HEAT PUMPS

Operation • Installation • Service

Randy F. Petit, Sr.

Turner L. Collins

esco press

HEAT PUMPS

Operation • Installation • Service

Randy F. Petit, Sr.

Turner L. Collins

Copyright ESCO Press

esco press
Mount Prospect, Illinois

Copyright © 2011
Esco Press

All rights reserved. Except as permitted under The United States Copyright Act of 1976, no part of this publication may be reproduced or distributed In any form or means, or stored in a database or retrieval system, without the prior written permission of the publisher, ESCO Press.

ISBN 1-930044-29-1

This book was written as a general guide. The authors and publisher have neither liability nor can they be responsible to any person or entity for any misunderstanding, misuse, or misapplication that would cause loss or damage of any kind, including loss of rights, material, or personal injury, alleged to be caused directly or indirectly by the information contained in this book.

Printed in the United States of America
7 6 5 4 3 2 1

Copyright ESCO Press

Table of Contents

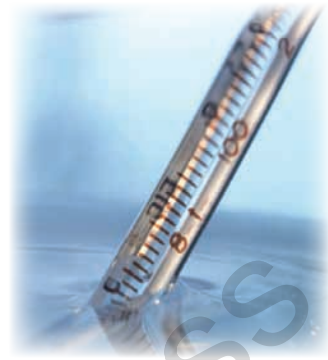
Copyright ESCO Press

Section 1: Basic Principles of Operation

Objectives

Upon completion of this section, the participant will be able to:

1. understand the history of heat pumps;
2. explain basic refrigeration terms and concepts;
3. identify the characteristics of different heat pump systems;
4. compare the three heat pump cycles/modes (cooling, heating and defrost).



A Brief Heat Pump History

When heat pumps were introduced in the 1950s, very little training was provided for their installation and service. The first generation of heat pumps also had some design problems that increased their failure rate as compared to air cooling only systems. Customers were not satisfied with the benefits of heat pumps versus their high cost and poor operation, so heat pumps failed to become a vital part of the market.

Heat pumps were reintroduced during the energy shortage of the early 1970s. Manufacturers realized many improvements would have to be made before heat pumps could compete with conventional heating and cooling systems. Training became a top priority for air conditioning companies. Through training, technicians and installers gained a working knowledge of how to calculate heating and cooling loads, properly install air ducting and system components, and, just as importantly, maintain and service these systems.

Many remarkable improvements have been made since that time. Seasonal Energy Efficiency Ratio (SEER) ratings have been raised from around 7 to 14 and higher. Modern compressors are now much more dependable and efficient, with longer warranties available. Fan and blower motors provide variable speed control. With these vast improvements, service and maintenance problems have been greatly reduced.

Due to the adverse effects of the chlorine contained in many common refrigerants, heat pump manufacturers are now using more environmentally friendly refrigerants, such as hydrofluorocarbons (HFCs). Today's technicians must learn the characteristics of these refrigerants and the correct procedures for their use. The industry is constantly evolving and exploring new ways to develop more efficient and economical heat pumps. Modern heat pumps are reliable, functional and can truly be considered an asset to any home or business.

Basic Refrigeration Overview

Temperature

Temperature is most commonly thought of as the measurement of heat, however, temperature is actually the speed of the motion of molecules in a substance. The lowest possible temperature, -460°F, is called absolute zero. At absolute zero, all molecular motion ceases and all heat has been removed.

Temperature tells us how hot something is but not how much heat it contains. For example, if two containers, one containing one gallon of water and the other containing ten gallons of water, are placed over identical heat sources, the temperature in the one-gallon container will rise faster than the temperature in the ten-gallon container. Ten times the heat energy must be added to the larger container in order to heat the water in both containers to an equal temperature.

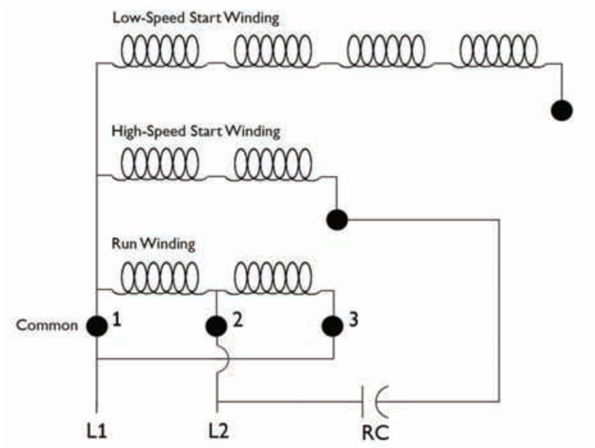
Measuring Temperature

Temperature is measured with a thermometer. Thermometers may be graduated in one of four different scales: Fahrenheit and Rankine are used in the United States, Celsius (Centigrade) and Kelvin are used in the metric system. On the Fahrenheit scale water freezes at 32°F and boils at 212°F. On the Celsius scale water freezes at 0°C and boils at 100°C.

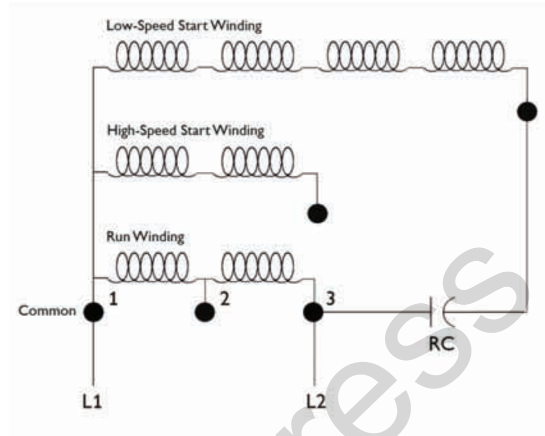
For scientific calculations, absolute temperature scales without negative numbers must be used. On the Rankine scale, absolute zero is 0°R. The freezing point of water is calculated as 492°R (32°F + 460) and the boiling point of water is calculated as 672°R (212°F + 460).

On the Kelvin scale, absolute zero is 0°K. The freezing point of water is 273°K and the boiling point of water is calculated as 373°K(100°C + 273). The Kelvin scale is also called Celsius Absolute (CA).

Copyright ESCO Press



Two-Speed Compressor in High-Speed Operation



Two-Speed Compressor in Low-Speed Operation

Fan motor mounting methods:

1. four studs holding the motor together
2. flange mount
3. frame mount
4. resilient mount

The most important part of the motor is the *Name Plate.*

The **name plate** tells horsepower, RPM, specified voltage, phase and Hertz, amperage draw, frame number, duty rating, type, thermal protection type, wiring information, lubrication (if needed) and motor rotation.

The Indoor Blower Motor

Air handler blower motors are usually Permanent Split Capacitor or variable speed which varies speed to meet manufacturer CFM requirement.

The Permanent Split Capacitor motor has two major parts: STATOR and ROTOR.

The Stator is the stationary part which houses the motor windings and stacked laminations.

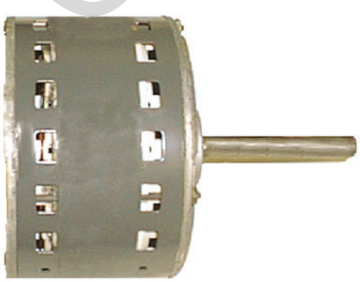
The Rotor consists of the shaft, rotor core and an internal fan for cooling the motor.

End Bells are the end covers housing the bearings. The bearings must hold the rotor in the exact center position inside the stator.

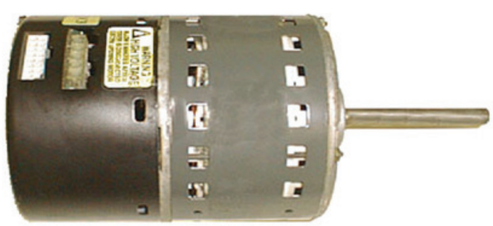
The variable speed motor or Electronically Commutated Motor (ECM) has factory preset speeds inserted into its digital logic control board and dip switches (or jumpers) for speed or CFM selection.

4-way/Reversing Valve

The four-way (or reversing) valve directs flow of refrigerant to either the indoor or the outdoor coil. An electrically operated pilot valve controls pressure on each side of the main slide valve (pilot valve may have 3 or 4 connections). There must be a minimum pressure difference of 75 PSI between the low and high sides to make the main slide valve move. Under normal operating conditions, only refrigerant vapor flows through the reversing valve. The refrigerant lines in the center of the valve connect to the compressor. The smaller line, located in the middle of the four-way valve, connects to the compressor discharge line. The larger center line of the three on the other side of the four-way valve connects to the inlet side of the suction accumulator (if used), or to the compressor suction line. The function of the two lines never changes. The two outside lines connect to the indoor and outdoor coils. Which line connects to the outdoor coil is determined by whether the valve is energized in cooling or heating mode. The two outside lines alternate from hot discharge vapor to cool suction vapor depending on mode of operation.



Indoor Blower Motor



Variable-Speed Indoor Blower Motor

Four-Way Reversing Valve

Copyright ESCO Press

When calculating air flow for a supply or return air grille, use the net free area of the grille not the dimensions of the grille. The net free area of a grille is the actual open space for the air to pass between the louvers. A return air filter grille has an average of 85% net free area.

Motor Speed	External Static Pressure				
	0.1	0.2	0.3	0.4	0.5
High	1,352	1,318	1,260	1,202	1,128
Medium	1,214	1,172	1,123	1,064	1,012
Medium-Low	997	994	960	923	884
Low	757	753	734	704	674

Example:

A 24 inch **x** 24 inch return-air grille has 576 square inches of total area.

576 square inches **x** 0.85 = 490 square inches of net free area

490 square inches ÷ 144 = 3.4 square feet

3.4 square feet would be considered the AK factor of the grille.

Another method is to use the blower performance chart supplied by the manufacturer of the equipment. By using an electronic or inclined manometer, the pressure drop or total static pressure across the indoor air handler can be determined. By plotting the static pressure and blower motor speed tap on the blower performance chart, the approximate CFM can be calculated.

Blower Performance

CFM: Temperature Rise Method with Electric Strip Heat

When using the temperature rise method, run the system until it stabilizes. A heat sequencer can take a few minutes to energize all the elements. When running on emergency heat, set the fan to the "on" position to insure the blower is running at the speed used for normal heat pump operation. The blower speed for emergency heating may be less than that used during normal heat pump operation.

NOTE: This method indicates the approximate CFM for field service. It is not as accurate as using meters designed to measure air flow (such as the air flow hood).

There are five steps for calculating the CFM:

1. Place the fan switch to the on position and the system switch to emergency heat, with the temperature setting high enough to keep the electric heat on.
2. Measure the line voltage and the total amperage draw of the indoor electric heat system to the nearest tenth of a volt and the nearest amp.
3. Measure the average temperature split across the indoor air handler (supply air temperature minus return air temperature).
4. Apply the formula: **Volts x Amperage x 3.14 = Btu**
5. Apply the formula: **Btu** (from step 4) ÷ **1.08** ÷ **ΔT** (TD from step 3) = **CFM**

Example:

230.4 volts **x** 44.8 amps **x** 3.14 Btu/watt = 32411 Btu
32411 Btu ÷1.08 ÷ 25˚F ΔT = 1200 CFM

CFM: Temperature Rise Method with Dual-Fuel Heating

The temperature rise method can also be used to calculate the approximate CFM of a fossil fuel furnace. It is important to remember that the input Btu rating should *not* be used; use the net or bonnet capacity in the calculations. The furnace must be set for proper combustion efficiency in order for this method to work. Allow the system to run until it stabilizes. Set the fan to the on position to insure the blower is running at the speed used for normal heat pump operation.

NOTE: This method indicates the approximate CFM for field service. It is not as accurate as using meters designed to measure air flow (such as the air flow hood).

1. Place the fan switch to the on position and the system switch to "emergency heat", with the temperature setting high enough to keep the furnace on.
2. Measure the average temperature split across the furnace (supply air temperature minus return air temperature). Apply the formula: **Net Btu ÷ 1.08 ÷ ΔT = CFM**

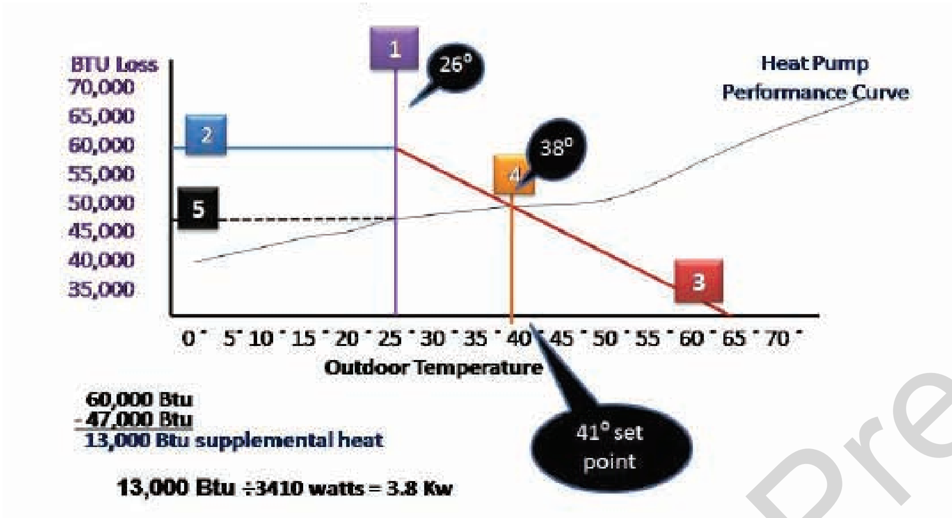
Outdoor System Air Flow

The air flow across the outdoor coil varies depending on the manufacturer and model. Some manufacturers build a system with a small footprint moving a lot of air, or a large footprint moving little air. A system with a 650 RPM fan does not make as much noise as a motor running at 1075 RPM.

The CFM for a condensing unit can be acquired from the manufacturer, and can be used to calculate total BTU removed while operating in the cooling mode.

The outdoor design fan speed and CFM are determined by the manufacturer. The fan speed may be controlled by an outdoor thermostat, pressure switch, or electronic speed control. In either case, the CFM must be known to calculate the net BTU capacity while operating in the cooling mode.

Copyright ESCO Press



Example Balance Point Calculation

this example, the 60,000 BTU structure heat loss minus 47,000 BTU output of the heat pump equals 13,000 BTU.

13,000 BTU is the supplemental heat required to satisfy heat loss for at design temperature. In this example, 39˚F is the actual balance point. The outdoor thermostat should be set three degrees higher or at 41˚. This allows the supplemental heat to be energized, providing enough additional heat to allow the system to cycle off.

To calculate the kilowatts of heat needed, use the following formula:

Btu ÷ watts = Kw

So: 13,000 Btu ÷ 3,413 watts = 3.8 Kw

Outdoor Thermostats

The outdoor thermostat (ODT) senses outdoor ambient air temperature and is set to close its contacts three degrees above calculated balance point. When the ODT senses temperature below the calculated balance point, the contacts close allowing the heat strips to be energized if the room thermostat 2nd stage is calling for heat. This provides supplemental heat in addition to the heat pump, and prevents the unit from running continuously during cold ambient conditions. Eventually, as the outdoor temperature rises above the ODT set point, the ODT contacts open, returning the system to heat pump operation only.

Outdoor thermostats can be used to energize multiple stages of heat. Setting multiple ODTs for lower temperatures can keep the strip heat off until predetermined temperatures are reached.

Outdoor thermostats are valuable to keep strip heaters off when not necessary thus helping to maintain a higher efficiency. If the occupant turns the room thermostat up more than two degrees higher than actual room temperature, the 2nd stage bulb tries to bring on all the electric strip heaters if the system does not have an ODT.

Strip heaters can be controlled by an ODT for each stage or bank of heaters. If the outdoor temperature is above the ODT setting, the room thermostats' 2nd stage bulb cannot bring all of the strip heaters on at one time. Just the strip heaters the ODT allows can operate as shown below.

Calculating Multiple Outdoor Thermostat Settings

1. **Outdoor design temperature line (Btu heat loss line from the structure Heat Loss Study)**

2. **Line from 65°F to intersection of outdoor design and structure heat loss intersection**
(*Note*: 65°F is considered the temperature at which there should be no need for heating or cooling.)

3. **First stage heat capacity line (17,070 Btu of heat for the first 5 Kw heat strip)**
The vertical line intersecting lines 3 and 4 indicates the lowest temperature at which the first stage heat is able to maintain the heating capacity. The first ODT is set to 57°F (three degrees warmer), which allows the next stage of heat to be energized. (*Note*: This line is drawn from the total Btu capacity of heat energized by the first stage thermostat.)

4. **Second stage heat capacity line (drawn from 34,140 Btu of total heat from strips 1 and 2).** The vertical line intersecting line 3 and 5 indicates the lowest temperature at which the 1st & 2nd stages of heat are able to maintain the heating. The 2nd ODT would be set to 43˚F (three degrees warmer) allowing the last stage of heat to be energized.

Copyright Esco Press

Objectives

Upon completion of this section, the participant will be able to:

1. identify the indoor system components
2. identify outdoor system components
3. identify components and the sequence of operation from a heat pump ladder diagram

Indoor Components

The main control for the system is the indoor thermostat. As shown in previous sections, the thermostat can be either mercury bulb or solid state digital type. The thermostat is normally wired with color coded wiring, and operates on low voltage (24VAC). The wiring size should be 18-gauge, unless the local codes prevail. It should be mounted 52" above the floor, near the main return and on an interior wall (not on an outside wall or by the structure's entrance/exit). The thermostat controls the room temperature, the system mode of operation: heat, cool, or emergency heat, and the indoor blower. A switch controls the blower fan motor. When in the ON position, the blower runs continuously and in the AUTO position, the fan cycles with demand for cooling or heating.

Another important feature of this thermostat is the "Emergency Heat Mode". When the system switch is moved to the Emergency Heat position, the thermostat does not make a circuit to the contactor bringing on the compressor and outdoor fan motor. Instead, the thermostat brings on the 2nd stage of heat to keep the structure warm. The indoor fan motor may run at a slower speed while the system in Emergency Heat mode, unless the fan switch is ON.

Most indoor thermostats have a subbase mounted on the wall before the control-section is attached. The subbase has terminals for the low-voltage control wiring. The color-coded low voltage wires are connected to the proper terminals on the subbase. It is very important the opening around the low voltage cable entrance is sealed with a filler material. Cold or warm air can pass through the wall opening and cause the thermostat to function at the wrong temperatures.

These color codes and terminal identifications are used by many heat pump and thermostat manufacturers:

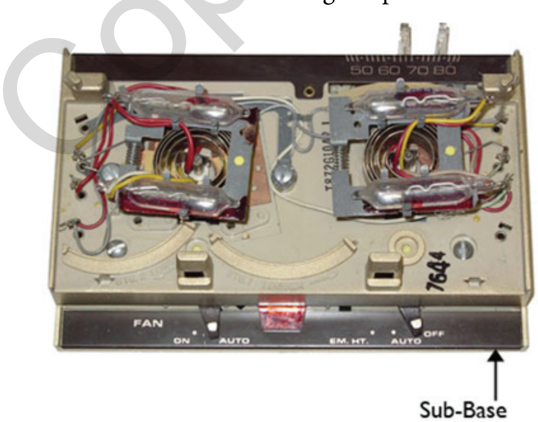
Red to R (24V feed),
Green to G (Fan)
Orange to O (Reversing valve)
White to W1 (Heat, 2nd)
Brown to W2 (Heat, 3rd) optional
Yellow to Y (Contactor)
Blue to C (24V Common)
Black to E or X2 (Emergency heat for some heat pumps)

Transformers reduce line voltage to 24 volts for control operation. Low voltage controls are easier to wire and easier to manufacture.

Transformers are rated in Volts X Amperes (VA). Some older systems used two 20VA transformers, one in the indoor unit and one in the outdoor unit. Most equipment manufactured today have only one 40 to 50VA transformer in the indoor unit which provides low voltage for both indoor and outdoor sections. This simplifies the wiring, making it easier to troubleshoot and service.

The indoor blower normally has a multi-speed PSC motor. The motor runs at speeds selected during installation.

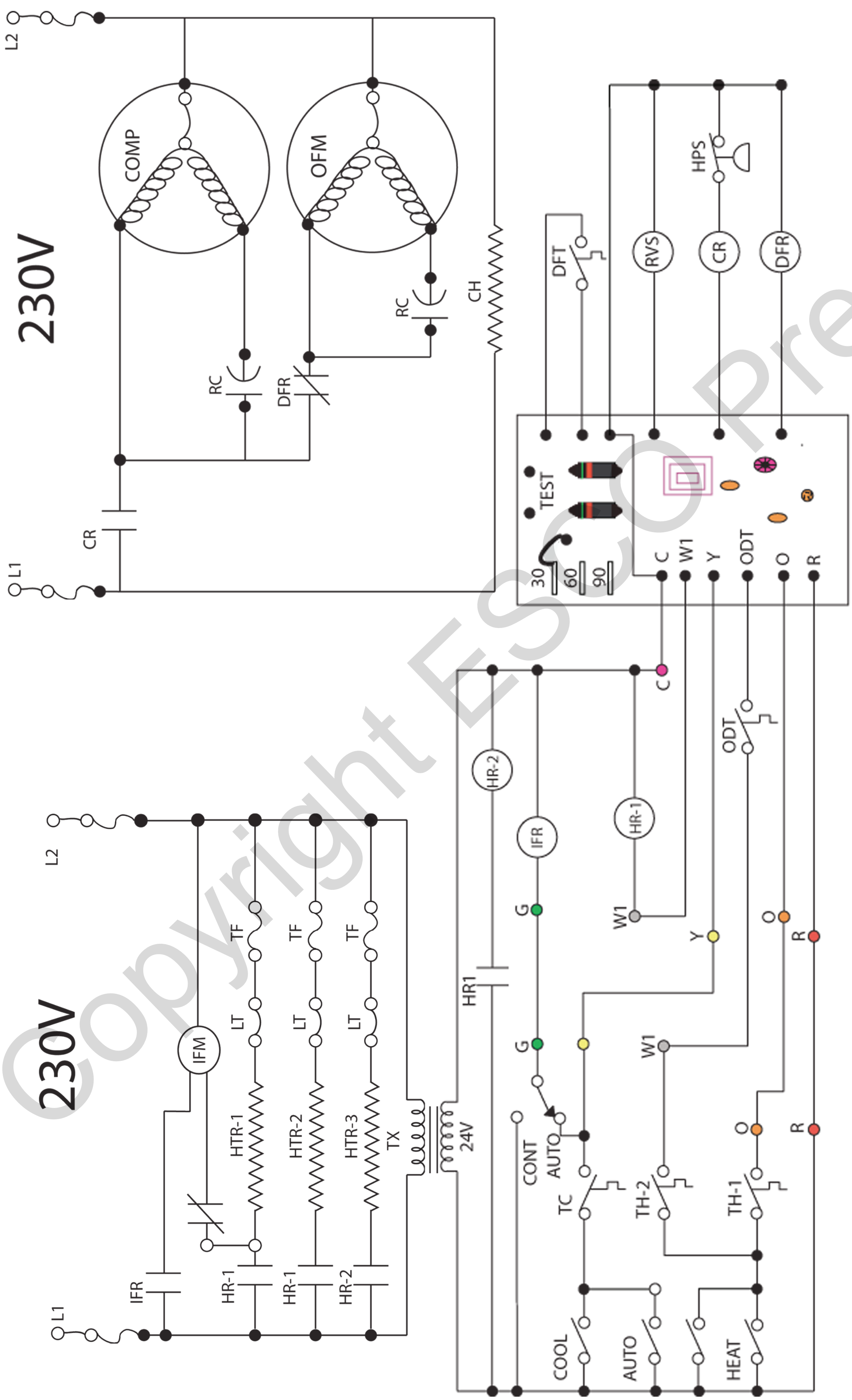
Electronically Commutated Motors (ECMs) are often used in high efficiency indoor systems instead of PSC. This motor can vary speed to match airflow requirements of the structure or mode of operation. This motor has been explained in earlier sections.



Indoor Thermostat Sub-Base

Indoor Thermostat

Copyright ESCO Press



DFT-Defrost Thermostat
OFM-Outdoor Fan Motor
TH-1-1st Stage Heat
TH-2-2nd Stage Heat
TC-Cooling Stage

HP-High Pressure Switch
CR-Compressor Contactor
IFR-Indoor Fan Relay
IFM-Indoor Fan Motor
DFR-Defrost Relay

TX-Transformer
LT-Limit Thermostat
TF-Thermo-Fuse
RC-Run Capacitor
DFC-Defrost Control

HR 1 & 2-Heat Sequencers
RVS-Reversing Valve Solenoid
HTR 1,2 & 3-Heating Elements
ODT-Outdoor Thermostat
CH-Crankcase Heater

Copyright ESCO Press

Section 8: Refrgerant Piping

Pipe sizing is one of the most important parts of an installation in today's high-efficiency equipment. With the advancement of dual capacity or variable speed compressors, velocity changes dramatically. The system may need to be designed with a higher pressure drop to ensure oil return at lower capacities. It may be necessary to use double risers and traps in the suction line for installations with a long vertical rise.

Refrigerant Pipe Installation and Insulation

There are multiple reasons to insulate the refrigerant vapor line. During the cooling cycle, the vapor line must be insulated to prevent condensation and increase in super heat. During heating cycles, insulation prevents a system capacity loss.

Always insulate the vapor line from the outdoor unit to the indoor coil with 1/2" to 3/4" thick closed cell foam insulation. Local codes may dictate the minimum thickness or "R" value for vapor line insulation. Beyond code requirements, insulation needs are determined by temperatures and conditions around the refrigerant lines. When the air handler is installed in an attic, capacity is improved by insulating the section of liquid line in the attic. The suction line and liquid line can gain superheat if exposed to attic high temperatures.

Secure the line set according to local codes to prevent vibrations, and make sure the horizontal runs are sloped toward the compressor to enhance the oil flow. An easy way to remember the function of the lines while in the heating or cooling mode:

The SMALL LINE is always the LIQUID LINE and is always at HIGH pressure.

The LARGE LINE is always the VAPOR LINE, but is NOT always at low pressure.

CAUTION:
The large line contains low-pressure vapor during the cooling and defrost cycles and high-pressure vapor during the heating cycle.

Many technicians learned this the hard way. Connecting the compound gauge (Blue) to the large vapor line in cooling mode, when the system is changed to heating mode, the large vapor line instantly fills with high pressure vapor. The sudden surge of high pressure usually damages the compound gauge and it has to be replaced. Manufacturers usually have a schrader valve connected to compressor suction for service access.

Copyright Esco Press

End of Section Review Questions

1. The pressure drop in the vapor line should equal less than a __________ °F change in temperature.

2. Liquid lines are affected by __________ and __________.

3. What may occur if the liquid line is too small?

4. The __________ line is always the __________ line and is always at __________ pressure.

5. The __________ line is always the __________ line, but is NOT always at low pressure.

Objectives

Upon completion of this section, the participant will be able to:

1. identify basic indoor and outdoor installation requirements

Indoor Systems - Key Points

The indoor section of a split system heat pump can be located in different places depending on the structure and suitable areas available. Air handlers may be in an attic, crawl space, indoor closet, garage or basement. They may be mounted horizontally or vertically.

Some basic installation requirements include:

- Install the air handler in a central location providing required clearances for operation and service.
- The air handler should be placed in a location that will keep the duct runs as short as possible to insure proper airflow and reduce costs.
- The strength of structural members must be adequate to hold equipment.
- Seal all return and supply air duct connections to prevent air leakage in or out of the system.
- Level the system to allow for proper condensate drainage.
- Install an auxiliary drain pan under the air handler if mounted in an attic to prevent water damage to the ceiling in case of a blocked drain. The auxiliary drain pan must have drain piping to outdoors.
- The air handler condensate drain piping must have a trap if located on the negative pressure side of the indoor coil. The drain line must drop two to three inches before entering the trap on a residential unit, and four inches on a commercial unit.
- Follow the manufacturer's installation instructions and all local codes.

Installations and Special Instructions

Horizontal air handlers are commonly used in attic crawl spaces when houses are built on a concrete slab. Locate the air handler to provide easy access to the indoor blower, auxiliary heaters and wiring. Install an auxiliary drain pan with a drainpipe to outdoors. Mount the air handler on proper mounting pads to absorb noise and vibration.

Horizontal air handlers can be mounted in a crawl space or basement by attaching to the floor joists using threaded piping and angle iron. For safety, most codes require a clear service access of 30" in front of the unit. If the basement floor does not have a drain, install a Condensate Pump to remove the condensate.

Remember:

- In humid summer months, gallons of condensate are extracted from the air inside the structure. Condensate can be routed to a dry well outside the structure. A dry well consists of a hole that has been dug in the ground, with sand and gravel inside.
- Vertically mounted air handlers are very versatile; follow the previous instructions given for drains and drain piping.
- *Service access* must always be considered, regardless of location, and all vibration and fan motor noises can be prevented by installing isolation pads.
- With increased use of HFC refrigerants and ester-based oils, it is more important than ever to use nitrogen when brazing refrigerant lines to prevent contamination. Nitrogen prevents oxidation when brazing and helps purge moisture from the system.
- Nitrogen and a trace amount of the appropriate refrigerant should be used to leak test the tubing connections.

SAFETY NOTE:
When HFCs or CFCs are exposed to an open flame, phosgene gas is a bi-product. The technician must avoid breathing or burning these extremely toxic fumes. The technician's exposure to this toxin can be minimized by using nitrogen during the brazing process.

Outdoor Systems - Key Points

Provide proper clearances from the structure.
Install above the normal snow line.
Install level to provide for defrost water runoff.
Install the unit away from prevailing winds.

Before the outdoor unit is installed, consider these important factors:

- **Wiring:** Where the power supply will be located, what size wiring will be needed, and the fuse/breaker size. Follow NEC guidelines for proper wiring sizes and requirements.
- **Noise:** The unit should be located so that noise will not be a problem, preferably at the side or back of the structure, although in some instances the front of the structure may be used. The unit may also be located on the rooftop in structures like apartment complexes.
- Ductwork: If the system is a package unit, the ductwork must connect to the unit. Consider potential conflict between ductwork and existing piping and drains.

Copyright ESCO Press

Objectives

Upon completion of this section, the participant will be able to:

1. describe the minimum requirements for system evacuation
2. list the steps in the triple evacuation method
3. understand the three charging methods; weight, superheat and subcooling

Evacuation

In the past, problems caused by poor evacuation techniques did not show up until sometime after the equipment was installed—usually after the compressor's warranty had expired. With industry's transition to HFC refrigerants and ester-based oils, it is detrimental to the equipment if proper installation techniques are not used. Air and moisture in these systems will cause major problems to develop much faster than equipment using other types of oils and refrigerants.

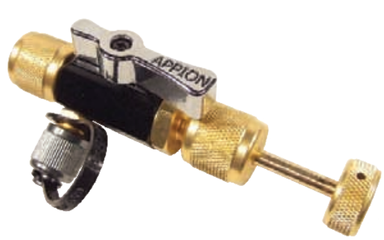
Ester-based oils absorb large amounts of moisture compared to other commonly used oils. This extra absorption can create more problems with the operation of heat pumps, especially in very cold climates. The only means of removing moisture from ester-based oils is by chemical reaction—using a liquid line filter drier.

When performing an evacuation, the best course of action is to install any refrigeration system to industry standards, using the proper tools and techniques for installation.

The following guide can be considered a **minimum** requirement:

1. Remove access valve cores with a core replacement tool.
2. Use a four-valve manifold gauge set with a 3/8- or 1/2-inch vacuum line.
3. Triple evacuate with a two-stage vacuum pump and use nitrogen to break the vacuum.
4. Use a micron gauge to evacuate the system to 500 microns.

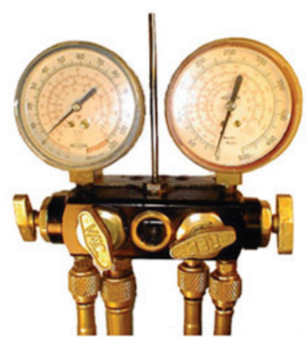
Micron Gauge



Valve Core Removal Tool

Performed properly, the triple evacuation method provides the same result as pulling a vacuum for twenty-four hours. The following steps should be used for triple evacuation:

1. Connect the manifold gauge set to the low and high side service valves.
2. Introduce nitrogen into the system until the pressure increases to 125 psig and check for leaks. Repair any leaks and recheck before proceeding.
3. Remove the nitrogen from the system: connect the micron gauge and vacuum pump.
4. Operate the vacuum pump, pulling from both the low and high side service valves until the micron gauge measures 1,500 microns.
5. Close the valve to the vacuum pump and reintroduce nitrogen into the system to a pressure of 1 or 2 psig.
6. After five minutes, bleed off the nitrogen pressure and pull the second vacuum until the micron gauge measures 1,500 microns.
7. Repeat step number 5.
8. After five minutes, bleed the nitrogen pressure and pull the third vacuum until the micron gauge measures 500 microns.



R-22 Manifold Gauge Set

Two-Stage Vacuum Pump

Charging

Weight method is the most accurate for any system. The installation instructions indicate the correct charge for the system and how much to add per foot of field installed line set.

System superheat is used for charging capillary tube or fixed orifice systems above 65°F outdoor temperature. This method cannot be used for charging a system that has a TEV metering device.

Copyright ESCO Press

Subcooling is used for charging a TEV system.

NOTE: Some systems will use both types of metering devices—a TEV for cooling and a fixed orifice for heating. Do not assume which is being used; always check the system and find out.

Weight Method

The amount of refrigerant for each component must be added together when installing a split system to determine the total and correct charge.

Outdoor Unit + Indoor Coil + Line Set + Accessories = Total Charge

The amount of refrigerant per foot of line set listed below can be used when the manufacturer's chart is not available.

R-22:
5/16" OD LIQUID LINE - 3/4" suction = .46 oz. per foot
3/8" OD LIQUID LINE - 3/4" suction = .68 oz. per foot
3/8" OD LIQUID LINE - 7/8" suction = .70 oz. per foot

R-410a:
5/16" OD LIQUID LINE - 3/4" suction = .36 oz. per foot
3/8" OD LIQUID LINE - 3/4" suction = .55 to .62 oz. per foot
3/8" OD LIQUID LINE - 7/8" suction = .55 to .62 oz. per foot

New systems usually have enough refrigerant for the indoor unit, outdoor unit, and either a fifteen- or twenty-five-foot line set. With longer line sets, the amount of refrigerant must be calculated to insure that the charge is within one ounce (above or below). Check installation instructions; each manufacturer's requirements are different.

When using filter driers, the following chart can be used to approximate the amount of refrigerant to be added for a proper charge.

Dessicant	Ounces of Refrigerant by Weight					
Cubic Inch	R-134a	R-22	R-404	R-407c	R-410a	R-507
3	1.9	1.9	1.6	1.7	1.7	1.6
5	4.9	4.8	3.9	4.2	4.2	4.1
8	6.9	6.8	5.6	6.0	5.9	5.8
16	11.0	10.8	8.9	9.5	9.4	9.3
30	17.6	17.3	14.2	15.2	15.1	14.9
41	24.7	24.3	19.9	21.4	21.1	20.9

System Superheat Method

System superheat is refrigerant temperature measured from the inside of the evaporator to the suction inlet of the compressor. Superheat equals the suction line temperature at the compressor minus the saturated evaporator temperature

Refrigerant Charging Scale

(from PT chart). The required superheat is determined by indoor wet-bulb and outdoor dry-bulb temperatures. Superheat can be as low as 5°F or as high as 40°F, depending upon ambient conditions. System superheat is used for charging capillary tube or fixed orifice systems operating at outdoor temperatures above 65°F. This method cannot be used for charging a system utilizing a TEV metering device.

NOTE: Some systems will use both types of metering devices—the TXV for cooling and the fixed orifice for heating. Do not assume which is being used; always check the system.

System superheat is used for charging fixed orifice or capillary tube metering devices on the cooling cycle only. The indoor temperature must be near normal (70-80°F) and the outdoor temperature above 70°F. As the outdoor temperature increases, the superheat goes down.

Example: 80°F ambient temperature and 64°F indoor wet-bulb temperature equals 15°F system superheat.

Measuring System Superheat

1. Find the saturated suction temperature (evaporator or suction line pressure changed to temperature, using a pressure/temperature chart).
2. Find the suction line temperature.
3. Suction line temperature minus saturated temperature equals system superheat.

NOTE: Measured superheat should be within 5°F of the required amount.

Subcooling Method

Subcooling is the additional cooling of refrigerant below its condensing temperature; it is the difference between the condensing temperature and the liquid line temperature.

Copyright ESCO Press

Objectives

Upon completion of this section, the participant will be able to:

1. describe checks included in pre-summer preventative maintentance
2. describe checks included in pre-winter preventative maintenance

Maintenance Checks

Heat pumps are usually dependable, working correctly for years; however, scheduled preventative maintenance before the heating and cooling seasons can still prove to be well worth the time and effort involved. Preventative maintenance assures an efficiently running system that reduces energy consumption. Many efficiency robbing problems can occur within a system and may not be noticed by the homeowner. A checklist should be used to insure that every item or function has been tested or checked for potential problems. A record should be made of the current thermostat setting and customer comments before starting any service or maintenance on the equipment. The customer and the technician should have a copy of the checklist, and the service company should keep the list on file for future reference.

Pre-summer preventative maintenance should include:

- Check indoor thermostat function, appearance, and level for operation, and make sure the cover is properly in place. If the thermostat is damaged, replace it with a new one. If it is digital with time set back, check the functions and operation.
- Check the return air grill and air filter. The air filter should be changed or cleaned (if it is a permanent filter) monthly for a residence; commercial systems may require a scheduled maintenance filter change more often.
- Check air vents, diffusers, and registers to insure proper unrestricted airflow. If the airflow is less than required, check the ducts and indoor coil for blockage or restrictions. Airflow can be hampered by loose fan blower belts, dirty coils, blocked vents, blocked ducting, blocked return air grill, or improper installation.
- Check the temperature split (temperature difference between the return and the supply register) after the system has stabilized.
- If the unit is a split system, check the entire blower assembly and fan motor to be sure the blower wheel is tight on the shaft.
- Check and clean the drain, drain pan, and condensate pump. Clean any mold and mildew deposits on or inside the air handler. If the problem is excessive, report it to the homeowner for further cleaning or replacements.
- Check for oil residue on the refrigerant coils and lines; this may indicate a refrigerant leak.
- Visually check the unit's ductwork system for damage and use duct tape or duct sealant on all air leaks and loose insulation.
- Check the outdoor unit for excessive fan noises or vibration, and proper operation.
- Check for loose wiring or damaged low voltage wiring; insulation damage may be caused by things like weed trimmers, or by animals.
- Check fuses or breakers for discoloration; this is caused by loose wiring or high amperes.
- Check the high/low voltage and amperage of system components and compare the readings to the manufacturer's nameplate.
- Make sure the outdoor unit is level and above the normal snow fall level.
- Plants, shrubs, privacy fences and porches or other coverings must not obstruct the outdoor unit's air intake or outlet vent paths.
- All panel screws and fasteners must be in place, or replaced by the technician if missing.
- All service valves must have caps to prevent refrigerant leaks (access valve cores are a secondary seal; the cap is the primary seal).
- If the system is not cooling properly, check the refrigerant charge. This should be done only if the system is not functioning properly. Every time gauges are used, the system loses refrigerant critical to the operation and system performance. If the charge needs to be adjusted, use the manufacturer's charts for exact performance pressures and temperatures for references. Lubricate all ports designed for that purpose.

Pre-winter preventative maintenance should include all the same basic checks, plus the following additional ones:

- The system should be energized in *heating* mode, and the heating cycle should be completely checked.
- Supplemental heaters should be tested or checked by the technician. Some heaters may have problems with open limits or open heat links due to airflow problems and hot spots.
- Check resistance heater wiring for burnt connections, loose terminals, corrosion, and discolored connections.
- Check the current draw of the heating elements (at 230 volts, the current should approximately 4.4 amps per kW).

Copyright ESCO Press

Compressor does not start or run, blows fuses, or kicks the breaker:

This condition is very similar to the previous one, but it has a different cause. A compressor with this problem has a locked rotor condition and will pull the Lock Rotor Amperes as shown on the nameplate. The best way to determine if there is a locked rotor is to go through the same procedures listed in the previous example: check all components, wiring, windings, and capacitors; if the compressor will not start, a locked rotor condition exists and the compressor must be replaced. A locked rotor can be the result of a seized shaft or small chips of copper, slag, or foreign materials inside the compressor bearing.

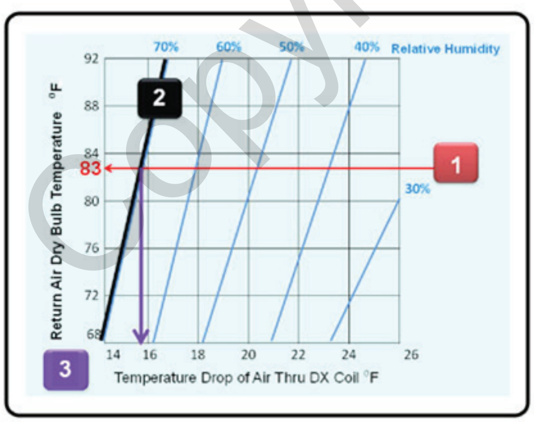
Compressor does not start or run:

When a compressor has an open winding, it may try to start on the remaining closed windings, but will not run. Find the open winding by checking the common terminals to start and run. If the open circuit exists only between the common and the other two terminals, check for an open internal overload. A very warm or hot compressor indicates an open internal overload; the measurements should confirm this diagnosis. However, if the compressor is cold and the open is found in the windings, the compressor must be replaced.

Refrigerant Components

Evaporator Temperature Split Check

The temperature split across the evaporator is a design factor based on the sensible heat ratio and is calculated using the heat load of the structure and the required CFM of air. The system runs with the required temperature split *only at design conditions*. As indoor relative humidity increases, the temperature split decreases. The following chart is used to calculate the temperature split for given conditions.



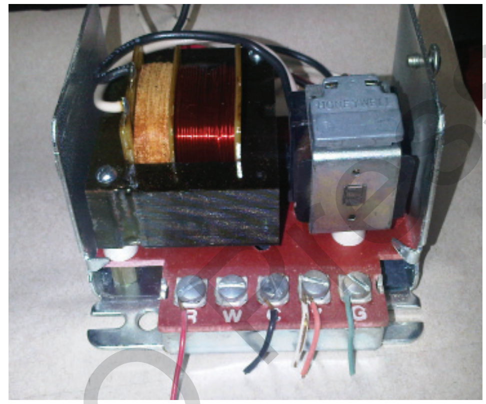
Line 1: Return Air Dry-bulb Temperature

Line 2: Indoor Relative Humidity

Line 3: Temperature Drop Through Evaporator

Electrical Components

The low-voltage controls in a heat pump system consist of many different components. Low voltage is supplied by a step-down transformer. Most heat pumps are either single-phase, 230-volt or three-phase 208/230, 440-volt, as with light commercial equipment.



Step-Down Transformer

Low voltage makes the system's control assembly safer, cheaper, and easier to manage. Almost all heat pump thermostats operate on low voltage, which can be checked safely with an AC voltmeter.

One easy method for checking many heat pump components is to go directly to the indoor thermostat and place the blower fan motor control in the On position. If the system is a split type, the transformer is usually found in the indoor section. If the blower comes on as it should (some are time-delayed) the technician knows there is high and low voltage available and the indoor fan motor is working.

Some manufacturers install a time-delay device in the indoor air handler which turns the indoor blower motor on and off. This device allows the system to come on in the cooling and heating modes, without the blower running, for about a minute. It also delays the blower's Off cycle.

Note: The resistance heating coils cannot come on without the blower running.

If the indoor section is operating properly, the problem is most likely with the outdoor unit.

On a split system, the outdoor section has the following low-voltage components:

Contactor

The contactor turns the compressor and outdoor fan motor on. The contactor has one low-voltage lead directly from the transformer (common) and the other lead is from the "Y" or

Copyright ESCO

Troubleshooting

Diagram 1 on the following page shows the meter reading 120 volts across the contacts. The red lead is connected to the L1 side of the contact and the black lead to the L2 side. The black lead is measuring voltage from L2, *through* the coil or load. With the contact open, the meter is in series with the load and completes the circuit. It measures the voltage because it has high resistance (approximately 20,000 ohms), which creates the largest voltage drop.

If the contacts were closed, the load would be energized and the meter would show a reading of zero volts. The electrons would take the path of least resistance through the contacts, bypassing the voltmeter.

This is only one of the checks that should be done, and it should not be used to determine whether main power to the circuit is off or on. If the load is defective or open, the voltmeter with not measure a voltage across the contact.

Diagram 2 shows the red lead on the line side of the contact and the black lead on the load side, as in Diagram 1. In this case, however, the meter is showing a reading of zero volts. Even though the meter indicates zero voltage, the circuit is energized with 120 volts going to the load. The electrical current is taking the path of least resistance through the contacts, bypassing the meter. If the voltmeter displays any voltage across closed contacts, it means that the contacts are defective or open.

Diagram 3 indicates zero voltage with the contact open. The red lead is connected to the line one side of the contact and the black lead to the load side. The voltmeter cannot measure the voltage due to the burned open spot indicated on the load. The voltmeter is in series with the load, but a complete path cannot be made to the L2 side of the circuit.

Diagram 4 indicates 120 volts with the test leads placed on the L1 and L2 sides of the load. This is the same as checking the power source to the circuit.

Troubleshooting a system that has an electrical problem can be both challenging and rewarding.

- Always remember that *the power may be on*.
- Always use eye protection and follow proper safety procedures.
- Some safety procedures may include keeping one hand in your pocket or away from the equipment at all times. This is to help prevent electrocution.

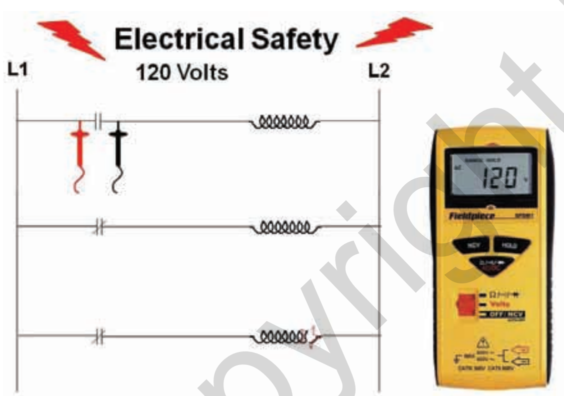


Diagram 1

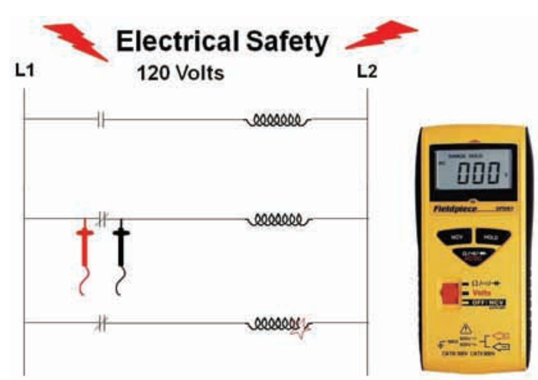


Diagram 2

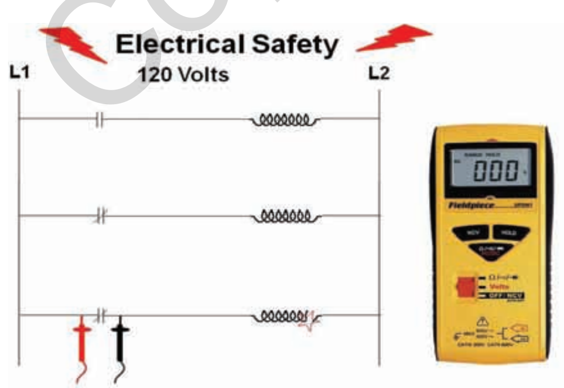


Diagram 3

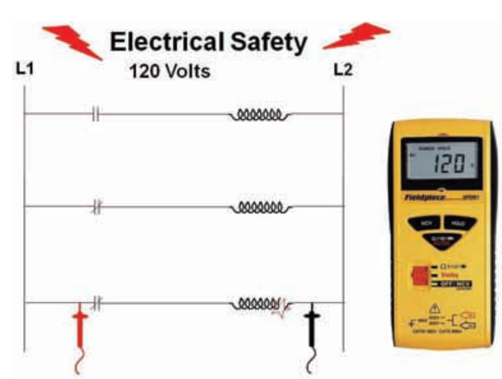


Diagram 4

Copyright ESCO Press

DETERMINE UNIT NET COOLING CAPACITY WORKSHEET

PROCEDURE:

1. **DETERMINE CONDENSER FAN CFM:**
   (From Manufacturer's Literature) __________CFM

2. **MEASURE CONDENSER ENTERING AIR TEMPERATURE:** __________ F.

3. **MEASURE CONDENSER LEAVING AIR TEMPERATURE:** __________F.

4. **SUBTRACT LINE 2 FROM LINE 3 TO OBTAIN TEMPERATURE SPLIT:** __________ ΔT.

5. **MEASURE VOLTS AND TOTAL AMPS AT CONDENSING UNIT THEN MULTIPLY V x A x 3.41 x POWER FACTOR OF UNIT. THE ANSWER IS MOTOR HEAT IN BTUH:** RECORD __________ BTUH

6. **UNIT NETCAPACITY= 1.108 x CFM x DT MINUS MOTOR HEAT (STEP 5):** RECORD ANSWER______________ BTUH
   (Should be ± 2,000 Btuh of system capacity)

Copyright ESCO Press

Outdoor section fan will not operate on Heat or cool

↓

Turn line voltage power off to outdoor system and check for loose or defective wiring

↓

Place system switch to heating with set point 5°F. higher than room temperature or cooling with set point 5°F. lower than room temperature

↓

Turn line voltage power on and measure voltage at the fan terminals or connections

↓

Line voltage measured at the fan motor connections

↓

Fan motor temperature high

↓

Turn off power, disconnect motor wiring and fan capacitor. If motor is hot and resistance measurements indicate an open overload, check the capacitor. A weak or open capacitor will cause the motor to overheat.

↓

Fan motor temperature same as ambient

↓

Turn off power, disconnect motor wiring and fan capacitor. If resistance measurements indicate an open overload or winding, replace the fan motor.

↓

No line voltage measured at the fan motor connections

↓

Check for defective contacts on defrost control board or defrost relay

NOTE: Always check the amperage draw of the fan motor. Ampere should not exceed name plate rating.

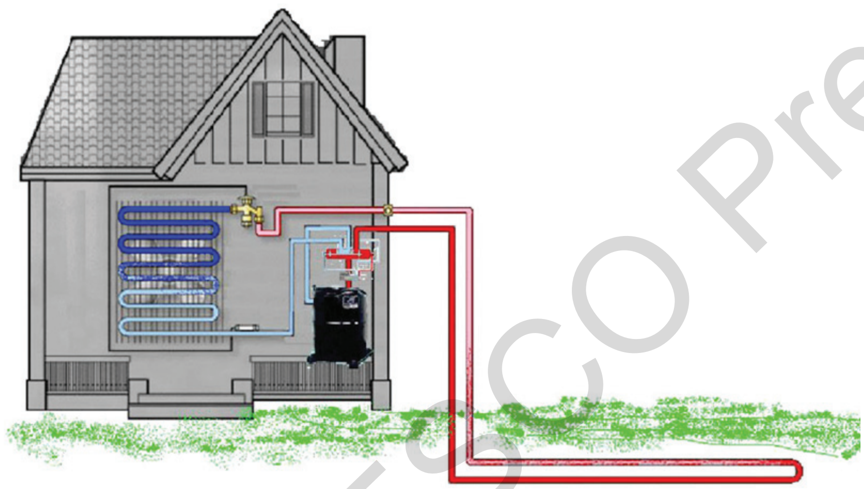
Copyright ESCO Press

Section 14: Geothermal Systems

Objectives

Upon completion of this section, the participant will be able to:

1. describe how a geothermal system operates
2. compare direct geothermal to water source heat pump systems
3. identify various piping options



Direct Exchange

Copyright ESCO Press

Principles of Operation

Geothermal heat pumps have a higher SEER rating than air-source heat pump systems. Using earth as the heat source allows the system to operate at stable temperatures. In northern climates, applications for air-source heat pumps are limited; geothermal or ground-source applications can be used in any climate. As long as the heat exchanger is below the thermal frost line, the ground temperature remains fairly constant.

Water-source heat pumps are package systems with all components housed in one cabinet. The water pump, expansion tank and plastic piping for circulating heat transfer fluid are the only additional components to be installed. The supply and return air duct systems are designed in the same way as any other heating and cooling system.

The control wiring on a water-source heat pump is simpler than on an air-source heat pump. In place of the outdoor coil is a tube-in-a–tube heat exchanger. Unlike in the air-source unit, the coil cannot ice up eliminating the need for a defrost cycle and control, increasing the system efficiency.

The water pump becomes another load which must be accounted for when calculating efficiency; it basically replaces the outdoor fan motor not used on the water-source unit. Many methods are used to create a heat exchange from the heat pump to the earth. One of the simplest is to use water from a lake, pond, river, or stream. Water is pumped from the source to the heat pump's heat exchanger and then to a ditch or back to the source. (When a pond is used, it must have a volume of water equal to or greater than twice the volume of the structure.)

The most common method does not circulate water from the ground but instead uses a glycol solution circulated in a closed loop buried in the ground, in a well hole or pond. The least common method is to bury the refrigerant line in the ground. The first systems to employ this method had problems with oil return to the compressor. Advancements in types of refrigerant lines and heat transfer grouts have reduced oil return problems making the use of this type heat pump more common.

Some models have energy efficiency options such as a heat exchanger that is used to produce domestic hot water. Some systems heat the water when the unit is running in the heating or cooling mode only; others have controls that run the heat pump only as needed to heat the water.

This book is designed to provide the reader with a comprehensive overview of the heat pump system, its operations and principles. It should be noted that the heat pumps covered in this book are basic systems. The intent of the book is to offer technicians information to build upon, in order to enhance their knowledge of the air conditioning and heating field, and more specifically, heat pumps. Before installing or servicing a heat pump system, the technician must have proper training and knowledge of air conditioning/refrigeration theory, principles and operation.

With today's energy demands and costs soaring, there is a tremendous need for highly efficient equipment, and trained technicians that can install, service and maintain this equipment. New heat pump systems using HFC refrigerant (R-410A) are being sold and installed. These systems pose new demands for installers and service technicians. A heat pump's efficiency can be greatly diminished, regardless of the type of refrigerant, if it is not properly installed, serviced and maintained.

This book covers problems and provides solutions to refrigerant charging, indoor airflow calculations, and methods of preventing unnecessary heat pump malfunctions.

Visit www.escogroup.org today to find out more!

ISBN 1-930044-29-1

Copyright ESCO Press