SATURN
RESOURCE MANAGEMENT

Water Vapor and Humidity

Water vapor is lighter than air and the water vapor molecule is smaller than air's other molecules — nitrogen and oxygen. Therefore, water vapor can rise faster and squeeze through smaller microscopic spaces than air. When water vapor moves through a solid material, this is called vapor diffusion.

Materials vary in their permeability to water vapor. Porous materials like brick and insulation transmit water vapor relatively rapidly and are said to have a high permeability. Plywood and drywall have a medium permeability. House wrap is a specially designed material that repels water while letting water vapor through because of house wrap's high permeability. Metals and plastic films, often called *vapor barriers*, slow vapor diffusion to a trickle.

A force called vapor pressure drives vapor diffusion. *Vapor pressure* is created by a difference in the amount of water vapor in two bodies of air, which are separated by some barrier, like a wall. The amount of water vapor in the air — called *absolute humidity* or *humidity ratio* — is expressed in pounds of water vapor per pound of dry air. Vapor pressure is the difference in absolute humidity between two air masses. The greater the vapor pressure, the faster water vapor flows through building materials separating the two air masses.

Relative humidity (rh) — the percentage of the maximum moisture that air at a given temperature can hold — is 100% when the air is saturated with moisture. Add more moisture to saturated air, and moisture condenses on cool objects. Relative humidity is 50% when the air at a particular temperature is only half saturated with water vapor. The moisture content of building materials is directly related to the relative humidity of the air surrounding them.

Converting Energy for Home Use

In all homes, energy is converted from one form to another — electricity to light, gas to heated water — within its walls to provide occupants comfort, water heating, refrigeration, lighting, entertainment, and a variety of other services.

Combustion Heating

Most homes in the United States are heated by combustion heating systems. When the carbon and hydrogen atoms in fuel molecules mix with oxygen and a flame, the chemical chain reaction we call burning begins. Heat is liberated in the chemical process, and we use this heat for space and water heating.

The heat from the flame and hot gases heats a metal structure, called a heat exchanger, which then heats air or water. The flame heats the heat exchanger first and foremost by radiation and also by convection of its combustion gases. Pipes or ducts carry the heated air or water to the building's rooms. The transfer of chemical energy into heat at the flame is usually more than 99% efficient. However the farther the heat travels away from the flame, into the heat exchanger and through the distribution system, the more heat is lost. These progressive heat losses make most central heating systems less than 70% efficient at converting the fuel's chemical energy to useful heat for the home.

See "Combustion Heating Basics" on page 142.

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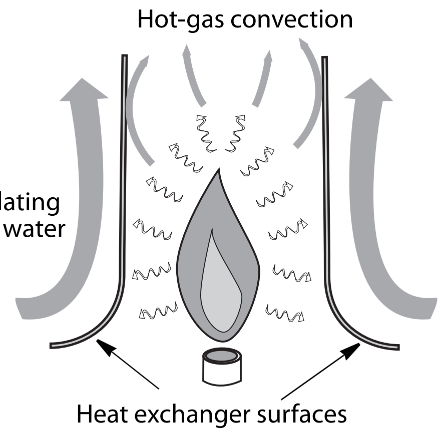
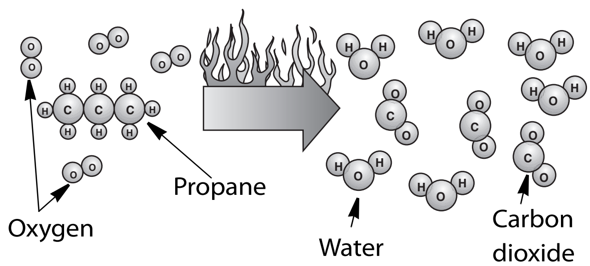
Heat Transfer from Combustion



The flame heats the surfaces of the heat exchanger by radiation and by convection of the hot combustion gases. Circulating water or air on the heat exchanger's other side conveys the heat to the home.

Combustion of Propane



Propane (C_3H_8) combusts by combining with oxygen (O_2) to form water (H_2O) and carbon dioxide (CO_2).

Electric Resistance Heating

Electric resistance heating changes electricity, usually generated by heat, back into heat. The electric current passes through resistive wires, bars, or plates. Electric heaters are often located in rooms and perform their heating through natural convection and radiation. Electric furnaces blow air through their electric resistance coils. Electric water heaters and heating boilers have their electric resistance bar surrounded by water, so they heat by conduction and convection.

See "Electric Heat" on page 180.

Lighting

Electricity is converted into light in residential buildings in *incandescent* or *fluorescent* lights. In an incandescent light bulb, a tiny metal wire called a filament glows white hot when electric current passes through it. Only 10% of the electricity is converted into light, with the other 90% becoming heat. Fluorescent lamps produce light by passing electric current through a metallic gas. The flow of electricity through the gas excites special chemicals called phosphors, causing them to glow or "fluoresce." The glowing phosphors coat the inside of the fluorescent tube. Fluorescent lamps convert 80% of the electricity they use into light. Using fluorescent lights instead of incandescent lights can reduce the amount of electricity used for lighting by about 75%.

For more information, see Chapter 7 Lighting and Appliances.

The Refrigeration Cycle

Refrigerators, air conditioners, and heat pumps move heat from one location to another using latent heat. One location is heated and one location is cooled. When liquid *refrigerant* vaporizes in the *evaporator* of an air conditioner, it absorbs heat from the metal in the evaporator coil. The evaporator coil then becomes cold and removes heat from the warm air being blown through the coil. The vaporized refrigerant carries the heat it collected from the indoor air to the *compressor*, where the refrigerant vapor is compressed and sent to the condenser. In the *condenser* the refrigerant condenses back to a liquid, releasing its latent heat of vaporization and heating the condenser coil. The condenser coil has a higher temperature than the air moving through it, so the heat flows from the coil to the air.

The liquid refrigerant collects in the condenser and flows toward the evaporator, pushed by the compressor's pressure. The *expansion device*, which is like a spray nozzle, sprays liquid refriger-

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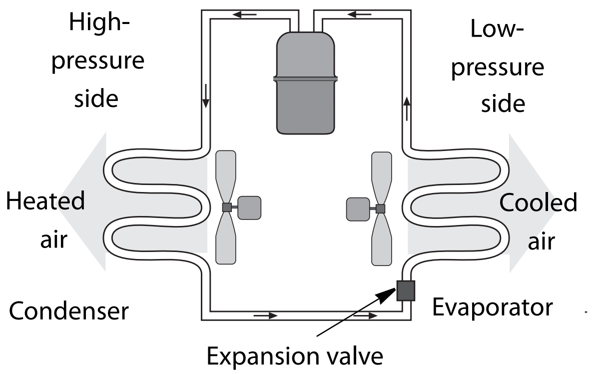
ant into the evaporator, where it evaporates once again. The evaporating refrigerant removes heat from the evaporator coil, and the cycle repeats.

See "Checking Refrigerant Charge" on page 221 for more detail on the refrigeration cycle.

The Refrigeration Cycle

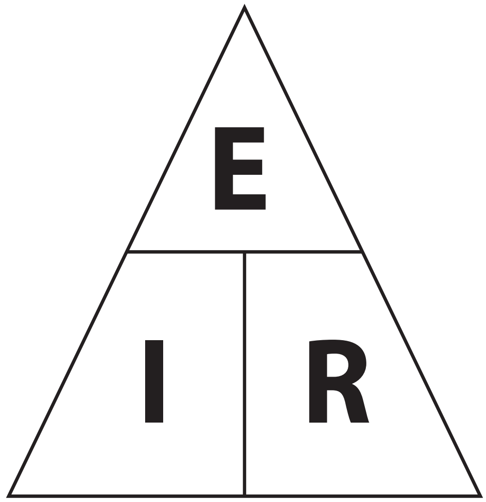


Refrigerant evaporates in the evaporator, absorbing heat from the metal tubes, fins, and passing air. The compressor compresses the refrigerant, preparing it to condense within the condenser. The refrigerant's latent heat is then transferred to the condenser's tubes and fins and then to the passing air.

Electric Circuits and Devices

Electrical principles are presented next because electricity is so important to home energy use. Electricity is the most refined and versatile form of energy. It can be converted into light, heat, or motion. Electricity heats homes, spins motors, lights lamps, cooks, and entertains. Electric circuits providing heat, light, or motion are called *power circuits*. Electricity also regulates most energy-using devices — furnaces, water heaters, and major appliances — using *control circuits*.

Ohm's Law



$$R = E \div I$$
$$I = E \div R$$
$$E = I \times R$$

$$P \text{ (watts)} = E \text{ (volts)} \times I \text{ (amps)}$$
$$Q \text{ (energy)} = P \text{ (watts)} \times t \text{ (hours)}$$

This common representation of Ohm's Law aids in remembering the position of the variables in the formula. E is voltage in volts. I is current in amps. R is resistance in ohms.

An electrical generator pushes electrons through a metal wire, imparting them with electrical energy. Whenever an abundance of electrical energy exists in one area along with a relative lack of electrical energy in another, *voltage* (also called *potential difference*) exists between the two areas. Electricity flows from electrically charged areas to electrically neutral areas. The earth is electrically neutral and is used for the neutral part of circuits.

Most electrical generators are turned by rotating machines called turbines. A turbine is turned by pressurized steam, flowing water, or wind. Heat for the steam turbine comes from the combustion of oil, gas, coal, or thermonuclear reaction.

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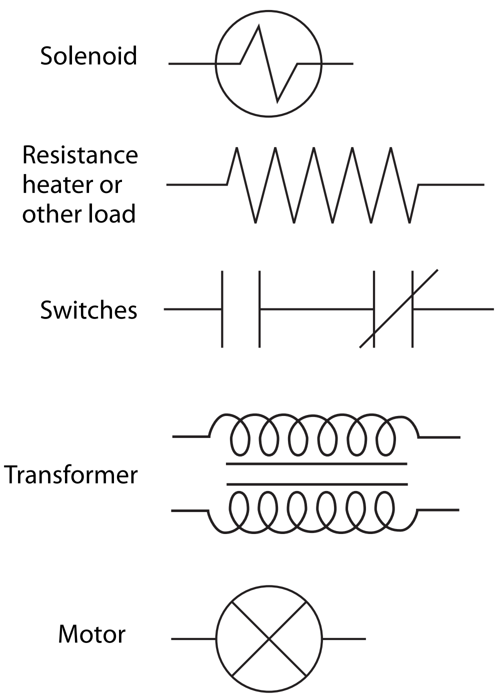
Electrical Symbols



These are common symbols used in electrical circuit diagrams.

An electric *circuit* consists of three essential parts: a source of electricity; a *path* for the electricity to flow; and a *load*, a device that uses electricity. Most circuits also have a *switch* to start and stop the flow of electricity. The switch creates an air gap in the hot wire of the circuit. We say that a switch is *open* if it is creating an air gap and stopping electricity, and *closed* if it is connecting the circuit.

Electrical Principles

The flow of electricity is described by a well-known formula called Ohm's Law — E (voltage) = I (current) x R (resistance). E stands for *electromotive force*, but is better known as voltage. *Voltage*, expressed in volts, measures the electrical pressure. *Amperes*, or amps, measures current — the flow of electrons. And resistance describes the circuit's opposition to current in units called *ohms*.

Current in amps multiplied by voltage in volts equals the power of the circuit in watts. And watts multiplied by time, in hours, equals watt-hours of energy. This simple relationship between current, voltage, power, and energy is true for electric-resistance devices like heaters and incandescent lights. However, actual energy consumption for motors, transformers, and other devices with coils is less than amperage times voltage because of an effect known as reactance, which is beyond the scope of this discussion.

Series Versus Parallel Circuits

Series circuits form a single looping path from the source to the load and back to the source. The electrical current is the same in all parts of the circuit. Series circuits control heating systems and simple appliances.

Several switches placed in series allow any of these switches to interrupt electrical current to the load. Therefore, a series control circuit can decide that both safety and necessity are present before connecting the load. Both the safety switch and control switch must be closed for electricity to flow to the load.

Parallel circuits form ladder rungs between the hot and neutral wires. In home wiring, each rung is a light, outlet, or appliance. In parallel circuits, voltage is the same on all rungs.

Several switches placed in parallel circuits allow any of these switches to connect a load. Heating and cooling systems often use parallel switches to start the blower — one switch for heating and one for cooling.

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Control Circuits

Control circuits are often low-voltage circuits using transformers to step down the voltage. This lower voltage is safer for remote controls and requires smaller and less expensive switches, wiring, and control components. Newer appliances have electronic controls that use even less power than traditional low-voltage control circuits.

A control circuit employs a *controller*, like a thermostat, with a *sensing device*, like a bimetal spring or thermistor to control electric power to a *final control element*, like a gas valve, oil burner, fan, or pump. Controllers and sensing devices may be the traditional electromechanical or the newer electronic types.

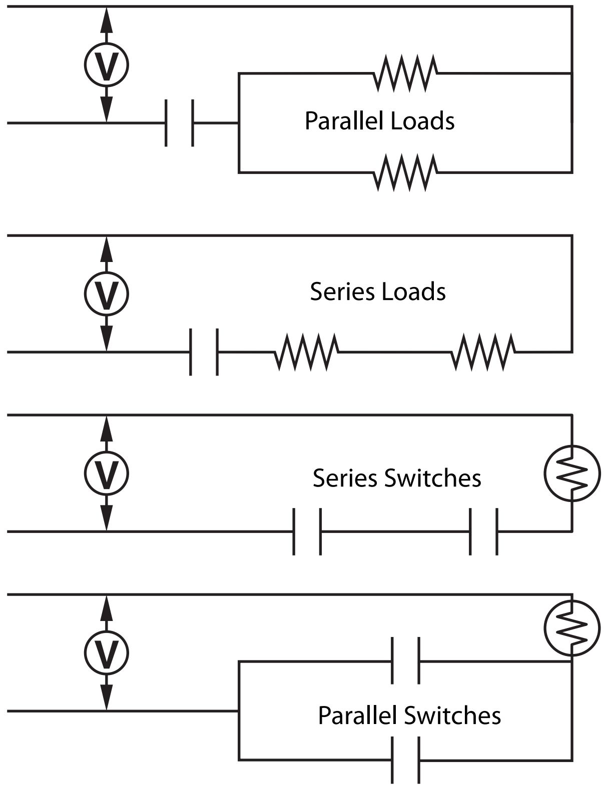
Transformers and Power Supplies

A *transformer* is a device that transforms or changes voltage from one circuit to another. Power companies use high voltage to transport electricity over long distances to reduce line losses, and then step voltage down with transformers to make it safe for local customers.

Step-down transformers within the home reduce voltage from around 115 volts to 24 volts for controlling heating and cooling systems. This lower voltage is safer and more convenient for installing the thermostat without having to run sheathed cable. Dedicated 24-volt controls provide more precise control of energy systems than their 115-volt counterparts.

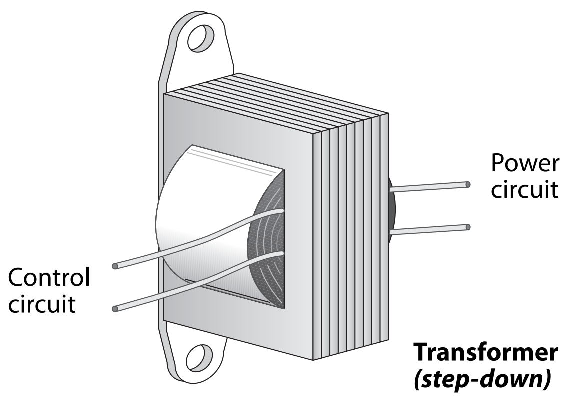
Electronic controls allow even more precise control than low-voltage electromechanical controls. An electronic power supply acts like a transformer to reduce voltages to levels required by the electronic sensing devices and microprocessors. A microprocessor is an electronic brain that can make decisions about control based on a number of inputs.

Types of Electric Circuits



These are the four possibilities for the arrangement of loads and switches in electric circuits.

Transformers



The transformer powers the control circuit to operate a relay for a solenoid valve via a thermostat, aquastat, or limit switch.

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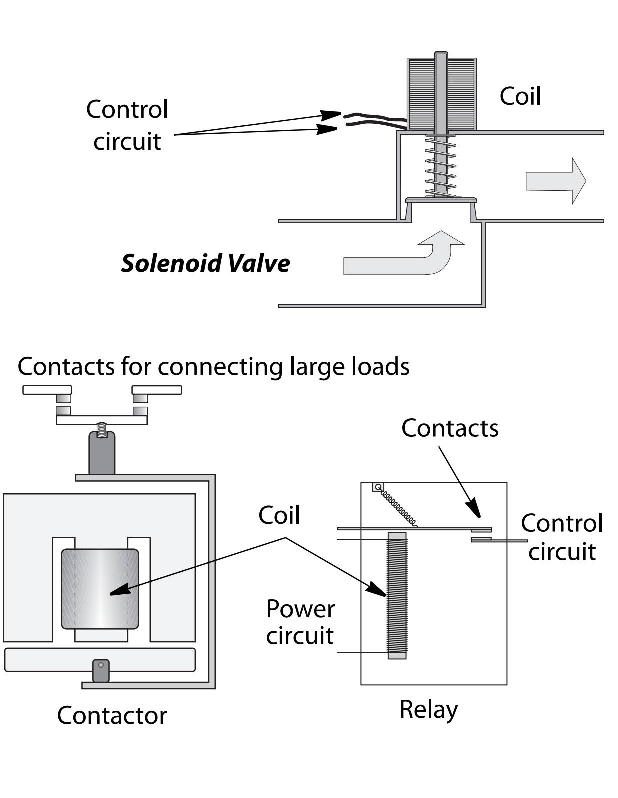
Solenoids

A wire coiled around an iron bar will magnetize it, causing it to move when electricity flows through the coil. This principle is called *solenoid action* and is used to open and close solenoid valves and switches called *relays* and *contactors*. An example of a solenoid valve is the automatic gas valve on a gas furnace. Relays are powered by the control circuit. Relays connect and disconnect loads like solenoids and small motors in the power circuit. Larger motors and electric heating elements require sturdier automatic switches called contactors.

Types of Solenoids



Solenoids can operate a switch, like a relay or contactor, or final control element, like a gas valve.

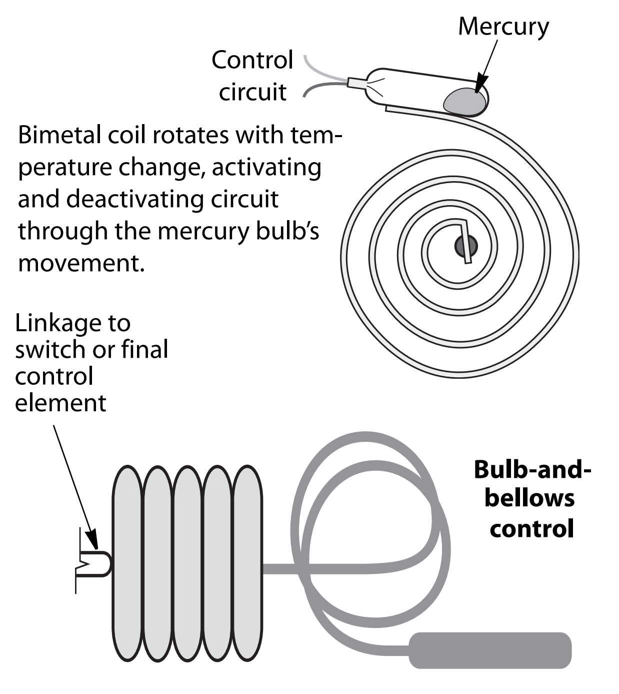
Temperature-sensitive Elements

Bimetal elements or bulb-and-bellows elements move electrical contacts or a valve stem in response to temperature changes. The most common devices using temperature-sensitive elements are thermostats and *limits*. Limits are safety switches that interrupt power if temperatures get too high.

Bimetal elements are temperature-sensitive metal coils and strips. A thermostat uses a bimetal element to turn the heating system on and off. The bimetal element is two thin metal pieces with different rates of expansion bonded together. It bends, rotates, or snaps inside out as the temperature changes. This motion is used to move a switch's contacts or a final control element.

Bulb-and-bellows controls use the variation in volume of a liquid or gas to move electrical contacts or a final control element.

Electromechanical Heat Sensor



A bimetal coil or bulb-and-bellows mechanism can operate an electrical switch or a final control element like a gas valve.

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