

Study Guide



HEAT PUMPS



Carrier Corporation 2004

Table of Contents

AIR CONDITIONING AND HUMAN COMFORT	1
AIR CONDITIONING THERMODYNAMICS	2
EFFICIENCY RATINGS.....	8
TEMPERATURE-PRESSURE	10
Gauges.....	11
AIR CONDITIONING SYSTEM COMPONENTS.....	12
HEAT PUMP CYCLE	18
HEAT PUMP SYSTEM COMPONENTS	19
TESTING HEAT PUMP COMPONENTS.....	21
DEFROST CYCLE.....	22
HEAT PUMP INSTALLATION	23
SERVICE TECHNIQUES.....	25
AIR SIDE BASICS	33
DUCT FABRICATION TYPES.....	35
COMMON AIR-RELATED COMPLAINTS	39
System Noise	39
System Smell	40
System Discomfort	40
THERMOSTATS.....	42



HEAT PUMPS

1. This refresher course covers topics contained in the **HEAT PUMPS** specialty section of the North American Technician Excellence (NATE) certification exam. Before beginning the Heat Pump review, some air conditioning basics need to be reviewed.

AIR CONDITIONING AND HUMAN COMFORT



“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.”



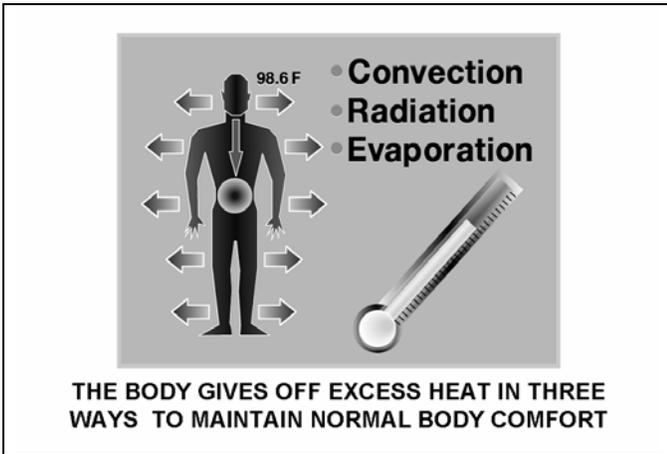
AIR CONDITIONING IS USED TO IMPROVE AN INDUSTRIAL PROCESS OR TO MAINTAIN HUMAN COMFORT

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 for example: extremely low temperatures required to manufacture and store certain drugs; very constant temperature and humidity in a printing plant to maintain consistency of paper size; or extremely dry conditions when packaging moisture sensitive products.

In food preservation, the required conditions are determined by the length of time the food is to be stored. The colder the storage temperature, the slower the bacteria growth rate and the longer the food can be maintained.

In human comfort the conditions are determined by a variety of factors. While IAQ (Indoor Air Quality) is a growing concern (controlling dust, dirt, molds, bacteria, and harmful gases), the greatest “comfort” issue is usually perceived as the proper human body temperature. Our bodies generate heat constantly and the surrounding air must be conditioned to remove the proper amount of heat to maintain our body temperature for optimum personal comfort.



4. Heat is rejected from our bodies through three processes: convection; radiation; and evaporation. To maintain a comfortable body temperature we must control the condition of the air around us.

Convection is the movement of air and can stimulate the transfer of heat from our warm skin to the air. For optimum comfort in a space, an air conditioning system should generate air movement of between 15 and 50 feet per minute (fpm).

Radiation is the radiant transfer of heat from our exposed skin to the surrounding air and to surfaces around us. (This could turn into a heat gain if the surrounding surfaces are warmer than our skin's 92° temperature.) We like to keep the surrounding conditions about 20 degrees below our skin temperature or 72 degrees.

Evaporation from sweating can provide the greatest cooling effect for people, if the surrounding air is sufficiently dry. Normal humidity design for a conditioned space is 40% to 50%. High humidity in a space decreases the evaporative effect for our sweat and therefore it's ability to cool our skin. Air that is too dry will actually increase the rate of evaporation from your skin, causing a person to feel cold. It also causes health concerns such as dry itchy and flaking skin and scalp, dry sinus passages causing colds and nose bleeds, and increases susceptibility to germs and viruses in the air.

AIR CONDITIONING THERMODYNAMICS

THERMODYNAMICS

LAW #1

**Heat is a form of energy
and cannot be created
or destroyed**

5. 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. For example, a cigarette lighter does not "create" heat. It changes fuel chemically to release heat.

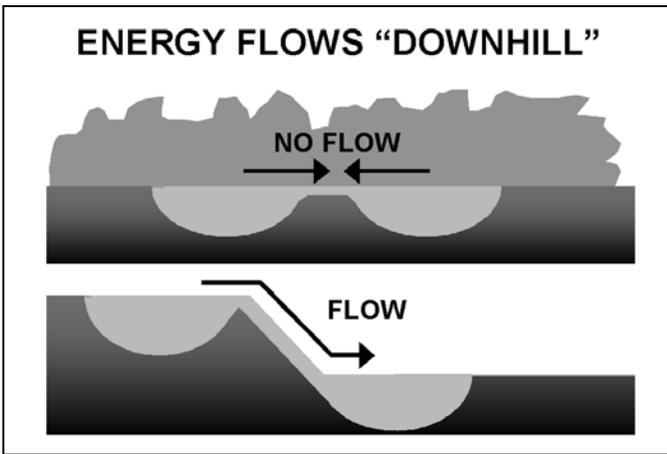
Heat *is not* like matter that exists as a liquid, solid or gas; so, it cannot be measured by weight or volume.

THERMODYNAMICS

LAW #2

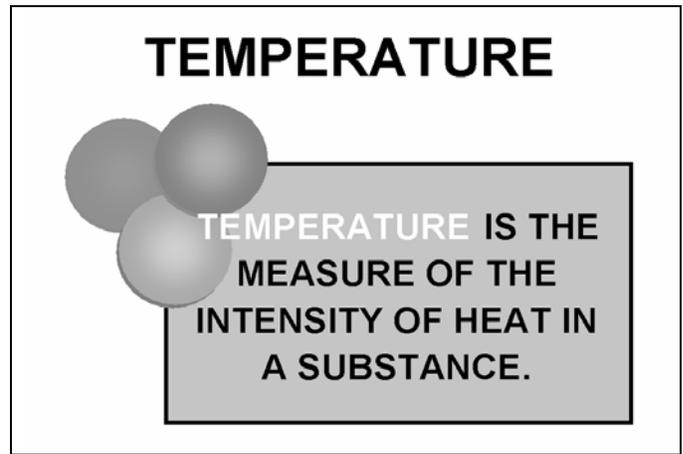
**Heat flows from
hot to cold and
seeks equilibrium**

6. 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.

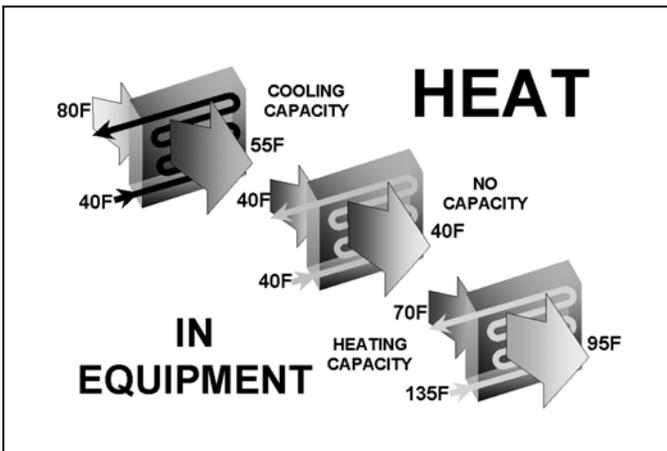


7. Like the flow of water from a higher to a lower level due to gravity, heat will not flow without a temperature difference. It flows from the higher energy level (warmer) to the lower energy level (cooler).

The greater the temperature difference, the faster the flow of heat.

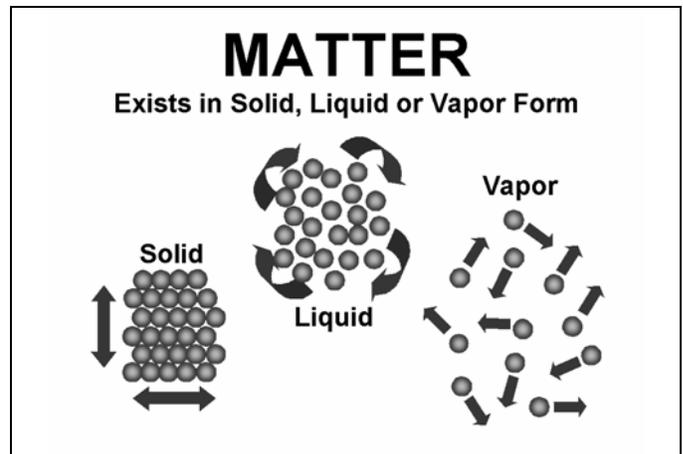


9. **Temperature** is the measure of the intensity of heat or the degree of heat in a substance. It *does not* measure the heat energy required to change the state of a substance from a solid to a liquid or a liquid to a vapor. In other words *temperature measures sensible heat, but not latent heat.*



8. 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; therefore, the coil provides no cooling capacity.



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

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 a 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. A **gas** is a superheated vapor.

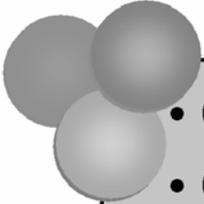
REFRIGERATION



REFRIGERATION IS
COOLING BY THE
REMOVAL OF HEAT.

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

HEAT IS TRANSFERRED IN THREE WAYS:

- 
- Conduction
 - Convection
 - Radiation

13. Heat is transferred by conduction, convection and radiation.

HEAT TRANSFER

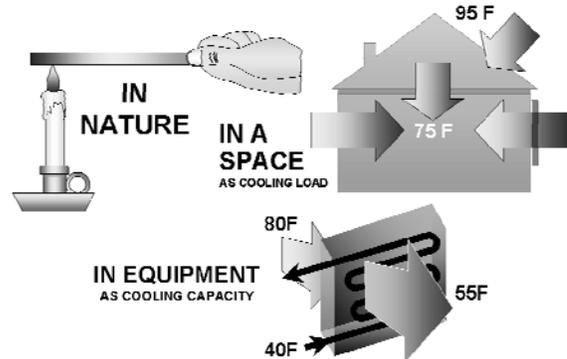


HEAT TRANSFER IS THE
MOVEMENT OF HEAT FROM
ONE PLACE TO ANOTHER,
EITHER WITHIN A SUBSTANCE
OR BETWEEN SUBSTANCES.

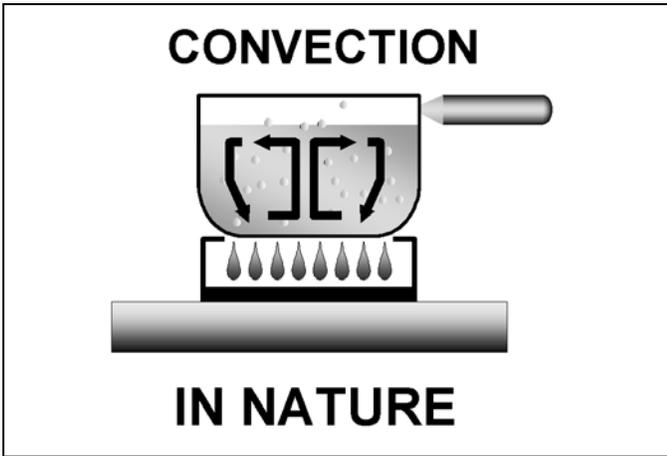
12. **Heat transfer** is the movement of heat from one place to another, either within a substance or between substances. Heat transfer is also called heat exchange, heat flow or heat flux.

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.

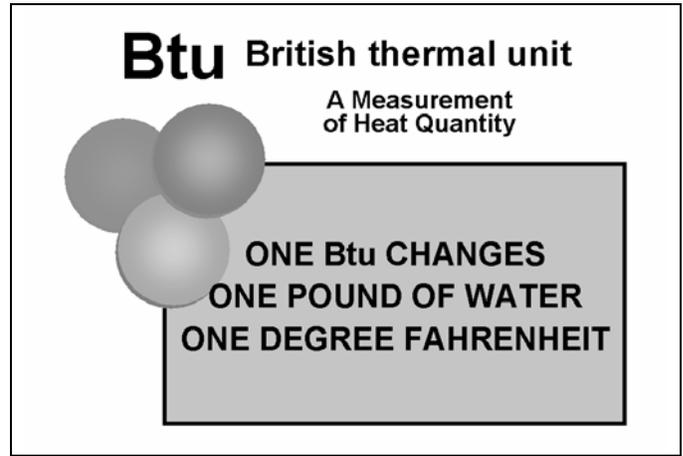
CONDUCTION



14. **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.

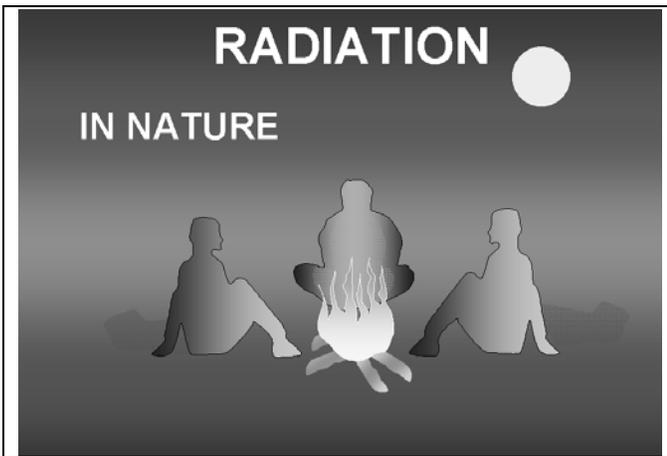


15. **Convection** is heat transfer by the movement of molecules from one place to another. Air flowing through the duct system of a furnace carries heat to another space through convection.

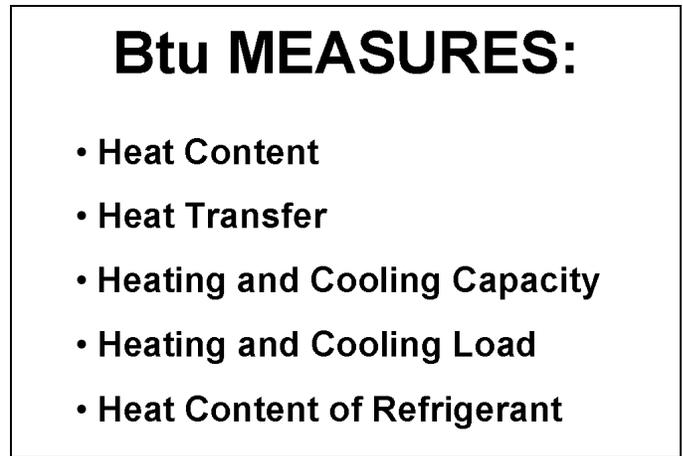


17. The unit of measure for heat content and heat transfer in mechanical refrigeration is the **British thermal unit** or **Btu**.

One Btu changes the temperature of one pound of water one degree Fahrenheit.

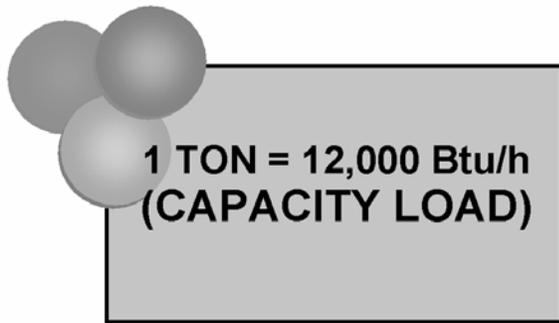


16. **Radiation** transfers heat by passing it from a source to an absorbant surface without heating the space in between. Radiant heat behaves as a waveform of energy, like light. A camper sitting in front of a fire on a cold night is warmed by radiant heat.



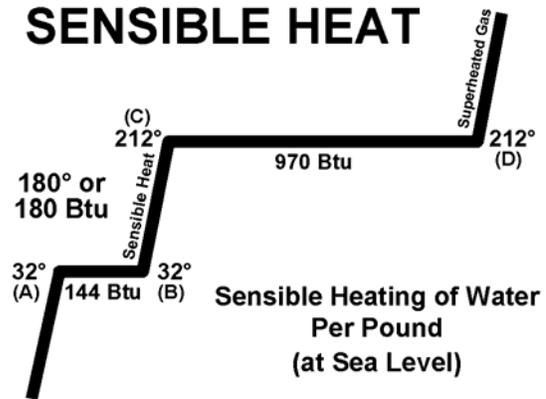
18. Btu is a measure of heat content, heat transfer, heating and cooling capacity, heating and cooling load, and heat content of refrigerant.

TON OF COOLING



19. The rate of heat transfer is measured in Btu/h or Btu. One ton of cooling equals 12,000 Btu/h, which represents capacity load. **Nominal capacity** is a system's capacity at a rated condition.

SENSIBLE HEAT

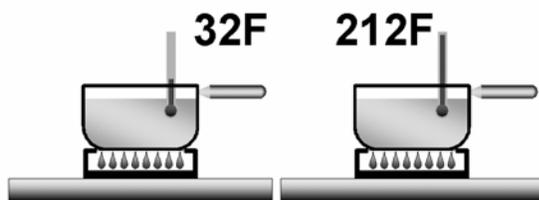


21. This diagram shows the sensible heating process for one pound of water at sea level.

The rise in temperature from 32°F liquid (B) 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 Btu, since each Btu is equivalent to the temperature necessary to raise one pound of water one degree Fahrenheit.

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

SENSIBLE HEAT PROCESS

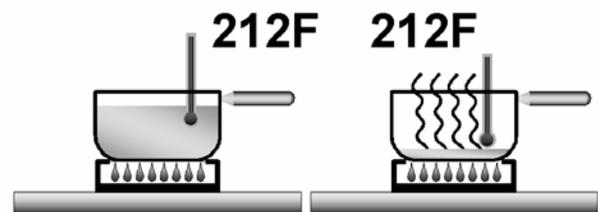


The temperature has changed but the state (liquid) has not because no boiling has occurred.

20. **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.

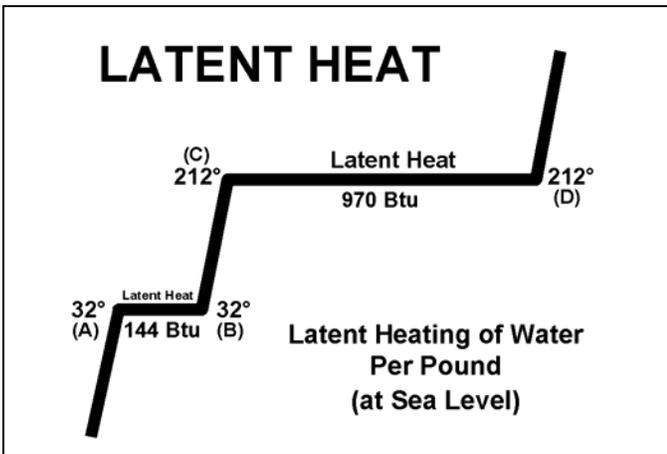
LATENT HEAT PROCESS



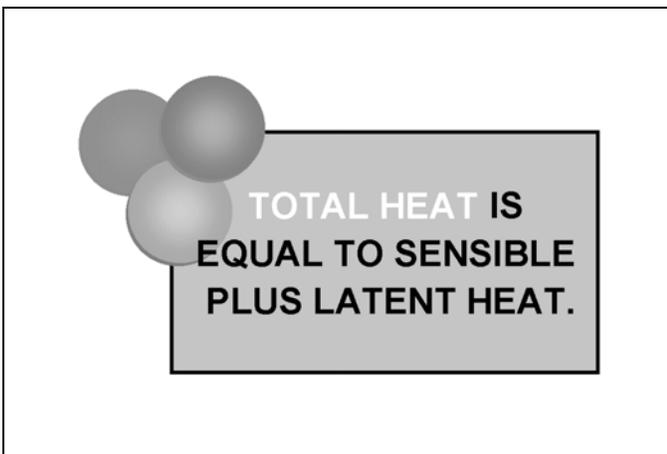
As heat is added, the temperature causes the liquid to boil and change state (gas).

22. **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.

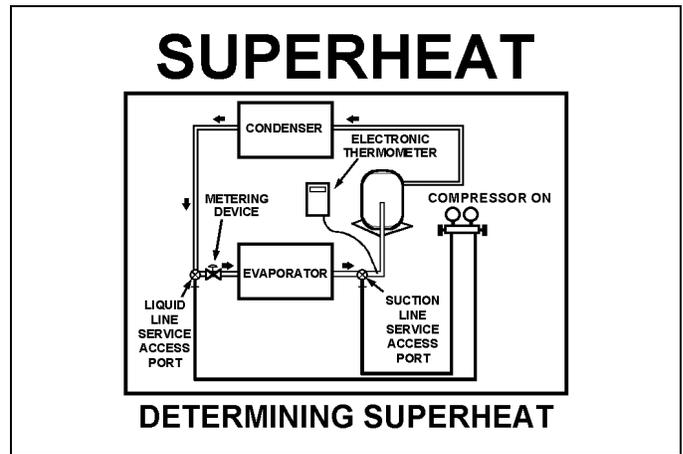
When heat is added, the liquid boils. As it continues to boil, the water changes state to a gas (steam). The temperature does not change but the state of the substance changes.



23. This diagram shows the latent heating process for one pound of water at sea level. Note that as heat is added, the state of the water changes while the temperature remains the same. It requires 144 Btu to change 32°F ice (A) to 32°F liquid (B) through latent heating. Similarly, it requires 970 Btu to change 212°F liquid (C) to 212°F vapor or steam (D).



24. **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.



25. When a liquid contains all the heat it can hold without changing into a vapor, it is 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**.

SUPERHEAT

DETERMINING SUPERHEAT

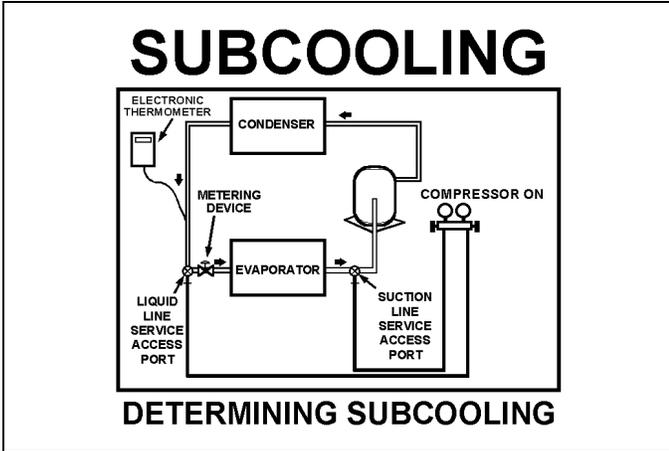
1. Check the suction pressure at the suction service valve using a gauge manifold set
2. Using a P-T card determine the suction saturation temperature
3. Place the probe of a temperature tester on the suction line next to the suction service valve
4. The number of degrees of measured temperature above the saturation temperature (from the P-T card) is the **SUPERHEAT**

26. In order to calculate an accurate superheat reading on a non-TXV system, the airflow must be correct. The system should be past the initial pulldown period (10 to 15 minutes) and should have a 15 to 25 degree temperature 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 Pressure-Temperature (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 number and the saturation temperature from the P-T card is the **superheat**.

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

27. Because a TXV maintains a constant superheat in systems using a TXV, we must calculate subcooling to check the charge. **Subcooling** is the temperature that is removed from refrigerant after it has condensed to a liquid.

29. When testing a system for superheat or subcooling, always allow the system to run for at least 15 to 20 minutes to get the system past the initial pulldown period. This allows the system to stabilize assuring accurate readings.

SUBCOOLING

DETERMINING SUBCOOLING

1. Check the liquid line pressure using 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 **SUBCOOLING**

28. Again, in order to take accurate subcooling readings on a non-TXV system, the airflow must be correct. The system should be past the initial pulldown period and should have a 15 to 25 degree temperature 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.

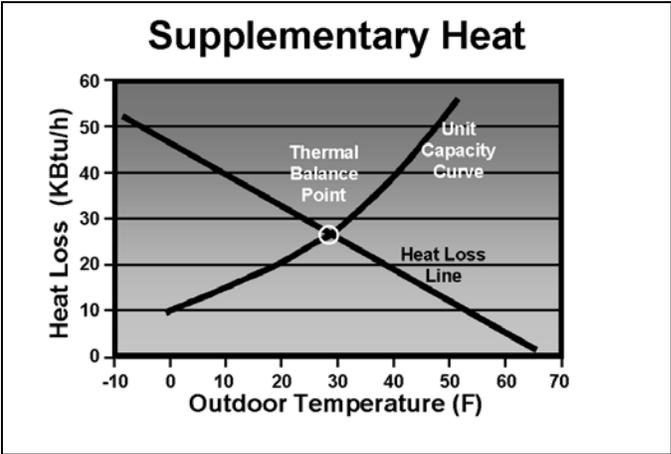
EFFICIENCY RATINGS

TO CALCULATE EER

$$\frac{\text{Btu OUT } 39,000 \text{ BTU/HR}}{\text{POWER IN } 4380 \text{ WATTS/HR}} = 8.9 \text{ BTU/WATT}$$

30. **EER** or **Energy Efficiency Ratio** was a cooling performance tool used for years to compare one residential refrigerator, air conditioner, or heat pump's efficiency to another. The energy efficiency ratio is nothing more than how many Btu you get out for every watt of power put in. It is determined by dividing the total capacity (in Btuh) of the system by the total electric consumed in wattage per hour.

The government has now added an additional equation to the formula to make the number more accurate and responsive to variable weather conditions. The new rating is called **SEER** or **Seasonal Energy Efficiency Ratio** and must be tested by an independent laboratory under specific operating conditions. This method compares Btu output to power or wattage input. The higher the number, the better the rating.



33. As the outdoor temperature decreases it becomes more difficult for a heat pump to extract heat from the air. This causes the SEER and COP ratings to decrease (although they are still better than electric heat). At some point the heat pump will no longer provide sufficient energy to heat the house by itself. This is called the **Thermal Balance Point**.

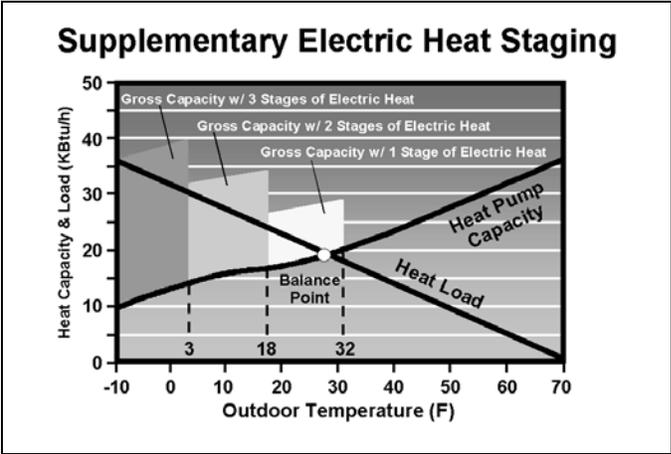
COP

1. Generally = $\frac{\text{Useable Energy Output}}{\text{Total Energy Input}}$

2. For Heat Transfer = $\frac{\text{Btu/h Output Equipment}}{\text{Btu/h Input}}$

E.G. Electric Resistance = $\frac{3413 \text{ Btu/h}}{1 \text{ KWH}} = \frac{3413 \text{ Btu/h}}{3413 \text{ Btu/h}} = 1$

31. Another method for rating a heat pump’s heating performance is **COP** or **“Coefficient of Performance.”** This method converts the input wattage to Btus so the resulting number is a comparison of Btu input to Btu output. Electric heat would give a result of “one.” The higher the number, the more efficient the unit and the less it costs to operate the system. In the end, you get what you pay for.



34. Below the thermal balance point electric heat is often used to provide **supplemental heat** to maintain the structure’s desired temperature. For best efficiency the electric heat can be “sequenced” in stages and controlled by outdoor thermostats so no more is turned on than is needed. Use a **Balance Point Worksheet** (shown above) to draw these lines and make these calculations.

TO DETERMINE COP

$$\frac{\text{Btu OUT}}{\text{Btu WE PAY FOR}} \times \frac{39,000 \text{ BTU/HR}}{4380 \text{ WATTS/HR} \times 3.413 \text{ BTU/WATT}} = 2.6$$

32. In a heat pump, a number higher than one demonstrates that some of the heat is from the outside air and is “free.” A COP of 2.6 means you are getting 2.6 Btu of heat for every one Btu you pay for!

Squeezing Out Operating \$

1. **Decrease Balance Point**
 - Oversize Heat Pump
 - Upgrade Building Ins. & Glazing
 - Turn Down the Thermostat
2. **Dual – Alternative Heating System**
3. **2 - Speed or Variable - Speed Heat Pump**

35. An alternative to auxiliary electric heat is to switch to an alternative heating unit such as a gas furnace. The temperature at which this switch is accomplished is called the **Economic Balance Point**. This calculation utilizes the cost of both fuels (electricity and natural gas) and factors in the efficiencies of both appliances (the heat pump and the furnace) to determine the most economical temperature to switch between the heat pump and the furnace. This switching can simply be accomplished with the use of a “**dual fuel thermostat**” which utilizes an outdoor air sensor and can be programmed to switch heating appliances at any outdoor temperature.

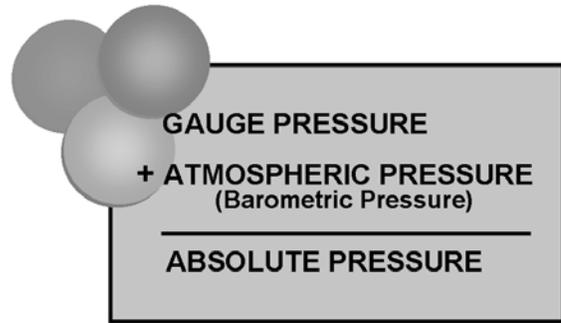
TEMPERATURE-PRESSURE

MEASURING PRESSURE

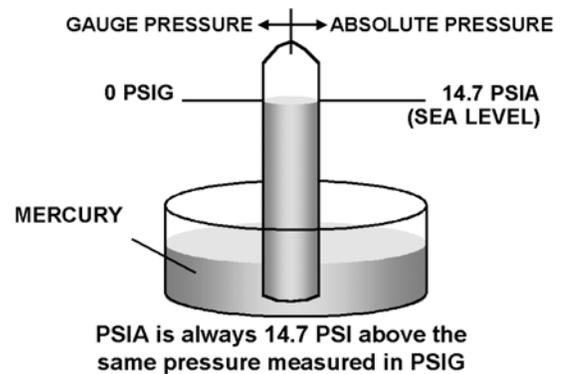
Absolute Pressure	Gauge Pressure
<ul style="list-style-type: none"> • Weather Reporting & Forecasting • System Engineering 	<ul style="list-style-type: none"> • Service Work • Permanently Installed System Refrigeration Gauges

36. When troubleshooting any mechanical problem in a refrigeration system, the first step is measuring the high and low-side refrigerant pressures. Pressure can be measured in either absolute pressure or gauge pressure.

PRESSURE



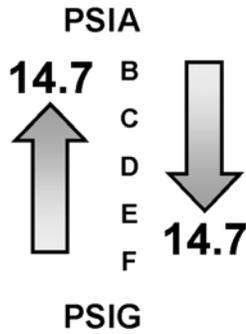
37. Gauge pressure + atmospheric pressure = absolute pressure. When pressure is stated as PSI, it represents the same reading in PSIG.



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

$$\text{PSIG} + 14.7 = \text{PSIA}$$

CONVERTING PSIA TO PSIG



39. Here is an easy method to determine the difference between PSIA and PSIG. Add 14.7 lbs. to a gauge pressure to convert to PSIA. Subtract 14.7 lbs. pressure to convert an absolute pressure to a gauge pressure.

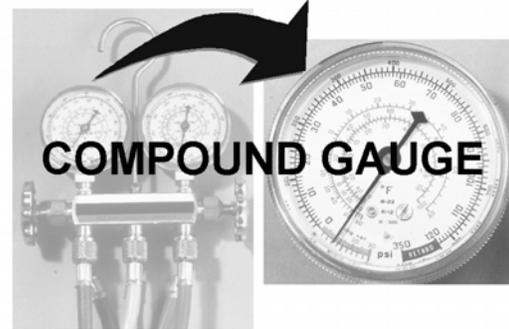
PRESSURE/TEMPERATURE CHART FOR R-22

TEMPERATURE PRESSURE CHART	
TEMP (°F)	HCFC 22
-20.00	10.2
-15.00	13.2
-10.00	16.5
-5.00	20.1
0.00	24.0
5.00	28.2
10.00	32.8
15.00	37.7
20.00	42.4

40. 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.

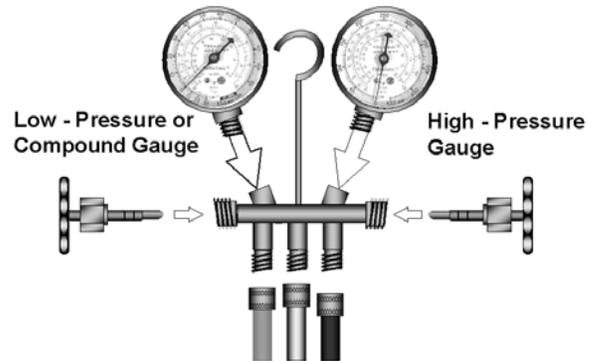
Gauges

GAUGE MANIFOLD SET



41. 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.

GAUGE MANIFOLD SET



42. 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 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.

COMPOUND GAUGE

R-22



MAXIMUM PRESSURE
OF 500 PSI

R-410A

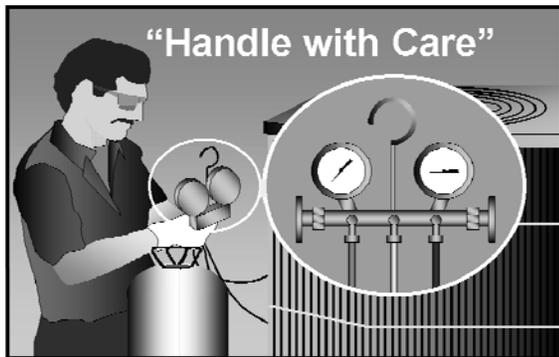


MAXIMUM PRESSURE
OF 800 PSI

43. High-pressure refrigerants may require different gauge manifold sets. Refrigerant R-22 uses gauges with a maximum gauge pressure of 500 psig (pounds per square inch gauge) and hoses with a maximum working pressure of 500 psig.

Refrigerant R-410A, on the other hand, requires special manifold gauges with a high side gauge pressure 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.

GAUGE MANIFOLD SET



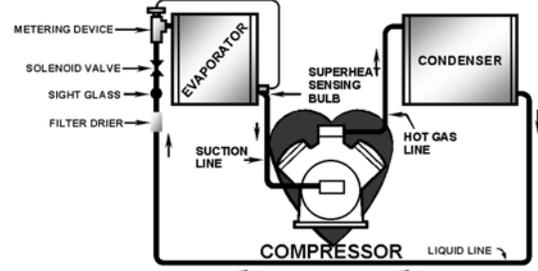
44. CAUTION! With the use of self-sealing fittings, high-pressure refrigerant can be trapped and remain in the service hoses after they have been disconnected from the equipment, causing possible injury or burns (frostbite from low temperature refrigerants).

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.

AIR CONDITIONING SYSTEM COMPONENTS

COMPRESSORS

THE COMPRESSOR IS THE "HEART" OF THE REFRIGERATION SYSTEM



45. 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.

TYPICAL COMFORT AIR CONDITIONING COMPRESSOR HEADINGS USING R-22

	@ 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	260.0
Enthalpy (Btu/Lb.)	110	125

95°F OUTSIDE TEMPERATURE

46. A comfort air conditioning system compressor with an air-cooling condenser typically operates at the temperatures and pressures seen in this table.

COMPRESSION RATIO

	@ 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	260.0
Enthalpy (Btu/Lb.)	110	125

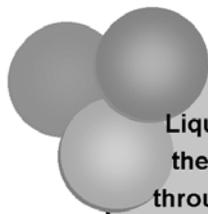
277.7 PSIA Absolute Discharge Pressure
 83.7 PSIA Absolute Suction Pressure
 $277.7 \text{ PSIA} \div 83.7 \text{ PSIA} = 3.32$

47. 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 first necessary to determine absolute pressure by converting psig to psia. Once psia is determined, divide the discharge pressure psia by suction pressure psia to get the compression ratio:

$$\frac{\text{Discharge Pressure psia}}{\text{Suction Pressure psia}} = \text{Compression Ratio}$$

One of the reasons compressor 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 the thinning and eventual carbonization of oil.

LIQUID SLUGGING



Liquid slugging occurs when the amount of liquid passing through the compressor grows large enough to restrict the internal motion of the compressor.

48. 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.

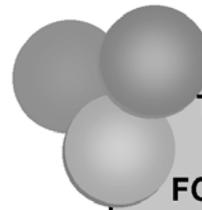
Small amounts of liquid may get in. Liquid **slugging** occurs when the amount of liquid passing through the compressor becomes large enough to restrict the internal motion of the compressor.

LIQUIDS IN COMPRESSORS CAUSE:

1. HIGH POWER USAGE
2. MOTOR OVERHEATING
3. COMPRESSOR OVERHEATING
4. OIL BREAKDOWN
5. IMPROPER COMPRESSOR LUBRICATION
6. NOISY OPERATION
7. VIBRATION
8. COMPRESSOR DAMAGE THROUGH DEFORMITY AND BREAKAGE
9. INADEQUATE CAPACITY

49. 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.

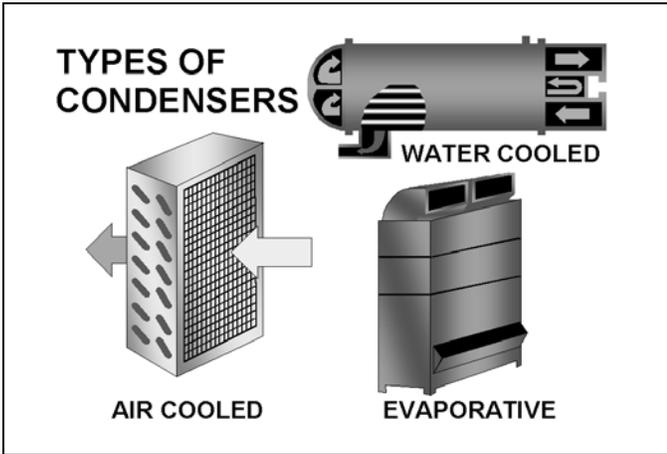
CONDENSERS



THE CONDENSER IS A DEVICE FOR REMOVING HEAT FROM THE REFRIGERATION SYSTEM

50. The **condenser** is a device (heat exchanger) for removing heat from the refrigeration system. The condenser accomplishes three processes. First, it de-superheats gas down to its saturated condensing temperature. It then condenses the gas to a liquid.

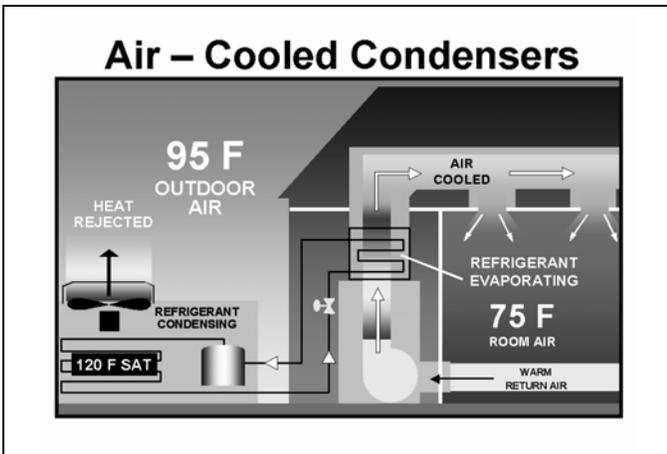
Finally, it subcools it below the saturated condensing temperature.



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

- ### COMMON CONDENSER PROBLEMS
- DIRTY COIL
 - RESTRICTED AIR FLOW
 - DIRTY FAN BLADES
 - FAN MOTOR FAILURE
 - RECIRCULATION OF AIR
 - NON CONDENSABLES

53. 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.



52. 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 air 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.

- ### METERING DEVICES
- THE METERING DEVICE:**
1. METERS REFRIGERANT INTO THE EVAPORATOR
 2. PROVIDES A PRESSURE DROP WHICH SEPARATES THE HIGH SIDE FROM THE LOW SIDE OF THE SYSTEM

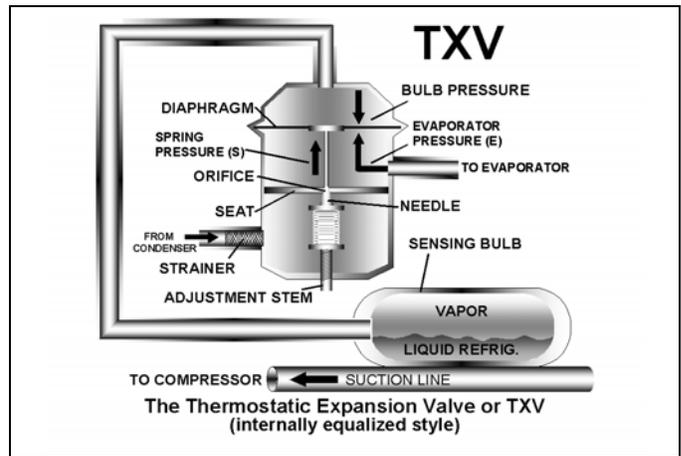
54. The metering device, located between the condenser outlet and the evaporator inlet serves two important functions in the Cooling Mode. First, it meters the liquid refrigerant flowing into the evaporator, allowing the rate at which it flows to match the evaporator's ability to change the liquid/vapor 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.

In a heat pump, during the heating mode when the refrigerant flow is reversed, a second metering is required in the liquid line where the liquid refrigerant enters the outdoor coil. It must utilize some sort of check valve, since only one metering is used at a time.

METERING DEVICES

FIXED	ADJUSTABLE
CAPILLARY TUBE	HAND EXPANSION VALVE
FIXED ORIFICE	LOWSIDE FLOAT VALVE
	HIGHSIDE FLOAT VALVE
	AUTOMATIC EXPANSION VALVE
	THERMOSTATIC EXPANSION VALVE
	ELECTRIC / ELECTRONIC EXPANSION VALVE

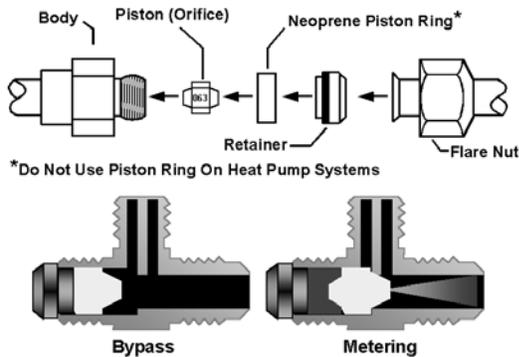
55. There are eight types of metering devices, divided into two categories: **fixed** and **adjustable**. Fixed metering devices and TXVs are the typical metering devices used in residential air conditioning today.



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

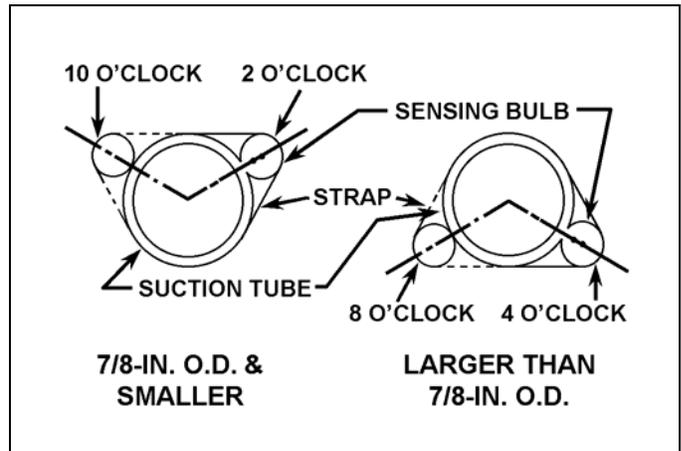
The adjustable device most often used is the thermostatic expansion valve or TXV. The TXV uses a diaphragm, needle valve and a remote sensing bulb, which contains its own refrigerant charge. The refrigerant pressure will increase or decrease, depending on the suction line temperature.

FIXED ORIFICE DEVICES



56. **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. In heat pump systems, the piston moves in the direction of the refrigerant flow, causing it to meter in one direction and to bypass in the other direction, eliminating the need for a check valve.

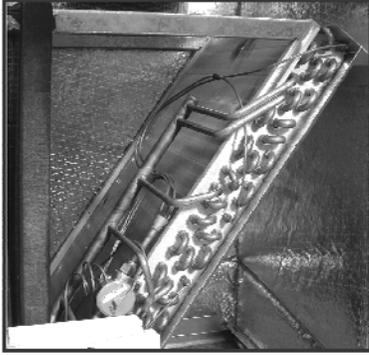
Choosing either type of fixed metering device requires careful selection to match system requirements and requires accurate system charging procedures.



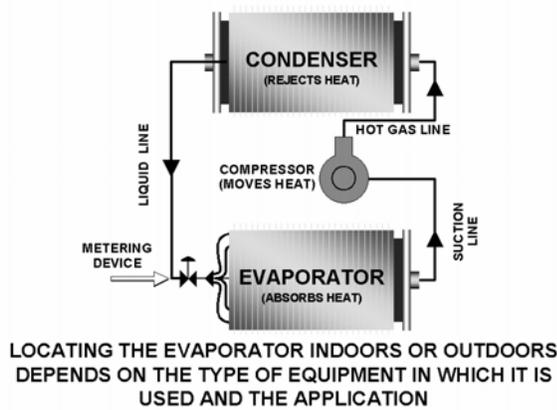
58. An expansion valve may open too much because the thermal bulb is not in good contact with the suction line or pipe. Loose clamping around the thermal bulb may cause such poor contact. Thermal bulbs also require proper insulation.

The mounting of the thermal bulb and its actual location is very important. The bulb must be in good contact with the outlet of the cooling coil so that it can sense, thermally, exactly what is going on in the suction line and the evaporator. The preferred position of the bulb on the suction line is determined by the valve manufacturer.

EVAPORATORS



59. 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.



60. 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.

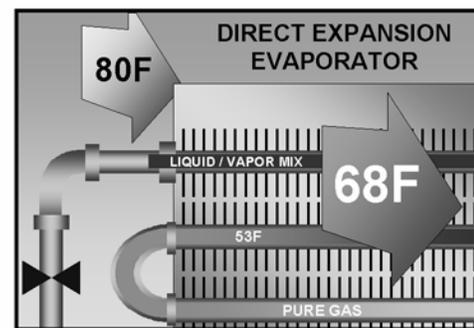
EVAPORATORS CATEGORIZED BY REFRIGERANT FLOW

1. **DRY EXPANSION**
"Wet Start", "Dry" at outlet
2. **FLOODED**
"Wet" from beginning to end

61. 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 (superheated vapor) at the outlet.

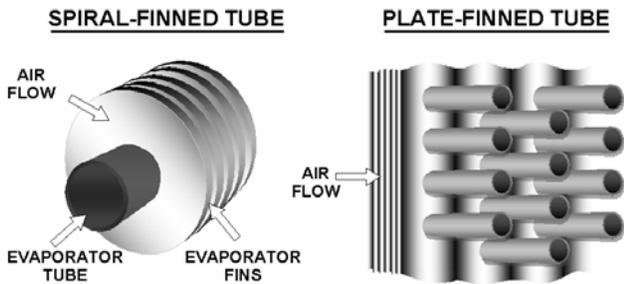
The flooded evaporator is "wet" (liquid) from the beginning to the end. This is usually a characteristic of large liquid chillers, not heat pumps.



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.

62. 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

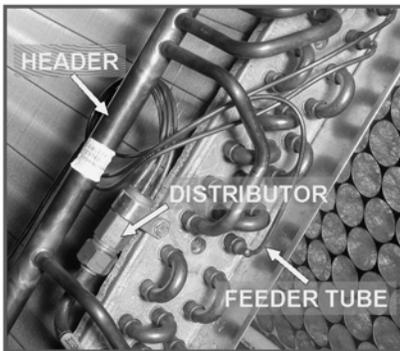


63. Finned-tube evaporators can have either spiral-finned tubes or plate-finned tubes. Spiral or plate fins increase surface area, therefore, greatly increasing heat transfer.

$$\text{SENSIBLE HEAT RATIO} = \frac{\text{Sensible heat removed}}{\text{Total heat removed}}$$

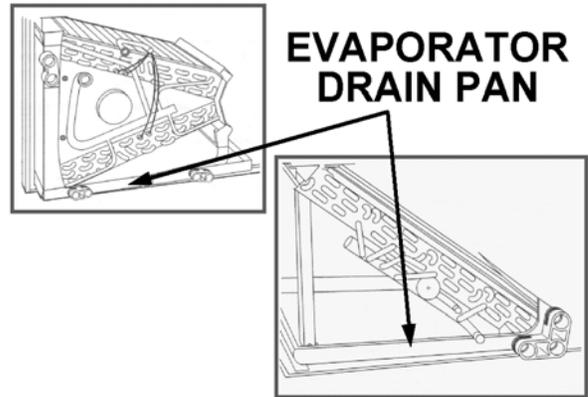
65. Removing moisture from the air (dehumidification) is an important part of the evaporator's job. Calculating the sensible heat ratio allows engineers to design coils for required dehumidification needs. The sensible heat ratio is the ratio of the sensible heat removed divided by the total heat removed.

COIL WITH DISTRIBUTOR AND HEADER

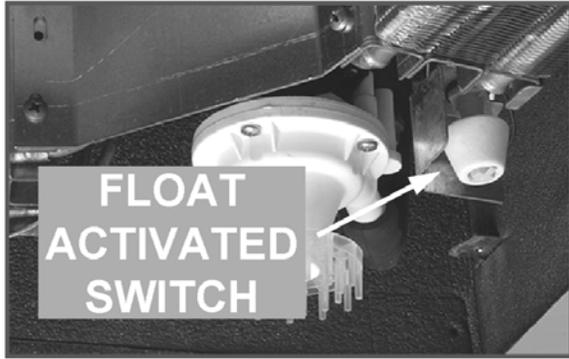


64. To minimize pressure drops in a coil, some manufacturers will run multiple circuits or multiple rows of coils.

EVAPORATOR DRAIN PAN



66. The drain pan of an evaporator should be installed level with or slightly tilted toward the drain line.



67. A **float activated switch** may be installed that will stop the unit from operating and prevent flooding if the condensate line becomes plugged. A rise in water level moves the switch and opens a set of normally closed contacts, shutting down the unit.

COMMON EVAPORATOR PROBLEMS

- **RESTRICTED AIRFLOW**
- Dirty Filters, Coils or Undersized Ducts
- **WRONG FAN SPEED**
- Inoperative Fan
- **PLUGGED METERING DEVICE OR DISTRIBUTOR**

68. Common evaporator problems include restricted airflow (caused by either dirty filters or coils or undersized ducts), incorrect fan speed or inoperative fan and a plugged metering device or distributor.

The Movement of Heat:

A REFRIGERANT IS A FLUID THAT PICKS UP HEAT BY EVAPORATING AT A LOW TEMPERATURE AND PRESSURE AND REJECTS HEAT BY CONDENSING AT A HIGHER TEMPERATURE AND PRESSURE.

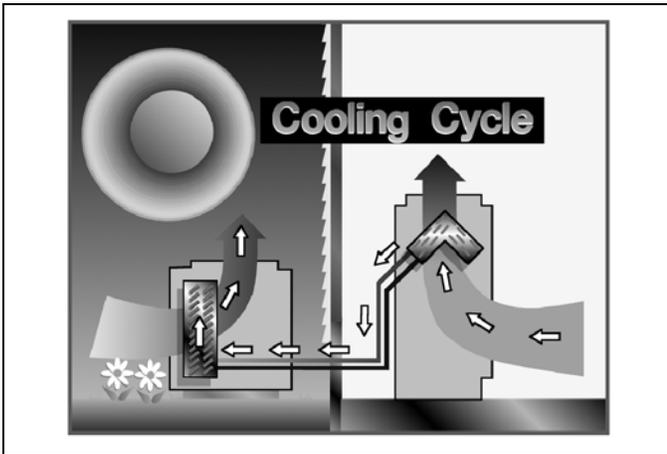
69. The last major component of a refrigeration system is the refrigerant itself. For years Refrigerant 22 (R-22) has been utilized almost exclusively for residential and light commercial sized air conditioning systems. Now, because of environmental concerns, R-22 is being replaced by R-410A. Although it is about 75% higher in pressure than R-22, it does not contain Chlorine and is therefore safer for the atmosphere.

HEAT PUMP CYCLE

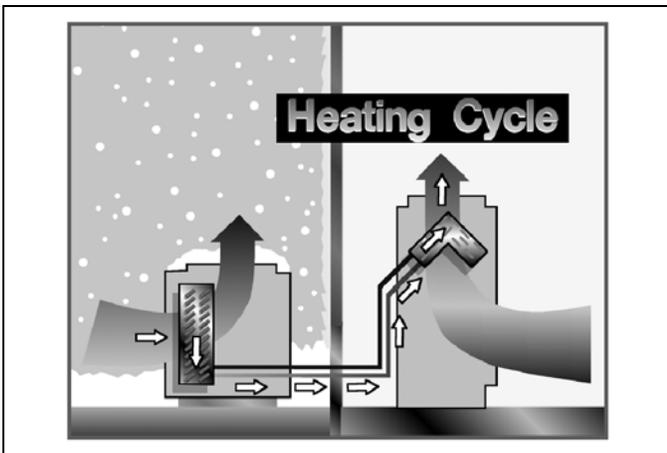
Even in Cold Weather Outside Air Contains a Relatively Large Amount of Heat.

70. How is "heat" extracted from cold outside air?

There is some heat in the air as long as the temperature is above absolute zero (-459°F). Therefore, if the refrigerant flowing through the outdoor coil is colder than the outside air, heat exchange will take place.



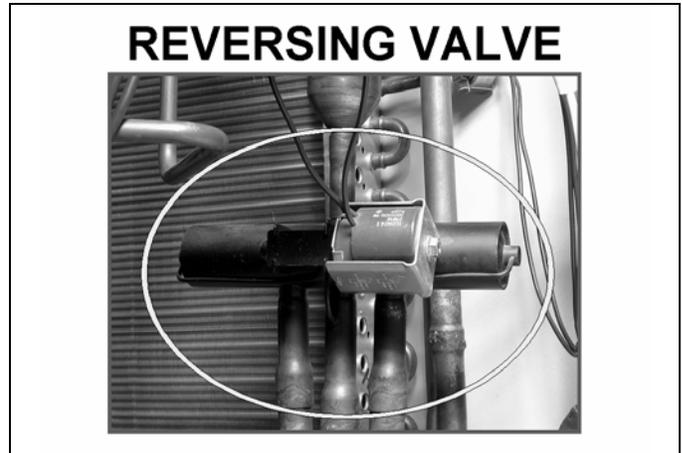
71. During the cooling season, the heat pump performs the same as any air conditioning system by picking up heat from the space to be conditioned and rejecting it outdoors. Notice that the flow of heat is to the outdoors.



72. During the heating season, the direction of heat transfer is to the indoors. The unit absorbs heat from the outdoor air and moves it to the conditioned space.

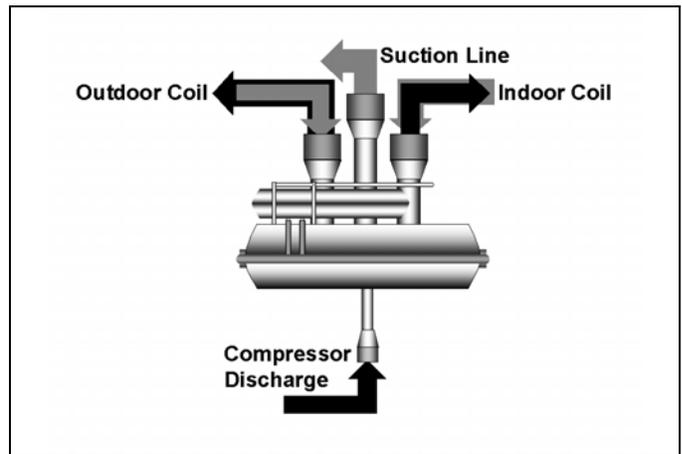
Because the unit changes from heating to cooling by reversing the direction of refrigerant flow, heat pumps are often called "reverse-cycle air conditioners."

HEAT PUMP SYSTEM COMPONENTS



73. In heat pumps, changeover between heating and cooling modes is accomplished with a **reversing valve**, also known as a **4-way valve**, which reverses the flow of refrigerant in the system.

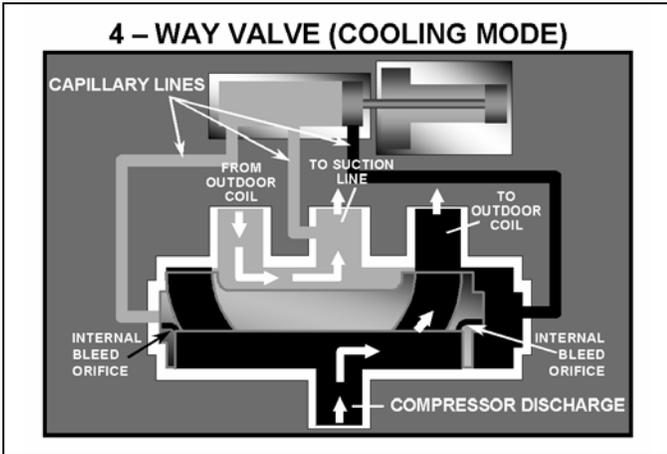
A solenoid-operated pilot valve, which is part of the 4-way valve, shifts the 4-way valve pneumatically.



74. The 4-way valve has four refrigerant connections: one to the compressor discharge, one to the compressor suction, and one to each coil. In some cases, the 4-way valve is electrically energized in cooling and de-energized in heating. On some systems, that arrangement is reversed.

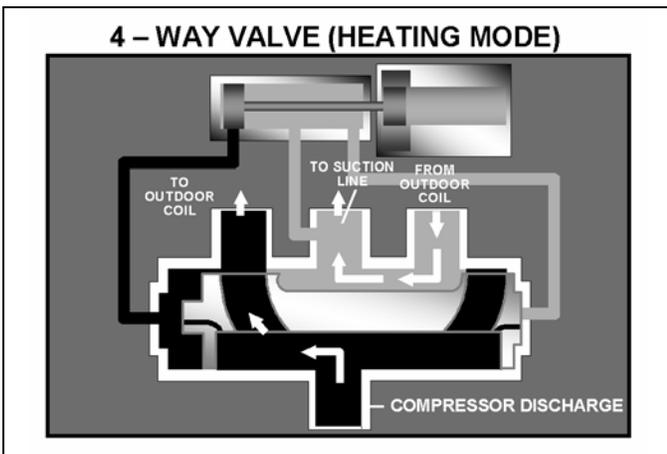
When troubleshooting a reversing valve, the unit must have a *full refrigerant charge*. If the charge is sufficient but the reversing valve is not shifting, it could be an electrical or mechanical problem. Symptoms of a non-shifting valve are lower discharge pressures and higher suction pressures, causing the compressor to cycle on the internal overload in both

modes of operation. The valve must be replaced. This problem could easily lead to compressor failure.

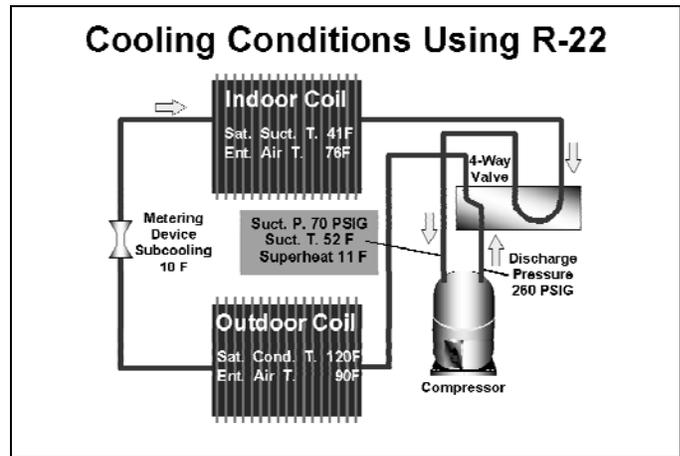


75. This illustration shows the arrangement inside the valve in the cooling mode, with the pilot valve energized. The main valve body is positioned so that the compressor discharge is routed to the outdoor coil; the compressor suction comes from the indoor coil.

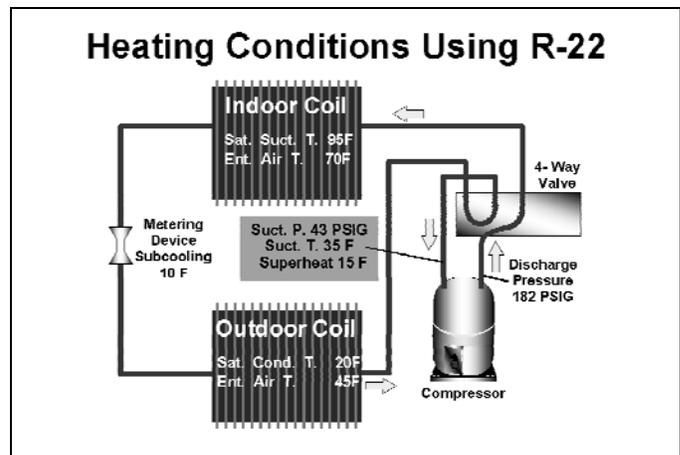
In some newer style reversing valves, the internal bleed orifices are eliminated and a fourth capillary line is added for a faster and more defined reversal of direction.



76. In the heating mode, when the pilot is de-energized, the compressor discharge is routed to the indoor coil and the compressor suction comes from the outdoor coil.



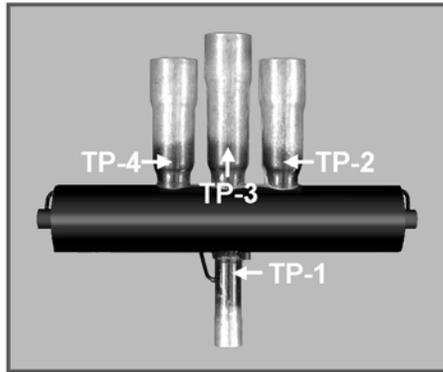
77. Temperature and pressure conditions for heat pumps operating in the cooling mode are about the same as those of a typical air conditioner. Typical heat pump conditions with 90°F outdoor air and 76°F indoor air are shown in this illustration.



78. Conditions for a heat pump operating in the heating mode vary significantly from cooling conditions. A typical heating condition may be 45°F outdoor air and 70°F indoor air. Typical operating pressures and temperatures for a heat pump operating at these conditions are shown here.

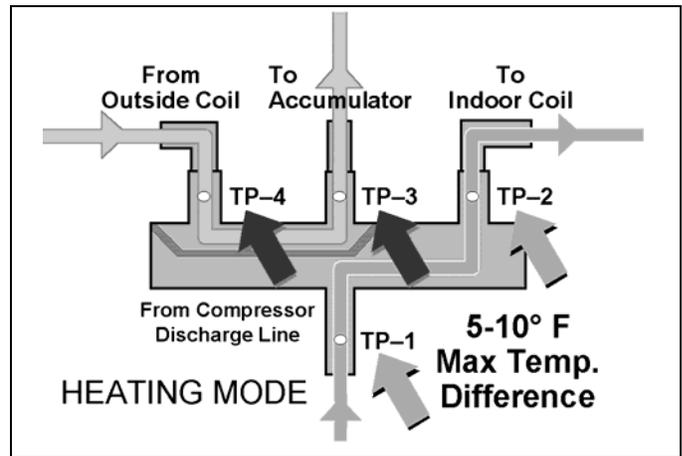
TESTING HEAT PUMP COMPONENTS

REVERSING VALVE

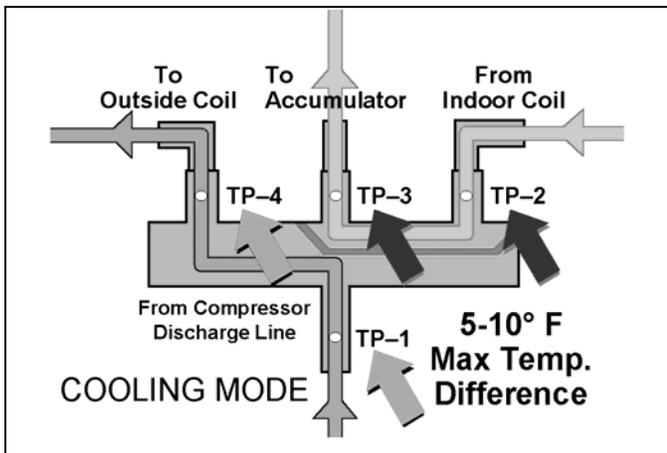


79. When testing a reversing valve, temperatures are best checked with a remote-reading electronic-type thermometer with multiple probes. Route the thermocouple leads through the inside of the coil area to the reversing valve.

One test probe is attached to each of the reversing valve's ports. Be sure to insulate the probes for accurate readings. Test in both the cooling mode and the heat pump mode.

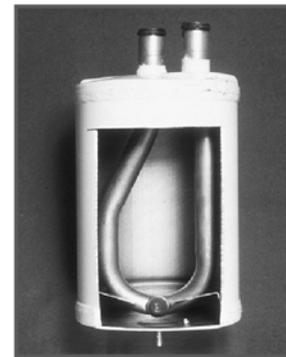


81. In the heating mode, the valve reverses; test points 1 and 2 are hot and test points 3 and 4 are cool or cold. Again, the maximum temperature difference is 5°-10°F. Record the temperatures. If the temperature differences are higher, the valve is either leaking, stuck or defective and must be replaced.



80. For checking the reversing valve in the cooling mode, read and record test points 2 and 3. These should be cool or cold and may have condensation on both lines. The maximum temperature difference across a normally operating valve is 5°-10°F for most manufacturers. Test points 1 and 4, the hot lines, should have 5°-10°F maximum across a normally operating valve.

ACCUMULATOR

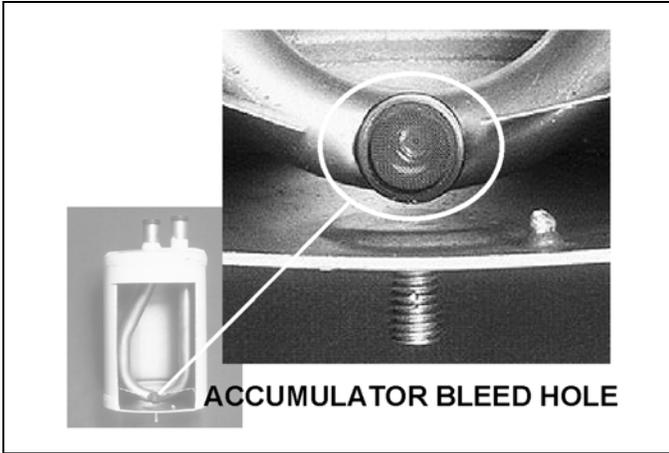


82. Most heat pump systems will have a factory-installed accumulator installed in it from the factory. The **accumulator** is a passive device that adds extra protection to the heat pump, especially when it runs under adverse conditions. It is located in the suction line between the compressor and the reversing valve.

The accumulator insures that liquid refrigerant, present in suction gas when the heat pump runs under light load conditions, does not enter the compressor. It accomplishes this by accumulating any liquid refrigerant traveling with the suction gas before it enters the compressor.

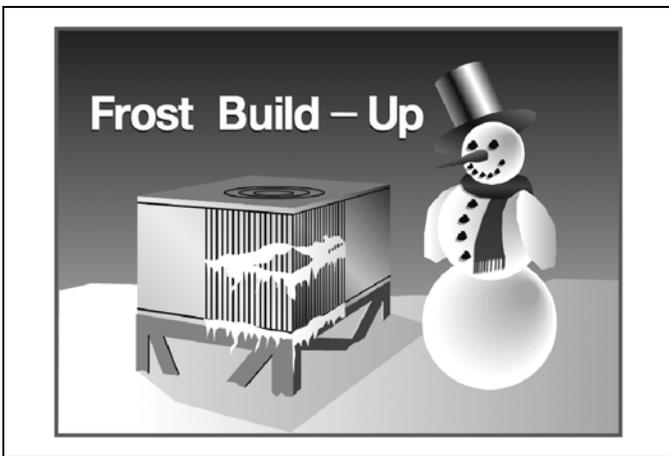
A bleed hole at the bottom of the suction gas return tube allows any collection of oil to be slowly but continuously injected back into the suction line to the compressor so that the accumulator doesn't turn into

an oil trap. It also allows a slow path for refrigerant liquid to enter the suction line, which is important for the cooling of the compressor motor during the low temperature heating operation in the winter season.



83. Occasionally, the accumulator's internal screen or bleed hole may become plugged with dirt or sludge from a motor burnout or from operating with moisture in the refrigeration system. Bleed holes are very small and are not accessible to clean. If they become plugged, the accumulator must be replaced. This problem could easily cause oil trapping and compressor failure.

DEFROST CYCLE



84. During the heating mode, outside air passing through the outdoor coil gives up its heat to the refrigerant because the refrigerant is colder than the air.

Even though the outside air may be 35 or 40°F, the lower refrigerant temperature within the outdoor coil

will cause moisture in the air to freeze, forming frost on the coil. Frost accumulation is greater during periods of high humidity, when the temperature is 30 to 40°F and less severe at lower temperatures because cold air contains less moisture.

Snow or rain falling on the coil may also cause ice buildup. Ice may not be removed by a simple defrost cycle, since it is a solid and may not completely melt and run down the coil when it is heated, as frost does. The cause for the ice may need to be determined and eliminated to solve this problem.

In any case, it is necessary to periodically defrost the coil; otherwise the buildup would block the coil and result in significant capacity reduction.

Defrost Methods

Timed Defrost

- Cyclic (30, 60, 90 Minutes)
- Time & Temperature

Demand Defrost

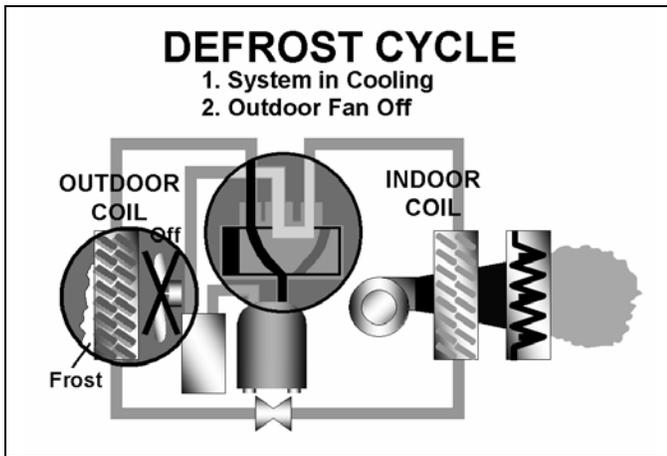
- Outdoor Air Temperature / Outdoor Coil Temperature Difference
- Air Pressure Drop
- Refrigerant Pressure

85. **Timed defrost** and **demand defrost** are the primary methods for initiating defrost.

In the timed method, defrost is initiated on a cycle (30, 60, 90 and sometimes 120 minutes) and requires that the outdoor or coil temperature be below a certain level to avoid unnecessary activation.

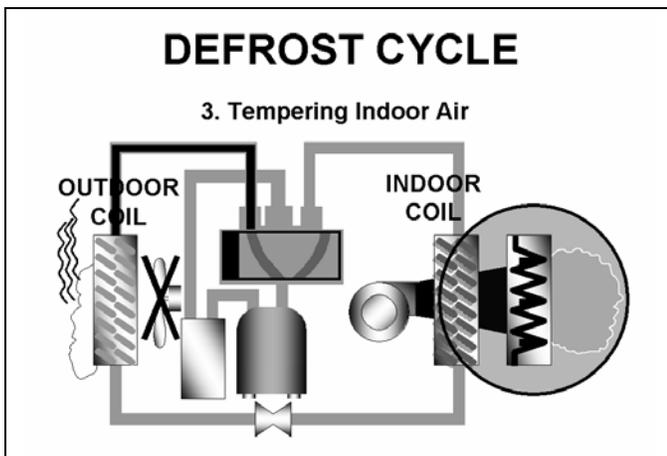
In demand defrost systems, one of three methods is used to sense when defrost is needed. In one method, the difference between outdoor air temperature and outdoor coil refrigerant temperature (which increases as frost accumulates) is sensed. In the second method, the air pressure drop across the outdoor coil is used. The third method uses a change in refrigerant pressure to indicate frost buildup and initiate defrost. Most systems use a combination of time and temperature to *terminate* defrost.

HEAT PUMP INSTALLATION



86. There are several methods for defrosting the outdoor coil. The most popular is to reverse the 4-way valve, placing the system in the cooling mode for a short period. The outdoor coil then acts as a condenser coil and hot discharge gas melts away the frost buildup.

The outdoor fan is normally shut off during defrost, so that cold air does not blow across the outdoor coil and hinder the defrost process.



87. In defrost, the system is running in the cooling mode. To offset the effect of cool air being blown into the conditioned space by the indoor fan, electric resistance heaters in the indoor air stream are energized.

When the defrost controls sense that the frost has melted, or when the maximum defrost has elapsed, the 4-way valve reverses and the system resumes heating operation. Since the outdoor coil is hot during defrost, "steam" may be observed rolling off the coil. This is a common occurrence and there is no need for alarm. A steam "cloud" is often created for a few seconds when the system re-starts the outdoor fan following defrosts.

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

88. First, properly locate the equipment. Make sure that it is level to allow for proper drainage. Keep the unit away from any overhangs to protect it from damage from snow or ice and away from windows to reduce noise transmission into the house. Make sure the unit is protected from wind by some sort of barrier, like shrubbery or a solid fence. Follow all code requirements pertaining to the unit's position to the house. Then, take the following steps.

Lay out the line set, making sure to follow the manufacturer's specifications as well as all applicable building codes for limits on lengths, connections, pitch, rise, etc. Check reference line sizes. *Undersized lines will cause decreased flow and loss of capacity.*

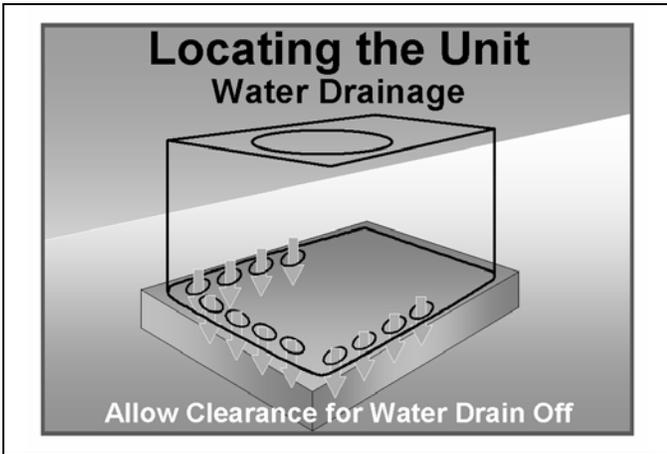
Next, make the system connections, using solders or brazes accepted by the equipment manufacturer and following local and national codes.

After all connections are made, leak test the line.

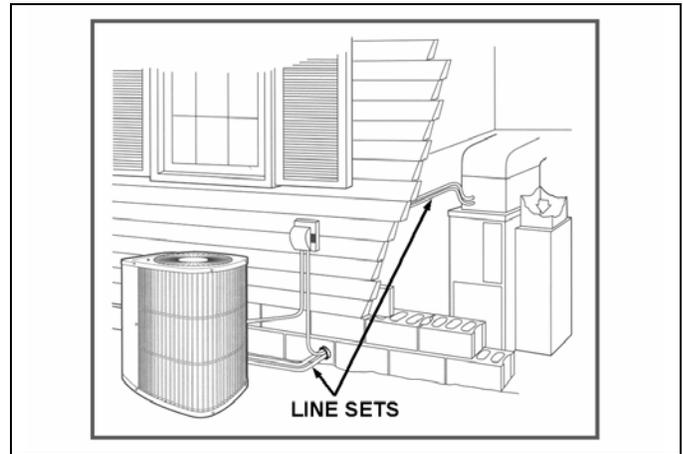
Once the system has been leak tested, the lines must be evacuated.

Check the system for proper airflow. Make sure that there is no significant air leakage through ductwork. EPA and DOE figures show that many duct systems leak from between 25 to 45% of conditioned air.

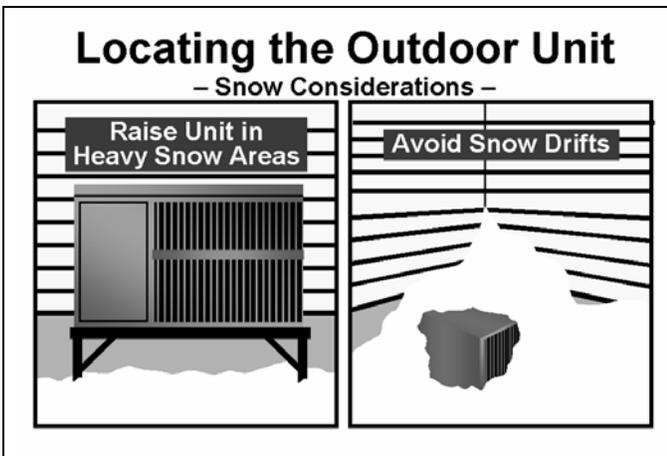
Finally, check the refrigerant charge. It may need to be adjusted to bring the system to manufacturer's specifications. Follow the manufacturer's recommended charging method.



89. Air source heat pumps have a defrost cycle. The installation must allow for safe and effective water drainage. In locations where snowfall is below 20 inches annually, the outdoor unit should be mounted on a concrete pad. Most units have a raised “footer” on the bottom to separate the unit from the pad and help in drainage. Check the cabinet for defrost drain hole locations and be sure the mounting pad does not block them. A gravel apron around the pad improves drainage and helps prevent the growth of vegetation near the unit.

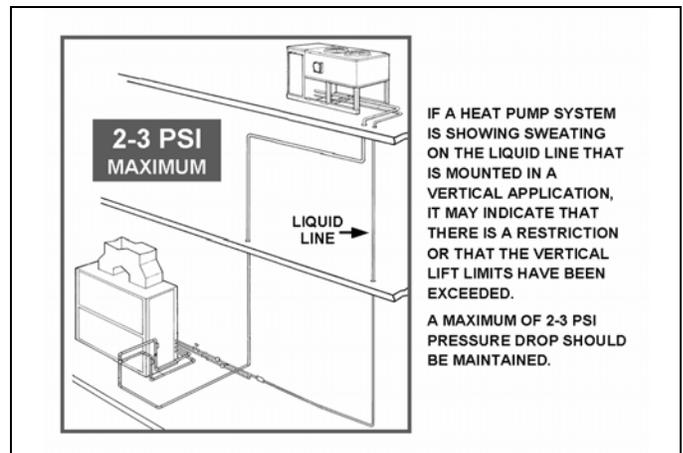


91. Line sets should be installed in such a way to also *prevent a pressure drop*. When running line sets through walls, remember to run the lines through a non-metallic sleeve or pipe to prevent damage and corrosion to the line.



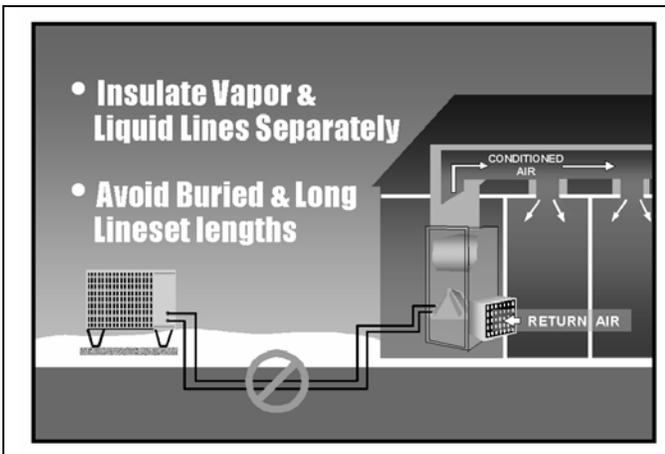
90. In areas that average 40 inches or less of annual snowfall, mount the unit on a rack that is at least 12 inches above the pad. In areas averaging more than 40 inches of annual snowfall, use a 16- to 24-inch rack.

As with all outdoor equipment, avoid locations under eaves, where rainwater collects, where snow and ice can fall on the unit and where snow may drift. Limit the length of refrigerant piping runs on a split system heat pump to 50 feet or less, if possible. Check the manufacturer’s limitations.



92. In a heat pump system, sweating on the liquid line mounted in a vertical application may indicate that there is a restriction or that the vertical lift limits have been exceeded.

A maximum of 2-3 PSI pressure drop should be maintained.



93. A possible cause of excessive power usage is heat loss due to insufficient insulation of the vapor line. Avoid buried and long runs of tubing that will lose additional heat. It is a good practice to insulate the vapor and liquid lines separately to avoid heat exchange between the two lines, which could also affect performance.

SERVICE TECHNIQUES

METHODS OF LEAK DETECTION

- VISUAL
- SOAP BUBBLES
- HALIDE TORCH
- ELECTRONIC
- ULTRASONIC
- RED DYE
- ULTRAVIOLET DYE

94. There are many methods of refrigerant leak detection, offering varying degrees of accuracy and demanding varying levels of expertise and expense.

Initially, we can make a **visual** inspection and look for telltale oil stains. **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 since regular household detergents can corrode solder connections. A **halide torch** is somewhat effective but CAUTION must be taken with the flame and the possible creation of toxic gasses. A halide torch cannot detect R-410A refrigerant. **Electronic** detection devices are the most accurate

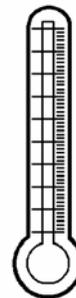
and are available in many different styles with varying degrees of accuracy and ease of use. Again, many electronic devices will not work with R-410A. **Ultrasonic** devices are very good but require a certain level of expertise and can be expensive, depending on the quality. Finally, the use of either a **red dye** or **ultraviolet dye** can be used in leak detection but red dye is not recommended by most compressor manufacturers and ultraviolet dye is not recommended by most compressor manufacturers in R-410A systems.

When testing a newly piped and empty system you may add a small “trace” amount of the type of refrigerant to be used in the system for the detector to sense, then back that up with a nitrogen gas charge (or any dry inert gas). Be sure to follow the manufacturer’s guidelines and do not exceed maximum test pressure levels. **NEVER USE OXYGEN TO PRESSURIZE A SYSTEM!!!** Contact with system oil can cause a fire or explosion.

SOLDERING AND BRAZING

Temperature Ranges for Soldering and Brazing

BRAZING
800° F – 1500 ° F



400° F – 800° F
SOLDERING

95. Soldering and brazing are used to join refrigerant pipes together by heating and melting a connecting alloy to join the pipes.

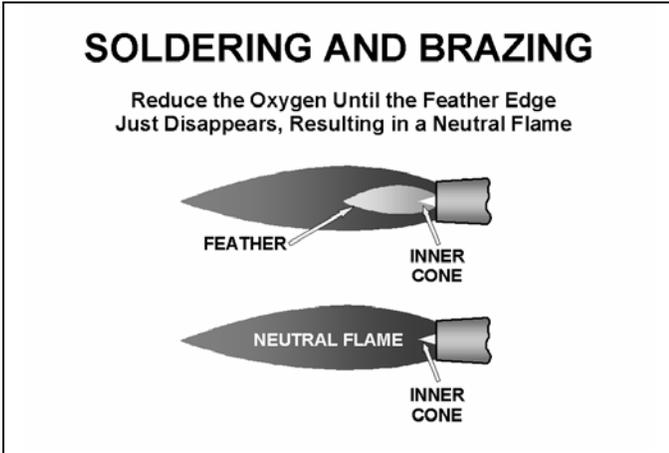
Soldering is accomplished below 800 degrees. Its advantage is that it does not damage the copper pipe itself and does not create the contaminating oxides that brazing does. Its disadvantages are that it is not as strong of a connection and requires the use of an acid flux to clean the pipes being joined. This makes it undesirable for use with new R410-A systems with their POE oil.

Brazing alloys require temperatures well above 800 degrees and create much stronger joints. Because of the high temperature, nitrogen must be injected inside the pipes being brazed to prevent contaminating

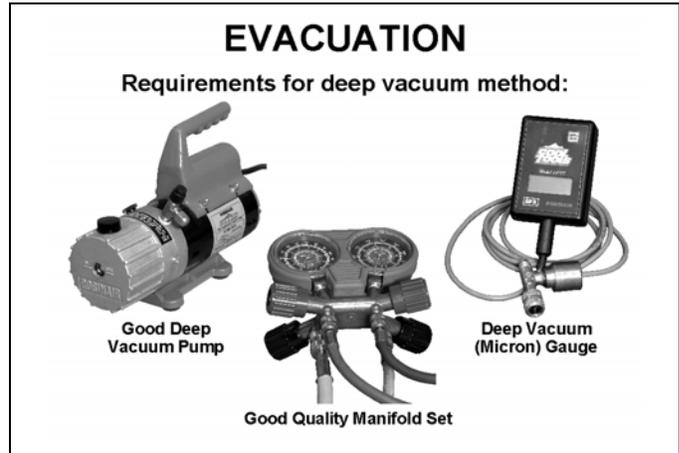
oxidation, which will damage the internal refrigeration system. Silver bearing braze rods allow the connection of dissimilar metals (such as joining copper to brass or steel). These alloys require the use of special flux, but this type is not harmful to the POE oils and is, therefore, recommended for use with refrigerant R-410A.

A mechanical bender is used for larger-diameter tubing and when a more accurate bend is required. These benders normally have a clip to hold the tubing while bending and a calibrated degree scale. They can be used to get smooth bends up to 180°.

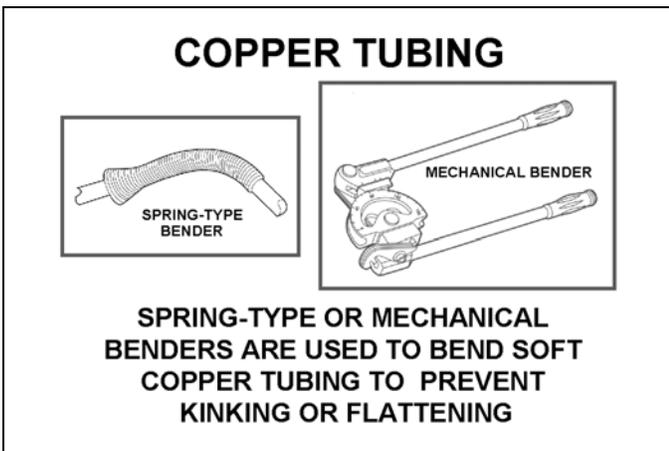
Never bend tubing simply with the hands or around a knee because this could lead to kinking.



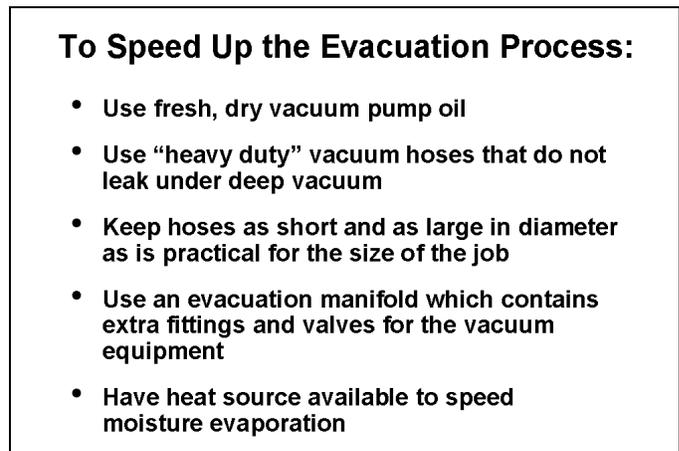
96. Soldering processes are often performed using a simple propane type torch. For brazing, however, the higher temperatures require a hotter torch. Air-acetylene torches require only one tank (acetylene) and are popular in the field. Jobs using larger pipes, however, may require even more heat. Oxyacetylene torches utilize pure oxygen instead of air but require a second gas tank (oxygen). When using these torch systems care must be taken to properly adjust the flame. A “neutral” flame provides a hot, clean, and precise flame for effective brazing.



98. The most effective method of evacuation is the **Deep Vacuum Method**. This requires a good deep vacuum pump capable of pulling at a rate of at least 1 cfm for residential equipment and 2.5 to 5 cfm or more for larger equipment. A deep vacuum gauge, usually calibrated in microns, is necessary to measure the vacuum. Manifold gauges are NOT accurate enough for this range. Most equipment manufacturers recommend a vacuum of 500 be reached. Finally, a good quality manifold set with vacuum hoses and valves is necessary.



97. A spring-type bender of the proper size should be used over soft copper tubing to prevent kinking or flattening the tube. Kinks restrict the flow of refrigerant.



99. To speed the evacuation process, use fresh, dry vacuum pump oil. Use “heavy duty” vacuum hoses that do not leak under deep vacuum and keep the

hoses as short and large in diameter as is practical for the size of the job. Use an “evacuation manifold” which contains extra fittings and valves for the vacuum pump, micron gauge, nitrogen tank, refrigerant charging cylinder, etc. Have a heat source (heat gun) available to speed moisture evaporation

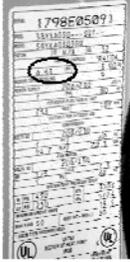
CAUTION: Never apply electrical power to a compressor motor when it is in a deep vacuum. Dangerous “arcing” could occur causing damage to compressor motor windings and possible personal injury.

**CHECKING AND ADJUSTING
HEAT PUMP REFRIGERANT CHARGE**

Heating Mode

• Heating Check Chart • Weight

HEATING		COOLING	
Pressure	Temperature	Pressure	Temperature
100	100	100	100
105	105	105	105
110	110	110	110
115	115	115	115
120	120	120	120
125	125	125	125
130	130	130	130
135	135	135	135
140	140	140	140
145	145	145	145
150	150	150	150
155	155	155	155
160	160	160	160
165	165	165	165
170	170	170	170
175	175	175	175
180	180	180	180
185	185	185	185
190	190	190	190
195	195	195	195
200	200	200	200



To Verify a Successful Evacuation

- Be sure that deep vacuum gauge is connected to the system ahead of vacuum pump valves
- Close the valves connecting the vacuum pump
- Turn off the pump and wait five minutes
- If the vacuum does not rise, system is dry and tight
- If the vacuum level rises to 1,000 or 2,000 microns and holds there: moisture still exists and further evacuation is necessary
- If the vacuum level rises toward atmospheric, a leak exists and location and repair of the leak are necessary before re-evacuating the system

100. Perform a “Drop Check” to verify the successful completion of the evacuation procedure. To insure total moisture removal and that there are no leaks in the piping system, most manufacturers recommend a vacuum of 500 microns.

Start by making sure that the deep vacuum gauge is connected to the system ahead of vacuum pump valves. Next, close the valves connecting the vacuum pump. Turn off the pump and wait five minutes. If vacuum does not rise above 1000 microns, the system is dry and tight. If the vacuum level rises to 1,000 or 2,000 microns and holds there, moisture still exists and further evacuation is necessary. If the vacuum level continues rising toward atmospheric, a leak exists and location and repair of the leak are necessary before re-evacuating system.

101. With a heat pump operating in the **Heating Mode**, some manufacturers provide a “Heating Check Chart” to see if the system pressures are in approximately the correct range to indicate a proper charge.

The only accurate way of actually charging in the winter is via the weight method. The equipment nameplate should indicate the proper refrigerant charge. Because a split system has refrigerant lines between the indoor and outdoor components, that charge will include some refrigerant for a certain length of refrigerant lines. If the lines are a different length, it is necessary to correct the charge amount.

**CHECKING AND ADJUSTING
HEAT PUMP REFRIGERANT CHARGE**

Heating Mode

For a unit containing a charge of 6 lbs. 2 oz. including 15 feet of refrigerant line and instructions indicating that a 3/8-inch liquid line contains 0.6 oz. of refrigerant per foot of line and the equipment has a 35-foot line set:

35 – 15 = 20 additional feet of length

20 × 0.6 = 12 oz. of refrigerant to be added

6 lb. 2 oz. + 12 oz. = 6 lb. 14 oz. ← TOTAL CHARGE

102. A unit contains a charge of 6 lbs. 2 oz., and this includes refrigerant for 15 feet of refrigerant line. The instructions indicate that its 3/8-inch liquid line contains 0.6 oz. of refrigerant per foot of line. If the system has a 35-foot line set, how much refrigerant needs to be added or removed? What would be the new total charge?

**CHECKING AND ADJUSTING
HEAT PUMP REFRIGERANT CHARGE**

Cooling Mode

- **Superheat**
 - Systems using Fixed Restrictor metering devices
- **Subcooling**
 - Systems using a TXV as a metering device
- **Weight**
 - Systems which are empty after having been evacuated or following refrigerant recovery

CHARGE ACCURACY

Undercharge	Overcharge	Proper Charge
<ul style="list-style-type: none"> • DECREASED SUBCOOLING • LOW LOW-SIDE PRESSURE • HIGH SUPERHEAT • OVERHEATED COMPRESSOR AND MOTOR • LOW SYSTEM CAPACITY • POOR EFFICIENCY • SLUDGE / CARBONIZATION • POSSIBLE FREEZE-UP OF EVAP. OIL 	<ul style="list-style-type: none"> • HIGH HIGH-SIDE PRESSURE • HIGH DISCHARGE TEMPERATURE • FLOODBACK • LOW SYSTEM CAPACITY • POOR EFFICIENCY • SLUDGE / CARBONIZATION 	<ul style="list-style-type: none"> • LONG LIFE • SAFE OPERATION • DESIGN CAPACITY • PEAK EFFICIENCY

103. Heat pumps operating in the **Cooling Mode** can be tested and charged like any air conditioning split system.

Checking and adjusting the refrigerant charge in a **Fixed Restrictor System** is accomplished by checking the evaporator superheat. The quantity of superheat will vary with the system's operating conditions so a "superheat calculator" of some sort is necessary. To utilize this device, it is necessary to identify the load on the outdoor coil by measuring the outdoor dry bulb temperature then determine the load on the indoor coil by measuring the indoor wet bulb temperature. A sling psychrometer or an electronic psychrometer is used to determine the wet bulb temperature. The required system superheat for the existing conditions can be determined with this information and then measured against the actual system superheat.

In a system using a **TXV** as a metering device the refrigerant charge is checked by measuring condenser subcooling. Proper superheat is still important and should be approximately 10 to 12 degrees. However, because superheat should remain constant through the operation of the valve, superheat **CANNOT** be used to check the system charge. The equipment manufacturer must supply the subcooling information, either on the equipment nameplate or in the service manual. The "rule of thumb" for subcooling in air conditioning systems is that it should be between 10 and 14 degrees. However, that is not good enough for actually adjusting the charge. Subcooling trends directly follow the quantity of charge.

Finally, as in the heating mode, the system's charge can be weighed in.

104. An undercharge of refrigerant will result in increased superheat, decreased subcooling, low suction pressure, poor compressor cooling, high discharge gas temperature and compression ratio, decreased capacity and efficiency and a possible freeze up of the evaporator oil.

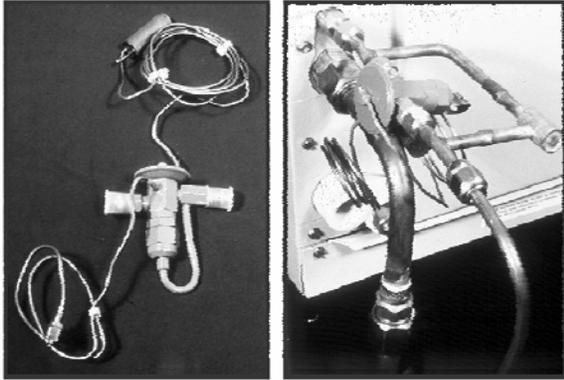
An overcharge of refrigerant will result in increased subcooling, elevated head pressure, high amp draw, high discharge gas temperatures and compression ratio and a decreased capacity and efficiency.

A low refrigerant charge in a heat pump system will also contribute to incomplete defrost and difficulty in moving the reversing valve slide when that action is required.

An overcharge can often be masked due to the presence of the accumulator, at least until the overcharge becomes excessive.

Charge properly to assure longer equipment life, safe operation at design capacity and peak efficiency.

METERING DEVICES



105. Heat pumps utilize two metering devices, therefore, require check valves or bypass restrictors to insure that only one is metering at a time. These devices can sometimes stick or not seat properly creating problems that need to be evaluated. For example, in the cooling mode with a fixed restrictor system, if the indoor piston does not fully seat it will allow excess refrigerant to leak past the piston. This will result in low superheat, high suction pressure (resulting in a warmer coil and poorer humidity control), high head pressure, low subcooling, and decreased efficiency and capacity.

COMMON HEAT PUMP VOLTAGES

- Residential Indoor Unit
 - 230V 1Ø
 - 115V
 - 24V
- Residential Outdoor Unit
 - 230V 1Ø
 - 24V
- Commercial Equipment
 - 230V 3Ø (major loads)
 - Compressor
 - Fan Motors
 - Electric Heaters

106. Residential equipment uses between 208 and 240 volt, single-phase power for the compressor, fan motors, and electric heaters. Three-phase power is generally not available to residential customers. A transformer is used to drop line voltage to 24 volts for thermostat and control circuits.

The maximum tolerance acceptable for the supply voltage in a single-phase circuit is $\pm 10\%$.

Commercial equipment utilizes 3Ø (three-phase) power for major loads whenever it is available. Three-phase power eliminates the need for capacitors and starting relays. It is more efficient, gives motors more starting torque, and increases running efficiency.

ELECTRICAL TROUBLESHOOTING is a logical process of elimination.

In order to effectively troubleshoot, you must know the unit electrically. You *must know*:

- What the unit is supposed to do and how it is supposed to do it
- The function of each component used in the electrical circuit
- The physical location of each component used in the machine
- The interrelationship of components
- Electrical symbols and be able to read a wiring diagram to determine the sequence of operation

107. Electrical troubleshooting constitutes the largest portion of our troubleshooting time. Even for a mechanical or air flow problem we must first operate the machine to determine which operating control or safety switch is causing the machine to cycle or prevent it from running.

Three things must first be considered:

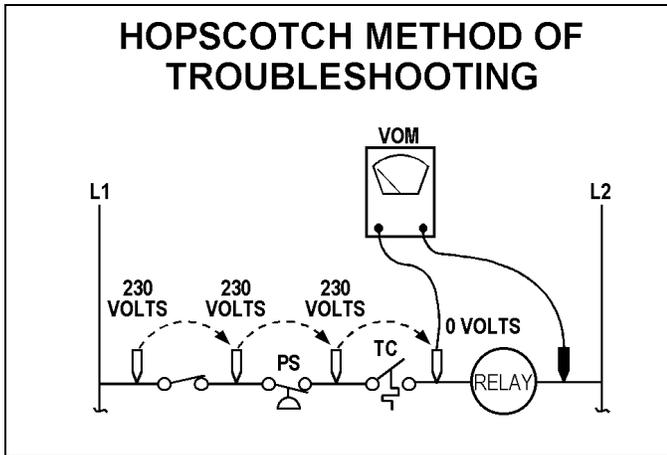
- How is the machine supposed to be working?
- What components are working properly?
- What is the machine NOT doing?

There is no point in troubleshooting properly operating circuits. Eliminate the operating circuits from the troubleshooting process and concentrate on the inoperative circuits.

Look for one malfunction. Evaluate the electrical circuit. The system's ladder diagram is the best tool for evaluating system operation. Look for one component or switch in the circuit that could be causing all the failure symptoms. Do not complicate the problem. One failed component is usually the cause of the problem. Do not overlook the simple solutions. Most problems are common failures and not necessarily the most difficult to find and solve.

Once you have identified the individual circuit that you think is causing the problem, you must troubleshoot that circuit to find the specific component causing the problem. If you have

identified more than one possible problem circuit, simply troubleshoot one circuit at a time. There is a specific order you should follow when testing a circuit. We call this process the **hopsotch** method.



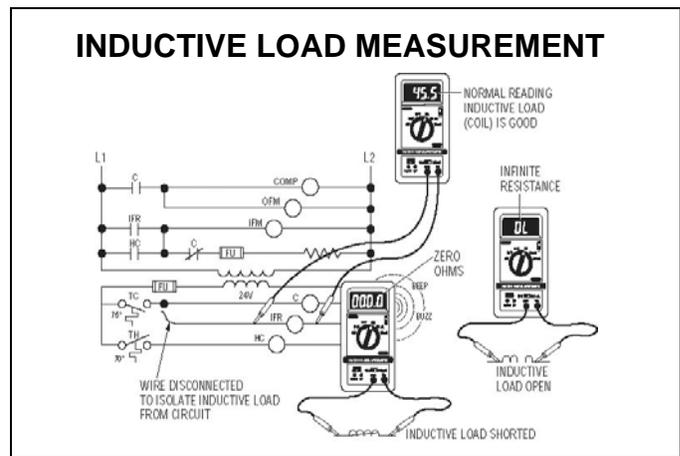
108. With power turned on, use a multi-meter set to the voltage function to test the circuit.

First, test for input potential to the circuit. Attach the black probe of the meter to the L2 side of the circuit with an *alligator* clip, which can be left there for the entire procedure, eliminating the need for placing both hands in the electrical circuit at the same time. This is a good safety practice! Then use the red meter probe to measure for voltage on the L1 side of the circuit.

Second, test for output potential, which will be the voltage to the load of this circuit. Move the red probe to the entering side of the load.

If you DO NOT have a voltage here, some component is electrically “open” before this point. You must now move the red probe back to the beginning of the circuit and “hopsotch” through the switches until you lose the voltage reading, showing that the component before that point is open. (Note that if you place the meter leads on each side of a closed switch in a powered circuit the meter will still read “0” volts because there is no “difference of potential” between the two test points. If the switch is “open” then you will read the voltage or “difference in potential” UNLESS there is another open in the circuit, in which case you will read “0” volts. This is confusing and is NOT a good method of troubleshooting!!)

If you DO read voltage entering the load, then the previous part of the circuit is electrically good and you must troubleshoot the load itself.



109. To troubleshoot the load:

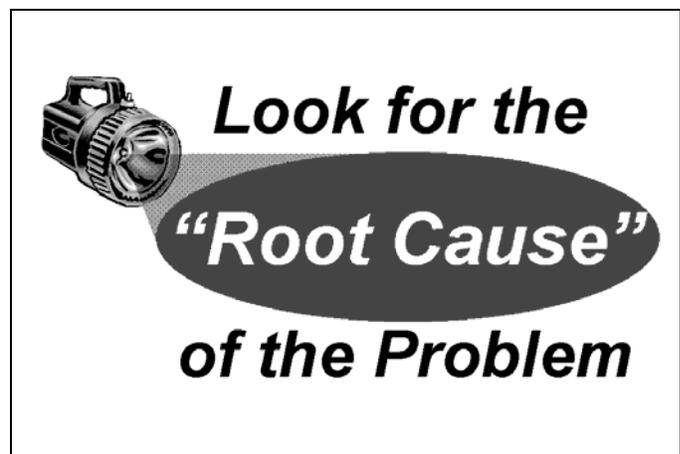
Step 1 Turn off the power.

Step 2 Isolate the component being tested from the rest of the circuit. (If there are any capacitors in the circuit, discharge them with a discharge tool or your meter.)

Step 3 Set your meter to the “Ohms” function.

Step 4 Measure the resistance of the load. If you do measure resistance, the load is probably electrically OK and you should look for a mechanical problem or a problem with the component that this load is controlling.

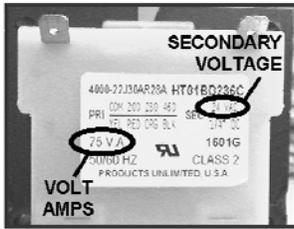
Step 5 If the load measures “open” then it is electrically faulty and needs to be replaced.



110. Do not forget to consider what may have caused the component to fail, even in cases of electrical failure. For example, an open high-pressure switch could be caused by a dirty condenser. A blown fuse may have a faulty capacitor or may indicate a problem with high motor amps in the circuit.

Total Allowable Amp Draw

$$\text{TOTAL AMP DRAW OF A CIRCUIT} = \frac{\text{VA RATING}}{\text{SECONDARY VOLTAGE}}$$



$$= \frac{75\text{VA}}{24\text{V}}$$

$$= 3.1 \text{ Amps}$$

COMMON MOTOR TYPES

- **PSC** – Permanent Split Capacitor
- **CSR** – Capacitor Start and Run

111. To determine the maximum allowable *amp draw* on a 75VA transformer when utilized in a 24-volt circuit, use the formula:

$$\text{Total Allowable Amp Draw} = \frac{\text{VA Rating}}{\text{Secondary Voltage}}$$

113. Residential air conditioning uses single-phase motors. Motor manufacturers split the winding into what they call a “Split Phase Motor” and often utilize capacitors to increase starting torque and running efficiency. The two most commonly used motors are Permanent Split Capacitor (PSC) and Capacitor Start-Capacitor Run (CSR) motors.

MAXIMUM VOLTAGE & CURRENT IMBALANCE

Maximum Voltage Imbalance in a 3-Phase Circuit is 2%

$$\% \text{ Voltage Imbalance} = \frac{100 \times \text{Max. Deviation from Average Voltage}}{\text{Average Voltage}}$$

Maximum Current Imbalance in a 3-Phase Circuit is 10%

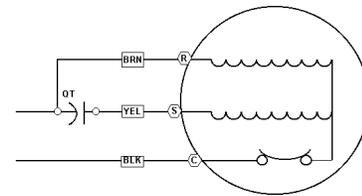
$$\% \text{ Voltage Imbalance} = \frac{100 \times \text{Max. Deviation from Average Current}}{\text{Average Current}}$$

112. The maximum *voltage* imbalance in a three-phase circuit is 2% and is determined using the formula in the graphic above.

The maximum *current* imbalance in a three-phase circuit is 10% and is determined using the formula above.

PERMANENT SPLIT CAPACITOR

**P
S
C**

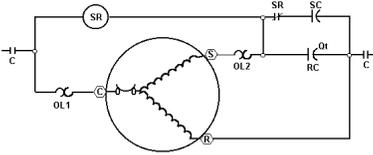


USES A RUN CAPACITOR
MODERATE STARTING TORQUE – EXCELLENT RUNNING EFFICIENCY

114. A Permanent Split Capacitor or PSC motor is the most common motor type. It uses a run capacitor to increase running efficiency and is commonly used for evaporator and condenser fans.

CAPACITOR START – CAPACITOR RUN

CSR



USES RUN CAPACITOR, START CAPACITOR & START RELAY
HIGH TORQUE – EXCELLENT RUNNING EFFICIENCY

115. Capacitor Start and Run or CSR motors are most commonly used in compressors, utilizing both a start capacitor for increased starting torque and a run capacitor for better running efficiency. If the start capacitor fails, the motor *may start if conditions are right*, but the motor will draw high amps. A start capacitor must be controlled by a relay and should only stay in the electrical circuit for one or two seconds. If it stays in the circuit longer, high current will trip a breaker or burn out a winding. Failure of the run capacitor will cause the motor to draw higher amperage and run hot. It could eventually cause winding failure.

RULES OF MOTOR TESTING

- The start winding is constructed of more turns of a smaller diameter wire than the run winding. The resistance of the start winding is *generally* 3 – 6 times the resistance of the run winding.
- The run winding resistance (C-R) plus the start winding resistance (C-S) must add up and equal what is read from R-S.
In other words, the readings must be additive.
If not, a short exists between both windings.

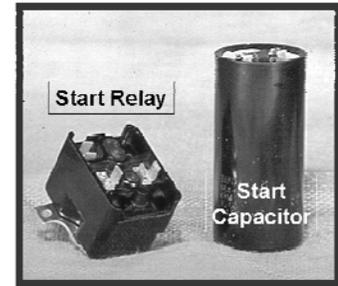
116. Motors are inductive, or magnetic loads. They will draw 3 to 6 times the normal running amps for one to three seconds while the motor is getting up to speed. This is called **starting amps** or **locked rotor amps**. Positive Temperature Coefficient (PTC) devices and starting capacitors are often used with single-phase compressor motors to give them more starting torque. Three-phase motors get extra torque from the three windings. Although they still draw

higher current during start-up they don't need any additional starting gear.

CAPACITORS



Run Capacitor



Start Relay

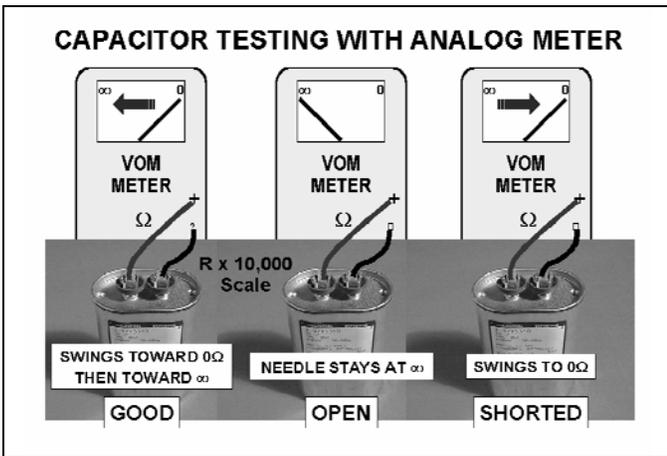
Start Capacitor

117. Capacitors electrically move the start winding out of phase with the run winding, improving the power factor of the motor. Run capacitors are generally larger and have a metal case. They are filled with an oil to help dissipate heat as motor current flows through them, the entire time the motor is running. Start capacitors are in a Bakelite or plastic shell since they are not in the circuit long enough to build up much heat. A resistor attached between the terminals of a start capacitor, dissipates voltage stored by the capacitor during the one or two seconds that it is in the electrical circuit.

CAPACITOR TESTING WITH DIGITAL METER



118. When testing a capacitor the easiest method to use is a digital multi-meter with a microfarad function. It will indicate whether the capacitor is “open” or “shorted” and also its microfarad rating.



119. If only an analog meter is available, a good capacitor will cause the needle to first swing toward the zero ohms side as it charges and then slowly glide back towards infinity. It is difficult to calculate the actual microfarad rating, but you can verify that the capacitor is neither open nor shorted.

When troubleshooting compressor motors and contactors, be sure to check that all connections are tightened properly and check contactor terminals for arcing or pitting. Loose terminals or pitted contacts cause resistance to current flow and generate heat, causing further damage and decreased current flow, resulting in potential motor failure.

AIR SIDE BASICS

Effective Air Conditioning requires:

- Proper *Air Delivery* for customer comfort
- Proper *Air Quantity* for correct system operation

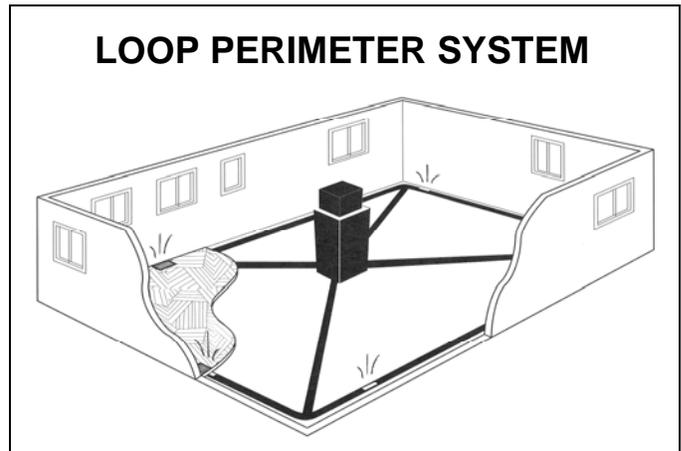
120. Correct quantity and delivery of airflow is important to the proper operation of any air conditioning system, and even more important for heat pumps. There are many aspects to the “air side” of our business and we will try to touch on some important points in this review.

UNDERFLOOR AIR DELIVERY SYSTEMS

- LOOP PERIMETER SYSTEM
- RADIAL PERIMETER SYSTEM
- EXTENDED PLENUM SYSTEM
- REDUCING EXTENDED PLENUM SYSTEM

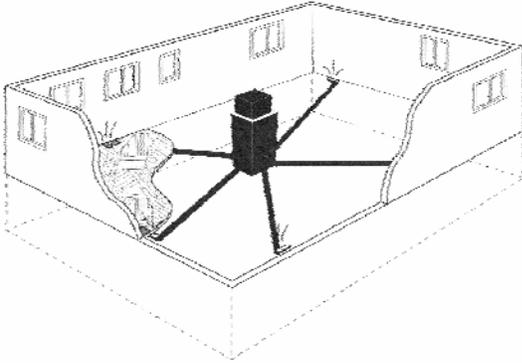
121. There are various air delivery systems available. Perimeter duct systems, which feed registers from underneath the floor are most common in northern climates, where heating is a more important consideration. The four common duct systems of this type are the loop perimeter system; the radial perimeter system, the extended plenum system and the reducing extended plenum system.

LOOP PERIMETER SYSTEM



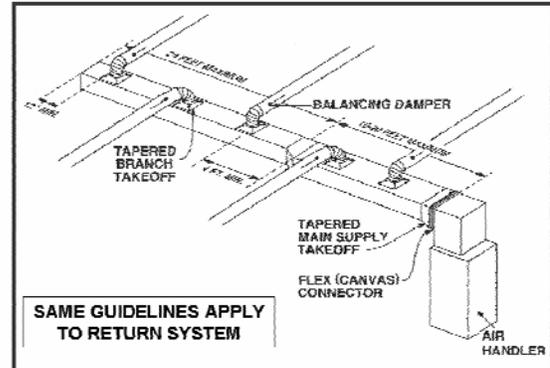
122. A **loop perimeter system** has a continuous loop around the outside of the house, fed by several branches from a central main supply air plenum. This system is very common in single story rectangular homes built on slabs. Generally it is used in systems under 100,000 Btu. This system provides good availability of supply air, but usually allows no or limited access for service.

RADIAL PERIMETER SYSTEM



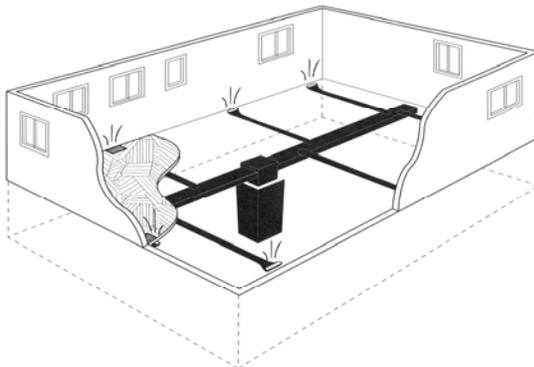
123. In a **radial perimeter system**, separate branch ducts feed each outlet from a central supply air plenum. This system uses less ductwork, but is less forgiving to airflow issues and is still not easily accessible for service.

REDUCING EXTENDED PLENUM GUIDELINES



125. A **reducing extended plenum system** is similar to the Extended Plenum System except that reducing transitions allow for longer main trunk runs.

EXTENDED PLENUM SYSTEM



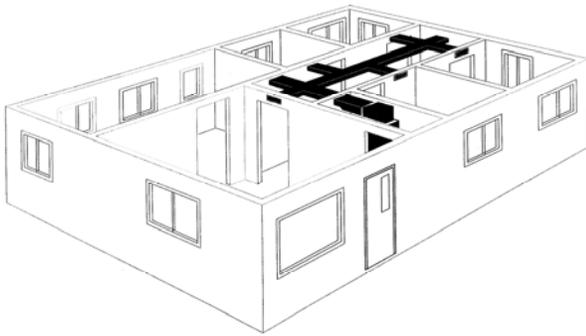
124. With an **extended plenum system**, a rectangular duct serves as the main supply trunk. Branch ducts run from it to feed the diffusers. The maximum recommended trunk length is less than 24 feet. This system requires a basement or crawlspace and is more accessible; but it is limited in sizes and proper air balance is important.

OVERHEAD AIR DELIVERY SYSTEMS

- **Trunk System**
- **Radial System**
- **Extended Plenum System**

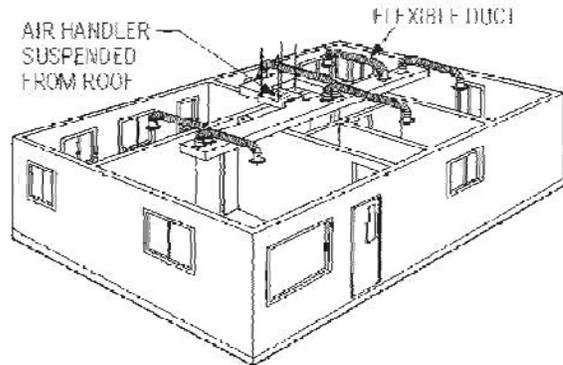
126. Overhead systems with ceiling or high wall diffusers are popular in Southern climates where cooling is the primary concern and heating requirements are minimal. Two common overhead systems, the overhead trunk system and the radial system, are available when there is no basement, crawlspace or attic and the air handler is on the first floor.

TRUNK SYSTEM



127. In a **trunk system**, the air handler and ductwork are often placed in a drop ceiling area, such as a hallway or a closet. The rectangular trunk ducts run from the side of the supply air plenum straight to each partition wall, where they feed a high sidewall register. The duct system is simple, short, and low cost. More extensive overhead trunk systems may run through soffit spaces. When the trunk duct extends more than 24 feet from the air handler, a reducing extended plenum should be used.

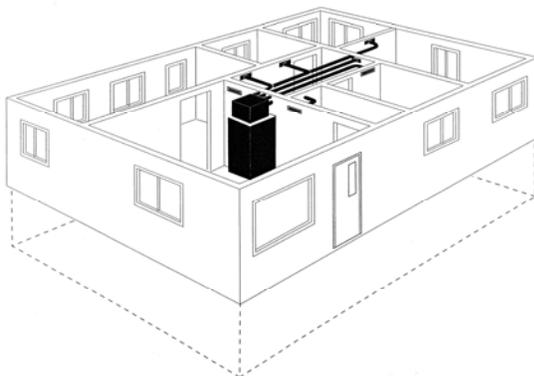
ATTIC – EXTENDED PLENUM SYSTEM



129. For homes with an attic that can accommodate both the air handler and the ductwork, an **extended plenum system** may be used. Flex duct connectors are commonly used because of their ease of installation and because they may be pre-insulated. However, flex duct is easily abused and care must be taken to prevent airflow restriction (explained later).

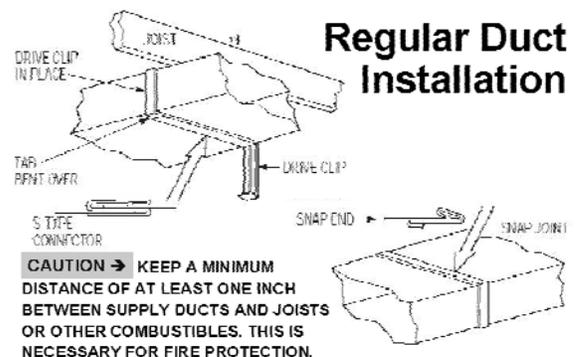
DUCT FABRICATION TYPES

RADIAL SYSTEM



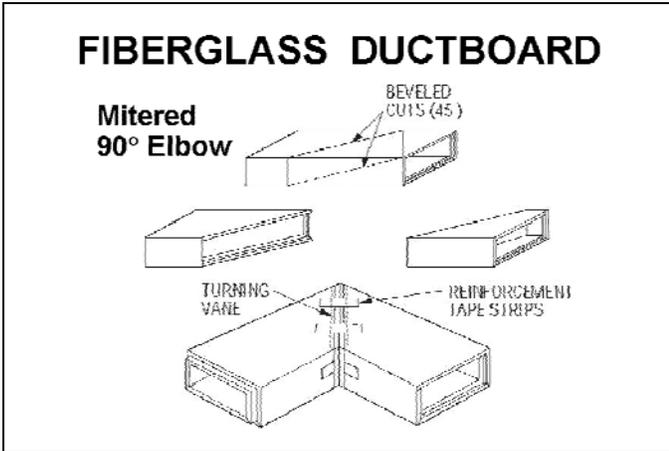
128. Like the trunk system, the **radial system** is ideal for apartments, houses built on slabs, and upper floors with separate air handlers but no attic. Separate branch ducts are run from a common supply air plenum to each high sidewall diffuser.

SHEET METAL DUCTWORK

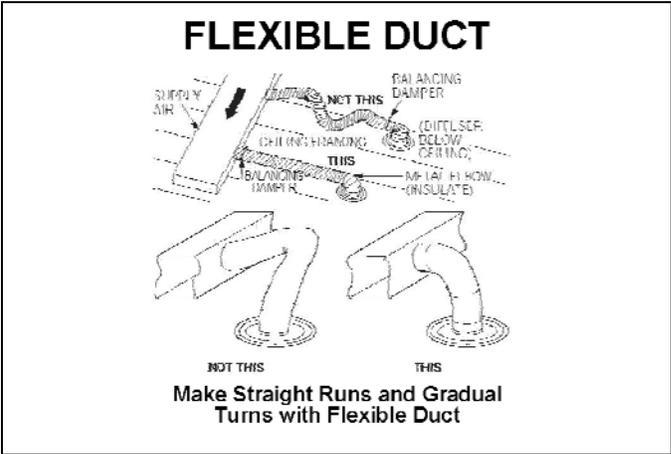


130. There are a variety of ductwork types. **Sheet metal ductwork** is rigid and remains straight for fairly long runs with a minimal resistance to air flow. However, it is heavy and must be supported according to code. It is also an excellent vapor barrier, but must still be insulated to prevent heat gain or loss and condensation problems when it is run through unconditioned spaces. Joints must be sealed to prevent air leakage and to prevent moisture from getting into the insulation. Unsealed joints can cause surprisingly large amounts of air leakage. Sheet metal duct can transmit blower noise throughout the system. Insulation applied inside the ductwork around the blower can dampen blower noise and reduce noise

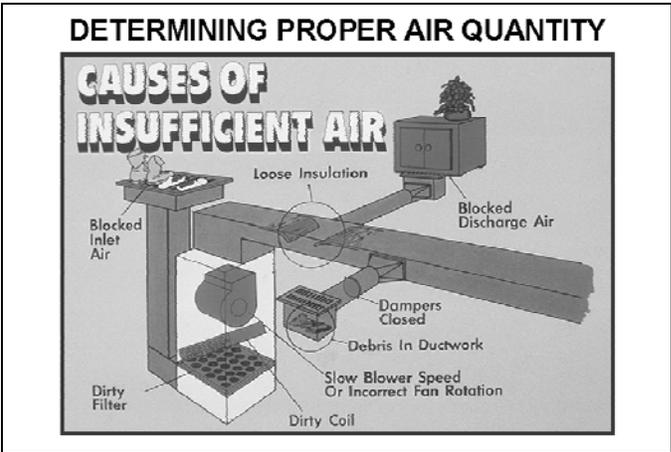
transmission. Internal insulation is usually applied during duct manufacturing and must be “coated” to prevent insulation wear by the system airflow.



131. **Fiberglass ductboard** is quiet, and effectively reduces blower noise through the ductwork. It should have an internal coating to prevent wear. Its fiberglass construction acts as an insulating material. It has its own foil vapor barrier, but must still be sealed properly with an approved system like foil tape and staples, then supported according to applicable code. Compared to sheet metal, it is lighter and can be transported flat and then assembled on the job. Special knives (identified by their color) are used to cut the duct board so it can be folded into rectangular shapes and then taped. When attaching one section to the next, edges are grooved into a “shiplap” shaped joint for strength. Special “staples” are used to secure sections together and then a heated “foil tape” or “mastic” sealing solution is used to assure that the joints are strong and air tight.



132. **Flexible duct** is easy to install and is the least expensive of all methods. It can also very easily be abused. Flex duct can be purchased with insulation and has its own foil or plastic vapor barrier. Flex duct must be carefully supported to prevent airflow restrictions, which can easily be 2 to 4 times that of metal duct. Stretching the duct run out to its full length reduces internal resistance of this type of duct. Long runs are not recommended. **Flex duct is not recommended for return air ducts.** Joints must also be sealed to prevent air leakage and moisture problems.



133. Many things, such as loose insulation, blocked air inlets or dirty filters or coils, can cause insufficient airflow. Insufficient airflow in the indoor unit can, in turn, cause many problems.

During the heating mode, insufficient airflow can cause high discharge temperature. While a customer may, in fact, like this condition, it is very bad for equipment. Insufficient airflow in heating can cause decreased air velocity, poor air distribution, high head

pressure, high amperage, and decreased capacity and efficiency, and possibly compressor failure.

During the cooling mode, insufficient airflow can result in low discharge air temperature and possible “sweating” of metal registers or grills. Decreased air velocity and poor air mixing resulting in a room with hot and cold spots can become a problem. Low suction pressure, causing possible coil freeze-up may occur. Decreased capacity, decreased efficiency as well as low superheat can also be the result of insufficient flow since the system runs longer to do the job.

DETERMINING AIRFLOW REQUIREMENTS

- **Verify Structure’s Heating & Cooling Load and Capacity**
- **Calculate Air Flow Capacity needed for the System**

“Rule of Thumb”:

A/C = 400 CFM/TON

HP = 450 CFM/TON

134. To determine the proper airflow requirements of an air conditioning system we must first determine the system’s capacity. Therefore, an accurate determination of a structure’s heating and cooling load and the required air conditioning system capacity requirement must be determined prior to developing airflow strategies.

A heat pump is normally sized to the cooling load. When located in cooler climates, however, a heat pump may be oversized to accommodate the heating requirements. No more than 25% over-sizing is recommended.

The “rule of thumb” from most manufacturers is that an indoor airflow quantity of 400 CFM per ton of system cooling capacity is required for cooling systems and a slightly higher or 450 CFM per ton is desired for heat pump systems. Some newer air handlers with Electronically Commutated Motors allow for a lower airflow, which will increase discharge air temperatures. This may make the customer happy with warmer air temperatures, but it will raise the head pressure of the system and decrease its electrical efficiency.

DETERMINING HEAT PUMP CAPACITY

Calculate Summer Heat Gain and Winter Heat Loss for Structure at Local Design Temperatures

**COLDER CLIMATES –
Never oversize cooling more than one size to meet heating requirements**

135. Over-sizing a system is most detrimental in the cooling cycle. It causes the system to short cycle, increasing electrical consumption; shortening the expected life of the equipment; and causing an excessive temperature swing. Over-sizing an air conditioning system will also cause poor dehumidification due to shortened run cycles.

For minimum noise levels we generally try to keep air velocity in residential supply ductwork below 500 to 600 fpm. Higher duct velocities allow smaller ductwork, but increase the noise level.



136. The following are some important terms relating to air movement:

Infiltration is the leakage of outside air into a structure. **Ventilation** is supplying fresh outside air into a conditioned space. **Circulation** is simply causing air to move, usually with system blowers or ceiling fans. **CFM** or **cubic feet per minute** is the standard air quantity measurement. **FPM** or **feet per minute** is the standard air velocity measurement. A **grille** is a louvered opening through which air passes.

A **register** is a grille with some sort of damper or flow control.

AIRFLOW FORMULAS

CFM = A × V

A is the AREA measured in square feet
V is VELOCITY measured in feet per minute

CFM = $\frac{\text{Btu}}{(1.08 \times \Delta T)}$

CFM is CUBIC FEET PER MINUTE
Btu is heating capacity (in electric heat derived by multiplying VOLTS X AMPS)
1.08 is a constant or factor derived from the specific heat and density of standard air x 60 minutes per hour
 ΔT is TEMPERATURE DIFFERENCE (Leaving Air Temp. – Entering Air Temp.)

137. Important airflow formulas are:

$$\text{CFM} = A \times V$$

Where:

A is area measured in square feet. V is velocity measured in feet per minute.

$$\text{CFM} = \frac{\text{Btu's}}{1.08 \times \Delta T}$$

Where:

CFM is cubic feet per minute. Btu is heating capacity (in electric heat derived by multiplying volts x amps). 1.08 is a constant or factor derived from the specific heat (.24) and density (.075) of standard air multiplied by 60 minutes per hour. ΔT is temperature difference (Leaving air temperature – entering air temperature).

TEMPERATURE RISE METHOD

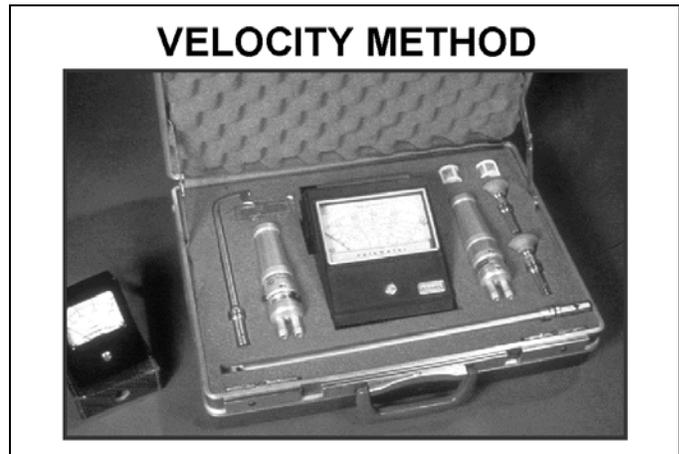
CFM = $\frac{\text{VOLTS} \times \text{AMPS} \times 3.414 \text{ BTU/WATT}}{1.08 \times \text{TEMP. DIFFERENCE}}$

= $\frac{230 \times 45 \times 3.414 \text{ BTU/WATT}}{1.08 \times 28}$

= 1170 CFM

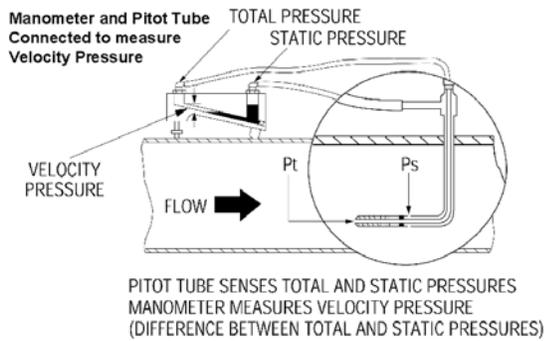
138. There are many methods of measuring airflow quantity. The **temperature rise method** uses the system’s electric heaters and measuring voltage, amperage, entering and leaving dry bulb air temperatures and the formula:

$$\text{CFM} = \frac{V \times A \times 3.414}{1.08 \times \text{Temperature Difference}}$$



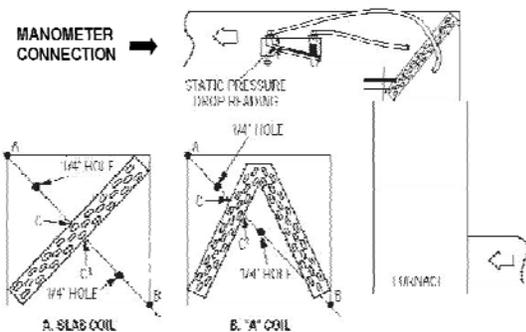
139. The **velocity method** uses an air velocity-measuring instrument such as an electronic vane anemometer and “traverses” the duct. “**Traversing**” a duct, means taking several equally spaced pressure readings and averaging them to get the average velocity. You then use the formula **CFM = A x V**.

VELOCITY PRESSURE METHOD



140. There are different pressure methods of measuring airflow. The **velocity pressure method** utilizes either an incline manometer or a magnehelic gauge with a pitot tube to traverse the duct to determine an average pressure reading, and then convert that pressure to a velocity in fpm. After determining the square foot area of the duct, use the formula $CFM = A \times V$.

STATIC PRESSURE METHOD



141. A second pressure method is the **static pressure method**. This method uses the same tools but takes the static pressure differential across the coil and applies that to a manufacturer's chart to determine CFM.

COMMON AIR-RELATED COMPLAINTS

- **SYSTEM NOISE**
 - Excessive Air Velocity
 - Blower Noise
 - Popping and Banging
 - Vibrations and Whistling
- **SYSTEM SMELL**
 - Ozone Smell
- **SYSTEM DISCOMFORT**
 - Clammy/Muggy Structure
 - Oversized Air Handler/Excessive Fan Speed
 - Blowing Cold Air
 - Equipment Fire
 - Insufficient Heat/Low Airflow
 - Excessive Cooling Run

142. Complaints may arise that necessitate troubleshooting a system for air related problems. Some complaints such as system noise or smell may be related to a specific mechanical problem, while others may be related to comfort concerns caused by a system's poor performance.

System Noise

When troubleshooting a noisy system, first listen and evaluate the type of noise and, if necessary, measure the system's airflow to compare it to the system requirements. The source and cause of the noise can often suggest an obvious solution.

Excessive air velocity can be caused by an **oversized air handler** or **excessive fan speed**. Lowering the fan speed can easily reduce the airflow and the noise. Noise may also result when *excessive air velocity* is used to compensate for **undersized ductwork**. This is a serious problem that often arises when a heat pump is used to replace a fossil fuel system without consideration being given to the system's ductwork. With the lower temperature differences created in a heat pump system, greater airflow is needed, requiring larger ductwork than fossil fuel systems.

In cases of *blower noise*, inspect the blower wheel for **dirt, damaged or bent vanes, bad bearings, or improper blower speed** (too fast). The *transmission of simple air noise in sheet metal ducts* can often be reduced by **insulating the inside of the duct**. A vibration **isolation sleeve** is needed between the air handler and the supply plenum.

Popping or banging noises, heard when a blower starts and stops, are usually generated by the system's

static pressure pressing on sides of ductwork and causing it to balloon out when the pressure changes. This is usually prevented by applying “cross breaks” to the ductwork during its manufacture. *Vibration or whistling* is usually the result of **loose internal insulation** or **vent dampers that are not tightened** and therefore flapping in the air stream.

System Smell

Electronic air cleaners generate 5,000 volts or more to electrically charge airborne particles and then remove them from the air. In older style EAC's, *slower airflow* often results in higher levels of “ozone,” indicated by an unpleasant smell. Increasing fan speed usually helps to minimize this problem.

System Discomfort

Other complaints relating to the air system may concern issues of system comfort. **Insufficient dehumidification** during the cooling season can often result in a “clammy” or “muggy” feeling structure.

The desired relative humidity for human comfort is between 40% and 50%. Relative humidity can be measured with various types of psychrometers. An increase in humidity can be seen when the wet bulb reading of a sling psychrometer approaches the dry bulb reading.

Insufficient dehumidification by a heat pump could be the result of an **oversized system**. The short cooling cycle does not have time to dehumidify the air. When sizing a system, bigger **IS NOT** better.

An **oversized air handler** or **too high of a fan speed** can also result in *insufficient dehumidification*. Slowing airflow will lower the temperature of the air on the cooling coil and increase moisture removal. Another common air-related complaint is that a room feels “**drafty**.” This means that the air exiting a diffuser in a room can be felt and moving air usually feels cool. Airflow in a room should only be between 15 and 50 fpm. To troubleshoot this problem, measure the cfm of the air exiting the diffuser and determine if it is excessive for that design of register or diffuser. Check the location, angle of installation, and positioning of the vanes to be sure the airflow is not aimed directly toward occupants. It should be traveling smoothly above the occupants' heads and

mixing the room air to a comfortable condition. Supply register velocity, throw and drop are the criteria of diffuser's design and should be correct if the cfm is correct.

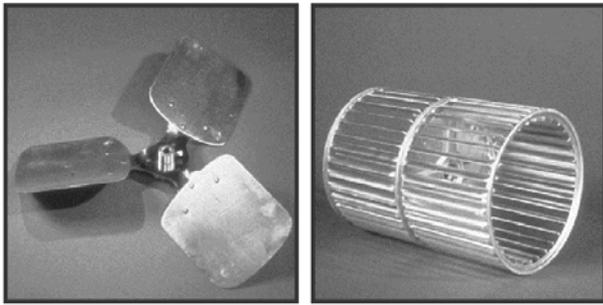
A common complaint of a heat pump in the heating season is that it is **blowing cold air**. Most heat pumps only deliver air at a temperature of approximately 95°F, compared to 135°F for a fossil fuel heating system. This will heat the house, but will feel cool if it blows directly on the customer. Re-positioning furniture or changing the wall diffuser to a type that delivers air up the wall instead toward the center of the room may help stem this complaint. Some systems slow airflow to provide warmer air to the space. However, this raises the system head pressure and lowers the efficiency of the system.

During the heating season, in the defrost cycle, the outdoor coil warms to melt the frost. When the outdoor fan starts at the end of the defrost cycle, the cold, dry, outside air picks up the warm moisture remaining on the outdoor coil. This results in a short blast of steam blowing into the air for a few seconds. Though this is the normal operation, customers often misinterpret it as an *equipment fire*.

Insufficient airflow is the number one air conditioning problem. In the heating cycle, dirty indoor filters or incorrect filter media (high-density filters which create too much pressure drop) will restrict airflow, raising the air temperature along with the system head pressure. Though increased air temperature may not cause a customer complaint, the decreased airflow probably will. This problem will also lead to compressor failure.

If the *system runs too long in cooling*, test the refrigeration system capacity. If the system capacity is insufficient, troubleshoot the refrigeration system. If the system refrigeration capacity is sufficient, re-evaluate the airflow side of the system. *Leaking supply-side ductwork* can cause the **loss of conditioned air**, therefore, reducing the quantity of cool air being supplied to the structure. *Leaking return-side ductwork* can bring in **extra hot and humid air**, significantly **increasing the load** on the system and raising the humidity level, therefore, reducing the system's ability to cool the structure.

HEAT PUMP FANS

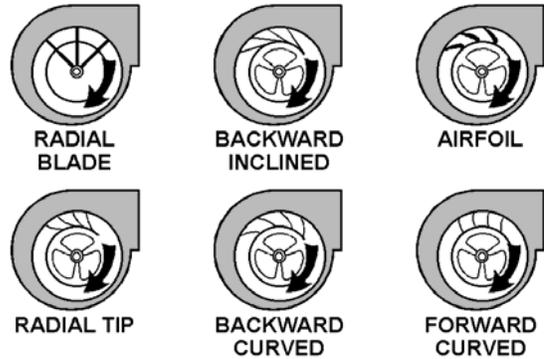


PROPELLER TYPE

CENTRIFUGAL TYPE

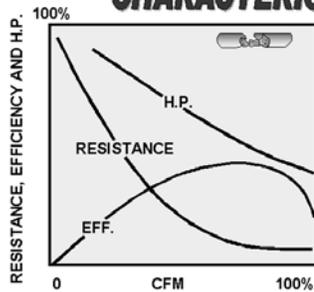
143. The propeller fan and centrifugal fan are the two types of fans used in a residential heat pump.

CENTRIFUGAL FANS



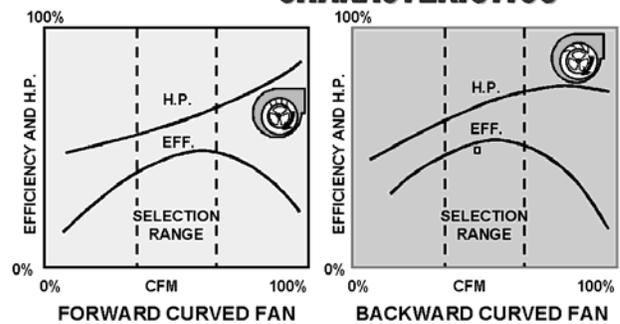
145. The heat pump's indoor fan is a **centrifugal fan** and is generally referred to as a **blower**. The vanes of a centrifugal fan come in several different styles.

PROPELLER FAN CHARACTERISTICS



144. Outdoors, a **propeller type fan** moves large quantities of air across the outdoor coil and is very efficient as long as the resistance is minimal. Dirty outdoor coils not only hurt the mechanical operation of the system, but will also increase the motor amperage, leading to overheating, increased utility bills, and possible motor failure. Dirty, bent, damaged, and improperly positioned fan blades will cause reduced airflow and subsequent refrigeration system problems.

HEAT PUMP FANS CHARACTERISTICS

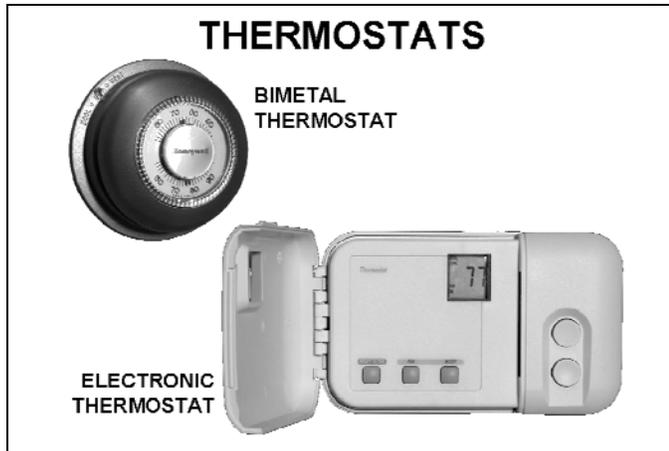


146. *Forward curved* vanes with direct drive motors are used almost exclusively in residential and small commercial size systems because of their efficiency, lower cost, lighter weight and quiet operation. Their design amperage is determined by the volume of air they move. If the indoor coil or filter becomes restricted, the cfm decreases and the motor amps actually decrease. This type of fan can, however, be overloaded. If it is supplied with more air than it is designed to handle, the fan could overheat and burn out the motor in an effort to move the air. Bent or damaged vanes on a fan will certainly result in decreased airflow and can also cause noisy operation, vibration, and increased bearing wear, leading to motor overheating.

As system size increases, the fan styles will change. Above the 10-ton range (no longer residential or light commercial) the system will probably require a non-

overloading **backward-curved vane fan**. It will probably utilize a three-phase motor and may be belt driven. With this type of fan and motor arrangement, belt tension and pulley alignment are very important. Spring gauges are available to check belt tension and a simple “straight-edge” can be used to check a pulley’s parallel and angular alignment.

THERMOSTATS



147. Thermostats are an important part of any air conditioning system and fall into two major categories.

Older thermostats utilize **bimetal** material for temperature sensing and most commonly had mercury bulbs for switches. Most utilized two stages of operation. The first stage closed the contacts, which set the reversing valve in the proper position for the desired mode. The second stage operated the compressor contactor, turning the heat pump on and off. The “O” contact on the sub-base, generally connected by an “orange” wire, was the signal that controlled the reversing valve.

Newer **electronic thermostats** utilize thermistor devices for temperature sensing. They provide more accurate control than the older electro-mechanical devices and offer many features not previously possible. Electronic thermostats can contain electronic clocks allowing them to be programmed for more daily and weekly functions. They can include automatic recovery or adaptive logic functions, which will start the heat pump earlier than the programmed setup time to allow the slow recovering heat pump to warm the space to the desired temperature by the thermostat’s programmed setup time.

New “dual fuel” thermostats can replace the old “optimizer” controls. This feature switches from heat pump heating to an alternate heat source such as a gas furnace at a predetermined outdoor temperature where the heat pump becomes less efficient than the furnace.

Electronic thermostats, in conjunction with electronically-commutated fan motors can offer several blower speeds. Where the highest fan speed is usually utilized for both the cooling and heating function of a heat pump, a somewhat lower speed is often utilized when electric heat is used by itself, such as in the “Emergency Heat” function. The “Continuous Fan” function can be set at any speed for specific functions like electronic air cleaner operation.

Some electronic thermostats have humidity sensing capability and can control both the humidification and de-humidification functions of the system.

THERMOSTAT

DO’s

- **Locate near a return air grill**
- **Locate on an inside wall**
- **Locate at approximately eye level (about 50 inches from the floor)**
- **Seal wall hole where wiring enters sub-base to eliminate cold drafts**
- **Level thermostat for appearance and for accurate control (mercury bulb)**

148. Proper thermostat installation is very important. Thermostats should be located on an inside wall, near a return air grill, approximately at eye level (about 50 inches above floor). Wall holes where wiring enters the sub-base should be sealed to eliminate cold drafts. Thermostats should be leveled both for appearance and for accurate temperature control if it is a mercury-bulb type unit.

THERMOSTAT

DON'T'S

- Locate near a supply air register
- Locate near a source of heat or humidity (stove, TV, humidifier, etc.)
- Locate on an outside or air conditioned wall
- Locate near a door or anything that could cause the wall to shake or vibrate
- Expose to direct or reflected sunlight

149. Improper location of the thermostat can cause it to either malfunction or function inefficiently. Do not locate a thermostat near a supply air register or near sources of heat or humidity (stove, lights, appliances, bathrooms, sinks, humidifiers, etc.). **DO NOT** locate a thermostat on an outside or unconditioned wall or near a doorway. Keep thermostats away from anything that would cause the wall to shake or vibrate or where it would be exposed to direct or reflected sunlight.

EXTRA CIRCUITS UNIQUE TO HEAT PUMPS

R to outdoor defrost board

C to thermostat for lights

E from defrost board for electric heat during defrost

151. The thermostat control wiring in heat pumps may have some unique requirements. The red thermostat wire (24 volt power) must be run to the outdoor unit to power the defrost circuit. The brown (24 volt common) wire may need to be run to the thermostat to provide a complete circuit in the thermostat for thermostat board circuits and lights. An extra wire on the "E" terminals of the outdoor defrost board and the air handler may be needed to activate the backup heat during the defrost cycle.

THERMOSTAT WIRES

RED	24 volt power
GREEN *	Fan
YELLOW	Cooling
WHITE **	Heating
ORANGE	Reversing Valve (heat pumps)
BROWN	Common

* In higher voltage circuits the green wire is used for GROUND

** In higher voltage circuits the white wire is used as the NEUTRAL wire and the black wire is the HOT wire

150. Thermostat wires are color-coded. The colors and functions agreed upon by most manufacturers and contractors are shown above

NOTE 1: In higher voltage circuits the green wire is used for "Ground."

NOTE 2: In higher voltage circuits the white wire is used as the "Neutral" wire and the black wire is the "hot" wire.



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