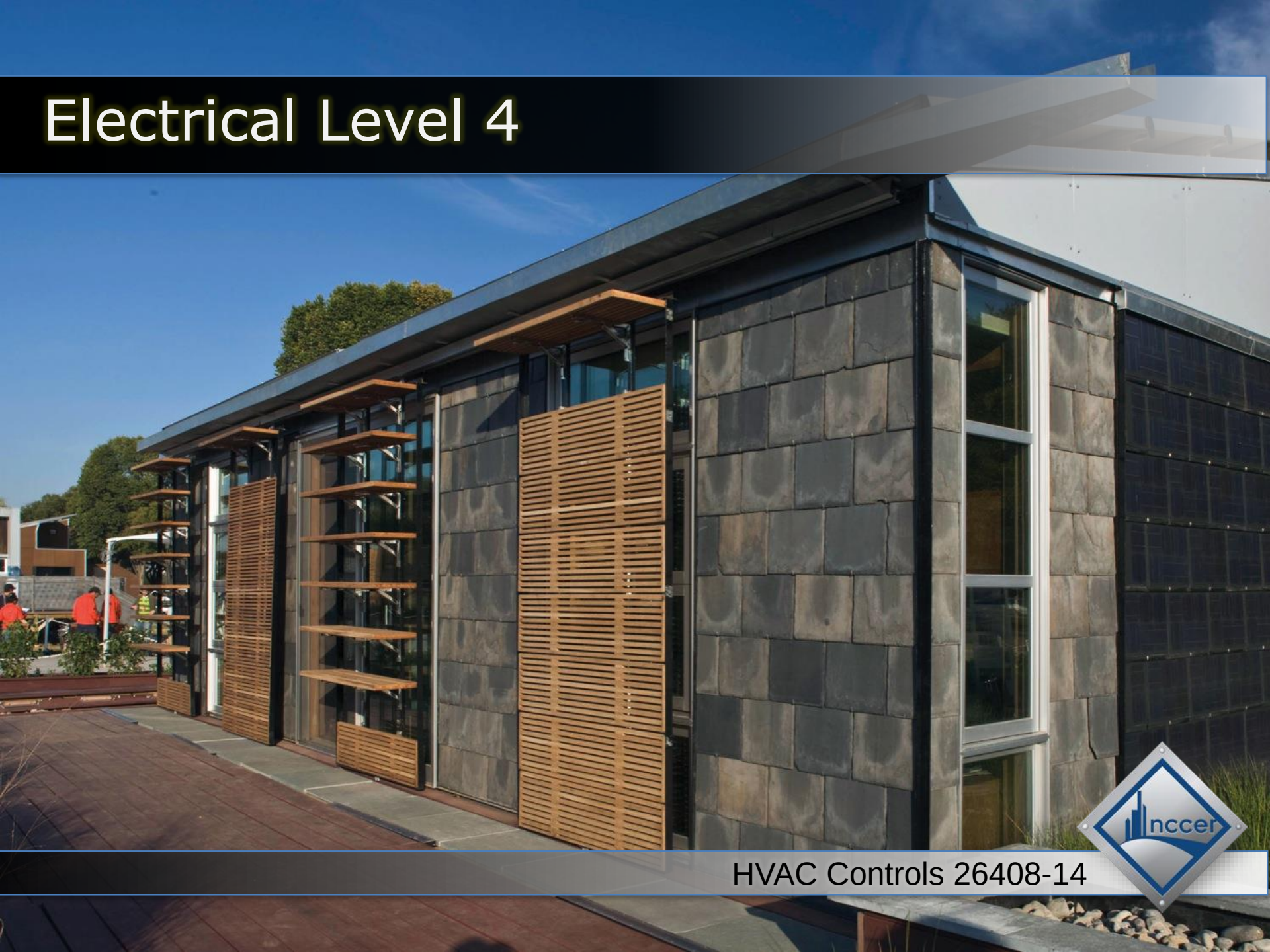
Electrical Level 4



HVAC Controls 26408-14

Objectives

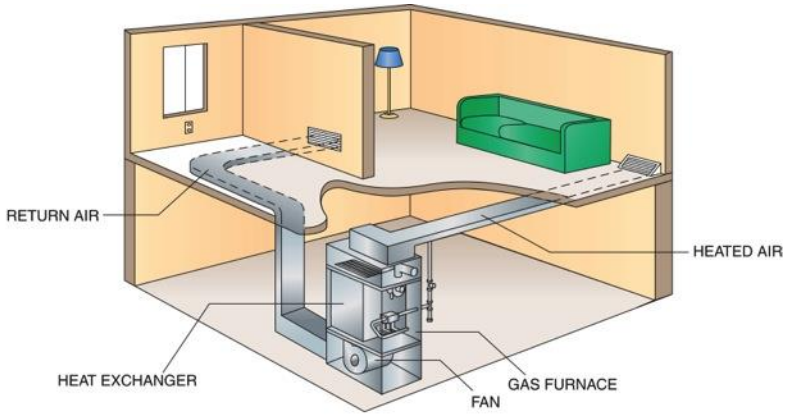
When trainees have completed this lesson, they should be able to do the following:

1. Identify the major mechanical components common to all HVAC systems.
2. Explain the function of a thermostat in an HVAC system.
3. Describe different types of thermostats and explain how they are used.
4. Demonstrate the correct installation and adjustment of a thermostat using proper siting and wiring techniques.
5. Explain the basic principles applicable to all control systems.
6. Identify the various types of electromechanical and electronic HVAC controls, and explain their function and operation.
7. State the *National Electrical Code*® (*NEC*®) requirements applicable to HVAC controls.

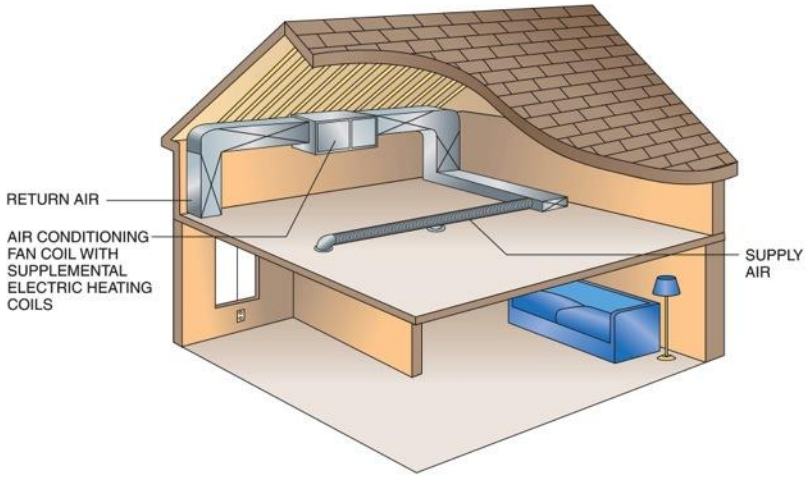
Performance Tasks

1. Identify various types of thermostats and explain their operation and uses.
2. Install a conventional 24V bimetal thermostat and hook it up using the standard coding system for thermostat wiring.
3. Check and adjust a thermostat, including the heat anticipator setting and indicator adjustment.

Introduction; Heating



BASEMENT INSTALLATION



ATTIC INSTALLATION

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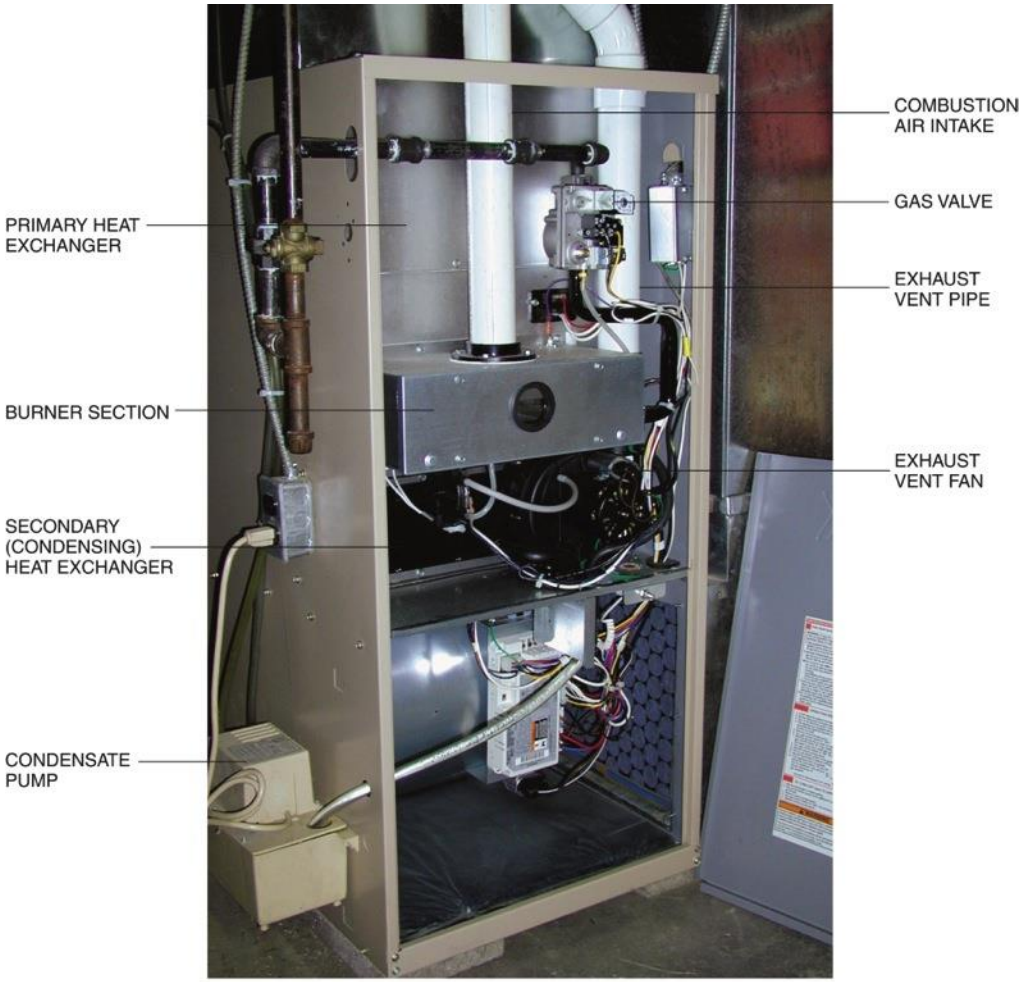
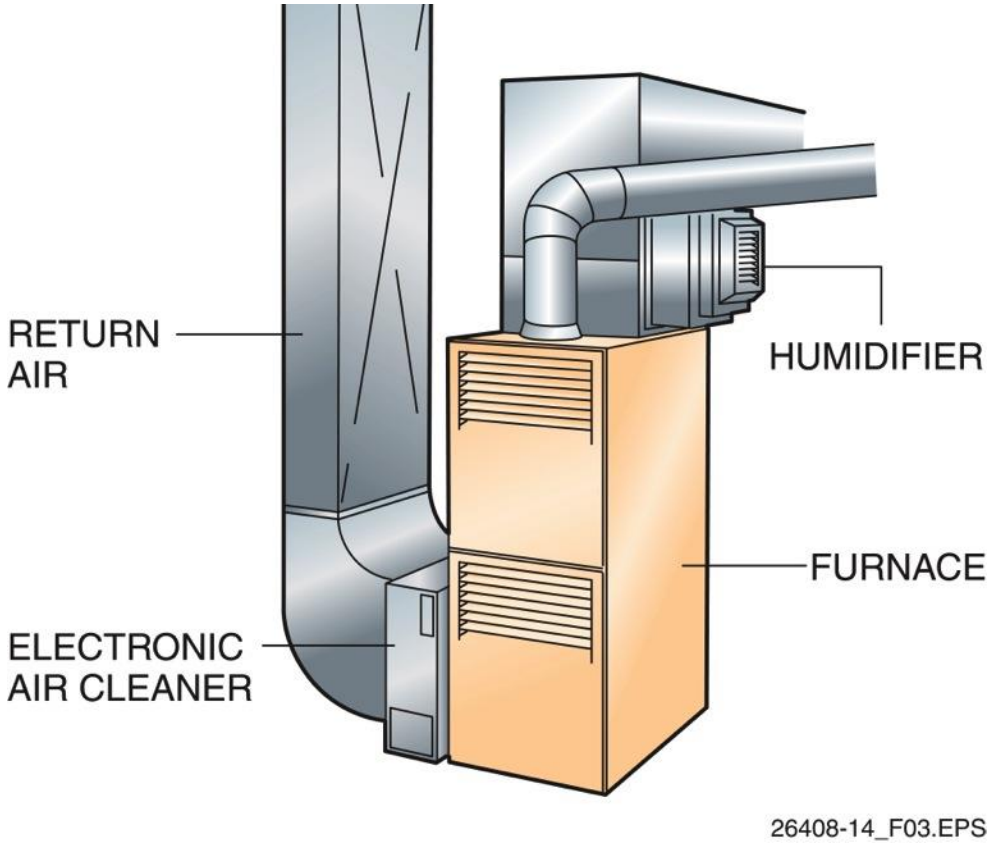
A High-Efficiency Condensing Furnace

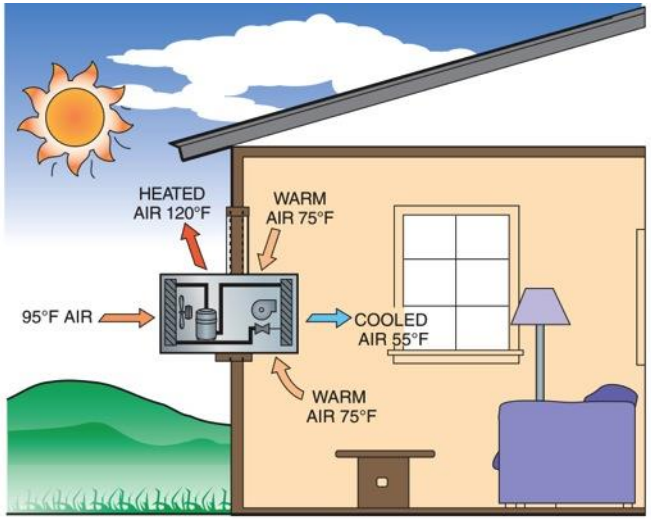


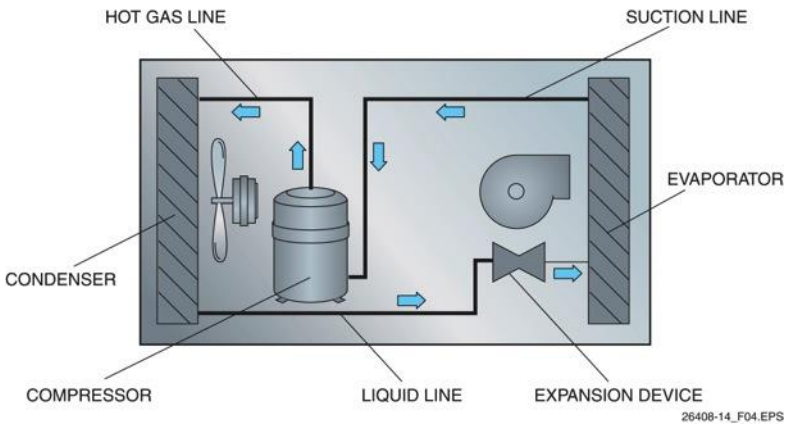
Ventilation

- Indoor air quality can be improved using humidifiers and electronic air cleaners.
- Many industrial environments require special ventilation and air management systems.



Air Conditioning





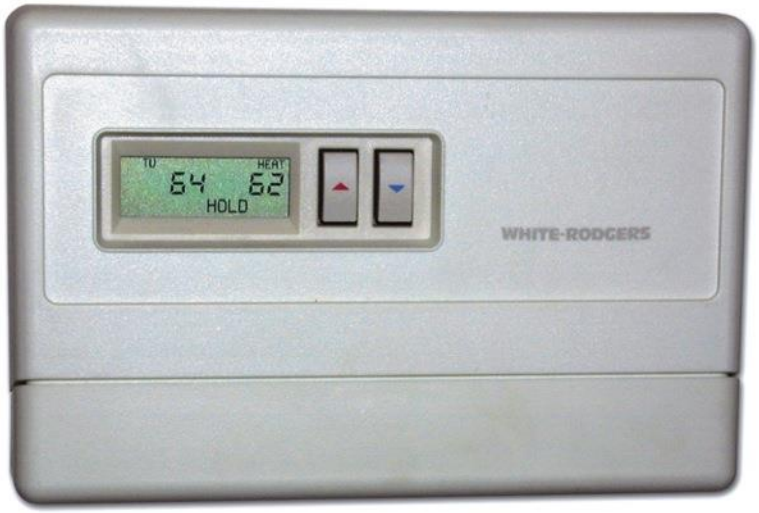
Next Session…

Thermostats

- Heat pumps are used in mild climates to provide both cooling and heating. Heat pumps operate on the principle that even when it is cold outside, heat may still be extracted from the outdoor air.
- In colder climates, heat pumps can be combined with supplemental heating systems.

Thermostats

- A room thermostat is the primary control in an HVAC system.
- Homes and small commercial spaces typically use a single thermostat, while larger commercial and industrial applications use two or more thermostats to control the temperature in specific zones.



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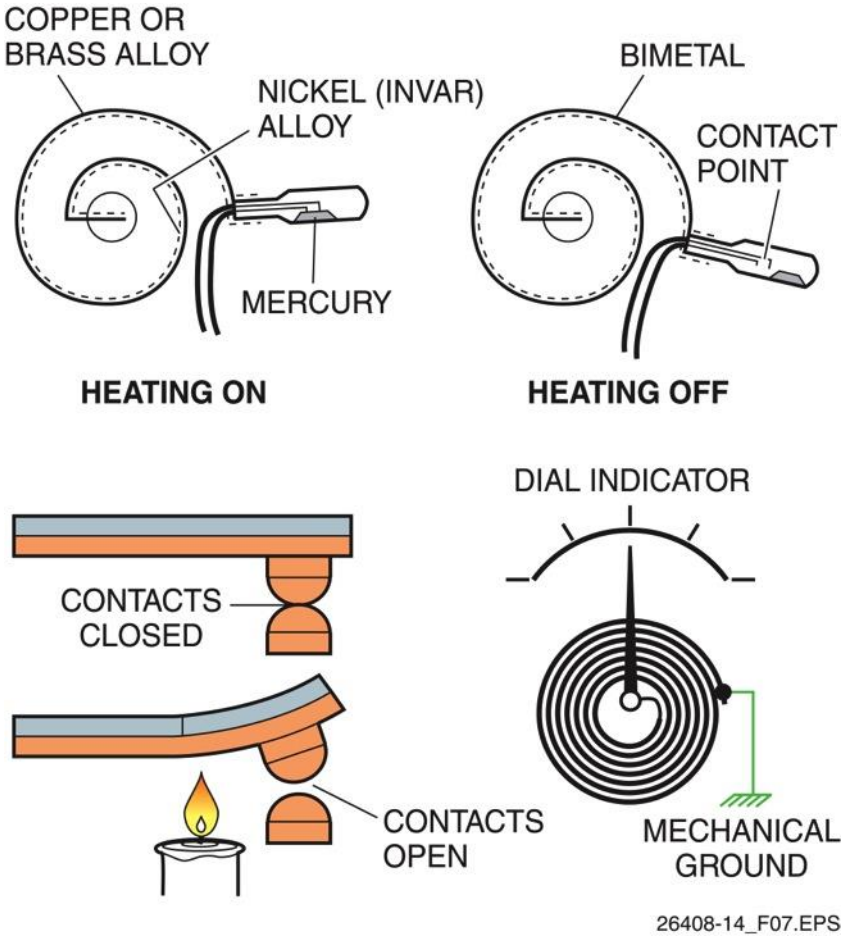
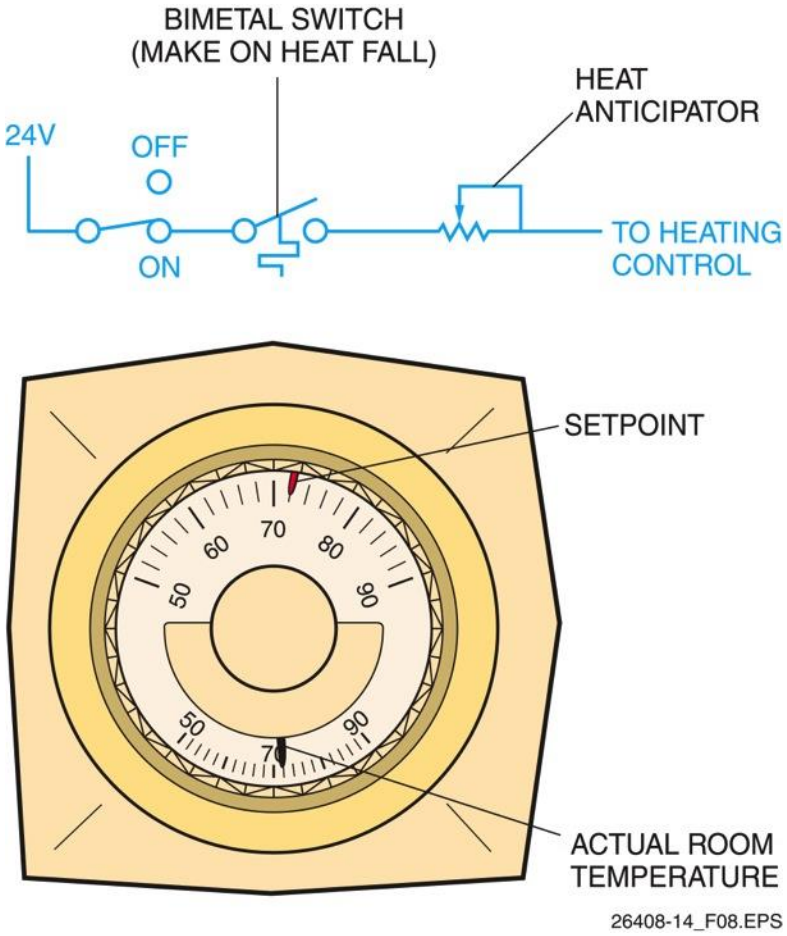
Bimetal Sensing Elements



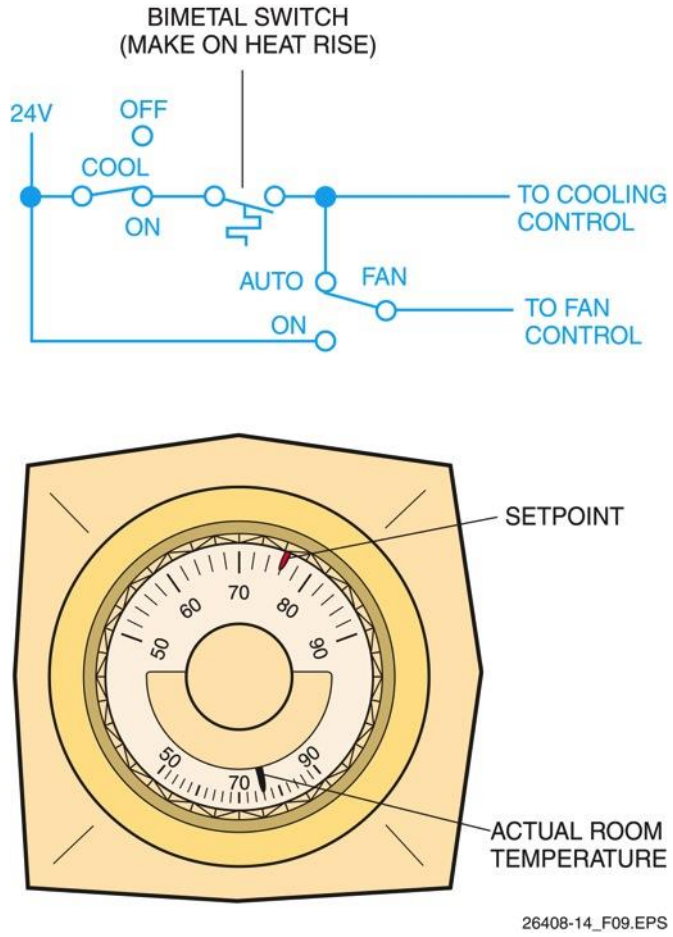
- Simple thermostats contain a bimetal element with a sealed glass tube containing switch contacts and a small amount of mercury.
- When heated or cooled, the bimetal changes shape to open or close the switch contacts in the thermostat.

Heating-Only Thermostat



- A heating-only thermostat contains a temperature-sensitive switch that controls the operation of a furnace.
- When the temperature reaches the setpoint, the contacts open, de-energizing the circuit. A heat anticipator is used to shut the furnace off early to allow the residual heat in the system to dissipate without overshooting the setpoint.

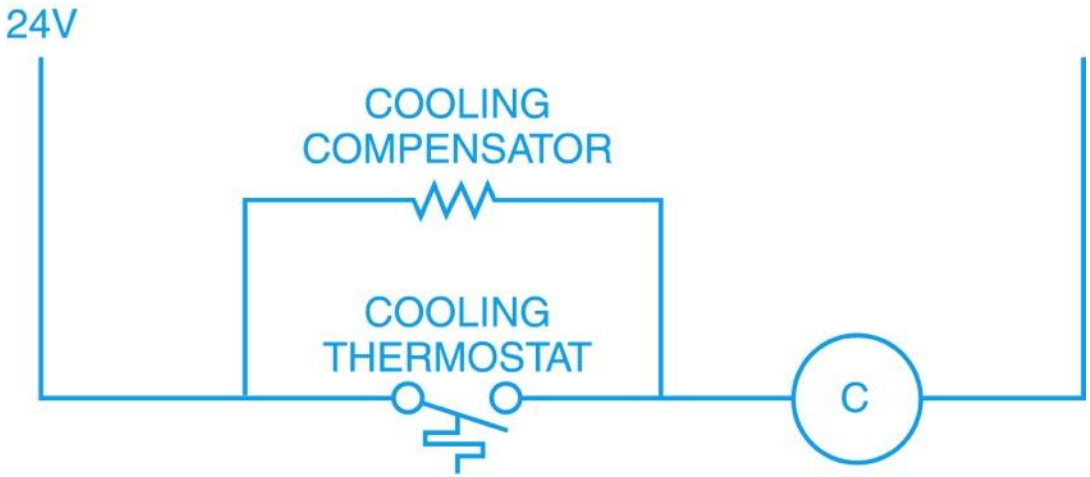
Cooling-Only Thermostat



- A cooling-only thermostat contains a temperature-sensitive switch that controls the operation of an air conditioning system.
- When the temperature reaches the setpoint, the contacts close, energizing the circuit.

Cooling Compensator

- A cooling compensator is used to turn the system on earlier to account for the lag between when the system calls for cooling and when it begins cooling the space.
- Unlike heating anticipators, cooling compensators are not adjustable.



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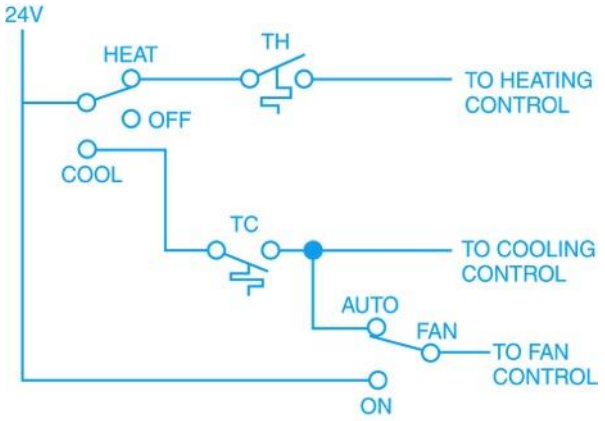
Heating-Cooling Thermostat

- A heating-cooling thermostat contains two temperature-sensitive switches that control the operation of both the heating and air conditioning systems.
- A bulb with two sets of contacts is attached to a bimetal element.



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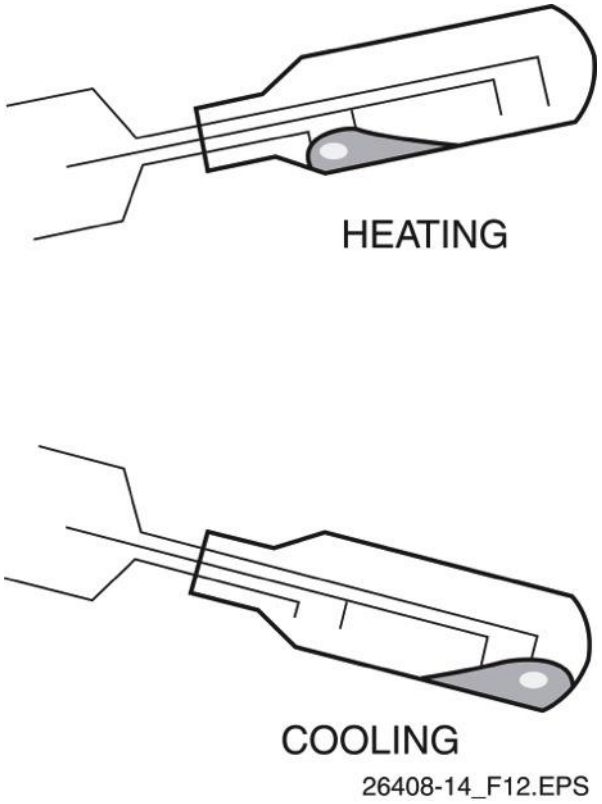
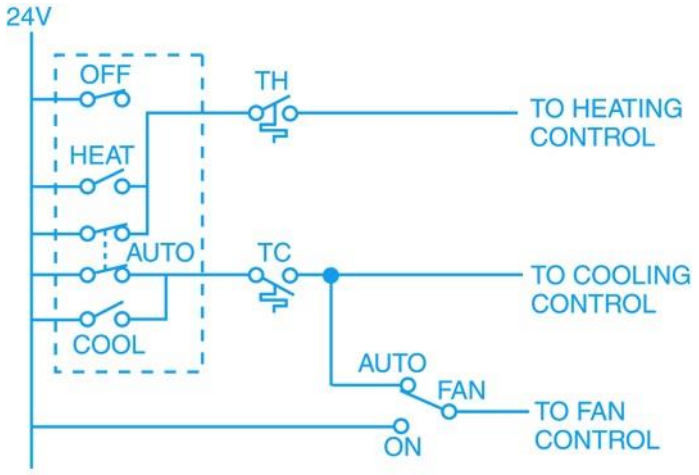
Heating-Cooling Contacts

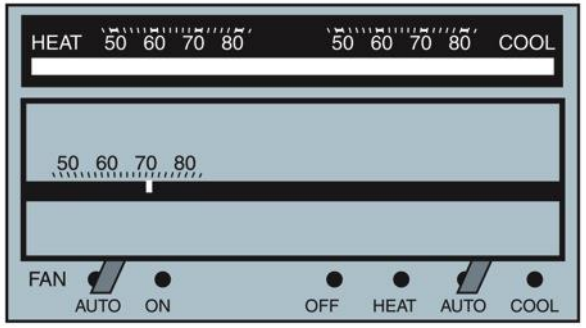
- When a mercury bulb is used in a heating-cooling thermostat, the heating contacts are located at one end of the bulb and the cooling contacts are located at the other end.
- A switch is used to select the desired mode of operation (Heating/Cooling/Off).



Automatic Changeover Thermostat

- Automatic changeover thermostats provide the convenience of automatically switching between heating and cooling while providing a deadband to keep the system from cycling back and forth.
- A switch is used to select the desired mode of operation (Heating/Cooling/Auto/Off).





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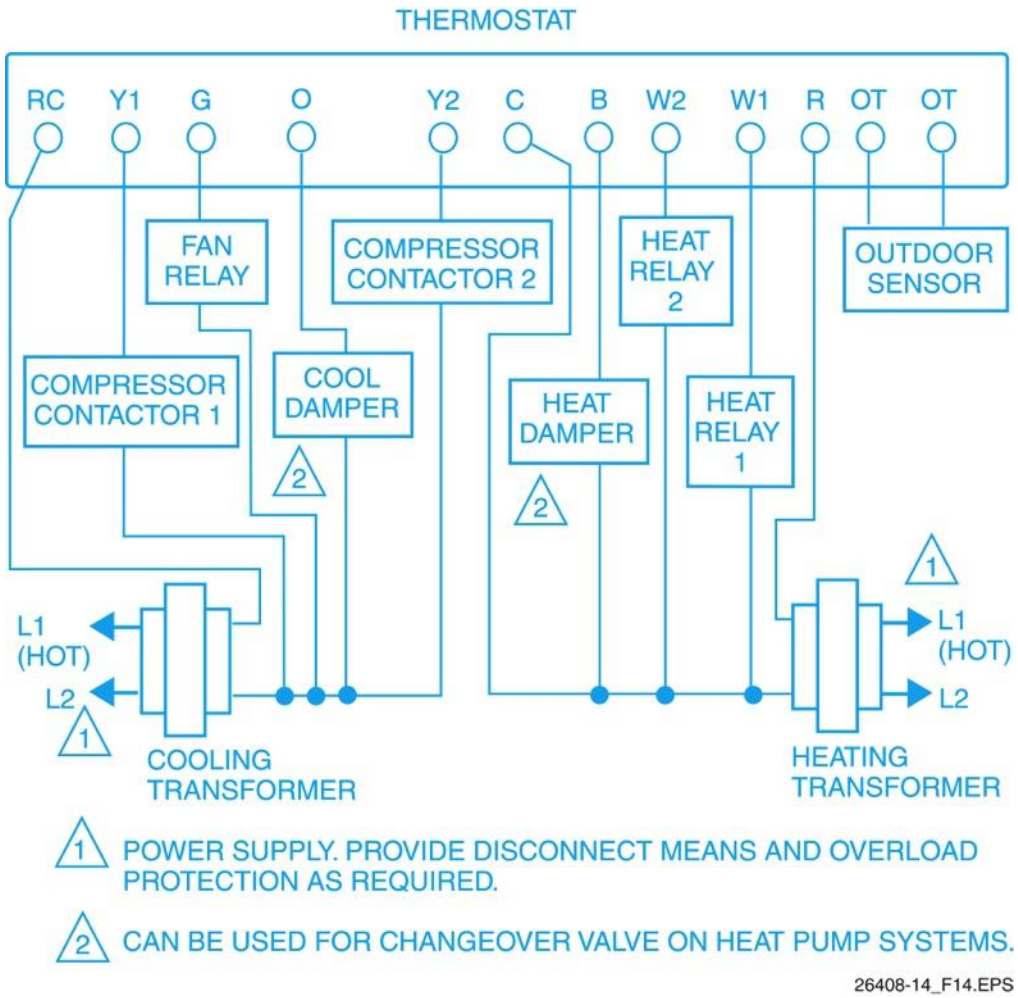
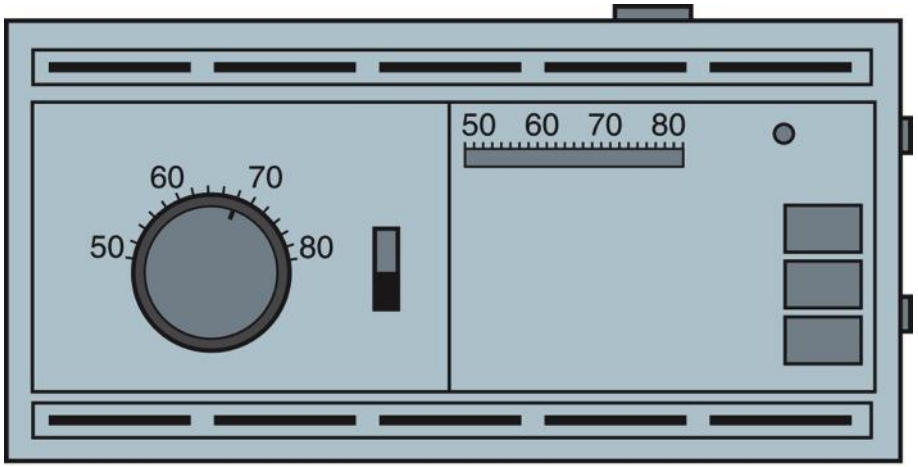
Multi-Stage Thermostat Hookup



Programmable Thermostat

- Older programmable thermostats contained a motor-driven time clock to raise or lower the temperature at the desired intervals.
- Modern programmable thermostats use a microprocessor to provide override control, energy-saving features, and maintenance tracking.



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Electronic Programmable Thermostat

- Modern programmable thermostats provide the ability to program different temperature settings when the space is unoccupied or the occupants are sleeping. Most thermostats can be programmed with different schedules for each day of the week.
- The use of a programmable thermostat can translate into a significant energy savings for the building owner.

26408-14_F16.EPS

Digital Line-Voltage Thermostat

- While most thermostats operate on 24V, line-voltage thermostats operate using the supply voltage to control the system directly rather than through a relay or contactor.
- Line-voltage thermostats are often used to control electric baseboard heating systems.

26408-14_F17.EPS

Thermostat Mounting

- Thermostats should be located on a solid inside wall away from drafts, air ducts, or radiant heat. Discharge static electricity before handling electronic components.
- Mercury-bulb thermostats must be carefully leveled in order to operate properly.

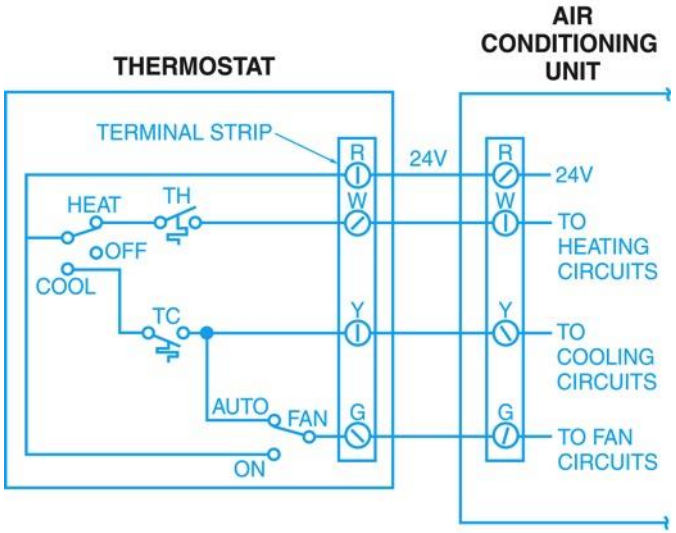
26408-14_F18.EPS

Thermostat Wiring

- A standard color code is used to designate terminals and conductors.
- When installing a thermostat, use a stripping tool designed for small-gauge wire and make sure the connections are tight. Seal the wire opening in the wall space so it is not affected by drafts.

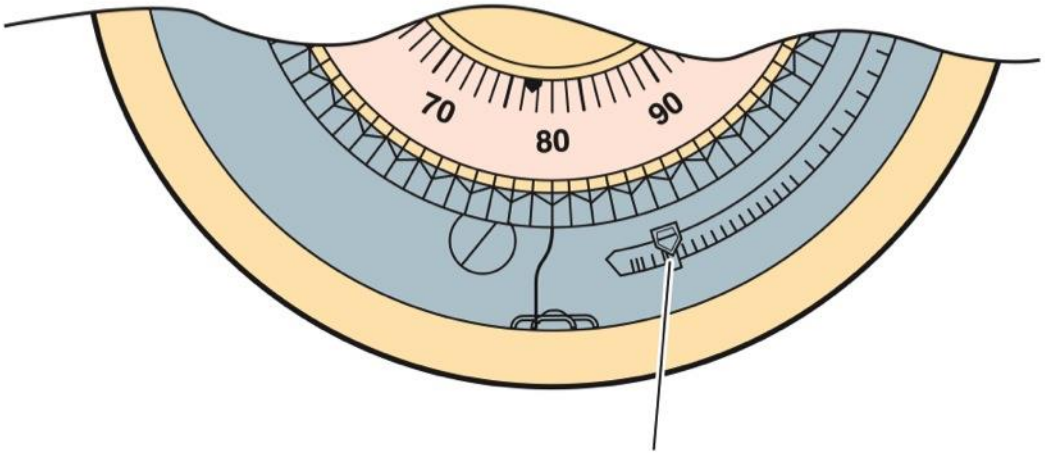
THERMOSTAT WIRING CODES

TERMINAL DESIGNATION	WIRE COLOR	FUNCTION
R	RED	POWER
G	GREEN	FAN CONTROL
Y	YELLOW	COOLING CONTROL Y1 = STAGE 1 Y2 = STAGE 2
W	WHITE	HEATING CONTROL W1 = STAGE 1 W2 = STAGE 2
O	ORANGE	HEAT PUMP REVERSING VALVE CONTROL



Thermostat Heat Anticipator

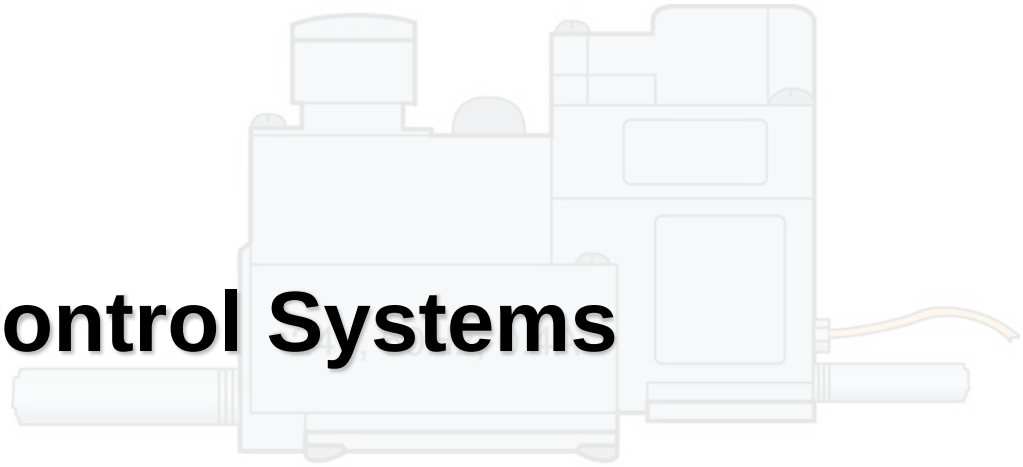
- After the thermostat has been installed, check the current draw of the primary control in the heating unit. It is normally printed on the furnace nameplate.
- Adjust the heat anticipator to the amperage indicated on the primary control.



Next Session…

Gas Valve Electric Ratings

If the current draw of the primary control in the heating unit is not printed on the furnace nameplate, it may be located on a primary control such as the gas valve.



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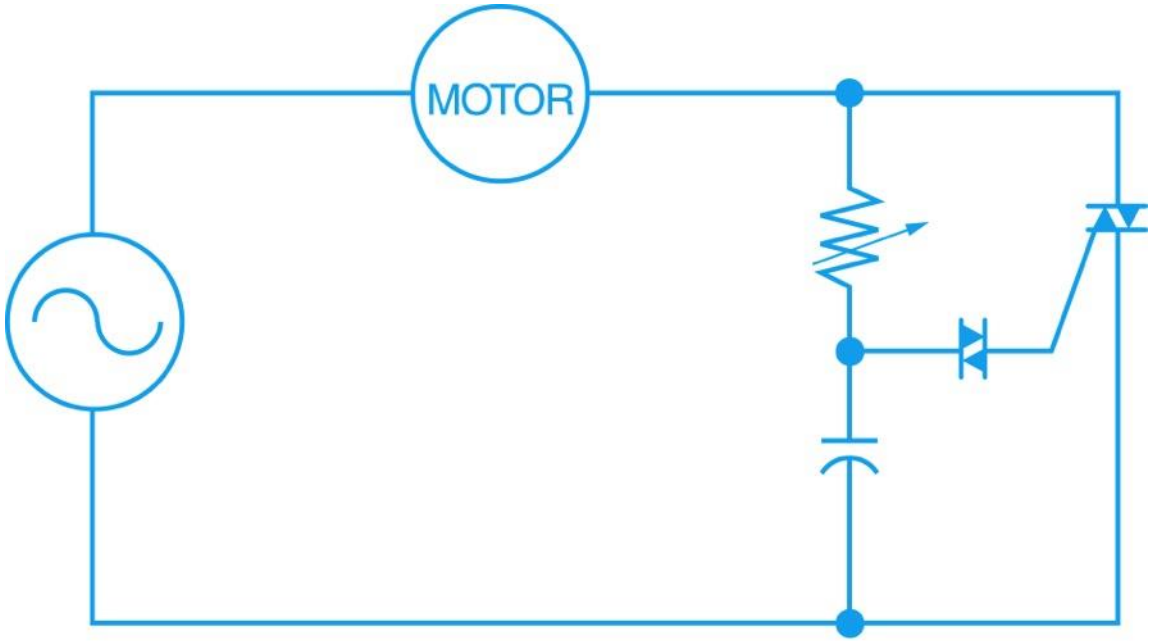
HVAC Control Systems

Performance Task

This session will conclude with trainees identifying various thermostats and installing and checking/adjusting a conventional 24V bimetal thermostat, including the heat anticipator setting and indicator adjustment.

HVAC Control Systems

- A triac is the most common type of motor speed control.
- A knob on the device is used to control the motor speed and is similar in operation to a dimmer switch.



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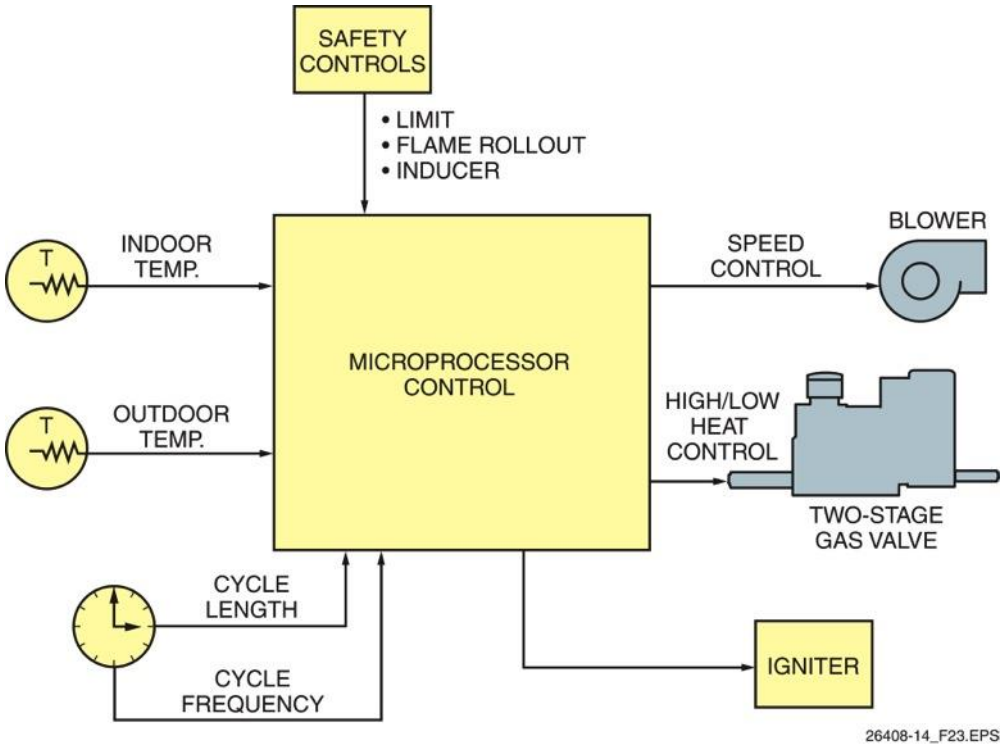
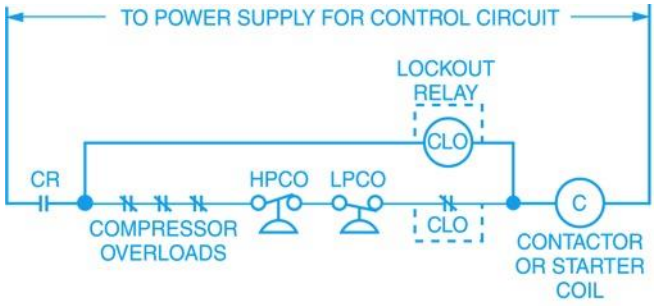
Electronic Variable-Speed Furnace Control

Microprocessor controls used in HVAC systems can control both the combustion system and the blower speed to optimize system operation for a variety of load conditions.



Lockout Relay Used in an HVAC Control Circuit

- A lockout relay prevents the HVAC equipment from restarting when one of the safety controls has been activated.
- Lockout relays require a system reset before the equipment can be restarted.



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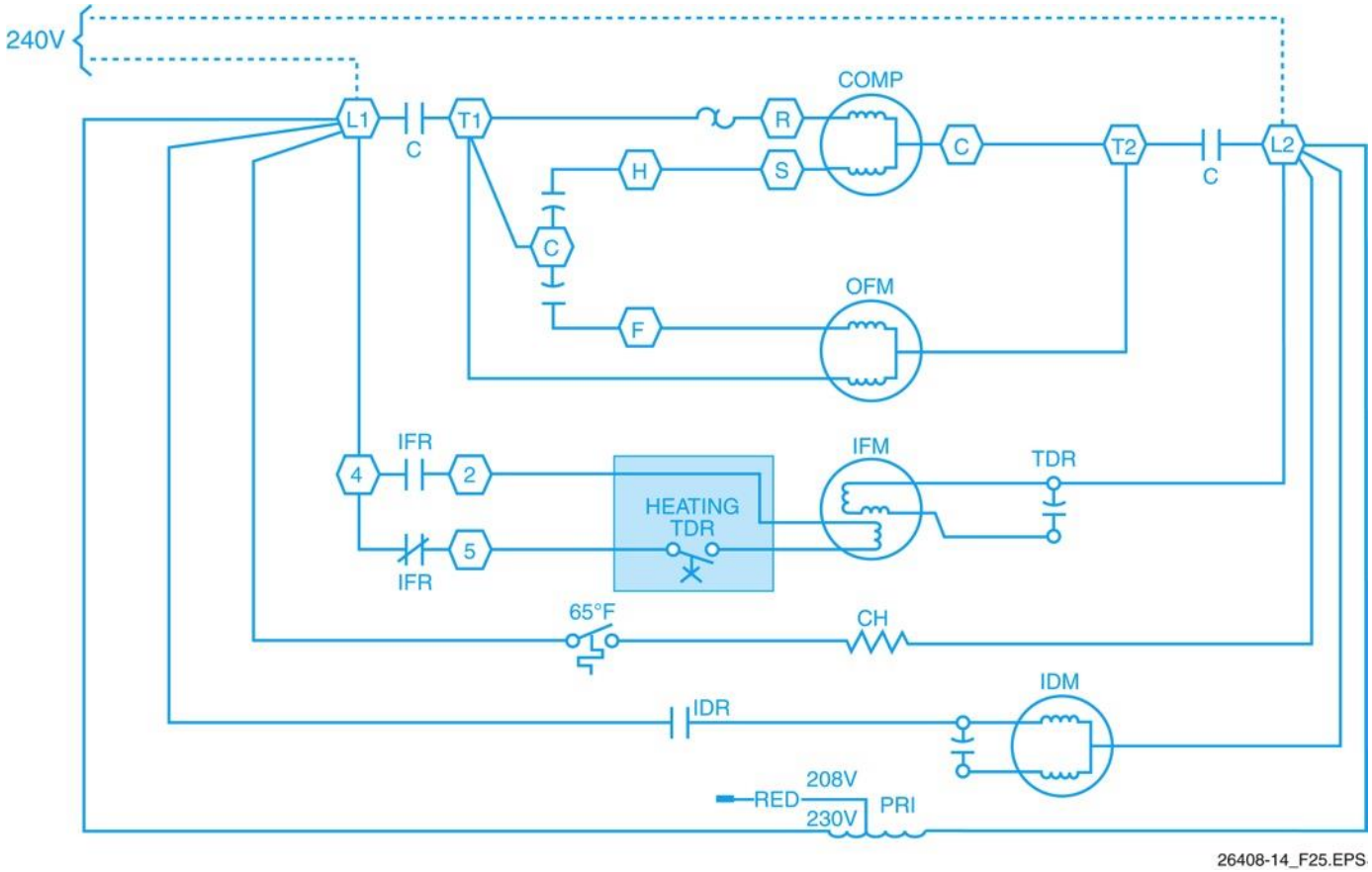
Time Delay Relay Used to Control a Blower



Freezestat

A freeze protection thermostat (FPT) or freezestat prevents the evaporator coil from freezing up.

The freezestat opens if the refrigerant temperature drops below a predetermined setpoint.

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Example of a High-Temperature Limit Switch

- Common furnace controls include the fan control, limit switch, thermocouple, and inducer proving switch.
- A high-temperature limit switch opens the circuit if the heat exchanger exceeds a preset temperature.

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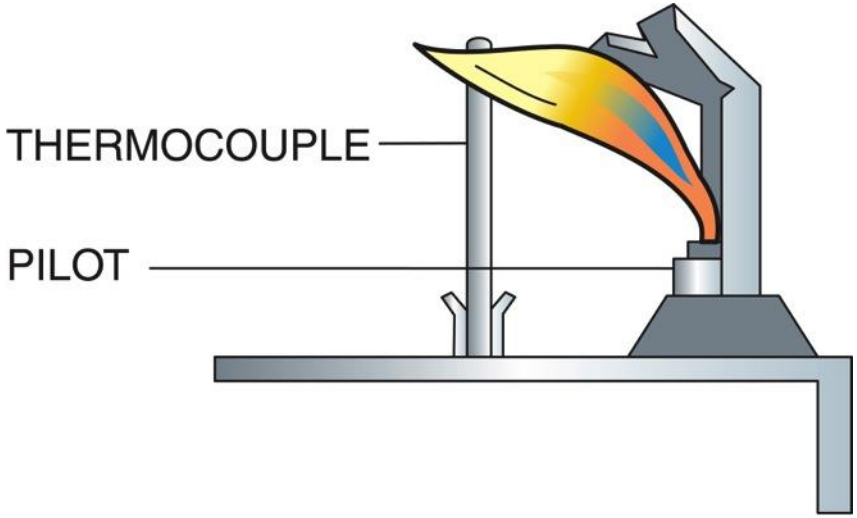
Thermocouple Used in a Safety Pilot

- A thermocouple uses dissimilar metals to control electron flow.
- A thermocouple is used to prove the presence of a pilot light in the furnace. If the thermocouple does not sense the presence of a flame, it shuts off the gas valve.



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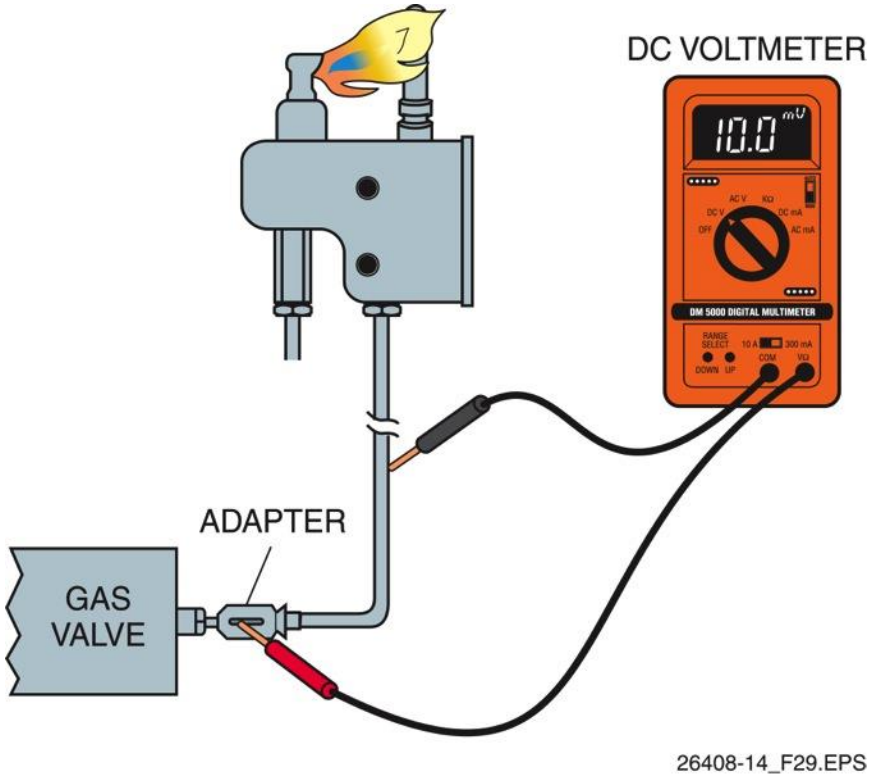
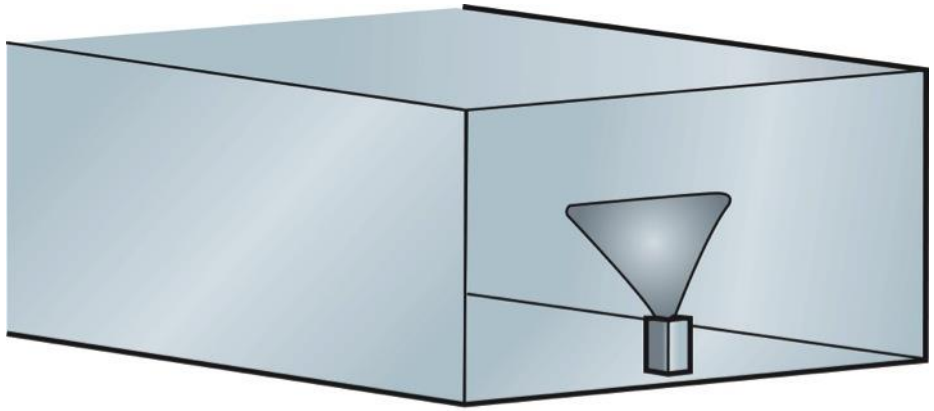
Thermocouple Testing

- The gas valve manual feed must be pressed for 45 to 60 seconds when lighting the pilot to allow the thermocouple to heat up.
- Thermocouples can be tested by measuring the voltage between the sensing rod and the end of the cable. An unloaded thermocouple should read at least 18mV.



Sail Switch

- A firestat stops the fan if the return air temperature exceeds 160˚ F.
- An airflow (sail) switch is installed in heating ductwork to ensure airflow before the heating elements are activated, or in cooling systems to verify airflow across the condenser/evaporator before the compressor is turned on.



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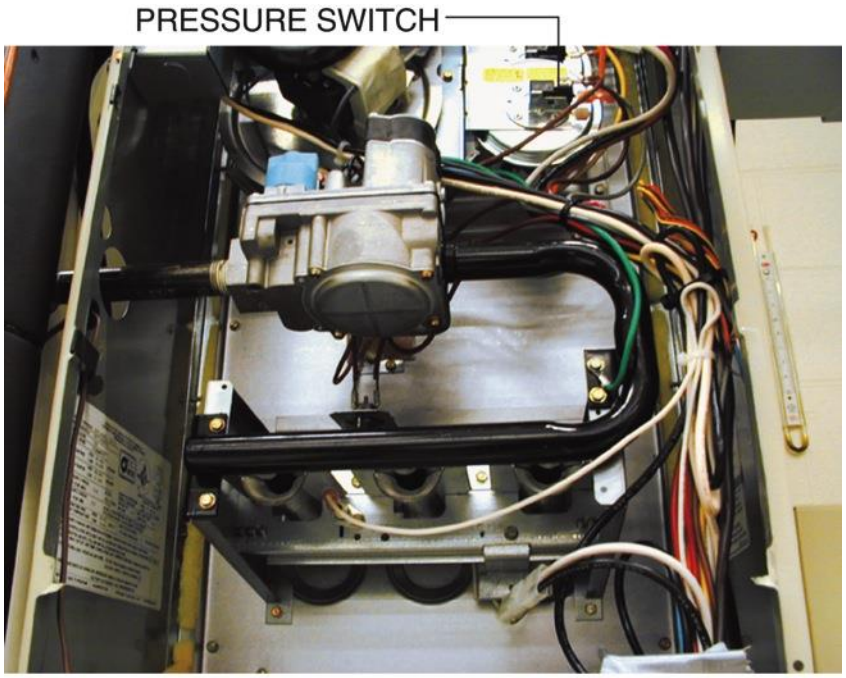
Combustion Airflow Pressure-Sensing Switch

- If the inducer motor fails to operate, the inducer switch opens and prevents control voltage from being applied to the gas valve.
- Either a centrifugal switch or a pressure-operated switch can be used as an inducer switch. Pressure switches are more reliable than centrifugal switches.



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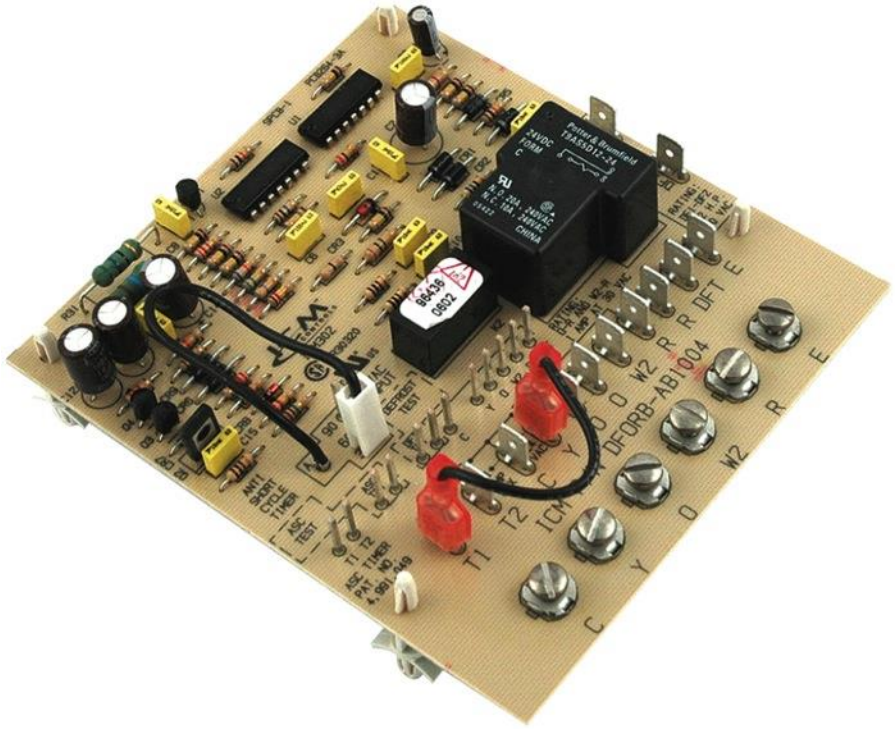
Electronic Defrost Control

- Due to the pressure/temperature relationships in an air conditioning system, moisture can build up and freeze on the outdoor coil, even at temperatures above 40° F.
- Heat pumps require a defrost control to prevent frost buildup on the outdoor coil.



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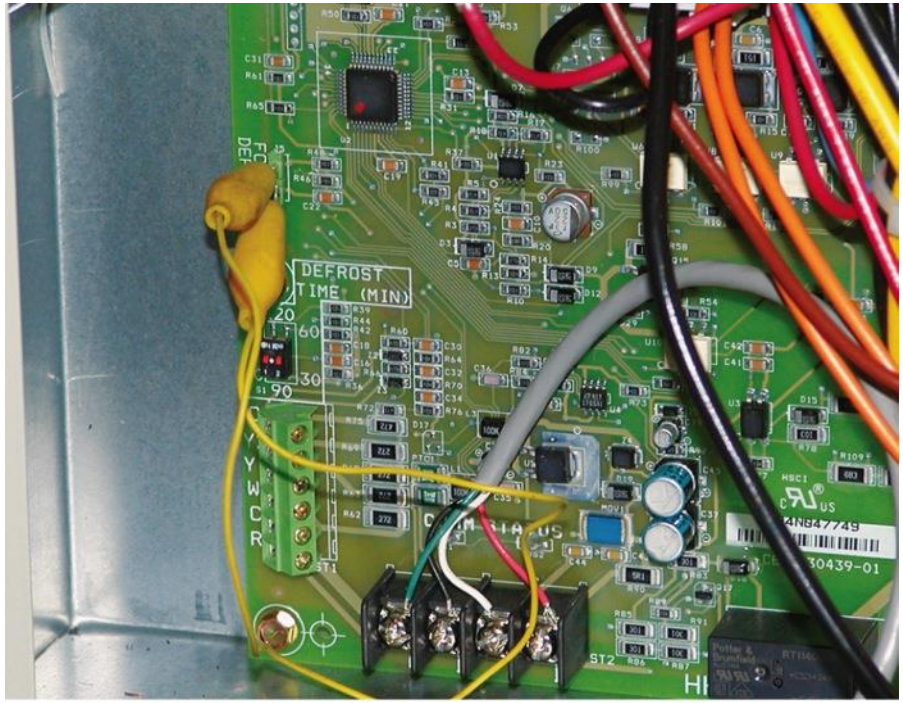
Defrost Speed-Up Jumper

- Modern heat pumps use an electronic defrost control board with an automatic timer that can be set to suit the local conditions.
- The defrost test cycle is activated by jumpering across two terminals on the board.



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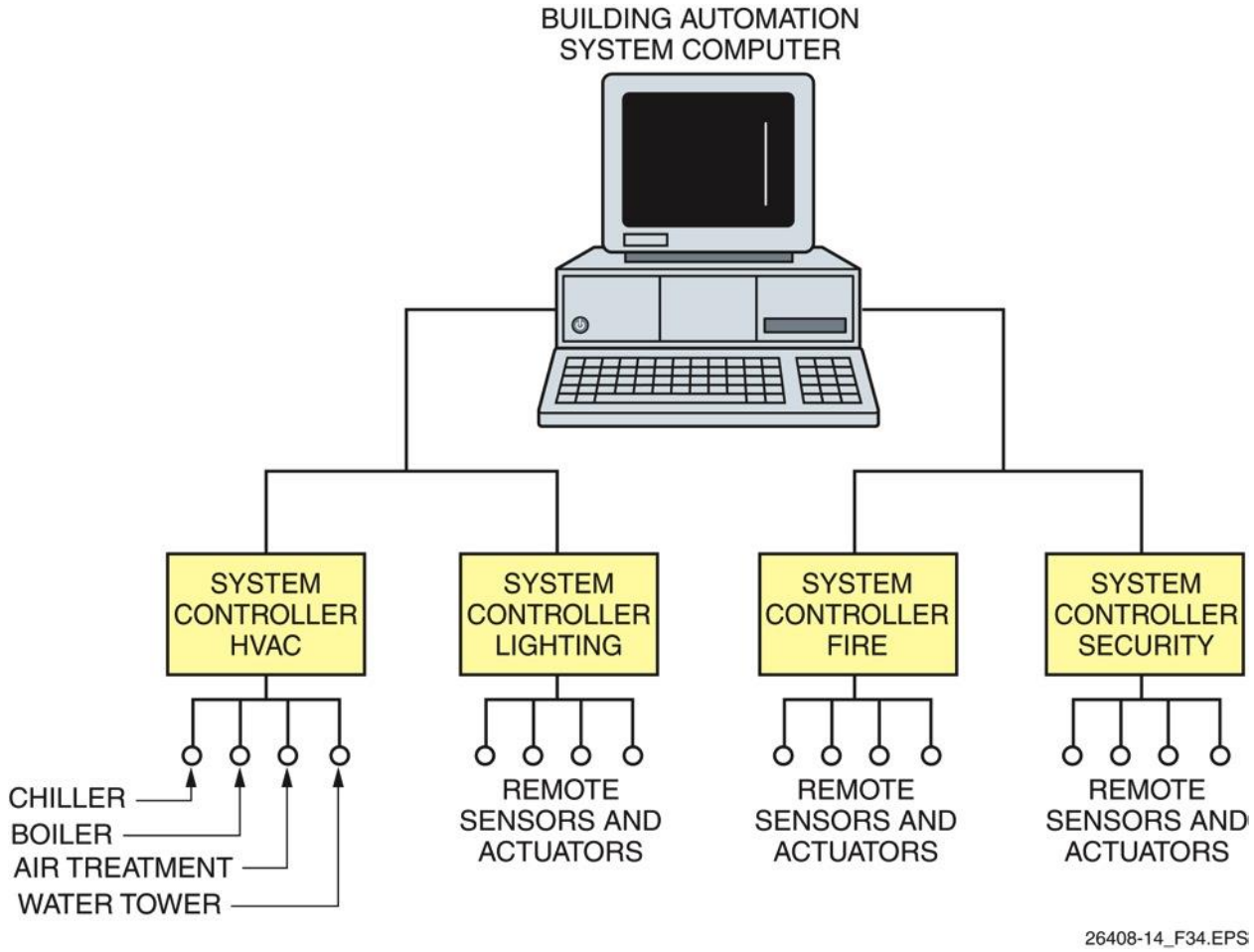
HVAC Digital Control Systems



HVAC System Control Module

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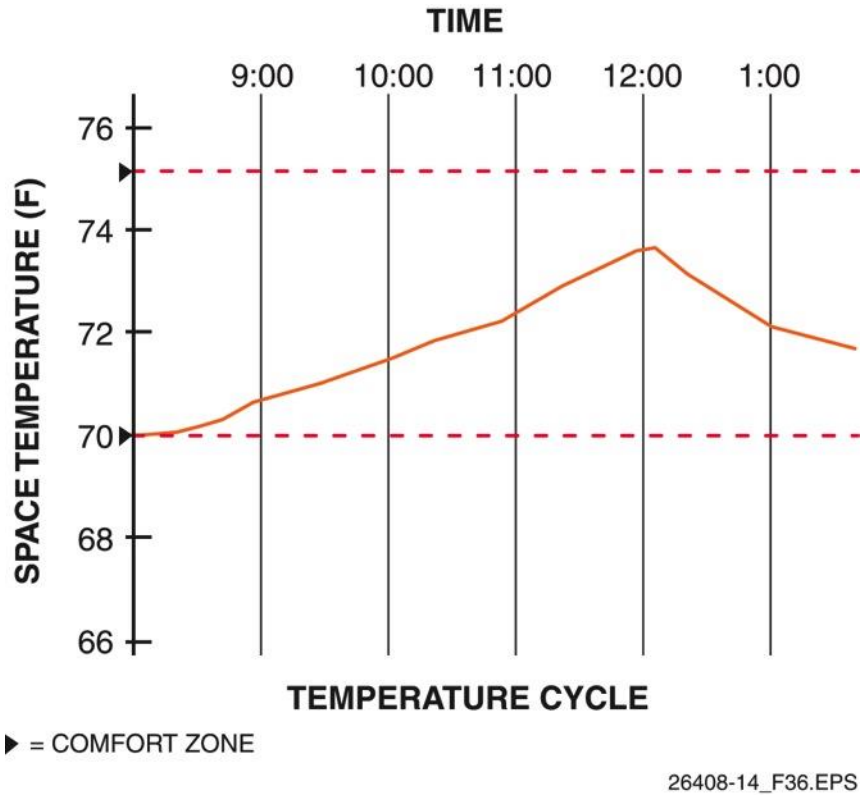
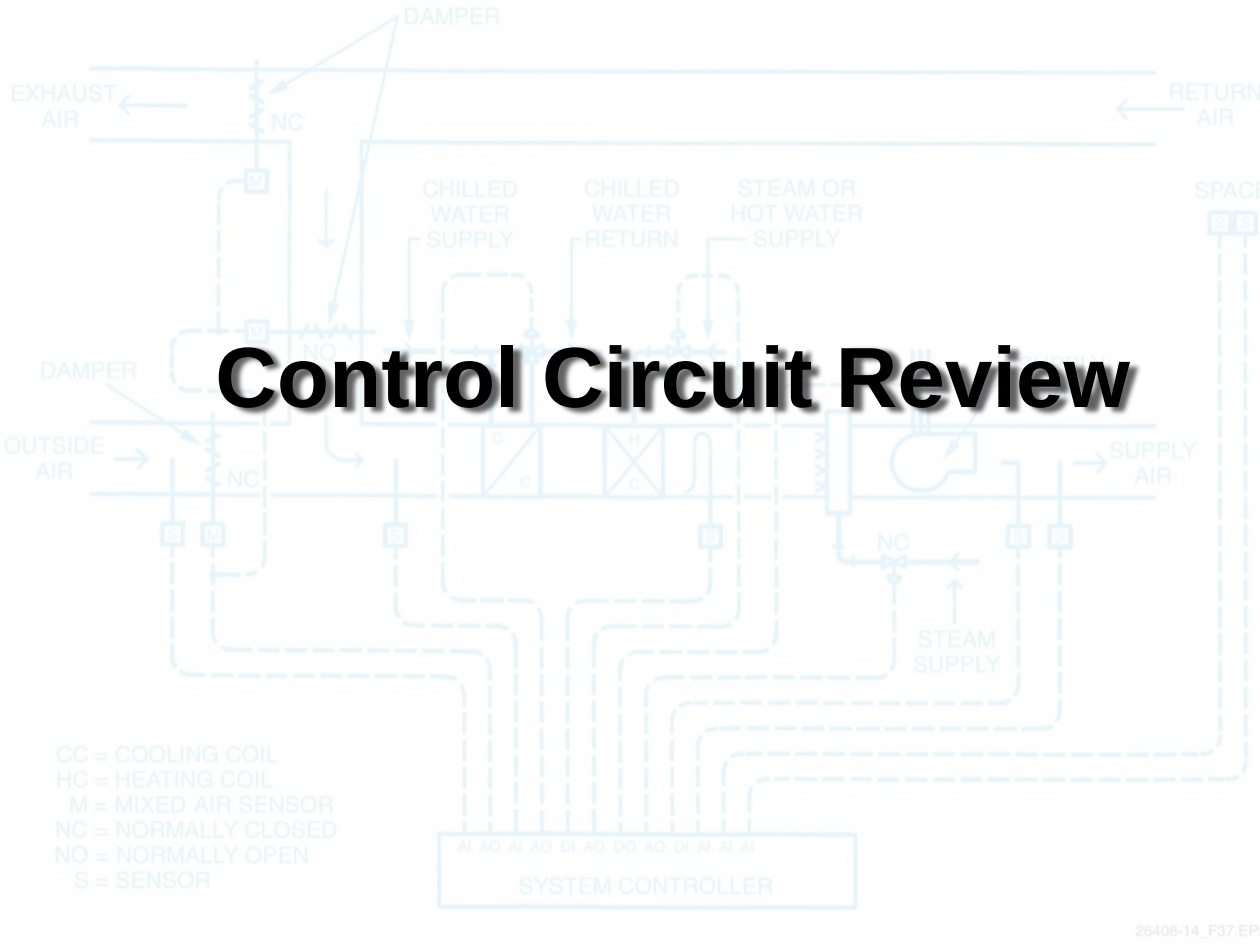
- A centralized building management system can be used to integrate all building systems for maximum comfort and efficiency.
- Processor modules, such as the one shown here, are used to control the interface between the building management system and the HVAC equipment.

Changes are Small and Occur Gradually



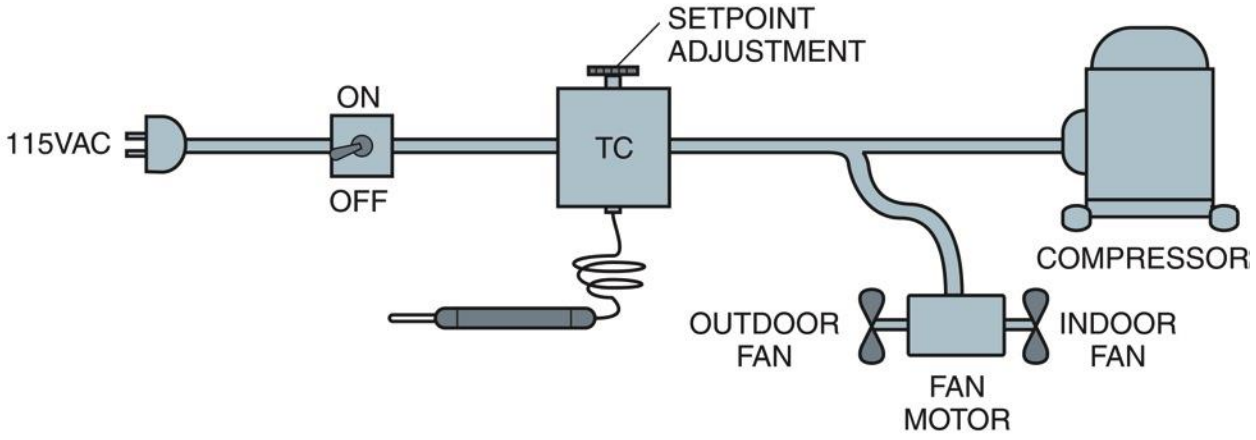
- Real-world processes that involve changes in pressure, temperature, liquid level, and fluid flow are best represented by an analog device.
- An analog-to-digital converter is used to convert small analog changes into a digital output for use with a two-state or binary device (digital).

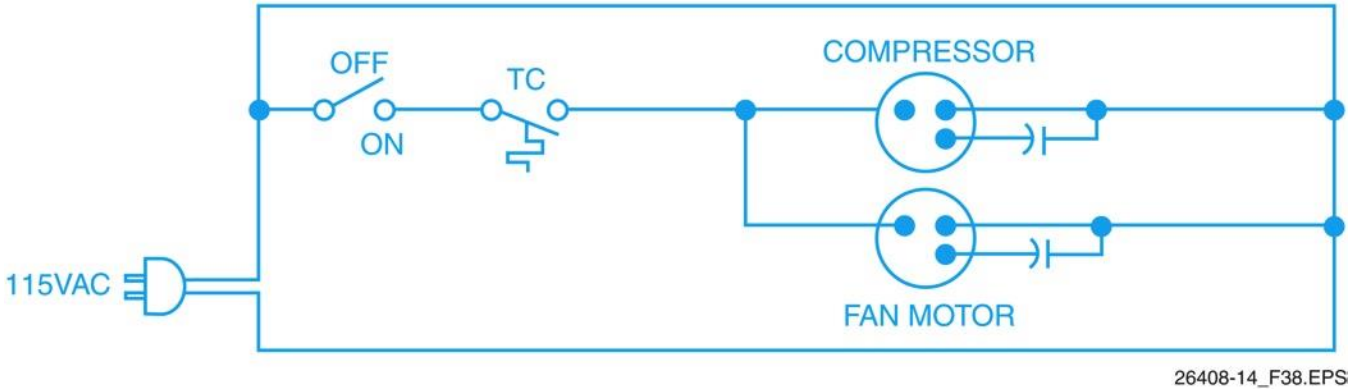
Next Session...



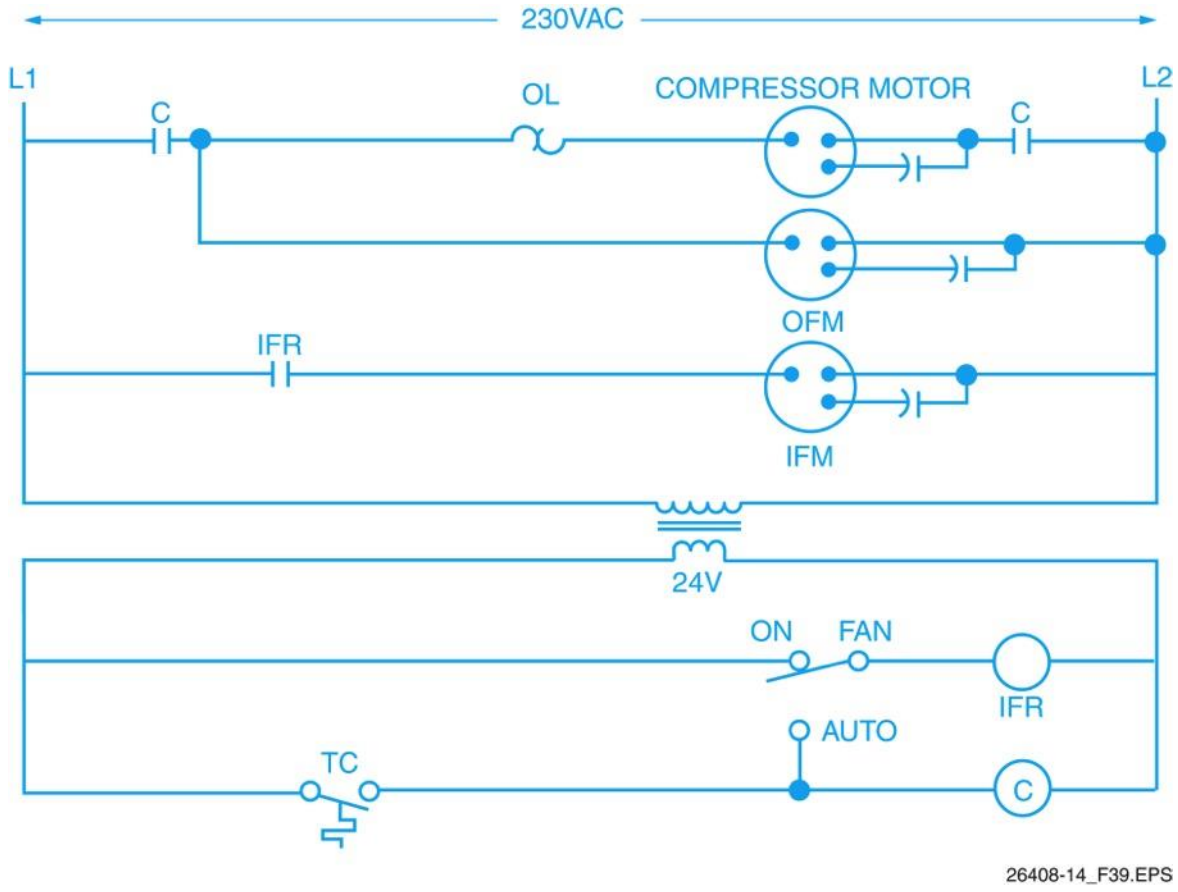
Control Circuit Review

Control Circuit Review

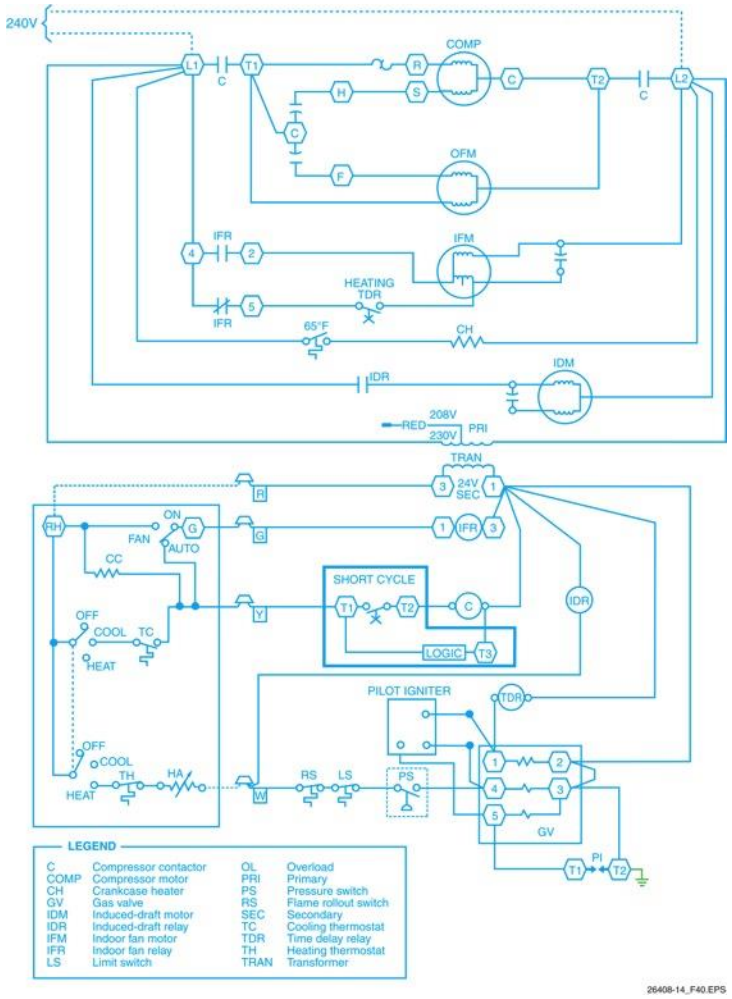




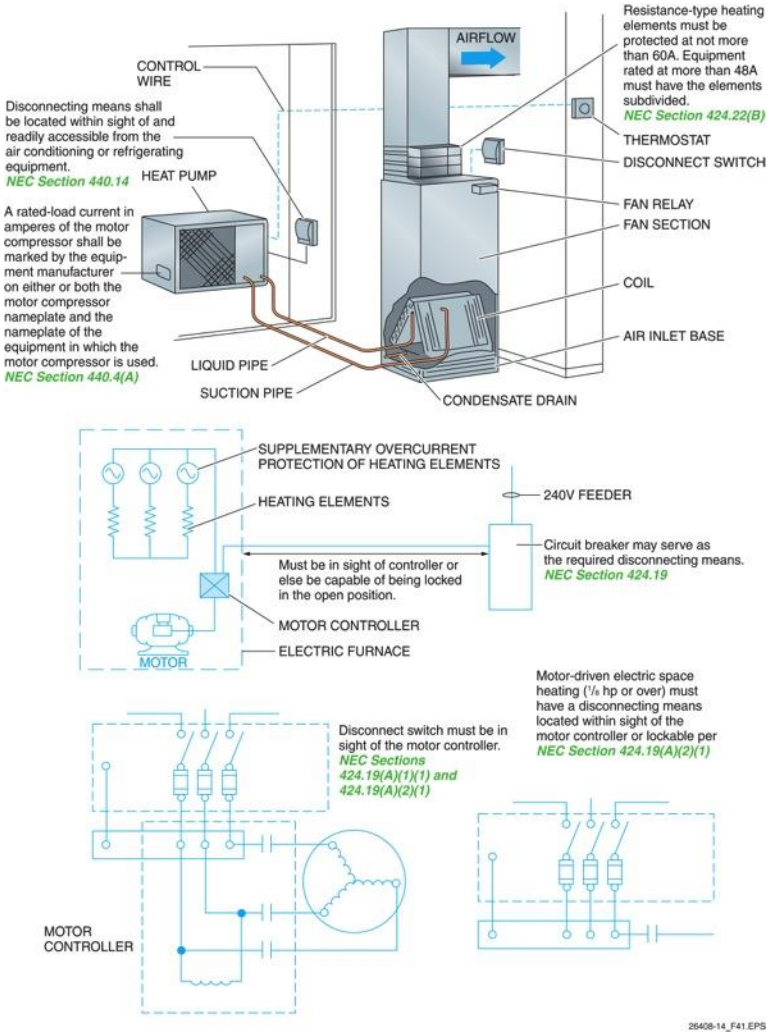
Typical Cooling System Control Circuit



Circuit Diagram of a Cooling/Gas Heating System



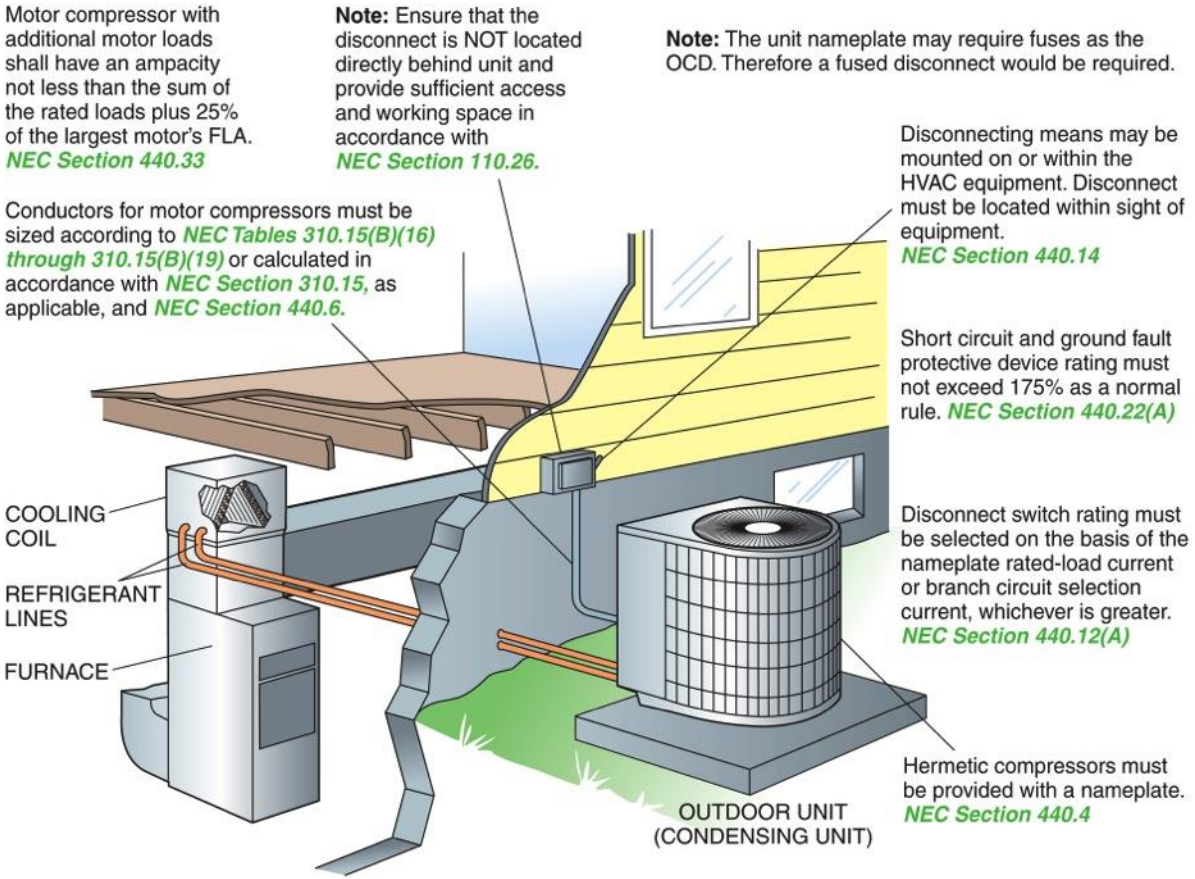
NEC® Requirements



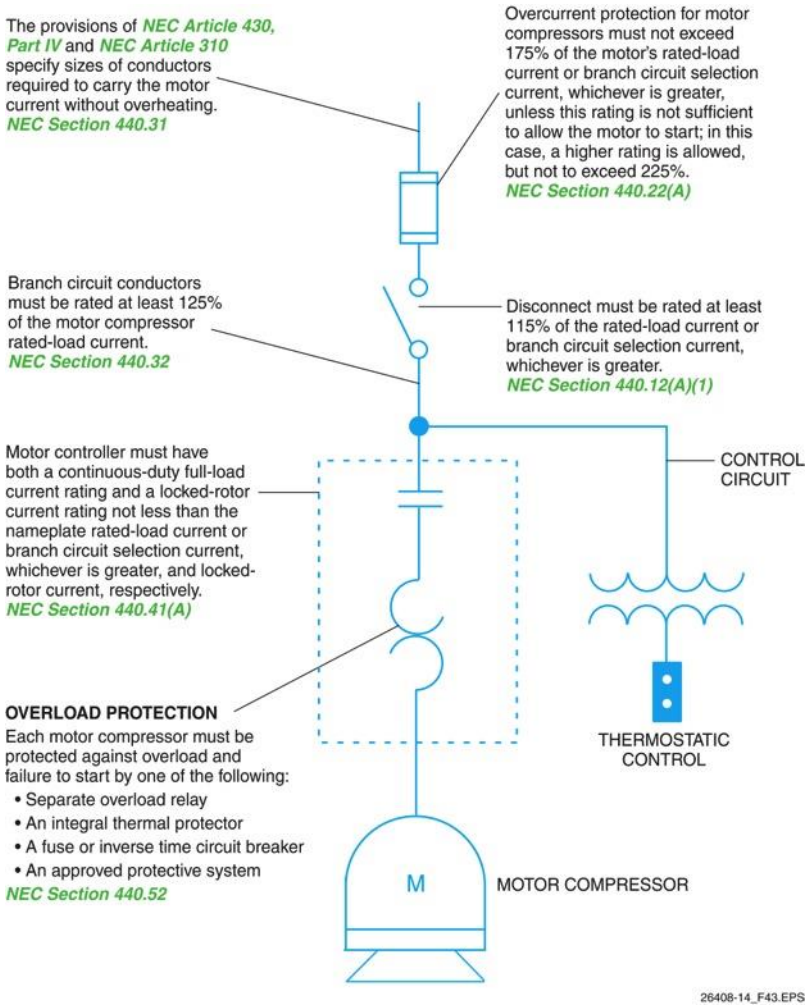
Summary of *NEC*® Requirements for Hermetically Sealed Compressors

Application	*NEC*® Regulation	*NEC*® Reference
Marking on hermetic compressors	Hermetic compressors must be provided with a nameplate containing the manufacturer's name, trademark, or symbol, identifying designation, phase, voltage, frequency, rated-load current, locked-rotor current, and the words *thermally protected*, if appropriate.	*NEC Section 440.4(A)*
Marking on controllers	Controllers serving hermetically sealed compressors must be marked with the maker's name, trademark, or symbol, identifying designation, voltage, phase, and full-load and locked-rotor currents (or hp rating).	*NEC Section 440.5*
Ampacity and rating	Conductors for hermetically sealed compressors must be sized according to *NEC Tables 310.15(B)(16) through 310.15(B)(19)* or calculated in accordance with *NEC Section 310.15*, as applicable.	*NEC Section 440.6*
Highest rated motor	The largest motor is considered to be the motor with the highest rated-load current.	*NEC Section 440.7*
Single machine	The entire HVAC system is considered to be one machine, regardless of the number of motors involved in the system.	*NEC Section 440.8*
Rating and interrupting capacity	The disconnecting means for hermetic compressors must be selected on the basis of the nameplate rated-load current or branch circuit selection current, whichever is greater, and locked-rotor current, respectively.	*NEC Section 440.12(A)*
Cord-connected equipment	For cord-connected equipment, an attachment plug and receptacle are permitted to serve as the disconnecting means.	*NEC Section 440.13*
Location	A disconnecting means must be located within sight of the equipment. The disconnecting means may be mounted on or within the HVAC equipment.	*NEC Section 440.14*
Short circuit and ground fault protection	Amendments to *NEC Article 240* are provided here for circuits supplying hermetically sealed compressors against overcurrent due to short circuits and grounds.	*NEC Section 440.21*
Rating of short circuit and ground fault protective device	The rating must not exceed 175% of the compressor rated-load current; if necessary for starting, the device may be increased to a maximum of 225%. [Do not exceed the manufacturer's value per *NEC Section 440.22(C)*].	*NEC Section 440.22(A)*
Compressor branch circuit conductors	Branch circuit conductors supplying a single compressor must have an ampacity of not less than 125% of either the motor compressor rated-load current or the branch circuit selection current, whichever is greater.	*NEC Section 440.32*
	Conductors supplying more than one compressor must be sized for the total load plus 25% of the largest motor's full-load amps.	*NEC Section 440.33*
Combination load	Conductors must be sufficiently sized for the other loads plus the required ampacity for the compressor as required in *NEC Sections 440.32 and 440.33*.	*NEC Section 440.34*
Multi-motor load equipment	Conductors must be sized to carry the circuit ampacity marked on the equipment as specified in *NEC Section 440.4(B)*.	*NEC Section 440.35*
Controller rating	Controllers must have both a continuous-duty full-load current rating and a locked-rotor current rating not less than the nameplate rated-load current or branch circuit selection current, whichever is greater, and locked-rotor current, respectively.	*NEC Section 440.41(A)*
Application and selection of controllers	Each motor compressor must be protected against overload and failure to start by one of the means specified in *NEC Sections 440.52(A)(1) through (4)*.	*NEC Section 440.52(A)*
Overload relays	Overload relays and other devices for motor overload protection that are not capable of opening short circuits must be protected by a suitable fuse or inverse time circuit breaker.	*NEC Section 440.53*
Equipment on 15A or 20A branch circuit; time delay required	Short circuit and ground fault protective devices protecting 15A or 20A branch circuits must have sufficient time delay to permit the motor compressor and other motors to start and accelerate their loads.	*NEC Section 440.54(B)*

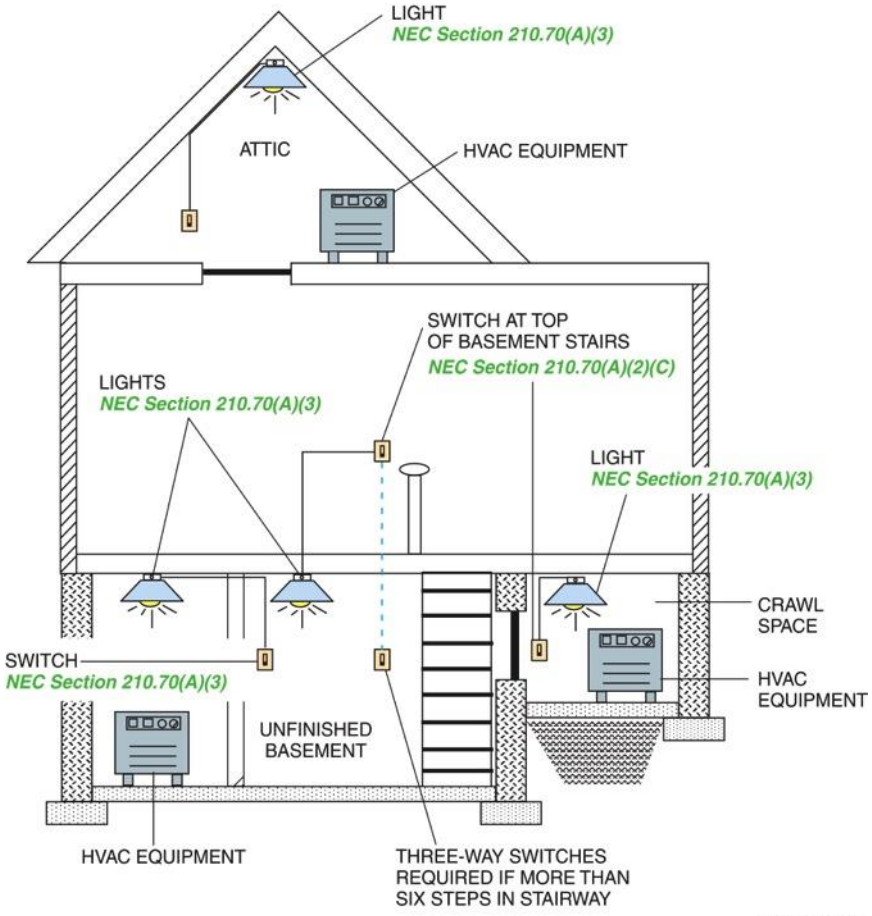
NEC® Regulations Governing Motor Compressors



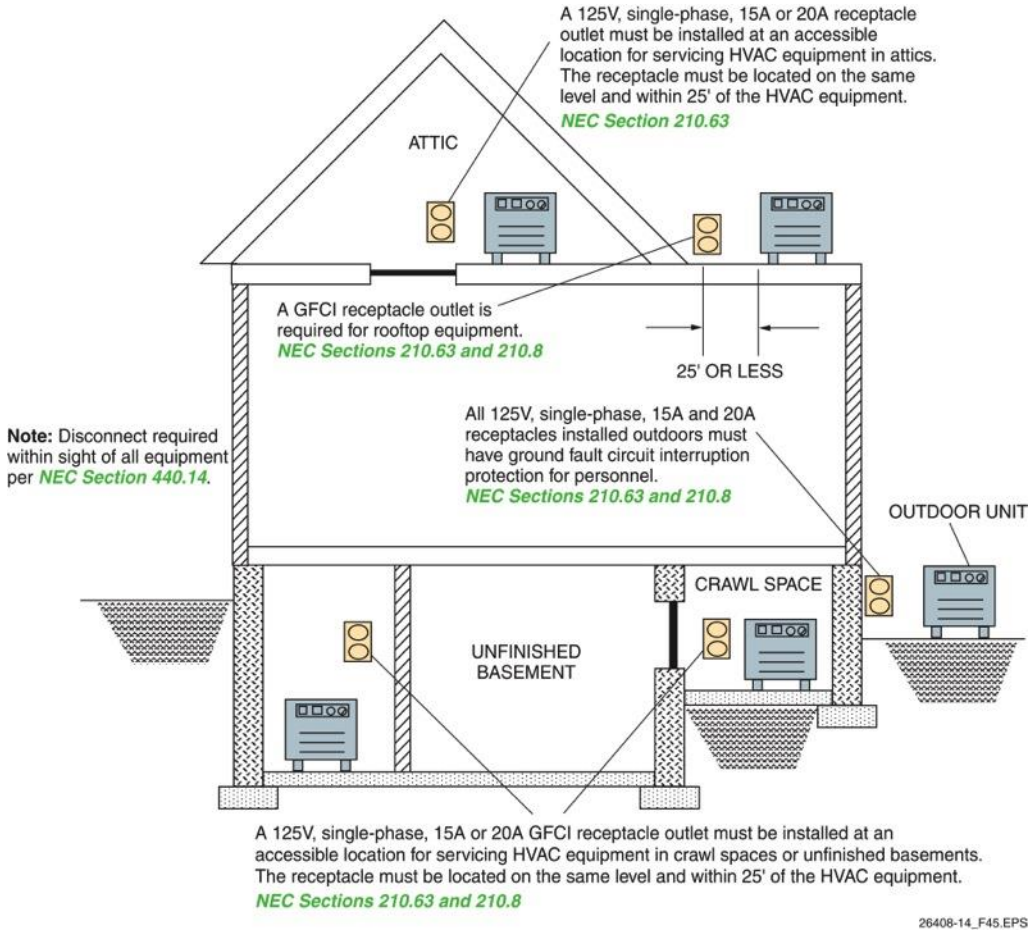
Compressor Branch and Control Circuits



NEC® Requirements for Lighting and Switches for HVAC Equipment

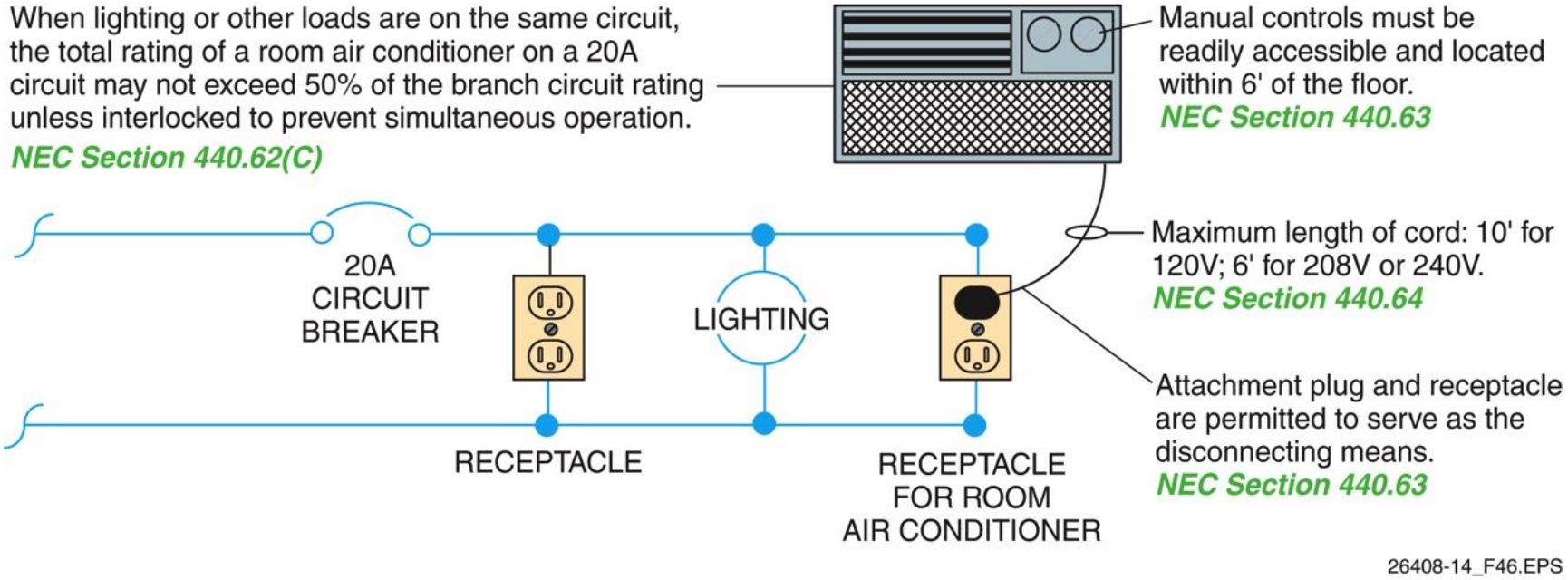


NEC® Requirements for Locating 125V Receptacles at HVAC Equipment

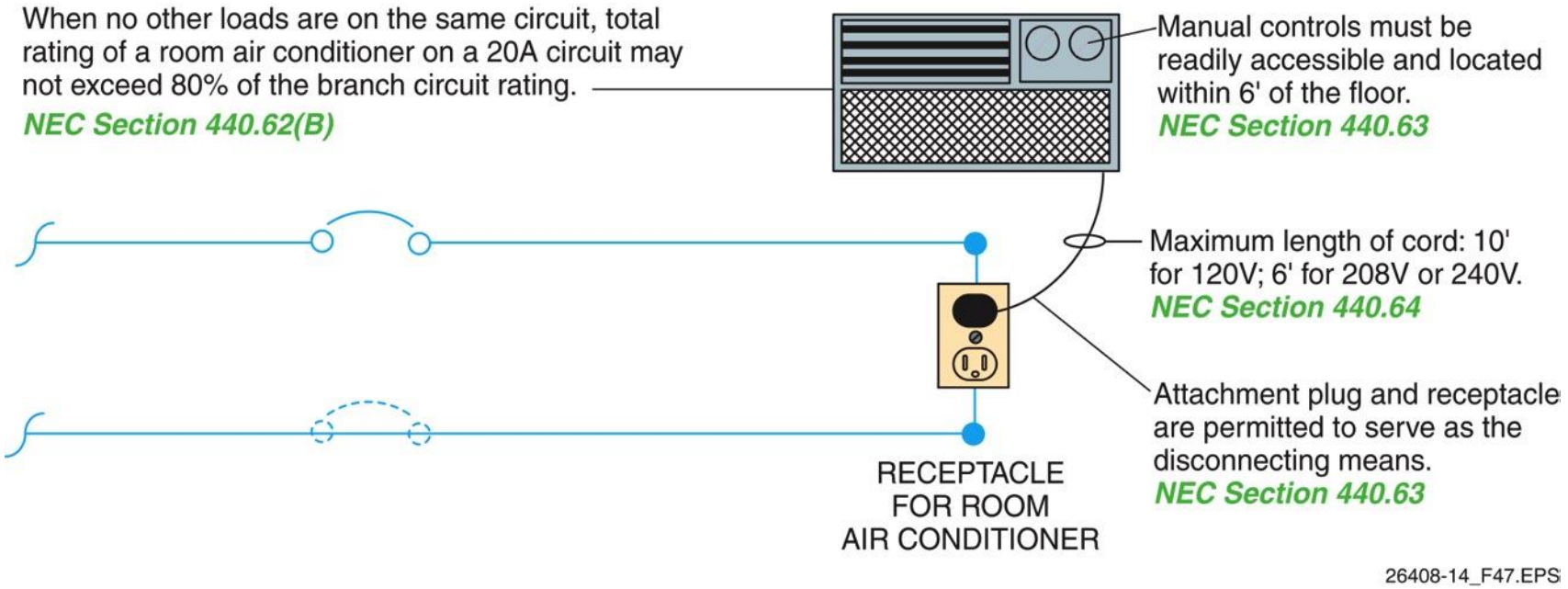


Branch Circuits for Room Air Conditioners

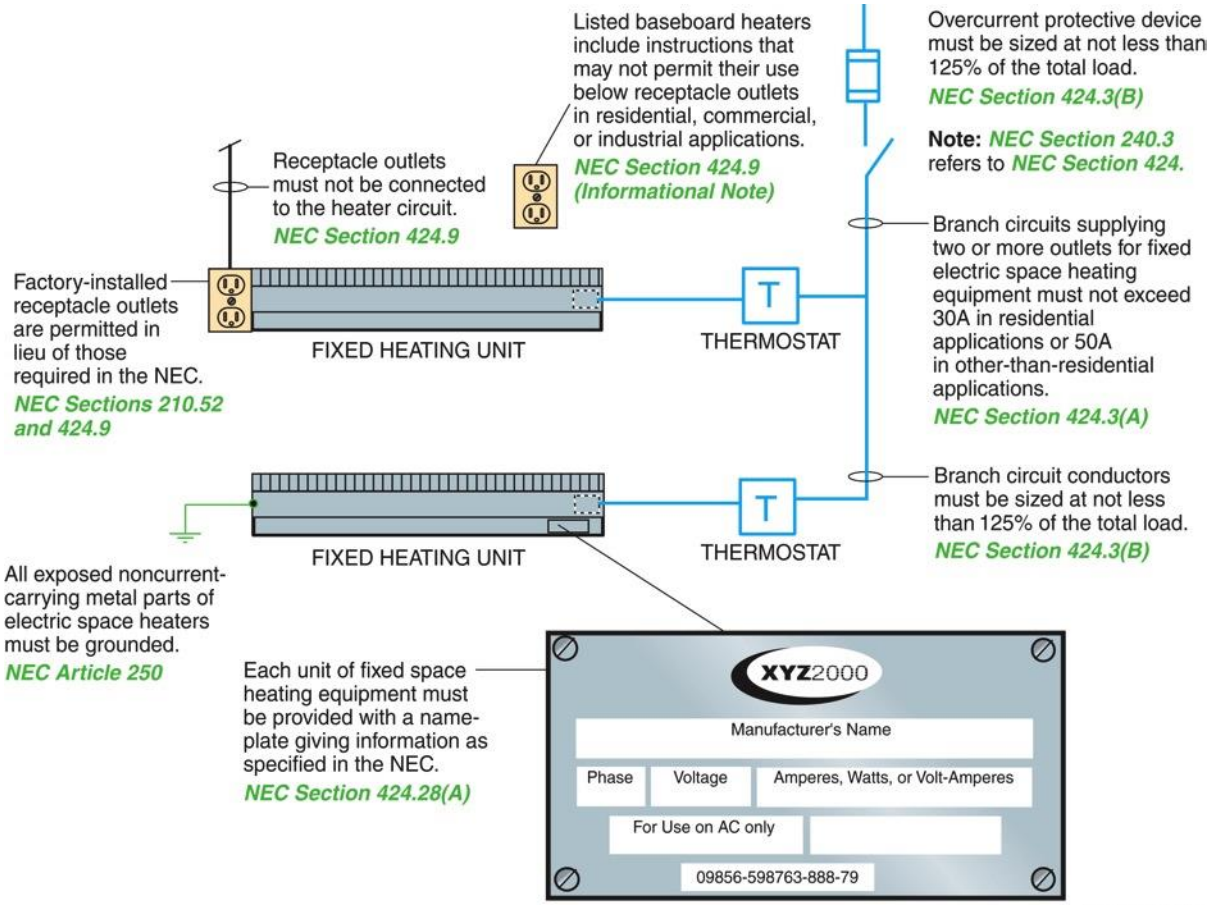
When lighting or other loads are on the same circuit, the total rating of a room air conditioner on a 20A circuit may not exceed 50% of the branch circuit rating unless interlocked to prevent simultaneous operation.
NEC Section 440.62(C)



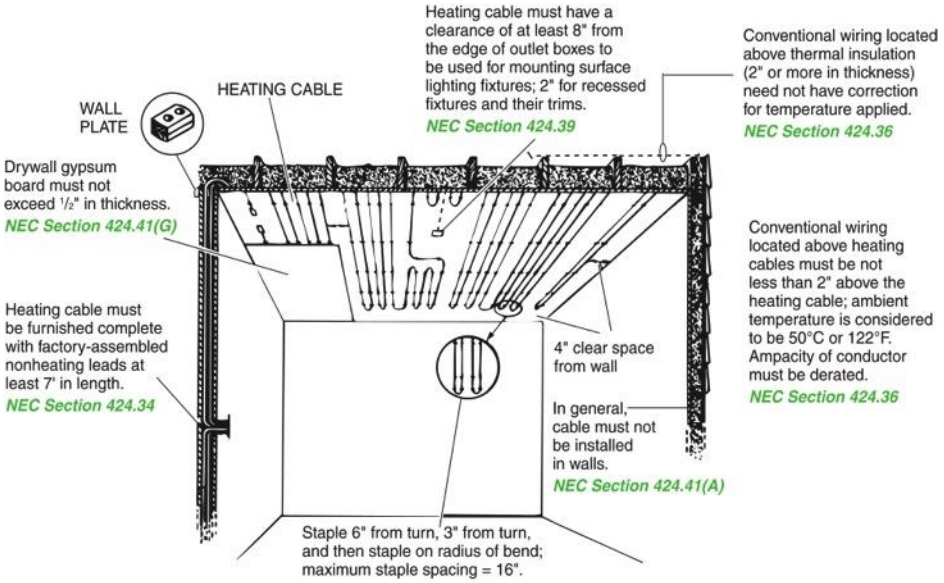
Fixed Air Conditioner Connected to a Branch Circuit



NEC® Installation Guidelines for Electric Baseboard Heaters



NEC® Regulations for the Installation of Electric Space Heating Cable



Each unit length of heating cable must have a permanent legible marking on each nonheating lead located within 3" of the terminal end; they must be color-coded as shown here.
NEC Section 424.35

YELLOW	= 120V nominal
BLUE	= 208V nominal
RED	= 240V nominal
BROWN	= 277V nominal
ORANGE	= 480V nominal

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Troubleshooting

Malfunction	Responses	Corrective Action
Compressor motor and condenser motor will not start, but the blower motor operates.	Check the thermostat system switch to ascertain that it is set to COOL.	Make necessary adjustments to settings.
	Check the thermostat to make sure that it is set below room temperature.	Make necessary adjustments.
	Check the thermostat to see if it is level. Mercury bulb thermostats must be mounted level; any deviation will ruin their calibration.	Remove cover plate, place a spirit level on top of the thermostat base, loosen the mounting screws, and adjust the base until it is level; then tighten the mounting screws.
	Check all low-voltage connections for tightness.	Tighten.
	Make a low-voltage check with a voltmeter on the condensate overflow switch; the condensate may not be draining.	The float switch is normally found in the condensate pump. Repair or replace.
	Make a low-voltage check of the pressure switches.	Replace if defective. Call a qualified HVAC technician to check the system charge.
Compressor, condenser, and blower motors will not start.	Check the thermostat system switch setting to ascertain that it is set to COOL.	Adjust as necessary.
	Check the thermostat setting to make sure it is below room temperature.	Adjust as necessary.
	Check the thermostat to make sure it is level.	Correct as required.
	Check all low-voltage connections for tightness.	Tighten.
	Check for a blown fuse or tripped circuit breaker.	Determine the cause of the open circuit and then replace the fuses or reset the circuit breaker.
	Make a voltage check of the low-voltage transformer.	Replace if defective.
	Check the electrical service against minimum requirements (correct voltage and amperage).	Update as necessary.
Condensing unit cycles too frequently.	Check room thermostat location.	Move if necessary.
	Check all low-voltage wiring connections for tightness.	Tighten.
	The equipment could be oversized.	Call qualified HVAC technician to check system capacity.
Inadequate cooling with condensing unit and blower running continuously.	Check for refrigerant leak or undercharge.	Call in a qualified HVAC technician to check for leaks in the refrigerant lines and/or to add charge.
	Check for undersized equipment.	Call qualified HVAC technician to check system capacity.

Troubleshooting

Malfunction	Responses	Corrective Action
Condensing unit cycles, but the evaporator blower motor does not run.	Check all low-voltage connections for tightness.	Correct structural deficiencies with insulation, awnings, etc., or install properly sized equipment.
	Make a voltage check of the blower relay.	Tighten.
	Make electrical and mechanical checks on the blower motor.	Replace if necessary.
	Check for correct voltage at motor terminals.	Repair or replace defective components.
	Mechanical problems could be bad bearings or a loose blower wheel. Bearing trouble can be detected by turning the blower wheel by hand (with the current off) and checking for excessive wear, roughness, or seizure.	
Unit shows continuous short cycling of evaporator blower and provides insufficient cooling.	Make electrical and mechanical checks.	Repair or replace motor if necessary.
Thermostat calls for heat, but the blower motor does not operate.	Check all low-voltage connections for tightness.	Tighten.
	Check all line-voltage connections for tightness.	Tighten.
	Check for blown fuses or a tripped circuit breaker in the line.	Determine the reason for the open circuit and replace the fuses or reset the circuit breaker.
	Check the low-voltage transformer.	Replace if defective.
	Make a low-voltage check of the fan relay.	Repair or replace if necessary.
	Make electrical and mechanical checks on the blower motor.	Repair or replace the motor if defective.
Thermostat calls for heat; blower motor operates, but it delivers cold air.	Make a visual and electrical check on the heating elements.	If not operating, continue to the next check.
	Make an electrical check of the heater limit switch; begin by disconnecting all power to the unit, then use an ohmmeter to check for continuity between the two terminals of the switch.	If the limit switch is open, repair or replace.
	Make an electrical check of the sequencer. Most are rated at 24V and have one set of normally open auxiliary contacts for pilot duty.	If the sequencer coil is open or grounded, repair or replace.
	Check the electric service entrance and related circuits against the minimum recommendations.	Upgrade if necessary.
Thermostat calls for heat and blower motor operates continuously; system delivers warm air, but the thermostat is not satisfied.	Check all joints in the ductwork for air leaks.	Make all defective joints tight.
	Check for a dirty air filter.	Clean or replace filter.
	Make a visual and electrical check of the electric heating element.	Repair or replace if necessary.
	Make an electrical check of the heater limit switch as described previously.	Repair or replace.
	Check for undersized equipment.	Call HVAC technician to check system capacity.

Troubleshooting

Malfunction	Responses	Corrective Action
Electric heater cycles on limit switches, but the blower motor does not operate.	Make an electrical check of the fan relay.	Repair or replace if defective.
	Make electrical and mechanical checks on the blower motor.	Repair or replace if defective.
	Check the line connections for tightness.	Make any necessary changes.
There is excessive noise at the return air grille.	Check the return duct to make sure it has a 90° bend.	Correct if necessary.
	Make a visual check of the blower unit to ascertain that all shipping blocks and angles have been removed.	Remove if necessary.
	Check the blower motor assembly suspension and fasteners.	Tighten if necessary.
There is excessive vibration at the blower unit.	Visually check for vibration isolators (which isolate the blower coil from the structure).	If missing, install as recommended by the manufacturer.
	Visually check to ascertain that all shipping blocks and angles have been removed from the blower unit.	Remove if necessary.
	Check the blower motor assembly suspension and fasteners.	Tighten if necessary.

10.0.0

Next Session…

Electric Heat Troubleshooting Chart

Generally the Cause Make these checks first.	Occasionally the Cause Make these checks only if the first checks failed to locate the trouble.	Rarely the Cause Make these checks only if other checks failed to locate the trouble.
Problem: No heat—unit fails to operate		
Power failure	Control transformer	Faulty wiring
Blown fuses or tripped circuit breaker	Control relay or contactor	Loose terminals
Open disconnect switch or blown fuse	Bad thermal fuse	
Thermostat switch not in proper position		
Element open		
Problem: Not enough heat—unit cycles too often		
Limit controls	Control relay or contactor	Loose terminals
Low air volume	Fan control	Low voltage
Dirty blower wheel	Thermostat level	Faulty wiring
Dirty filters	Thermostat location	Loose blower wheel
Element fuse	Outdoor thermostat	Ductwork small or restricted
Heat sequencer	Blower bearings	
Heat relay		
Thermostat heat anticipator improperly set		
Problem: Too much heat—unit cycle is too long		
Thermostat heat anticipator incorrectly set	Thermostat level	Control relay or contactor
Thermostat out of calibration	Thermostat location	
Problem: No heat—unit runs continuously		
Thermostat faulty	Faulty wiring	Thermostat not level
Control relay or contactor		Thermostat location
Problem: Cost of operation too high		
Blower motor	Low air volume	Low voltage
Dirty filters	Insufficient building insulation	Fan control
Outdoor thermostat setting incorrect	Excessive building infiltration	Blower belt broken or slipping
		Dirty blower wheel
		Ductwork small or restricted
Problem: Mechanical noise		
Blower bearings	Blower motor	Low voltage
Blower out of balance	Cabinet	Control transformer
Blower belt slipping		
Problem: Air noise		
Blower	Ductwork or grilles restricted	Blower wheel
Cabinet		Dirty filters
Dirty coil		
Problem: Odor		
Foreign substances (dirt or dust) on heating elements	Low air volume	Faulty wiring
	Humidifier containing stagnant water	Loose terminals
	Water or moisture	Control transformer
		Dirty filters
		Dirty or plugged heat exchanger

Wrap Up

Wrap Up

3-2-1

3 – Write 3 important things learned during class

2 – Write 2 questions you have about the material

1 – Write 1 thought you had about the material

Next Session…

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.