AST580 Refrigerant Dryers
Prework Manual

Fundamentals
Mechanical Refrigeration Basics
Analyzing the System
Glossary

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Overview

In this section, you will learn the terminology and principles of heat and heat transfer as it relates to mechanical refrigeration systems.

Principles of Heat Transfer

In this section you will learn the fundamental principles of heat transfer. These principles are the foundation for your understanding of temperature control.

The primary purpose of refrigeration and air conditioning is to produce desired temperatures within a specific area by transferring unwanted heat to a location where it is not objectionable or transferring heat to an area where it is desired. To achieve this purpose, the technician must have a working knowledge of heat flow, how heat enters a space, and how heat may be transferred. In any refrigerated area, heat can leak through the walls, open doors or gaskets.

What's the difference between refrigeration and air conditioning? It really is the same except for the temperatures being controlled.

Heat is a form of active energy. It cannot be seen, shaped, created, or destroyed. It is known only through its effect on the temperature, or heat content of matter. Heat (sensible) intensity is measured in degrees. Temperature is a measure of the intensity of heat. This is referred to as "sensible heat". Heat quantity is a measure that takes not only the temperature of a substance into account but also the quantity of heat in the substance.

The total absence of heat is -460°F. This is called *absolute zero*. It is unlikely that you will ever experience "no heat". Even ice cream at -20°F contains heat energy. We know this by the simple fact that the ice cream can be made even colder by removing additional heat energy. Refrigeration units don't make cold—they remove heat!

Three additional principles of heat transfer affect the design and operation of refrigeration units—*radiation*, *conduction* and *convection*.

Radiation

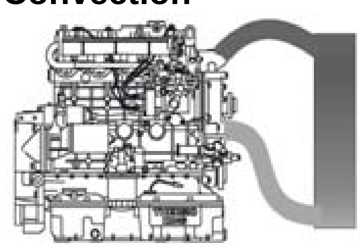
Radiation is a method of heat energy transfer. Radiant energy travels through empty space. The sun's energy is an example of radiant energy. Energy from the sun must pass through 93 million miles of space before reaching our atmosphere. It does not warm the emptiness of outer space; it only becomes heat energy when absorbed by an object.

Conduction

Spoon Cooling Spoon Heating

Conduction occurs when heat energy moves through a solid object, through a fluid, or when it moves directly from one substance to another in direct contact. If a "warm" spoon is placed in ice water, heat energy will be quickly conducted from the spoon to the surrounding water (hot to cold). If a "cool" spoon is placed in hot water, heat energy will be quickly conducted from the water to the spoon (hot to cold). A refrigeration unit effectively uses the principle of conduction to move heat from one place to another.

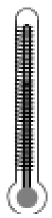
Convection



Convection is the movement of heat within a moving fluid. The fluid can be a liquid (such as water) or a gas (such as air). For example, in an engine cooling system, convection contributes to coolant flow between the engine and radiator. A pump, fan or blower is often used to increase fluid movement. Refrigeration units often include powerful fans to force air movement throughout the temperature-controlled compartment.

A refrigeration unit simply removes unwanted heat from a temperature-controlled compartment. If heat is removed faster than it enters, the compartment gets colder. If heat is removed at the same rate it enters, compartment temperature remains the same.

Heat measurement / Intensity



Heat measurement is part of our daily lives. When someone says, "It's too hot today", you understand what they mean. But the words "hot" and "cold" are relative-their meaning is defined by the subject at hand. A thermometer, scaled in °F or °C is commonly used to measure and communicate heat intensity. If an object contains a great deal of heat energy, the temperature is high. If an object contains little heat energy, the temperature is low.

Sensible Heat (Changing Temperature)

Sensible heat is defined as heat that can be measured or felt. Sensible heat causes a change in temperature of a substance but it will not cause a change in state of that substance.

A thermometer can only indicate heat intensity—it cannot indicate heat quantity. A candle flame and a camp fire may be the same temperature (intensity) but the camp fire contains much more heat energy. The standard of measurement is a British Thermal Unit or BTU. A BTU is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

BTUs = amount of water (in lbs) x Δ (delta) T

Or BTUs = lbs. x (T2-T1)

Example: The temperature of 4 lbs of water is changed from 80° F to 68° F.

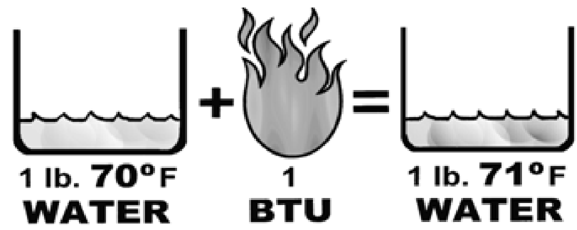
The temperature change ΔT = 80° F- 68° F = 12° F

$\Delta T = 12° \Phi$

To determine the BTUs (cooling) need for this change, multiply ΔT x W (weight).

$\Delta T \times W = 12 \times 4 = 48$ BTUs

The illustration above shows how the temperature of one pound of water is raised from 70° F to 71° F when a single BTU is added.



Latent Heat (Changing States)

When a substance changes from one state to another (solid to liquid, liquid to vapor, liquid to solid, or vapor to liquid), no change in temperature will be measurable. However, for this change of state to occur, an increase or decrease in heat is necessary. This heat, which again is not measurable, is called Latent Heat. There are four stages of latent heat.

Latent Heat of Vaporization

The amount of heat required to make the phase change from liquid to vapor is the latent heat of vaporization. 970 BTUs of latent heat are absorbed for the liquid became vapor. The heat energy absorbed when liquid becomes vapor is the *latent heat of vaporization.*

Latent Heat of Condensation

Just as 970 BTUs were absorbed to change liquid to vapor, 970 BTUs are released as vapor cools and returns to the liquid state. The heat energy released when vapor becomes liquid is the *latent heat of condensation.*

Latent Heat of Fusion

The amount of heat required to make the phase change from liquid to solid is the latent heat of fusion. 144 BTUs are released as liquid cools and returns to the solid state. The heat energy released when liquid becomes solid is the *latent heat of fusion.*

Latent Heat of Melting

Just as 144 BTUs were absorbed to change liquid to vapor, 144 BTUs are adsorbed as solid melts and returns to the liquid state. The heat energy adsorbed when solid becomes liquid is the *latent heat of melting.*

Understanding latent heat is your key to understanding refrigeration systems. To explain this concept, let's begin with the physical behavior of something familiar–water!

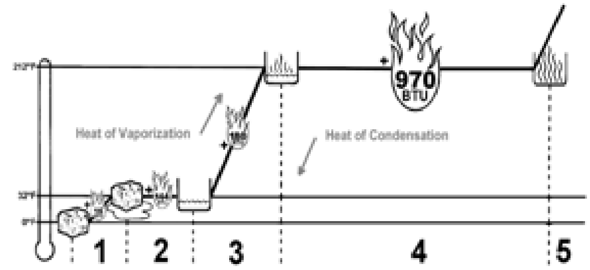
Water, like many substances, can exist in three physical states–solid, liquid and vapor. If you add heat to a block of ice it becomes water. It changes from the solid state to the liquid state. This is called a phase change. If you add enough heat to water, the water boils and becomes steam. The water changes state from liquid to vapor (steam). It works the other way, too. If you remove heat from steam (if you cool it), the steam returns to water. If you continue to remove heat from water, it becomes ice.

As you add heat to a block of ice, a thermometer will not indicate a temperature rise. The ice will eventually become water and the temperature will begin rise. If more heat is added, the water will turn to steam. But if you watch the thermometer very carefully, you will notice that the thermometer will not indicate a temperature rise while the water is boiling. You are adding latent heat.

During each change of state, the heat is being absorbed to make the phase change possible. Heat that cannot be measured on the thermometer is latent heat. A large amount of latent heat is absorbed or released as a substance changes state.

This illustration will help you understand how heat energy is used to convert one pound of ice at 32°F (0°C) to steam at 212° F (100°C).

When the ice temperature reaches 32°F (0°), it begins to melt. However, the temperature rise stops while 144 additional BTUs are absorbed by the ice. This heat cannot be sensed with a thermometer. This is latent heat. Latent heat is always involved in a change of state. While the 144 BTUs of latent heat are absorbed, the ice changes to water.



After the ice becomes water, we continue to add BTUs and the water temperature rises. We add 180 BTUs of sensible heat, the water temperature steadily rises from 32° F (0°C) to 212° F (100°C).

Remember, one BTU is the amount of heat required to raise the temperature of one pound of water 1°F. Here we have one pound of water being raised 180°F, from 32 to 212°F (100°C, from 0 to 100°C) .

When the water temperature reaches 212°F (100°C), it begins to boil. However, the temperature rise stops while 970 additional BTUs are absorbed by the water. Just as latent heat was absorbed to change the ice to water, an even larger quantity of latent heat is required to change water to steam. 970 BTUs of latent heat are absorbed while the water changes to steam.

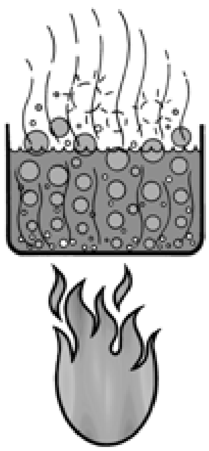
If we continue adding heat to the steam, the steam becomes super heated. Super heated gas contains heat beyond the amount required to maintain it as a vapor. Super heated water vapor is a gas with a temperature above 212°F (100°C).

Converting One Pound Ice to Steam

change from ice to water	144 BTUs
reach boiling point	180 BTUs
Change water to steam	970 BTUs
Total BTUs required	1294 BTUs

The Pressure/Temperature Relationship Affects the Boiling Point of Liquids

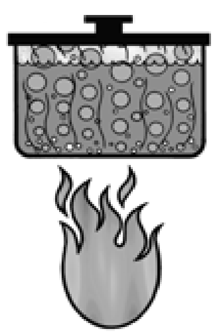
At sea level, water in an open container boils at 212°F (100°C). If you increase the heat source, the water will boil more violently but the water temperature will never rise above 212°F (100°C). This is because the boiling water releases heat with the rising vapor.



However, the temperature of water in a closed container can rise above 212°F (100°C). Trapped vapor builds pressure on the water's surface. Increased surface pressure raises the boiling point of liquid, therefore the water must get hotter than 212°F (100°C) before it can boil and release excess heat energy.

Raising the Boiling Point

Raising the boiling point of liquid by pressurizing the container is a common practice. The automobile uses a special radiator cap that allows pressure in the cooling system to rise while also preventing excess pressure build-up. Raising the system pressure (and boiling point) is necessary because automobile cooling systems often operate at 230°F. Non-pressurized water would violently boil out of the radiator and the engine would overheat. Simply maintaining a cooling system pressure of 10 psi raises the boiling point to 240°F. The addition of an anti-freeze solution will raise the boiling point even higher.



Lowering the Boiling Point

If raising pressure raises the boiling point, it stands to reason that lowering pressure will lower the boiling point.

At sea level, the earth's atmosphere presses down on all objects with a force of 14.7psi (1bar). At this pressure, the boiling point of water is 212°F (100°C). As you move higher in the earth's atmosphere (when you're climbing a mountain, for example), atmospheric pressure is reduced. At 5000', atmospheric pressure is only 12.3 psi and the boiling point is reduced to 203°F. For every 550' above sea level, the boiling point of water is reduced by approximately 1°F.

Pressure and Boiling Points

Pressure	Water	R134a	R22
28" vacuum	101°F	-100°F	-123°
	38°C	-73°C	-86°C
0 psi	212°F	-15°F	-41°F
0 bar	100°C	-26°C	-40°C
70 psi	303°F	69°F	40°F
4.8 bar	150°C	20°C	4°C
99 psi	327°F	121°F	58°F
6.8 bar	163°C	49°C	14°C

Mechanical Refrigeration

In this section, you will learn how mechanical refrigeration systems work. You will also the components in a refrigeration system and their purpose.

Principles of Refrigeration

This section will help you understand the four basic components of any standard refrigeration system and how they work together to absorb heat in one place and release it somewhere else.

At its simplest, a refrigerator requires four components and a refrigerant. The four components are

- The compressor
- The condenser
- The metering device
- The evaporator

The Compressor

The compressor performs two important functions:

- It moves refrigerant through the system allowing it to carry heat energy
- It creates high pressure on one side of the refrigeration system, and low pressure on the other. These two pressures cause refrigerant to boil in the evaporator and condense in the condenser.

The compressor is a very high pressure pump capable of establishing operating system pressures above 350 psig. This very high pressure results in very high temperature.

Hot gas travels from the compressor to the condenser. Refrigerant gas traveling through the condenser is normally thirty degrees or more above ambient temperature. Because the refrigerant gas is very hot, heat energy naturally moves to the colder ambient air (remember–*hotter to colder*!). Even if the ambient temperature is 100° F, heat readily transfers from the hot refrigerant gas to the cooler outside air.

The Condenser

The condenser is similar to the radiator in an automobile. The automobile's radiator transfers heat from the engine to the ambient air. This keeps the engine cool. In a refrigeration system, the condenser releases heat to the outside air. The condenser is always on the outside of the refrigerated compartment. The condenser relies on two key principles of heat transfer:

Heat energy always moves from "hotter" to "colder".

Heat energy transfers faster between objects having a larger temperature difference.

The condenser consists of tubes to contain the hot refrigerant and hundreds of delicate fins to transfer heat from the copper tubes to the cool air passing around the fins. These fins are tightly attached to the copper tubes to provide excellent heat transfer. They also provide an extremely large surface area for maximum exposure of heat to the cool ambient air. Copper or aluminum fins are used because they are good conductors of heat energy. The condenser (often called the condenser coil is a very efficient heat transfer component).

As the hot refrigerant vapor passes through the condenser, it loses enough heat to change from vapor to liquid. A large amount of latent heat energy is released as vapor cools and changes to the liquid state. The condenser makes good use of the Latent Heat of Condensation principle. The boiling point of refrigerant in the condenser must always be above ambient temperature so that the "cool" ambient air causes the refrigerant vapor to condense. If the refrigerant vapor fails to condense, only a small amount of heat will transfer to the ambient air.

The refrigerant exiting the condenser coil is actually cooler than the corresponding temperature on the P-T chart. This is because the refrigerant has become “sub cooled.” Sub cooling is an important concept for you to understand as a technician. It is defined as the additional sensible heat removed from the refrigerant after the refrigerant has changed state.

Metering Devices

There are three types of metering devices we use.

#1-The Expansion Valve

After passing through the condenser, the high pressure liquid refrigerant travels to the expansion valve. The expansion valve restricts and controls the flow of liquid refrigerant to the evaporator. This restriction helps maintain high pressure in the condenser to keep the boiling/condensation point high (above ambient). This restriction also allows low pressure to develop on the outlet side of the expansion valve. This low pressure reduces refrigerant pressure, refrigerant temperature, and the refrigerant’s boiling point in the evaporator. The expansion valve assembly constantly responds to changes in evaporator outlet temperature and pressure to precisely meter the correct amount of

refrigerant through the evaporator.
Regardless of system or load conditions, the expansion valve attempts to modulate open and closed in an attempt to maintain a constant superheat. Too much refrigerant will "flood" the evaporator. This will reduce or eliminate the important boiling effect that must occur for efficient operation. It also may damage the compressor.

Too little refrigerant will not provide the volume of moving refrigerant necessary to absorb large amounts of heat from the refrigerated compartment.

#2-Capalilary Tube

A capillary tube acts as a fixed metering device. After passing through the condenser, the high pressure liquid refrigerant travels to the capillary tube. The capillary tube restricts and controls the flow of liquid refrigerant to the evaporator. Only with a capillary tube, the flow will not be regulated. This is why this type of metering device is used on what is normally called a critically charged system

#3-Constant Pressure Valve

A constant pressure valve is a device (usually adjustable) to maintain a constant pressure in the evaporator. The setting of the constant pressure valve is determined by the type of refrigerant used. It is usually set to maintain the evaporator pressure (temperature) to above freezing. Remember, temperature and pressure at a saturated state are easily determined with a P/T chart.

The Evaporator

Like the condenser, the evaporator consists of copper or aluminum tubes and hundreds of delicate fins that transfer heat very efficiently. While the condenser releases heat to the outside air, the evaporator absorbs heat from the refrigerated compartment. The evaporator is always inside the refrigerated compartment.

Like the condenser, the evaporator relies on the same two key principles of heat transfer. Heat energy always moves from "hotter" to "colder". Heat energy transfers quickly between objects having a large temperature difference.

As low pressure, liquid refrigerant passes through the evaporator; it absorbs heat from the refrigerated compartment, and begins to boil. Even if the evaporator temperature is well below 0° F, the refrigerant boils and takes full advantage of the latent heat of vaporization. As the refrigerant boils, the evaporator surface is much colder than the air passing through it. Evaporator pressure and refrigerant boiling point must be lower than the temperature of air passing through it. (Opposite of the conditions required in the condenser.)

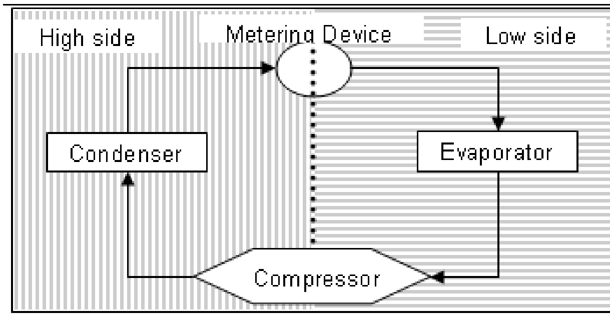
Once the refrigerant had fully boiled off (“evaporated”) in the evaporator coil, additional heat is picked up by the refrigerant. This additional sensible heat is known as superheat. The superheat value in a system is a critical measurement.

Too much superheat will create problems with compressors overheating, as they are cooled by cool suction gas.This results in a capacity loss. Too little superheat can be cause liquid flood back issues and damage the compressor with liquid refrigerant getting to the crankcase.

Low Side / High Side

The metering device and the compressor divide the refrigeration system into two sides - the high side and the low side. The "high side" is the high pressure part of the system between the compressor discharge and the metering device inlet. The "low side" is the low pressure part of the system between the metering device outlet and the compressor inlet.

A refrigeration technician uses a gauge manifold to measure low side and high side pressures. System pressures provide important clues to system malfunctions.



Refrigerants

From our earlier explanation of heat transfer principles, you learned that large amounts of heat are absorbed as water boils into vapor. This same concept applies to refrigerant as it changes from liquid to vapor however, most refrigerants boil at temperatures well below 0°F.

Refrigerant Boiling Point

One important characteristic of each refrigerant is its boiling point. As you know, the boiling point of any substance is affected by pressure. A P/T chart shows the boiling points of common refrigerants under the pressure of one atmosphere (atmospheric pressure at sea level.) Refrigerants with very low boiling points are capable of refrigerating to extremely low temperatures.

Saturation Point

If you pour R134a into an open container, it will instantly absorb heat from its surroundings and violently boil away. That's because room temperature is "hot" compared to the boiling point of the refrigerant. The boiling point of R134a is -15°F (-26°C) when it is open to the atmosphere and at room temperature.

However, if you close the container, the refrigerant liquid will only boil until vapor pressure above the liquid reaches the saturation point. Saturation point is a combination of pressure and temperature that allows liquid and vapor to co-exist in a state of equilibrium. The saturation point of water at sea level pressure is 212°F (100°C). Of course, the boiling point / saturation point are affected by pressure. Lowering the pressure lowers the boiling point and vice versa.

A refrigerant pressure/temperature chart shows us the saturation point for various refrigerants at various temperatures and pressures. For example, at 70°F (21°C), a closed container of R-134a will have a pressure of 70.7 psig. The refrigerant liquid and vapor are at equilibrium, in other words, they are at the saturation point.

If we place the container in a freezer and lower its temperature to -15°F (-26°C), the tank pressure will fall to establish the pressure-temperature equilibrium for that temperature. According to the P-T chart, the saturation pressure of R134a at -15°F is zero psig. If we continue to chill the container to -50°F, pressure will drop to meet a saturation point of 18.6" Hg (vacuum). The key point is to know that changing temperature changes pressure.

For every temperature on the P-T chart, there is a corresponding pressure. And conversely, for every pressure there is a corresponding temperature.

When discussing refrigerant, the term "pound" has two different meanings - a pound of pressure and a pound of weight. For example, a container may have three pounds of refrigerant (by weight), but the pressure in the container is 70.7 pounds (psig) at 70°F (21°C). If we remove one pound of refrigerant, two pounds remain in the container. As the one pound is removed, pressure in the container drops and boiling occurs. Over a period of time, pressure again stabilizes at 70.7 psig at 70°F (21°C).

The Pressure/Temperature Chart

If the 70°F (21°C) container of R134a has a pressure of 77.8 psig, we have a problem! According to the pressure/temperature chart, the pressure should be 70.7 psig. Two possibilities exist for this higher than expected pressure: First, air (or some other refrigerant) is mixed with the R-134a; second, the container is mislabeled and contains another refrigerant - not R134a.

Air should never be allowed to mix with refrigerant. Air causes serious system operation problems and shortens the life of system components. When working on refrigeration units, technicians must be very careful to avoid air contamination when installing and removing test and service equipment.

Additional System Components and Controls

Filter Drier

The filter drier has a sintered charge, a so-called solid core. This is pressed by the spring against the polyester pad and corrugated perforated plate. The charge or core in the filter drier consists of desiccant material which effectively removes moisture, harmful acids, foreign particles, sediment and the products of oil breakdown.

Hot Gas Bypass Valve

The hot gas valve is a pressure regulating valve which maintains the refrigerant pressure in the evaporator at a constant level, thus ensuring constant evaporator temperature. If the suction pressure falls, the valve opens. Remember, pressure = temperature. A hot gas bypass valve is commonly used on a constant run type of system where the compressor is operating anytime the dryer is turned on.

Liquid Receiver (Used with a TXV only)

A liquid storage receiver is fitted to the system primarily for the purpose of providing a reserve of refrigerant so that under all conditions of changing thermal load a supply of liquid refrigerant is available to the expansion valve. The liquid receiver can often be used to store refrigerant while maintenance work is carried out on other parts of the system.

Low Pressure Cut Out Switch

A pressure switch installed on the low pressure side of the system, its purpose is to prevent damage to the compressor. The settings of the cut in and cut out are determined by the type of refrigerant the system is using. The low pressure switch is to the suction side of the refrigeration system.

High Pressure Cut Out Switch

A pressure switch installed on the high pressure side of the system, its purpose is to prevent damage to the compressor. When pressure rises above the setting on the high pressure side, the circuit is broken. The differential is usually fixed and not adjustable.

Sight Glass/ Moisture Indicator

The sight glass has a color indicator that changes color when the moisture content of the refrigerant exceeds the critical value. The color indication is reversible, it changes back to normal when the plant has been dried (by replacing the filter drier and evacuating the system).

The sight glass must be placed immediately before the expansion valve. It has a glass top so that the flow of refrigerant liquid can be seen.

Solenoid Valve

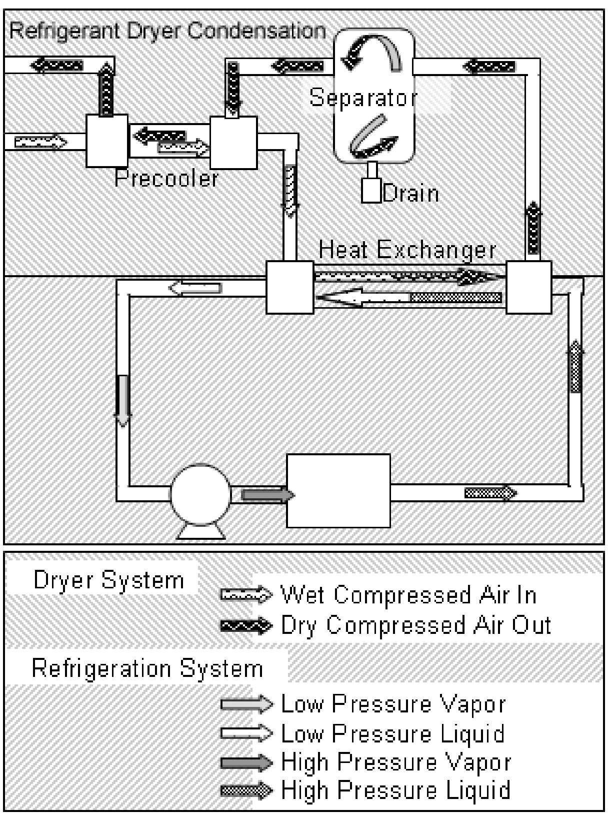
The solenoid is fitted to the liquid supply pipe, before the expansion valve. Its purpose is to stop liquid passing into the evaporator during the compressor off cycle, and thus avoids the possibility of liquid being drawn into the compressor suction when it re-starts. The solenoid is sometimes wired in series with the compressor motor so that when the compressor stops, the solenoid valve will stop the refrigerant flow, allowing the compressor to pump down and shut off on the low pressure switch. When the solenoid valve closes, no further liquid can flow into the evaporator.

Suction Line Heat Exchanger

Suction line heat exchangers are typically used with variable speed drive systems such as the VCD or “R” series dryers.

This component heats the cold vapor/liquid leaving the evaporator and cools the warm liquid leaving the condenser, before it reaches the expansion valve. The outer spiral-formed chamber channels hot refrigerant liquid in a flow counter to the flow of cold refrigerant liquid in the inner chamber.

The heat exchanger is manufactured in brass and copper and has very small dimensions in relation to its heat transmission capacity. The spiral-formed outer chamber forces the hot refrigerant liquid over the entire heat transmission surface, and prevents the formation of condensate on the outer jacket. The built-in offset fin section in the inner chamber produce turbulent flow in the refrigerant vapor/liquid. Heat transmission from warm liquid to cool vapor/liquid is therefore very effective. At the same time, pressure drop is kept down to a reasonable level.



The drawing above displays the interaction between the compressed air system and the refrigeration dryer system. The refrigerant and compressed air travel past each other, each within its closed system. As they do so, the heat from the compressed air is absorbed by the refrigerant. The refrigerant carries the heat away from the heat exchanger, and the cooled compressed air enters the separator where the water vapor is removed.

Chiller vs. Precooler/Reheater

Precooler/Reheaters do two very important things for refrigerated air dryers.

First, it reduces the amount of mechanical refrigeration required to reach dew point by reducing the air temperature going to the evaporator.

Second, chillers will allow condensation on air outlet piping. Addition of precooler/reheater eliminates outlet piping condensation

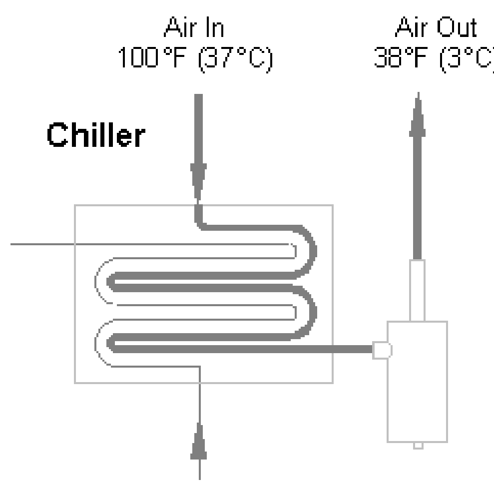
Air temperature reduction prior to chiller allows reduction in mechanical refrigerant requirements.

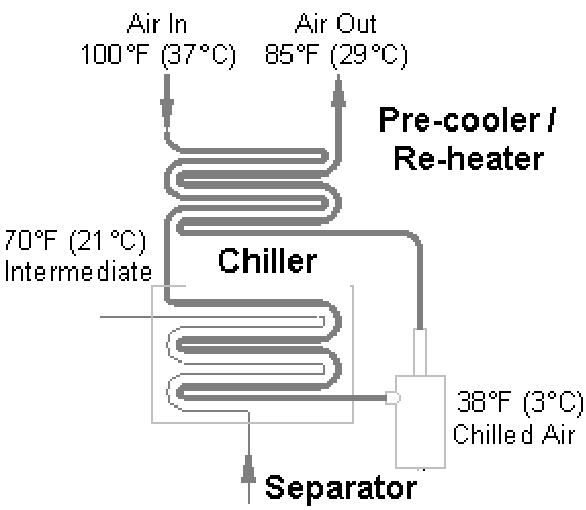
Chiller

1 HP = 100 SCFM of drying

Precooler/Reheater

1 HP = 200 SCFM of drying





Analyzing the System

Troubleshooting in a refrigeration circuit requires that we use our knowledge of the effect of pressure and temperature on liquid and vapor.

Remember, the refrigerant in a refrigeration system will exist in one of the following three states:

- All liquid
- All vapor
- Saturated State (A mix of liquid and vapor)

Saturation State

When the Pressure-Temperature (P-T) relationship holds true, refrigerant is "saturated."

The important thing to remember is that the pressure –temperature relationship as shown on a P-T card is only valid when there is a mixture of refrigerant liquid and vapor.

Therefore, there are only two places in the normally operating refrigeration system where the P-T relationship is certain. That is the evaporator and the condenser. Places where a mixture of liquid and vapor are known and expected to exist. When both refrigerant liquid and vapor exist together, the condition is known as "saturation."

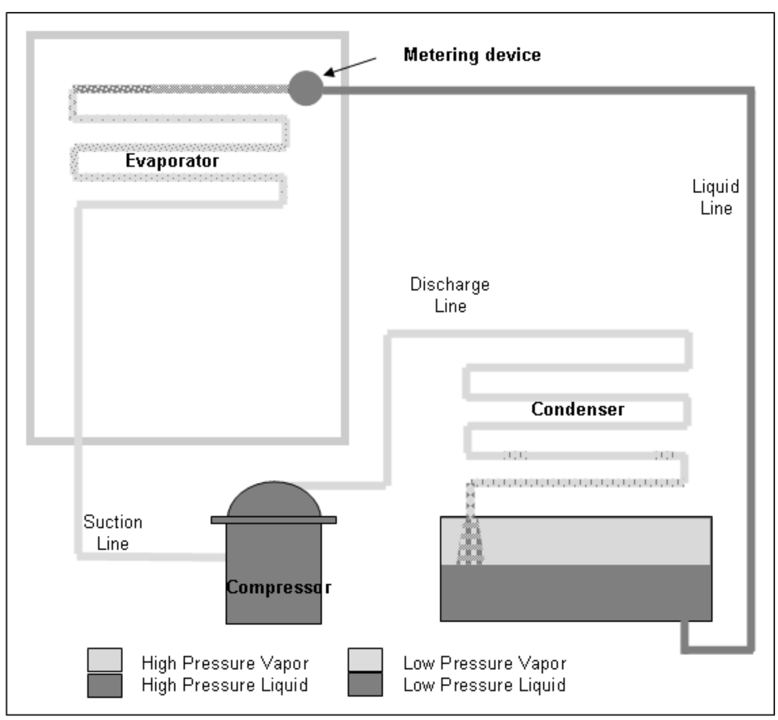
The physical laws controlling the refrigerant allow us to use a P-T card to determine either the pressure or temperature, provided we have one or the other.

Superheat

At the points in the system where we expect to see only vapor, the actual temperature should be above the temperature indicated on the P-T chart for the pressure we are measuring. In this case, the difference between the measured temperature and the temperature corresponding to the pressure that exists at the point in question, is a measure of superheat.

Sub cooling

The converse is true as well. In a part of the system where it is known that all liquid is present, the measured temperature will be below the temperature corresponding to the pressure on the P-T chart. The difference between the measured temperature and the temperature corresponding to the P-T relationship, is a measure of liquid sub cooling.



Analyzing an Actual System

The figure on the next page shows some actual pressure—temperature measurements throughout a normally operating system using refrigerant 134a.

A gauge installed in the suction line measures 18 psi. If there were a mixture of liquid and vapor at this point, the measured temperature would be the same as the P-T relationship temperature of 19°F. However, actual measured temperature at the outlet of the evaporator in this case is 27°F. The amount of superheat in the vapor at this point in the system is the difference between the measured temperature of 27°F and the indicated temperature according to the P-T chart of 19°F. The superheat therefore is 8°F.

The gauge installed in the liquid line reads 155 psi. According to the P-T relationship the temperature will be 114°F. If we placed a thermocouple at the condenser at this point, we would find a measured temperature of 124°F. The sub cooling is therefore 10°F.

Sub cooling is a lowering of a temperature below the P-T relationship. It is important to maintain some liquid sub cooling in the liquid line to minimize flash gas from forming in the liquid line and entering the metering device.

With the use of the P-T card we should be able to determine the condition of the refrigerant at any point in the system by measuring both the temperature and the pressure and observing the following rules.

When liquid and vapor are present together, the measured temperature corresponds to the P-T relationship.

Superheated vapor is present when the measured temperature is above the temperature corresponding to the P-T relationship. The amount of superheat is indicated by the difference.

Sub cooled liquid is present when the measured temperature is below the P-T relationship. The amount of sub cooling is represented by the difference.

The illustration has located gauges at points not always feasible in an actual installation. Because of this sometimes we must make deductions and assumptions when dealing with a live system.

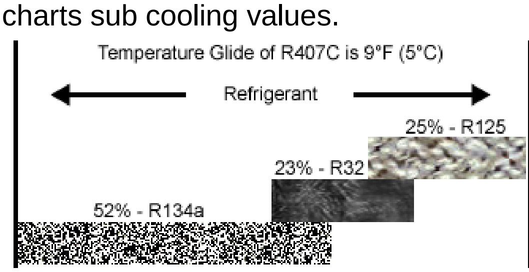
As an example, we assume that the 158 psig at the compressor discharge is also the pressure that exists in the compressor. We are assuming there is no pressure loss of any consequence between the compressor and the condenser.

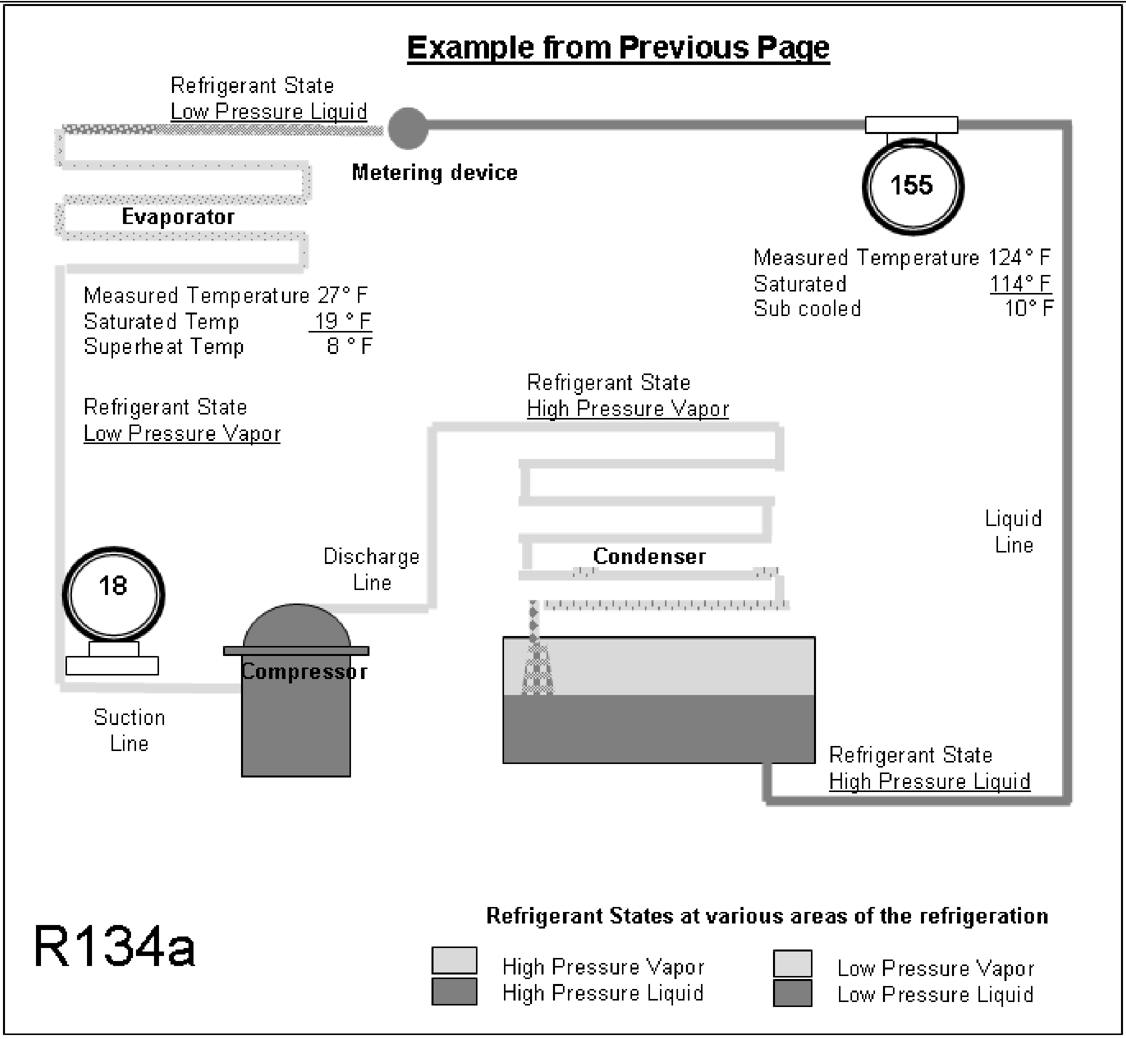
It is also common practice to assume that the pressure measured a the suction service valve of the compressor is the same pressure that exists at the outlet of the evaporator at the expansion valve bulb location. However, to eliminate any doubt as to the amount of suction line pressure drop and to be absolutely precise in measuring superheat, a gauge should be installed in the suction line at the outlet of the evaporator. If not available, care must be taken to make reasonable allowance for pressure drops within a system.

Blended refrigerants are a popular choice of refrigerant. Blended refrigerants have different boiling points and therefore have what is referred to as a “Glide” while changing states. When checking the sub cooling or superheat on any blended refrigerant, be aware of the glide. If you experience any leak at all on a refrigerated dryer using blended refrigerants, recover the charge remaining in the system and weigh in new refrigerant according to the unit data tag. Because blended refrigerants boil at different temperatures, when they leak, they fractionize. When this happens, it disrupts the blend.

Use the “Dew Point “ values on your P/T charts for superheat calculations.

Use “Bubble Point” values for on your PT charts sub cooling values.





Practice Calculations using a PT Chart

Coolant: R-22

At the Evaporator Outlet location the readings are:

Measured Temperature 55°F (12°C)

Measured Suction Pressure 70 psi

Saturated ____________

Superheated _________

At the Condenser Outlet location the readings are:

Measured Temperature 128°F (53°C)

Measured pressure 260 psi

Saturated _________________

Sub cooled ________________

Coolant: R-134a

At the Evaporator Outlet location the readings are:

Measured Temperature 44°F (6°C)

Measured Pressure 28 psi

Saturated _________________

Superheated _______________

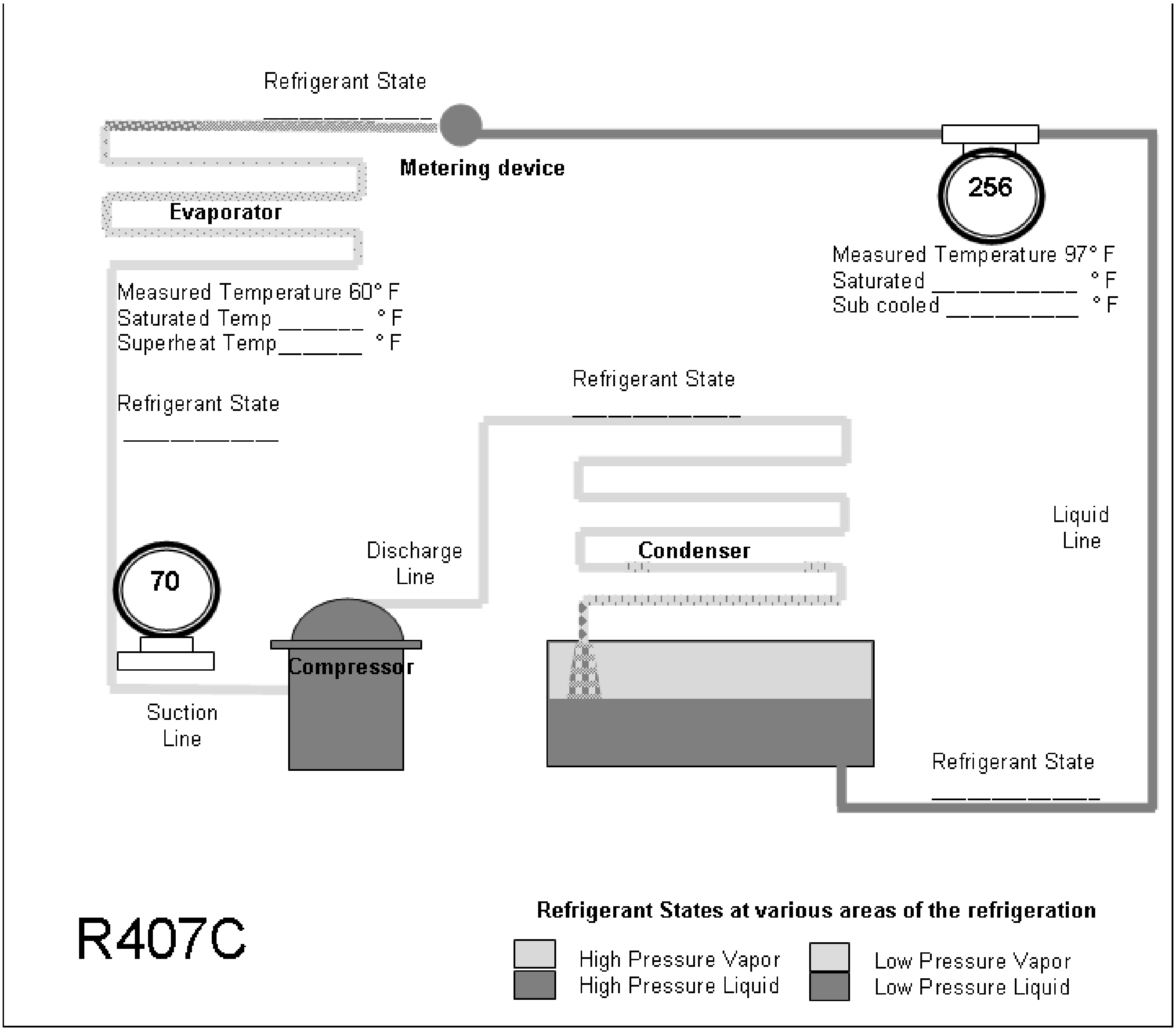
At the Condenser Outlet location the readings are:

Measured Temperature 119°F (48°C)

Measured pressure 220 psi

Saturated _________________

Sub cooled ________________



Blended Refrigerants

Use the figure above and the chart and the PT charts to test your knowledge and use of the P-T relationship.

The pressure and temperature are shown at various points in the system. Fill in the line that indicates the condition of the refrigerant at each point. In the case of superheated vapor and sub cooled liquid, indicate the amount in °F on the lines provided.

To determine sub cooling for Blended Refrigerants use Bubble Point values (Temperatures above 50°F—gray background)

To determine superheat for Blended Refrigerants, use Dew Point values (Temperatures 50°F and below.)

Temp °F	R-22	R-410A	R407C	R-12	R-134a
-16	12.6	29.7	8.4	2.1	0.7
-14	13.9	31.8	9.5	2.8	0.4
-12	15.2	33.9	10.7	3.7	1.2
-10	16.5	36.1	11.9	4.5	2.0
-8	17.9	38.4	13.2	5.4	2.8
-6	19.4	40.7	14.6	6.3	3.7
-4	20.9	43.1	15.9	7.2	4.6
-2	22.4	45.6	17.4	8.2	5.5
0	24.0	48.2	18.9	9.2	6.5
1	24.8	49.5	19.6	9.7	7.0
2	25.7	50.9	20.4	10.2	7.5
3	26.5	52.2	21.2	10.7	8.0
4	27.4	53.6	22.0	11.3	8.6
5	28.3	55.0	22.8	11.8	9.1
6	29.1	56.4	23.7	12.4	9.7
7	30.0	57.9	24.5	12.9	10.2
8	31.0	59.3	25.4	13.5	10.8
9	31.9	60.8	26.2	14.1	11.4
10	32.8	62.3	27.1	14.7	12.0
11	33.8	63.9	28.0	15.3	12.6
12	34.8	65.4	29.0	15.9	13.2
13	35.8	67.0	29.9	16.5	13.8
14	36.8	68.6	30.9	17.1	14.4
15	37.8	70.2	31.8	17.7	15.1
16	38.8	71.9	32.8	18.4	15.7
17	39.9	73.5	33.8	19.0	16.4
18	40.9	75.2	34.8	19.7	17.1
19	42.0	77.0	35.9	20.4	17.7
20	43.1	78.7	36.9	21.1	18.4
21	44.2	80.5	38.0	21.8	19.2
22	45.3	82.3	39.1	22.5	19.9
23	46.5	84.1	40.2	23.2	20.6
24	47.6	85.9	41.3	23.9	21.4
25	48.8	87.8	42.4	24.6	22.1
26	50.0	89.7	43.6	25.4	22.9
27	51.2	91.6	44.7	26.1	23.7
28	52.4	93.5	45.9	26.9	24.5
29	53.7	95.5	47.1	27.7	25.3
30	54.9	97.5	48.4	28.5	26.1
31	56.2	99.5	49.6	29.3	26.9
32	57.5	101.6	50.9	30.1	27.8

To determine sub cooling for refrigerant R-407C use Bubble Point values (Temperatures above 50°F—gray background); to determine superheat R-407C, use Dew Point values (Temperatures 50°F and below).

Temp °F	R-22	R-410A	R407C	R-12	R-134a
33	58.8	103.6	52.1	30.9	28.6
34	60.2	105.7	53.4	31.8	29.5
35	61.5	107.9	54.8	32.6	30.4
36	62.9	110.0	56.1	33.5	31.3
37	64.3	112.2	57.5	34.3	32.2
38	65.7	114.4	58.9	35.2	33.1
39	67.1	116.7	60.3	36.1	34.1
40	68.6	118.9	61.7	37.0	35.0
41	70.0	121.2	63.1	37.9	36.0
42	71.5	123.6	64.6	38.9	37.0
43	73.0	125.9	66.1	39.8	38.0
44	74.5	128.3	67.6	40.8	39.0
45	76.1	130.7	69.1	41.7	40.0
46	77.6	133.2	70.6	42.7	41.1
47	79.2	135.6	72.2	43.7	42.2
48	80.8	138.2	73.8	44.7	43.2
49	82.4	140.7	75.4	45.7	44.3
50	84.1	143.3	77.1	46.7	45.4
55	92.6	156.6	106.0	52.1	51.2
60	101.6	170.7	116.2	57.8	57.4
65	111.3	185.7	127.0	63.8	64.0
70	121.5	201.5	138.5	70.2	71.1
75	132.2	218.2	150.6	77.0	78.6
80	143.7	235.9	163.5	84.2	86.7
85	155.7	254.6	177.0	91.7	95.2
90	168.4	274.3	191.3	99.7	104.3
95	181.9	295.0	206.4	108.2	113.9
100	196.0	316.9	222.3	117.0	124.1
105	210.8	339.9	239.0	126.4	134.9
110	226.4	364.1	256.5	136.2	146.3
115	242.8	389.6	274.9	146.5	158.4
120	260.0	416.4	294.2	157.3	171.1
125	278.1	444.5	314.5	168.6	184.5
130	297.0	474.0	335.7	180.5	198.7
135	316.7	505.0	357.8	192.9	213.5
140	337.4	537.6	380.9	205.9	229.2
145	359.1	571.1	405.1	219.5	245.6
150	381.7	607.6	430.3	233.7	262.8
155	405.4	645.2	456.6	248.6	281.0

Glossary

After cooling The removal of heat from a gas after compression is complete.

Ambient Temperature The environmental temperature surrounding the equipment being considered.

Atmospheric Pressure The absolute pressure of the atmosphere as measured at the place under consideration. At sea level, the atmospheric pressure is 1 bar gauge (14.7 PSIA).

Back Seated (See Refrigerant Service Valve) The case when a refrigeration service valve is turned fully in a counterclockwise direction, thus allowing flow of refrigerant through the system.

Blended Refrigerants HFC refrigerants that contain a blend of two or more Hydrofluoro-carbon refrigerants to make a single compound (R-404A, R-407C)

CFC A pure chlorinated refrigerant Chlorofluorocarbon (R-12)

Capillary Tube A fixed metering device varying in diameter and length to regulate liquid flow into the evaporator.

Condensate The liquid formed from vapor due to a reduction in the temperature and/or an increase in pressure.

Condensation Occurs when heat loss in gas (vapor) molecules causes them to slow down, they are pulled together and form a liquid.

Condenser A heat exchanger wherein the process of condensation takes place.

Constant Pressure Valve An adjustable metering device used to maintain a constant evaporator under varying load conditions.

Dew Point The temperature at which a vapor is 100% RH begins to condense a liquid.

Dryer A device which reduces the water vapor content in a gas.

Evacuation The process of removing contaminating air and moisture from a refrigeration plant. Measured with a Micron Gage

Evaporation The process where, due to heating of a liquid, the molecules within that liquid speed up enough to break the surface tension layer and become a gas.

Evaporator A heat exchanger where the process of evaporation takes place.

Thermal Expansion Valve A valve operated by the temperature and pressure, designed to regulate liquid flow into the evaporator to maintain a constant superheat under varying loads.

External Equalizer A pipe used to connect the evaporator outlet to the underside of the bellows unit of a thermostatic expansion valve to help minimize pressure drops through an evaporator.

Factorization When blended refrigerants leak, separate and become unstable blends.

Flushing The process of removing refrigeration system contaminants by purging with refrigerant or similar fluid.

Freon A trade name for a family of synthetic liquids with low boiling points, used as refrigerants in modern refrigeration systems.

Front Seated (See Refrigerant Service Valve) Refers to a refrigeration service valve turned in a fully clockwise direction thus closing the refrigerant path.

Fusible Plug A fitting made with low melting point metal which acts as a safety device to release pressure in the event of a fire.

HCFC A chlorinated refrigerant containing a Hydrogen atom Hydrochlorofluorocarbon(R-22)

HFC A non chlorinated refrigerant Hydrofluorocarbon. It can be a single compound refrigerant (R-134a) or a blended refrigerant (R-404A, R407C)

Hot Gas Bypass Valve A pressure controlled valve installed in the refrigerant circuit to maintain a constant evaporating pressure.

Latent Heat The amount of heat required for a change of state of a substance. Latent heat of Fusion is 144 BTU's and Latent heat of Condensation is 970 BTU's.

Liquid Line The pipe which carries liquid refrigerant from the condenser (or liquid receiver, if present) to the expansion valve.

Pumping Down The action of using the refrigeration compressor against a closed solenoid valve in the liquid line to reduce the pressure. Used on larger TMS dryers.

Purging The action of releasing Nitrogen through the system in order to minimize oxidation while brazing.

Refrigerant Service Valve A valve designed to allow access and isolation of the refrigeration system.

Relative Humidity The ratio of actual water content in the air to the maximum water content the air can hold at a specific temperature and pressure. RH is expressed as a percentage.

Sensible Heat Heat that can be measured with a thermometer.

Slugging A condition in which liquid refrigerant or oil (non compressible) enters the compressor suction, this often results in valve and/or rotating assembly (rods, pistons, crankshaft) damage.

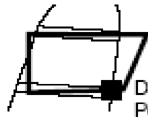
Sub cooled The temperature of a liquid cooled below its saturation state.

Suction Line Pressure Regulator A pressure regulator fitted to the inlet line of the compressor which maintains a constant pressure in the evaporator when the compressor is running. Mainly seen on TMS and VCD "R" series refrigerated dryers to control pressure in the crankcase of the compressor. Also referred to as a load limiting or high ambient valve.

Superheat The temperature of vapor above boiling temperature of its saturation state.

Superheat—Saturated Vapor Pressures

Typical pH Diagram Superheat—Reference Point



Dew Point—Saturated Vapor (psig)

°F	Suva® MP39 (R-401A)	Suva® MP66 (R-401B)	Suva® HP80 (R-402A)	Suva® HP81 (R-402B)	Suva® 407C (9000) (R-407C)	Suva® 408A (R-408A)	Suva® 409A (R-409A)	°C
–50	18.4"	17.2"	1.0	1.1"	11.2"	2.5"	18.6"	–46
–48	17.6"	16.4"	1.8	0.3	10.0"	1.0"	17.9"	–44
–46	16.9"	15.5"	2.7	1.1	8.9"	0.3	17.1"	–43
–44	16.1"	14.7"	3.7	1.9	7.6"	1.1	16.4"	–42
–42	15.2"	13.8"	4.6	2.8	6.3"	1.9	15.6"	–41
–40	14.3"	12.8"	5.6	3.7	4.9"	2.8	14.7"	–40
–38	13.4"	11.8"	6.7	4.7	3.5"	3.7	13.8"	–39
–36	12.4"	10.7"	7.8	5.7	2.0"	4.6	12.9"	–38
–34	11.4"	9.6"	8.9	6.7	0.4"	5.6	11.9"	–37
–32	10.3"	8.5"	10.0	7.8	0.6	6.6	10.9"	–36
–30	9.2"	7.3"	11.3	8.9	1.4	7.6	9.9"	–34
–28	8.1"	6.0"	12.5	10.1	2.3	8.7	8.8"	–33
–26	6.9"	4.7"	13.8	11.3	3.2	9.8	7.6"	–32
–24	5.6"	3.3"	15.2	12.5	4.2	11.0	6.4"	–31
–22	4.3"	1.9"	16.6	13.8	5.2	12.2	5.2"	–30
–20	2.9"	0.4"	18.0	15.2	6.2	13.4	3.8"	–29
–18	1.5"	0.6	19.5	16.6	7.3	14.7	2.5"	–28
–16	0.0	1.3	21.1	18.0	8.4	16.1	1.1"	–27
–14	0.8	2.2	22.7	19.5	9.5	17.5	0.2	–26
–12	1.6	3.0	24.4	21.0	10.7	18.9	0.9	–24
–10	2.4	3.9	26.1	22.6	12.0	20.4	1.7	–23
–8	3.2	4.8	27.9	24.3	13.3	22.0	2.5	–22
–6	4.1	5.8	29.7	26.0	14.6	23.6	3.4	–21
–4	5.0	6.8	31.6	27.7	16.0	25.2	4.3	–20
–2	6.0	7.8	33.5	29.5	17.4	26.9	5.2	–19
0	7.0	8.9	35.6	31.4	18.9	28.7	6.1	–18
2	8.0	10.0	37.6	33.3	20.5	30.5	7.1	–17
4	9.1	11.1	39.8	35.3	22.1	32.3	8.1	–16
6	10.2	12.3	42.0	37.4	23.7	34.3	9.2	–14
8	11.3	13.5	44.3	39.5	25.4	36.3	10.3	–13
10	12.5	14.8	46.6	41.7	27.2	38.3	11.4	–12
12	13.7	16.1	49.0	43.9	29.0	40.4	12.6	–11
14	15.0	17.4	51.5	46.2	30.9	42.6	13.8	–10
16	16.3	18.8	54.0	48.6	32.9	44.9	15.0	–9
18	17.6	20.3	56.7	51.1	34.9	47.2	16.3	–8
20	19.0	21.8	59.4	53.6	37.0	49.5	17.6	–7
22	20.5	23.3	62.2	56.2	39.1	52.0	19.0	–6
24	22.0	24.9	65.0	58.8	41.3	54.5	20.5	–4
26	23.5	26.5	68.0	61.6	43.6	57.1	21.9	–3
28	25.1	28.2	71.0	64.4	46.0	59.8	23.4	–2
30	26.7	30.0	74.1	67.3	48.4	62.5	25.0	–1
32	28.4	31.8	77.3	70.3	50.9	65.3	26.6	0
34	30.1	33.5	80.5	73.3	53.5	68.2	28.3	1
36	31.9	35.5	83.9	76.4	56.2	71.2	30.0	2
38	33.7	37.5	87.3	79.7	58.9	74.2	31.8	3
40	35.6	39.5	90.9	83.0	61.7	77.4	33.6	4
42	37.6	41.6	94.5	86.4	64.6	80.6	35.5	6
44	39.6	43.7	98.2	89.8	67.6	83.9	37.5	7
46	41.7	45.9	102.0	93.4	70.7	87.3	39.5	8
48	43.8	48.2	106.0	97.1	73.8	90.7	41.5	9
50	46.0	50.5	110.0	100.8	77.1	94.3	43.6	10

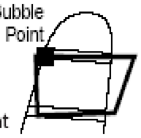
"Denotes inches of mercury ("Hg)

To obtain the Dew Point of saturated refrigerants above 50°F (10°C), use its Bubble Point temperature *plus* the value listed below:

MP series use 10°F (5°C), 9000 use 11°F (6°C), HP80 and HP81 use 2°F (1°C), 409A use 15°F (8°C), 408A use 1°F (0.6°C).

Subcooling Saturated Liquid Pressures

Typical pH Diagram Subcooling—Reference Point



Bubble Point—Saturated Liquid (psig)

°F	Suva® MP39 (R-401A)	Suva® MP66 (R-401B)	Suva® HP80 (R-402A)	Suva® HP81 (R-402B)	Suva® 407C (9000) (R-407C)	Suva® 408A (R-408A)	Suva® 409A (R-409A)	°C
50	58	62	114	106	96	96	61	10
55	64	69	125	116	106	105	67	13
60	71	76	136	126	116	115	74	16
65	78	84	148	138	127	126	82	18
70	86	92	161	150	139	137	90	21
75	94	101	174	162	151	149	98	24
80	103	110	188	175	163	161	107	27
85	112	119	203	189	177	174	116	29
90	122	130	218	204	191	188	126	32
95	132	140	235	220	206	203	137	35
100	143	152	252	236	222	219	148	38
105	154	164	270	253	239	235	159	41
110	166	176	289	271	257	252	172	43
115	179	190	309	290	275	270	184	46
120	192	203	330	310	294	289	198	49
125	206	218	353	330	315	309	212	52
130	220	233	376	352	336	330	227	54
135	236	249	400	375	358	351	242	57
140	252	266	425	399	381	374	258	60
145	268	284	451	423	405	398	275	63
150	286	302	479	449	430	423	293	66

To obtain the Bubble Point of saturated refrigerants below 50°F (10°C), use its Dew Point temperature *minus* the value listed below:

MP series use 10°F (5°C), 9000 use 11°F (6°C), HP80 and HP81 use 2°F (1°C), 409A use 15°F (8°C), 408A use 1°F (0.6°C).

DuPont Fluorochemicals
Wilmington, Delaware 19880-0711
(800) 235-SUVA

In Canada (800) USE–SUVA

Honeywell Products

VAPOR PRESSURES

TEMP °F	113	141b	123	11	114	142b
35.0	25.2"	20.5"	19.5"	17.2"	2.3"	7.6
40.0	24.5"	19.3"	18.1"	15.6"	0.4	9.9
45.0	23.8"	18.1"	16.6"	13.9"	2.0	12.5
50.0	22.9"	16.7"	15.0"	12.0"	3.8	15.3
55.0	22.0"	15.1"	13.1"	10.0"	5.8	18.2
60.0	21.0"	13.5"	11.2"	7.8"	7.9	21.4
65.0	19.9"	11.7"	9.0"	5.4"	10.1	24.9
70.0	18.7"	9.7"	6.6"	2.8"	12.6	28.5
75.0	17.3"	7.5"	4.1"	0.0	15.2	32.4
80.0	15.9"	5.2"	1.3"	1.5	18.0	36.6
85.0	14.3"	2.6"	0.9	3.2	21.0	41.1
90.0	12.5"	0.7	2.5	4.9	24.1	45.9
95.0	10.6"	1.5	4.2	6.8	27.5	50.9
100.0	8.6"	3.1	6.1	8.8	31.1	56.3
110.0	3.9"	6.6	10.3	13.2	39.1	68.0
120.0	0.7	10.7	15.0	18.3	48.0	81.2
130.0	3.8	15.4	20.5	24.0	58.0	95.8

TEMP °F	124	134a	12	BUBBLE (liq) MP39	DEW (vap) MP39	500	BUBBLE (liq) MP66	DEW (vap) MP66	BUBBLE (liq) 409A	DEW (vap) 409A	22	BUBBLE (liq) 407C	DEW (vap) 407C	BUBBLE (liq) 408A	DEW (vap) 408A	502	BUBBLE (liq) 404A	DEW (vap) 404A	BUBBLE (liq) HP81	DEW (vap) HP81	AZ-50**	BUBBLE (liq) HP80	DEW (vap) HP62	125	AZ-20***
-40.0	22.1"	14.7"	11.0"	8.1"	13.2"	7.6"	6.5"	11.8"	5.7"	13.6"	0.5	2.7	4.6"	3.8	3.4	4.1	4.8	4.3	5.5	4.3	5.5	6.8	6.3	7.2	11.6
-35.0	20.8"	12.3"	8.4"	5.1"	10.7"	4.6"	3.3"	9.1"	2.4"	11.1"	2.6	5.1	0.9"	6.1	5.7	6.5	7.4	6.8	8.2	6.8	8.2	9.6	9.1	10.1	14.9
-30.0	19.4"	9.7"	5.5"	1.7"	7.9"	1.2"	.2	6.1"	0.6	8.4"	4.9	7.7	1.6	8.8	8.3	9.2	10.2	9.6	11.0	9.5	11.1	12.6	12.1	13.1	18.5
-25.0	17.7"	6.8"	2.3"	1.0	4.8"	1.2	2.1	2.8"	2.6	5.4"	7.4	10.5	3.9	11.7	11.2	12.1	13.3	12.6	14.2	12.5	14.3	16.0	15.4	16.5	22.5
-20.0	15.9"	3.6"	0.6	3.0	1.4"	3.2	4.3	.5	4.7	2.0"	10.1	13.7	6.4	14.8	14.3	15.3	16.7	16.0	17.6	15.8	17.8	19.6	18.9	20.2	26.9
-15.0	13.9"	0.0	2.4	5.2	1.2	5.4	6.6	2.5	7.1	.8	13.2	17.1	9.2	18.2	17.7	18.8	20.4	19.6	21.3	19.5	21.7	23.6	22.9	24.2	31.7
-10.0	11.7"	2.0	4.5	7.7	3.3	7.8	9.2	4.7	9.6	2.8	16.4	20.9	12.3	22.0	21.4	22.6	24.5	23.6	25.4	23.4	25.8	27.9	27.1	28.6	36.8
-5.0	9.2"	4.1	6.7	10.3	5.5	10.4	12.0	7.1	12.4	5.0	20.0	25.0	15.7	26.0	25.4	26.7	28.9	27.9	29.8	27.7	30.3	32.6	31.7	33.4	42.5
0.0	6.5"	6.5	9.1	13.2	8.0	13.3	15.1	9.7	15.5	7.5	23.9	29.5	19.4	30.4	29.7	31.1	33.6	32.6	34.6	32.3	35.2	37.6	36.7	38.5	48.6
5.0	3.5"	9.1	11.8	16.3	10.7	16.4	18.4	12.6	18.7	10.1	28.2	34.3	23.4	35.2	34.4	35.9	38.8	37.7	39.7	37.3	40.5	43.1	42.1	44.1	55.2
10.0	0.2"	12.0	14.6	19.7	13.7	19.7	22.0	15.8	22.3	13.0	32.8	39.5	27.8	40.3	39.5	41.0	44.3	43.2	45.3	42.7	46.2	49.0	48.0	50.1	62.3
15.0	1.7	15.1	17.7	23.4	16.9	23.3	25.9	19.2	26.1	16.1	37.7	45.2	32.6	45.8	44.9	46.5	50.3	49.1	51.3	48.5	52.2	55.3	54.2	56.6	70.0
20.0	3.6	18.4	21.0	27.4	20.4	27.2	30.1	23.0	31.3	19.5	43.0	51.3	37.8	51.7	50.8	52.5	56.7	55.4	57.7	54.8	58.8	62.1	60.9	63.6	78.3
25.0	5.8	22.1	24.6	31.7	24.2	31.4	34.6	27.0	34.7	23.2	48.7	57.8	43.4	58.1	57.1	58.8	63.6	62.2	64.5	61.5	65.8	69.3	68.1	71.1	87.3
30.0	8.1	26.1	28.4	36.4	28.3	36.0	39.5	31.4	39.5	27.1	54.9	64.8	49.4	64.9	63.8	65.6	71.0	69.6	71.9	68.7	73.3	77.1	75.8	79.1	96.8
35.0	10.6	30.4	32.6	41.3	32.8	40.8	44.8	36.1	44.6	31.4	61.5	72.4	56.0	72.1	71.0	72.8	78.9	77.4	79.7	76.3	81.3	85.4	84.0	87.7	107.1
40.0	13.3	35.0	37.0	46.6	37.6	46.0	50.4	41.1	50.1	36.1	68.5	80.4	63.0	79.9	78.7	80.5	87.3	85.8	88.1	84.5	89.8	94.2	92.8	96.9	118.0
45.0	16.2	40.1	41.7	52.4	42.7	51.6	56.4	46.6	56.0	41..0	76.0	89.0	70.6	88.1	86.9	88.7	96.3	94.7	97.0	93.3	98.9	103.6	102.2	106.6	129.7
50.0	19.4	45.4	46.7	58.5	48.2	57.5	62.8	52.4	62.2	46.3	84.0	98.2	78.7	96.9	95.7	97.4	105.9	104.2	106.4	102.6	108.6	113.6	112.1	117.1	142.2
55.0	22.8	51.2	52.0	65.0	54.1	63.9	69.6	58.7	68.9	52.0	92.5	108.0	87.3	106.3	104.9	106.7	116.1	114.3	116.5	112.5	118.8	124.3	122.6	128.2	155.5
60.0	26.4	57.4	57.7	71.9	60.4	70.6	76.9	65.4	75.9	58.1	101.6	118.4	96.7	116.2	114.8	116.4	126.9	125.1	127.1	123.0	129.8	135.5	133.8	139.9	169.6
65.0	30.4	64.0	63.7	79.3	67.2	77.7	84.7	72.5	83.4	64.7	111.2	129.4	106.6	126.7	125.2	126.7	138.4	136.5	138.4	134.1	141.3	147.4	145.6	152.4	184.6
70.0	34.6	71.1	70.2	87.1	74.4	85.4	92.9	80.1	91.4	71.6	121.4	141.1	117.2	137.8	136.3	137.6	150.5	148.5	150.3	145.9	153.6	160.0	158.1	165.7	200.6
75.0	39.0	78.6	77.0	95.4	82.1	93.4	101.6	88.2	99.8	79.0	132.2	153.5	128.5	149.5	148.0	149.1	163.4	161.3	162.9	158.3	166.6	173.3	171.3	179.7	217.4
80.0	43.8	86.7	84.1	104.2	90.2	101.9	110.9	96.8	108.7	86.9	143.6	166.6	140.4	161.9	160.3	161.2	177.0	174.8	176.2	171.4	180.3	187.3	185.3	194.5	235.3
85.0	48.9	95.2	91.7	113.6	98.9	110.9	120.7	106.0	118.1	95.2	155.6	180.4	153.2	175.0	173.4	174.0	191.3	189.1	190.1	185.3	194.8	202.0	200.0	210.1	254.1
90.0	54.4	104.3	99.7	123.4	108.1	120.5	131.0	115.6	128.0	104.1	168.4	196.0	166.7	188.8	187.1	187.4	206.4	204.1	204.9	199.9	210.2	217.6	215.4	226.6	274.1
95.0	60.1	113.9	108.2	133.8	117.9	130.5	141.9	125.9	138.4	113.4	181.7	210.4	181.0	203.3	201.5	201.4	222.3	220.0	220.4	215.3	226.4	233.9	231.7	244.0	295.1
100.0	66.3	124.1	117.1	144.8	128.2	141.1	153.4	136.8	149.4	123.4	195.9	226.5	196.1	218.6	216.8	216.2	239.0	236.6	236.6	231.4	243.5	251.0	248.8	262.3	317.2
110.0	79.7	146.4	136.4	168.5	150.6	164.0	178.3	160.4	173.1	144.9	226.3	261.4	229.0	251.5	249.5	247.9	275.0	272.6	271.6	266.2	280.7	287.8	285.5	301.8	365.0
120.0	94.6	171.1	157.6	194.7	175.6	189.2	205.7	186.6	199.2	168.9	259.8	299.9	265.6	287.6	285.5	282.7	314.6	312.1	309.9	304.3	321.9	328.2	325.8	345.3	417.6
130.0	111.4	198.7	180.9	223.6	203.2	217.0	235.9	215.6	227.8	195.5	296.7	342.0	306.1	327.2	325.0	320.9	358.0	355.6	351.8	346.2	367.8	372.3	369.8	393.1	475.5
140.0	129.9	229.2	206.5	255.3	233.8	247.4	268.9	247.6	259.1	224.8	337.2	388.0	351.0	370.4	368.2	362.6	405.5	403.0	397.4	391.8	418.7	420.2	417.8	445.3	539.0
150.0	150.4	262.8	234.5	289.8	267.4	280.7	305.0	282.8	293.1	257.0	381.4	438.1	400.5	417.4	415.2	408.4	457.1	454.8	446.9	441.4	475.3	472.3	470.0	502.4	608.1

TEMP °F	13	23	503	508B
-120.0	4.5"	3.9"	3.1	3.2
-110.0	2.1	2.9	9.3	9.4
-100.0	7.6	9.0	16.9	17.0
-95.0	10.8	12.7	21.4	21.7
-90.0	14.3	16.7	26.3	26.4
-85.0	18.2	21.3	31.8	32.2
-80.0	22.5	26.3	37.7	37.9
-75.0	27.2	31.8	44.2	44.8
-70.0	32.3	37.9	51.3	51.6
-65.0	37.8	44.6	59.0	59.7
-60.0	43.9	52.0	67.3	67.8
-55.0	50.4	60.0	76.4	77.3
-50.0	57.5	68.7	86.1	86.8
-45.0	65.1	78.1	96.6	97.9
-40.0	73.3	88.3	107.8	109.0
-35.0	82.2	99.4	119.9	121.9
-30.0	91.6	111.3	132.8	134.7
-25.0	101.7	124.1	146.7	149.4
-20.0	112.5	137.8	161.4	164.1

Pressure: Psig

* inches mercury vacuum
** AZ-50 as an azeotrope of 125/143a.
*** AZ-20 is an azeotropic mixture of 32/125.

Review Questions

1. Conduction is the transfer of heat by means of ________ contact between two substances.

2. Heat is an active form of _________. It cannot be seen, shaped, created, or destroyed.

3. Matter can exist in _____ different physical states.

4. The two types of heat we use in mechanical refrigeration are__________ and__________.

5. Heat is measured in _______.

6. An increase in pressure causes an __________ in boiling point.

7. Calculate the number of BTUs required to make the following changes in temperature.

° F Change	Weight of water	BTUs
45°F to 50°F	**5 lbs.**	______________ **added**
100°F to 86°F	**0.5 lbs**	______________ **removed**
60°F to 70°F	**1 lb.**	______________ **added**
50°F to 65°F	**1.5 lb.**	______________ **added**

8. The two kinds of heat are determined by the effect which they produce upon a substance.
 ___________ heat changes the temperature of a substance, but not its state.
 ___________ heat changes the state of a substance, but not its temperature.

9. The most basic law of heat transfer is: Heat always travels from a _________ substance to a _________ substance.

10. Latent heat of Vaporization is ________ BTUs.

11. How does refrigeration transfer heat?

12. What are the 4 components required for the most simple refrigerator?

13. An example of a fixed metering device is a ___________.
14. Which component in a refrigerant dryer is shared between the compressed air system and the refrigerant system?
15. What is the purpose of a Hot Gas Bypass Valve?
16. A suction line heat exchanger is typically used on a ___________ type dryer.
17. What is the definition of “Saturation point”?
18. What are the two purposes of a precooler/reheater?
19. The split between the High side and the Low side occur at what two components in the refrigeration system?
20. For every temperature on a PT Chart there is a corresponding___________.
21. How do you know you are at a “Saturated State”?
22. What is the definition of Superheat?
23. What is the definition of Sub Cooling?
24. You must use _______________ values on blended refrigerants when calculating Superheat.
25. Why must you replace the complete charge on a system with blended refrigerants?
26. Using a P-T Card, in a system using R-134a refrigerant, at 70° F, what should the psig be?
27. Using a P-T Chart, in a system using R-22 is measured at a point in the refrigeration system to have a pressure of 61 psig, what should it’s saturation temperature be?