Study Guide

NORTH AMERICAN TECHNICIAN EXCELLENCE®

NATE

AIR CONDITIONING

Carrier®

GT70-01A (Rev. 03/03)

Cat. No. 020-016

AIR CONDITIONING

1. This refresher course covers topics contained in the **AIR CONDITIONING** specialty section of the North American Technician Excellence (NATE) certification exam.

AIR CONDITIONING BASICS

AIR CONDITIONING

"The process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space."

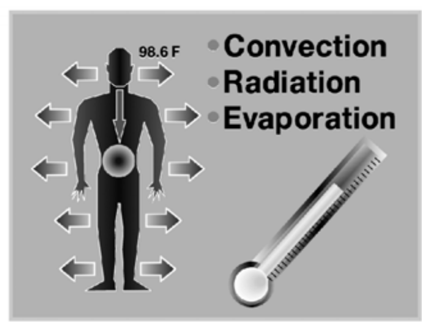
-ASHRAE

2. According to the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), air conditioning is "the process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space."

AIR CONDITIONING IS USED TO IMPROVE AN INDUSTRIAL PROCESS OR TO MAINTAIN HUMAN COMFORT

3. Air conditioning is used to improve an industrial process or maintain human comfort.

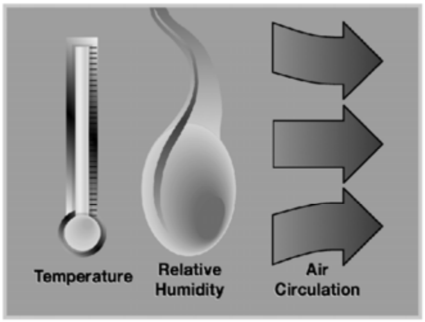
In an industrial system, the conditions to be maintained are determined by the process or material being handled, while in a comfort system, conditions are determined by the requirements of the human body.



THE BODY GIVES OFF EXCESS HEAT IN THREE WAYS TO MAINTAIN NORMAL BODY COMFORT

4. Heat is given off from the body by convection, radiation and evaporation. To maintain body comfort, we must control and adjust those three conditions of heat transfer.

All three methods of heat transfer are used at the same time but, depending on the surrounding conditions, one method may be used more than the others.



CHANGING THREE SURROUNDING CONDITIONS WILL AFFECT THE BODY'S ABILITY TO REJECT HEAT

5. Temperature, relative humidity, and air motion are three conditions affecting the body's ability to reject heat. Changing these conditions will help speed up or slow down convection, radiation, or evaporation, thus, helping to control body comfort.

PRINCIPALS OF AIR CONDITIONING

TEMPERATURE

- Heat always flows from higher to lower temperature.
- The greater the temperature difference, the faster the flow of heat.
- The higher the air temperature, the slower the rate of heat transfer.
- Lower surrounding surface temperature, increases the cooling effect the body feels through radiation.
- Higher surrounding surface temperature, increases the warming effect by reversing the radiation process.

6. Heat always flows from higher to lower temperature. The greater the temperature difference, the faster the flow of heat. The higher the air temperature, the slower the rate of heat transfer. Lower surrounding surface temperature increases the cooling effect the body feels through radiation. Higher surrounding surface temperature increases the warming effect by reversing the radiation process.

PRINCIPALS OF AIR CONDITIONING

RELATIVE HUMIDITY

- A measure of how much moisture is in the air and an indication of how much moisture the air can absorb.
- Affects the amount of heat the body can give off through evaporation.
- There is a direct correlation between relative humidity and temperature.
- Cool air has less capacity to hold moisture than does warm air and changing temperature affects humidity.
- The higher the relative humidity, the less able the body is to give off heat through evaporation.

7. Relative humidity is the measure of how much moisture is in the air and an indication of how much moisture the air can absorb. Relative humidity affects the amount of heat the body can give off through evaporation.

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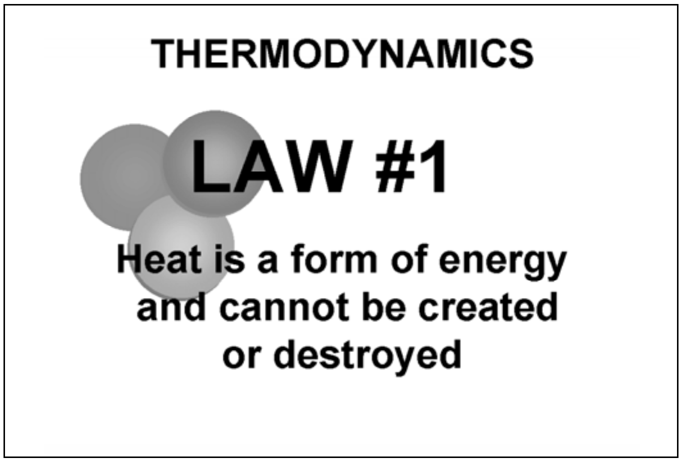
PRINCIPALS OF AIR CONDITIONING

AIR CIRCULATION

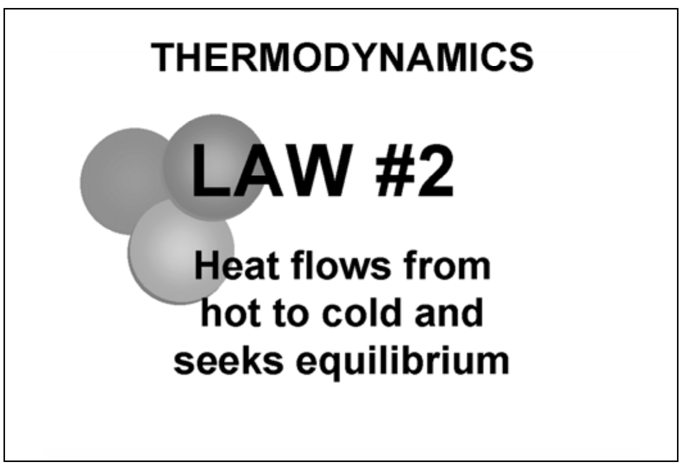
- Increases the rate of evaporation.
- Air moving across the body forces away saturated air, allowing moisture to evaporate.
- Decreasing relative humidity through air circulation increases body comfort.
- Air motion speeds up convection by removing warm air close to the body and carrying away the heat.
- Air in motion can also remove heat from surfaces surrounding the body, like walls and ceilings.

8. Air circulation increases the rate of evaporation. Air moving across the body forces away saturated air, allowing moisture to evaporate. Depending on a person's location, decreasing relative humidity through air circulation increases body comfort.

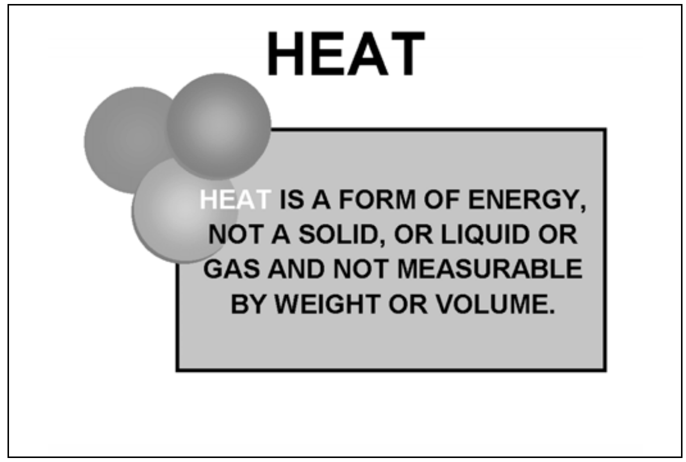
Air motion speeds up convection by removing warm air close to the body and carrying away the heat. Air in motion can also remove heat from surfaces surrounding the body, like walls and ceilings.



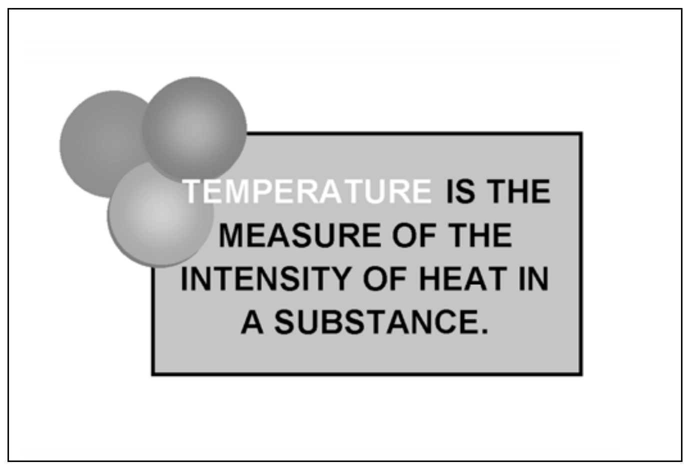
9. The first law of thermodynamics is that heat is a form of energy that cannot be created or destroyed. It can be moved but the total amount of heat after it is transferred will still be the same.



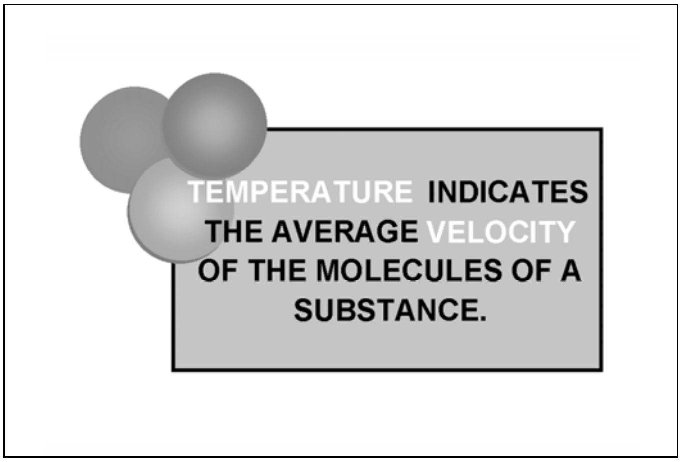
10. The second law of thermodynamics is that heat moves from hot to cold or from higher to lower intensities. The rate at which it moves depends on the temperature difference (ΔT) and the larger the temperature difference, the faster the heat will be transferred.



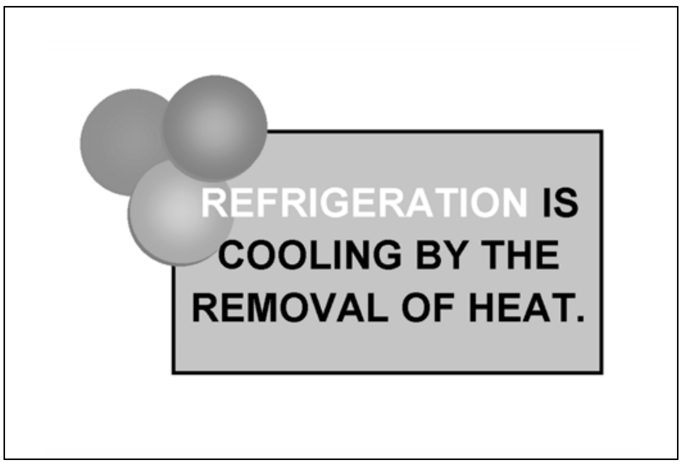
11. **Heat** is a form of energy, which can exist on its own and can be moved from one place to another. It *is not* matter that exists as a liquid solid or gas, so, it cannot be measured by weight or volume.



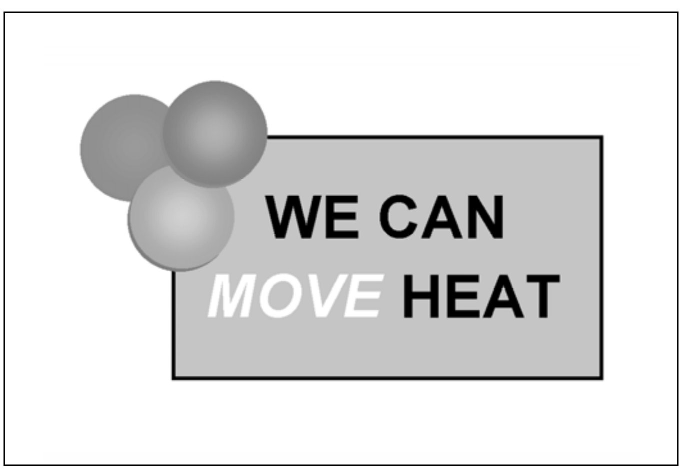
12. **Temperature** is the measure of the intensity of heat or the degree of heat in a substance. It *does not* measure the heat energy required to change the state of a substance from a solid to a liquid or a liquid to a vapor. In other words *temperature measures sensible heat, but not latent heat*.



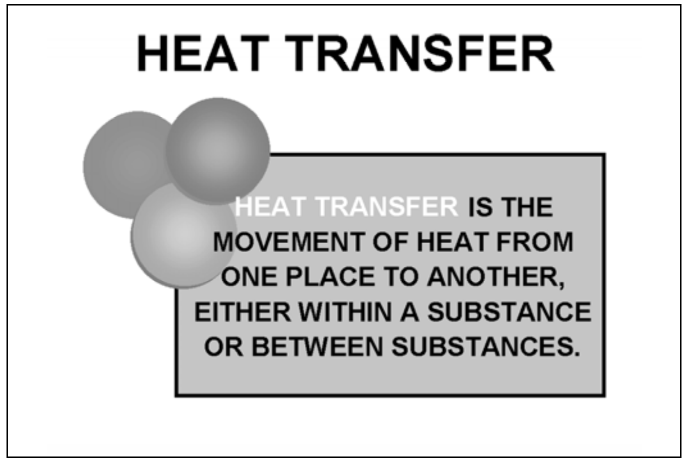
13. Temperature indicates the average **velocity** of the molecules of a substance.



14. Refrigeration is cooling by the removal of heat from a substance or space.

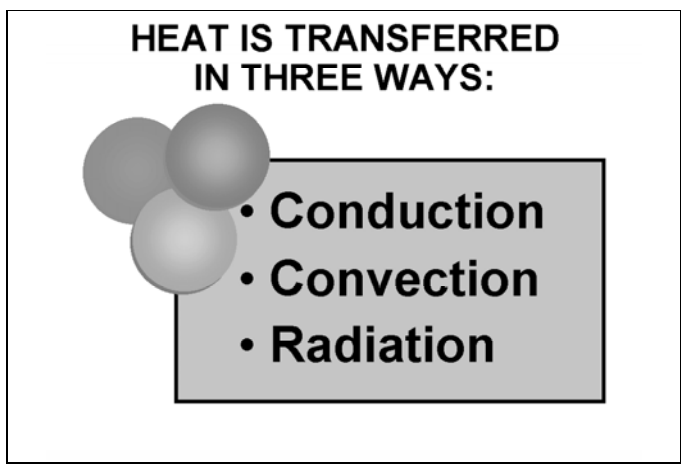


15. Heat, which is a form of energy, can be moved. Cooling is simply the movement of heat from an area where it is objectionable to an area where it is less objectionable.

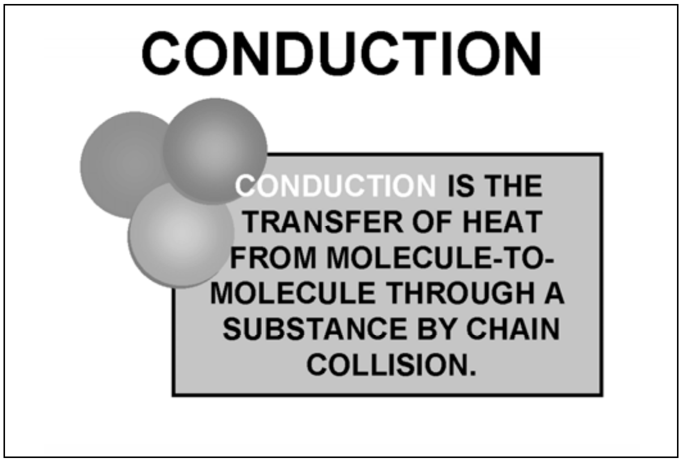


16. **Heat transfer** is the movement of heat from one place to another, either within a substance or between substances.

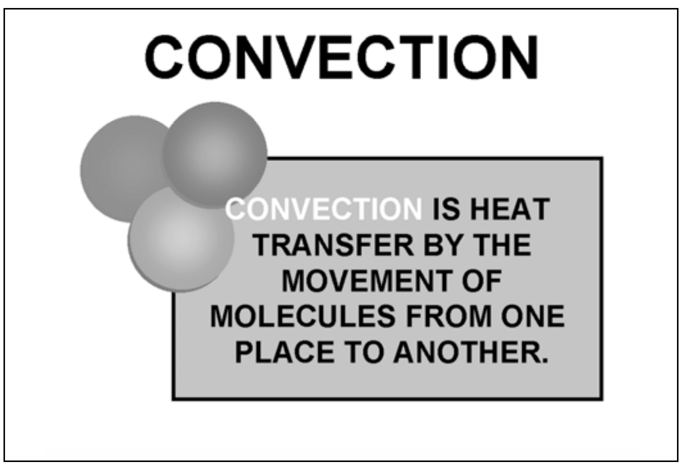
Heat content is not the same thing as heat transfer since it deals with *how much* heat energy a substance contains while heat transfer deals with *how much heat is moved* from one substance to another.



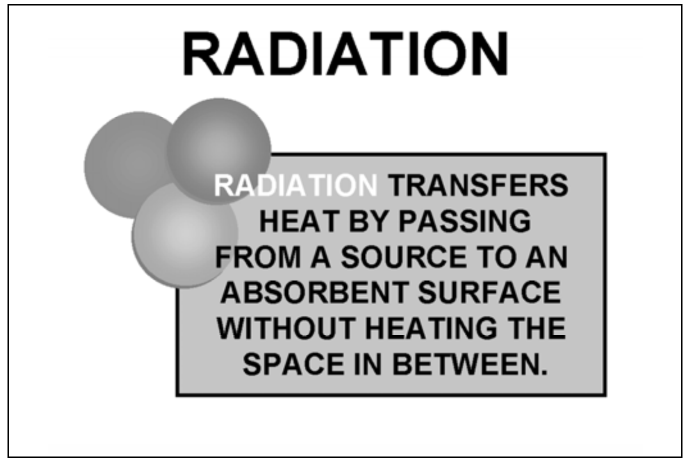
17. Heat can be transferred by either conduction, convection or by radiation.



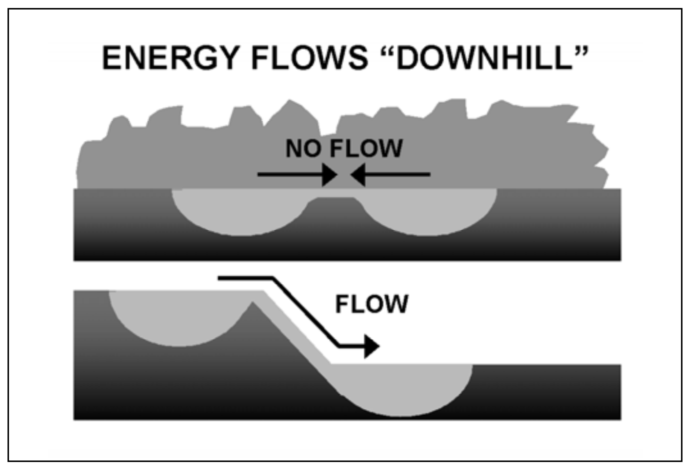
18. **Conduction** is the transfer of heat from molecule to molecule through a substance by a chain collision. A metal bar, heated on one end will ultimately transfer the heat energy to the other end through conduction.



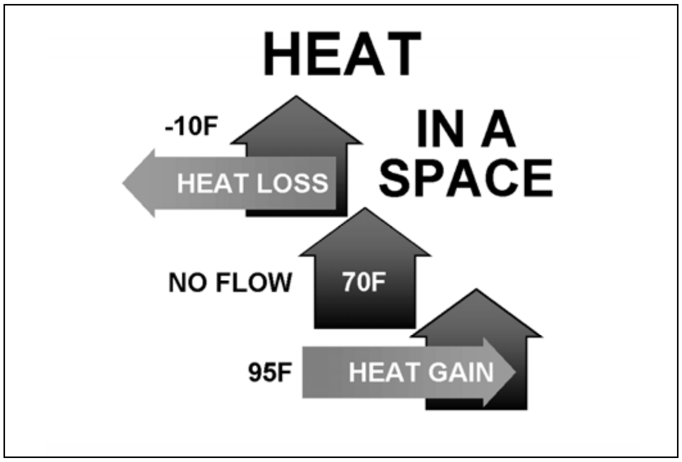
19. **Convection** is heat transfer by the movement of molecules from one place to another. Air flowing through the duct system of a furnace, carries heat to another space through convection.



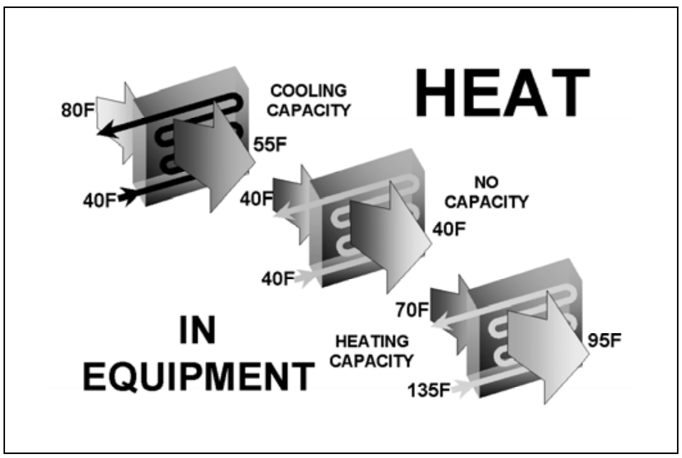
20. **Radiation** transfers heat by passing it from a source to an absorbant surface without heating the space in between. Radiant heat behaves as a wave form of energy, like light. A camper sitting in front of a fire on a cold night, is warmed by radiant heat.



21. Energy flows "downhill" from areas of greater intensity to areas of less intensity and tends to seek a level of equilibrium.

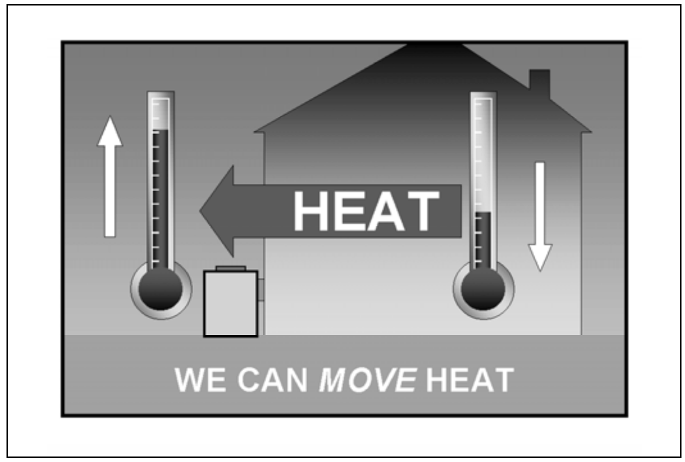


22. The rate at which heat flows from indoors to outdoors is known as the **heat loss** of the structure. The larger the heat difference between the indoors and the outdoors (ΔT), the faster the heat flows out and the greater the heat loss.

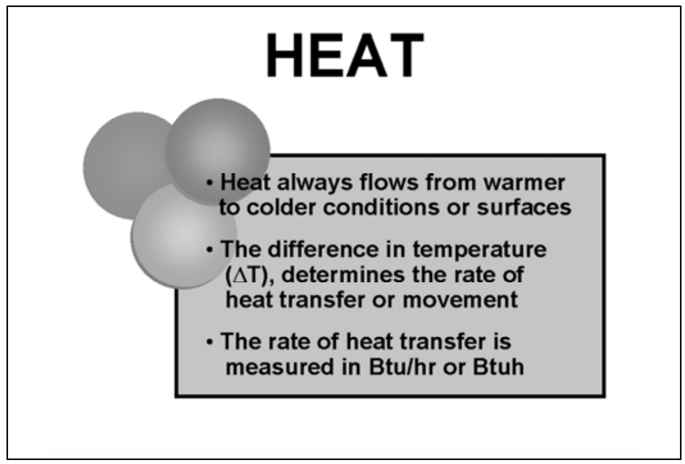


23. The same principles that apply to moving heat in our surroundings apply to the movement of heat in equipment. For example, if the temperature of the air flowing over a coil is higher than that of the refrigerant in coil tubes, heat will flow from the air to the refrigerant. The coil, in this case, provides cooling capacity.

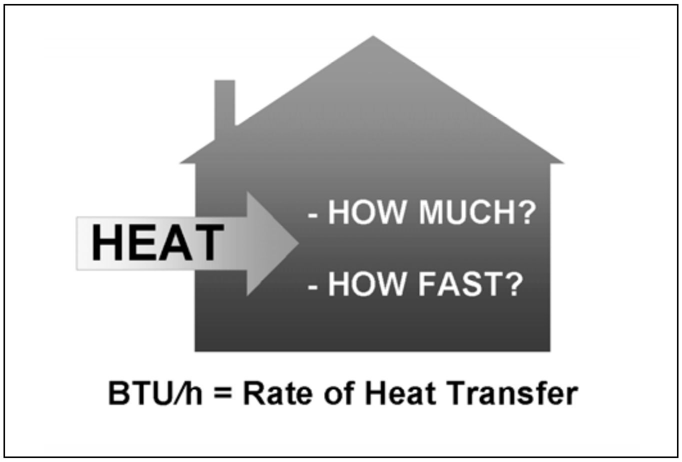
If the refrigerant temperature is equal to the air flowing over the coil, there is no heat transfer and therefore no cooling capacity provided by the coil.



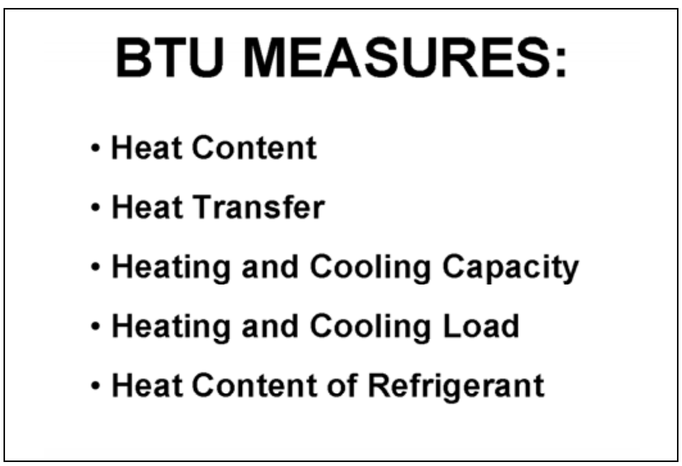
24. When heat is moved, the temperature of the substance it moved *from* drops, while the temperature of the substance it moves *to* rises.



25. Heat always flows from warmer to colder conditions or surfaces. The difference in temperature (ΔT), determines the rate of heat transfer or movement, measured in Btu/hr (Btuh).

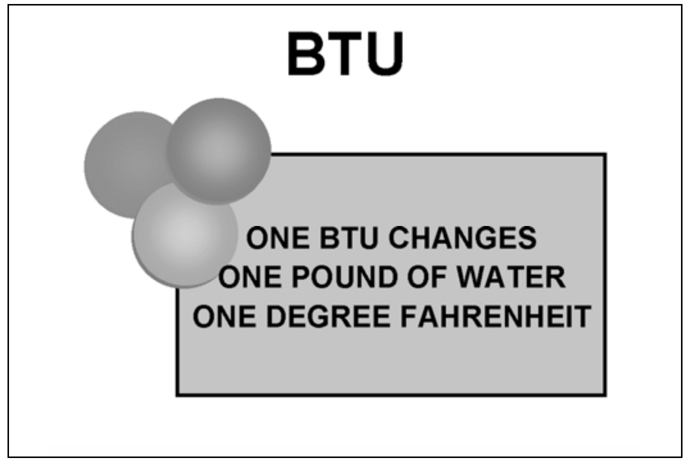


26. We use **Btuh** (Btu's per hour) to measure the **rate** of heat transfer. The crucial issue in dealing with heat gain is how much heat is entering a building *during each hour* or *how fast* heat is entering the building.

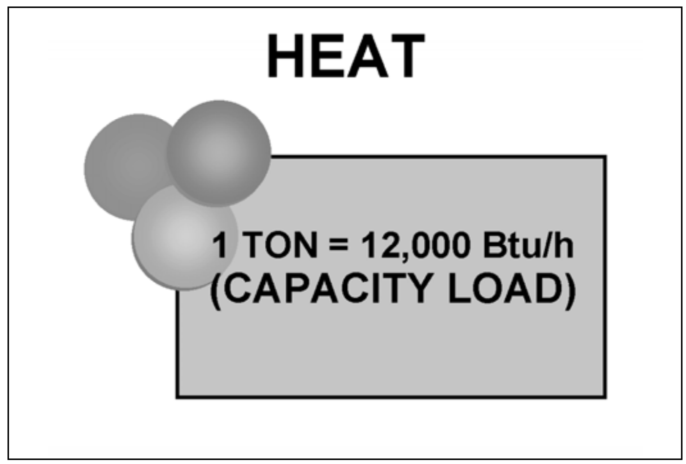


27. The unit of measure for heat content and heat transfer in mechanical refrigeration is the **British thermal unit** or **Btu**.

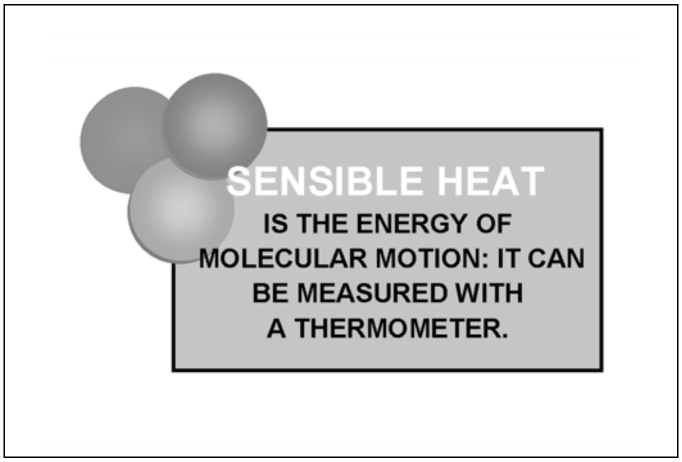
BTU measures heat content, heat transfer, heating and cooling capacity, heating and cooling load, and heat content of refrigerant.



28. One Btu changes one pound of water one degree Fahrenheit.

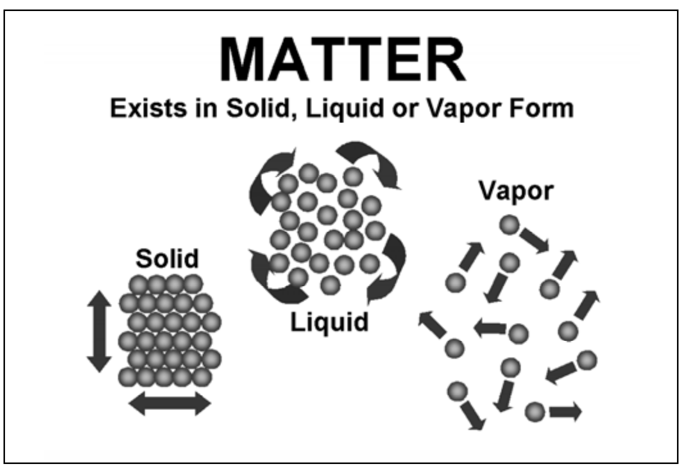


29. The rate of heat transfer is measured in Btu/hr or Btuh. One ton equals 12,000 Btuh, which represents capacity load.

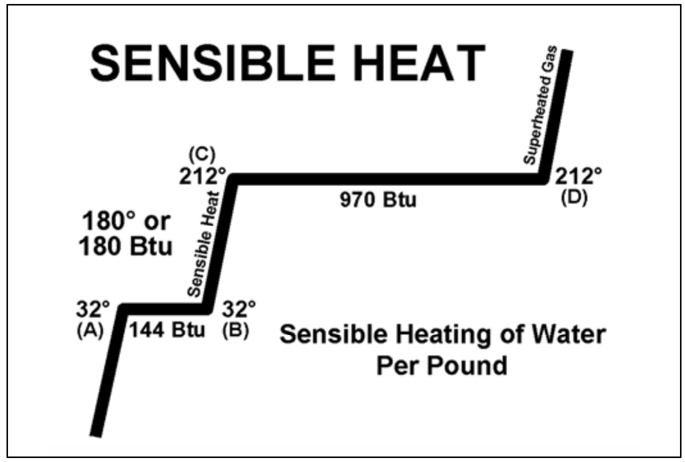


30. **Sensible heat** is the energy of molecular motion that can be measured by a thermometer. It is the heat that is added or removed from a substance that changes that substance's temperature but does not change its physical state.

Because a thermometer can only measure the heat content of a substance and not the amount of heat required to reach a certain temperature, it is necessary to use a standard quantity of heat for measurement. The **British thermal unit**, or **Btu**, is the measure of the heat required to move one pound of water one degree Fahrenheit.



31. Matter exists in **solid**, **liquid** or **vapor** form. All substances above absolute zero will have molecules in motion dependent on the pressure, temperature and heat content of that substance. For example, water can be in the form of solid (ice), liquid, or vapor (steam), with each form exhibiting molecules moving at different relative speeds. The addition or subtraction of heat will affect the form of matter.

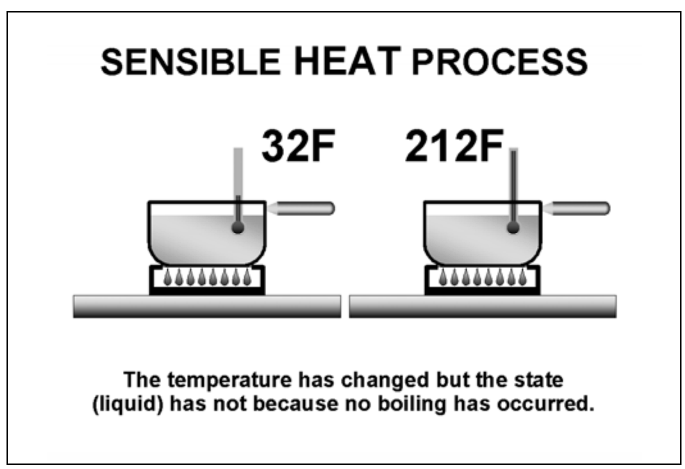


32. This diagram shows the sensible heating process for one pound of water. The 32°F (A) represents water in its solid form (ice). It requires 144 Btus to change 32°F ice to 32°F liquid (B) through latent heating.

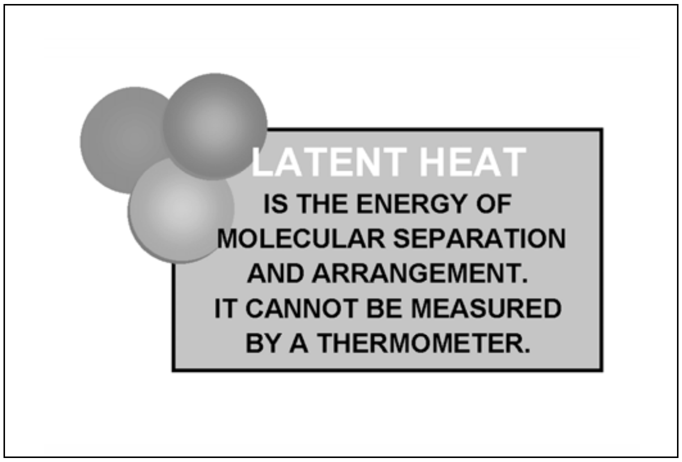
The rise in temperature from 32°F liquid to 212°F liquid (C) represents the **sensible heating process** in which heat is added to water until it reaches 212°F but does not change state. Note that there is a change of 180° in the process, which also represents 180 Btus, since each Btu is equivalent to the temperature necessary to raise one pound of water one degree Fahrenheit.

When enough heat is added to the 212°F (D) the water changes state from a liquid to a vapor or steam (latent heat). 970 Btus are expended in this process.

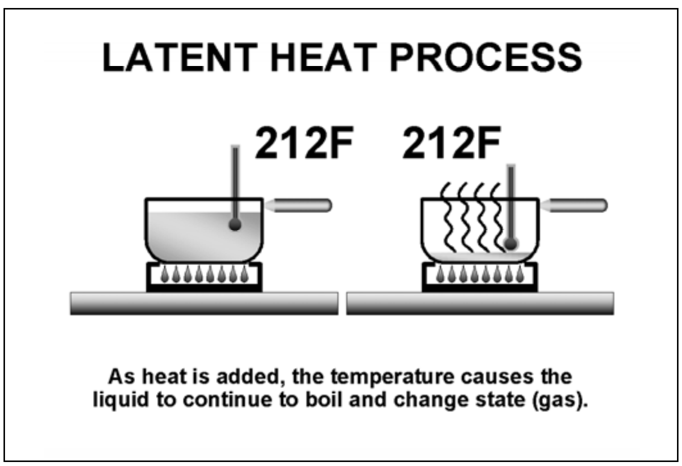
Finally, as more heat is added to the water, the excess heat becomes superheat.



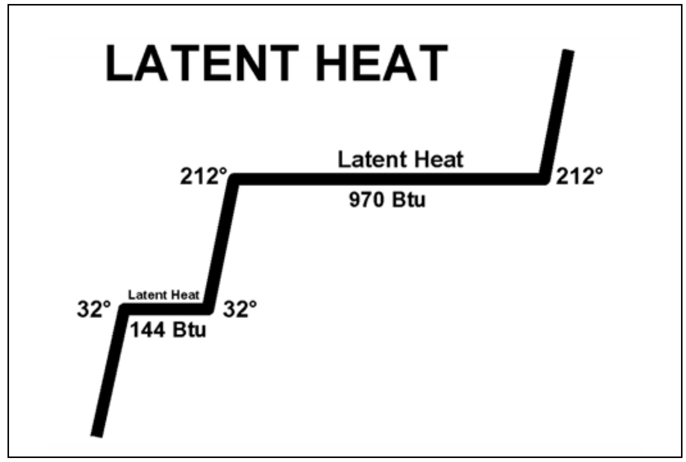
33. **Sensible heat** is the energy of molecular motion: it can be measured by a thermometer and always causes a temperature change in the substance heated.



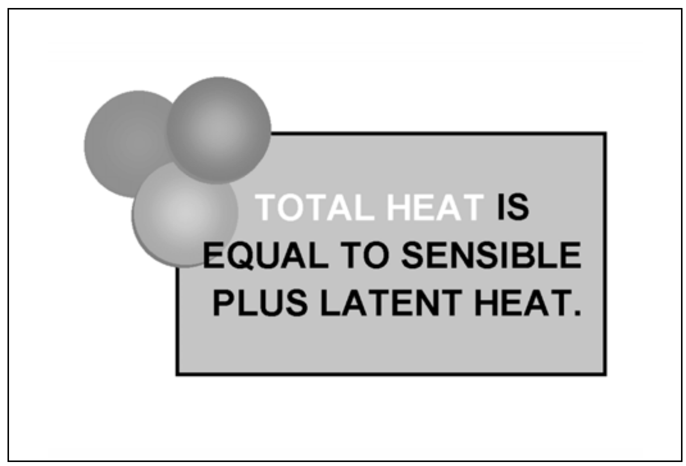
34. **Latent heat** is the energy of molecular separation and arrangement. It is the heat that is added or subtracted from a substance that causes that substance to change its state. It cannot be measured by a thermometer.



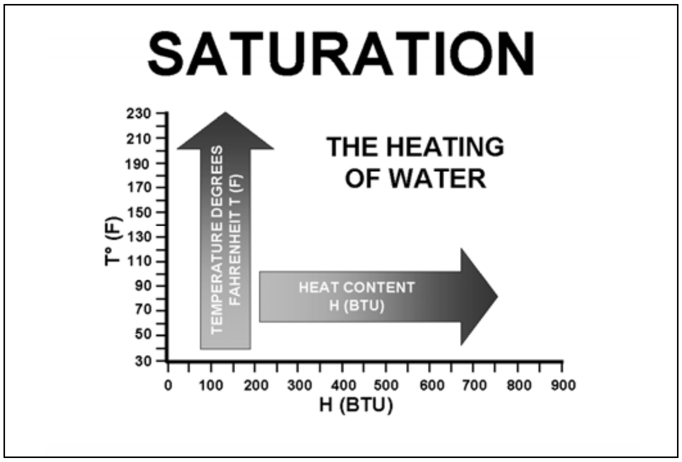
35. Heat is added until liquid boils and as it continues to boil, the water changes state to a gas (steam). The temperature does not change but the state of the substance changes.



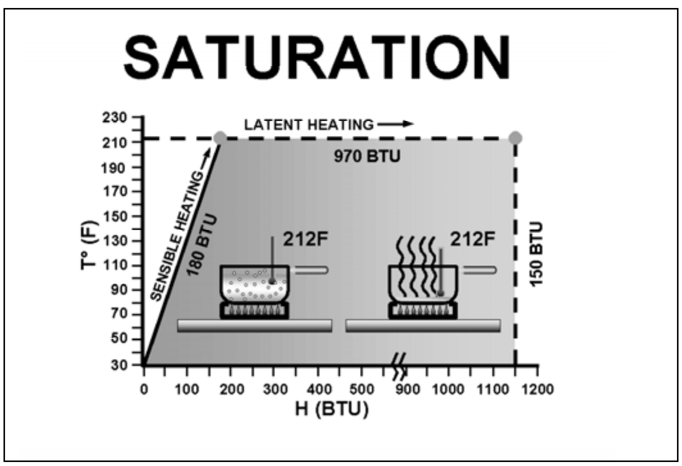
36. This diagram shows the latent heating process for one pound of water. Note that as heat is added, the state of the water changes while the temperature remains the same.



37. **Total heat** is equal to sensible plus latent heat and will change if either its temperature or state changes. Liquids and gases contain both sensible and latent heat.

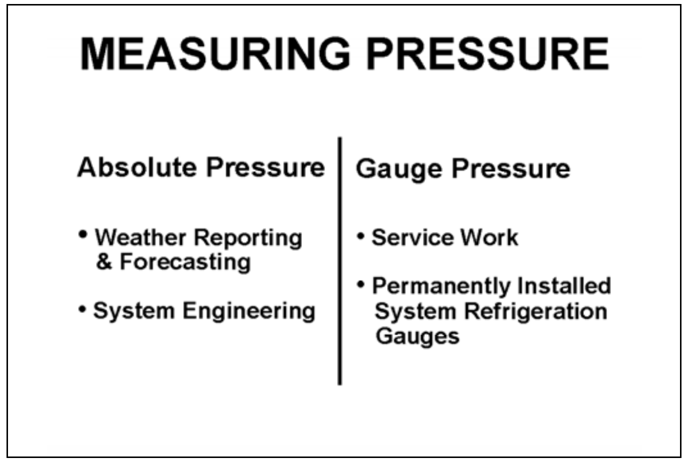


38. This is a graph of the sensible heating process for one pound of water. Heat content or enthalpy, abbreviated H, is plotted horizontally, and temperature is plotted vertically in degrees Fahrenheit.

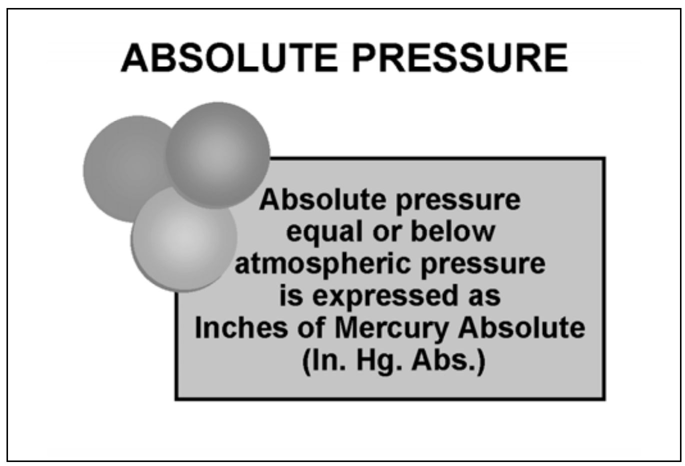


39. The first point for the latent heating process is the last point for the sensible heating process. Once it has reached its boiling point, it has absorbed all the heat it can hold without changing state into a gas. It is said to be in a **saturated condition**. Adding heat will begin the latent heating process in which liquid will begin to turn to gas.

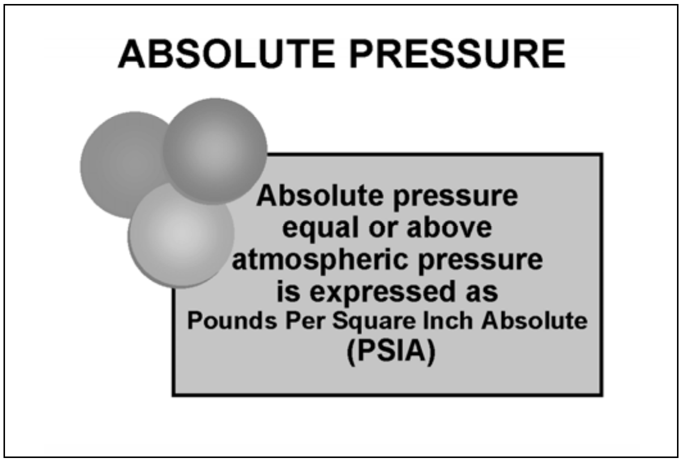
TEMPERATURE-PRESSURE



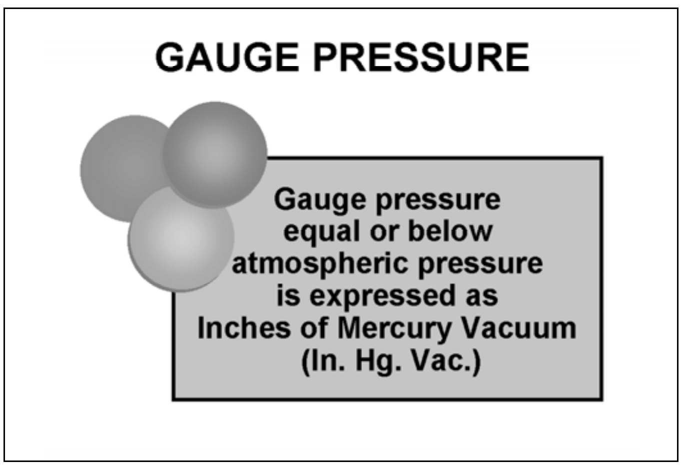
40. Pressure can be measured in either absolute pressure or gauge pressure.



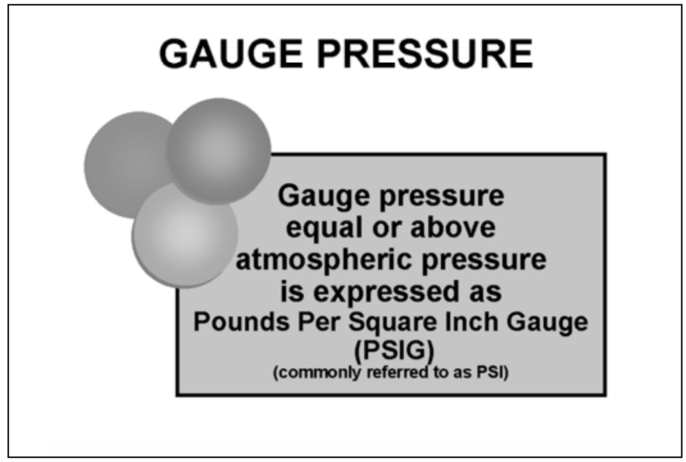
41. Absolute pressure equal to or below atmospheric pressure is expressed as Inches of Mercury Absolute (In. Hg. Abs.)



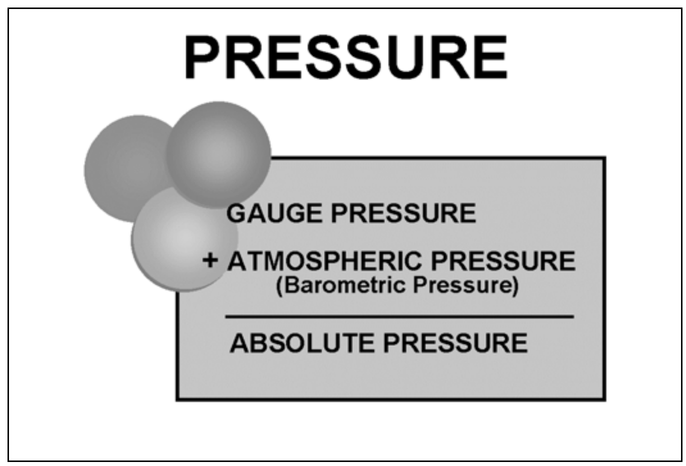
42. Absolute pressure equal to or above atmospheric pressure is expressed as Pounds Per Square Inch Absolute (PSIA).



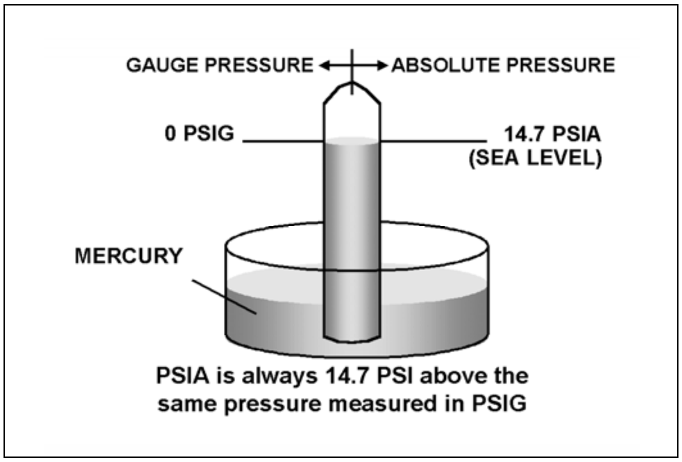
43. Gauge pressure equal to or below atmospheric pressure is expressed as Inches of Mercury Vacuum (In. Hg. Vac.)



44. Gauge pressure equal to or above atmospheric pressure is expressed as Pounds Per Square Inch Gauge (PSIG), commonly referred to as PSI.

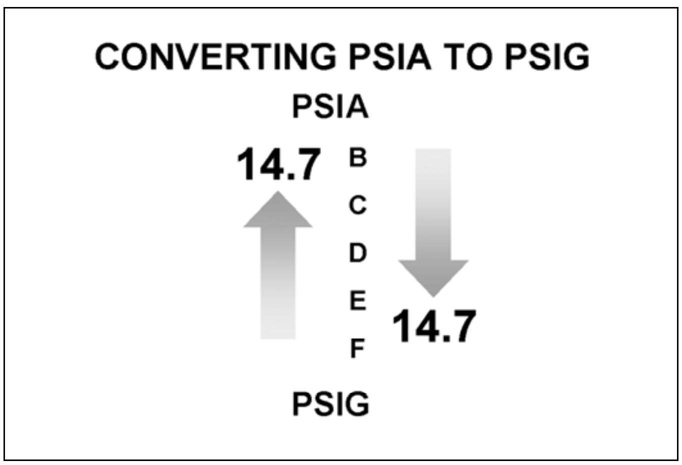


45. Gauge pressure + atmospheric pressure = absolute pressure.

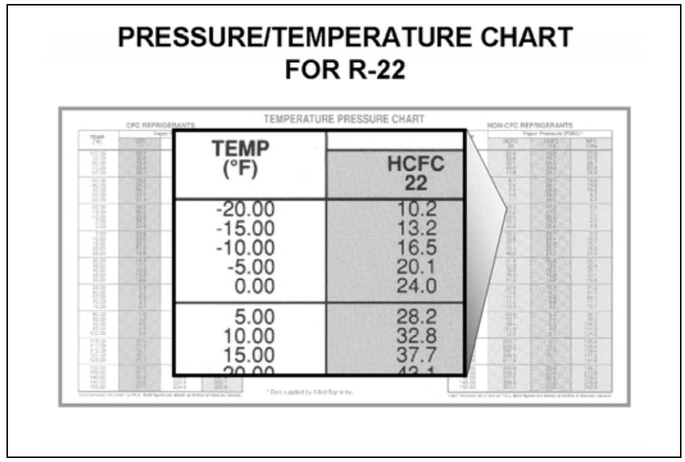


46. To get the absolute pressure, take a pressure reading with manifold gauges and then convert from PSIG to PSIA by using the formula:

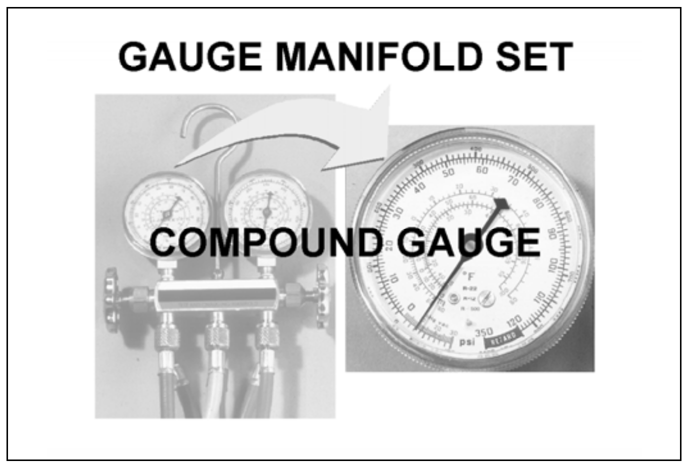
PSIG + 14.7 = PSIA



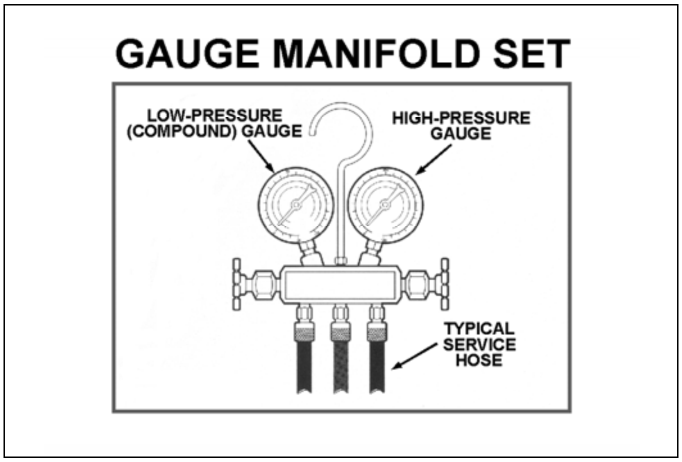
47. Here is an easy method to determine the difference between PSIA and PSIG.



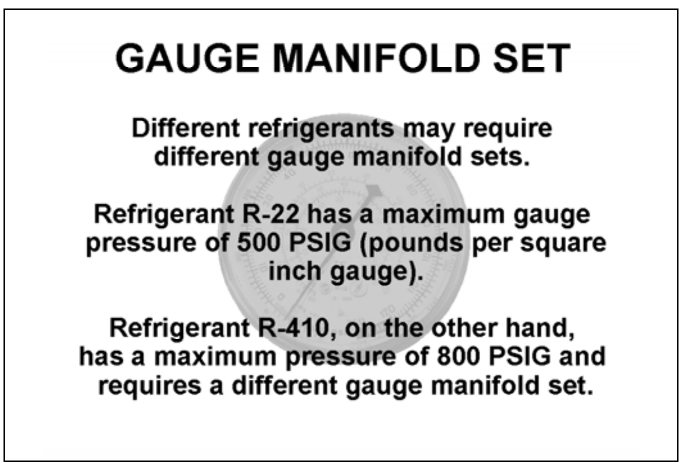
48. This enlarged segment of the pressure/ temperature chart shows the temperature and corresponding vapor pressure (PSIG) above and below 0°F for refrigerant R-22.



49. This **compound gauge** has readings above and below atmospheric pressure combined on one gauge. The PSIG readings decrease toward zero as pressure drops toward atmospheric pressure. As pressure continues dropping below atmospheric pressure, readings increase toward 30 In. Hg. Vac., as it approaches a perfect vacuum.



50. A typical two-valve gauge set has a compound gauge, high-pressure gauge, two hand valves and three hose ports. The hand valves are adjusted to monitor system pressures on the compound gauge and high-pressure gauge and to route the flow of refrigerant to and from the system during servicing. The gauge manifold set hose ports are connected to the system being serviced and other service instruments through a set of high-vacuum/high-pressure service hoses.

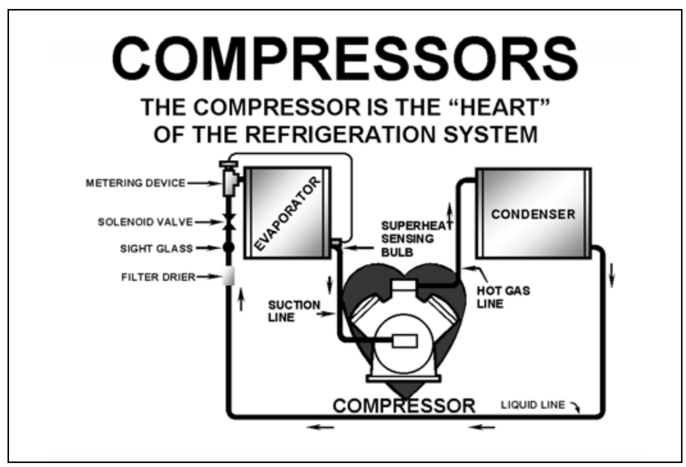


51. Different refrigerants may require different gauge manifold sets. Refrigerant R-22 has a maximum gauge pressure limit of 500 psig (pounds per square inch gauge) and hoses with a maximum working pressure of 500 PSI.

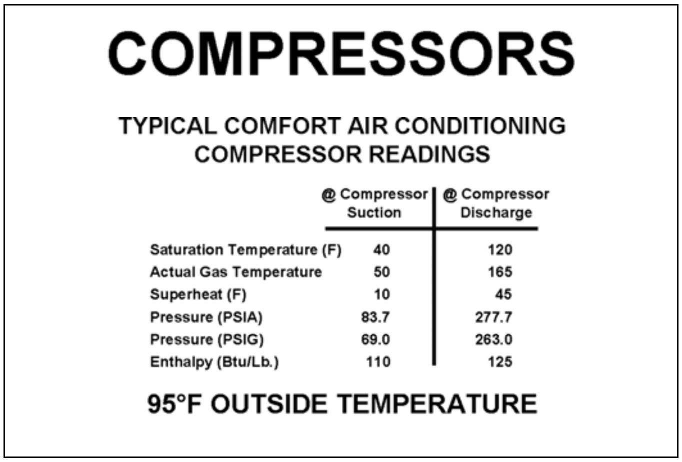
Refrigerant R-410A, on the other hand, requires special manifold gauges with a high side gauge limit of 800 PSI and hoses with a recommended maximum working pressure of 800 PSI. Using an R-22 manifold gauge set with refrigerant R-410A could be dangerous because of the inability to handle the higher pressures.

52. **CAUTION!** With the use of self-sealing fittings, high-pressure refrigerant can be trapped and remain in the service hoses after they have been disconnected from the equipment, causing possible injury or burns. **Do not** over-tighten the valves on the gauge manifold set when closing (front-seating) the valves. Over-tightening the valves may damage the manifold.

COMPONENTS

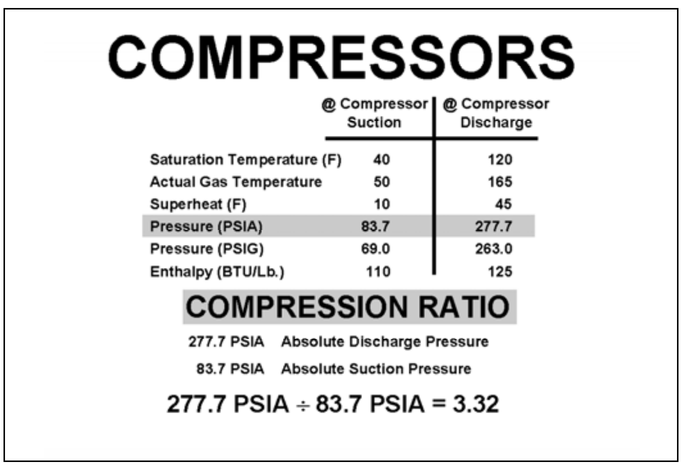


53. The compressor is the "heart" of the air conditioning or refrigeration system. It generates refrigerant flow through the system, taking refrigerant vapor at low temperature and pressure, and raising the vapor to a higher temperature and pressure.



	@ Compressor Suction	@ Compressor Discharge
Saturation Temperature (F)	40	120
Actual Gas Temperature	50	165
Superheat (F)	10	45
Pressure (PSIA)	83.7	277.7
Pressure (PSIG)	69.0	263.0
Enthalpy (Btu/Lb.)	110	125

54. A comfort air conditioning system compressor and an air-cooling condenser typically cause the changes seen in this table.



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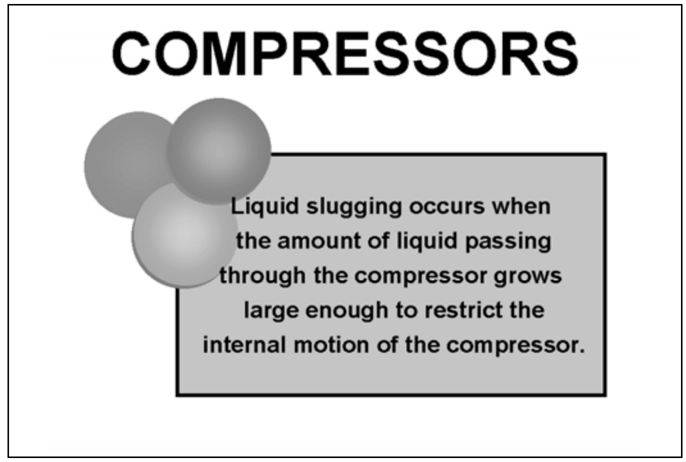
55. The pressure change accomplished by the compressor is sometimes expressed as a ratio of the absolute discharge pressure to the absolute suction pressure. This is the **compression ratio**. To find the compression ratio of a system, it is necessary to determine absolute pressure by converting PSIG to PSIA. Once PSIA is determined we divide the discharge pressure PSIA by the suction pressure PSIA to get the compression ratio:

Discharge Pressure/Suction Pressure PSIA = Compression Ratio

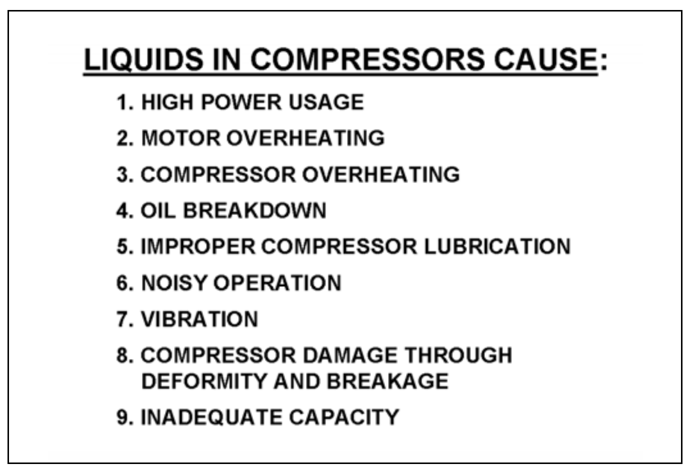
One of the reasons compression ratio is especially important when it approaches a high limit is because high compression ratios will cause a loss of efficiency and an excessive superheating of discharge gas. Compressor overheating could then result in compressor damage due to carbonization of oil.



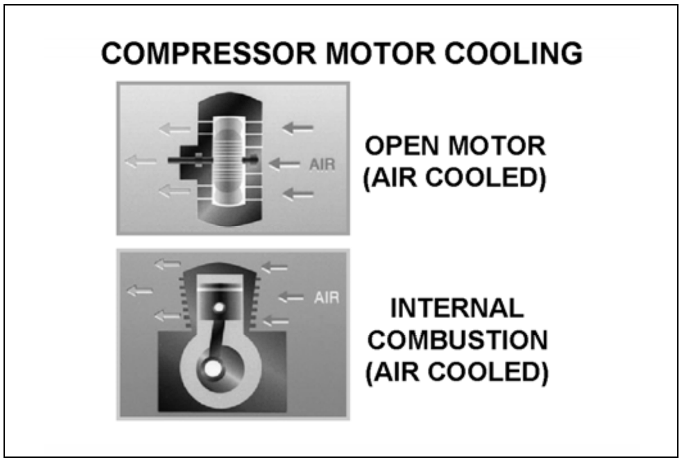
56. A refrigerant compressor is designed to work on refrigerant in its gaseous form.

Liquid refrigerant can damage the compressor, so refrigeration systems are designed to minimize the liquid refrigerant that gets into the compression area of the compressor.

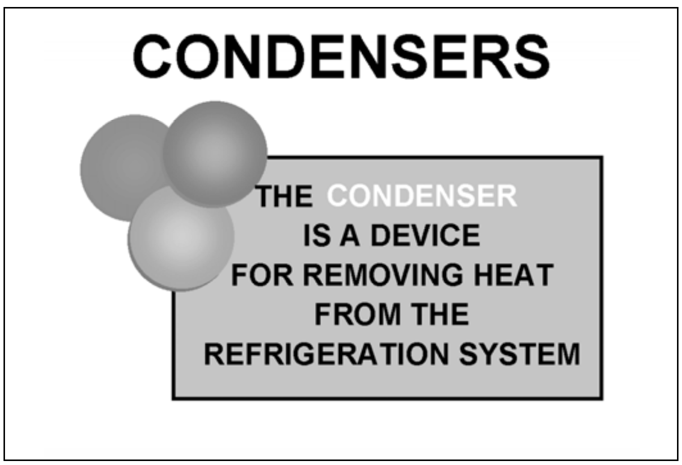
Small amounts of liquid may get in. Liquid **slugging** occurs when the amount of liquid passing through the compressor grows large enough to restrict the internal motion of the compressor.



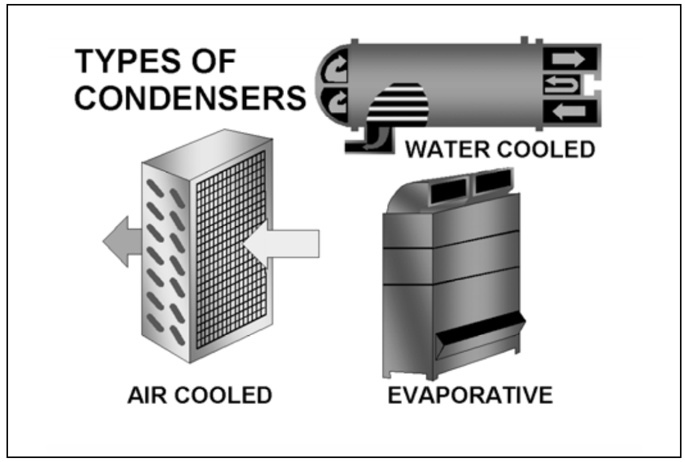
57. Excessive liquids in compressors can cause a number of problems. Some compressor designs tolerate liquid better than others. In residential split-systems, the reciprocating compressor is the least tolerant while the scroll compressor is the most tolerant.



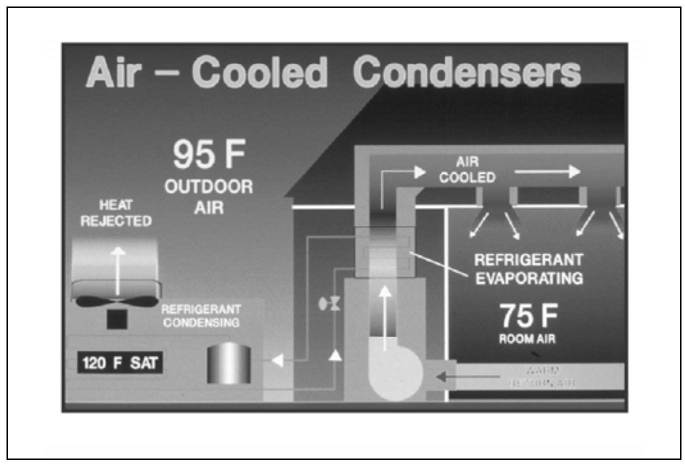
58. Compressor motors use different methods of cooling. Compressors used in residential or light commercial applications are cooled by either a refrigerant/oil mixture, air, or the combination of all three.



59. The condenser is a device (heat exchanger) for removing heat from the refrigeration system.

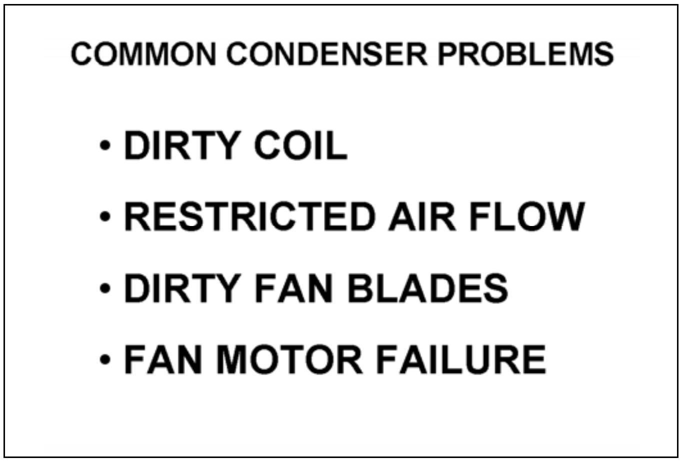


60. There are three types of condensers: air-cooled, water-cooled and evaporative.

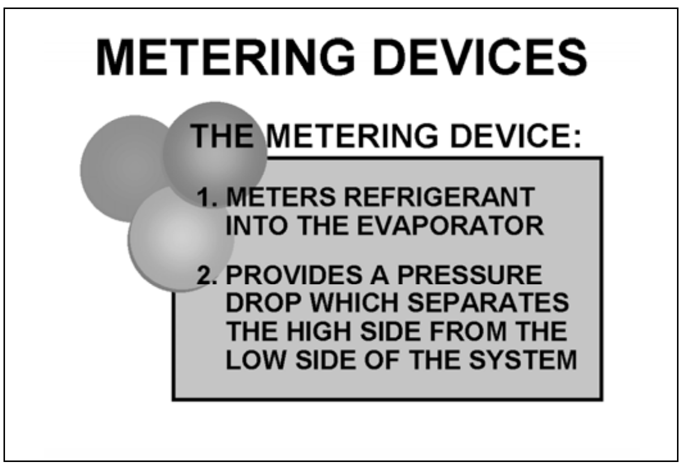


61. Air-cooled condensers reject the heat absorbed by the refrigerant directly to the outdoor air. Compared to a water-cooled system, the air-cooled system requires a bigger difference in temperature between the refrigerant and the medium that cools it.

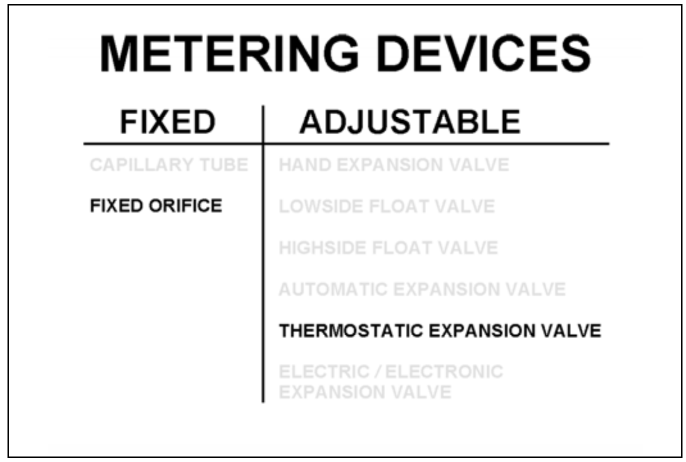
Although this makes it less energy-efficient, the air-cooled system's simple design keeps first cost and maintenance cost low. For this reason, the vast majority of residential air conditioning (up to 5 tons) and commercial air conditioning equipment (up to 50 tons) use air-cooled condensers.



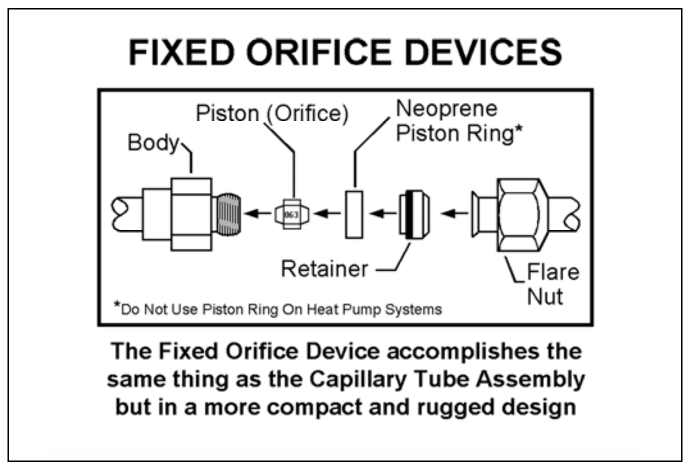
62. There are a number of condenser problems that can contribute to compressor failure. Dirt is often the significant factor in causing a compressor to fail.



63. The metering device, located between the condenser outlet and the evaporator inlet, in the cooling mode, serves two important functions. First, it meters the liquid refrigerant flowing into the evaporator, allowing the rate it flows to match the evaporator's ability to change the liquid/vapor mixture into 100% vapor. Second, the meter provides a pressure drop which separates the high side from the low side of the system, allowing the refrigerant in the evaporator to boil at a low enough temperature to absorb heat into the refrigerant.

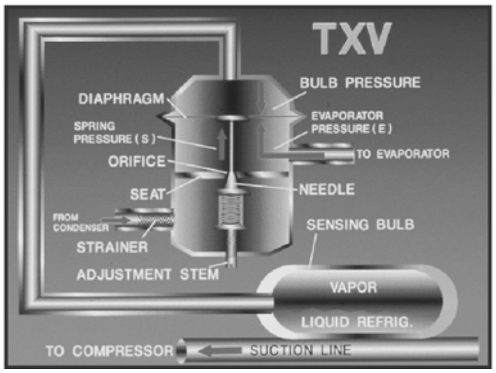


64. There are eight types of metering devices, divided into two categories: **fixed** and **adjustable**. Fixed metering devices and TXVs are the typical metering devices used in residential air conditioning today.



65. Capillary tube and fixed orifice devices are the two types of fixed metering devices we see in the residential market. The fixed orifice device accomplishes the same thing as the capillary tube but is more rugged and compact.

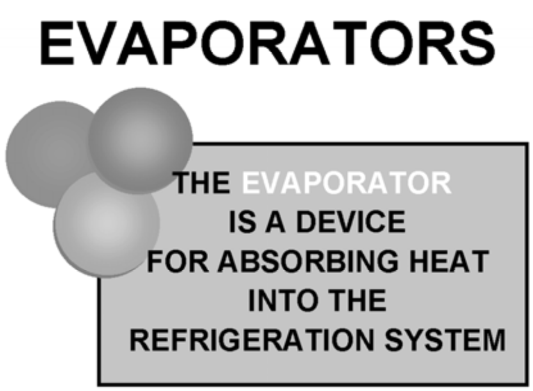
Choosing either type of fixed metering device requires careful selection to match system requirements and requires accurate system charging procedures.



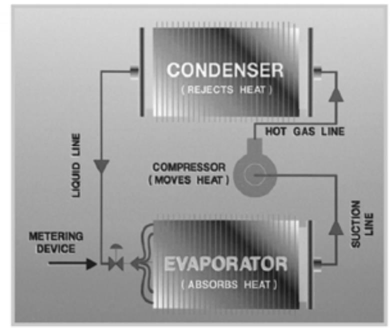
The Thermostatic Expansion Valve or TXV

66. Adjustable metering devices are the second category of metering devices.

One adjustable device often used is the thermostatic expansion valve or TXV. The TXV uses a diaphragm, needle valve and a remote sensing bulb, which is filled with refrigerant. The refrigerant will increase or decrease pressure, depending on the suction line temperature.

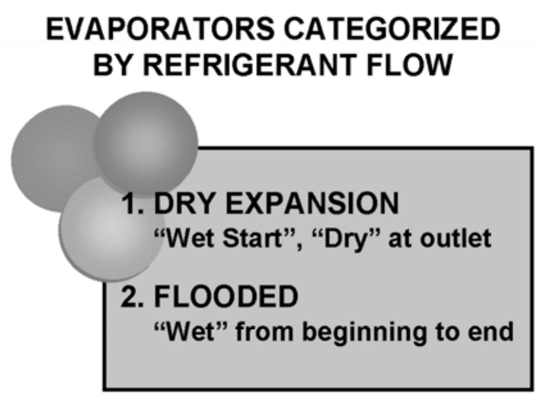


67. The evaporator is a heat exchanger that absorbs heat into the refrigeration system. It takes low-pressure, low temperature liquid refrigerant and changes it into a vapor. The cooler temperature is then removed from the refrigerant and transferred to the ambient air surrounding the coil.



LOCATING THE EVAPORATOR INDOORS OR OUTDOORS DEPENDS ON THE TYPE OF EQUIPMENT IN WHICH IT IS USED AND THE APPLICATION.

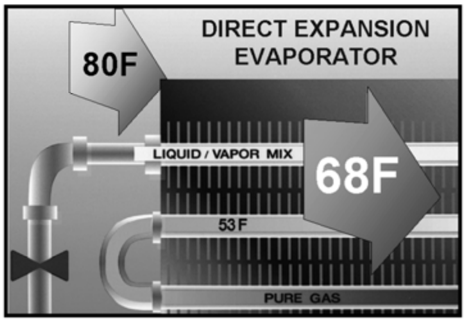
68. In the cooling mode, the evaporator is located downstream of the metering device. The location of the evaporator indoors or outdoors depends on the type of equipment in which the evaporator is used and the system application.



69. There are two types of evaporators, the **dry or direct expansion** (DX) evaporator or **flooded** evaporators.

The dry or direct expansion (DX) evaporators are most often seen in residential split systems and are "wet start" (liquid) but dry (vapor) at the outlet.

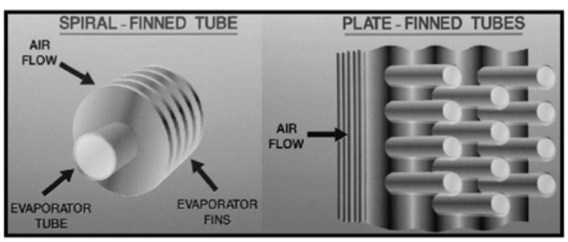
The flooded evaporator is "wet" (liquid) from the beginning to the end.



The air leaving the coil is considerably cooler than when it entered; a 15°F to 25°F temperature drop is normal for comfort air conditioning systems.

70. In a direct expansion evaporator, the air leaving the evaporator coil is considerably cooler than when it entered. The normal temperature drop is about 15° F to 25° F ΔT through the coil.

FINNED-TUBE EVAPORATORS



71. Finned-tube evaporators can have either spiral-finned tubes or plate-finned tubes. Finned or plate tubes increase surface area and therefore greatly increase heat transfer.

SPLIT SYSTEM INSTALLATION

SPLIT SYSTEM INSTALLATION

1. Locate Unit
2. Run Line Set
3. Braze Connections
4. Leak Check the Lines
5. Evacuate the System
6. Check System Airflow
7. Check/Charge System

72. First, locate the equipment, then take the following steps.

Lay out the line set, making sure to follow the manufacturer's specifications as well as building codes for limits on lengths, connections, pitch, rise, etc.

Next, make the system connections, using solders or brazes accepted by the equipment manufacturer and following local codes. When brazing, use nitrogen to purge the lines of oxygen. Oxygen can cause oxidation inside the lines while brazing, and lead to refrigeration system deterioration.

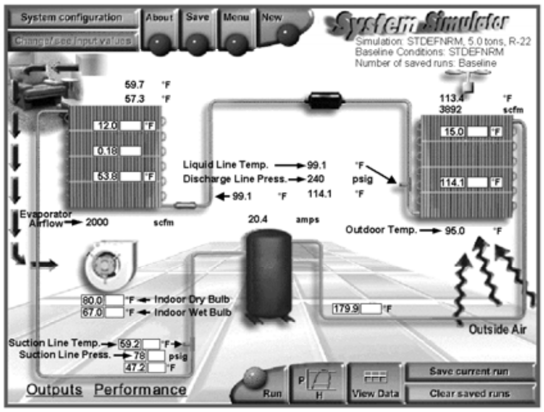
Once all connections are made, leak test the line. Pressurize the lines using nitrogen making sure to add trace amounts of the refrigerant *to be used in that system.* Be sure to follow the manufacturer's guidelines for maximum test pressure levels.

Various devices and methods can be used for leak detection. Electronic leak detectors are the most accurate. Ultrasonic detectors are good but require a certain level of expertise. Halide detectors may also be used for certain refrigerants like R-22 but cannot be used with others like R-410A.

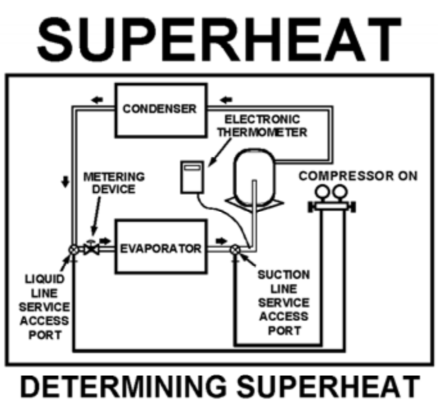
Soap bubbles are often used to detect leaks but may not expose very small leaks. When using this method, only use soaps designed for leak testing. Regular household detergents corrode solder connections.

Once the system has been leak tested, the lines must be evacuated. Most manufacturers recommend evacuation to 500 microns. After this is achieved, close the manifold valves and shut off the vacuum pump. Wait for five minutes. If the vacuum holds, this verifies the absence of leaks and moisture in the system. For these procedures, a deep vacuum gauge, such as a micron gauge should be used. Manifold gauges are not adequate.

Finally, check the system airflow and refrigerant charge. The refrigerant charge may need to be adjusted to bring the system to manufacturer's specifications.

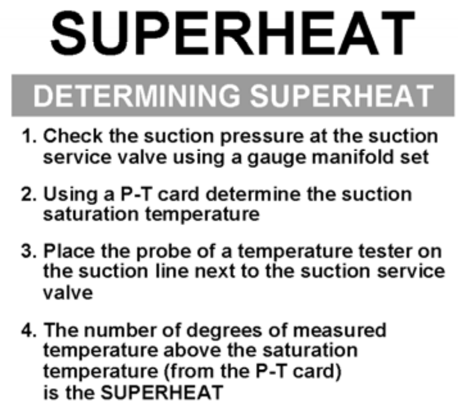


73. Using the Air Conditioning Simulator, we are able to show the temperatures and pressures that are vital to proper system operation. This simulation is for a normal, standard-efficiency (STDEFNRM) 5-ton split system with a fixed orifice meter and a scroll compressor using R-22 refrigerant.



74. When a liquid contains all the heat it can hold without changing into a vapor, it said to be a saturated liquid. Continuing to add heat will begin the latent heating process, which will cause the liquid to change to a saturated vapor. This vapor is as saturated with heat as a gas can be without rising above its saturation temperature.

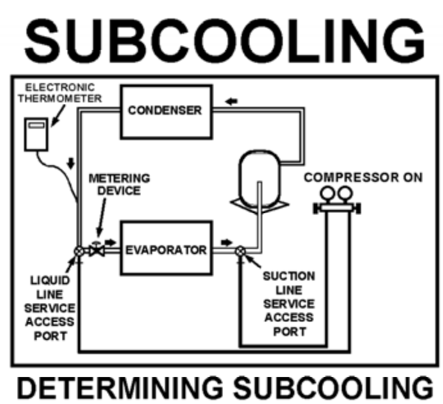
Once the vapor is heated above its saturation temperature it becomes a superheated gas. The heat content of refrigerant vapor above its saturation point is called **superheat**.



75. In order to take accurate superheat readings on a non-TXV system, the airflow must be correct and the outdoor temperature must be above minimum. The system should be past the initial pull down period and should have a 15 to 25 degree delta drop across the evaporator. Finally, the system should be leak free.

To determine superheat, check the suction pressure at the suction service valve, using a gauge manifold set. Using a P-T card, determine the suction saturation temperature.

Next, place the probe of a temperature tester on the suction line next to the suction service valve. The difference between this figure and the saturation temperature from the P-T card is the SUPERHEAT.



76. Because a TXV maintains a constant superheat over a range of load conditions, an alternative to the

superheat method must be used to determine proper charging of systems with TXVs.

In cases involving a TXV we check the subcooling to check the charge. **Subcooling** is the temperature that is removed from refrigerant after it has condensed to a liquid.

SUBCOOLING

DETERMINING SUBCOOLING

1. Check the liquid line pressure using a a gauge manifold set
2. Convert the pressure using a P-T card to determine the saturation temperature
3. Place the probe of a temperature tester on the liquid line leaving the condenser
4. The difference between the temperature tester reading and the saturation temperature (from the P-T card) is our SUBCOOLING

77. In order to take accurate subcooling readings on a non-TXV system, again, the airflow must be correct and the outdoor temperature must be above minimum. The system should be past the initial pull down period and should have a 15 to 25 degree delta drop across the evaporator. Finally, the system should be leak free.

To determine subcooling, check the liquid line pressure, using a gauge manifold set. Convert the pressure using a P-T card to determine the saturation temperature.

Next, place the probe of a temperature tester on the liquid line leaving the condenser. The difference between this temperature and the saturation temperature from the P-T card is the SUBCOOLING.

SYSTEM TESTING

DETERMINING SUPERHEAT

FOR AN ACCURATE READING ALWAYS ALLOW THE SYSTEM TO RUN FOR AT LEAST 15 MINUTES SO THAT THE SYSTEM STABILIZES

DETERMINING SUBCOOLING

78. When testing a system for superheat or subcooling we should always allow the system to run for at least 15 minutes to get the system past the initial pull down period. This allows the system to stabilize and therefore allow for accurate readings.

NOTES

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