UNIT 36

Electrical Components

OBJECTIVES

After completing this unit, you will be able to:

1. determine the resistance value of a color-banded fixed resistor.
2. provide examples of where and how transformers are used.
3. identify paper and film, electrolytic, ceramic, and mica capacitors.
4. identify the different types of thermostats.
5. explain cut-in, cut-out, and differential on pressure switches.
6. test transformers, capacitors, contactors, and relays.
7. list the different types of fuses and overloads.
8. explain the difference between relay logic and solid-state logic.
9. describe how a silicon rectifier operates.

36.1 INTRODUCTION

Most HVACR service work deals with electrical problems. These problems can be caused by component failure, improper installation, or misuse. It is therefore important that HVACR technicians have a thorough and complete understanding of electrical components and wiring diagrams. Electrical circuits on different pieces of equipment will have similarities. Most circuits will have resistors, capacitors, relays, contactors, switches, and transformers. Understanding the function of each of these components will help you better understand how to troubleshoot a circuit. Electronic circuits with solid-state components are quickly replacing traditional electrical circuits, but many similar operating principles still apply. Therefore, this unit includes not only information on basic circuit components but also introduces the most common solid-state components.

36.2 RESISTORS

Resistors are found in many circuits (Figure 36-1). They are designed to allow for a measured resistance that can affect either voltage or current as calculated by using Ohm's law.

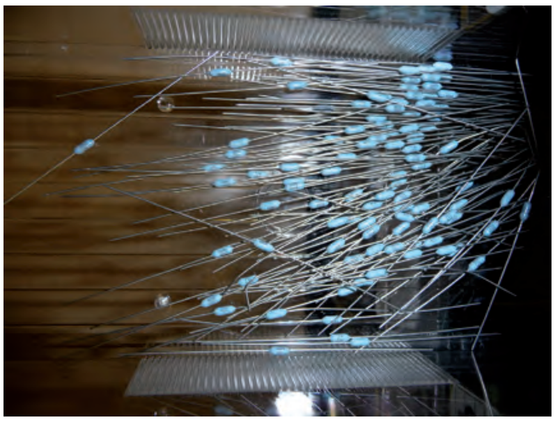


Figure 36-1 Resistors.

As an example, a resistor could be used in an electrical test meter to limit the current flow. Fixed resistors can be made from nickel wire wound on a ceramic tube and then covered with porcelain. Smaller fixed resistors are made from mixtures of powdered carbon and insulating materials molded into a round tubular shape (Figure 36-2). Variable resistors have a tightly wound coil of resistance wire made into a circular shape (Figure 36-3a,b). The resistance value is changed by turning an adjustment that moves the point of contact along the circular coil. Some variable resistors can be controlled by a small knob, while others are adjusted with a screwdriver (Figure 36-3c). Adjustable resistors are often used for electronic circuits.

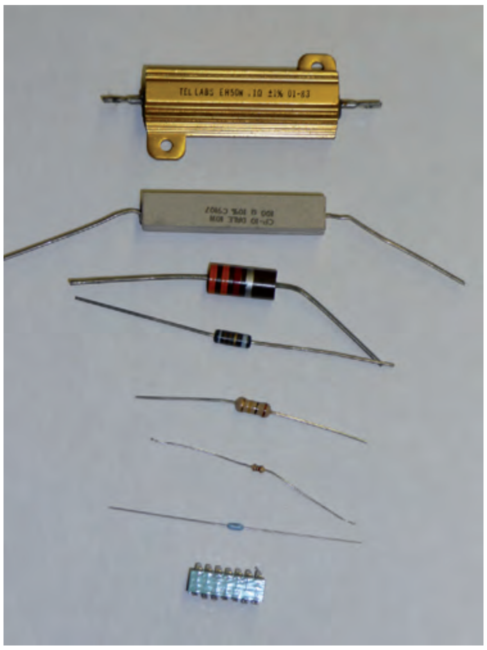
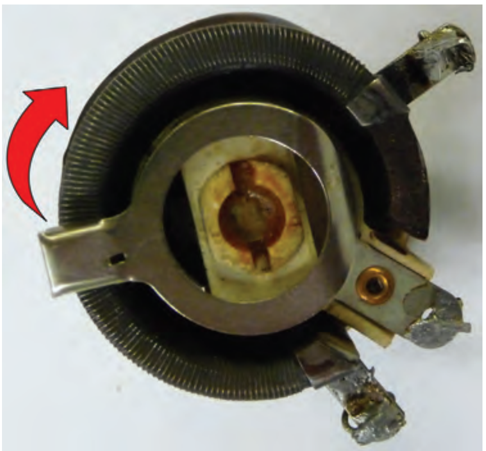
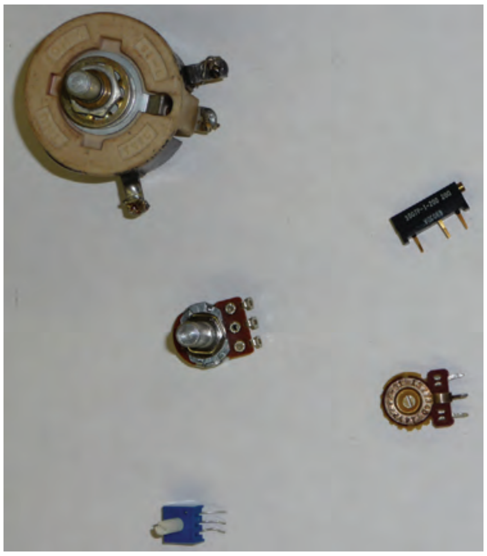


Figure 36-2 Example of different types of fixed resistors.



(a)



(b)

(c)

Figure 36-3 (a) Resistance changes at different points along the resistance coil; (b) assortment of variable resistors; (c) a small, flat-tipped screwdriver would be require to turn the adjustment to change the resistance.

0	BLACK
1	BROWN
2	RED
3	ORANGE
4	YELLOW
5	GREEN
6	BLUE
7	VIOLET
8	GREY
9	WHITE
0.1	GOLD
0.01	SILVER
5%	GOLD-TOLERANCE
10%	SILVER-TOLERANCE

Figure 36-4 Resistor color-code chart.

Figure 36-5 The resistor color code is orange, orange, red, silver.

Resistor Color Bands

Markings on resistors can vary. Larger resistors have printed resistance values, while smaller resistors have color-coded bands. To determine the resistance of a color-coded resistor, start from the end opposite the silver or gold band. Use the color code chart from Figure 36-4 to determine the resistance values. The first two bands identify the first and second digits of the resistance value, and the third band indicates the number of zeroes. However, if the third band is silver, this will indicate a 0.01 multiplier. If the third band is gold, this will indicate a 0.1 multiplier. The fourth band indicates tolerance. Silver indicates a +/− 10 percent tolerance, and gold indicates a +/− 5 percent tolerance. If there is no fourth band, the resistor tolerance is +/− 20 percent.

Calculate the resistance of the resistor shown in Figure 36-5. The first band is orange, which is listed as number 3 on the chart. The second band is also orange, and the third band is red. The resistance therefore would be 3,300 ohms with a tolerance of 10 percent.

36.3 CAPACITORS

A capacitor will store energy when an electric charge is forced onto its plates from a power source. A capacitor will still retain this charge even after disconnection from the power source. However, it would be impractical to try to discharge the power from the capacitor into a different circuit, as you would do, for example, by placing charged batteries into your radio. Compared to a storage battery, the total amount of energy stored by a capacitor is relatively small. Also, the discharge rate of a capacitor is rapid, so the release of the stored energy only occurs during a short time interval. However, a mishandled capacitor will deliver a shock that can be severe and even fatal, especially for large capacitors charged to a high voltage.

Capacitor Types

Capacitors are rated for a maximum voltage by the manufacturer. This rating is usually expressed as the direct current working voltage (DCWV). Exceeding this voltage will shorten the life of the capacitor.

Capacitors can be used for a number of different applications. As an example, they can be used for tuning,

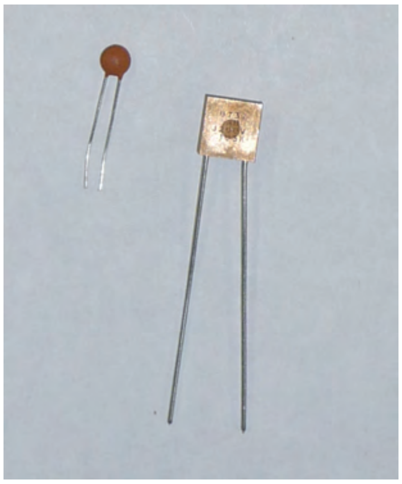


Figure 36-6 Disc ceramic capacitors.

filtering, energy storage, power factor correction, and motor starting. Capacitive filters are used to smooth pulsating DC and separate low-frequency AC from high-frequency AC. Capacitive tuners are used for tuning radios and television sets to the proper channel. Energy-storage capacitors are used in industrial applications such as capacitor discharge welding, where a large amount of stored energy is discharged rapidly. The leading current of a capacitor offsets the lagging current in an inductive load to allow for power factor correction. Many electric motors also utilize capacitors to produce a current phase shift in their windings.

Not all capacitors are made of the same materials. There are paper and film, electrolytic, ceramic, and mica capacitors. Disc ceramic capacitors are commonly found on electronic circuit boards and are typically 0.1 microfarads (mfd) or less (Figure 36-6). Mica capacitors are limited to even lower values than this (Figure 36-7).

For larger-capacitance requirements, paper and film capacitors are used (Figure 36-8). They are constructed using a rolled-foil technique. Once rolled, the capacitor may be dipped into a plastic insulating material. Capacitors of this type used for electronic circuits are rated at generally less than 1 mfd. However, they can also be designed for industrial applications to meet the requirements of several hundred microfarads. In this case, they would be housed in a metal container filled with special insulation oil.

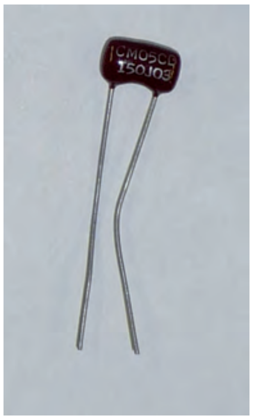


Figure 36-7 Mica capacitor.

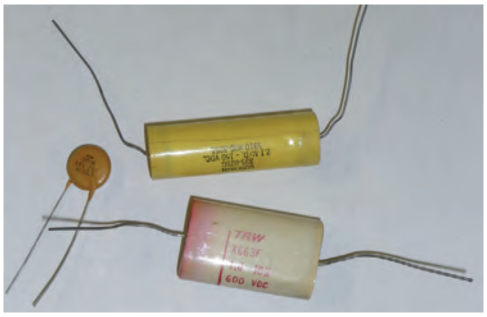


Figure 36-8 Rolled film and paper capacitors.

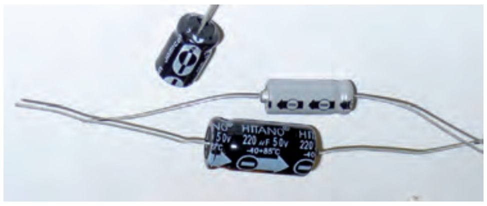


Figure 36-9 Electrolytic capacitors marked for polarity.

The type that provides for the most capacitance in relationship to their size and weight are electrolytic capacitors, which are commonly polarized. The polarity is marked on the body of the capacitor in some manner, as shown in Figure 36-9. Never reverse the polarity on this type of capacitor. This will lead to excessively high current, overheating, and possible explosion of the capacitor. A pop-out hole on some capacitors allows for the insulation to expand if the capacitor is overheated (Figure 36-10). If the hole is ruptured, the capacitor must be replaced.

Motor Capacitors

Capacitors for motors are classified as either starting capacitors or running capacitors. In replacing a capacitor, it is desirable to use an exact replacement. This means a capacitor with the same mfd rating and voltage limit rating. Do not interchange start and run capacitors (Figure 36-11). Start capacitors are high-capacity (50–700 mfd) electrolytic units that are intended for momentary use in starting

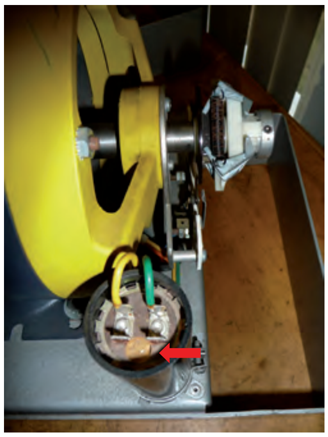


Figure 36-10 Motor-start capacitor with pop-out hole.

Figure 36-11 Assortment of both motor-start and motor-run capacitors.

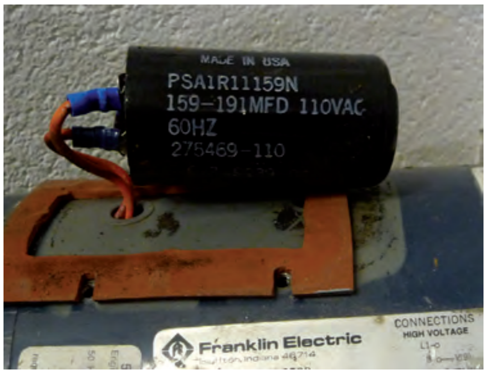


Figure 36-12 159 to 191 mfd motor-start capacitor.

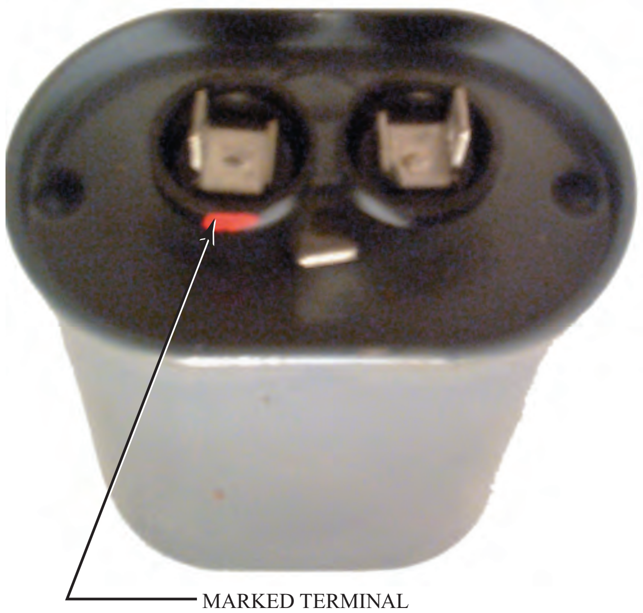


Figure 36-13 The marked terminal on the run capacitor should be connected to the run terminal of the compressor.

motors (Figure 36-12). They are normally encased in plastic. Run capacitors have much lower capacitance ratings (2–40 mfd) but are made for continuous-duty use. They are normally sealed in a metal can.

Motor-start capacitors are in series with the start switch and starting winding. This allows for a large phase shift to create a good starting torque. Since it is a starting capacitor only, it is not rated for continuous duty and is limited to about twenty starts per hour.

Motor-run capacitors are rated for continuous duty and are commonly used for permanent split-capacitor motors. The capacitor is matched to provide a 90° phase shift between current in the auxiliary and main motor windings at 80 to 100 percent of rated power. It stores and releases an electrical charge in the auxiliary winding to increase the current lag between it and the main winding. This is to balance the effective inductance and inductive reactance of the windings. The capacitor remains in the circuit the entire time the motor is running.

Some run capacitors have some sort of a mark, usually a red dot, as shown in Figure 36-13, to indicate the terminal that should be connected to the run terminal. With this arrangement, an internal short circuit to the capacitor case will blow the system fuses without passing the current through the motor start winding.

36.4 TESTING CAPACITORS

The first operation in testing a capacitor is to discharge it. Do not discharge it by shorting out the terminals, as this can damage the capacitor. To avoid electrical shock, the technician should never place fingers across the terminals before properly discharging the capacitor.

The proper way to discharge a capacitor is to put it in a protective case and connect a 20,000 Ω, 2 W resistor across the terminals, as shown in Figure 36-14. Most start capacitors have a bleed resistor across the terminals. This makes it so the capacitor can be tested with the bleed resistor in place. Even so, it is good practice to make sure the charge has been bled off.

Capacitors can be roughly checked by using an ohmmeter. The ohmmeter used in testing capacitors should be able to read a high resistance and have at least an R × 100 scale. To test the capacitor, disconnect it from the wiring and place the ohmmeter leads on the terminals, as shown in Figure 36-15.

If the capacitor is not shorted, the needle will make a rapid swing toward zero and slowly return to infinity. If the capacitor has an internal short, the needle will stay at zero, indicating that the instrument will not take the charge. What you are actually doing is attempting to charge the capacitor using the battery in the ohmmeter (be sure the battery in the ohmmeter is good). An open capacitor will read high with no dip and no recovery.

The use of a capacitor analyzer is highly recommended (Figure 36-16). This instrument will read the mfd rating and detect any breakdown in the dielectric underload conditions. It will detect any capacitors that have failed to hold

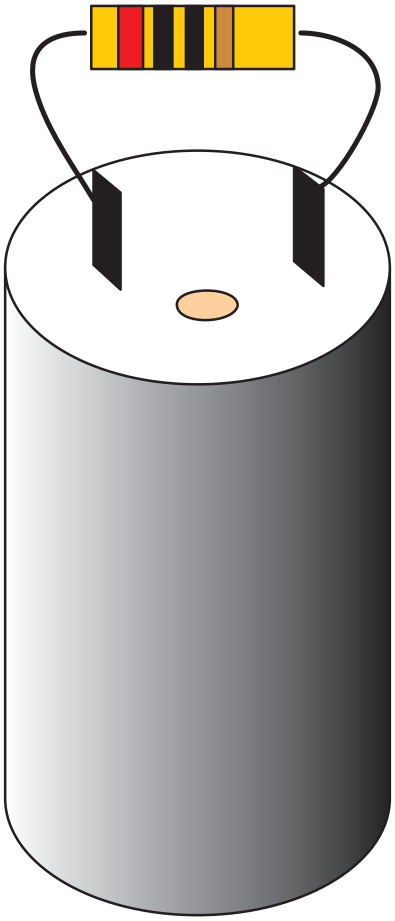


Figure 36-14 Using a bleed resistor on a start capacitor.

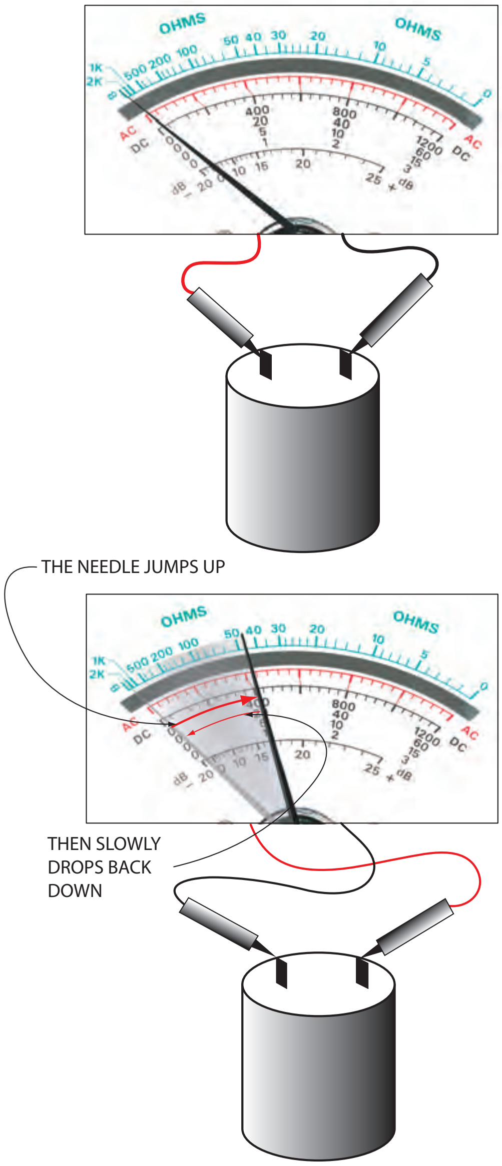


Figure 36-15 Using an ohmmeter to test capacitors.

Figure 36-16 Capacitor test meter.

their ratings. It also is useful in measuring the rating of a capacitor that has an unreadable marking.

Most digital multimeters now have scales for testing capacitors. Set the meter to the capacitance test function and place the leads on the capacitor terminals (Figure 36-17).

36.5 TRANSFORMERS

HVACR equipment often requires more than one voltage. One or more transformers are often used to step down the line voltage to supply load or control requirements. Occasionally a stepup transformer may be used.

TECH TIP

There are several reasons that most HVACR equipment uses 24 V as the control voltage. First, under most state and local guidelines, an electrician's license is not required to install and service these low-voltage wires. Second, most codes do not require that these connections be made at electrical junction boxes. And third, under OSHA regulations, circuits that have less than 80 V fall under less stringent safety requirements.

Figure 36-17 Testing a capacitor using the capacitor test function on a multimeter.

Transformer Design

Transformers are constructed using the induction characteristics of AC power. When current flows through a coil, a magnetic field is produced. When a second coil is placed in the field of the current-carrying coil (primary), electric current can be transferred to the second coil (secondary) (Figure 36-18). The process is made more efficient by wrapping the coils around a common metal core. The voltage transferred is directly in proportion to the ratio of the number of turns on the primary coil to the number of turns on the secondary coil. For example, a control transformer with a 240 V primary winding and a 24 V secondary winding has a 10:1 ratio: 10 turns of wire in the primary for every turn in the secondary.

More than one secondary coil can be used if additional voltages or circuits are required. Likewise, some transformers are made with more than one primary. These multiple windings can then be connected in series or parallel to change the voltage or current capability of the transformer.

Center-tapped transformers allow for a small change in the windings voltage rating by changing taps. Typical residential voltage is 120 V, but this can vary. A center-tapped transformer could be connected to meet varying requirements. As an example, a transformer that has multiple primary taps could be connected for 120 V, 208 V, or 240 V, depending on the tap used (Figure 36-19). Variable autotransformers also allow for changing the voltage output (Figure 36-20).

Three-phase transformers are generally used for three-phase power. However, a single-phase transformer for each leg (three single-phase transformers) would produce the same results.

Transformer Application

There are many different types of transformers for many different applications. Large power transformers are designed to operate at electric utility voltages from 115 V to several thousand volts (Figure 36-21). A common use for some smaller transformers is to provide low-voltage AC to

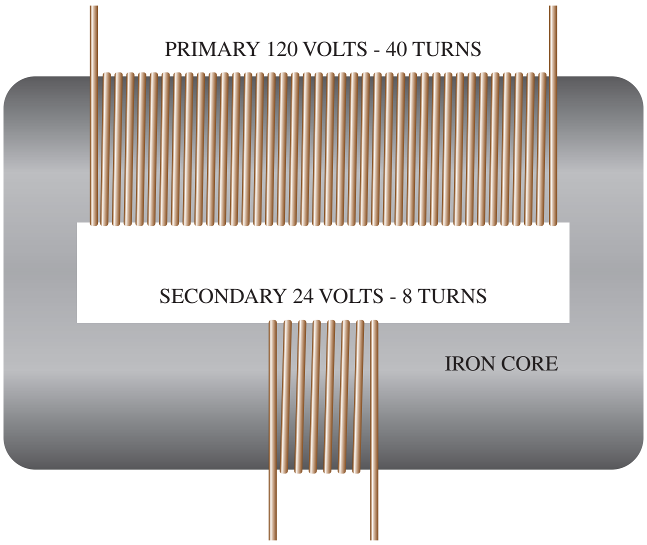


Figure 36-18 Primary and secondary voltages of a step-down transformer.

Figure 36-19 The primary voltage for this transformer depends upon the tap used.

Figure 36-20 Variable autotransformer.

Figure 36-21 Typical line voltage power transformer.

rectifiers for conversion to DC. These would be called rectifier transformers. Air-conditioning systems use low-voltage transformers to provide 24 V AC to control circuits to operate relays and solenoids. These step down the voltage from line voltage to 24 V and are referred to as control transformers (Figure 36-22).

Equipment that is very sensitive to voltage changes use constant voltage transformers. Electronic devices may use the metal chassis where components are mounted as a common conductor. If you touch the metal chassis accidently while there is power, you will receive a shock. Isolation transformers are used to break the circuit and protect the technician.

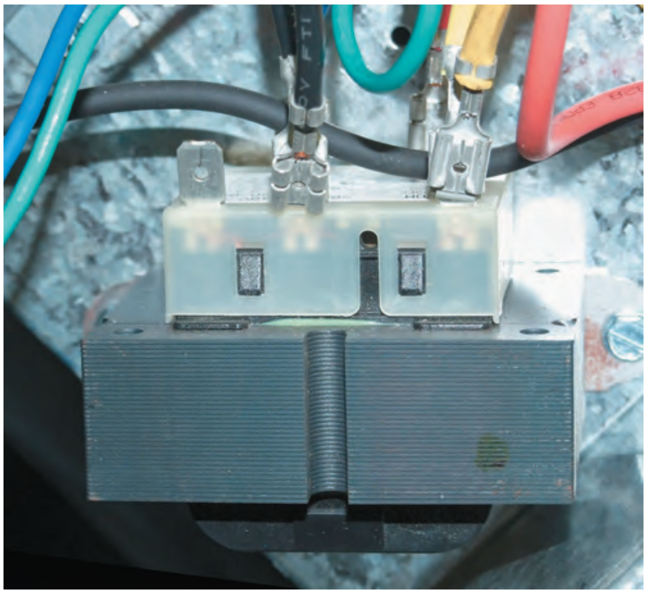


Figure 36-22 Control voltage transformer.

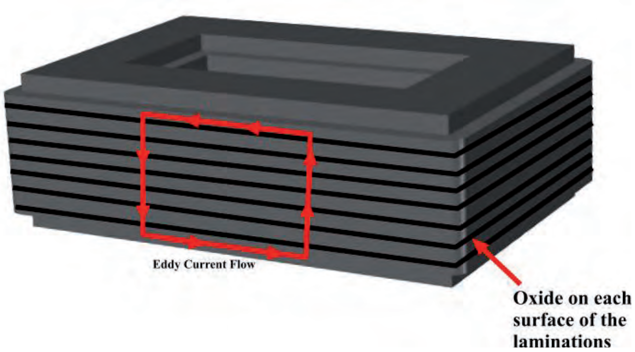


Figure 36-23 Stray eddy current flow through the transformer core is reduced by the oxide surface treatment of the laminations.

Transformer Construction

Transformers will heat up during operation. This production of heat is inefficient. Transformer cores are made of thin sheet-metal strips in the form of a laminate. There are a number of advantages to using thin sheet-metal strips. It is far easier to manufacture thin sheets because they can be stamped, where the thicker material would have to be cut. Also, the voltage induced in the core will cause current, called eddy current, to circulate (Figure 36-23). Each metal strip is insulated with a thin layer of oxide, which resists the flow of eddy currents (Figure 36-24). This reduces unwanted current circulation through the core and excessive heating of the transformer.

Transformer Operation

The voltage ratings for transformers are specified by the manufacturer for both primary and secondary windings. A primary winding operating at above its rated voltage will overheat. Current ratings are often only provided for the secondary winding. This is because the primary winding current capacity cannot be exceeded before the secondary winding. When the current rating of the secondary is exceeded, the voltage output drops below the secondary voltage rating. This causes the transformer to heat up, shortening its life.

Transformers are commonly rated by volt-ampere ratings, abbreviated VA (Figure 36-25). The VA rating is literally the voltage multiplied by the current, amps. VA ratings are used because they apply to any load, whether resistive, reactive, or combination (impedance). Inductive loads convert electricity to magnetism. The coils of relays, contactors, and solenoids are all examples of inductive loads. The current and voltage get out of phase in inductive loads, so the wattage is actually less than the volts times the amps. VA ratings show the combined effect of volts and amps on the transformer regardless of the type of load on the transformer.

Note that the amp draw of the secondary is much higher than the amp draw of the primary. Take, for example, a 48 VA transformer with a 120 V primary and a 24 V secondary. The primary current = 48 VA/120 V = 0.4 amps. The secondary current equals 48 VA/24 V = 2.0 amps. Note that this example ignores the heat given off. This is why the

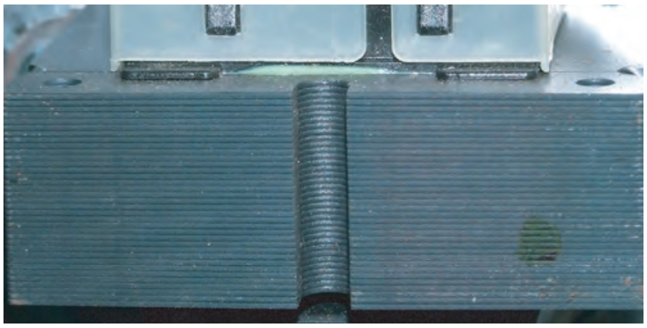


Figure 36-24 Laminations are clearly visible on most transformers.

Figure 36-25 Industrial control transformer with a .050 KVA rating.

Figure 36-26 Residential service entrance panel with the access cover open to provide access to the circuit breaker switches.

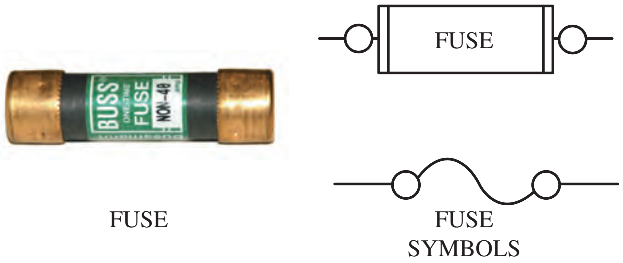


Figure 36-27 A cartridge fuse and its common symbols.

secondary winding is made from heavier-gauge wire than the primary winding.

Efficiencies for transformers are higher when they operate more fully loaded. The primary winding current is mostly inductive, making it nearly as much as 90° out of phase with the voltage. The mostly resistive secondary winding current will offset this at higher transformer loads so that the total current is more in phase with the voltage and therefore more efficient. When operating without a load, all the current the transformer draws is waste. When operating fully loaded, most of the current is going to the load.

36.6 FUSES

Where the power comes into the building, it enters a service entrance panel for distribution to the various electrical loads (Figure 36-26). Each electrical circuit that comes from this panel is electrically protected by either a fuse or a circuit breaker.

A sample fuse and two commonly used fuse symbols are shown in Figure 36-27. A fuse is a special electrical conductor that is placed in series with a load and melts when excessive current flows through it, opening the circuit. Fuses are available in different types and sizes so that they can be selected to match the requirements of specific loads (Figure 36-28). If they are too small, they melt before they should. If they are too large, they do not offer the proper protection. Their selection follows the rules set forth in the electrical code or in the specifications accompanying the load.

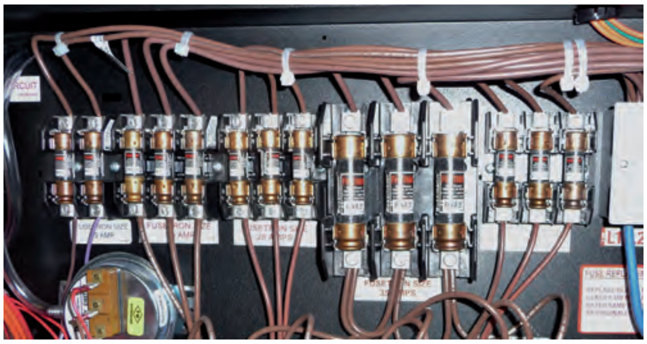


Figure 36-28 Fuses located in an air-conditioning console.

Figure 36-29 250 volt fuses: 30 amp on left and 60 amp on right.

Cartridge fuses are the most common in HVACR. They are rated by voltage, current, and maximum instantaneous current. All their values should be matched when replacing a fuse. Fuses are grouped by physical size. Up to 30 amps is one physical size; over 30 amps and up to 60 amps is a larger size (Figure 36-29). Fuses are also rated for voltage. Fuses designed for 600 volts are much larger than fuses designed for 250 volts (Figure 36-30). Fuses must withstand incredibly high amounts of energy when they are subjected to a direct short. Not all fuses have the same ability to withstand the same levels of energy. Less expensive fuses have lower instantaneous current ratings. The two fuses in Figure 36-31 are both 600 V, 30 A fuses, but the one on the right has a rating of only 50,000 amps while the one on the left can withstand 200,000 amps. The fuse on the right would literally explode if it were subjected to 200,000 amps.

Because motors draw four to five times their normal operating current when they start, standard fuses often blow during normal motor operation. Where fuses are used to protect motors in the circuit, a special type of fuse is used called a dual-element time-delay fuse. This type of fuse has a built-in delayed action that will tolerate momentary heavy starting current on motor power-up but functions the rest of the time to protect the motor against excessive running current.

Figure 36-30 Both fuses are rated at 30 amps. The larger one is rated at 600 V, while the smaller one is rated at 250 V.

Figure 36-31 Even though both fuses are 600 V 30 amp fuses, the fuse on the left has an IR rating of 200,000 amps, while the fuse on the right has an IR rating of 50,000 amps.

CODE TIP

UL requires a dual-element time-delay fuse to withstand 500 percent of the fuse amp rating for 10 seconds. Dual-element fuses achieve the time delay by using two separate elements: one for short circuit protection and another for overload protection.

36.7 CIRCUIT BREAKERS

All residences have some type of electrical panel, where the electrical service enters the building and is distributed to the circuits in the building. Each circuit has some type of protective device to automatically disconnect the power in case the circuit is overloaded. This protection can either be a fuse as described above or a circuit breaker. Note the symbols used to represent a circuit breaker in an electrical wiring diagram (Figure 36-32). The advantage of a circuit

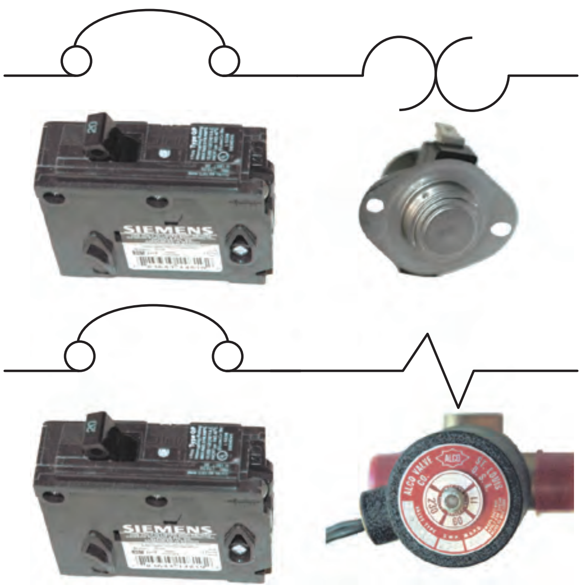


Figure 36-32 A circuit breaker and its common symbol.

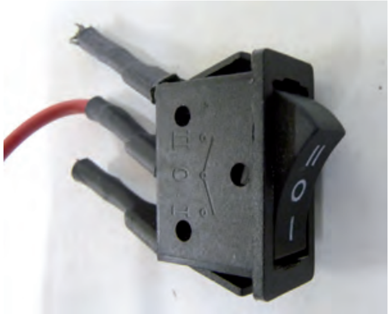


Figure 36-33 Small power switch.

breaker over a fuse is that it can be manually reset at the electrical service panel after an overload, rather than replaced. Also, the circuit can be manually opened in case there is a need to perform service on the circuit. Three types of breakers are available: standard, GFCI, and AFCI. Standard breakers protect circuits against too much current, but they cannot detect if current is going where it should not go. In addition to protecting against too much current, ground fault circuit interrupter (GFCI) breakers protect against current that flows somewhere outside of the normal current path. An arc fault circuit interrupter (AFCI) protects against electrical arcs.

36.8 SWITCHES

Switches can come in all shapes and sizes (Figure 36-33). Often they are normally open and when the switch position is changed from OFF to ON, the switch contacts will close and energize a circuit, the same as when you turn on a light. Switches can also be designed to be normally closed, which de-energizes the circuit when the contacts open (Figure 36-34). An example would be a stop switch to shut down a motor. Proximity switches often limit motion and are often operated by the movement of a mechanical device (Figure 36-35). An example would be a switch that stops the motor used for opening air inlet dampers once they have reached a full open position.

General-duty switches are designed for use in residential and commercial applications. These are used for relatively

Figure 36-34 The black switch is pushed to start (normally open), while the red switch is pushed to stop (normally closed).

Figure 36-35 This proximity switch is operated by some controlled mechanical movement.

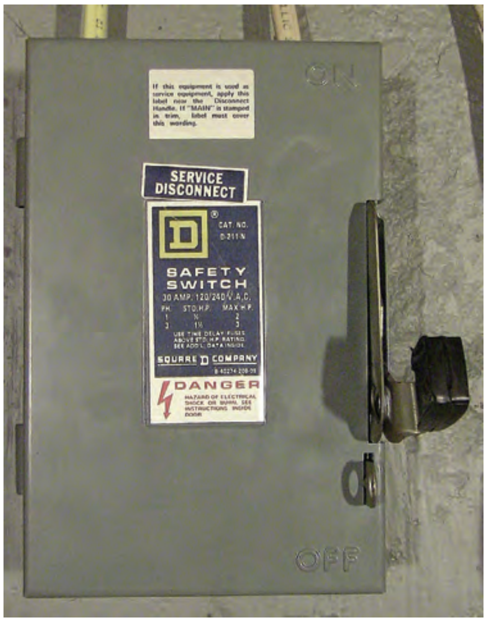


Figure 36-36 Residential safety switch.

light-load applications such as general air-conditioning and appliance loads. There are several different kinds of these switches, and some will have fuses while some others will not. A typical residential safety switch is shown in Figure 36-36. Switches are rated by the voltage and current they can safely switch (Figure 36-37). Operating a switch on a higher voltage or heavier current than its rating is dangerous.

Air-conditioning systems use many switches that open and close based on a particular condition. Examples include thermostats that open and close based on changes in temperature, humidistats that open and close based on changes

Figure 36-37 This switch is rated for 120 V and 15 amps.

in humidity, and pressure switches that open and close based on changes in pressure. These can be divided into two general categories: line voltage and low voltage. Line-voltage switches are referred to as line duty, while low-voltage switches are referred to as pilot duty.

36.9 LOW-VOLTAGE THERMOSTATS

A thermostat is a switch that is operated based on changes in temperature. Low-voltage thermostats operate on 24 volts and normally do not switch more than 2 amps. Low-voltage thermostats typically control several system functions. They operate like a bunch of switches, each one with a specific function. However, instead of operating the system by manually flipping all the appropriate switches, the thermostat does it automatically for you.

Low-voltage thermostats have two manual switches: a system switch and a fan switch. The system switch controls the operating mode: Off, Cooling, Heating (Figure 36-38). The fan switch controls cycling of the fan. In the ON position, the fan operates all the time, regardless of the thermostat setting. In the AUTO position, the fan cycles with the system (see Figure 36-38).

For many years, thermostats were electromechanical, using bimetal coils to move mercury bulb switches (Figure 36-39). The bimetal element is composed of two different metals bonded together. As the temperature surrounding the element changes, the metals will expand or contract. Since

Figure 36-38 The system switch and fan switch on a typical low-voltage thermostat.

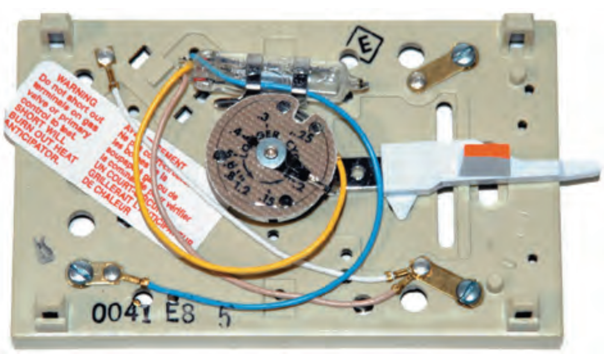


Figure 36-39 Older bimetal element and mercury bulb thermostat.

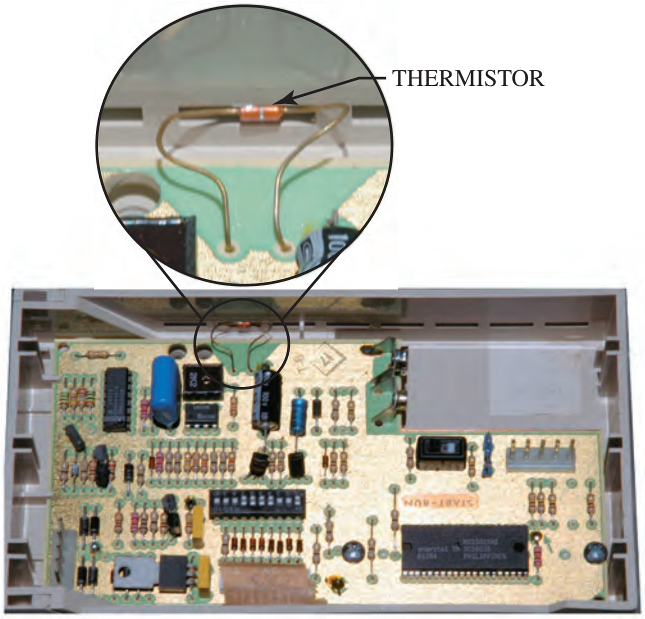


Figure 36-40 Thermistor sensor used in electronic thermostat.

the metals have different coefficients of expansion, one will expand or contract faster than the other. This creates movement in the bimetal such as twisting or turning. A mercury bulb attached to the bimetal acts as a switch. The contacts are enclosed in an airtight glass bulb containing a small amount of mercury. When the bimetal tilts the bulb, mercury in the bulb will roll to one end and complete the electrical circuit.

Newer low-voltage thermostats are now digital, using thermistors to sense the temperature and logic to control the operation of electronic switches or relays inside the thermostat (Figure 36-40). Electronic digital thermostats are considerably more accurate than older electromechanical thermostats. They will control the temperature within 1°F, while the bimetal thermostat controls to an accuracy of about 3°F. Digital thermostats require voltage to operate their logic boards. Some require both sides of the 24 V control power to operate, others steal power from the circuits they are controlling, and many use batteries. Some may work with either 24 volts or batteries.

Many thermostats are now touchscreen units with no actual switches at all (Figure 36-41). However, they still retain the same basic functions of the old electromechanical thermostats. They still have a virtual system switch that selects the system operating mode and a virtual fan switch to select continuous operation or automatic cycling (Figure 36-42).

System operation is controlled by energizing terminals that energize different parts of the unit. Because the operation of furnaces and heat pumps are quite different, thermostats are normally designed to control furnaces and air conditioners, or they are designed to control heat pumps. However, many digital thermostats now will work with furnaces, heat pumps, or a combination of both depending upon the thermostat configuration. The specific terminals that are energized in heating or cooling operation and the way they cycle are determined by the thermostat configuration. Figure 36-43 shows a configuration screen from a touchscreen thermostat that can be configured for many types of systems.

Figure 36-41 Touchscreen thermostats have no physical switches.

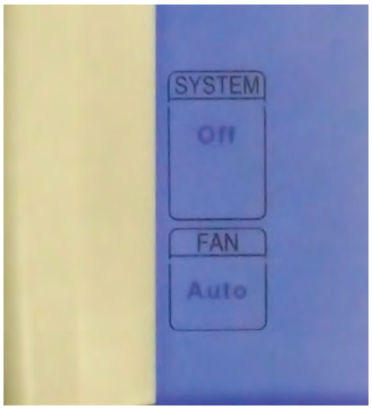


Figure 36-42 Virtual fan switch and system switch on a touchscreen thermostat.

Staging thermostats allow more than one stage of heating or cooling. In general, operating just the amount of heating or cooling necessary saves energy and money. The unit can use less energy by operating on first stage at a lower capacity most of the time. Heat pump systems typically use the second stage of heat to control auxiliary heat. If the first stage cannot meet the demand, a second stage is energized. Many two-stage furnaces are now available with low-fire and high-fire operation. Air conditioners and heat pumps are also commonly available with two capacity compressors. Staging thermostats are required for all these applications. Often, a configurable staging thermostat is used so that the thermostat function can match the system needs. More details on low-voltage thermostats and their circuits can be found in Unit 39, Control Systems.

Electronic programmable thermostats can be set for different temperatures for time periods throughout the week.

Figure 36-43 Configuration setup screen on a touchscreen thermostat.

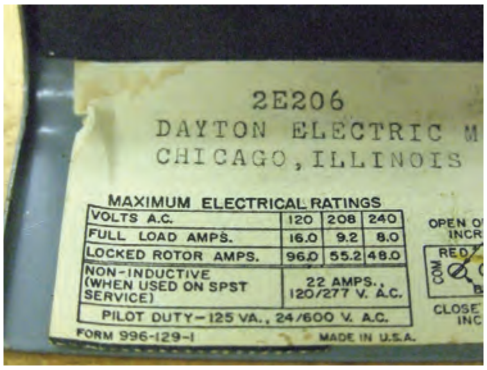


Figure 36-44 The current ratings on a line voltage thermostat.

These settings will take effect automatically. Most programmable thermostats divide the day into four periods: waking, leaving for work, arriving home, and going to bed. They allow you to set a different temperature for each of these four periods. A heating thermostat with night (or unoccupied) setback will automatically reduce the control set point during preset periods when lower than normal temperatures are acceptable. A cooling thermostat will have setup to raise the set point during scheduled hours. The intent of setup and setback is to reduce cooling and heating energy usage. Three levels of programmable thermostats are available: one program, separate weekday and weekend programs, or full 7-day programmability. The least expensive run the same program every day. The weekday-weekend thermostats have one program for the week and another for the weekend. The 7-day programmable allows a different program for every day of the week.

36.10 LINE VOLTAGE THERMOSTATS

Line voltage thermostats are designed to switch circuits that operate on the line voltage supplied to the unit, such as 120 V or 240 V. The switching action is described as open on rise or close on rise. An open on rise thermostat is used to control heating, while a close on rise switch is used to control cooling. They typically can handle 15 to 25 amps at 120 V (Figure 36-44). All line voltage thermostats have a switch, a sensing mechanism, and a mechanical linkage to allow the sensing mechanism to operate the switch (Figure 36-45).

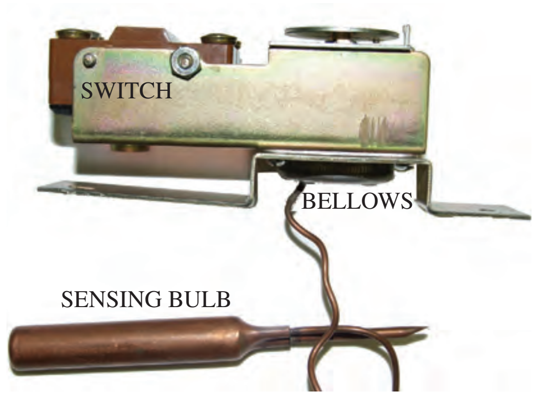


Figure 36-45 The switch, sensing bulb, and bellows on a line voltage thermostat.

Figure 36-46 Remote bulb thermostat.

The most common temperature-sensing mechanisms are charged bulbs and capillary tubes.

Charged bulbs contain a volatile fluid that increases in pressure when its temperature is increased. This pressure pushes on a bellows that operates the switch. An adjustable spring pushes against the bellows, allowing temperature adjustment. Figure 36-46 shows a charged bulb thermostat. This thermostat is sometimes referred to as a remote bulb thermostat. The controlling bulb can be placed in a location away from the body of the thermostat. For example, the bulb for a commercial refrigeration cooler can be placed inside the cooler with the capillary tube run through the wall to the thermostat located outside the room. Thermostat adjustments can be made without entering the refrigerated room.

Capillary-tube thermostats use a diaphragm mechanism instead of a bellows (Figure 36-47). In this control, the diaphragm is completely filled with liquid. The liquid expands and contracts with a change in temperature. The movement of the diaphragm is very slight, but the pressure that can be exerted is tremendous. Because the coefficient of expansion of liquid is small, relatively large-volume bulbs are used on the control. This results in sufficient diaphragm movement and also ensures positive control from the bulb.

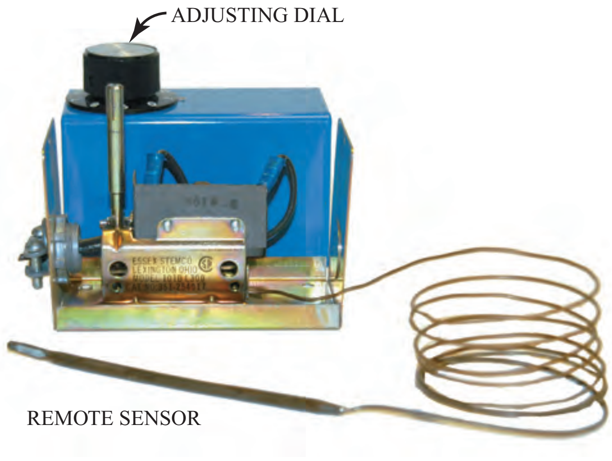


Figure 36-47 Capillary-tube thermostat.

36.11 HUMIDISTATS

Humidistats control the operation of their switch based on changes in humidity. Hygroscopic elements are used on these controls, including human hair (Figure 36-48). As the moisture content of the air increases and the humidity rises, the hair expands and allows the electrical contacts to close (or open). As the humidity level decreases and the hair begins to dry, it contracts and once again activates the electrical contacts. This type of control is susceptible to dirt and dust in the air.

A more common form of humidistat uses a nylon element instead of human hair (Figure 36-49). The nylon is bonded to a light metal in the shape of a coil spring. The expanding and contracting of the nylon creates the same effect as that found in the spiral bimetallic strip used in thermostats. Another type uses a thin, treated nylon ribbon as a sensor.

An electronic circuit board can have hygroscopic properties, and lithium salt is used for this purpose. Another arrangement uses carbon particles embedded in a hygroscopic material. In both cases, the sensing element acts as a thermistor. Changes in the humidity affect the resistance of the material and alter the current in the electronic circuit.

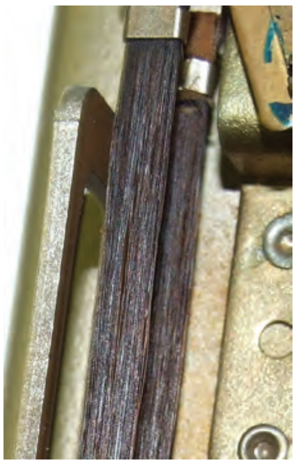


Figure 36-48 Humidistat with hair for the sensing element.

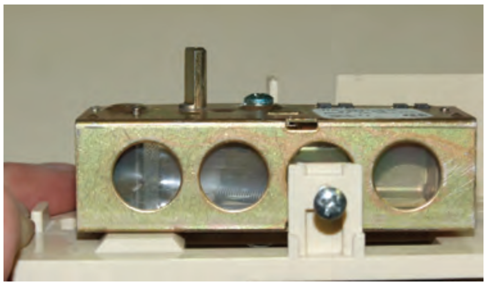


Figure 36-49 Humidistat with a nylon sensing element.

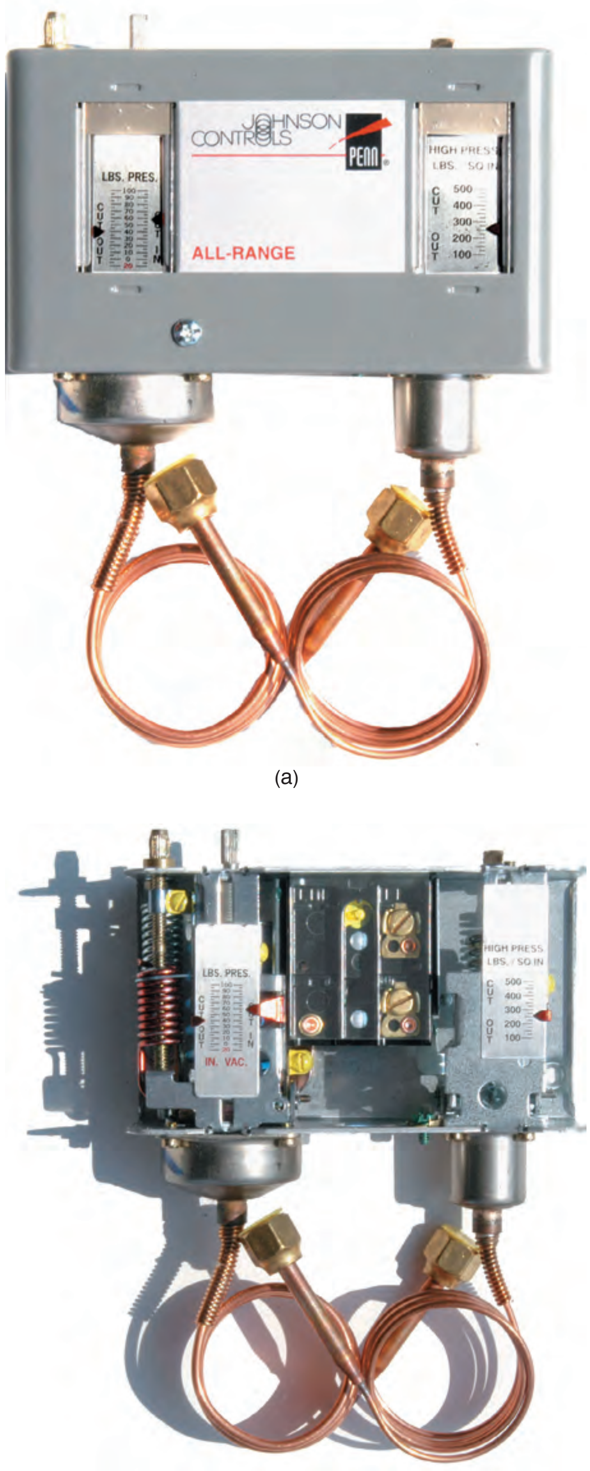
36.12 PRESSURE SWITCHES

Similar to a line voltage thermostat, a pressure switch uses a diaphragm or bellows to operate a switch. The difference is that the pressure operating the pressure switch comes directly from the refrigeration system. The pressure switch is either attached directly to the system, as in Figure 36-50, or it has a capillary tube that connects the pressure switch to the system, as in Figure 36-51.

The switching action of a pressure switch is described as either close on rise or open on rise. A high-pressure switch whose purpose is to shut the unit off when the high-side pressure exceeds a safe level uses an open-on-rise switching action. A low-pressure switch whose purpose is to shut off the system when the low-side pressure drops below a safe level uses a close-on-rise switching action. Because many commercial refrigeration systems use both a close-on-rise low-pressure safety switch and an open-on-rise high-pressure safety switch, dual-pressure switches combine the two switches into one mechanism (Figure 36-52).

Figure 36-50 Pressure switch attached directly to the system.

Figure 36-51 Pressure switch connected to the system with a capillary tube.



(a)

(b)

Figure 36-52 (a) Combination high- and low-pressure switch; (b) the high- and low-pressure sides of this control are separated inside the switch.

These have two pressure bellows controlling the same set of electrical contacts. The contacts will open if the high-side pressure exceeds the setting of the high-pressure switch or the low-side pressure falls below the setting of the low-pressure switch.

The pressure at which a switch closes and the pressure at which it opens cannot be the same pressure. There must be a difference between the two for the switch to work. The point where the switch closes is called cut-in, and the point where the switch opens is called cut-out. The difference between the two is differential.

Adjustable pressure switches allow adjustments to the operating point and the differential. Adjustable pressure switches are often used in commercial refrigeration. Close-on-rise switches have an adjustment for the cut-in and the differential. The cut-out is set by setting the cut-in and differential. For example, a switch with a cut-in of 250 psig and a differential of 50 psi would have a cut-out of 200 psig (Figure 36-53). Open-on-rise switches used for safety controls typically only have an adjustment for the cut-out. The differential is pre-set and not adjustable.

Air-conditioning systems typically use small, fixed pressure switches connected directly to the system (Figure 36-54). These switches are not adjustable and are manufactured to open and close at a pre-set pressure. These small, fixed pressure switches are normally pilot-duty switches, rated only for low-voltage, low-current applications. Typical applications include high-pressure and low-pressure safety cut-out switches. They are usually wired in series with the contactor coil. When they open, they break the circuit to the contactor coil and the contactor opens to turn off the compressor.

Figure 36-54 High-pressure switch on residential air conditioner.

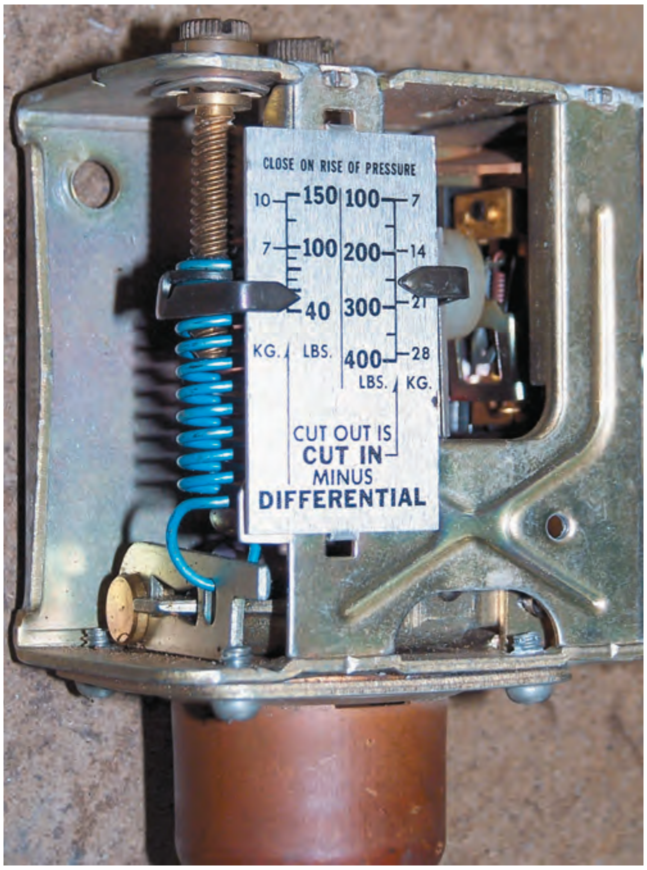
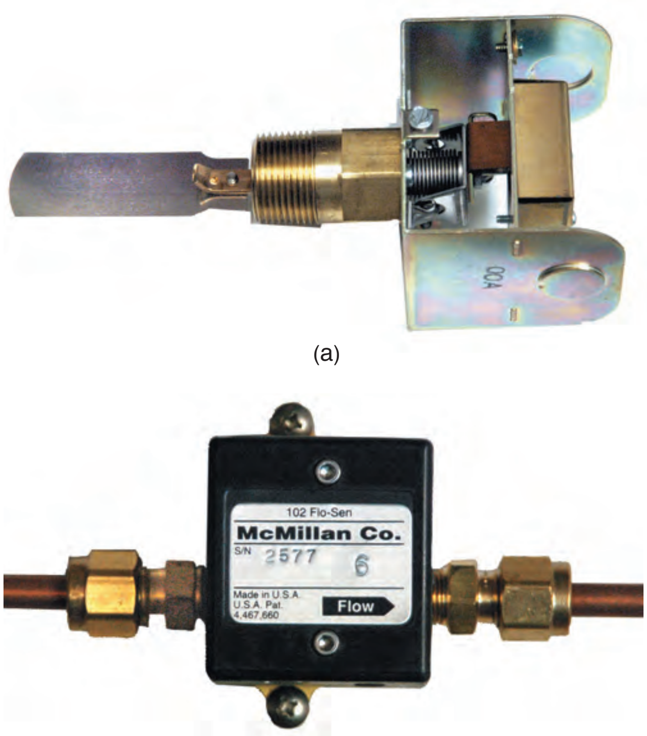


Figure 36-53 The cut-out on this low-pressure switch is 200 psig: 250 psig cut-in and 50 psi differential.

36.13 FLOW SWITCHES

Flow switches open or close based on the movement of fluid. Note that both air and water are fluids. The sail switch, shown in Figure 36-55, is a protective device to prevent the operation of a unit when there is inadequate fluid flow. In an air system, the sail switch is placed in the duct to sense the flow of air. Unless there is an adequate supply of air over the coil, the unit is either not started or shut down. Switches of this type can also be placed in a waterline feed of a water-cooled condenser. If there is an inadequate supply of water, or no water, the unit is prevented from running.



(a)

(b)

Figure 36-55 (a) Sail switch to detect airflow; (b) electronic flow switch.

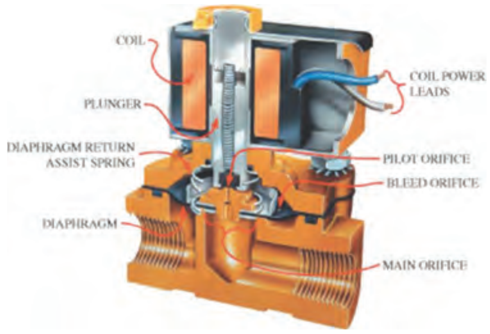


Figure 36-56 Cutaway of a solenoid valve.

36.14 SOLENOID COILS

A solenoid coil is a doughnut-shaped coil of wire that produces a strong magnetic field when energized. Solenoid coils typically have steel plungers that are attracted to the coil when it is energized. The movement of the plunger can be used to control many HVACR electrical devices including solenoid valves, gas valves, relays, and contactors.

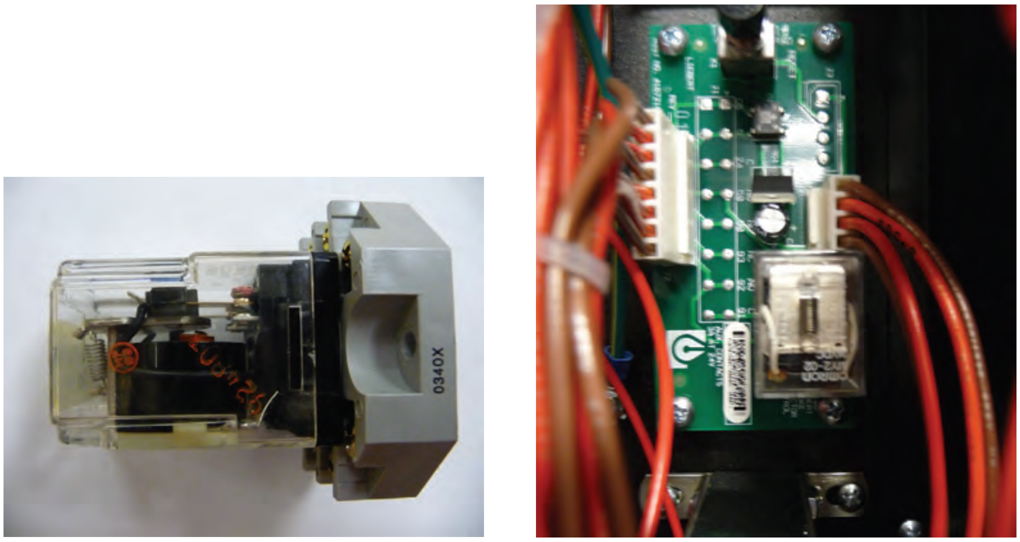
Figure 36-56 shows a cutaway of a solenoid valve. A solenoid valve is an electrically operated valve that controls the flow of a fluid by opening or closing when the solenoid coil is energized. They may be either normally open or normally closed. When the coil is energized, the valve will change position. Normally open valves will close; normally closed valves will open.

36.15 RELAYS

An automatic switch requires some method for opening and closing. This is often accomplished through the use of a relay (Figure 36-57). A relay is an electrically operated switch that uses an electromagnet to open or close a set of electrical contacts (Figure 36-58). Normally only a small amount of current is required to energize the electromagnet. This allows for a device with a high current rating, such as an electric heater, to be operated by a control relay operated by a low-current signal. The control wires can be much smaller and separate from the large main supply lines required for the main load.

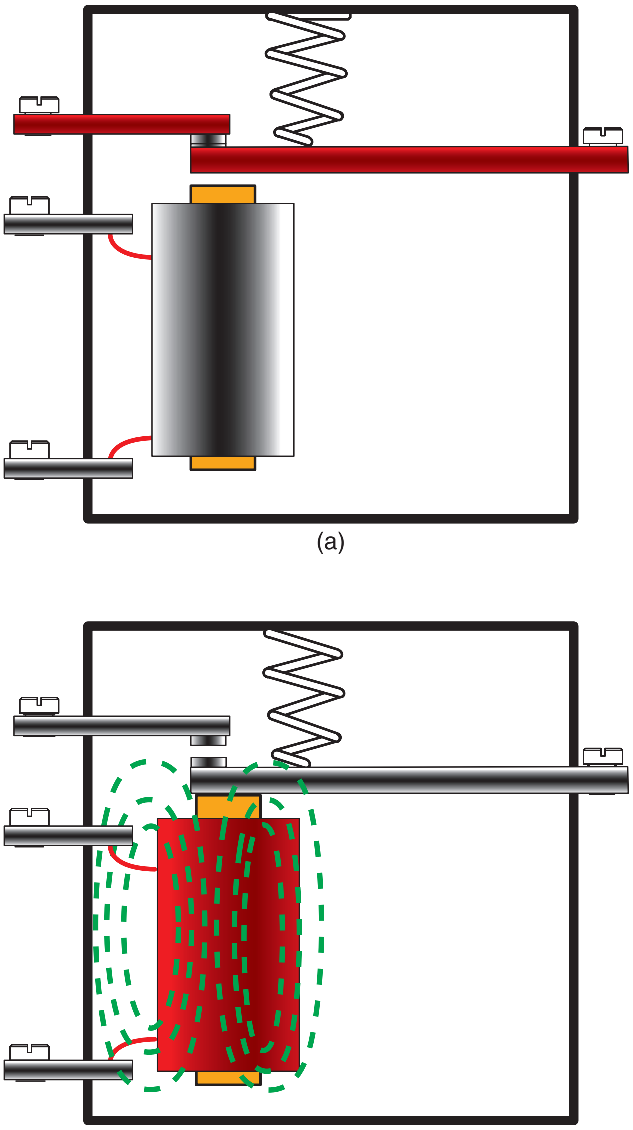
Figure 36-58 The visible coil of fine wire is the part of the electromagnet arrangement of this relay.

Relays can be designed for normally open switches or normally closed switches. The normal position of the switch is always the position of the switch when the relay coil is de-energized. Figure 36-59a shows a normally closed set of contacts with the relay coil de-energized. A spring is used to hold the contacts together. When the coil is energized (supplied with current) (Figure 36-59b), a magnetic field is set up that attracts the lower contact toward the coil. This will separate the two contacts and open the circuit. As long as the current flows through the coil, the relay is energized, and the switch will remain open. With a normally open



(a) (b)

Figure 36-57 (a) Control relay; (b) control relay connected in the circuit.



(a)

(b)

Figure 36-59 (a) The coil is de-energized and the contacts are held closed by spring force; (b) the coil is energized and the contacts are opened by the magnetic attraction of the coil.

set of contacts, the spring holds the contacts open. When the coil is energized, the magnetic field pulls the contacts together.

Relay coils are available in all common voltages, including 24 V, 120 V, and 230 V. There is no electrical connection between the coil and the contacts. The contacts are separate electrical devices and have their own rating. The contacts are rated for both voltage and amperage. It is common for the contacts to switch higher voltage than the coil voltage.

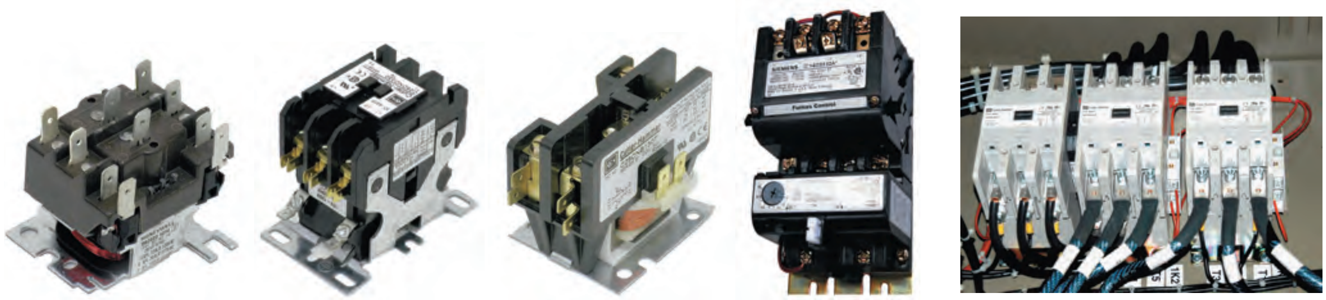
36.16 TESTING RELAYS

The relay coil can be tested by checking its resistance. The coil should be disconnected from the circuit to ensure that you are only checking the coil. This can be done by disconnecting the wires from the coil. Relay coils should have a measureable resistance: not open and not shorted. A meter reading of infinite Ω (OL on most digital meters) indicates that that the coil is open. A reading of 0 Ω indicates that the coil is shorted. The coil resistance will vary depending upon the design of the relay and its operating voltage. The contacts should ohm as either open or shorted because they are a switch. With the coil de-energized, the normally open contacts should read infinite Ω (OL) and the normally closed contacts should read 0 Ω. When the coil is energized, the readings reverse: the normally open contacts should read 0 Ω and the normally closed contacts should read infinite Ω (OL).They should never have a measurable resistance.

36.17 CONTACTORS AND STARTERS

Relays, contactors, and starters all have contacts that open and close to complete or disconnect a circuit (Figure 36-60). Contacts for control relays are often very small (Figure 36-61). This is because they do not need to be connected to the load current, since they are only relaying the signal. Typically, relay contacts are rated for 15 amps or less.

Contactors that are connected in the load circuit will need to be larger (Figure 36-62). The operation of a contactor is shown in Figure 36-63. There may be one or more sets of contacts located on the armature. Contactor poles are the number of contact sets. A single-pole contactor has one set of contacts, a two-pole has two sets, and a three-pole has three sets. The armature moves up and down in



(a) (b) (c) (d) (e)

Figure 36-60 (a) Fan relay; (b) three-phase contactor; (c) single-pole contactor; (d) motor starter; (e) large-amperage systems may use multiple contactors all wired together.

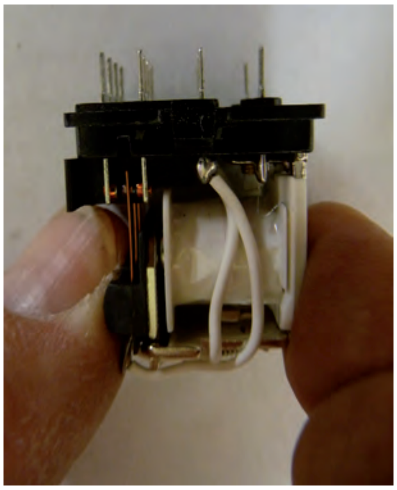
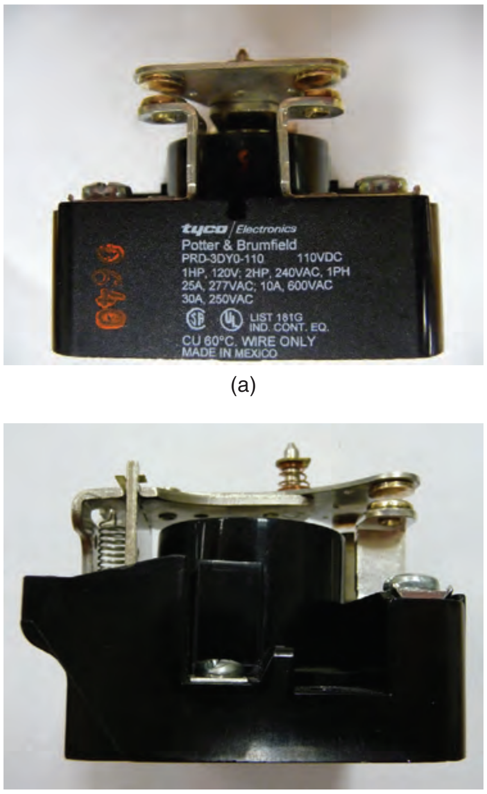


Figure 36-61 The contacts for this control relay are very small.



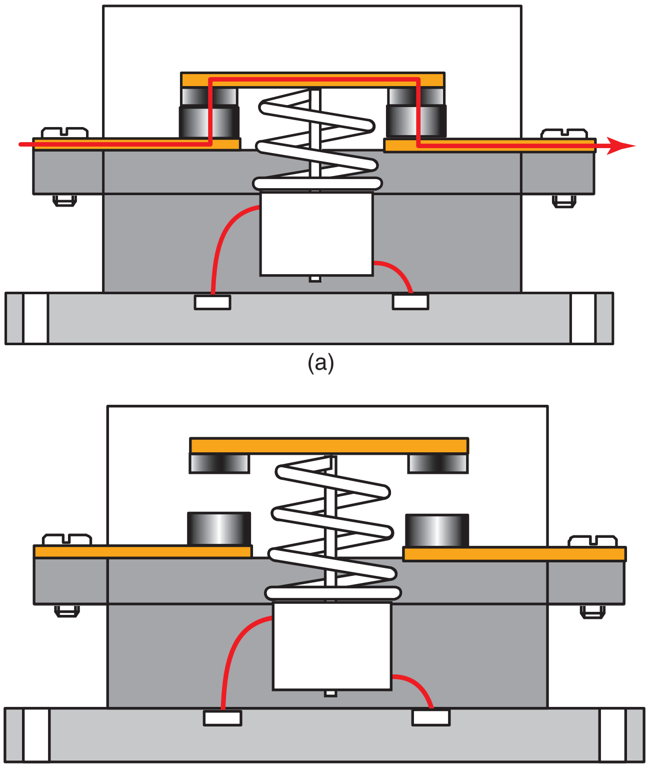
(a)

(b)

Figure 36-62 (a) Front view of contacts; (b) side view of contacts.

the holding coil. When the coil is energized the armature moves and closes the contacts. The contacts are considered normally open since they are open when no current is applied to the coil. Contactors may also be designed to have normally closed contacts that are closed when the coil is de-energized.

The contacts are rated by the voltage and current they can switch. There are normally three current ratings: resistive, FLA, and LRA (Figure 36-64). The resistive rating is the



(a)

(b)

Figure 36-63 (a) Contacts closed to complete the circuit; (b) contacts opened to break the circuit.

amount of current the contacts can switch for a resistive device such as an electric strip heater. The resistive rating is higher than the FLA (full load amps) rating because resistive loads do not have a high starting current. FLA is the current rating for motors. A motor's FLA current is the amount it draws when doing the full amount of work it was designed to do. A contactor's FLA rating is lower than its resistive rating because of the high starting current of motors. The LRA rating stands for locked rotor amps. A motor's LRA is the amount of current the motor draws if it is energized while its rotor is not moving. This current is very high, typically four to five times as high as the FLA operating current.

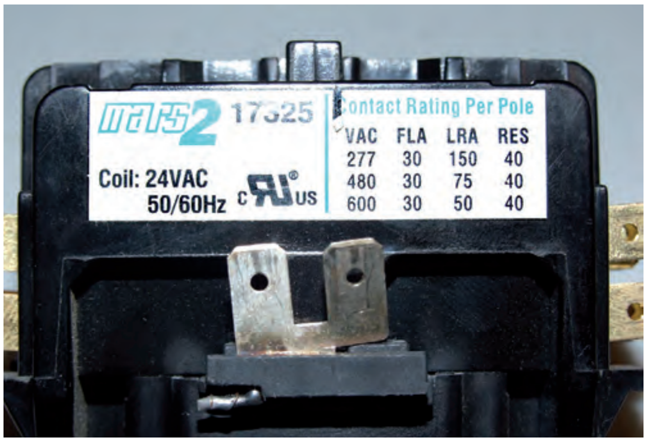


Figure 36-64 The current ratings on a contactor.

SERVICE TIP

The contact surface in relays and contactors is coated with a special alloy of very conductive material. This coating is very thin but effective in preventing the contacts from becoming quickly damaged from the momentary arc as they open and close. This arc would normally cause the contacts to weld themselves together. Over time this protective coating will wear away and the contactors may eventually begin to occasionally stick. When sticking occurs, the contactor or contactor tips must be replaced. They cannot be reconditioned in the field with point files. The substructure of the contact is a thermally conductive material that helps carry the heat away from the coating. It is not resistant to arcing and welding itself together. A reconditioned contact surface will stick again very quickly. Do yourself and your customer a favor and replace sticking contacts whenever they are found.

Starters for motors need to be even larger. A motor starter or magnetic starter is essentially a contactor with built-in overload protection. The current passing through the contacts also passes through overloads. If any of the overloads open, they break the circuit to the starter coil, shutting it down. The control voltage is used to operate the holding coil on a starter as well as for many other control functions. Motor starters work on the same magnetic coil principles as relays and contactors, but the actual contact size will be greater. The contacts should snap open and close with spring assist to reduce arcing across the contacts. A magnetic starter is shown in Figure 36-65.

Motor starts are often used with three-phase motors. Since three-phase motors have three circuits, opening any one leg of power still leaves an energized circuit. The overload in a magnetic starter protects the motor by breaking the circuit to the starter coil, which then opens the contacts, de-energizing all three circuits.

Figure 36-65 Magnetic motor starter.

Figure 36-66 Manual reset overload.

36.18 CURRENT/TEMPERATURE SAFETY COMPONENTS

Electrical overloads provide for protection against excessive current. Overloads can be line duty or pilot duty. Line-duty overloads break the power to the device they are protecting. Pilot-duty overloads operate like relays. They have a separate coil and contacts. Once they have tripped, some overloads reset themselves automatically after cooling down. These are called automatic reset overloads. Others use a mechanical design that requires a button to be pushed to reset it (Figure 36-66).

Line-Duty Overloads

Thermal bimetal overloads used with electric heaters are a good example of a line-duty overload (Figure 36-67). They open to break the circuit to the heater if the strip heater overheats.

The bimetal overloads are often used on small hermetic compressors (Figure 36-68). They have a small heater and a bimetal that controls a set of contacts. When the current passing through the heater exceeds the overload rating, the heater will cause the bimetal to warp, opening up the contacts and breaking the circuit. Many current overload

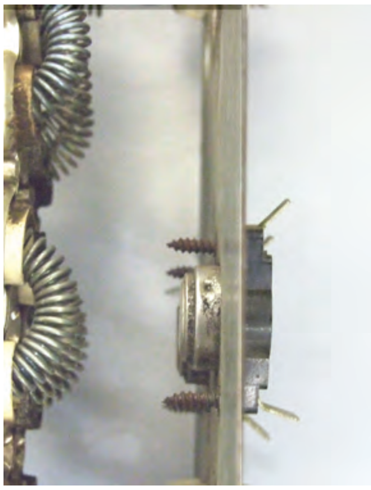


Figure 36-67 Thermal overload used to protect electric strip heaters from overheating.

Figure 36-68 Bimetal current overload used on small hermetic compressor.

devices sense both the current and temperature of the motor. These devices, like those located within the Bakelite cover of small compressors, must be in their enclosure to function properly. If the Bakelite cap is left off, the overload will only sense the current and not the temperature. This reduces their sensitivity and removes a large portion of the overload safety protection from a motor.

Pilot-Duty Overload Relays

Pilot-duty overloads are called overload relays because they have a coil that senses the overload and a set of contacts. The coil can be either thermal or magnetic. Overload relays are used in conjunction with contactors. When a contactor is used, there is both a control circuit, in which the primary control is inserted, and a load circuit, which is opened and closed by the contactor. When excessive current is drawn in the load circuit, this device will open the control circuit.

The thermal overload relay is shown in (Figure 36-69). The current for the contactor coil passes through the normally closed overload contacts. If the load current passing through the bimetallic element in the overload coil becomes too high, the element bends to the side, forcing the contacts apart. This breaks the control circuit and allows the contactor to open, thereby interrupting the power to the load. The bimetallic element will now cool and return to its original position, but because of the slot in the bottom arm, the contacts will not be remade. The control circuit will remain broken until the reset button is pushed. The reset moves the arm to the right and closes the control-circuit contacts. Because this control must be reset by hand, it is usually referred to as a manual-reset overload. Some overload relays may be field adjusted for manual or auto-reset function.

Magnetic overload relays are another type of pilot-duty overload (Figure 36-70). The advantage of this type of overload is that it is only slightly affected by ambient temperatures, thereby avoiding nuisance trips. The magnetic overload relay is made up of a sealed tube completely filled with a fluid and holding a movable iron core. When an overload occurs, the movable core is drawn into the magnetic field, but the fluid slows its travel. This provides a necessary time delay to allow for momentary high current during motor startup (locked rotor amps) without tripping the overload. When the core approaches the pole piece, the magnetic force increases and the armature is actuated, thus breaking the control circuit.

Figure 36-69 The overload on the bottom of this magnetic starter will break the circuit to the starter coil if the current exceeds its setting.

Figure 36-70 Magnetic overload relay.

On short circuits, or extreme overloads, the movable core is not a factor because the strength of the magnetic field of the coil is sufficient to move the armature without waiting for the core to move. The time-delay characteristics are built into the overload and are a function of the core design and fluid selection.

36.19 ELECTRONICS AND LOGIC CIRCUITS

Electrical circuits can have any number of input devices. Some examples are pushbuttons, mechanical limit switches, pressure switches, and photo cells. This input is then transmitted in a logical fashion to an actuating device. These could be relays, contactors, motor starters, solenoids, or some component that will start a series of event to satisfy the initial input.

Relay Logic

Many systems have been designed to use relay logic. These circuits will make decisions based upon the initial input. Take, for example, that the input is a call for heat by the thermostat. This input signals for contacts to close, which will energize a relay, and this begins a sequence of events to start the furnace. If a flame is detected, the furnace continues to run. If not, the furnace shuts down. This could be seen as an OR function. Stay running OR shutdown.

From this example, it can be seen that with relay logic, relay coils are designed to control other relay coils. Two contacts wired in series would be considered an AND function. First one contact closes AND the second contact closes to energize the load. Contacts in parallel will produce an OR function. Contact 1 OR contact 2 will close.

Relay logic is quickly becoming replaced by electronic systems. One reason is that mechanical switches never truly make a good, clean closing contact. The points tend to bounce against each other several times before fully closing. Sometimes this causes minor sparking. Relays like this cannot be used in an explosive environment unless they are enclosed in an airtight container. Sometimes capacitive switch filters are used to help smooth out this bounce.

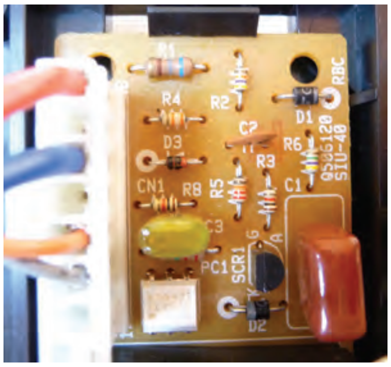
Contacts also wear out over time as they continually open and close. They are exposed to any chemicals or dust in the air, and mechanical linkages can eventually stick and the contacts become pitted. In comparison to electronic solid-state logic, relays are slow and heavy.

Solid-State Logic

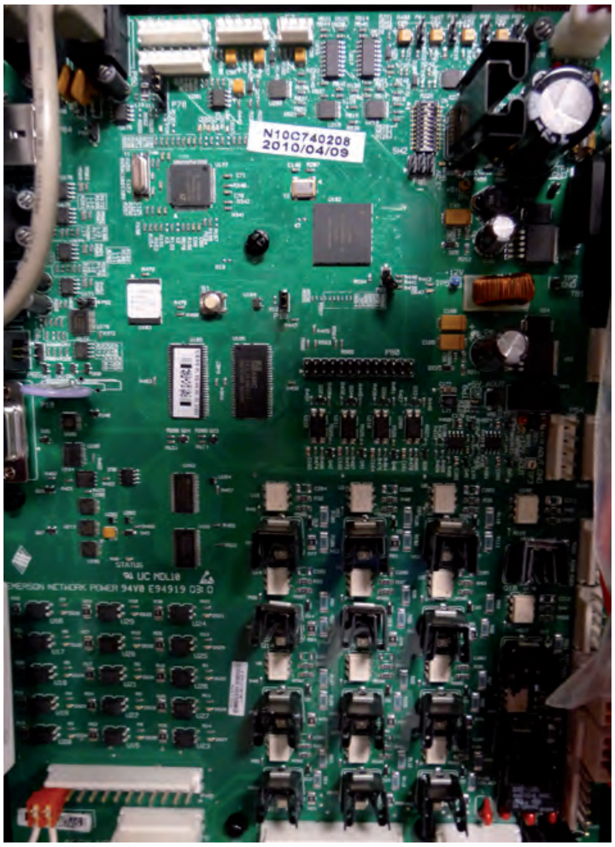
Unlike relay logic, solid-state components have no moving parts (Figure 36-71). They are sealed from the atmosphere. They take up less space because most of the components are attached to a compact circuit board (Figure 36-72). They generally cost less and require less power. Most important, they can be more than a thousand times faster than relays.

Solid-state logic circuit input signals are used to slightly vary voltage rather than operate contacts. These signals can be designed as low and high. A low voltage (0 V) might be used to open the circuit, while a higher voltage (+5 V) could

Figure 36-71 Solid-state relays.



(a)



(b)

Figure 36-72 (a) Circuit board for gas heater; (b) circuit board for an air-conditioning console.

be used to close it. Since this voltage is low, it consumes little power, but an output amplifier is still required for the actuating device, such as a solenoid. The output amplifier will increase the low-voltage/low-current power to higher-voltage/higher-current output power.

Relay Logic Compared to Solid-State Logic

It is obvious from the descriptions of both systems that electronic solid-state logic systems are faster, cheaper, lighter, and last longer than conventional relay-logic systems. The older conventional relay systems will continue to be replaced. However, relay systems still do have a few distinct advantages. If the circuit is small and simple, they can actually be a cheaper alternative. Outside extraneous noise pickup and signals will not affect relay operation but can raise havoc on some solid-state systems. Solid-state components will generate a lot of heat and need to be cooled, while relays are capable of operating in higher-temperature locations. One last most important consideration is the technician. Many technicians in the field have been trained on relay logic and they fully understand it, which is not the case with many solid-state electronic circuits.

36.20 TRANSDUCERS

Transducers are electrical or electromechanical devices that are often used to provide a control signal (Figure 36-73). They can be used to sense changes in pressure, temperature, light, sound, and vibration. They are most often semiconductors that convert mechanical force into an electrical signal. The signal is used by a control device or microprocessor to stop, start, or adjust a system's operation. For example, a vibration sensor located on a large air handler would stop the motor when excessive vibration occurred. Another example would be a water depth gauge, which would sense water pressure in a container. This signal could be used to stop or start a pump or turn a water valve on or off.

Because transducers are relatively low in cost and have high reliability, they are used frequently to provide remote sensing for HVACR equipment. Transducers have increased the life of systems and improved operating efficiencies by providing constant monitoring.

Figure 36-73 Pressure transducer and electrical lead.

36.21 SOLID-STATE COMPONENTS

Circuits using solid-state components are different than conventional mechanical switching devices because the electrons are confined entirely within the solid material. Some common solid-state components include transistors, diodes, and silicon rectifiers.

Semiconductors

Some materials are good conductors of electricity, while others are insulators. A semiconductor is a material that is neither a good conductor nor a good insulator. Semiconductor materials are often made from germanium and silicon. These materials, due to their peculiar crystalline structure, may under certain conditions act as conductors and under other conditions act as insulators. This ability to either conduct current or block current flow can be useful in a control circuit.

Transistors

Transistors were one of the first most popular solid-state devices used and became well known for the mass production of transistor radios. They can be used as a switch or to amplify an electrical signal. As an example, in a HVACR system, these can be used to amplify a signal of low-voltage/low-current power to a higher-voltage/ higher-current power to operate a relay.

Diodes

A diode is a semiconductor that acts similar to a check valve, allowing for one-way flow through an electrical circuit. A diode has an anode and a cathode (Figure 36-74). If the anode is connected to the positive terminal, then the diode is forward biased and current will flow. If the anode is connected to the negative terminal, then the diode is reverse biased and no current will flow. Diodes can vary from the size of a pinhead to much larger sizes for ratings of 500 amperes or more (Figure 36-75).

Silicon Rectifier

Using the principle of the diode, a simple full wave-bridge rectifier can be configured to convert alternating current into direct current. Rectifiers are commonly used because many devices such as meters and control systems often require DC power. Power supplies for battery-operated devices such as cell phones and laptop computers require AC to DC converters. Figure 36-76a shows the current flow to a direct current meter through diode rectifiers 3 and then 2. When the AC current reverses, the meter will still

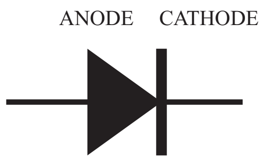


Figure 36-74 Diode showing anode and cathode.

Figure 36-75 Common diodes.

Figure 36-77 Silicon rectifier.

be operating on direct current with current flow through diode rectifiers 1 and 4, as shown in Figure 36-76b. Silicon rectifiers can be designed to operate throughout a wide range of current and voltage levels and are therefore used on many different types of applications (Figure 36-77). They are small, lightweight, and can be made shock resistant. Silicon rectifiers can have efficiencies as high as 99 percent.

Silicon-Controlled Rectifier (SCR)

The increased concern about energy efficiency has led to more systems using variable and controlled power. There are a number of examples, such as lighting, that can be adjusted through a range rather than always at a maximum brightness. Refrigeration compressors and fans use variable-speed motors that can slow down or speed up depending on the demand.

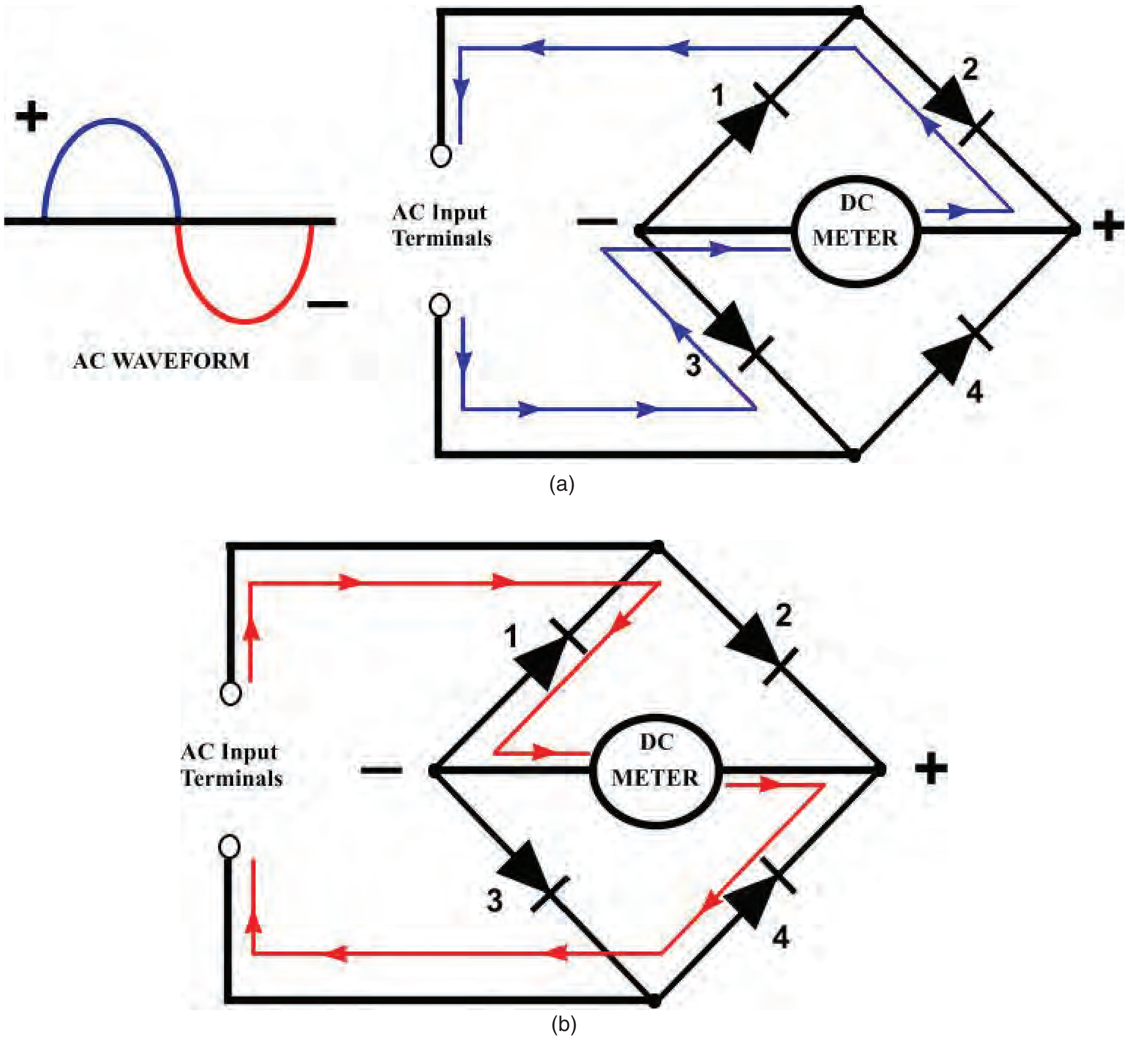


Figure 36-76 (a) Full-wave silicon rectifier; (b) full-wave silicon rectifier with opposite current flow.

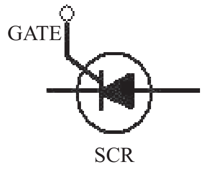


Figure 36-78 Silicon-controlled rectifier with gate control.

Figure 36-79 TRIAC bidirectional device.

Conventional systems use large, expensive transformers that allow for a variable adjustable secondary coil output. These are being replaced by silicon-controlled rectifiers (SCRs) because they are small, relatively inexpensive, require virtually no maintenance, and are very efficient. They can be found in small control circuits as well as in large circuits of several hundred amperes with operating voltages over 1,000 V.

The SCR is similar to a diode in that it will block reverse current. The difference is that the SCR can also block forward current. More important, it can be switched electrically to allow forward current conduction by a pulse of current flowing through its gate (Figure 36-78). When the SCR is triggered by a gate pulse, conduction begins. The important application for an SCR is that it can be turned on and off like a switch without the need for electrical contacts. The speed of switching is also much faster than traditional contacts, and the timing can be varied during operation. A TRIAC, shown in Figure 36-79), is a bidirectional device of two SCRs connected in parallel-opposed with a common gate. A positive voltage applied to the gate will “fire” the TRIAC in either direction.

UNIT 36—SUMMARY

Resistors and capacitors are commonly found in most circuits. Electronic circuits often use variable resistors that allow for adjustment. Capacitors are used for many applications, such as tuning, filtering, energy storage, power factor correction, and motor starting. Transformers have primary and secondary windings that can be configured to step up or step down the voltage. A motor powered by a 440 line voltage will normally require a step-down transformer to lower the voltage for the relays and controls. Fuses and circuit breakers are used to limit the current flow in a circuit to avoid overheating and fire. Switches, relays, and contactors are used to close and open circuits. Relays can be used in combination to start, stop, and engage safety cutouts. This type of relay logic is quickly being replaced by solid-state logic, but many systems still combine some combination of both.

UNIT 36—REVIEW QUESTIONS

1. A fixed resistor has the following color bands: orange, red, brown, gold. What is the rated resistance?
2. A fixed resistor has the following color bands: orange, red, gold, gold. What is the rated resistance?
3. Does a capacitor lose its charge once it is disconnected from the power source?
4. How do ceramic and mica capacitor mfd ratings compare to paper and film capacitors?
5. How do motor-start capacitors differ from motor-run capacitors?
6. Why are some run capacitors marked with a red dot?
7. What is the first step in testing a capacitor?
8. What is the control voltage used by most residential HVACR equipment?
9. What is a center-tapped transformer?
10. What is an isolation transformer?
11. Why are transformer cores laminated?
12. Do transformers operate more or less efficiently when fully loaded? Explain your answer.
13. What is the advantage of a circuit breaker as compared to a fuse?
14. What is a proximity switch, and how does it operate?
15. What type of applications is a close-on-rise thermostat normally used for?
16. What system functions does a low-voltage thermostat normally control?
17. What two manual switches are found on most low-voltage thermostats?
18. What types of systems use staging thermostats?
19. What do modern electronic thermostats use to sense temperature?
20. What types of material are used to sense humidity in humidistats?
21. What three ratings should always be matched when changing fuses?
22. What type of fuses should be used to protect motor circuits?
23. What is a relay?
24. When checking the resistance of the different parts of a relay, what resistance should you expect for the coil, normally open contacts, and normally closed contacts?
25. What is the difference between a relay and a contactor?
26. What is the difference between a contactor and a magnetic starter?
27. What is the cut-out for a close-on-rise pressure switch with a cut-in setting of 45 psig and a differential setting of 20 psi?
28. On a close-on-rise pressure switch, what should the differential be set to for a cut-out of 15 psig if the cut-in setting is 25 psig?
29. Why is the contact surface in relays and contactors coated with a special coating of very conductive material?
30. Consider basic relay logic. What is meant by an AND function? What is meant by an OR function?
31. What are the major differences between relay and solid-state logic?
32. What is a semiconductor material?
33. What is a diode?
34. What is a silicon rectifier?