23 Residential Split Air-Conditioning Systems

LEARNING OUTCOMES

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23.2 Comfort Cooling Controls

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23.3 Central Air-Conditioning Systems

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TECHNICAL TERMS

access valve lock
biocide tablet
blank-off plate
central air-conditioning system
DIP switches
ductless split system
free cooling
low-voltage thermostat
overflow switch
power-stealing thermostat
programmable thermostat
quick-connect coupling
Wi-Fi enabled thermostat

RectorSeal

Introduction

The ability to comfortably and cost effectively condition the air within multiple rooms in homes has led to an increased demand for central air conditioning. What was once considered a luxury for homeowners is now a standard feature. Therefore, it is important for the technician to be familiar with these systems.

23.1 Split Air-Conditioning Systems

A split air-conditioning system has its components in two or more separate locations. A split system's condensing unit is typically located outdoors, and its evaporating unit is placed indoors.

Most split systems fall into one of two categories:

- **Central air-conditioning system.** Often simply called *split systems*, a central air-conditioning system uses a single indoor unit connected to a duct system. A blower distributes the conditioned air through supply air ducts into multiple rooms. A return air duct system allows air from the conditioned spaces to return to the air handler to be conditioned. See **Figure 23-1**.

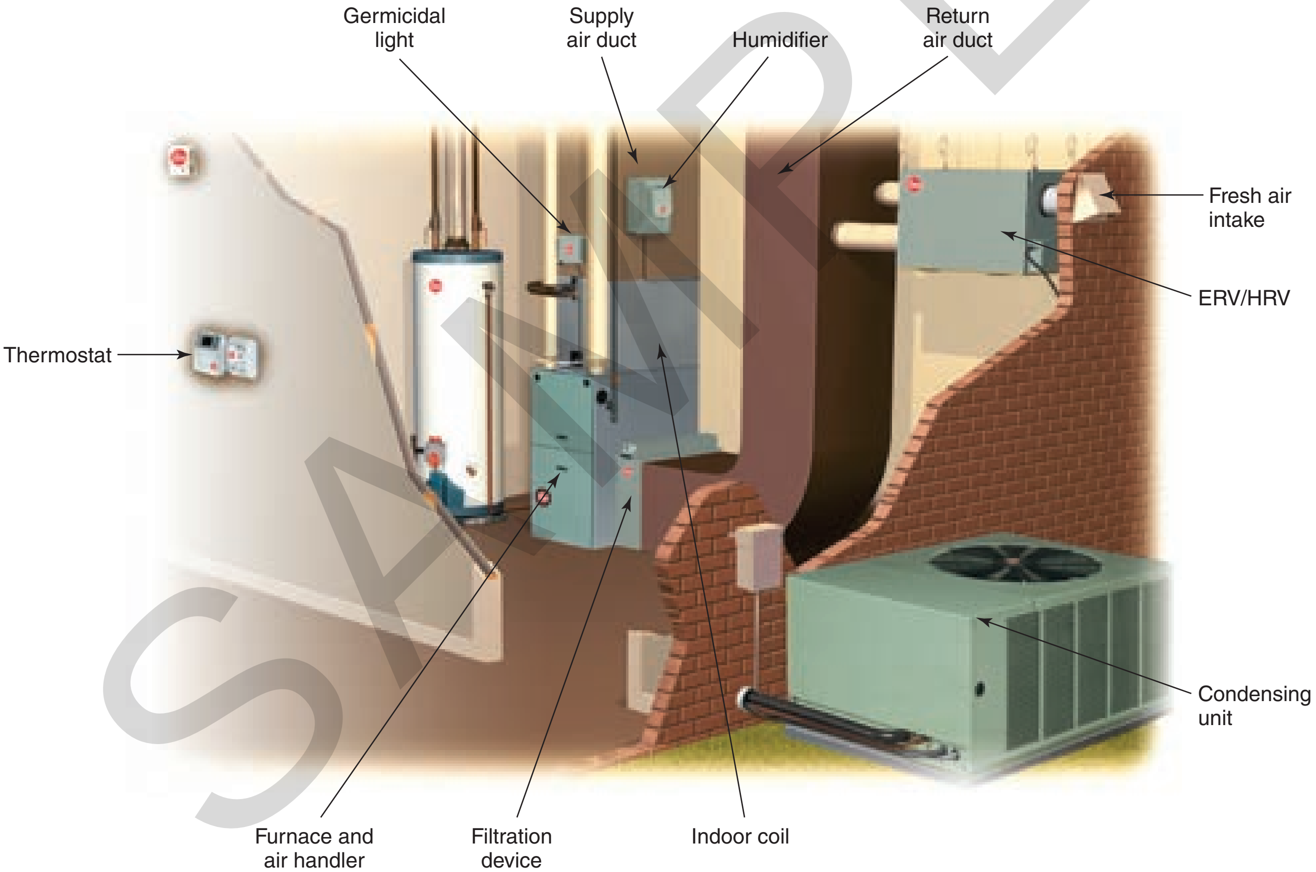
- **Ductless air-conditioning systems.** In ductless systems, the indoor unit with an evaporator and fan is placed within the room or area to be cooled. No ductwork is needed. Ductless air-conditioning systems can be further classified as mini-split systems that provide cooling to a single indoor unit, multi-split systems that provide cooling to multiple indoor units, and VRF systems that provide cooling to a larger number of indoor units. See **Figure 23-2**.

The table in **Figure 23-3** provides a comparison of a central air-conditioning system and the three types of ductless air-conditioning systems. These systems are discussed in detail in this chapter.

Heat pump systems are split systems that can provide both cooling and heating. Heat pumps include a reversing valve that changes the flow of refrigerant. When a heat pump is in heating mode, the high-pressure vapor leaving the compressor flows to the indoor unit. The coil in the indoor unit, which serves as the evaporator in cooling mode, serves as the condenser in heating mode. Heat is released as the vapor condenses to liquid, and this heat is released in the indoor unit. Liquid refrigerant then flows to the outdoor unit, where the coil serves as the evaporator.

23.2 Comfort Cooling Controls

Controls for comfort cooling include operating controls and safety controls. Operating controls regulate the normal operation of the system. Safety controls regulate safe operation by turning components on or off in order to protect system components and building occupants.



Rheem Manufacturing Company

Figure 23-1. A complete residential central air-conditioning system.

Mitsubishi Electric, HVAC Advanced Products Division

Figure 23-2. A ductless split system. A refrigerant line set connects the indoor and outdoor units. This room is being cooled by its cooling unit.

Operating controls can include thermostats, pressure switches, humidistats, motor starters, and relays. Safety controls can include electrical fuses, circuit breakers, thermal overloads, internal motor overloads, refrigerant pressure limit controls, and oil pressure controls. Many of these controls are described in Chapter 17, *Electrical Control Systems*.

Some operating controls may function for both the cooling system and the heating system. The heating controls govern the operation of the heating system. A room thermostat calls for heat until the desired room temperature is reached. Then, the electrical circuit is opened and the heating device deactivated. Details concerning the arrangement, installation, and operation of heating system controls are provided in later chapters.

Comparison of Residential Split Air-Conditioning Systems

	Central Air-Conditioning System	Single-Zone Ductless System	Single-Zone Multi-Split Ductless System	VRF System
Also Called	Split System	Mini-Split	Multi-Split	VRV System
Outdoor Unit	Single outdoor unit typically includes hermetic compressor, condenser, and condenser fan.	Single outdoor unit includes inverter-driven compressor, EEV, condenser, and condenser fan.	Single outdoor unit includes inverter-driven compressor, EEVs, condenser, and condenser fan.	Single or multiple outdoor units include inverter-driven compressors, condensers, and condenser fans.
Indoor Unit	Single indoor air handler contains metering device, evaporator coil, and blower. Furnace may be contained in air handler.	Single indoor unit contains evaporator and fan.	Multiple indoor units, each containing an evaporator and a fan. Maximum number of indoor units may be 8.	Multiple indoor units, each containing an EEV, an evaporator, and a fan. Maximum number of indoor units may be 64.
Airflow	Duct system distributes supply air from and provides return to the air handler.	Air blown over evaporator in conditioned space.	Air blown over each evaporator in conditioned space.	Air blown over each evaporator in conditioned space.
Metering Device	TXV or fixed orifice in indoor unit, typically.	EEV in outdoor units.	EEVs for each indoor unit.	EEVs in each indoor unit.
Controls	Single thermostat in central location controls cooling.	Thermostat on indoor unit controls cooling.	One indoor unit serves as the master thermostat for the system.	Thermostats on each indoor unit control cooling. Each indoor unit can be set to a different temperature. In heat recovery systems, some indoor units can provide cooling while others provide heating.
Other Notes	• Single evaporator provides cooling to all conditioned space in building. • May be air conditioner or heat pump. • Duct system facilities installation of additional air treatment accessories such as humidifiers, air cleaners, and ERVs/HRVs.	• Single evaporator provides cooling to a single conditioned space. • May be air conditioner or heat pump.	• Multiple evaporators provide variable cooling to each conditioned space. • May be air conditioner or heat pump.	• Multiple evaporators provide variable cooling or heating to each conditioned space. • May be heat pump system (all indoor units must cool or heat) or heat recovery system (some indoor units can cool while others can heat). • Available for residential applications, but more commonly used in commercial applications.

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Figure 23-3. This chart compares characteristics of central air-conditioning systems and three types of ductless air-conditioning systems.

A thermostat controls comfort cooling. Central air-conditioning systems generally use a single thermostat to control the cooling system. The thermostat turns on the comfort cooling system when the temperature of the room rises above a certain set point. It shuts off the cooling system when the temperature has been lowered to the desired level. A simplified electrical wiring diagram of a thermostat circuit is shown in **Figure 23-4**.

Many residential comfort cooling systems use a low-voltage thermostat. The thermostat controls a contactor that closes the compressor's motor circuit. Pressure safety devices are also installed in the circuit. A high-pressure safety switch is wired in series with the starter coil. It will open the circuit if pressures become too high, **Figure 23-5**.

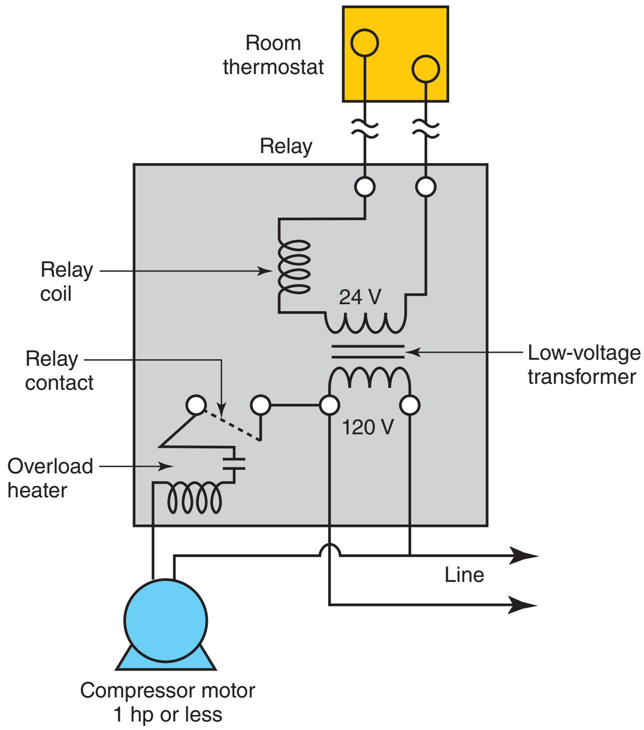

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Figure 23-4. A simplified wiring diagram of a thermostat relay circuit for small cooling systems. The room thermostat closes when the temperature rises to the cut-in temperature for cooling. The low-voltage relay coil is energized, which closes the relay contact in the high-voltage circuit, energizing the compressor. A relay would be used for small compressors only. For larger compressors that require greater ampacity, a contactor would be used in place of the relay.

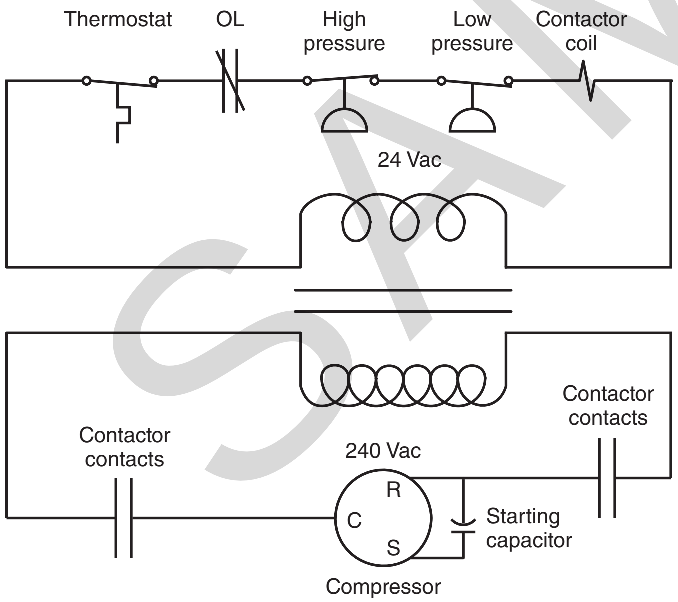

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Figure 23-5. Simplified wiring diagram for a compressor control circuit. When the thermostat closes to call for cooling, the contactor coil is energized. The energized contactor coil closes the contacts and energizes the compressor. The low-voltage circuit includes three normally closed safety switches: a thermal overload monitoring the compressor temperature, a high-pressure switch monitoring the discharge pressure, and a low-pressure switch monitoring the suction pressure.

Automatic controls make it possible for a central system to change from heating to cooling. If the outside air is at a certain temperature above the heating thermostat setting or a certain temperature below the cooling thermostat setting, some systems will draw in outside air to maintain a comfortable temperature inside the building. In such cases, the air-conditioning system is performing only as an air distribution and air-cleaning system. This permits the greatest economy of operation, as comfort is maintained and the minimum amount of fuel is consumed.

23.2.1 Low-Voltage Thermostats

A ***low-voltage thermostat*** is a thermostat that typically operates at 24 Vac supplied by a step-down transformer. A heating and cooling system uses a 120 Vac to 24 Vac step-down transformer to power a low-voltage thermostat's control circuit board. This includes the display showing a variety of relevant information to occupants, **Figure 23-6.**

Low-voltage thermostats often control relays and contactors. These relays and contactors are often used to switch line-voltage circuits on and off. Low-voltage thermostats carry only a small amount of electrical power. This is an advantage, as these lower current levels are safer, having lower shock potential than line voltage, **Figure 23-7.**

Transformers are usually rated by their primary and secondary voltages, as well as the volt-ampere (VA) rating of their design. For example, a step-down transformer may come with a rating of 120 V to 24 V and a VA rating of 40. This means that the primary side input voltage is 120 V, the secondary side output voltage is 24 V, and the current rating on the secondary side of the transformer is 1.67 A (40 VA ÷ 24 V = 1.67 A).

Be aware of the current load of a circuit in which a transformer is being placed. Drawing too much current on its secondary can cause a transformer to fail. When possible, include a properly sized fuse on the secondary side of a transformer circuit. The fuse should be rated high enough

Insteon

Figure 23-6. A low-voltage thermostat's display showing temperature measurements, temperature set point, humidity, time, and other information.

York International Corp.

Figure 23-7. Low-voltage thermostat wiring going to an air conditioner's condensing unit uses relays to switch the higher current loads of the compressor and condenser fan.

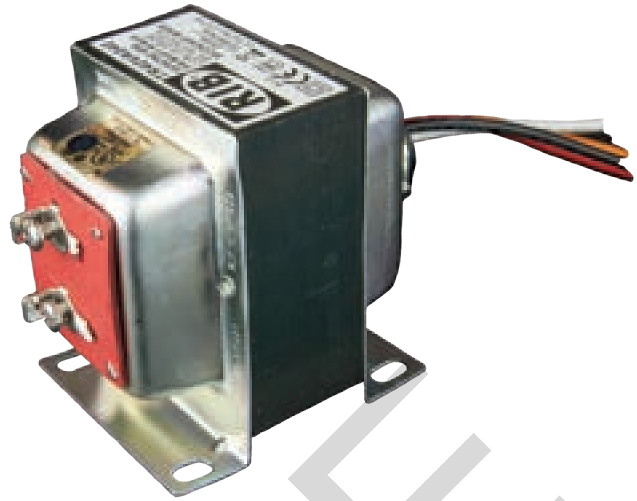
that all loads can operate without a problem. However, the fuse should be rated low enough to protect the transformer from a high current draw that could burn out the windings, **Figure 23-8**.

Overloading 24 V Transformers — Pro Tip

Most 24 V transformers will produce between 27 V and 28 V when properly placed into a circuit. If the technician measures a voltage of 24 V or lower, it is time to check the transformer and the loads on the circuit for excessive current draw or failure.

Low-Voltage and Line-Voltage Devices — Caution

Low-voltage thermostats will be damaged if connected to line-voltage (120 V or 240 V) circuits. Be careful to check an electrical device's voltage and current before installing it and energizing the circuit.



Jackson Systems, LLC

Figure 23-8. Many step-down transformers used with HVAC systems are rated 40 VA. These can safely provide 1.67 A at 24 Vac.

Low-voltage thermostats normally use 18 AWG wire for distances up to 50′ (15 m). For distances over 50′, 16 AWG wire is typical. Thermostats require multiple wire connections. Always review system and thermostat specifications before buying thermostat cable for installation to ensure it has enough conductors.

Thermostat Wiring Diagrams — Pro Tip

Because of the variety of systems and optional controls, not all manufacturers follow the same wiring color code or lettering system. Be sure to connect wires as indicated in the wiring diagrams provided by the manufacturer. When installing a replacement thermostat, always mark the existing thermostat's wires according to their terminal connection before disconnecting any wires.

Class 2 Circuits — Code Alert

Low-voltage thermostats control the power to low-voltage controls of Class 2 (power) circuits as defined by the National Electrical Code (NEC). Class 2 circuits are generally used for remote control or signaling circuits. These are power-limited circuits, which means there is less chance of electric shock or fire initiation. Some municipalities require that a licensed electrician complete the wiring for these circuits. For more information on Class 2 circuits, see Article 725 of the NEC.

The thermostat mounting usually requires other parts. The subbase—the part to which the thermostat is attached—contains the wiring terminals. Sometimes it holds other parts, such as switches, indicator lamps, and batteries. Beneath the subbase may be a wall plate. This is the part attached to an outlet box or wall. **Figure 23-9**

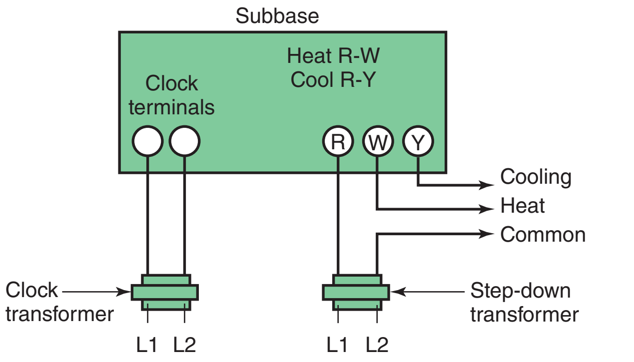


Figure 23-9. Low-voltage thermostat wiring diagram. Note that not all thermostats have clock terminals, and not all require a clock transformer.

shows a simple wiring diagram for a low-voltage thermostat.

Most low-voltage thermostats sense temperature using a thermistor. A thermistor is a device that changes its electrical resistance based on temperature. These thermostats have numerous advantages over older bimetal coil and mercury switch thermostats:

- Environmentally friendly—a thermistor replaces a hazardous mercury switch.
- Programmable—digital input allows easy programming by the homeowners.
- Durable—few or no moving parts or contacts to sustain wear.
- Expandable—programming may allow additional stages of operation and sensors.
- User friendly—touch screen models allow easy operation and access to information.
- Remote access—wireless interface via the web and smart device applications.
- Easily serviced—trouble codes may be accessed from user screen or USB port.

23.2.2 Digital and Programmable Thermostats

Advances in electronic circuitry and controls have revolutionized the thermostat and its capabilities. Electronic thermostats use the same basic operating principles as earlier models. However, the various functions are all accomplished with electronic components, such as transistors, solid-state relays, integrated circuit chips, and microprocessors. The versatility of electronics allows a thermostat to control and monitor numerous circuits through its ability to communicate with compatible transducers and sensors. These functions include sensing, switching, timing, and staging.

Wireless Thermostats

Wireless thermostats electronically activate a responder on the furnace or air conditioner. This can be done up to a distance of about 120′ (36.5 m). Wireless thermostats may also include remote wireless sensors, such as outside temperature sensors, air filter sensors, and humidity sensors. Each sensor sends a signal to the thermostat that is programmed to operate the heating and cooling unit and various zone valves or dampers throughout a building.

A wireless thermostat may be moved from room to room. It responds to the temperature of whatever room it is in. Since it is an electronic battery-powered unit, the thermostat has no moving parts. It can have an accurate adjustable differential from 0°F to about 5°F (0°C to about 3°C). Many have a range of 45°F to 90°F (7°C to 32°C).

An advantage of a wireless thermostat is that it may interface via Wi-Fi to mobile devices, such as a tablet PC, phone, or laptop. This provides the homeowner with the ability to change the set temperature from anywhere. Remote control also allows the user the ability to precondition the home. For example, the user may raise or lower the home's temperature while still at work so that the home is heated or cooled prior to the owner's arrival. Many HVAC manufacturers offer a mobile application that may be downloaded to a phone or mobile device to control the HVAC system remotely, **Figure 23-10**.

Power-Stealing Thermostats

Power-stealing thermostats are electronic thermostats that draw a small amount of power from the low-voltage side of the HVAC system control to operate the thermostat electronics. The current draw is in the milliamps (mA) range. Power-stealing thermostats are efficient and do not require a separate power source to operate. **Figure 23-11** shows one type of power-stealing thermostat display.

A power-stealing thermostat "steals" power for the control board by tapping into the fan, cooling, or heating terminals. When the heating or cooling is operating, a small amount of current flows into the thermostat to recharge its internal battery.

Caution

Power-Stealing Thermostat Compatibility

Power-stealing thermostats may not be compatible with some HVAC system circuit boards. The small voltage draws required by the thermostat may result in activation of the relay from which the thermostat is attempting to draw power. This may result in HVAC control board failures or relay issues. To prevent this condition, it may be necessary to install a small bypass resistor. The bypass resistor is placed between the power-stealing thermostat leg and common. The resistor prevents overcurrent conditions to the control board. **Figure 23-12** illustrates a power-stealing thermostat wiring diagram with a bypass (bleed) resistor installed. Also, some zone valves used in hot water heating systems require a small bleed resistor to be installed across two pins on the zone valve.

Courtesy of Nest Labs, Inc. Copyright © 2012 Dwight Eschliman

Figure 23-10. Wireless thermostats allow for easy adjustment and monitoring. A—Controlling a thermostat remotely through a laptop. B—Reviewing HVAC system energy usage over time using an app.

Control4 Corporation

Figure 23-11. A power-stealing thermostat with a touch screen interface. Note this unit is a whole home management system.

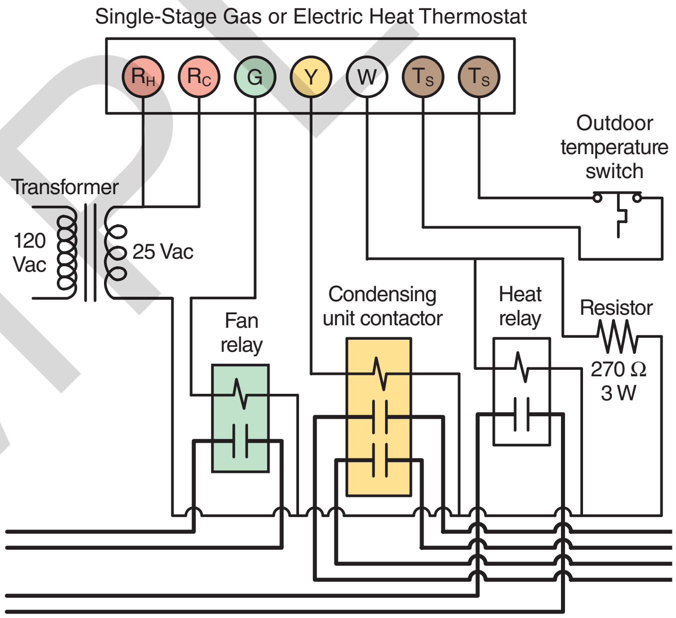


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Figure 23-12. Single-stage combination thermostat wiring diagram with 270 Ω 3 W bypass resistor in the circuit for power-stealing setup.

Programmable Thermostats

A ***programmable thermostat*** contains a microprocessor that functions as a clock and allows users to select different indoor climate conditions for different blocks of time. The precision and responsiveness of solid-state controls result in the best operation for high-efficiency operation. These same controls are often used to detect, monitor, and display for the user the system conditions. The conditions are indicated by instruments, lights, and recorders. Electronic components of a solid-state thermostat usually include a thermistor (temperature sensor) and an integrated circuit board.

Many heating-cooling systems use a programmable thermostat governed by a clock. It changes the temperature range during the night and returns the range to normal during the day. Many also provide seven-day settings, which enable different temperature settings for weekdays and weekends. This type of control can provide a lower operational cost by operating an HVAC system only when needed and operating less when occupants are away. **Figure 23-13** shows a single day's schedule as governed by a thermostat's clock.

Unlike line-voltage or mercury switch thermostats, many electronic thermostats do not have heat anticipators because they often use remote sensing units. A remote sensing unit includes a temperature sensor that is at the end of a cable run from the thermostat to within a few feet from a supply register, so it will more accurately sense the actual room temperature.

Through the use of electronic circuitry rather than mechanical controls, a greater variety of control options

Venstar

Figure 23-13. This programmable thermostat's display is showing the time and temperatures for system operation for Fridays.

and features are available in a thermostat of the same size as an older mechanical thermostat. A typical electronic thermostat can perform the following functions:

- Fully programmable temperature settings. Various temperatures can be programmed to achieve maximum comfort throughout the day. These settings can also be varied for each day of the week depending on occupancy, allowing high levels of efficiency.
- Multistage and combination control. A single device can control various stages of heating and cooling. For heat pump applications, programmable thermostats designed specifically for heat pumps should be used, **Figure 23-14**.
- Override control. This feature overrides the thermostat's normal programming to maintain a preset temperature condition. An example would be a vacation setting. A single temperature might be desired for those periods of time when no one is home.
- Digital display using a back-lit LCD screen. Room temperature, desired temperature, time, and date are displayed at the push of a button.
- Battery backup. Most electronic thermostats are low-voltage thermostats, and most models have a battery backup. The battery backup prevents loss of an entire program in case of a power failure.
- USB or wireless interface. Some thermostats can be programmed and monitored using a USB cable or wireless connection from a laptop or handheld device.

Additional features that can be found on some models include the following:

- Maintenance alerting. The unit can automatically keep track of the number of days that the air filters, humidifiers, and other components are in use. Then, it will automatically signal with a light or tone when maintenance is required, **Figure 23-15**.
- Outside ambient temperature sensor. Some electronic thermostats sense outside temperature and include this value in calculations to determine the length of a heating and cooling system warm-up or cool-down time. They adjust the operating cycles accordingly. Outside temperature can often be digitally displayed.
- Security protection. The thermostat requires a security code before allowing the user to modify settings. This feature is sometimes used in commercial settings in which the thermostat is in a public location.

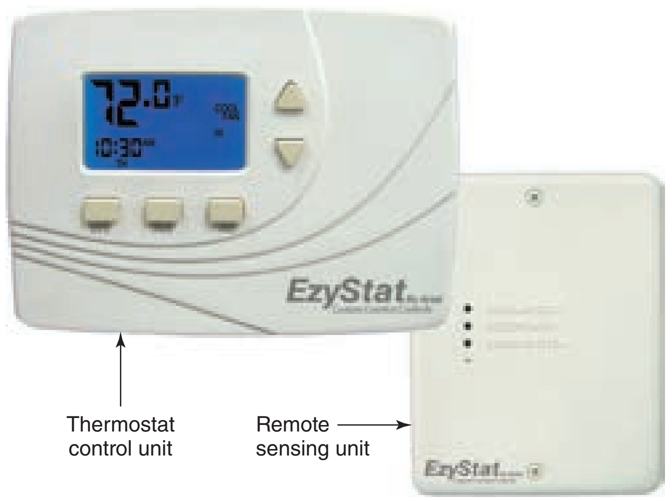
Programmable thermostats vary somewhat with each manufacturer. Some are available as a control unit with one or more separate temperature sensing units, **Figure 23-16**. The sensors can be mounted in a conditioned space, and

Venstar

Figure 23-14. A programmer must input how many stages of cooling and heating operation will be used with the system connected to a thermostat.

Venstar

Figure 23-15. This thermostat allows its user to select the frequency of equipment service reminders.



Arzel Zoning Technology, Inc.

Figure 23-16. An electronic thermostat with a separate control and sensing unit.

the control unit can be mounted elsewhere, such as a manager's office.

Programmable thermostats, due to their precision components, offer exact temperature control. Usually, temperature can be controlled within 1°F (0.6°C) of the set temperature. Programmable thermostats offer significant energy savings without reducing overall comfort. This is accomplished through simple preprogrammed temperature settings. Once the unit has been programmed, little effort is required from the owner.

Programming a Thermostat

A programmable thermostat allows an occupant to tailor indoor comfort to suit individual preference and schedule. Often, they are used to change the temperature settings for night and reset them for different periods through the day. Most units include preset programs but allow the operator to modify the program to desired temperatures for different times and days of the week.

Most thermostats permit programming on three basic levels:

- Time of day.
- Day of the week.
- Heating or cooling.

Programming a thermostat involves adjusting the on-off schedule and temperature of a building to meet the occupant's desired comfort while maximizing the efficiency of the HVAC system. Programs allow the temperature in a room to rise and fall based on occupancy levels.

Depending on the season and weather, systems may be programmed to allow the temperature set point to raise or drop at night when the occupants are sleeping, or the building is vacant. Systems can then either raise or lower the set point to a more comfortable temperature in the morning just prior to wake-up or occupancy. If a building is left vacant all day, the set point may be set lower or higher for the entire day, depending on the season.

Figure 23-17 illustrates a cooling program. In the morning, prior to the peak power rate hours and a reduced thermal load from the sun and outdoor temperature, the air conditioning cools the building to 70°F (21°C). During the day, when occupants are away, the building temperature is allowed to rise up to a 73°F (23°C) set point. Before occupants return home, the thermostat turns on the air conditioning to cool the building back down to 70°F (21°C) by 4:00 pm. In the later evening, with lower solar load, the set point is allowed to rise back up to 73°F (23°C). It is important to not allow the building to heat up during the day. The air-conditioning system would then have to remove the large amount of heat accumulated throughout the day.

The advantage of using a programmable thermostat is that it can provide energy savings when a building is not required to maintain a high or low set point, such as when occupants are away. Many electric utilities charge higher rates for "peak times," when energy consumption is at its highest. During daylight working hours, energy usage is at its peak. By programming the heating and cooling system to a more moderate set point during peak periods, daily energy consumed is reduced, which results in a smaller power bill. Home energy monitoring systems can display the cost of kilowatt per hour and energy usage data. This can serve as a reminder to conserve energy as much as possible, **Figure 23-18**.

Manufacturers are developing new technologies and thermostat features that allow increased self-monitoring of energy usage over time. These thermostats can show occupants hours of system run time, electrical energy used, and other useful information, **Figure 23-19**.

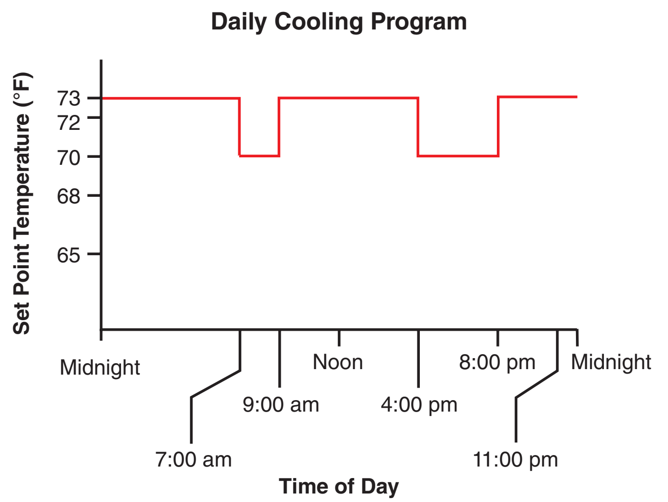


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Figure 23-17. Daily cooling program.

Insteon

Figure 23-18. This home energy monitor displays the cost of kilowatts per hour next to indoor temperature.

Venstar

Figure 23-19. This thermostat shows hours of heating system operation over the course of several days. By knowing our habits and temperature preferences, we can program thermostats to run only as much as needed to prevent wasting energy.

Thinking Green

Programming a Thermostat

A properly programmed thermostat can significantly reduce a customer's utility bill without sacrificing comfort. The thermostat should be programmed to adjust temperature to save energy during periods that the occupants are typically asleep or away. However, the system must maintain the energy-saving temperature for an extended period (several hours) or the energy used to restore the normal temperature will offset any savings.

23.3 Central Air-Conditioning Systems

A ***central air-conditioning system*** includes a single evaporator installed in a central air handler cabinet that is connected to a network of ducts. Cooled and dehumidified air is distributed to the conditioned spaces through a series of supply ducts and returned to the air handler and evaporator through return ducts. Central air-conditioning systems usually provide heating, cooling, humidity control, ventilation, and air cleaning to multiple spaces.

Often, the heating system shares the air handler, blower, and duct system with a central air-conditioning system. A central air-conditioning system shown in **Figure 23-20** uses a gas-fired furnace to provide heat. A compression refrigeration system provides the cooling, **Figure 23-21**. In the system shown, an A-coil evaporator is located in the furnace plenum chamber. The condensing unit (compressor, condenser, and condenser fan) is located outside the building.

Generally, a central air-conditioning system uses a TXV or fixed orifice metering device to control refrigerant flow into its evaporator. The type of metering device used depends on system size and application. See Chapter 9, *Basic Refrigeration and Air-Conditioning System Components*, for more information.

Soft Skills for HVACR — **Telephone Etiquette**

It is important to use good manners when speaking on the telephone. Always be courteous, and be mindful of the volume and tone of your voice. Place a caller on speaker only if the phone call requires it, such as during a conference call that involves multiple participants in one location. If the situation requires you to place a caller on hold, be sure to explain why you are leaving the conversation and return to the call as quickly as possible. There may be times you cannot answer your phone, such as when you are working with another customer. Be prompt when returning phone calls. Industry standard is to return a call within 24 hours after a request for a return call is received. Returning a call promptly lets a caller know he or she is important.

Discussion Questions

1. You are with a customer presenting an estimate for a new air-conditioning system. You have forgotten to place your phone on silent, and it begins to ring. How can you handle this situation in a professional manner?
2. You have just left a jobsite and the client calls to tell you that you have tracked dirt through his home. How can you handle this in a professional manner?

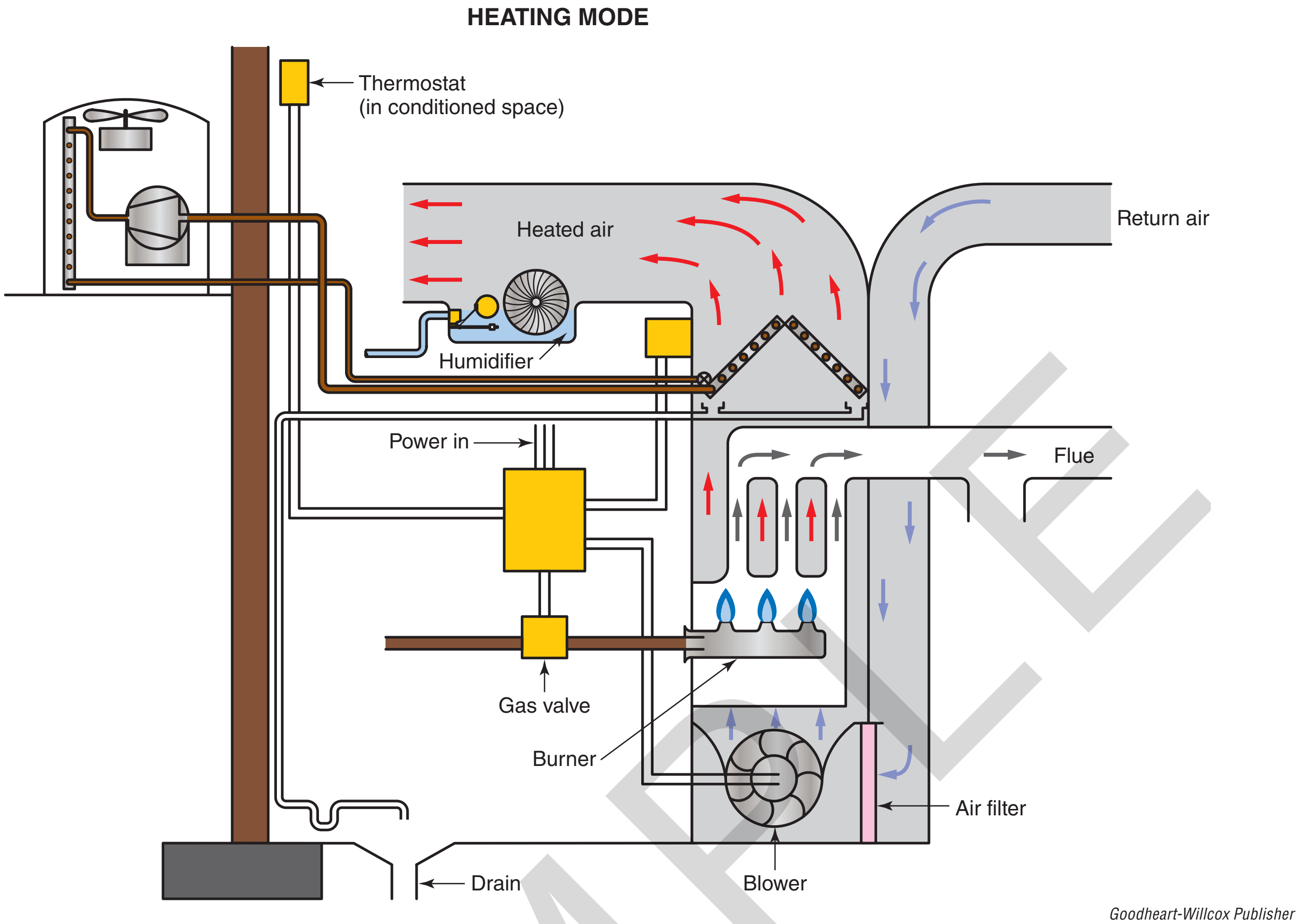

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Figure 23-20. A complete central air-conditioning system that provides both heating and cooling. The heating cycle is shown here, using a gas-fired furnace. A humidifier in the plenum chamber adds moisture to the warmed air. The same blower and air filter are used for both heating and cooling operations.

A single combination heating and cooling thermostat is often used in central air-conditioning systems. Conditioned air is forced throughout a building by a blower. The blower is typically positioned just after an air filter and the return air plenum. With this arrangement, the air filter in the return air plenum cleans the air before it reaches the blower. An arrangement is sometimes provided to bring in fresh outside air as needed. The fresh air inlet may be controlled thermostatically, manually, or by air pressure.

Some systems use a humidistat to control relative humidity in the conditioned space. Such systems usually have a humidifier in the plenum chamber that adds moisture to the air when the furnace is operating.

The outdoor unit, or condensing unit, contains the compressor, condenser, and condenser fan. The condenser coil of outdoor, air-cooled condensers normally lines the inner walls of the unit. A condenser fan draws air into the condensing unit, around the condenser coil, and then discharges upward and outward, **Figure 23-22**.

Outdoor units for heat pumps are similar to those for central air conditioning, with some exceptions. See **Figure 23-23**. A heat pump outdoor unit contains a reversing valve, which determines if the compressor discharge line is directed to the outdoor coil (cooling) or indoor coil (heating). Heat pump outdoor units also include an accumulator, which stores excess refrigerant when the

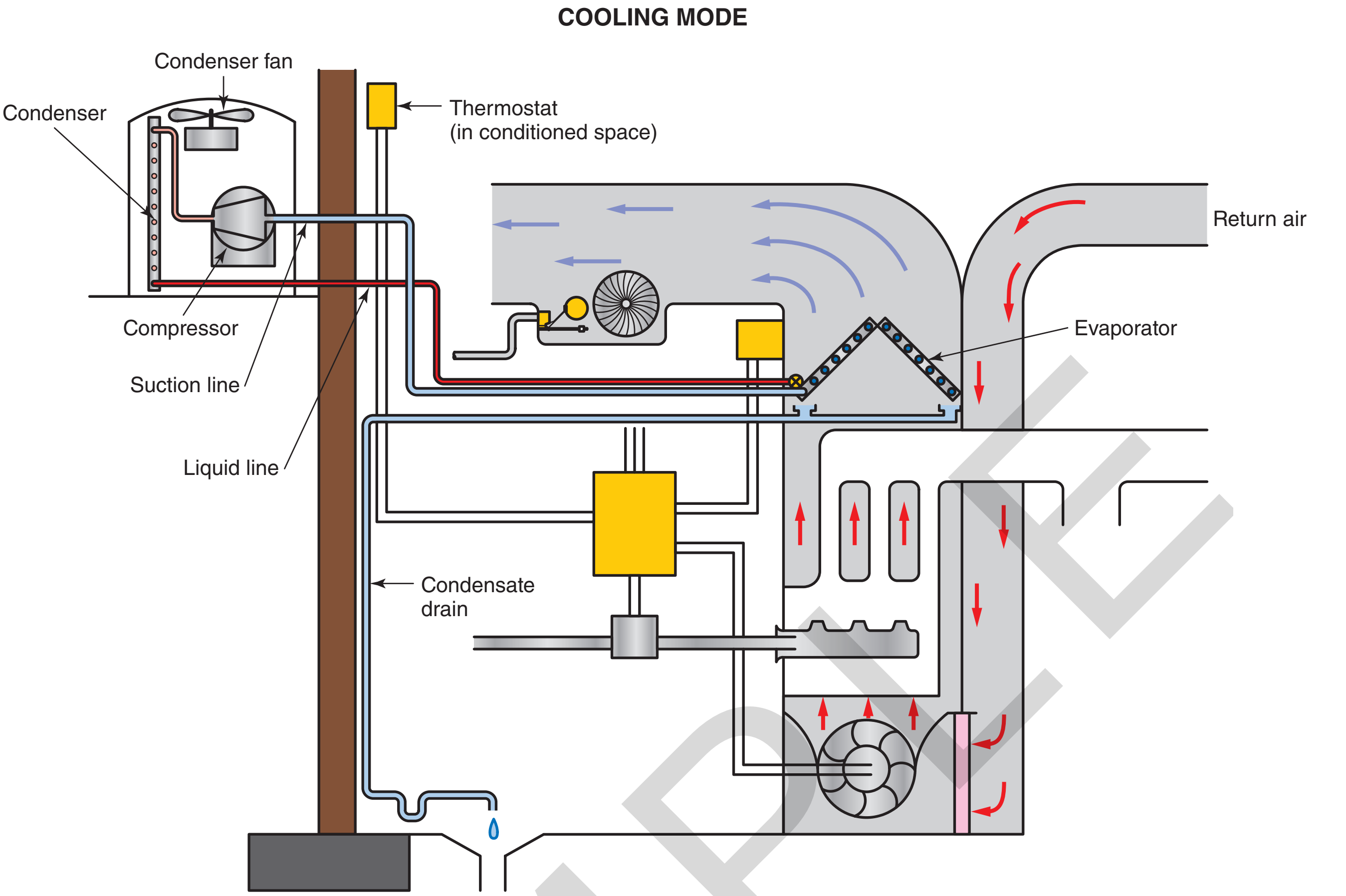

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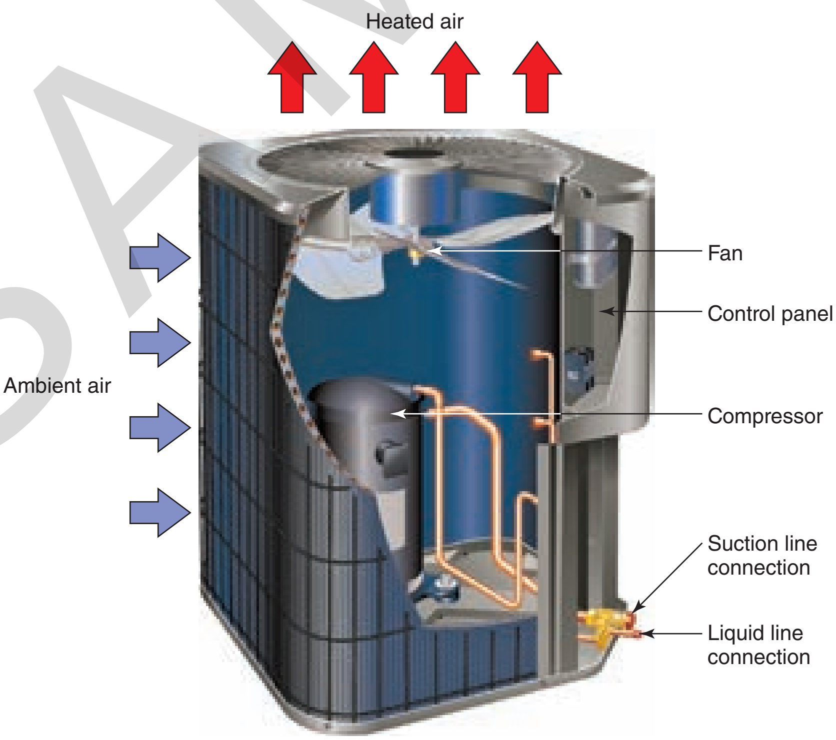
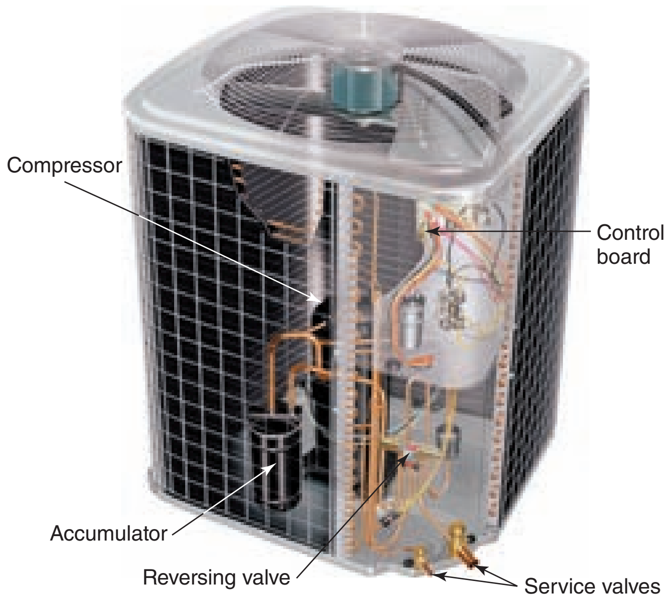
Figure 23-21. A central air-conditioning system in cooling mode. An A-coil evaporator coil in the plenum cools air blown over it by the blower. The outside condensing unit rejects the heat that was absorbed in the evaporator. Humidity is removed by condensing excess moisture on the evaporator surface. A drain tube carries away the condensed moisture.



Lennox Industries Inc.

Figure 23-22. To condense and subcool the circulating high-pressure refrigerant, a central air-conditioning condensing unit draws in ambient air through the sides of the unit and discharges it out of the top of the unit.



Tempstar

Figure 23-23. Note the location of the reversing and the service valves in this cutaway view of a heat pump. A technician can attach a manufacturer-supplied control reader to the control unit to obtain system performance data.

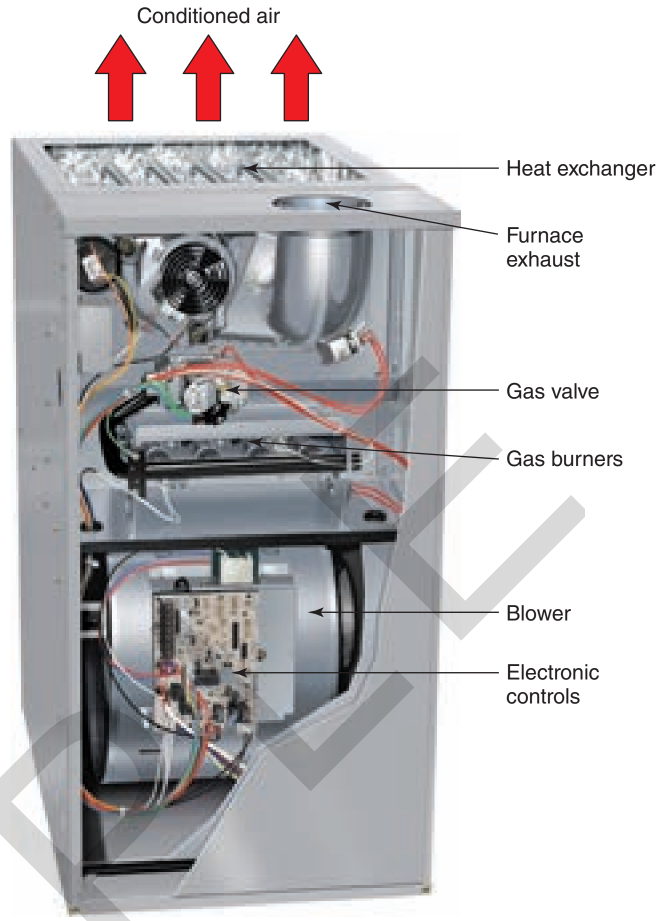
system is operating in heating mode. Heat pumps may also be equipped with a defrost mode, which prevents ice from building up on the outdoor coil.

In heat pump–based central air conditioning, an electronic thermostat like the one shown in **Figure 23-24** monitors both indoor and outdoor temperatures. The LCD on the thermostat face shows the indoor temperature and outdoor temperature. It also shows whether the unit is in a heating or cooling mode.

The indoor unit of a central air-conditioning system is also called the air handler. **Figure 23-25** shows an air handler with gas furnace used to distribute conditioned air throughout a building. To add cooling to this furnace, an evaporator would be installed in the plenum above the heat exchanger, **Figure 23-26.** The air handler "pulls" air in from the return duct system and "pushes" air out through the supply duct system.

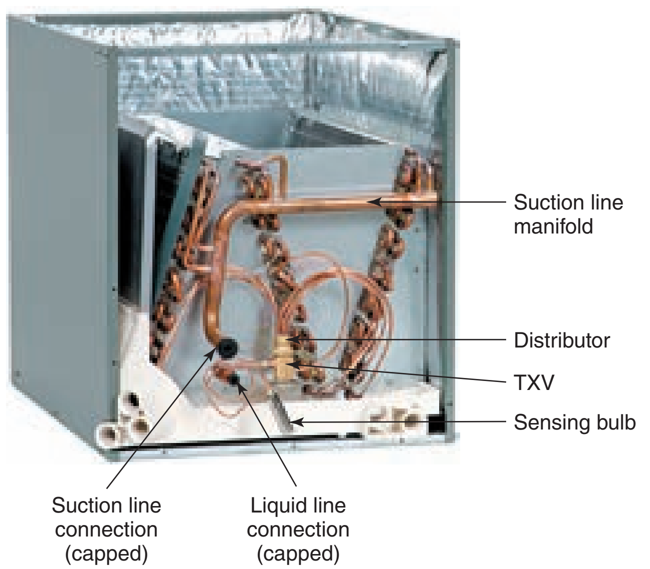
Rheem Manufacturing Company

Figure 23-24. A typical electronic wall thermostat with an LCD screen that displays indoor temperature, outdoor temperature, and heating or cooling mode. The thermostat can be used to raise the temperature, lower the temperature, take indoor and outdoor temperature readings, select heating or cooling mode, and select continuous or automatic fan operation.



Tempstar

Figure 23-25. This air handler contains a gas furnace and heat exchanger for warming air circulated by the blower.



Rheem Manufacturing Company

Figure 23-26. This evaporator is already fitted into a plenum and ready to be added onto a forced-air furnace installation.

23.4 Installing Central Air Conditioning

Before installing an evaporator and condensing unit to an existing furnace or air handler, examine the existing system. If a furnace is old and worn or its efficiency rating is low, consider replacing the furnace with a higher efficiency model. After deciding, systems are assembled onsite in four steps:

1. Install the condensing unit.
2. Install the evaporator.
3. Install the suction and liquid lines.
4. Install the electrical wiring.

Thinking Green

Replacing an HVAC System

When replacing an HVAC system, always calculate the heating and cooling loads to properly size the replacement system. Do not assume that the replacement system should have the same capacity as the system it is replacing. The original system may have been sized incorrectly. Changes made to the building since the previous system was installed, such as the addition or removal of windows, doors, and insulation, may make a larger or smaller system more efficient. Even changes in shading due to maturing trees or new construction around the building can have a significant effect on the heating and cooling loads.

Thinking Green

Life Cycle Cost Analysis

Often, the initial cost (purchase and installation) of a system is less than 10% of the lifetime cost of the system. When comparing systems, it is often beneficial to compare the total life cycle costs of the systems rather than the initial costs. This type of evaluation takes into consideration such factors as energy efficiency and maintenance costs.

23.4.1 Installing a Condensing Unit

Most condensing units blow outdoor air over the condenser coil to cool the coil. However, some systems have water-cooled condensers. Condensing units can be installed in a number of different locations. Some condensing units are mounted inside the building. In this arrangement, ducts bring outdoor air to the condenser and discharge warm air outside. Some condensing units are mounted on an outside wall.

A popular practice is to mount a condensing unit on a permanent concrete slab or manufactured pad outside the building. This slab is located 12″–24″ (31–61 cm) away from the building. A concrete slab at least 4″ (10 cm) thick and reinforced with steel mesh is recommended. Manufactured pads are available in different sizes and thicknesses. Be mindful of local building codes to install a slab or pad having the proper thickness and the proper distance from any building or obstruction. Adequate work space is necessary. A condensing unit should be installed so that outlet air moves in the same direction as the prevailing summer winds. **Figure 23-27** shows various condensing unit arrangements.

The location of the condensing unit is important. The suction and liquid lines and electrical power lines should be as short as possible. The condensing unit should be carefully located:

- Away from bedrooms, patios, and neighbors (to minimize noise pollution).
- At least 24″ (61 cm) away from walls (for air circulation and adequate work space).
- Away from inside corners (for air circulation).
- Not under eaves (to not obstruct airflow).

Figure 23-28 shows acceptable and unacceptable locations for a condensing unit. If possible, a condensing unit should be placed along the north side of a building, where it will enjoy shade throughout the day and not endure the heat load of the sun.

A condensing unit should be mounted level, and with the proper clearances around the unit. **Figure 23-29** shows a typical condensing unit and the required clearances around the unit. Always follow the manufacturer's recommendations for locating the condensing unit.

Pro Tip

Preventing Refrigerant Theft

A condensing unit that is in plain sight or monitored by security cameras can discourage refrigerant theft. Another method of prevention is the installation of ***access valve locks***. These devices are installed on the access valves of service valves. Keys and tools used to unlock these devices should only be made available to homeowners and HVACR technicians.

23.4.2 Installing an Evaporator

An evaporator must be mounted level and solidly in the furnace bonnet or plenum chamber. The design of the evaporator and its condensate drain depend on the type of furnace (upflow, downflow, or horizontal flow). Removable panels are installed in the plenum or chamber so the evaporator can be accessed for periodic cleaning and servicing as required.

A cutout is made in the plenum and covered with a cover plate. The cover plate is slightly larger than the cutout and is secured with sheet metal screws. The bottom of the coil assembly is secured and supported by blank-off plates and rails. ***Blank-off plates*** are sheet metal plates that support the evaporator coil and block off areas of the plenum so that all the air passing through the plenum is directed through the evaporator coil. **Figure 23-30** shows a typical slant evaporator installation.

In some cases, the metering device is supplied with the evaporator coil. If the metering device is not supplied with the coil, the proper size metering device must be selected and installed at the evaporator coil inlet.

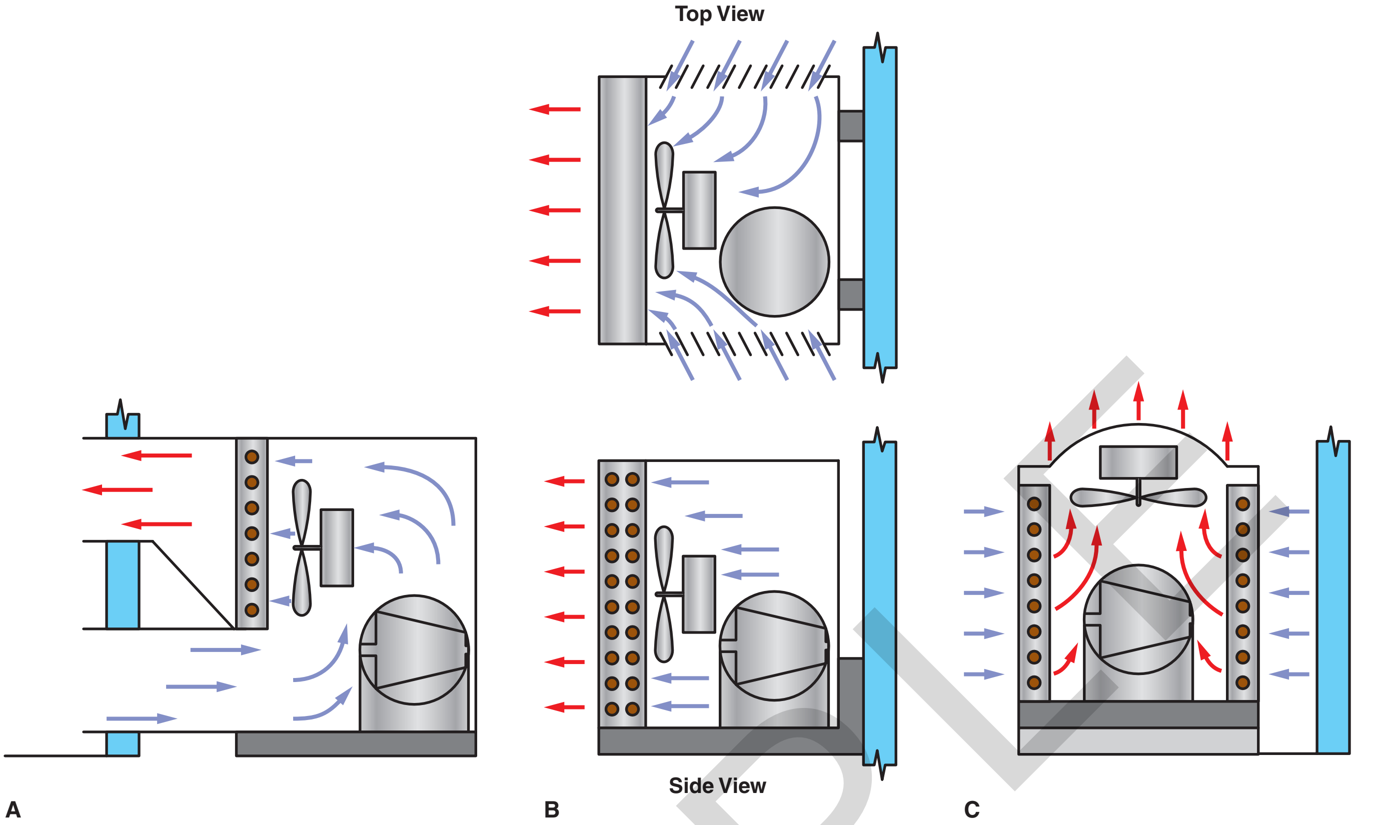


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Figure 23-27. Three types of air-cooled condensing units for residential air-conditioning installations. A—Condensing unit inside building. B—Unit hung on outer wall (usually through window). C—Unit mounted on concrete slab outside building.

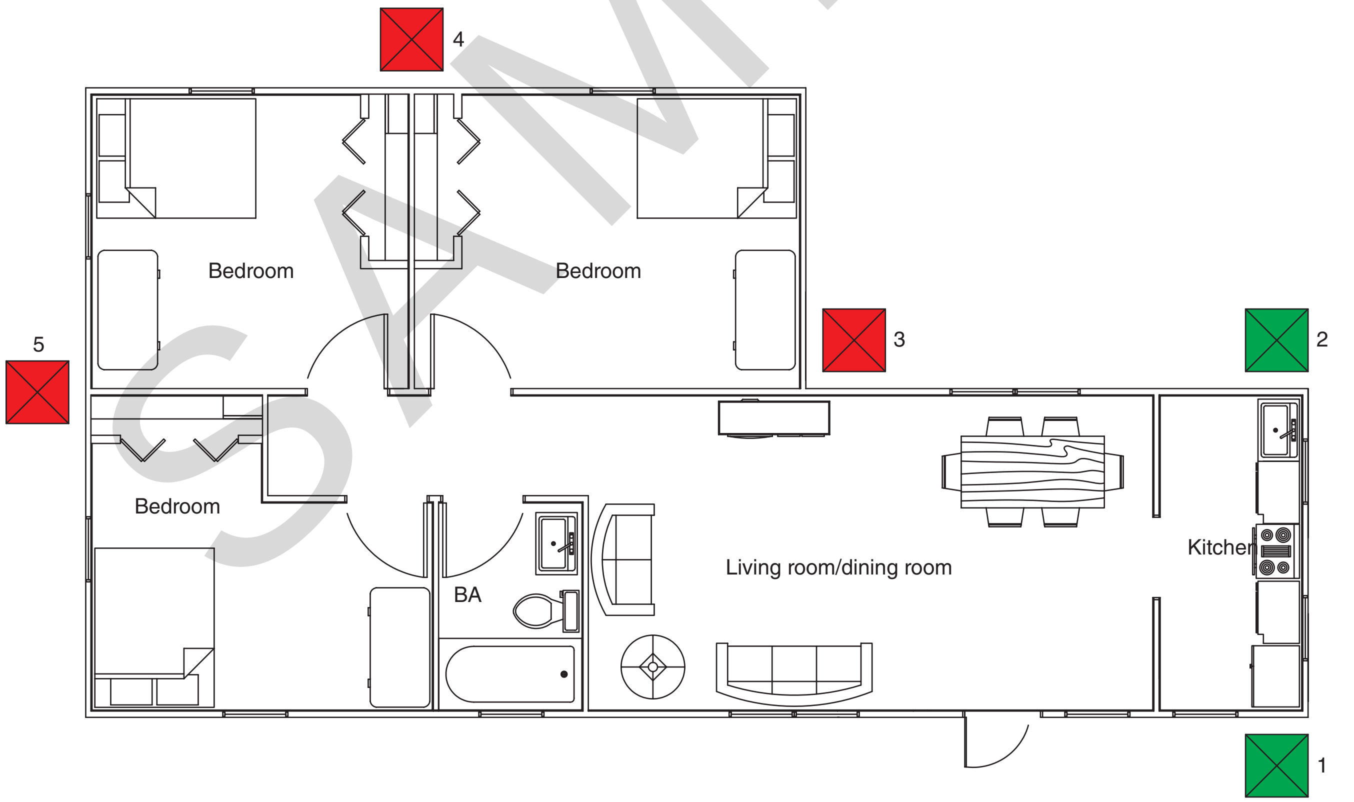

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Figure 23-28. Choose a location for an outdoor air-cooled condensing unit for best airflow and least noise. Locations 1 and 2 are good locations. Location 3 is not recommended because it is in a pocket where there would be restricted airflow and is also too near a bedroom. Locations 4 and 5 are also too near bedrooms.

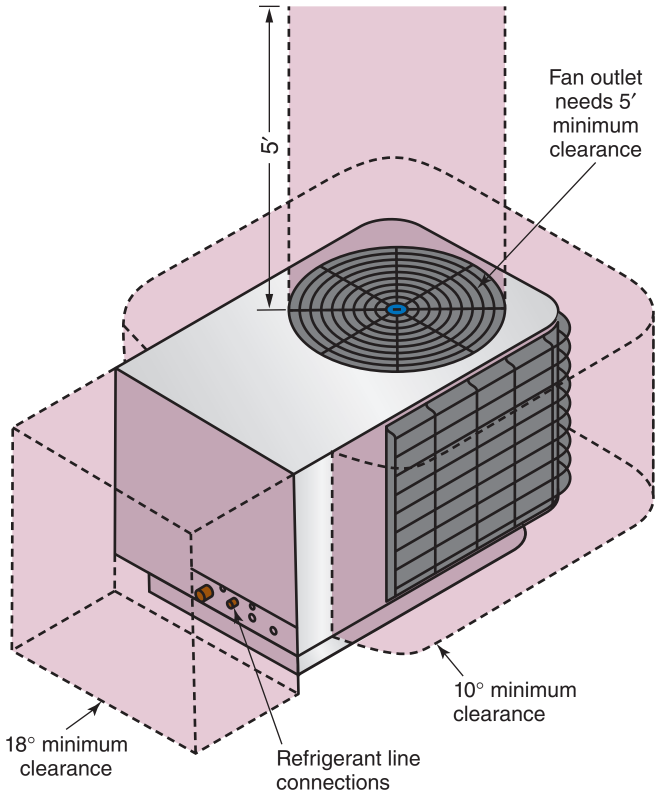

Figure 23-29. A typical condensing unit installation showing the minimum acceptable clearances around such units.

The condensate drain should be piped to an open drain. There should be an air break at the drain. Plastic drainpipe should be kept away from the warmer parts of the furnace. Some technicians install a 4″ U-trap in the drain line to stop airflow through the line. A condensate drain pan is built into the evaporator, as is the drain connection.

Code Alert

Condensate Drainage

Check the local building code for condensate drainage requirements. In some installations, a drain pump must be installed to remove the condensate to the outdoors.

23.4.3 Installing Refrigerant Lines

The suction and liquid lines between the condensing unit and the evaporator coil may be connected with flared connections, brazed connections, or quick-connect couplings. The flared and brazed connections were discussed in Chapter 5, *Working with Tubing and Piping*. Quick-connect couplings are discussed later in this chapter.

Refrigerant lines should be kept as short as possible. The proper diameters for the refrigerant lines are determined by the size of the condensing unit and the length of the lines to connect the condensing unit to the evaporator. If the system is being installed in a hot, humid climate, the

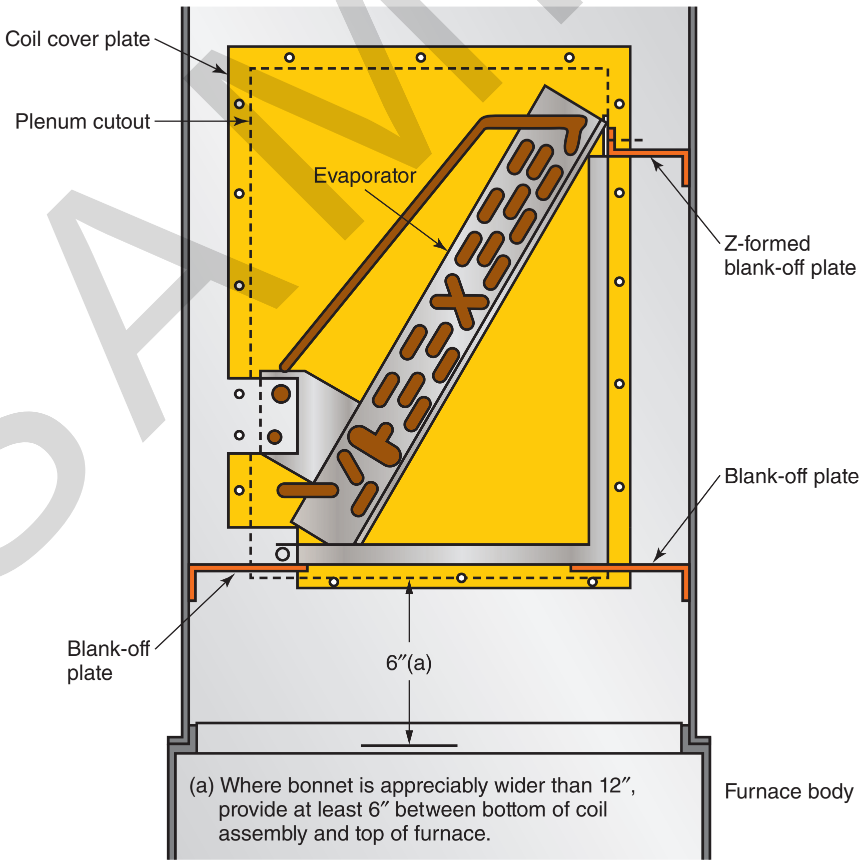

Figure 23-30. A slant evaporator installed in a furnace plenum. The blank-off plates support the coil and direct all air through the evaporator coil.

manufacturer may recommend a larger diameter than would be recommended for a more temperate climate. Always follow the manufacturer's sizing recommendations.

Caution

Brazing Refrigerant Lines

If the refrigerant lines are to be connected by brazing, remove the Schrader valve cores from the service valves before brazing the lines to the stubs. If the valve cores are not removed, heat from the brazing process will damage the rubber and plastic parts in the valve core. Also, wrap the service valves with a wet cloth before brazing the joints. This will protect the valves from overheating.

Many condensing units are installed at a higher elevation than the evaporator. Therefore, a U-bend should be put in the suction line to assist in oil return. The suction line should slope downward slightly toward the condensing unit. It should also be insulated. If the suction line is not insulated, moisture from the air will condense on the outside of the suction line and drip. An uninsulated suction line would also absorb additional heat from unconditioned space, which will need to be rejected at the condenser. As a result, system efficiency will decrease, and the compressor will not be cooled as effectively.

A filter-drier and a sight glass should be put in the liquid line. The refrigerant lines should be supported and free of kinks and sharp bends. Any openings for the liquid and suction lines in the plenum and the building's wall should be sealed with weatherproof, nonhardening sealing compound and tape.

Caution

Liquid Line/Capillary Tube Installation

Some systems use the liquid line as the capillary tube. Larger-bore (ID) tubing reduces the chance of clogging from dirt or moisture. To ensure proper operation, do not shorten or lengthen a combination liquid line/capillary tube during installation.

Once refrigerant lines are installed, check the refrigerant lines and evaporator for leaks. Repair any leaks. Evacuate the refrigerant lines and evaporator. Next, charge the system with refrigerant. If the condensing unit is precharged, the isolation valves are opened and the charge is allowed to fill the system. If the condensing unit did not come precharged, the proper charge must be weighed in. General leak testing, evacuation, and charging procedures were described in Chapter 12, *Working with Refrigerants*. Always follow the manufacturer's recommendations.

23.4.4 Installing Electrical Wiring

The wiring requirements for central air-conditioning systems vary from system to system. The electrical installation must be completed as shown in the wiring diagram furnished with the system. The wiring requirements usually consist of providing a 240 V connection to power the condensing unit and a 24 V connection from the thermostat to control the condensing unit. The 240 V circuit is equipped with an electrical disconnect so the system can be quickly disconnected for service, **Figure 23-31**.

Code Alert

Disconnecting Means

According to the National Electrical Code, a condensing unit's electrical disconnecting means must be within sight from the condensing unit's location and readily accessible. *Within sight* means that the disconnect can be no more than 50′ away. *Readily accessible* means that personnel will not need to climb, use tools, or remove obstacles to reach the disconnect.

When installing wiring that is to be exposed to outdoors, check that its insulation is properly rated for such use. Outdoor use means that the wiring will be exposed to moisture from precipitation and also to the powerful rays of the sun. Not all wiring is intended to withstand such exposure.

Code Alert

Electrical Wiring

Electrical circuits must be installed in accordance with local building codes, which often specify that work be done in accordance with the National Electrical Code. Consult your local electrical utility concerning the primary service capacity.

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Figure 23-31. Electrical disconnect box. Note that the pullout contact can be pulled out or flipped upside down to disconnect the condensing unit so it can be serviced.

23.4.5 Thermostat Installation

Thermostat wiring varies by manufacturer. Each thermostat should come with installation instructions, which must be followed to ensure proper operation. When replacing a thermostat, it is common practice to use the existing thermostat wiring from the furnace, boiler, or heat pump. It is always a good practice to note which wires were connected to the old thermostat terminals and label these accordingly.

Thermostat Wiring

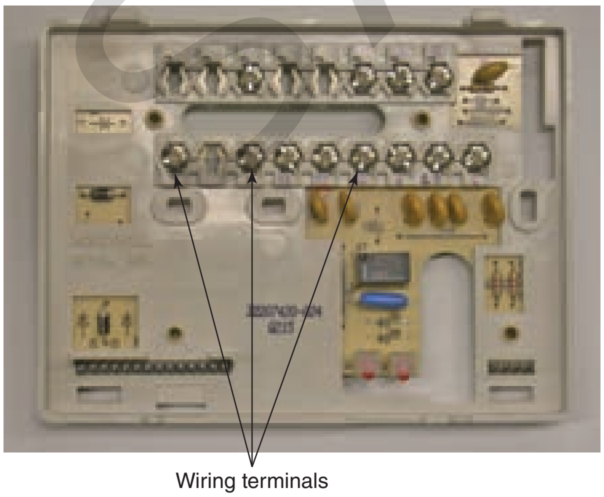
Although thermostats and units may be wired differently, there are some basic conventions and terminal designations used when wiring a thermostat:

- Rc—cooling power.
- Rh—heating power.
- R—power.
- Y—condensing unit (compressor) contactor.
- Y2—compressor contactor (stage 2).
- C—24 V common connection.
- W—heat relay (stage 1).
- W2—heat relay (stage 2).
- G—fan relay (cooling only).
- CR—cooling relay.
- O/B—heat pump reversing valve.
- Aux/E—heat pump auxiliary heat.
- HMD—humidification.
- DHD—dehumidification.
- Ts—outdoor temperature switch.
- Out, Temp, OD, OAS, or ODT—outdoor air temperature sensor.
- In or IDT—indoor temperature sensor.
- M1 or DMP—air duct damper control.

Thermostats with auxiliary functions may use different terminal designations from those shown here. Always refer to manufacturer literature to be certain.

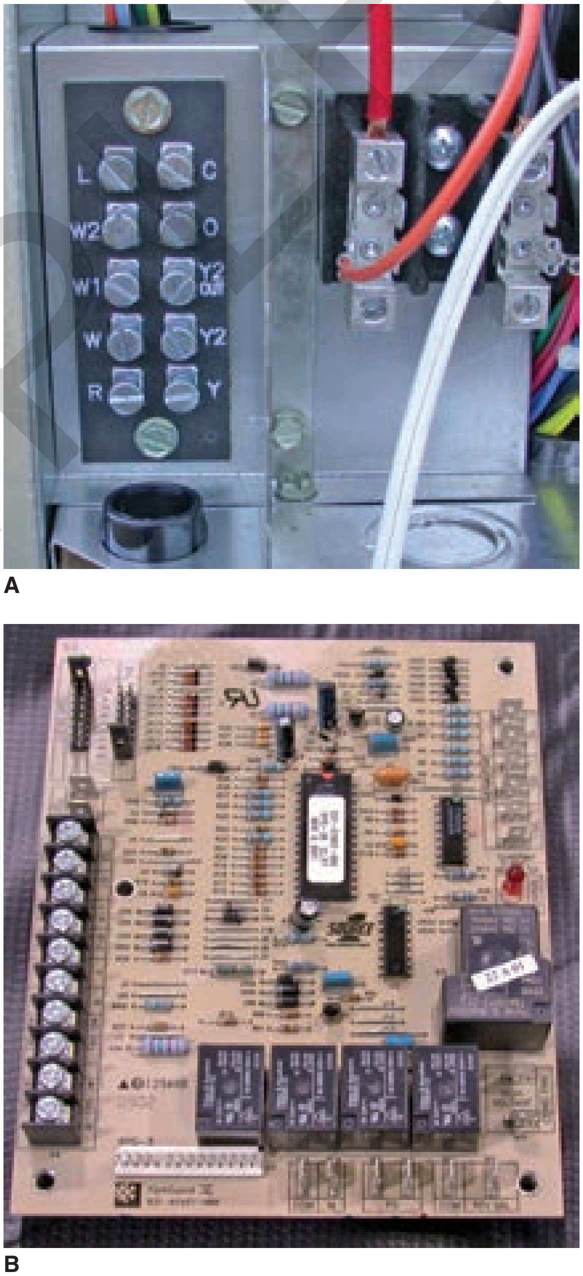
Removing an installed thermostat reveals its subbase. Wiring terminals with letters show what parts of a system are controlled by the thermostat, **Figure 23-32**. Look for the corresponding wiring terminals in a system's condensing unit, air handler, and any other system control board, **Figure 23-33**.

The subbase may also contain other components. Of importance to thermostat subbase installation are ***DIP switches***. *DIP* stands for *dual in-line package*. These are small switches grouped together in a single package. They are commonly found on circuit boards and used to manage system settings. Usually, they are positioned once for the commissioning of a system and then left alone. A subbase may have DIP switches used to indicate the type of heating and cooling system that will be connected to the thermostat, **Figure 23-34**.



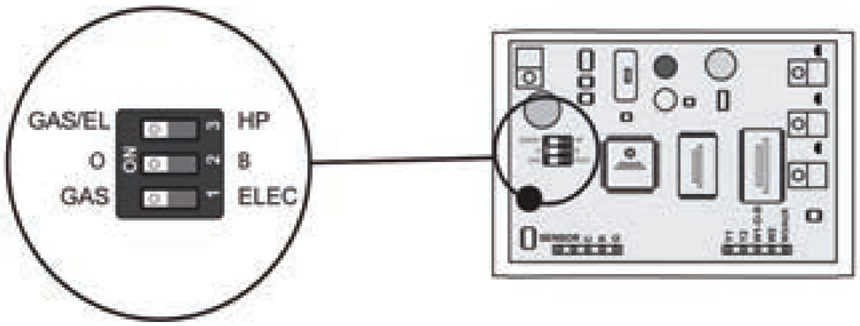
York International Corp.

Figure 23-32. Subbase of a low-voltage thermostat.



York International Corp.

Figure 23-33. Note the thermostat wiring terminals located on the left side. A—In a condensing unit. B—On a system control board.



Venstar

Figure 23-34. This thermostat subbase has three DIP switches. The top switch tells the thermostat whether the system is a heat pump or uses gas or electric heat. The middle switch determines whether the heat pump reversing valve is energized for cooling or for heating. The bottom switch tells the thermostat whether the system uses gas or electric heat.

After installing a new thermostat, always test it to make sure that it operates as it should. Some thermostats include some self-diagnostic capabilities. To check wiring connections before programming a thermostat, use the test outputs function available on certain thermostat models. This initiates operation immediately by bypassing any time delays, which confirms whether the wiring is correct before programming all days, times, and set points, **Figure 23-35**.

Free Cooling

Building owners and system designers continue to look for energy saving methods and technologies. A great way to reduce electrical power consumption is to use free cooling. However, this is only available under certain conditions. Indoor air must be warm and in need of cooling. Outdoor air must be low in temperature and preferably also low in humidity.

Free cooling is the use of an air-side economizer to draw in cool outdoor air to reduce indoor air temperature. An air-side economizer controls an HVAC system's blower and duct dampers. By opening and closing certain dampers, a system's blower can draw in the cool outdoor air and exhaust warm indoor air. This is considered *free cooling* because only dampers and the blower are using electrical power. The compressor does not run during free cooling. Since a compressor consumes much more electrical power than a fan does, using a few dampers and a blower to draw in cool outdoor air is comparatively, but not actually, "free," **Figure 23-36**.

A thermostat must be equipped to control free cooling. The thermostat will need to have an outdoor air temperature sensor connected. When outdoor air temperature is low enough, free cooling operation can begin. Some systems may also monitor outdoor humidity. For these systems, relative humidity must be low enough before operation begins. This is called *enthalpy control*. For more information on enthalpy control, see Chapter 25, *Commercial Air-Conditioning Systems*.

To operate free cooling, a thermostat often must be capable of controlling more than one stage of cooling operation. Stage one cooling (Y1) can be used to operate free cooling. Stage two cooling (Y2) can be used for running

Venstar

Figure 23-35. The test outputs function bypasses any time delays and initiates operation immediately. This function quickly checks the wiring connections and can be a quick starting point for troubleshooting a system.

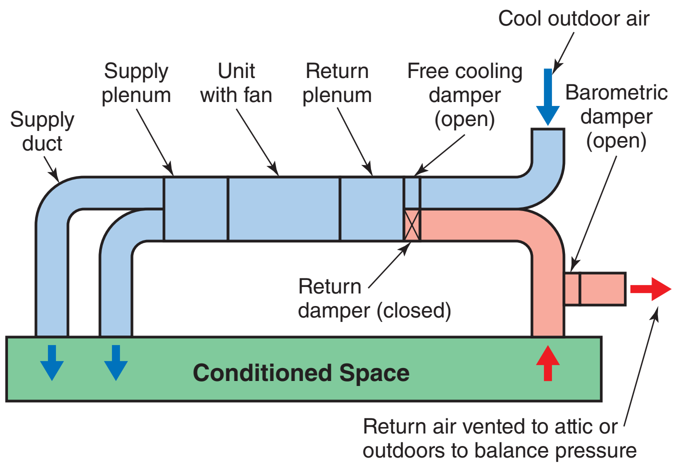


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Figure 23-36. A forced-air system diagram using an air-side economizer for free cooling. As indoor pressure rises, a barometric damper opens and releases return air to an unconditioned space or outdoors.

the air conditioning. Thermostat terminal Y1 controls the damper positions. The diagram in the example earlier showed two motorized dampers. To control and operate these dampers requires additional step-down transformers and relays. See the wiring diagram for controlling the free cooling damper in **Figure 23-37**.

When the outdoor temperature sensor senses the cut-in temperature (65°F in this example), the thermostat initiates stage one cooling (Y1) for free cooling. The thermostat signals the damper relay, which energizes the free cooling damper. The indoor blower also turns on to begin drawing in the cool outdoor air. When outdoor air temperature rises too high or the thermostat is satisfied with the cooling indoors, the thermostat cycles off the free cooling operation.

Installing Wireless Thermostats

The use of wireless thermostats with remote sensors has made the location of such thermostats less critical. Remote, wireless temperature and humidity sensors allow the control to be placed in a convenient location, while the sensors are located in the best location to measure room conditions. The location of a thermostat sensor is important. Similar to a traditional thermostat, it should be located in an average-temperature location. An example would be an inner wall about 5′ above the floor. It should be out of the way of furniture and beyond the reach of small children. The location of a temperature sensor should be changed if it is affected by any of the following:

- Drafts or dead air spots behind doors and in corners.
- Hot or cold air from ducts.
- Radiant heat from the sun or an appliance.
- Concealed pipes and chimneys.
- Unheated areas behind it, such as an outside wall.

With ***Wi-Fi enabled thermostats***, a user can operate the thermostat while away from the building. Whole home automated systems enable a homeowner to monitor and adjust settings using an internet-connected device, **Figure 23-38**.

Wi-Fi enabled home automation systems include a controller that is connected to the building's lighting, window shades, and security system. Whole home automation allows maximum energy conservation. For example, at night the system can automatically reduce the thermostat set point, shut off room lights, and close blinds to conserve energy.

Control4 Corporation

Figure 23-38. Thermostat operation from a tablet and phone app.

Pro Tip

Setting Up Online Account and Downloading Apps

Learning and Wi-Fi enabled thermostats often require setting up an online account and downloading software to operate the thermostat from a wireless device or the internet. Following installation, remember to assist the homeowner in setting up their online account and selecting the correct app. This will allow the homeowner to monitor their energy savings and operate their thermostat remotely.

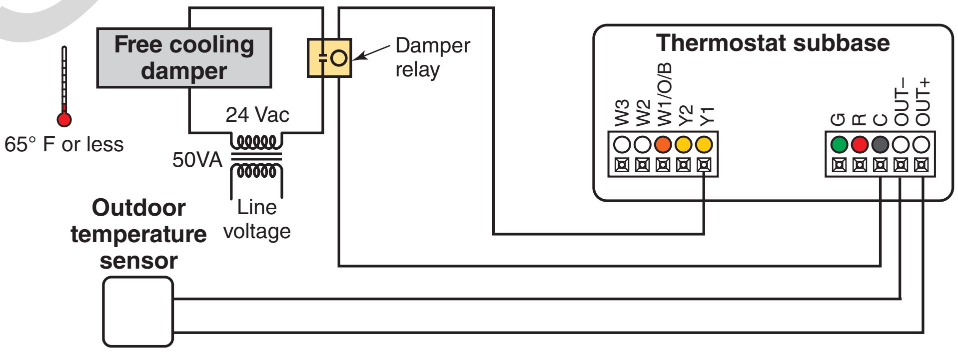

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Figure 23-37. A forced-air system wiring diagram for free cooling.

23.4.6 Installing Assembled and Charged Systems

Sometimes a split system is ordered completely assembled and charged. It will include the condensing unit, evaporator, controls, and tubing. The complete assembly is shipped as a single package. The tubing needed is usually wrapped around the evaporator.

Work required at the point of installation includes the following steps:

1. Uncrating and carefully unwinding the tubing from the evaporator.
2. Installing the condensing unit and evaporator in their proper places.
3. Making the necessary electrical and control connections.

This type of preassembled refrigeration system requires careful handling since it is charged with refrigerant. Be careful while uncrating the tubing to avoid creating kinks. The kinked areas might later crack and leak.

Another type of system consists of an evaporator, condensing unit, and line set that come as an unassembled but matched set, sized for the application. One or more of the components come precharged. The precharged components contain enough refrigerant for the entire system. The technician then connects the various components on-site.

Some manufacturers provide flare fittings for connecting the evaporator coil and compression or braze fittings for connecting the condensing unit. Other manufacturers provide ***quick-connect couplings*** for connecting the parts. These couplers may be connected without losing refrigerant or getting air into the system.

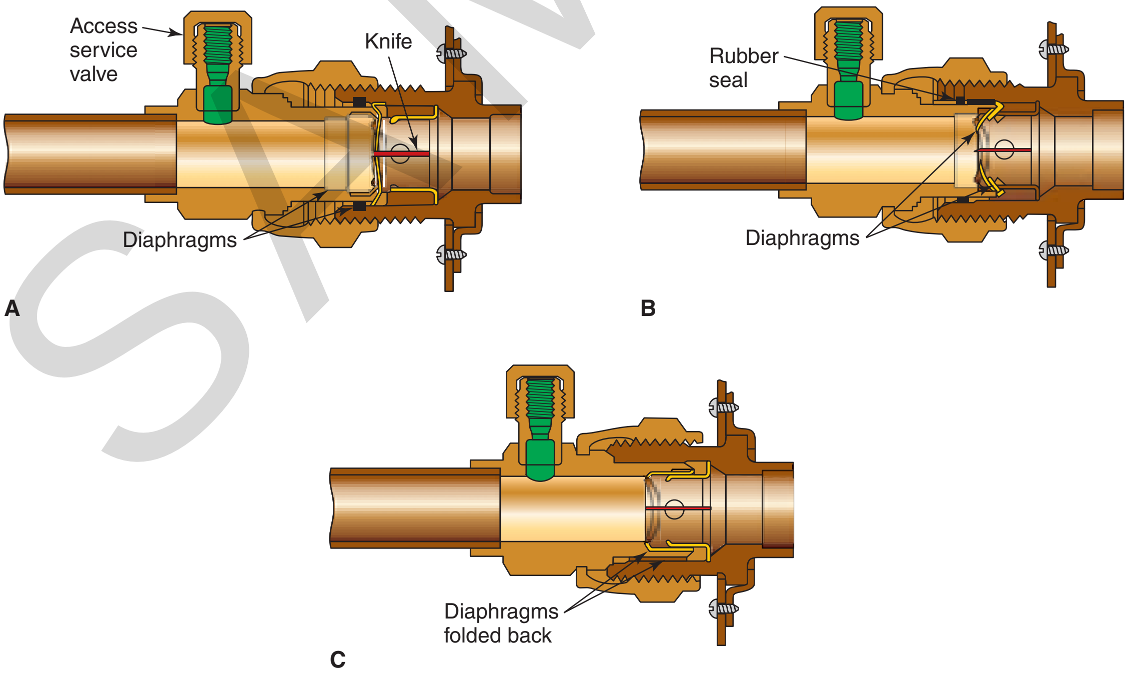
Quick-Connect Couplings

Quick-connect couplings enable manufacturers to produce precharged refrigeration and air-conditioning units. Necessary tubing is also provided in separate packages. These separate units can be assembled at the installation site. They are ready to operate without evacuating, charging, or cleaning.

Quick-connect couplings are brazed directly to the tubing. Flared joints are not needed. There are two types of quick-connect fittings:

- Those that can be connected and disconnected many times with very little loss of refrigerant. When this type of coupling separates, independent springs force valves in both halves of the coupling to close. This prevents the escape of refrigerant. This type of coupling is seldom used.
- Those that can only be quick-connected once. The ends of these couplings are sealed off with diaphragms. When the two halves of the coupling are connected, the diaphragms are punctured. This allows refrigerant to pass through the coupling. See **Figure 23-39**. If these couplings ever need to be disconnected, the refrigerant must first be removed from the system.

To assemble either type of quick-connect fitting, align the couplings and tighten the coupling nut. This draws the



Aeroquip Corp.

Figure 23-39. Quick-connect coupling equipped with a service valve. A—A knife edge aligns with and begins piercing the diaphragm. B—As the fitting is tightened, the diaphragm is punctured. C—When the diaphragm is punctured, refrigerant can flow through the coupling. The flow of refrigerant folds the remnants of the diaphragm out of the way.

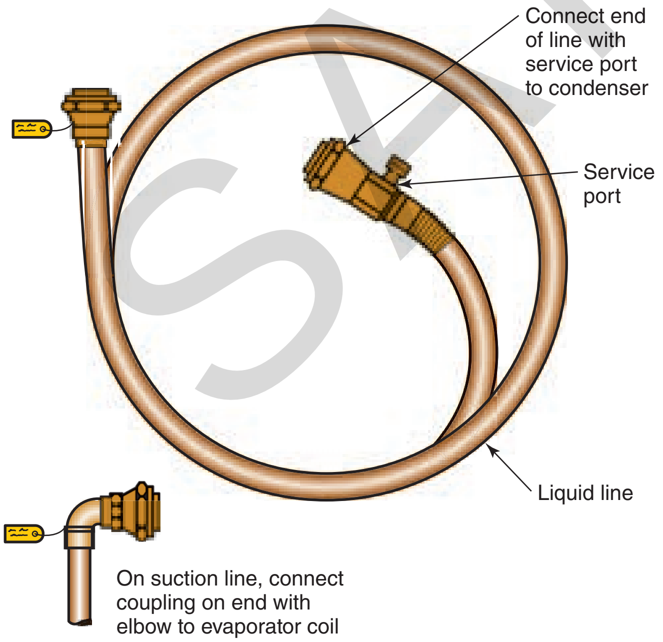
coupling together. Quick-connect fittings are used mostly on precharged residential air-conditioning systems. They are also used on precharged transportation units. Units are usually charged at the factory. The condensing unit, refrigerant lines, and evaporator are charged separately. **Figure 23-40** shows a liquid line that has an access (service) port.

The gasket that joins the quick-connect fittings should be covered with clean, dry refrigerant lubricant just before assembly. When tightening quick-connect fittings, avoid applying excessive pressure to the wrench. Excessive pressure may distort the fitting and cause it to leak. Two wrenches should be used to tighten the fitting to prevent the tubing from twisting, **Figure 23-41**. Certain quick-connect fittings can be resealed several times with the use of a special tool.

23.5 Servicing Central Air-Conditioning Systems

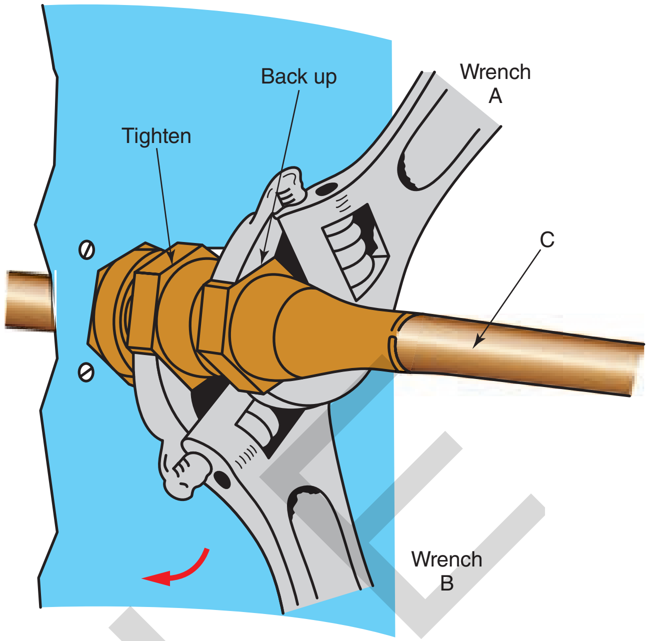
For residential air-conditioning systems, service generally falls into three categories:

- Scheduled periodic maintenance. Scheduled maintenance is normally performed annually on residential air-conditioning systems, preferably before the start of the cooling season. Scheduled maintenance consists of inspecting and cleaning to ensure proper operation.
- Unexpected problems. Unexpected problems occur when the owner notices that the system is not operating properly and contacts the service provider to schedule a service call.



York International Corporation, Unitary Products Group

Figure 23-40. Liquid line equipped with quick-connect fittings. The service port is used for making gauge manifold high-side pressure connections.



Aeroquip Corporation

Figure 23-41. Correct way to tighten a quick-connect coupling. Wrench A is held firmly while wrench B is turned. Note that the sleeve closest to the wall turns, but the sleeve on tubing C does not.

- System replacement or expansion. This type of service involves adding to an existing air-conditioning system or replacing parts of the existing system with new equipment.

23.5.1 Scheduled Periodic Maintenance

The purpose of an annual inspection and cleaning is to ensure that the system is ready for the upcoming cooling season. The service includes a visual inspection and measurements to identify potential problems.

Each HVACR service company has a procedure for annual air-conditioning system maintenance. The following is a list of items generally included in the procedure:

General

1. Refer to the manufacturer's annual maintenance list for the specific equipment in the air-conditioning system. Note any item not included in your company's general checklist.
2. If you have access to previous service records for the residence, compare the measurements from the previous maintenance with the current measurements.

In Residence

1. Record thermostat type (nonprogrammable, programmable), mode setting, and temperature setting. Record indoor wet-bulb temperature, dry-bulb temperature, and relative humidity.
2. Inspect the duct registers; note if registers are fully open, partially open, or closed. Note if any registers are blocked by furnishings or other items.

Condensing (Outdoor) Unit

1. Record the outdoor air temperature.
2. Check the ground surrounding the condensing unit for signs of erosion. Clear away any plants, shrubs, and branches from the outdoor unit so there will be good airflow across the condenser coil.
3. Inspect disconnect box, compressor and condenser fan motor capacitors, contactors, relays, circuit boards, electrical connections, and equipment grounding. Look for any signs of burning, damage, or wear.
4. Record the compressor amp draw and the condenser fan motor amp draw.
5. Inspect the refrigerant lines and connections for damaged insulation, signs of leaks, or other damage.
6. Record suction and discharge pressures.
7. De-energize the unit at the disconnect box (test to ensure that no voltage is present) and clean the condenser coil. The condenser should be blown clean of debris. Any bent fins should be straightened. A carbon dioxide blower or vacuum cleaner can be used to clean the unit. Pressurized washing wands are useful to clean the coils from the inside out, **Figure 23-42**. Clean the fan blades if needed.

SpeedClean

Figure 23-42. This technician is using a pressurized mix of chemicals and water flowing outward through the condenser coils.

Thinking Green

Dirty Coils Decrease Efficiency

Dirt on evaporator and condenser coils decreases the coil's ability to transfer heat and, in extreme cases, increases resistance to airflow across the coil. To keep the system operating at maximum efficiency, the coils should be cleaned regularly.

Air Handler (Indoor Unit)

1. Clean or replace the air filter.
2. Inspect disconnect box, indoor fan motor capacitor, contactors, relays, circuit boards, electrical connections, and equipment grounding. Look for any signs of burning, damage, or wear.
3. Record the blower motor amp draw.
4. Record static pressure and ΔT across the evaporator. Compare measurements to manufacturer's target.
5. De-energize the unit at the disconnect box (test to ensure that no voltage is present) and clean the evaporator coil.
6. Inspect condensate pan and drain for biological growth. Clean pan, drain, and condensate trap and piping. Condensate that escapes the drain pan may drip on the furnace heat exchanger, corroding (rusting) it. If the condensate drain is clogged, it may be possible to blow out the blockage using compressed gas, **Figure 23-43**. Place algaecide tablets in the pan. See **Figure 23-44**.
7. Inspect and clean the blower. Lubricate the motor as appropriate. If the fan is belt-driven, inspect the belt and pulleys for wear. Check the belt for proper tension.
8. Inspect the refrigerant lines and connections for damaged insulation, signs of leaks, or other damage.
9. Inspect all ductwork for leaks and broken dampers. Make sure that all supply ducts and returns are not obstructed, and that sufficient airflow is observed.

Pro Tip

Educating Your Customer

An annual maintenance service visit provides an opportunity to educate the homeowner about how the air-conditioning systems operate, the value of maintenance, and any specific indicators of problems that the homeowner can monitor.

23.5.2 Troubleshooting Central Air-Conditioning Systems

Many service calls are initiated by unexpected problems. In these cases, the air-conditioning system is not operating properly. The homeowner observes a problem and requests service.

There are several possible causes of comfort cooling–related service calls:

- No cooling or insufficient cooling.
- Indoor air too humid.

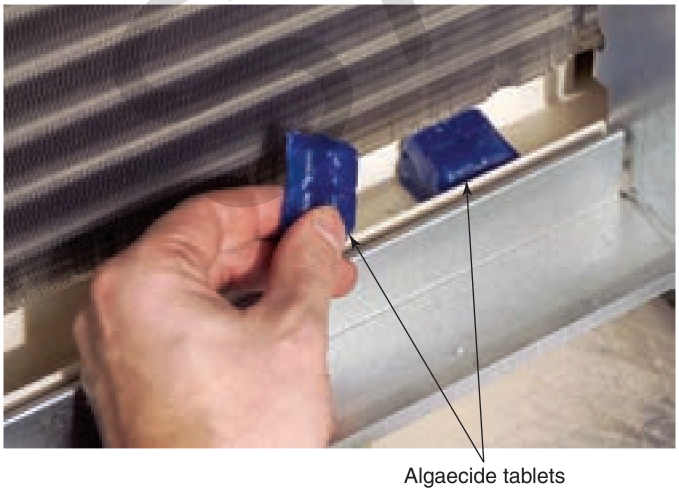
- Air in building is stuffy (stale).
- Excessive (indoor or outdoor) noise.
- High cost of operation.
- System will not start.

When servicing a system with an unknown root cause, use a systematic troubleshooting procedure. The general systematic troubleshooting procedure shown in **Figure 23-45** was introduced in Chapter 3, *Service Calls*. The following are the steps in this general procedure:

- **Customer interview.** The customer may be able to provide information that will help you troubleshoot the system, but you must ask the right questions. **Figure 23-46** lists some sample questions that may result in useful information.
- **Initial inspection.** Often, the initial inspection will provide clues to the cause of the problem or at least to potential issues with the system. As you perform

DiversiTech Corporation

Figure 23-43. This drain cleaning gun blows away drain blockages using dry, compressed carbon dioxide.



DiversiTech Corporation

Figure 23-44. Placing algaecide tablets in the condensate drain pan.

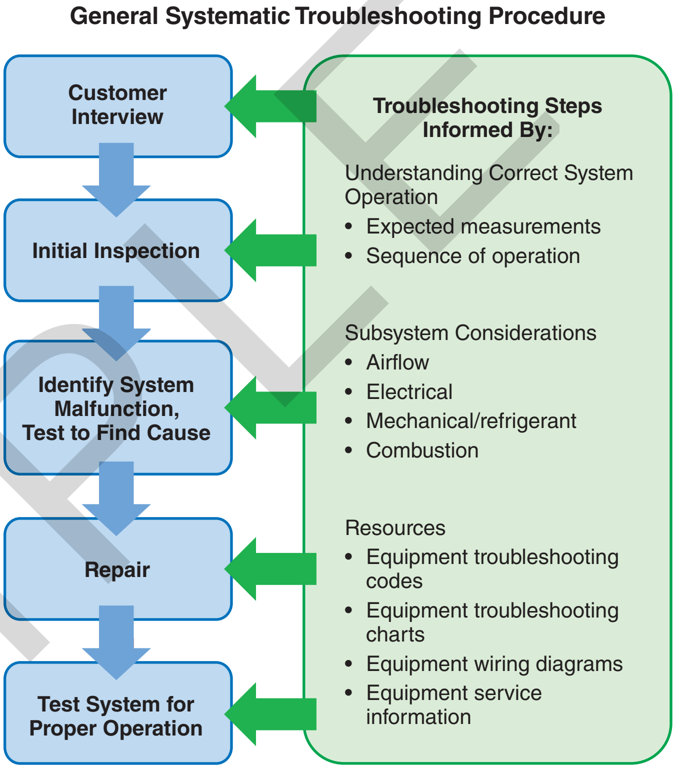


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Figure 23-45. This general troubleshooting procedure can be used to service any HVACR system, including air-conditioning systems. A thorough understanding of proper system operation is critical for successful troubleshooting.

Customer Interview Questions
Residential Air-Conditioning Service Call

- ✓ Please describe the problem you are having with your air-conditioning system.
- ✓ When did you first notice this problem?
- ✓ How was the system working before this problem occurred?
- ✓ Did you do anything about the problem? If so, what did you do?
- ✓ When is the last time the system was serviced?
- ✓ Has the system had other problems? If so, what was the problem and when did it occur?
- ✓ How old is the system?
- ✓ Have you had any work done on your house recently?
- ✓ Have you ever performed any repairs or modifications to the system?

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Figure 23-46. Potential questions for use during the customer interview stage of an air-conditioning system service call.

the initial inspection, consider the three subsystems of an air-conditioning system: airflow, electrical, and mechanical/refrigerant.

- **Identify system malfunction, test to find cause.** The initial inspection may reveal or suggest system malfunctions. Use equipment-specific troubleshooting charts, wiring diagrams, and other service material to help pinpoint potential faults.
- **Repair.** Once a fault has been identified, discuss the needed repair and the cost of the repair with the homeowner. If the homeowner approves the work, perform the repair.
- **Test system for proper operation.** After making a repair, restart the system and let it run for at least 10 minutes. Then take measurements to ensure that the system is operating properly.

To execute any troubleshooting procedure, you must understand how the subsystems within the air-conditioning system operate to achieve proper system performance. This includes the sequence of operation for the system, **Figure 23-47**. A technician's prior experience with the specific equipment will also inform the troubleshooting process.

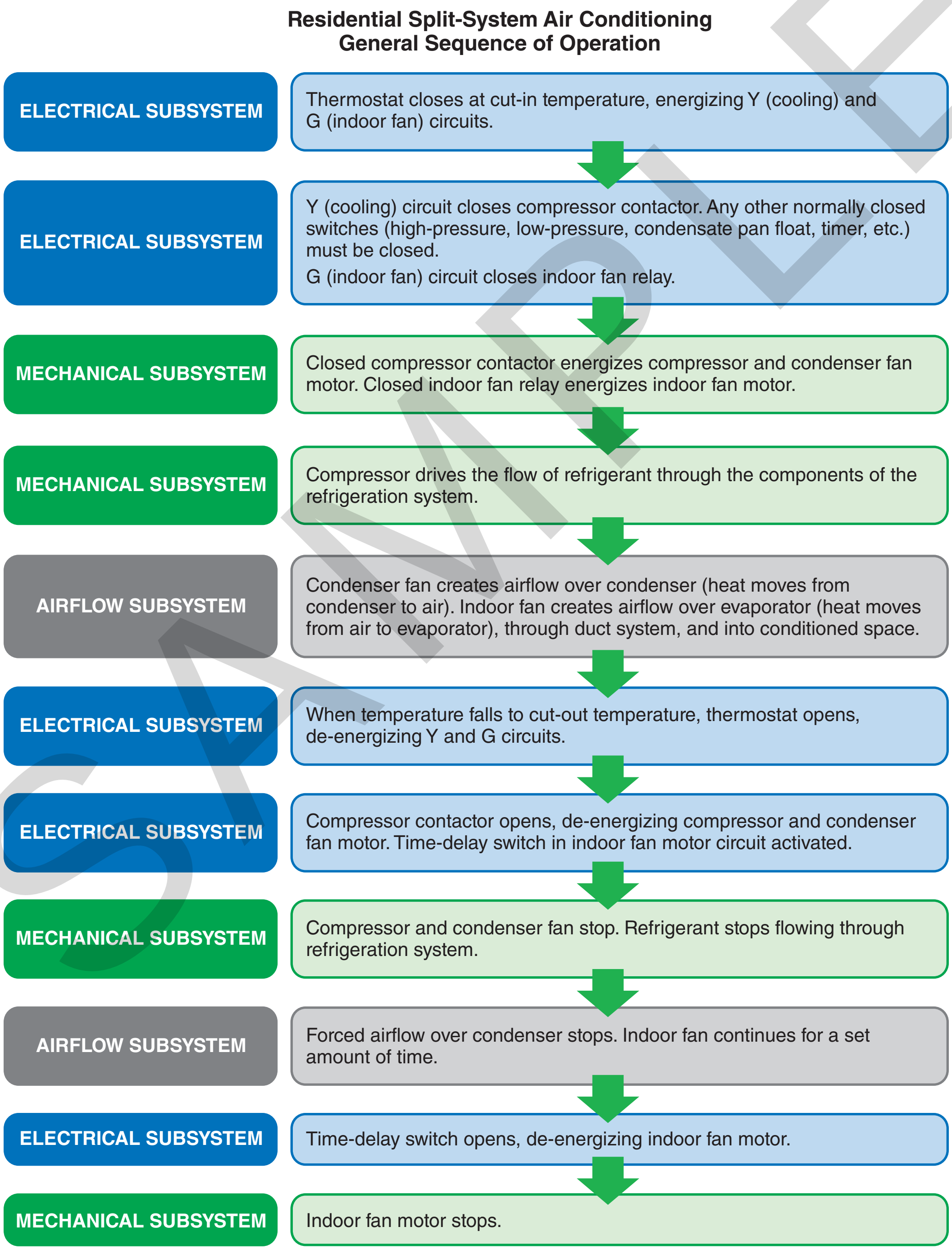

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Figure 23-47. A simplified sequence of operation for a central air-conditioning system.

After the customer interview and initial inspection are completed, the system malfunction must be identified. This is accomplished by testing system components and comparing measured test results with expected values.

A general procedure for testing a central air-conditioning system is shown in **Figure 23-48**. Begin by investigating any potential faults identified in the customer interview or initial inspection.

Use equipment-specific troubleshooting codes and troubleshooting charts prepared by the manufacturer to guide your testing. Using equipment-specific tools is generally more effective than applying a generic troubleshooting method. Wiring diagrams, motor information, system design conditions, and other information is often found on stickers affixed to the inside face of access panels. See **Figure 23-49**.

Most air-conditioning system problems occur in the airflow or electrical subsystems. Thus, focus on these areas first. Ensure that the airflow subsystem is operating correctly before taking any measurements of the refrigerant system. If the airflow over the condenser and evaporator is not sufficient, other system measurements will be affected.

After the system airflow has been checked, focus on checks of the electrical system. Electrical testing is

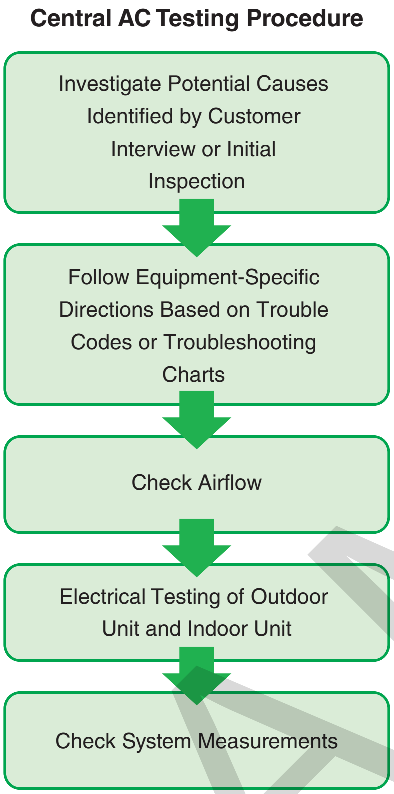

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Figure 23-48. A basic general testing procedure for identifying a fault in a central air-conditioning system. This procedure presents the steps in one possible sequence, but a different sequence could be used based on technician preference, experience with the specific equipment, or other factors.

Cool Air Corp.			
MODEL NO: 74ACDX383			
SERIAL NO: 1923F23499			
CONTAINS HFC-401A		DESIGN PRESSURE	
FACTORY CHARGE		HI 448 PSIG	
5 LBS 2 OZS		LO 236 PSIG	
ELECTRICAL RATING		NOMINAL VOLTS: 208/203	
1 PH	60 HZ	MIN 197	MAX 253
COMPRESSOR		FAN MOTOR	
PH	1	PH	1
RLA	12.8	FLA	1.1
LRA	64.0	HP	1/5
MIN. CKT. AMPACITY AMPERAGE MINIMUM	17.1	MAX FUSE OR CKT. BKR. FUSIBLE/COUPE CIRCUIT (HACR PER NEC)	25

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Figure 23-49. A condensing unit will have a label with information about the compressor motor, condensing fan motor, and system design pressures.

Service Call Troubleshooting — 23A: Residential Central Air Conditioning: Poor Cooling

Overview

The owner of a 1500 ft² residence, Mr. Gonzalez, has reported that his split central air-conditioning system seems to be running constantly but is not able to cool the house enough to reach the temperature set on the thermostat. Upon arriving at the residence, the technician, Sharon, identifies herself and verifies that Mr. Gonzalez requested service. Before entering the residence, Sharon puts on shoe covers.

Customer Interview

Sharon asks Mr. Gonzalez a few questions before beginning her inspection.

Analyze and Discuss

1. Based on the information provided, list three questions Sharon could ask Mr. Gonzalez.
2. What is Sharon hoping to learn from the questions she asks?

discussed generally in Chapter 18, *Electrical Troubleshooting Fundamentals* and detailed troubleshooting of thermostats is explained in the following section. If a compressor motor, condenser fan motor, or indoor fan motor is not starting, check to see if the proper voltage is available at the device. If voltage is available, the problem is with the motor. If the proper voltage is not available at the device, troubleshoot the 24 V control circuit and the power circuit to find the fault.

If the problem does not appear to be an electrical problem and the system is operating, measure the operating conditions and compare the measurements to the manufacturer's design specifications. The following measurements will help identify potential problems:

- Suction pressure
- Discharge (head) pressure
- Superheat
- Subcooling
- Compressor amperage draw
- ΔT across evaporator

The table in **Figure 23-50** shows how some common refrigerant system problems impact these measurements.

Service Call Troubleshooting — 23B: Residential Central Air Conditioning: Poor Cooling

Overview

Continuing from *Service Call Troubleshooting* 23A, Sharon completes the customer interview with Mr. Gonzalez.

Initial Inspection

Sharon first inspects the thermostat, then the indoor air handler, and finally the outdoor unit.

Analyze and Discuss

1. When Sharon inspects the thermostat, what are some things she should be checking?
2. When Sharon inspects the indoor unit, what are some things she should be checking?
3. When Sharon inspects the outdoor unit, what are some things she should be checking?
4. What is the purpose of inspecting the system prior to beginning testing to find a problem?

System Problems with Corresponding Measurement Change

Problem	Suction Pressure	Discharge (Head) Pressure	Superheat	Subcooling	Compressor Amps
Undercharge	↓	↓	↑	↓	↓
Overcharge	↑	↑	↓	↑	↑
Liquid line restriction	↓	Normal ↓	↑	↑	↓
Suction line restriction	↓	↓	↑	↑ Normal	↓
Heavy load	◦	◦	◦	◦ Normal	◦
Light load, low evaporator airflow	↓	Normal ↓	↓	Normal ↓	Normal ↓
Noncondensables, condensing coil restriction	↑	↑	↓	↓	↑
Low outdoor ambient temperature	↓	↓	↑	↑ Normal	↓
High outdoor ambient temperature	◦	◦	◦	Normal	◦
Dirty condenser, low outdoor airflow	◦	◦	Normal ↓	Normal ↓	◦
Evaporator coil restriction	↓	↓	↓	↓	↑
Overfed metering device	↑	↓	↓	↓	↑
Underfed metering device	↓	↓	↑	↑	↓

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Figure 23-50. This chart provides a list of some common air-conditioning system problems and their impact on various system measurements.

Service Call Troubleshooting — **23C: Residential Central Air Conditioning: Poor Cooling**

Overview

Continuing from *Service Call Troubleshooting* 23A and 23B, Sharon's customer interview with Mr. Gonzalez revealed no significant information other than confirming that the system has not had any previous problems. Her initial inspection also did not identify any potential problems. All system components are operating, but the system is not able to keep up with the moderate cooling load.

System Testing

Sharon begins testing the system with the goal of identifying the problem.

Analyze and Discuss

1. What are some items that could aid Sharon in her system troubleshooting?
2. What would be a good overall approach for Sharon to apply to find the cause of the problem?
3. What would be a poor approach for Sharon to apply?
4. What is the difference between a good troubleshooting approach and a bad troubleshooting approach?

23.5.3 Thermostat Diagnostics

It is good practice to begin troubleshooting a comfort cooling or heating system using the thermostat. This is a quick way of locating the source of system malfunction. The process usually determines that the cause is one of the following:

- Wiring problem.
- Furnace/air handler problem.
- Thermostat problem.

The diagnostic sequence for a heating thermostat and a cooling thermostat is almost the same with two major differences in operation. A heating thermostat is considered "calling for heat" if the setting on the thermostat is two or more degrees *over* room temperature. A cooling thermostat is considered "calling for cooling" if the set point is two or more degrees *under* room temperature. A technician can check whether a thermostat is operating according to these principles by measuring voltage across its electrical terminals. See **Figure 23-51** for terminal configuration for heating and cooling operation.

Before checking voltage, make sure the thermostat's fan switch is set to auto. When taking a voltage reading, the meter is sensing a difference in electrical potential. The voltage across an "open" connection is the source voltage. The voltage across a "closed" connection is 0 V. There is no voltage difference between the two sides of a closed switch, **Figure 23-52**.

Before taking measurements, determine what type of thermostat is installed. The two most commonly used thermostats are low-voltage and line-voltage. On a low-voltage thermostat, source voltage will most often be 25–28 Vac. On a line-voltage thermostat, source voltage will be 120 Vac or 240 Vac. Always use a meter to identify what the source voltage is before attempting any diagnostics or repairs.

Cooling System Diagnostics

Diagnosing a cooling system problem using a thermostat is similar to diagnosing a heating system problem. The main difference is to check across terminals R and Y and also across terminals R and G, instead of R and W. When a thermostat is calling for cooling, the R to Y terminals will be closed to energize the cooling contactor or relay in the condensing unit. In addition, the R to G terminals will be closed to energize the relay controlling the indoor blower motor.

Thermostat Terminal Checking Chart

Wiring Terminals	HVAC System Mode of Operation: Heating On	HVAC System Mode of Operation: Cooling On
R and W	Closed	Open
R and Y	Open	Closed
R and G	Open	Closed

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Figure 23-51. A thermostat's electrical terminal configurations for a comfort heating and cooling system. This table assumes that the thermostat's fan setting is on auto.

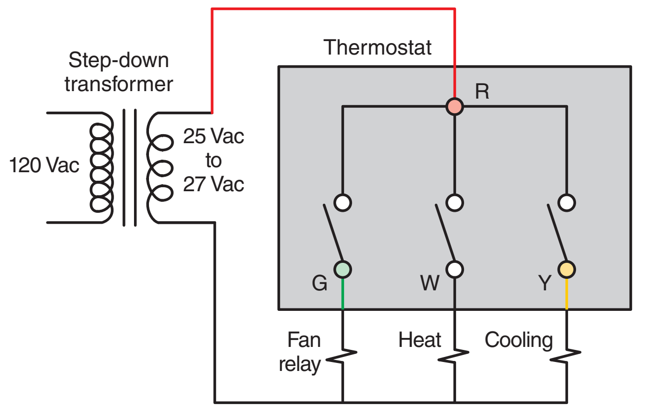

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Figure 23-52. A basic low-voltage thermostat wiring diagram.

Thermostat Vibration — Pro Tip

If a building owner notices that a system frequently turns on and then off without running for the entire duration of its scheduled operation, seek out the location of the thermostat. Systems may short cycle because the thermostat is exposed to vibration. Examples would include stairways or shaky walls. Always mount a thermostat to a firm structure.

Multistage HVAC Systems

Thermostats that have a W2 or Y2 terminal are considered multistage thermostats. A thermostat in heating mode will not close across terminals R and W2 until the temperature drops down below the set point by more than 3°F, in most cases. In cooling mode, terminals R and Y2 will not close until the temperature rises above the set point by more than 3°F. These temperature separations between first and second stages are adjustable in many cases. When troubleshooting second-stage problems, be sure to adjust the thermostat to close the correct terminals.

Low-Voltage Measurements

Voltage readings of 24 Vac and below do occur on low-voltage circuits, but this low value should be seen as a sign of a problem. A 24 Vac measurement means that the transformer is aging or one of the loads on the circuit is pulling more electrical current than can be provided by the transformer. In some cases, this can be caused by the addition of accessories that draw more current into the circuits. Take measurements to find if a high current draw is causing the excessive voltage drop.

More Than Just Measurements — Pro Tip

While working through a system and taking amperage readings at each load, listen to the loads in operation. Chattering contactors or relays are a sign that a load is not functioning properly. Be certain to run through all modes of operation (heating, cooling, fan-on, and fan-auto), as each mode energizes different control voltage loads. If the system uses a heat pump, check the reversing valve and run through the defrost sequence.

Procedure — Diagnosing a High Current Draw on a Transformer

When looking for voltage drops or high current draws, you apply the principles of Ohm's law. Electrical loads in series drop voltages. Loads in parallel add amperages. For a control circuit that has low voltage, rule out one of these problems and focus on the remaining.

1. Begin by tracing the thermostat circuit from the step-down transformer to the R terminal at the furnace or air handler, then to the thermostat, and then to the heating relay or cooling contactor. Look for any electrical loads that are connected in series with these conductors.
2. If you find a load that should not be in the circuit, remove it and retest the voltage to see if the problem is solved.
3. Trace the parallel loads in the circuit. While tracing the circuit, create a ladder diagram schematic that includes all the electrical loads, switches, and other devices. If a manufacturer's schematic is available, use it as a guide but verify that the actual system matches the schematic. The circuit may have been modified after being installed. While tracing through the circuit, look for any add-on devices, such as humidifiers, air cleaners, and zone control panels. All of these devices should have their own transformers but may be installed incorrectly. Always refer back to manufacturer directions regarding proper installation practices and wiring recommendations.
4. After identifying all the electrical loads in the control circuit from the secondary side of the step-down transformer back to common, add all the current ratings, then multiply this total by the control circuit voltage (typically 24 V) to determine the actual volt-amperes (VA) load. This value should be less than the VA rating of the secondary of the transformer. If the number is not lower, replace the transformer with another transformer that has a VA rating greater than the value calculated.
5. Check the amperage of each load. Start with one branch of the parallel circuit and use a clamp-on ammeter that has a .10 A scale. If that is not available, wrap the wire around the clamp 10 times and then divide the resulting reading by 10. Energize the circuit and record each reading on the ladder diagram.
6. Compare each amperage load measurement with the current rating on the device's label. The current measured should never be greater than the current rating on the label of the electrical load. If it is greater, replace that electrical load. Most low-voltage loads cannot be repaired.

Note: There are certain electrical loads to look at more closely. These include the following: cooling contactors in the condenser, time delay relays in the condenser, fan relays in the air handler, solenoids in the liquid line, gas valve solenoids, zone dampers, zone control panels, zone valves, gas ignition controls, oil primary controls, and some thermostats themselves.

Overview

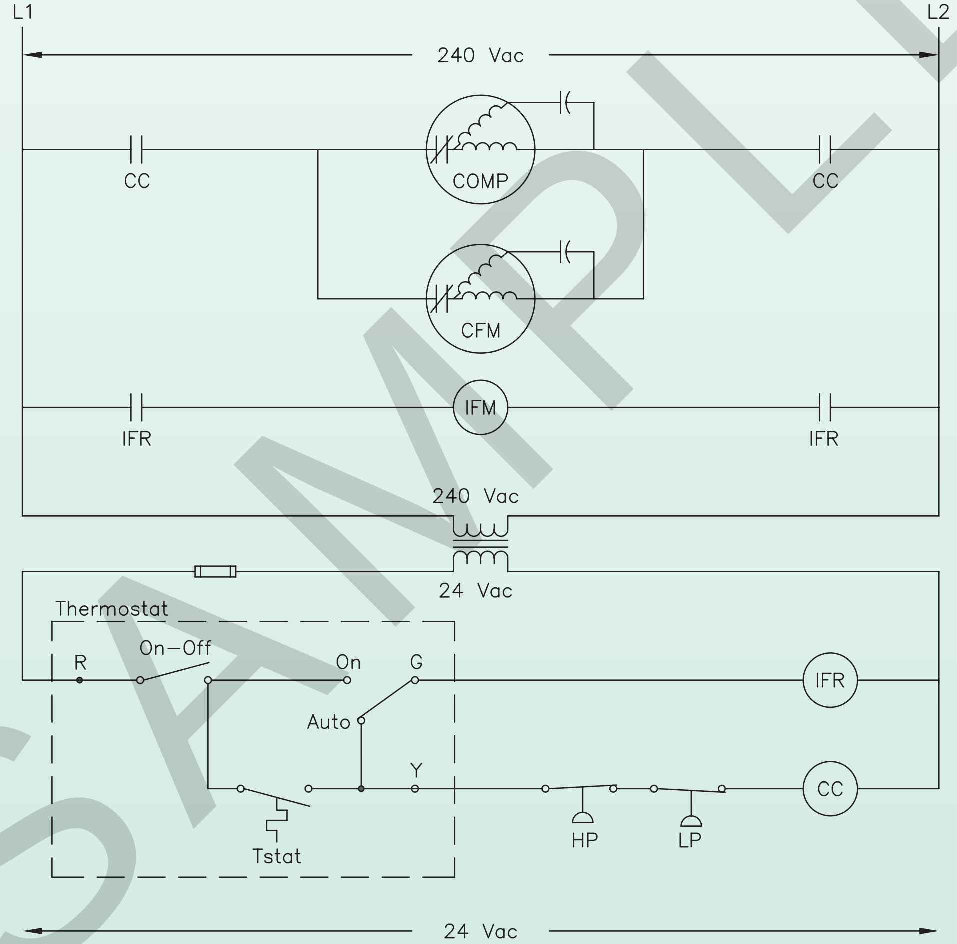
The owner of a 2300 ft^2 residence, Mr. Floyd, has reported that his split central air-conditioning system is not providing cooling. Upon arriving at the residence, the technician, José, identifies himself and verifies that Mr. Floyd requested service. Before entering the residence, José puts on shoe covers.

Customer Interview

Mr. Floyd explains that the air-conditioning system is not blowing cold air, so he turned the thermostat to Off. José asks questions to learn that Mr. Floyd noticed the problem the previous day and that the system had been operating fine two days ago. José also learns that the system was serviced earlier in the year and that no repair work has been needed for the system.

Initial Inspection

José begins by inspecting the thermostat. The digital display is working. José inspects the indoor unit and finds that the air filter appears to have been changed recently. He inspects the interior of the air handler and sees nothing that indicates a problem. The ductwork looks fine and there are no signs of leaks on the refrigerant tubing. José inspects the outdoor unit and does not see any problems. The simplified ladder diagram for the system is shown here.



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System Testing

José sets the thermostat to call for cooling. He hears the thermostat click and hears the indoor blower start. He goes to the outdoor unit and observes that the compressor starts, runs briefly, and then stops. The condenser fan does not start.

Analyze and Discuss

1. Based on the information provided, what are some possible causes of the problem?
2. What could be some useful tests for José to perform to identify the problem?
3. Select one of the possible causes you identified in Question 1 and describe the procedure for repairing the issue.
4. After completing the repair described in Question 3, how would José check to ensure that the repair was done correctly? How would José check the system to ensure that the repair solved the original problem?

23.5.4 Closing a Troubleshooting Service Call

After repairing a thermostat wire problem or replacing a thermostat, ask the customer if they want to keep the broken part. If not, remove and properly dispose of any parts or digital thermostats. In addition, survey the workspace and double-check that any jumpers have been removed, covers replaced, and electrical switches returned to their proper position. Show the customer that the repair worked and help them set the thermostat for their comfort. Make sure to leave any manuals or paperwork that came with the thermostat.

If any older thermostats were replaced with a web-enabled internet thermostat, ensure that the customer knows how to access the thermostat from their computer or smartphone. Taking the time to make sure the customer fully understands the equipment now will increase the customer's satisfaction and may prevent a callback in the future.

Service Call Troubleshooting | **23E: Residential Central Air Conditioning: No Cooling**

Overview

The owner of an 1800 ft^2 residence, Ms. Washington, has reported that her split central air-conditioning system is not providing cooling. Upon arriving at the residence, the technician, Maria, identifies herself and verifies that Ms. Washington requested service. Before entering the residence, Maria puts on shoe covers.

Customer Interview

Ms. Washington explains that the air-conditioning system has been blowing hot air for the past two days. "I don't get it. It's over 80°F in here. I set the temperature for 75°F, but it's blowing hot air! Do I need a new system?" Maria asks questions to learn that Ms. Washington noticed the problem the previous day and that the system had been operating fine. Maria also learns that no repair work has been needed for the system in the past few years.

Initial Inspection

Maria begins by inspecting the thermostat. It is calling for cooling and set to 75°F, and the current temperature is 82°F. Maria inspects the indoor unit and finds that the blower is running and the air filter appears clean. She inspects the interior of the air handler and sees nothing that indicates a problem. The ductwork looks fine and there are no signs of leaks on the refrigerant tubing. Maria inspects the outdoor unit. The outdoor unit is quiet. Neither the compressor nor the condenser fan is running.

System Testing

Maria measures 240 V at the disconnect and then measures 240 V on the line side of the contactor. Wearing gloves and using a nonconductive tool handle, Maria presses in the contactor's contacts, and the compressor and condenser fan start and run as they should. When Maria releases the contactor's contacts, the compressor and condenser fan turn off.

Analyze and Discuss

1. Based on the information provided and the ladder diagram from *Service Call Troubleshooting* 23D, what are some possible causes of the problem?
2. If neither the compressor nor the condensing fan started when Maria manually closed the contactor, what should she consider as potential problems?
3. Select one of the possible causes you identified in Question 1 and describe the procedure for repairing the issue.
4. After completing the repair described in Question 3, how would Maria check to ensure that the repair was done correctly? How would Maria check the system to ensure that the repair solved the original problem?

Service Call Troubleshooting — **23F: Residential Central Air Conditioning: Poor Cooling**

Overview

Continuing from *Service Call Troubleshooting* 23C, Mr. Gonzalez's split central air-conditioning system is not cooling sufficiently. The technician, Sharon, has interviewed Mr. Gonzalez and inspected the system, but neither activity has suggested any specific potential causes. Sharon now begins measuring some system performance values.

System Testing

Sharon attaches a gauge manifold to the service valves at the condensing unit and measures suction pressure and discharge pressure. She takes temperature measurements of the suction line and the liquid line and calculates superheat and subcooling. She also measures the amp draw of the compressor. She compares these values to the design values provided by the manufacturer for the equipment. She finds:

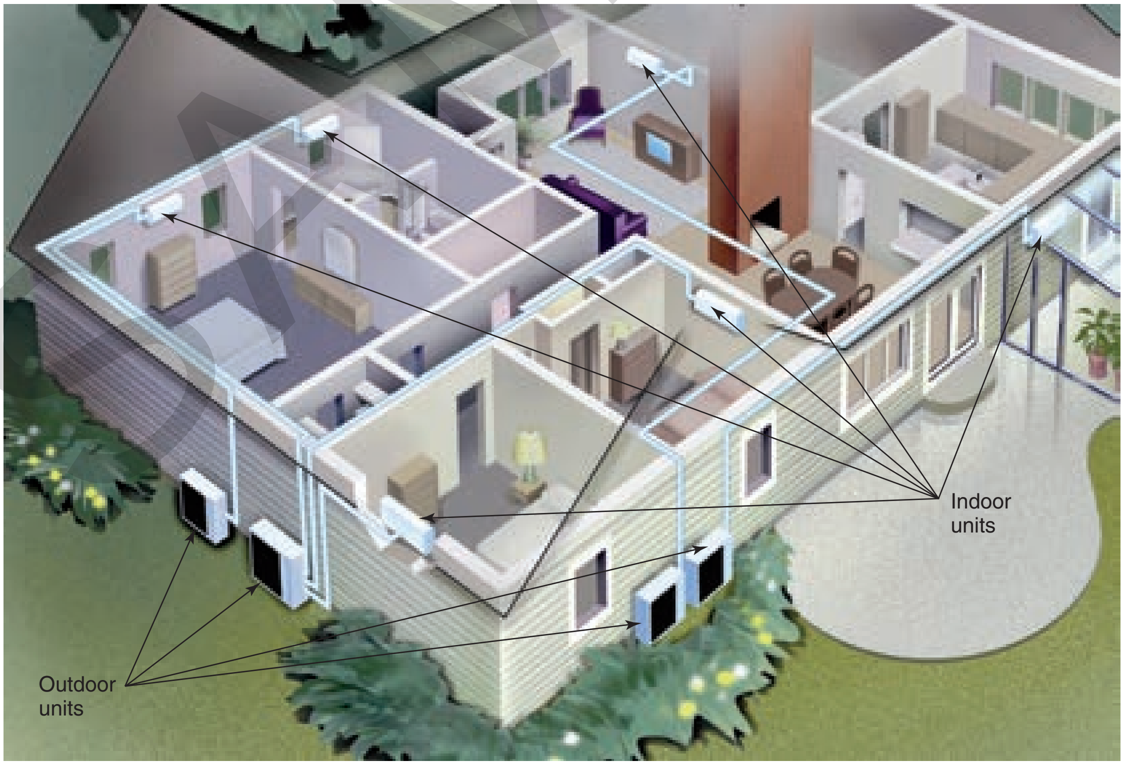
- Suction pressure is low.
- Discharge pressure is low.
- Superheat is high.
- Subcooling is low.
- Compressor amp draw is low.

Analyze and Discuss

1. Based on the information provided, what are some possible causes of the problem?
2. Select one of the possible causes you identified in Question 1 and describe the procedure for repairing the issue.
3. After completing the repair described in Question 2, how would Sharon check to ensure that the repair was done correctly? How would Sharon check the system to ensure that the repair solved the original problem?

23.6 Ductless Split Systems

A ***ductless split system*** is a split air-conditioning system that does not use forced-air ductwork as a primary means of distributing cooled air. Like a traditional split system, a ductless split system has an outdoor unit (compressor and condenser) outside a building that is connected by a line set to an indoor unit (evaporator) inside the building. Ductless split systems often use multiple indoor units throughout a building. These cool the air in individual rooms. The cooling units use fans to pull in warm air, absorb heat into the refrigerant in the evaporator, and blow cool air back into the room. No ductwork is used, **Figure 23-53**.



Mitsubishi Electric, HVAC Advanced Products Division

Figure 23-53. This multizone ductless split system consists of four outdoor units and six indoor units. Refrigerant line sets connect the outdoor units to the indoor units.

Ductless split systems are popular for adding air conditioning to both new construction and to older buildings that are not equipped with air duct systems. Ductless systems are frequently used in offices, motels, multifamily dwellings, and houses that use hydronic heating, electric baseboard heat, or space heaters. Ductless split systems offer a convenient solution for providing heating and cooling to room additions and small apartments, where extending or installing distribution ductwork for a central air conditioner or heating system may not be an option.

Ductless split systems can be categorized into three groups:

- **Mini-split systems.** Mini-split systems consist of one indoor unit and one outdoor unit. A mini-split is a single-zone system because the system has a single indoor unit.
- **Multi-split systems.** Multi-split systems consist of a single outdoor unit connected to several indoor units. In a single-zone multi-split system, each indoor unit has a line set connected to the outdoor unit. An outdoor unit may be able to support two to eight indoor units. In some cases, the indoor units are controlled by a single thermostat. In other cases, each indoor unit has its own thermostat.
- **VRF systems.** VRF (variable refrigerant flow) systems are multi-split, multizone systems. A single outdoor unit is connected to many indoor units, with each unit having its own thermostat setting. Instead of the individual line sets used in mini-split systems, VRF systems use a trunk and branch piping system to connect the outdoor unit to the indoor units.

Most ductless systems are available as cooling-only systems and as heat pump systems. The heat pump systems can reverse the refrigerant flow so the outdoor coil serves as the evaporator and the indoor coil serves as the condenser. VRF systems are available as heat pump systems and heat recovery systems. VRF systems are discussed in Chapter 25, *Commercial Air-Conditioning Systems*.

23.6.1 Ductless System Components

Ductless systems include three primary components: an outdoor unit, an indoor unit, and a line set that connects the two. Some systems, including VRF systems, include Y-fittings and distribution boxes in the line set distribution system.

The outdoor unit contains the compressor, condensing coil, and condenser fan. Outdoor units for heat pump systems include a reversing valve and often a defrost heater to prevent ice buildup in cold conditions. In single-zone mini-split systems, an EEV is typically contained in the outdoor unit.

Several types of indoor units can be used in ductless systems. See **Figure 23-54**. These indoor units are often called "heads." Wall-mount units are installed in the upper part of walls. Floor units are wall-mount units positioned on the lower part of the wall. Ceiling cassettes can be

Fujitsu General America, Inc.

Figure 23-54. The selection of an indoor unit type in the ductless system may be influenced by design, installation, or utility concerns. Various types of indoor units can be used in a single ductless system, providing flexibility.

installed flush with the ceiling or can be installed below the ceiling. Small ducted air handler units can also be included in a "ductless" system.

Each indoor unit has its own refrigerant coil, coil thermistor, air thermistor, blower, air filter, condensate pan, condensate drain, and electrical connection. See **Figure 23-55**. Indoor units on some systems will contain the metering device for the unit. Some indoor units may have a condensate pump or a heating unit.

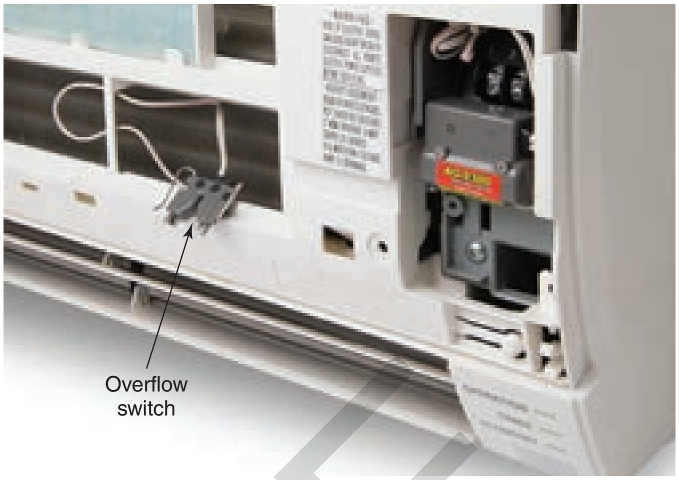
The thermistors measure the coil temperature and air temperature. These readings are continuously communicated back to the control board. Based on these readings, the system can adjust EEVs and the compressor output.

As an indoor unit operates, moisture condenses on the coil and flows into a condensate pan. Some units are designed to drain by gravity, and other units use a condensate pump. This moisture usually drains out. However, if the drain line becomes blocked or the condensate pump fails, water could overflow the pan. The overflowing water could damage walls, ceilings, flooring, and furnishings. To avoid an overflowing drain pan, many indoor units are equipped with an ***overflow switch***. See **Figure 23-56**. When the overflow switch senses, it opens a switch to shut off operation to the indoor unit. With no more refrigerant moving through the refrigeration coil, water stops condensing on the coil and draining into the pan.

Some indoor units include an occupancy sensor. An occupancy sensor senses when a room is occupied and when a room is not occupied. A system with occupancy sensors can be programmed to one temperature set point for an occupied room and a different set point when the room is unoccupied.

Mitsubishi Electric, HVAC Advanced Products Division

Figure 23-55. This indoor unit is shown with its cover and air filters removed.



RectorSeal

Figure 23-56. This overflow switch mounts to the condensate pan and turns off the indoor unit when an accumulation of condensate is sensed.

Typically, an indoor unit is controlled with a remote control, **Figure 23-57**. The remote control may be used to turn the unit on or off, change the temperature setting, change the fan speed, and change the direction of the supply air. Note that the thermostat is located in the unit, not in the remote control. Wall-mounted thermostats are also available with most systems.

A line set typically contains the refrigerant lines, electrical wiring, and a condensate drain. Electrical power is

Fujitsu General America, Inc.

Figure 23-57. Ductless split systems are easily programmed using a remote control or a smartphone app using WiFi.

supplied to the indoor unit through the line set, so a separate electrical connection is not needed for the indoor units.

> **Code Alert**
>
> **Indoor Unit Disconnect**
>
> Some building codes and building inspectors may determine that the outdoor electrical disconnect is too far from one or more indoor units. In these cases, an electrical disconnect for the indoor unit must be installed in a location acceptable to the authority having jurisdiction.

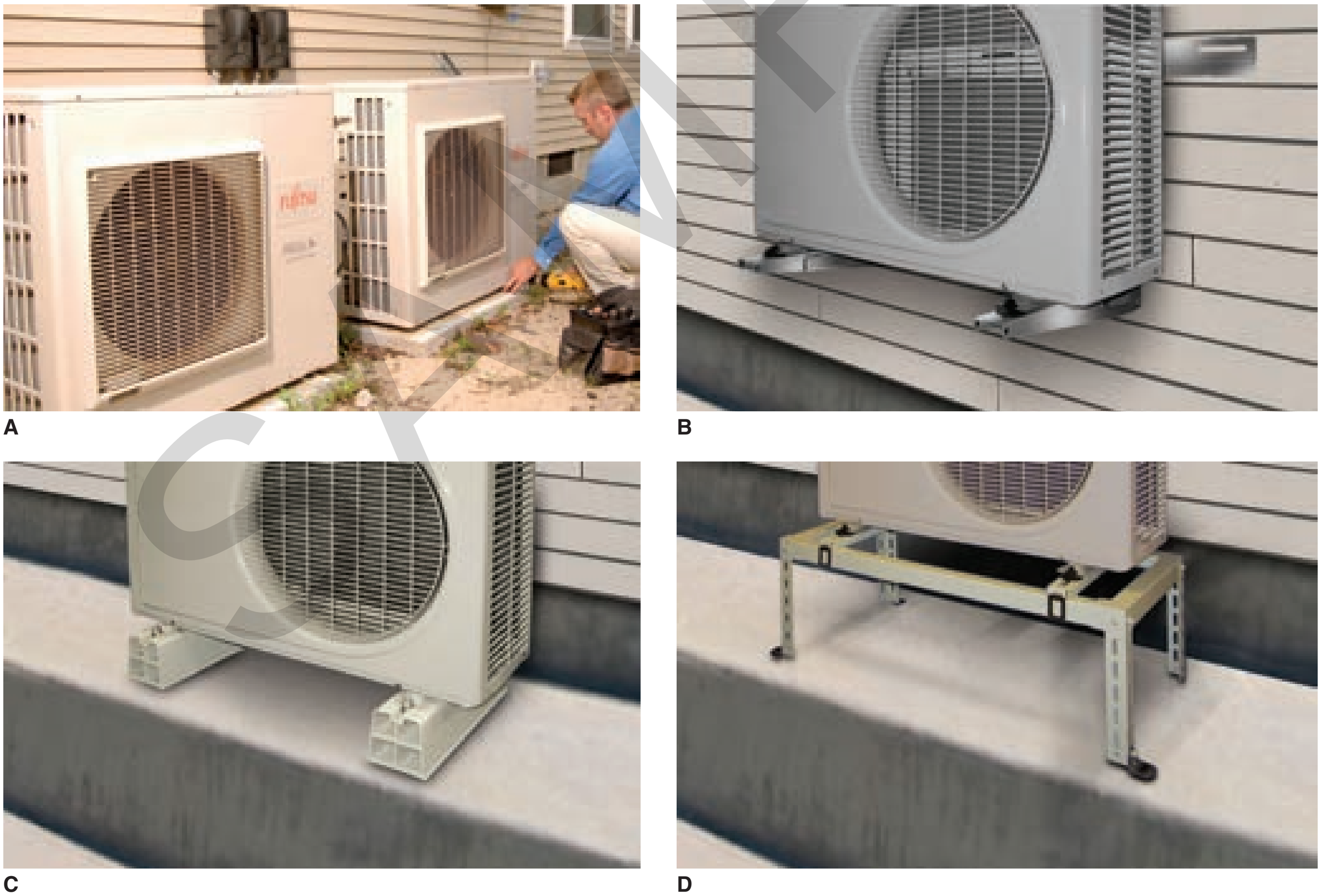
One common component that is typically not included in ductless systems is a filter-drier. Since ductless systems do not contain a filter-drier, extra care is needed to ensure that contaminants are not introduced into the refrigerant lines.

23.6.2 Ductless System Installation

Compared to installing a central air-conditioning system, installing a ductless system is generally much easier. However, with ductless systems, all installation instructions provided by the manufacturer must be followed. These instructions may vary from manufacturer to manufacturer and even from unit to unit, so always be sure to have the correct installation guides.

The outdoor unit is mounted outside. This can be done in a variety of manners depending on the building and the space available. Common installations are on a concrete slab, pads, a wall-mounted bracket, a riser, or metal stand, **Figure 23-58**. Larger outdoor units are often mounted on a concrete slab or mounting pad, **Figure 23-59**. Wall brackets include rubber mounts to keep the vibration from the unit from transferring into the house. When installing a unit on a concrete slab or mounting pad, be sure to maintain any required clearance under the unit. In addition, maintain all clearances around and above the outdoor unit as specified in the manufacturer's installation guide.

For heat pump systems in cold climates, the outdoor unit must be installed off the ground so it remains above any snow. If an outdoor heat pump unit is surrounded by snow, airflow through the outdoor coil will be blocked and the unit will not operate properly. The outdoor unit may include a base pan heater to defrost snow and ice. In these cases, the melted snow and ice must be able to drain away



Fujitsu General America, Inc.; RectorSeal

Figure 23-58. Ductless split system outdoor units. A—Two outdoor units mounted on pads. B—Wall-mounted bracket. C—Riser mounting. D—Metal stand mounting.

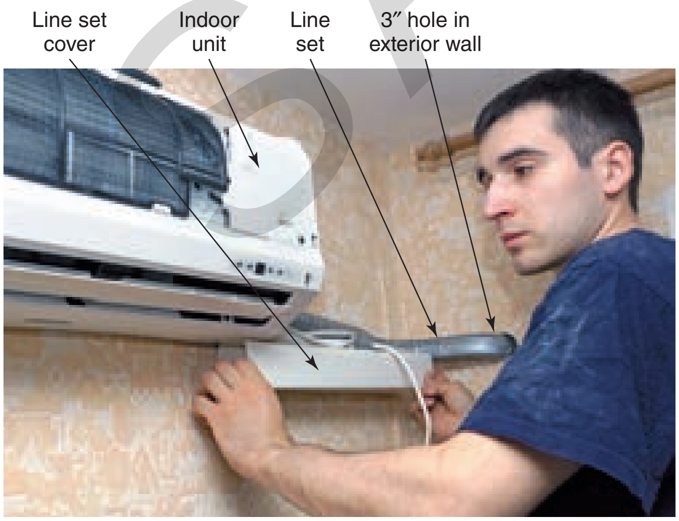
Fujitsu General America, Inc.

Figure 23-59. Two technicians positioning an outdoor unit on a mounting pad.

from the unit. If storms and wind generally come from the west, locating the outdoor unit on the east side of the home provides additional shielding for the unit.

To install a wall-mount indoor unit, first install the wall bracket. The wall bracket is attached to two wall studs. Be sure to level the wall bracket. If the bracket is not level, the unit will look crooked on the wall and the condensate drain may not function correctly.

After the wall bracket is installed, drill a 3″ hole in the wall for the line set. Use the installation guide to determine the hole's location. See **Figure 23-60**.



Shcherbakov Ilya/Shutterstock.com

Figure 23-60. A line set from the outdoor unit passes through the building's exterior wall and connects to the indoor unit.

Many indoor units are mounted on walls, near the ceiling. It can be difficult to hold the unit in place while necessary wiring and other connections are made. Once the wall plate is secured into place, a bracket can be attached to hold the indoor unit in place, **Figure 23-61**.

Ductless systems have minimum and maximum lengths for line sets. Line sets are also limited to a maximum vertical change. Always measure and record the line set lengths and verify that the measurements fall in the acceptable range for the product.

The condensate drain is generally 5/8″ flexible hose. Do not use 3/8″ clear plastic condensate tubing in a ductless system. This smaller tubing may bend, resulting in blockages. Any condensate drain issues are major problems with a ductless system because if the drain pan overflows, it will immediately cause damage in a living area. Slope the condensate drain hose a minimum of 1/4″ per foot. If a gravity drain is not possible, install a condensate pump.

Flared connections are used for the refrigerant line connections. (Flared connections are discussed in Chapter 5, *Working with Tubing and Piping*.) Poor flared connections are a common problem with ductless systems, so be sure to follow best practices when making these connections.

After cutting refrigerant tubing, point the cut end of the tubing toward the ground as you deburr or ream the inside edge. This way, any small tubing particles will fall out of the tubing. Ductless systems do not have a filter-drier to eliminate contaminants, so extra care is required. When making the flared connection, use a torque wrench to torque the flare nut to the specification in the installation manual.

After the refrigerant line connections, wiring connections, and drain connections have been made, the system is ready to be commissioned. First, the system is pressure tested. Follow the manufacturer's instructions, but

RectorSeal

Figure 23-61. This wall bracket allows an indoor unit to be securely held in place while connections are made.

a pressure test is likely to be in the range of 500 psi for 24 hours. Using nitrogen for a pressure test rather than air is preferable because using air introduces additional moisture into the system.

Once the system passes the pressure test, the system is evacuated using the triple-evacuation method. The third evacuation generally must pull a vacuum of less than 500 microns. This evacuation is critical to ensure that moisture and any other contaminants are cleared from the systems before refrigerant is added. Charge with refrigerant after the evacuation is complete.

Pro Tip

Manufacturer's Training for Ductless Systems

Manufacturer's training is the best way to prepare for installing and servicing ductless systems. These systems use proprietary control systems, and installation and service guidelines vary from system to system. The more training you receive, the better your installations and service will be.

23.6.3 Ductless System Maintenance

Much of the scheduled maintenance performed on ductless systems is similar to that performed on central air-conditioning systems, such as inspecting the system and cleaning the condenser coil. But there are differences as well.

Always refer to and follow the maintenance guidelines provided by the manufacturer. Maintenance procedures will vary from product to product, so be sure to check.

Maintenance of indoor units takes place in living spaces. Therefore, making sure the room stays clean is critical. Use drop clothes or tarps to cover furnishings and flooring. Wear shoe covers so you do not track dirt into the house.

Remove and clean the air filters in the indoor units. See **Figure 23-62**. If a filter is damaged or worn, replace it. A common maintenance task is cleaning or replacing the air filters in the indoor units.

Biological material including mold can grow in the condensate pan, on the coil surface, on blower wheel blades, and elsewhere inside the indoor unit. To prevent microorganisms from forming in an indoor unit, add ***biocide tablets*** to the condensate pan. These are designed to prevent the formation of slime, algae, mold, and other common contaminants, **Figure 23-63**.

Clean the inside of the unit thoroughly. If the unit is equipped with a condensate pump, clean the pump as well. It may be easier and neater to remove the drain pan and condensate pump and move them to another location to be cleaned.

Evaporator coils in indoor units also need to be cleaned. To do this, remove outer panels, air filters, and any other accessories that could block the flow of cleaning fluid. Set up a large plastic bag or bib to catch and contain the

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Figure 23-62. This technician is examining an air filter from an indoor unit.

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Figure 23-63. Adding biocide tablets to an indoor unit's condensate pan is often included as part of the unit's maintenance.

cleaning fluid. This can be directed into a bucket for later draining, **Figure 23-64**.

23.6.4 Ductless System Service and Troubleshooting

When servicing and troubleshooting a ductless system, manufacturer information is critical to success. Manufacturers generally provide installation and service information on a website or phone app. Be familiar with these resources and follow the manufacturer's service procedures.

The most common problems with ductless systems are the result of poor installation practices. Flare connections that were not made properly will begin leaking within 12 months. Use leak detection methods to identify poor

SpeedClean

Figure 23-64. Use a pressurized washer with a plastic bib and bucket while cleaning an indoor unit's evaporator.

connections. Wiring problems occur as well. Compare the wiring connections to what is specified in the installation guide.

Improper mounting of the outdoor unit can create problems. A heat pump outdoor unit in a cold climate that is mounted directly to a concrete slab (without adequate clearance beneath) can be damaged by the refreezing of water created by the defrost cycle. If the water is prevented from flowing out from under the unit, the coil can be damaged.

Ductless systems use complex computer controls that are continually monitoring the system conditions and adjusting EEVs accordingly. Due to this high degree of system monitoring, the control system is able to provide trouble codes to help troubleshoot problems. When working on ductless systems, you may need to contact the manufacturer's technical support group to provide specific troubleshooting guidance.

Thermistor failure is a common problem for ductless units. A thermistor is an electronic device with resistance that changes as the temperature changes. In a PTC (positive temperature coefficient) thermistor, resistance increases as temperature increases. In an NTC (negative temperature coefficient) thermistor, resistance decreases and temperature increases.

A thermistor problem is normally identified by a trouble code. When this occurs, the thermistor should be removed from the unit and tested. To test a thermistor, you first need to find a chart listing the resistance of the thermistor at various temperatures. This information may be available in the manufacturer's service materials or from other resources. Simply measure the resistance between the two terminals of the thermistor and compare the measured value to the expected value. A common method of testing a thermistor is to submerge the thermistor in ice water for several minutes and then check its resistance. Compare this measured value to the expected value at 32°F. If the thermistor testing confirms that all thermistors are working properly, the problem is most likely the control board. The control is receiving the correct signal from the thermistor, but the signal is not being communicated correctly within the control board, resulting in the thermistor trouble code.

EEV motor failure is another relatively common problem for ductless systems. This failure can occur due to wear.

Chapter Review

SUMMARY

23.1 Split Air-Conditioning Systems

- Split air-conditioning systems usually fall into one of two categories, including central air-conditioning systems and ductless air-conditioning systems. A split system has its condensing unit outdoors and its evaporator indoors.
- Heat pump systems are split systems that can provide both cooling and heating. A reversing valve changes the flow of refrigerant.

23.2 Comfort Cooling Controls

- Comfort cooling systems are equipped with operating controls and safety controls. Operating controls, such as thermostats, pressure switches, humidistats, motor starters, and relays, regulate the normal operation of the system. Safety controls monitor conditions and shut off the system or specific components to protect system components and building occupants.
- A single combination heating and cooling thermostat is often used in central air-conditioning systems. In some systems, a humidistat controls the relative humidity in the conditioned space.
- Low-voltage thermostats operate at 24 Vac from a step-down transformer. Most low-voltage thermostats use a thermistor to sense temperature.
- Digital and programmable thermostats, like wireless and power-stealing thermostats, are able to perform sensing, switching, timing, and staging functions due to their use of electronic components.

23.3 Central Air-Conditioning Systems

- A central air-conditioning system includes a single evaporator installed in a central air handler cabinet that is connected to a network of ducts.

23.4 Installing Central Air Conditioning

- Installing central cooling onto an existing furnace is done in four steps: installing the condensing unit, mounting the evaporator, installing the refrigerant lines, and making the electrical connections.
- When installing a thermostat, follow the manufacturer's wiring diagrams. Set subbase DIP switches according to the type of system that the thermostat will control. Test wiring for proper connections and operation before programming the thermostat.
- Free cooling is the use of an air-side economizer. The economizer operates when outdoor air temperature (and sometimes humidity) is low. Duct dampers are adjusted so that the indoor blower draws in outdoor air for cooling.
- Quick-connect couplings are used on assembled and charged systems to allow installation of an air-conditioning system without the need to evacuate, charge, or clean refrigerant.

23.5 Servicing Central Air-Conditioning Systems

- Servicing a central air-conditioning system begins with a check of the system's general condition. During this inspection, check for leaks, malfunctioning controls, and moisture-related problems. Fans and motors should be cleaned and lubricated, worn belts should be replaced, and the condenser and evaporator coils should be cleaned. Record any service work in company records and system records for the homeowner.
- Using thermostat diagnostics can help quickly locate the source of a system malfunction.

23.6 Ductless Split Systems

- A ductless split system is a split air-conditioning system that does not use forced-air ductwork as a means of distributing cooled air. These systems have an outdoor unit and one or more indoor units connected by refrigerant lines. Air is circulated in a given space by an indoor unit's fan and cooled by the evaporator. No air ducts are used.
- Ductless systems can be categorized into three groups: mini-split systems, multi-split systems, or VRF systems.

REVIEW QUESTIONS

23.1 Split Air-Conditioning Systems

1. A _____ air-conditioning system uses a single indoor unit connected to a duct system.
   A. ductless
   B. mini-split
   C. central
   D. VRF
2. Heat pump systems include a(n) _____ that changes the flow of refrigerant.
   A. thermostat
   B. reverse valve
   C. evaporator
   D. humidistat

23.2 Comfort Cooling Controls

3. Which of the following is *not* considered a type of safety control?
   A. Oil pressure controls
   B. Electrical fuses
   C. Humidistats
   D. Internal motor overloads
4. A(n) _____ controls comfort cooling.
   A. air handler
   B. humidistat
   C. refrigerant pressure control
   D. thermostat
5. Low-voltage thermostats typically operate at _____.
   A. 30 mVdc
   B. 5 Vdc
   C. 24 Vac
   D. 120 Vac
6. Low-voltage thermostats often use _____ and contactors to switch line-voltage circuits on and off.
   A. expansion valves
   B. relays
   C. solenoids
   D. fuses
7. The temperature-sensing component that reacts to temperature change by changing its electrical resistance is a _____.
   A. bimetal strip
   B. diaphragm
   C. thermistor
   D. thermocouple
8. Being able to adjust conditioned space temperature remotely using a tablet PC, smartphone, or laptop is specifically an advantage of a _____ thermostat.
   A. multistage
   B. millivolt
   C. power-stealing
   D. wireless
9. Tapping into a fan, cooling, or heating terminal and drawing a small milliamp current to recharge its internal battery is a feature of a _____ thermostat.
   A. multistage
   B. millivolt
   C. power-stealing
   D. wireless
10. A programmable thermostat uses a(n) _____ that functions as a clock and controls indoor climate for different blocks of time.
    A. anticipator
    B. mercury switch
    C. microprocessor
    D. reed switch

23.3 Central Air-Conditioning Systems

11. A standard split system that provides central air conditioning includes which one of the following system components?
    A. An air handler
    B. A chiller water pump
    C. An inverter
    D. A Y tube
12. The outdoor unit of a central air-conditioning system contains all of the following, *except* the _____.
    A. compressor
    B. condenser
    C. evaporator
    D. condenser fan

23.4 Installing Central Air Conditioning

13. An air-cooled condensing unit should be installed _____.
    A. beside a building along an inside corner with two outer walls no more than 3″ away
    B. beyond a building's roof overhang and eaves
    C. inside a well-insulated and unventilated room within a building
    D. tightly surrounded on all sides by tall, thick bushes
14. The purpose of blank-off plates is to _____.
    A. block the evaporator so air does not pass through when the furnace is operating
    B. block off areas of the plenum so all the air passes through the evaporator
    C. prevent airflow-related noises in the ductwork
    D. provide access to the evaporator for service
15. Which of the following statements regarding refrigerant lines is *not* true?
    A. A liquid line should be insulated to prevent condensation.
    B. Refrigerant lines may be connected with flare connections.
    C. Refrigerant lines should be kept as short as possible.
    D. Any openings in refrigerant lines should be sealed with weatherproof, nonhardening sealing compound and tape.
16. The electrical connections to a central air-conditioning condensing unit typically include a 240 V connection for powering the compressor and a _____ connection for control.
    A. 24 V
    B. 36 V
    C. 100 V
    D. 480 V
17. The thermostat wiring designation for power from the step-down transformer is _____.
    A. C
    B. R
    C. W
    D. Y
18. The thermostat wiring designation for the fan relay is _____.
    A. Aux/E
    B. C
    C. G
    D. O/B
19. When installing a thermostat's subbase, some system settings may need to be managed using _____ switches.
    A. bellows
    B. diaphragm
    C. DIP
    D. reed

20. When outdoor air is low in temperature and humidity, a forced-air system can provide free cooling by using the following components, *except* _____.
    A. a barometric damper for exhaust air
    B. duct dampers
    C. the compressor
    D. the indoor blower
21. A good location where a thermostat should be installed is _____.
    A. behind a door or in a tight corner
    B. in direct sunlight
    C. on an inner wall
    D. on an uninsulated outer wall
22. Which of the following statements regarding quick-connecting couplings is *true*?
    A. Quick-connect couplings are connected using flared joints.
    B. Quick-connect couplings cannot be disconnected once installed.
    C. Quick-connect couplings must be connected using only one wrench.
    D. Quick-connect couplings are used to connect parts of a system without losing refrigerant.

23.5 Servicing Central Air-Conditioning Systems

23. Scheduled periodic maintenance does *not* involve inspecting _____.
    A. the thermostat
    B. duct registers
    C. the air handler
    D. system operation costs
24. When troubleshooting an air-conditioning system, first check the _____ subsystem.
    A. airflow
    B. electrical
    C. mechanical
    D. refrigerant
25. When taking measurements on an energized circuit for low-voltage thermostat diagnostics, a 0 V reading indicates a(n) _____.
    A. closed switch
    B. good relay coil
    C. open switch
    D. blown fuse
26. A voltage reading well below 24 Vac on a low-voltage thermostat circuit indicates that the _____.
    A. thermostat needs to be replaced
    B. transformer may be old
    C. load on the circuit may be pulling less electrical current than can be provided by the transformer
    D. circuit may not be complete

23.6 Ductless Split Systems

27. Which device is used to prevent spilling of condensate from a ductless split system's indoor unit?
    A. Air filter
    B. Biocide tablets
    C. Mounting bracket
    D. Overflow switch
28. When installing a ductless split system indoor unit, a _____ is typically necessary.
    A. 3″ (8 cm) hole wall opening
    B. 42″ × 16″ wall opening
    C. gas supply drip leg
    D. typical window opening
29. Which of the following statements is true of ductless split systems?
    A. The system can have multiple outdoor units attached to a single indoor unit.
    B. The system cannot have multiple indoor units.
    C. They are a popular choice for adding air conditioning to buildings that are not equipped with ducts.
    D. The system can only supply cooling.
30. Which of the following statements regarding ductless split systems is *not* true?
    A. A single, central thermostat controls the temperature in all conditioned spaces.
    B. A line set connects an indoor unit and outdoor unit.
    C. A variety of different indoor unit styles is available.
    D. A remote control is typically used to control an indoor unit.
31. What should be added to a ductless split system's indoor unit to prevent the growth of microorganisms?
    A. Biocide tablets
    B. A condensate pump
    C. A high-temperature cutoff switch
    D. An overflow switch

CRITICAL THINKING

1. Explain how a low-voltage thermostat controls temperature in a comfort cooling system.
2. List some building and local area changes that might require using a replacement air-conditioning system with a different capacity from the original.
3. Explain some of the things that may happen if a suction line is *not* insulated.
4. Explain why "free cooling" operation is considered free.
5. List four things a technician should check when inspecting a condensing unit on a central air-conditioning system?
6. Describe the different ways an outdoor unit for a ductless split system may be installed.