Chapter 8

Basic Electricity


OIL
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ON
ON
OFF
EMERGENCY
SWITCH

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Chapter 8

Basic Electricity

Electrical Safety

Systems require electricity to operate. In a typical system, line voltage flows in a series circuit from the fuse or circuit breaker to a remote toggle switch located away from the heating unit. From there it continues to a service switch at the oil-fired appliance, then to the limit controls, and then to the primary control which distributes power to the oil burner components to manage the combustion process.

Working on a system often requires one to perform tasks related to the various electrical switches and controls incorporated into the system. **It is imperative that technicians fully understand each of the components they work on, that they always follow governing codes and ordinances, and that they always abide by safe work practices.**

Because it has become such an integral part of their daily lives, techs tend to forget that electricity can be hazardous. Before attempting to service electrical components, take a few moments to be sure to understand the dangers involved and to follow ALL the correct safety procedures.

When working with electricity, always:

- Avoid working in wet areas and utilize protective equipment if working in areas which *may* become wet.
- Inspect power tools and equipment prior to use.
- Use insulated tools and double check that the insulation isn't compromised.
- Use the correct size UL approved extension cords.
- Make sure that the equipment being serviced, and any electrical tools being used, are properly grounded. NEVER use a two-prong, ungrounded adapter with a three-prong appliance or extension cord.
- Avoid overloading circuits.
- Whenever possible, de-energize equipment before servicing.
- Remember that switches can fail! **ALWAYS test to be sure that circuits are de-energized before commencing work.**

To safely discharge a capacitor you will need a 20,000 ohm 5 watt resistor, two insulated screwdrivers and two jumper wires with alligator clips on both ends. Connect one jumper wire clip to one wire of the resistor and clip the other jumper wire to the other resistor wire. Connect the clips on the opposite ends of both jumper wires to different screwdrivers, hold the handles of the screwdrivers and touch the blades to opposite terminals of the capacitor.

OSHA requires that lockout and tagout must be used for equipment that is de-energized. Lock-out involves applying a physical lock to the power source(s) of circuits and equipment after they have been shut off and de-energized. Then, tag out the circuit with an easy-to-see sign or label that lets everyone know that someone is working on the circuit. Since equipment lockout often isn't practical, OSHA considers shutting off the equipment in two places as the equivalent of lockout. For example, tagout without a lockout will be adequate if the equipment is shut off and tagged at both the breaker and at the unit. **Remember: While tagout might take a few extra moments, it's worth the effort to prevent someone from accidentally energizing a circuit while it is being worked on.**

For more on electrical safety, download a free copy of the National Institute for Occupational Safety & Health publication *Electrical Safety, Safety & Health for Electrical Trades* available at cdc.gov/niosh/docs/2009-113/pdfs/2009-113.pdf?id=10.26616/NIOSHPUB2009113

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Introduction

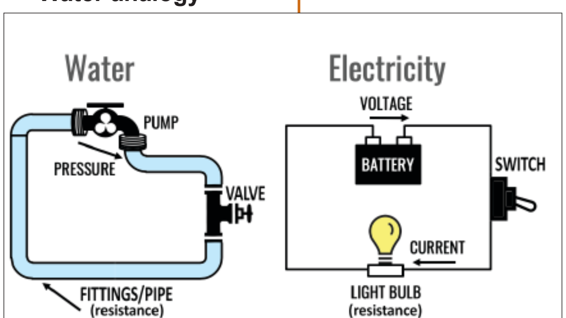
The objective for this chapter is to help technicians feel more comfortable working with electricity and to provide information needed to service and troubleshoot systems.

Electricity is referred to as a secondary energy source because it is produced by converting primary energy sources such as coal, natural gas, oil, solar and wind energy into electrical power. Electricity is also referred to as an energy carrier, which means it can be converted to other forms of energy such as mechanical energy or heat.

Electricity powers motors (mechanical energy) and ignitors (heat) and is used to control the entire heating process through the use of various controls and switches.

Electrical flow is similar to water flow

Figure 8-1:
Water analogy



Electricity is simply defined as the flow of electrons through a circuit, similar to the way water flows through a piping system, Figure 8-1. A comparison of electron flow vs water flow is used in the next few sections to help visualize electrical terminology.

Volts...like water pressure

Voltage is the potential to perform work in a circuit and is abbreviated with the letter "V" (volts) or sometimes the letter "E" (electromotive force.) Most heating systems include both line voltage and low voltage circuits. In this manual, line voltage means 120 volts AC and low voltage means 24 volts AC. Voltage can be measured with a voltmeter.

Voltage is the pressure to move electrons on a path through the components of the electrical circuit similar to the water pressure on a plumbing system. If a switch is closed, the electrons stay idle at the "hot" end of the electrical circuit similar to water pressure being held back by a closed valve. Turn a switch on and voltage will push electrons through an electrical circuit, just as opening a valve allows water pressure to push water through a plumbing system.

Amps...like water flow

Current is the rate of flow of electrons in a circuit, it is expressed in units called amperes and is abbreviated with the letter "A" (amps) or sometimes the letter "I" (intensity). Amperage can be measured with an ammeter.

Amps are similar to the gallons per minute of water flow through a pipe.

Ohms...like resistance to flow

Ohms is the resistance to electron flow through the wiring and components of an electrical circuit and is represented with the symbol "Ω" (ohms) or sometimes with the letter "R" (resistance). Ohms can be measured with an ohmmeter.

As electrons flow through a circuit there will be more or less resistance due to the size of the wiring and components (motors, controls, transformers etc.) of the circuit, similar to the resistance water is exposed to depending on the size of piping and components (valves, meters etc.) in a plumbing system.

To summarize the comparison of electricity to plumbing, think of voltage as water pressure, amps as water flow and ohms as pipe size.

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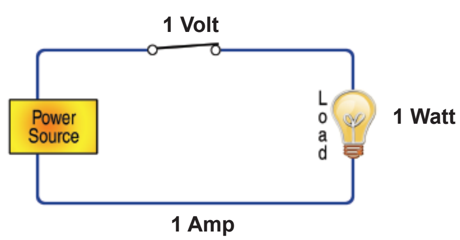
What's a watt?

Watts are the power consumed by an electrical circuit. One amp (the amount of flow) driven by one volt (the amount of pressure) through a circuit equals one watt of power, see Figure 8-2. This work can also be called horsepower (hp). One horsepower equals 746 Watts.

Figure 8-2: What's a Watt?



For reference, a typical residential burner motor is 1/7 hp (107 watts) and consumes about the same amount of power as a typical incandescent light bulb.

Conductors

Some materials offer very little resistance to the flow of current. These materials are called conductors. Most metals are good conductors such as gold, silver, copper, and aluminum. Copper is the most common conductor found in electrical circuits.

Insulators

Materials that offer a lot of resistance to the flow of current are called insulators. Air, glass, porcelain, plastic, and rubber are all good insulators. These materials are used to contain or control the flow of current along a conductor, such as a copper wire. Because air is a good insulator, its resistance stops the flow of current at the end of a wire like a wooden plug stuck in the end of a pipe stops the flow of water. However, if enough pressure is put against the plug, it will pop out and water will flow. Similarly, if enough electrical pressure (volts), is applied, air can become a conductor and allow electricity to flow in the form of a spark. The 10,000 to 20,000 volts generated by an ignitor can make an electrical spark "jump the gap" between a burner's electrode tips.

Did you know?

Electric company bills are based upon kilowatts per hour, kwh.
A kilowatt is 1,000 watts.

Loads

A load is a device that converts electrical energy to some other form of energy in order to do work. A load also creates resistance that opposes electrical flow. For example: an incandescent light bulb converts electric energy to heat and light because the filament resists the flow of electricity, getting so hot it actually glows. Another example: a motor changes electrical energy into mechanical energy.

Some of the loads found in oil burner circuits are:

- *Motors*
- *Ignitors*
- *Electromagnetic coils* (in relays and solenoid valves)
- *Transformers*

Electrical circuits

It is important to understand the electric circuit. Current has to flow from the live

The math

Volts, amps, ohms and watts are all related to each other. If you change one, you change the others too. These relationships are described by two math formulas:

volts = amps times ohms

and watts = volts times amps

Remember, if one changes, it affects the others.

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(hot) side of the source out into the circuit and back to the neutral side of the source.

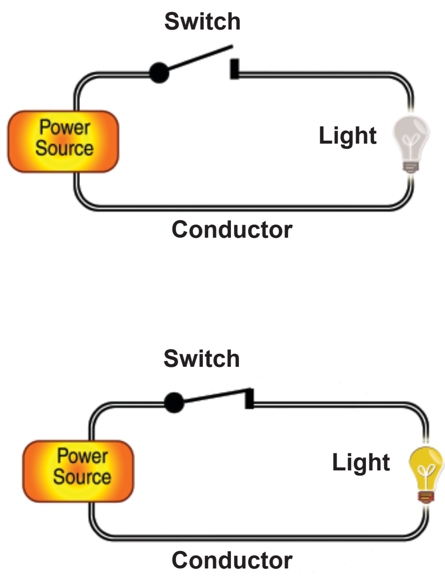
A simple circuit has a conductor that carries the electric current from the source, through a switch, to a load and back to the source. Current only flows in a complete circuit. However, the energy it gains in the electromotive force (measured in volts) from the power source is lost in the resistances (measured in ohms) it encounters in the circuit.

A switch is a device that interrupts the circuit. When it's open, current can't flow. When the switch is closed, the circuit is complete and the current flows. Figure 8-3.

A complete circuit must always include a load. If a conductor runs from the source back to the source without going through a load, it becomes a short circuit which can cause harm to people and/or property. Short circuits can also occur when wire insulation is compromised and a bare "hot" wire becomes exposed and crosses with a neutral wire or to a grounded electrical box. Fuses or circuit breakers are installed to prevent short circuits from causing damage. Circuit breakers are automatic switches that cut off the current if it reaches dangerous levels. Figure 8-4.

Resistance (measured in ohms) opposes flow. Voltage overcomes resistance to create flow. Any change in ohms will cause the opposite change in amps because volts from the power source are relatively constant. An increase in ohms reduces amps. A decrease in ohms increases amps. Increasing volts increases amps, this is called Ohms Law, which states, "It takes 1 volt to push 1 amp through 1 ohm." See Figure 8-5.

**Figure 8-3:
Open and closed switches**



Series Circuit

A series circuit has only one path for current to flow. Imagine that the lights in a home were wired in a series circuit where, if one burned out, they all went out? That is a classic series circuit. Aside from the problem of losing one load and shutting off all the rest, the drawback to a series circuit is that the supply voltage is shared among the components' "loads" in the circuit.

Figure 8-4: Fuse or circut breaker protects the circut

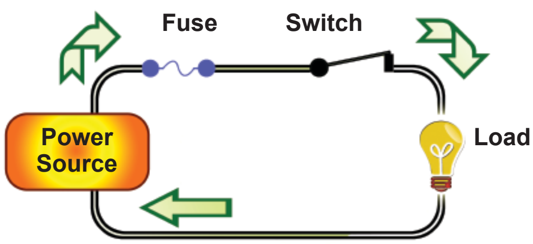


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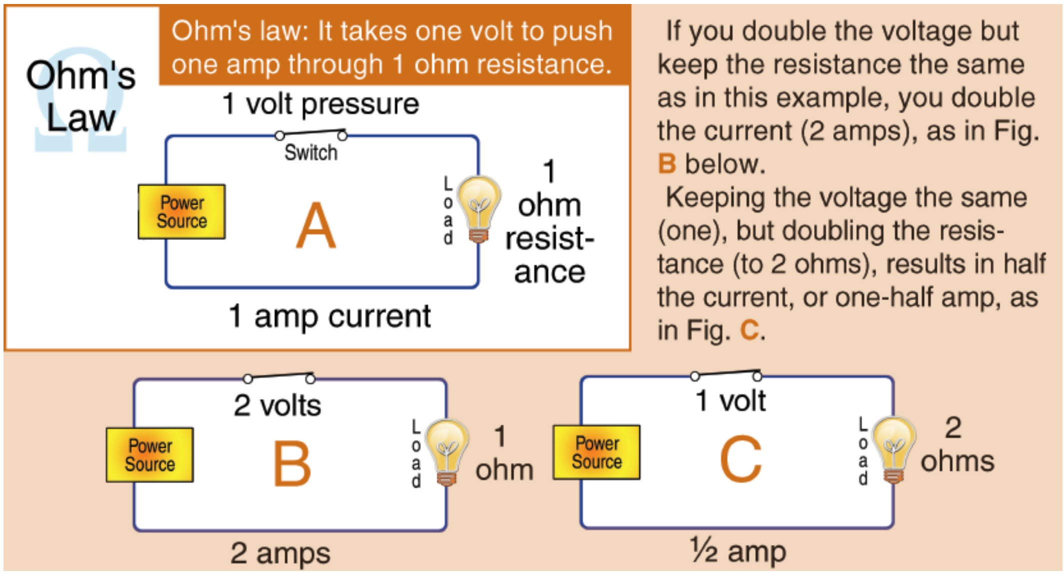
Figure 8-5



Therefore loads (burner components and circulators for example) are never wired in series in a heating system and switches (limit controls) always are.

Parallel circuit

A parallel circuit has separate branch circuits for each load. This way, all loads receive the same voltage and if one load is shut off or fails, it will not affect the other loads.

In a parallel circuit, loads can be turned on and off independent of one another. For example, the burner and the circulator can run separately, allowing the circulator to run after the burner is shut down and continue pumping heated water through the system.

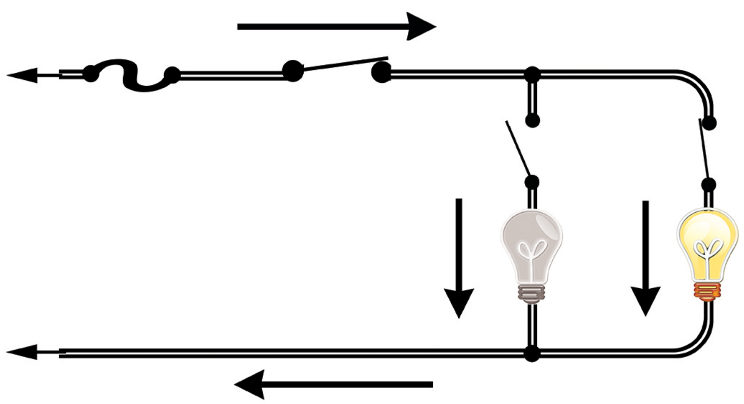
Similarly, multiple appliances are normally wired in parallel. This way each can be turned on and off separately. See Figure 8-6.

As the number of branch circuits increases, the total current draw increases. A situation can occur in a heating system that has too many loads on a single circuit. For example, a large system that has many circulators could exceed the capacity of the circuit breaker and wiring. In these cases, the appliance should be wired on its own circuit and the circulators wired on an additional circuit or circuits.

Combination circuit

Systems use what is called a combination circuit, a mixture of both series and parallel connections in the same circuit. See Figure 8-7 on following page. The main switch and all burner limit controls (switches) are wired in series with the primary control. If any one of these switches opens, the electrical current to the burner is cut off.

Figure 8-6: Parallel circuit



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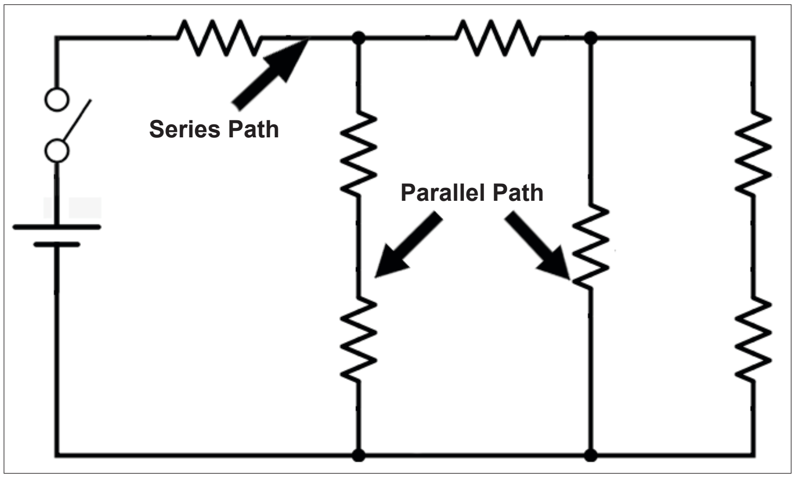
Loads such as the burner, circulator, blowers, etc. are wired in parallel to each other to allow individual component control and to ensure full voltage is supplied to each load.

Figure 8-7: Combination circuit



Polarization

Separating electricity into two wires is called polarization. It is a way of making sure the current goes where it is wanted safely. Most appliance plugs have a wide blade and a thin blade so there is only one way to plug them in. If the outlet has been wired correctly, the wide blade connects to the neutral wire and the thin blade connects to the hot wire so the appliance's switch will control the hot wire, not the neutral wire, allowing for a safe shut-off of current.

If polarization is reversed in heating systems, some components will function normally, but the burner switch and limit controls will interrupt the neutral wire. This creates a dangerous situation because, with the service switch controlling the neutral wire, voltage will still be present with the switch turned off. A technician working on such a system could receive an electrical shock and serious injury or death are possible because the circuit could be completed by flowing through them.

To be safe, test the circuit for voltage after turning off the switch and always treat the system as energized.

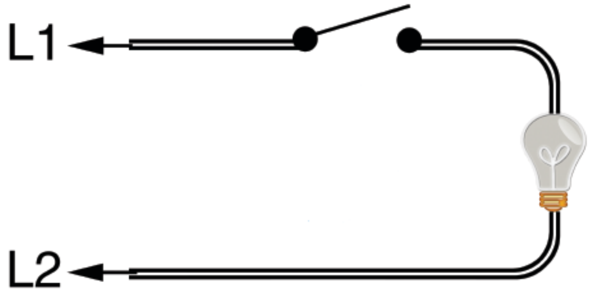
Wiring diagrams

Wiring diagrams are like road maps or blueprints that show how a circuit is designed. To install or service electrical equipment, technicians should be able to read the wiring diagram.

One of the confusing things about wiring diagrams is that a complete circuit is always needed, but a diagram starts out with a space between the two wires feeding the circuit. These two wires are labeled L1 (hot) and L2 (neutral.) When these labels are seen, it means there is a complete circuit even though it isn't shown as such.

Notice that when following L1 and L2 off to the left off the page, they go back to the circuit breaker and then all the way back to the power plant. Remember, the arrows on L1 and L2 are pointing at the power plant, and they represent a complete circuit. Figure 8-8.

Figure 8-8:
L1 and L2 point to the power source



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L1 is the electrically charged line that causes current flow and L2 is the return (neutral) line back to the source.

Wires

Wire comes in many different sizes. Wire sizes run from 0000 (the largest) to 40 (the smallest); the lower the number, the larger diameter of the wire. To size a wire, consider the maximum voltage rating of the wire and the amperage draw of all loads in the circuit.

The number of wires bundled together in the wire sheathing (insulating jacket) is printed on the sheathing after the wire gauge number (14/2 and 14/3). Only insulated wires are counted, so 14/2 has a black, white, and a bare ground wire which is not insulated and therefore not in the count. 14/3 has an added red wire. Figures 8-9.

Thermostat cables (usually 18 or 20 gauge) can have from two to seven wires in them (18/2 - 18/7), depending on the added functions of the thermostat (air conditioning, humidifier and fan). To make identification easier, the wire coating is color coded.

The spot where wires are joined together or connected to a control is the weakest link in a circuit. Be very careful when making these connections. All line voltage connections must be in a junction box or protected control box with clamps at the entrance and exit to be sure stress is not placed on connections if the wires are pulled.

Connections may become dirty or corroded if exposed to high heat or humidity. Always check exposed connectors and always seal hidden connections with electrical tape. Copper wire is recommended for all burner wiring.

Figure 8-9:
Wires bundles together (14/2)

Figure 8-9:
Wires bundles together (14/3)

Practical tips

Splicing wires

To splice wires, first strip the insulation from the wires with a wire-stripping tool. (Don't use a knife; it might nick the wire, reducing its current carrying capacity.) Slip the wire into the correct hole in the stripper, squeeze, twist, and pull off the insulation.

Next hold the stripped wires together and grab the ends with lineman's pliers. Twist clockwise, making sure all wires turn. Twist them together into a neat looking spiral. Now snip off the end leaving enough exposed metal so the wire nut will just cover it. (About a half inch is good.) Now slip on an appropriately rated wire nut as far as it will go and turn it clockwise until tight, Figure 8-10. Finally wrap electrical tape around the bottom of the nut and wires.

Figure 8-10:
Wire nut

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Connecting wires to terminal screws

Before starting, understand that many devices come with the terminal screws unscrewed. Screw in any terminal screws for terminals that are not going to be used. Then get ready to connect the wiring.

Don't use a knife to strip insulation from a wire. It might nick the wire reducing its current carrying capacity. Always use a wire stripping tool.

1. First, use a wire stripper to strip 3/4 inch of wire insulation from each. conductor to be connected. Take care not to nick the metal wire itself. Using the proper opening on the wire stripper will prevent this.
2. Use a pair of needle nose pliers to bend the exposed metal tip of the wire into a J-shaped hook with the opening to the right.
3. Now, loop the wire hook around the screw terminal with the opening to the right so the hook will tighten the wire closed, not force it open. This means, essentially, that the wire should be looped around the screw terminal in a clockwise direction while looking down at the screw head from above.
4. Tighten the screw terminal firmly down onto the wire. Make sure that there is no wire insulation under the head of the screw.

Avoid attaching two or more wires to one terminal screw. To make a multiple connection, make a "pigtail" wire by cutting a six-inch length of wire, strip both ends, splice the multiple wires to one end, and then attach the other end to the terminal screw.

Armored cable

NORA recommends that any wiring around an oil-powered appliance should be protected by either flexible metal conduit or armored cable. There are two kinds of armored cable: BX and MC.

BX has no ground wire. Its metal sheathing serves as the ground. Some people mistake the thin metal bonding strip in the cable for a ground wire. The strip is easily broken and is used only to make a conductive connection to a metal junction box. Older BX used heavy steel sheathing. Aluminum is now used because it is lighter, easier to cut, and is a better conductor.

MC cable is like BX, but with a green insulated grounding wire.

Flexible metal conduit has no conductors installed in it. The National Electrical Code® specifies how it can be used and how many conductors may be installed in the conduit.

Installing armored cable

To cut armored cable, use a cable cutter such as a Seatek Roto-split RS-101, Klein Tools 53725 or Ripley Miller ACS-2. See Figure 8-11.

Figure 8-11: Cable cutter

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If a cable cutter is not available, bend the cable about one foot from the end and squeeze the bend until the armor breaks apart slightly. Figure 8-12.

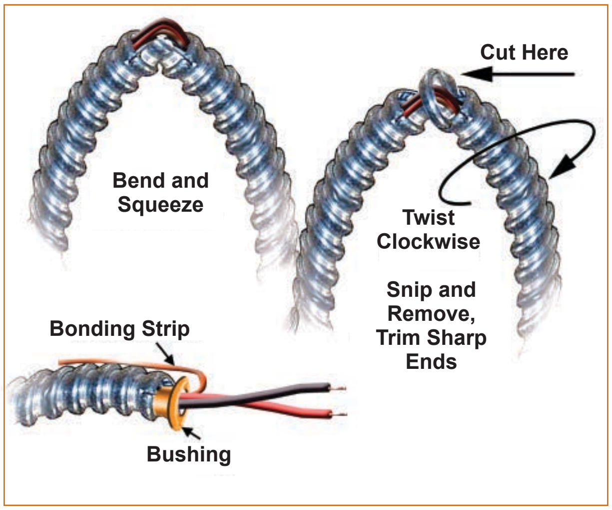
Grasp the cable firmly on each side of the break and twist clockwise until the armor comes apart enough to slip in cutters.

Cut through one rib of the armor with a pair of side-cutting pliers. Slide the waste armor off the wires. Remove the paper wrapping and plastic strips. Leave the thin metal bonding strip alone. Use side-cut pliers to trim away pointed ends of the sheathing that could nick a wire.

The next step is to slip the plastic bushing (aka "redhead") over the wires. Slide it down into the armor so it protects the wires from the sharp edges of the armor. If there is a bonding strip, cut it to about two inches and wrap it over the bushing and around the armor to ensure conductive contact between the armor and the box.

Next attach a connector to the cable. Remove the lock nut from the connector and

Figure 8-12: Cutting armored cable



slide the connector down over the bushing as far as it will go. Then tighten the screw. Figure 8-13.

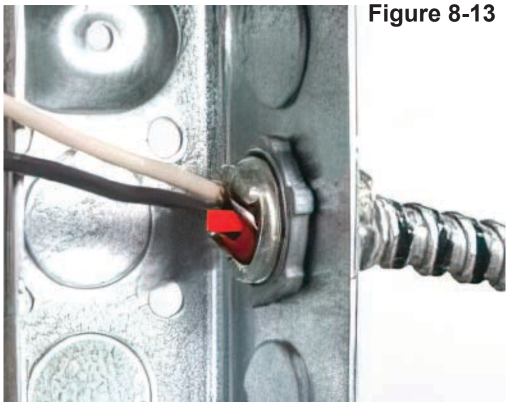


Figure 8-13

Finally remove the knockout from the junction box, and install the wire and connector into the hole. Slide the locknut over the wires, and securely thread it onto the connector.

Switches

A switch is an electrical component that can disconnect or connect the conducting path of an electrical circuit. Switches are considered open when they stop the flow of electricity and closed when they allow the flow of electricity. Switches can be manually or automatically operated. Switches should always be on the hot side of all loads.

There are typically two manual switches on an oilheat system:

- one outside of the boiler room, often located at the top of a staircase
- and a "service switch" typically located at the appliance, Figure 8-14, following page

There are many different types of switches. The most common switch is a single pole, single throw switch, or SPST for

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Figure 8-14: Service switch

short. They are either on or off. This is a swinging gate that can disconnect the flow path in a conductor when it is open and connect the path when it is closed. A SPST switch turns everything in a single circuit on and off. There can be many SPST switches in one hot line. The service switch (manual) and low water cutoff (automatic) are examples of SPST switches.

Most other types of switches in a heating system are "automatic" switches that are operated by temperature, pressure or water level.

Other switch configurations are:

- Single pole double throw, or SPDT. This switch is used to turn the electricity on or off in one or the other of two separate circuits. This would be like a Y intersection where a car can drive on one road or the other but not both. Some heat/cool thermostats have SPDT switches.
- Double pole single throw (DPST) switches can make or break two separate circuits at the same time. The two circuits being switched can be of the same voltage or different voltages.
- Double Pole Double Throw (DPDT) switches re-direct the power of two separate supply lines to two different circuits. Some switching relays include DPDT switches. See Figure 8-15.

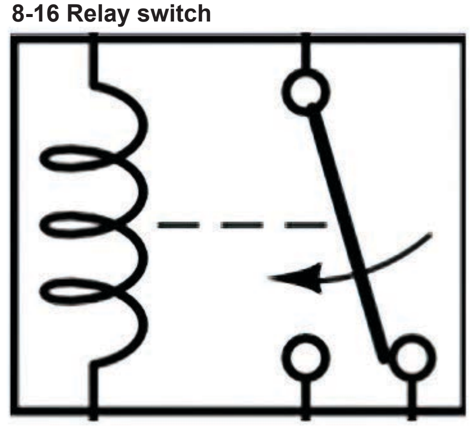
The contacts of automatically operated switches in wiring diagrams are shown in their normal (at rest) position when the unit is not operating. Contacts on automatically operated switches are classified as normally open (NO) or normally closed (NC). The determination is made by the position of the contacts when the device is either not energized or not sensing the condition it is designed to sense.

Automatic sensing switches respond to a change in conditions such as temperature, pressure, flow and liquid level.

Relay switches

Relays are electrically operated switches that open and close a circuit by receiving electrical signals from outside sources such as thermostats. Older relays, such as those found in obsolete primary controls, limit controls and switching relays used electromagnets to open and close. Figure 8-16.

8-16 Relay switch



Relays are represented in wiring diagrams as a coil of wire and a switch. The coil is usually energized by low voltage. The switch can control either a high or low voltage circuit. The working limit of the switch is determined by the amperage draw of the circuit it is controlling. Many relays are single pole double throw switches, so some include both a low voltage switch and a line voltage switch. The way to keep track of all this is to label the coil with a number and a letter like 1K. Then label the switch contacts controlled by that coil 1K1 and 1K2.

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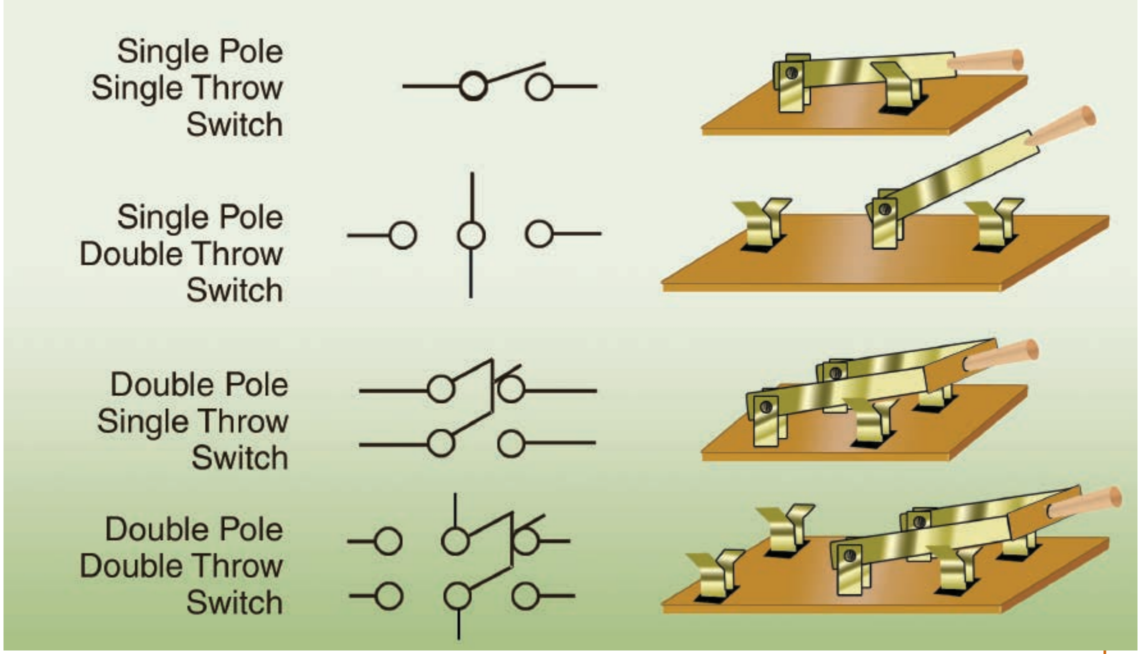
Figure 8-15: Switching arrangements (various setups)



A problem area that many technicians experience with relays is the contacts. Dirty or corroded contacts add resistance to the circuit, resulting in reduced voltage to the load, which can create arcing that shortens the life of the contacts. The good news is that most new relays are enclosed in plastic to keep them clean. A properly working relay will not cause any voltage drop when closed.

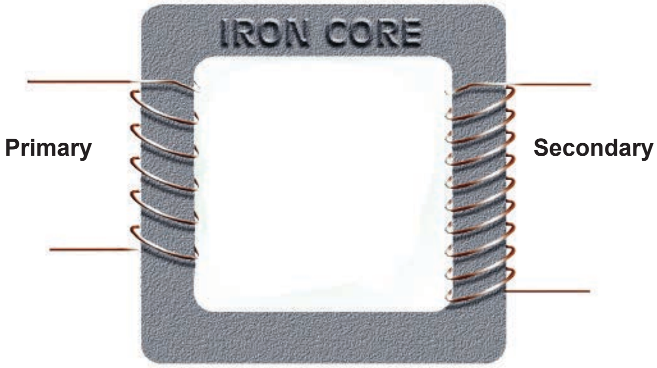
Transformers

A transformer is an electrical device that transfers alternating current from one circuit to another with an increase or decrease in voltage. They are made of an iron core with two separate wire coils wrapped around two sides.

The coil where the current enters is the primary coil, and the coil where the current exits is the secondary coil. Figure 8-17.

There is no electrical connection between the primary and secondary coils. The only connection between the two is the magnetic field. When voltage is applied to the primary coil, a magnetic field is generated which creates voltage in the secondary coil. The amount of voltage generated in the secondary coil is

Figure 8-17:
Basic design used in an iron core transformer



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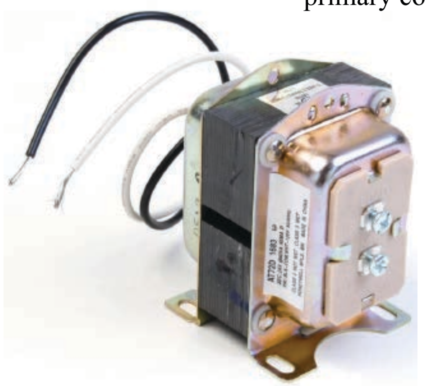
determined by the ratio of coils between the primary and secondary coils.

- Step-down transformers have more primary coils than secondary and reduce voltage, these are typically 120V on the primary side and 24V on the secondary side. They are used to operate thermostat circuits, zone valves, dampers, and air-conditioning control circuits. Figure 8-18.

Figure 8-18: 24V transformer



- Step up transformers have more secondary coils than primary coils and increase voltage, they are usually 120V on the primary side and 10,000V to 20,000V on the secondary side. They are used to produce an arc to ignite fuel.

Measuring electricity

Since electricity can't be seen, measuring devices are needed in order to properly troubleshoot heating and air conditioning systems. To measure voltage, current, and resistance most technicians use a digital multimeter.

Using a multimeter

Figure 8-19: Multimeter

Before using a multimeter, it must be properly set for what will be measured (i.e. voltage, current or resistance) and what reading (range of value) is expected. Each function has a maximum and minimum range. For example, if measuring voltage, the meter must be set for the type of voltage (AC or DC) and the range. Since the voltage supplied to a typical oilheat system is 120 volts AC, the meter should be set to AC voltage (VAC) and the scale should be set to a value higher than the expected reading of 120. The meter shown in Figure 8-19 is set to 400 VAC.

Since different meters have varying capabilities, it's important to become thoroughly familiar with the manufacturer's instructions that come packaged with the meter or meters that the technician uses. In general, it's a good practice to:

- Protect the meter from moisture and high temperatures
- Replace worn or cracked test leads
- Store the meter in its case when not in use
- Check the battery often for corrosion
- Remove the batteries during long storage periods

Measuring voltage

A voltmeter is used to measure the difference in electric pressure between two points.

A voltmeter allows very little current to go through it. It has very high resistance, so it has almost no effect on the circuit being measured. When the leads from the voltmeter are connected to two different points in the circuit, it measures the difference in potential (volts) between those points.

For example, to measure the voltage coming into a control, touch one of the voltmeter's leads to L1 and the other to L2. The display should show 120 VAC.

There will be no voltage drop across a closed switch. If the leads are placed on either side of a toggle switch while the switch is in the on position, the reading will be zero because there is no difference in potential—there will be 120 VAC at both sides. If the switch is turned off, there will be a difference in potential and the meter will read 120 VAC.

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Measuring current

An ammeter measures the rate at which the electric current flows from the power source, through the wire and load, and back to the source.

There are two kinds of ammeters: in-line and clamp-on. In-line ammeters are not commonly used by service technicians in our industry. They are primarily used during bench testing.

The clamp-on ammeter is easy to use. It uses electromagnetic induction. Whenever electricity flows through a wire, it creates a magnetic field around that wire. The clamp-on ammeter converts the strength of the magnetic field into a current reading.

To use a clamp-on ammeter, first pick the correct scale (when in doubt start high) then open the jaws of the meter, insert one line between the jaws, close the jaws and take a reading. This meter can be used safely on a live circuit without disconnecting the power since the magnetic field is not affected by the wire's insulation. See Figures 8-20 and 8-21.

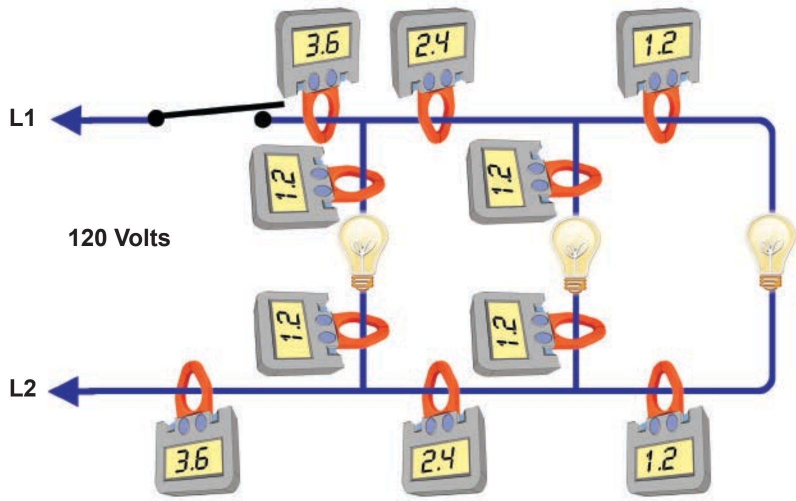
The reason the jaws are placed over only one line is because the magnetic fields from each wire cancel each other out. If both the hot and neutral lines were between the jaws, the reading would be zero even if there was current flowing in the wires. Either the hot or neutral line can be tested, but not both at the same time.

Figure 8-20 Clamp-on ammeter

The design current draw of a load is usually listed on the rating plate, see Figure 8-22 on following page. The listed design current draw is for steady-state normal operation. On start-up and under increased motor load, there is a higher required torque and a slower operating speed, so the motor current will be higher.

Figure 8-21

Clamp-on Ammeters (Each Load is 100 ohms)



The surge current draw on initial start-up of a motor may be four or five times its normal current draw. Sometimes the surge current draw is also listed on the rating plate.

Measuring resistance

The ohmmeter is used to measure resistance between two points. It can measure just one load or a whole circuit.

Since an ohmmeter provides its own power (from a battery), the circuit or device to be tested must be isolated from its power source. The ohmmeter measures the

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34:32

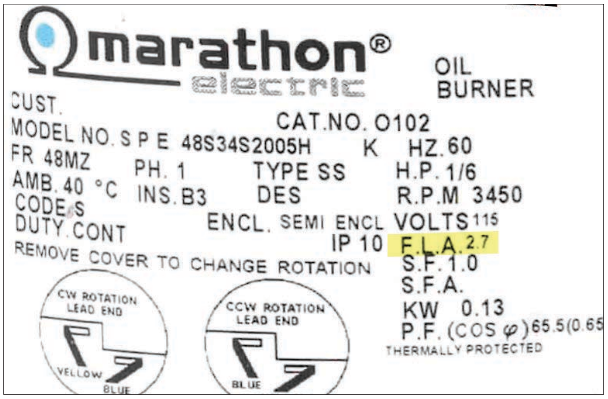


Figure 8-22: Rating plate

If a fuel unit has rust in its gear set, the burner motor will not be able to function normally and the current draw will be more than the listed "running amp" rating. If the fuel unit becomes bound, the motor will shut off on overload.

resistance between two points by applying a steady voltage from the meter's battery to a de-energized circuit or device. Figure 8-23.

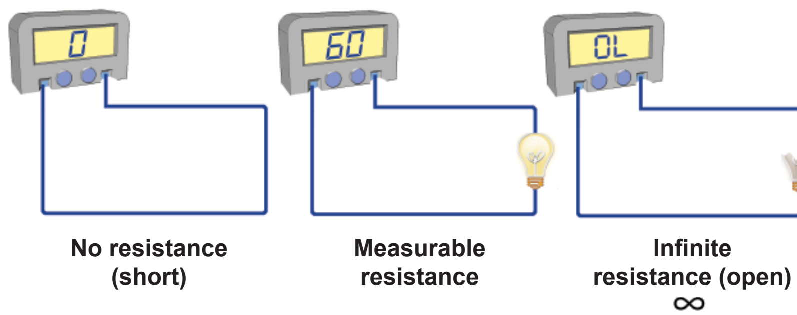
Ohmmeters are often used to determine the resistance through a cad cell. With the burner off, the technician disconnects the leads from the FF terminals of the cad cell primary control, installs a jumper across the terminals and connects the meters leads to the cad cell wiring. Then, when the burner is turned on, the control won't allow it to start because the jumper simulates a flame in the combustion chamber. Disconnect the jumper and when the burner starts, reconnect it to keep the burner running, then read the resistance.

An ohmmeter can also be used to see if there is a complete circuit. This measurement is called continuity. If there is continuity between two points, current will flow. If there is no continuity, current won't flow. If current doesn't flow, it means the pathway between the two points is broken.

For example, to determine if there is a break in a low voltage thermostat circuit connected to a primary control, raise the heating thermostat to its highest setting, disconnect the wires from the T-T terminals and touch one ohmmeter lead to each of the wires at the same time.

If there is no continuity the ohmmeter will read OL, for open loop and there is a break in the thermostat circuit. To determine if the break is in the wiring or in the thermostat itself, disconnect the wires from the thermostat and connect them with a jumper or wire nut and check for continuity again. If there is continuity, the problem is with the thermostat. If there is not, the problem is with the wiring.

Figure 8-23: Ohmmeter readings



Chapter 8: Additional Resources

NORA has compiled a library of additional technical resources for your continued education. Scan the QR code or go to the web address. Check back often, as NORA will continually add content as it becomes available.

You will find:
- Videos
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