of water.

steam’s superheat is calculated using this equation: $232^{\circ}\text{F} - 212^{\circ}\text{F} = 20^{\circ}\text{F}$.

A complication with determining superheat is the fact that the pressure exerted on the fluid influences its saturation temperature. Water boils at 212°F only at 14.7 psia, which is the average atmospheric pressure at sea level. As pressure increases on water, or any other fluid for that matter, its saturation temperature increases. Conversely, as pressure on a fluid decreases, its saturation temperature decreases.

This fact comes as no surprise to a resident in Denver, CO, who must boil their pasta longer to properly prepare it than an individual in Chicago, IL. In Denver, the average atmospheric pressure is 12.2 psia, or 2.5 psi below atmospheric pressure at sea level. At 12.2 psia, water boils at only 203°F , which certainly slows down the cooking process.

This actuality brings up the importance of the pressures and corresponding

saturation temperatures for a fluid—its **saturation curve**. This curve also is referred to as the **pressure-temperature** or **PT curve**. A section of the saturation curve for water is shown in Image 3.

KNOW YOUR SUBCOOLING

Proper understanding of superheat also requires an understanding of subcooling. Water temperature that is below its saturation temperature *and* in its liquid state is in its subcooled state. So if the temperature of water in a cup of hot coffee is 172°F , what is its amount of subcooling, assuming an atmospheric pressure of 14.7 psia?

The amount of subcooling in a liquid is determined by subtracting the actual liquid temperature from the saturation temperature. For example, at a temperature of 172°F , the water is subcooled by 40°F ($212^{\circ}\text{F} - 172^{\circ}\text{F} = 40^{\circ}\text{F}$).

This brings us to refrigerants. These fluids generally have much lower satu-

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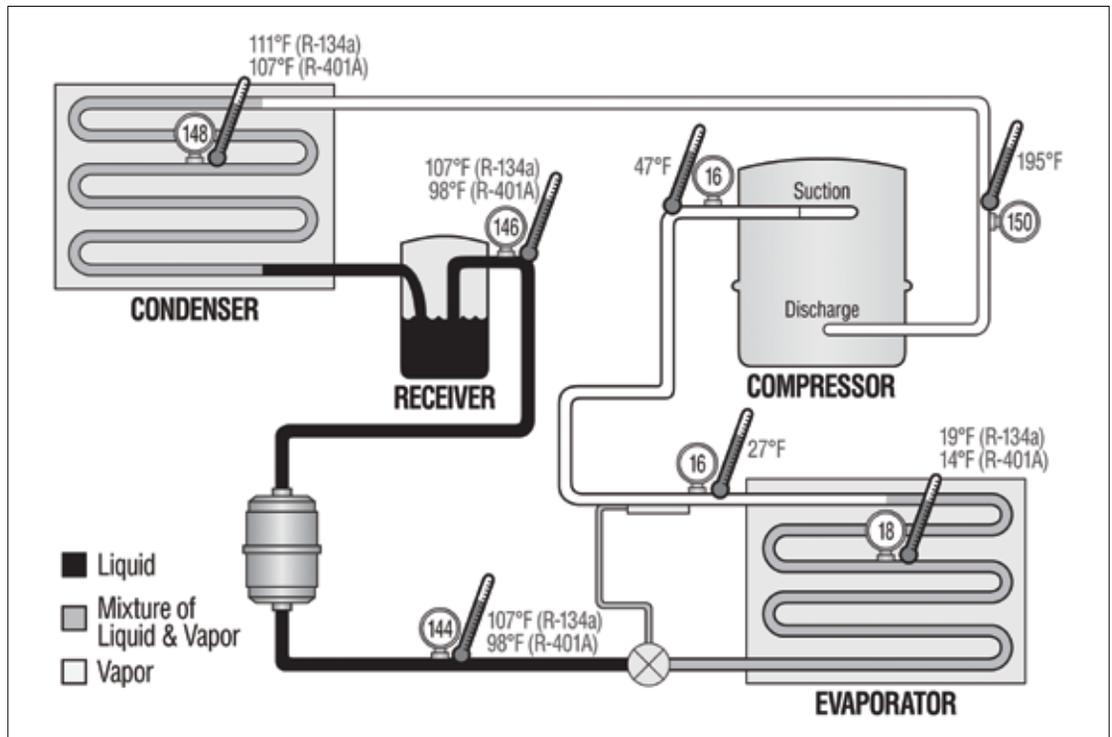
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>> **Image 4** This illustration shows all the basic components of a refrigeration system. Readers can use the corresponding information and temperature readings (as well as the information included in the chart on the following page) to calculate various superheat/subcooling values.



ration temperatures than water, and provide operating pressures desirable for compressor efficiency.

Why is it necessary to understand superheat and subcooling with a refrigeration system? Because as refrigerant circulates around the system, it becomes subcooled, saturated and superheated. The ability to measure superheat and subcooling will determine if the system is operating properly. A basic refrigeration system consisting of a compressor, condenser, receiver, TXV and evaporator is shown in Image 4.

If the system is operating properly, the high side of the system (from the compressor to the TXV) will contain refrigerant in all three states: subcooled, saturated and superheated. The discharge line contains high-pressure superheated vapor. As the refrigerant vapor flows through the condenser, its temperature is reduced and condenses into a liquid-vapor mixture, and finally to a liquid that normally has a small amount of subcooling.

The low side of the system (from the TXV to the compressor) normally contains refrigerant in two of the three states: saturated and superheated. The refrigerant flows into the evaporator as a liquid-vapor mixture, where it evaporates into a superheated vapor before entering the compressor.

In addition to the condenser and evaporator, the technician will find refrigerant at saturation in the receiver. Due to the fact that there is potential to have subcooled refrigerant entering and leaving the receiver, the tech can expect both subcooled and saturated refrigerant at the liquid-vapor interface in the receiver.

Referring to Image 4 again, pressure and temperature measurements are shown at various locations in the system, with R-134a as the refrigerant. Image 5 on pg. 17 lists pressure-temperature values for R-134a, which are used to determine the amount of subcooling or superheat present at each location. As an exercise, use the temperatures specified for R-134a where two temperatures are listed to determine the proper superheat and subcooling values. The answers to these questions are provided in RSES News on pg. 36.

REFRIGERANT BLENDS

Refrigerant blends combine more than one refrigerant to achieve desired properties. They have become prevalent during the past 20 years due to efforts to eliminate the use of CFC and HCFC refrigerants, and the need to match them with suitable alternatives. Popular refrigerant blends carry an ASHRAE 400 or 500 series refrigerant designation.

Refrigerant blends can be categorized into two groups: azeotropes and non-azeotropes. Azeotropes behave like single-constituent refrigerants, and the procedures discussed above to measure superheat and subcooling apply.

Non-azeotropes, however, present an interesting issue with respect to superheat and subcooling measurements. Unlike azeotropes and single-constituent refrigerants, non-azeotropes do not have a constant saturation temperature at a given pressure.

Recall that a fluid at its saturation temperature can exist in two phases: as a liquid or vapor; or as a mixture of both. In the case of a non-azeotrope refrigerant blend, the saturation temperature rises as it moves from a saturated liquid to a liquid-vapor mixture and, finally, to a saturated vapor.

The temperature at which the refrigerant blend begins to boil is the saturated liquid temperature, or **bubble point**; and the temperature at which the refrigerant begins to condense is the saturated vapor temperature, or **dew point**. The difference between dew-point and bubble-point temperatures is often referred to as **temperature glide**.

→To calculate superheat with a non-azeotrope refrigerant, use the dew-point temperature:
Actual vapor temperature – dew-point temperature = superheat.

→To calculate subcooling with a non-azeotrope refrigerant, use the bubble-point temperature:
Bubble-point temperature – actual liquid temperature = subcooling.

R-401A, a non-azeotropic refrigerant blend, was designed as a substitute for R-12. Bubble- and dew-point temperatures

» **Image 5** This chart lists various pressure-temperature values for R-134a and R-401A. Use these values to help determine subcooling and superheat at each location listed in Image 4 on the preceding page.

for R-401A are listed in Image 5. Looking at the bubble- and dew-point temperatures at 20 psig, R-401A begins to boil at 11°F and does not become a saturated vapor until it reaches 21°F. Therefore, R-401A has a 10°F temperature glide at this pressure (21°F – 11°F = 10°F).

Pressure-temperature charts for non-azeotropic refrigerant blends will normally list both bubble- and dew-point values so that subcooling and superheat measurements can be easily determined.

Referring again to Image 4 on pg. 16, use the pressure and temperature measurements shown there and the R-401A data listed in Image 5 to determine the amount of subcooling or superheat present at each location. Use the temperatures specified for R-401A where two temperatures are listed. Answers are provided on page 36. ☺

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Pressure (psig)	R-134a	R-401A	
	Temperature (°F)		
		Bubble Point	Dew Point
10	7	-5	5
12	10	-2	8
14	13	2	12
16	16	5	15
18	19	8	18
20	22	11	21
136	105	97	105
138	106	98	106
140	107	98	107
142	108	99	107
144	109	100	108
146	110	101	109
148	111	102	110
150	112	103	111
152	112	104	112
154	113	105	113
156	114	106	113
158	115	106	114
160	116	107	115

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