Heating System Basics

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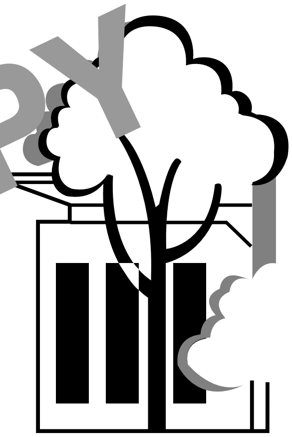
HEATING SYSTEM BASICS

Lesson One

Heat Energy



TPC Training Systems

44201

Lesson

1 Heat Energy

TOPICS

Heating System Requirements
Heat and Energy
Temperature
Sensible Heat and Latent Heat
Heat Transfer
Energy Conversions
Electric Motors

OBJECTIVES

After studying this lesson, you should be able to…

- Name the three main requirements of heating systems and various kinds of energy related to heating systems.
- Define terms related to the basic concepts of heating systems.
- Describe differences between standard temperature scales and explain how to convert between Fahrenheit and Celsius scales.
- State the two basic laws of heat transfer and describe the three ways heat is transferred from one location to another.
- Explain how to convert between kilowatts (kW) and brake horsepower (bhp).
- Briefly describe various kinds of single-phase motors used in heating systems.

KEY TECHNICAL TERMS

Heat energy 1.16 a form of energy having intensity, measurable as temperature in °F or °C, and quantity, measurable as enthalpy in Btu/lb

British thermal unit (Btu) 1.25 the amount of heat required to raise the temperature of 1 lb of water 1°F

Specific heat 1.26 the number of Btu required to raise the temperature of 1 lb of a substance 1°F

Sensible heat 1.27 the measurable change in temperature as heat is added to a substance

Latent heat 1.28 heat added to or removed from a substance that is undergoing a change of state; there is no temperature change

Conduction 1.31 the transfer of heat from a region of higher temperature to one of lower temperature, generally within a single solid material

Convection 1.32 the transfer of heat from one place to another by the movement of one portion of a fluid (liquid or gas) with another portion at a different temperature

Radiation 1.33 the transfer of energy by waves without a transfer medium such as air or water

Synchronous speed 1.41 having a rotor turning at the same speed as the rotating magnetic field; the no-load speed of the motor

Slip 1.42 the difference between a motor's synchronous speed and actual rotor speed

Throughout this course and the next, you will read about many kinds of heating systems and equipment. Although the focus of these courses is on smaller heating systems, the concepts carry over to larger systems as well. These lessons will discuss traditional as well as unusual energy sources.

This lesson discusses the basics of heat energy and defines important terms associated with heat and energy and their relationships. You will read about temperature and its measurement, British thermal units, and specific heats for various substances. You will also study the characteristics of sensible heat and latent heat. In addition, you will compare conduction, convection, and radiation, the basic methods by which heat is transferred from one location to another. This lesson also discusses single-phase motors commonly used in heating systems.

Heating System Requirements

1.01 When considering building heating systems, people generally think first of the obvious and probably the most common method, which is fire. In heating terms, fire is the burning of a fuel to generate the heat energy necessary to warm us in cold weather. This has been the case since humans first discovered how to make and control fire, as illustrated in Fig. 1-1.

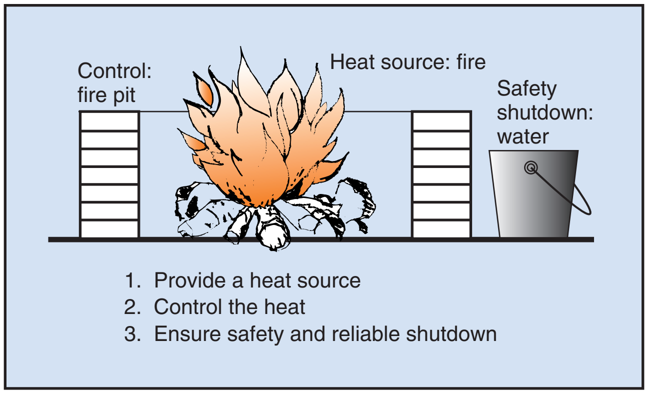
1.02 Even today, burning a fuel in a controlled manner is the primary means of converting potential fuel energy into heating energy throughout the world. Throughout this and later lessons, remember the term *control*. It is an essential concept in effective heating systems.

1.03 Fire for heating (or any useful purpose) without adequate control may become a raging inferno. Thus this course will also include discussions of combustion, required air flow, chimneys, venting, and the safety considerations that govern modern heating equipment. Controls permit heating systems to function automatically and, in case of a failure, to shut the system down safely.

1.04 As illustrated in Fig. 1-2 on the following page, three specific elements are of major importance in heating systems. They are the following:

Fig. 1-1. Keeping warm years ago

Fig. 1-2. Heating system basics



- a heat source
- some means of controlling the heat
- safety provisions and reliable system shutdown.

1.05 In addition to fire as a heat source, electricity also plays a major part in heating systems. Electric resistance coils convert electric energy into heat energy. This conversion is used in electric furnaces, duct heaters, baseboard heaters, and even within floors and ceilings to provide warmth. Electric motors drive fans to distribute heat throughout buildings and also run the compressors on heat pump systems, which provide both cooling and heating. All of these items will be covered in the lessons that follow.

1.06 Various other heating sources are much less common. This category includes solar radiation, which is the collecting of radiant energy and its conversion to heat energy in a useful manner.

1.07 Heat recovery provides another source, in which waste or available heat is recovered and reused. Heat recovery is especially useful in certain locations—for example, in areas having hot springs or geothermal activity. Recovered waste heat from an engine or local steam facility also can be used as a heat source.

Heat and Energy

1.08 A number of terms relative to heating have been used in the previous paragraphs. This section describes the relationships between these heating concepts. Terms you should understand clearly include the following:

- energy
- heat
- heat energy
- fuel
- potential fuel energy
- electricity
- electric energy
- solar energy
- geothermal energy
- heat recovery.

1.09 The paragraphs that follow contain standard definitions for a number of terms relating to heat and energy. First, *energy* is the capacity for doing work or supplying power. *Work* is the transfer of energy from one body or system to another. *Power* is work over time. *Potential energy* is energy available for doing work—for example, electricity or steam can be used to perform work.

1.10 *Heat* is the condition of being hot or the degree to which something is hot. It is also the warmth supplied throughout a building, as from a furnace. The heat energy contained by an object or a substance is due to the rate of vibration of its molecules. *Fuel* is a substance that readily produces energy in the form of heat when it is burned. *Potential fuel energy* is the amount of available, unused energy within a fuel (coal, gas, oil, or wood, for example) that can be released when the fuel is burned. Each kind of fuel has a different amount of potential fuel energy. In later lessons, you will read about the many different fuels available and what characteristics make each of them desirable as a heat source.

1.11 *Electricity* is energy in the form of electrons flowing through a conductor—an electric current. Electricity provides the power for lighting, heating, and the operation of motors and other electromechanical devices. Less common forms of energy are solar energy and geothermal energy.

- *Solar energy* is the energy transmitted from the sun by radiation. Solar energy can be collected by several methods, with the energy either stored as heat or generated into electricity.

- *Geothermal energy* involves the collection of heat energy from an earth source. This may be from hot springs, volcanic activity, or directly from the ground. Some heat pump systems use the heat of the ground.

1.12 The term *heat recovery* refers to the transfer of available heat energy (waste heat) from one stream to heat a more useful stream. Heat recovery generally takes place within a heat exchanger where the two systems are piped closely together so that there is an energy transmission without the two streams intermixing. This is an effective method of obtaining inexpensive heat. It is also a good way to save heat energy that would normally be thrown away or wasted.

1.13 Heat energy, fuel energy, electrical energy, or energy in any form can be converted from one form to another. For example, electrical energy is converted to heat energy in a resistance heating element. Also, heat energy in the form of steam can drive a turbine to generate electricity. In the conversion, the amount of energy given up by the first system would be equal to that gained by the second system if there were no system inefficiencies.

1.14 Later in this lesson you will read about units of energy and how they are interrelated among the various forms of energy. But first, it is important to understand the difference between temperature and heat and also the means by which heat is moved from the source into the building for our comfort.

Temperature

1.15 Heat is a form of energy that we can sense by touch, as a sensation of warmth or cold. Heat as a form of energy is measurable. Cold, on the other hand, is only the absence of heat. You read earlier that heat energy is the result of the vibration of the molecules of a substance. Removing heat slows the molecular vibrations. When all molecular vibration ceases, the substance is said to be at *absolute zero*. This is the lowest temperature that can be achieved. It is equivalent to –460°F (–275°C).

1.16 *Heat energy* has two aspects—intensity and quantity. The intensity of the heat is measured as temperature. The quantity of heat (the total amount of heat energy in a substance) is measured as enthalpy, which is discussed in detail later. For now, we will concentrate on measuring the intensity of heat.

1.17 There are two common temperature scales in use in the world. In the United States we use the Fahrenheit scale. Most of the rest of the world, however, uses the Celsius scale. Gabriel Daniel Fahrenheit, an instrument maker, developed the Fahrenheit scale in the early 1700s. Fahrenheit was also the inventor of the mercury thermometer. His scales were based on a mixture of salt and ice to obtain 0°F at the low end of the scale. The high end of the scale was based on a mistaken idea that the normal body temperature is 96°F. Extension of the Fahrenheit scale results in water freezing at 32°F and water boiling at 212°F at atmospheric pressure.

1.18 Anders Celsius was a Swedish astronomer who lived about the same time as Fahrenheit. His centigrade scale was renamed Celsius with the advent of SI (International System of Units) metric units. In this scale, water freezes at 0°C and boils at 100°C. Table 1-1 shows some corresponding values in Fahrenheit (°F) and Celsius (°C) temperatures.

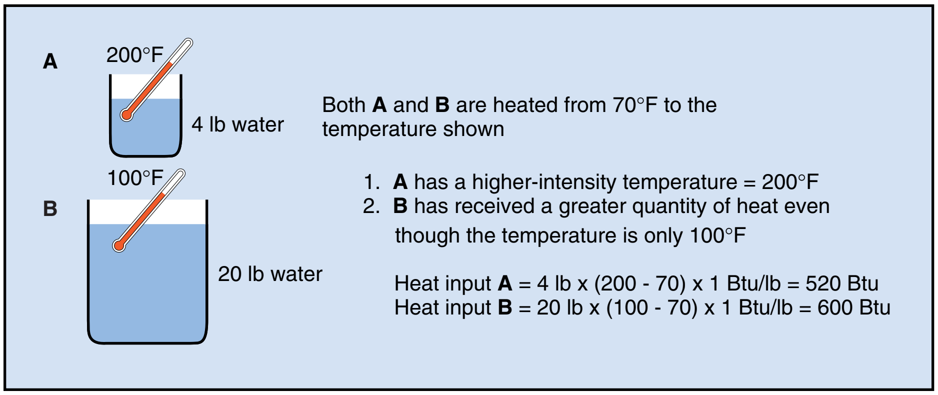
1.19 The exact temperature conversions from Fahrenheit to Celsius or from Celsius to Fahrenheit can be obtained by using one of two equations. To convert from Fahrenheit to Celsius, use the following equation:

$$°C = (°F - 32) \div 1.8$$

Table 1-1. Comparison of temperature scales

°C	°F
40.0	104
30.0	86
20.0	68
10.0	50
0.0	32
-10.0	14
-20.0	-4
-30.0	-22
-40.0	-40

Fig. 1-3. Heat intensity and quantity



For example, to convert 68°F to Celsius,

$$°C = (68 - 32) \div 1.8 = 36 \div 1.8 = 20$$

1.20 To convert from Celsius to Fahrenheit, use the following equation:

$$°F = (°C \times 1.8) + 32$$

For example, to convert 35°C to Fahrenheit,

$$°F = (35 \times 1.8) + 32 = 63 + 32 = 95$$

1.21 Recall that removing all heat from a substance causes the molecular vibrations to cease, which occurs at a condition called absolute zero. Because the Fahrenheit and Celsius scales were arbitrarily chosen, they have different values at absolute zero. The Fahrenheit scale reads –460°F, whereas the Celsius scale reads –273°C.

Table 1-2. Typical specific heat values

Material type	Substance	Specific heat (C_p, Btu/lb/°F)
Gas	Air	0.24
Liquid	Water	1.0
Liquid	Ethyl alcohol	0.68
Liquid	Kerosene	0.50
Solid	Cardboard	0.32
Solid	Concrete	0.16
Solid	Copper	0.09
Solid	Steel	0.12
Solid	Ice	0.50

1.22 Two additional scales measure temperature starting from absolute zero. The scale that corresponds to Fahrenheit is known as Rankine, designated by °R. Similarly, the scale that corresponds to Celsius is known as Kelvin, designated by K (without the degree symbol). Absolute temperatures are used by scientists and heat exchanger designers, but have no specific use related to heating systems.

1.23 Remember that temperature measures only one aspect of heat—the intensity of the heat, or how hot a substance or object has become. The quantity or amount of heat in a given substance, *enthalpy*, is measured in units called British thermal units (Btu). Enthalpy is normally expressed as the Btu per pound (Btu/lb) of a substance.

1.24 As shown in Fig. 1-3, a small vessel at a very high temperature can have a smaller quantity of heat than a larger vessel at a much lower temperature. The smaller vessel has the higher quality or intensity of heat (temperature), but the larger vessel has the higher quantity of heat (enthalpy).

1.25 A *British thermal unit (Btu)* is defined as the amount of heat required to raise the temperature of 1 lb of water 1°F. Therefore, raising 10 lb of water 1°F will require 10 Btu. Raising 10 lb of water 10°F will require 100 Btu.

1.26 The definition of a Btu relates specifically to water. Other substances can be compared to water by means of specific heat. The *specific heat* (C_p) of a substance is the number of Btu required to raise the temperature of 1 lb of that substance 1°F. If the substance is water, the specific heat is 1.0, because that is the number of Btu required to raise the temperature of 1 lb of water 1°F. Most other substances have specific heats that are less than 1, but some substances have specific heats higher than 1. A specific heat less than 1 means that it will take less than 1 Btu to increase the temperature of 1 lb of the substance 1°F. Note that, although the specific heat of water is 1, the specific heat of ice is only 0.50. Table 1-2 lists specific heat values for various common substances.

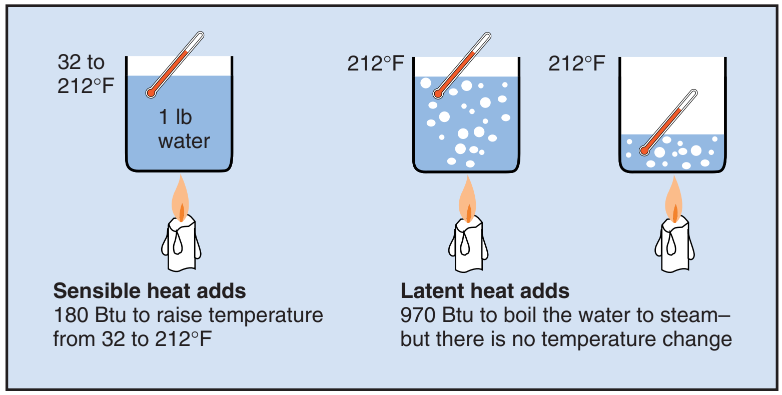
The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. The main means of heating involves burning a(n) ________ in a(n) ________ manner.	1-1. FUEL; CONTROLLED Ref: 1.02
1-2. A heating system requires a heat ________, a means of ________, and provisions for ________.	1-2. SOURCE; CONTROL; SAFETY AND SHUTDOWN Ref: 1.04
1-3. The capacity for doing work or supplying power is called ________.	1-3. ENERGY Ref: 1.09
1-4. Heat ________ is the transfer of a waste heat stream to a useful heat stream.	1-4. RECOVERY Ref: 1.12
1-5. When energy is converted, the amount picked up by one system is ________ to the amount given up by the other system.	1-5. EQUAL Ref: 1.13
1-6. The intensity of heat energy is measured as ________, and its quantity is measured as ________.	1-6. TEMPERATURE; ENTHALPY Ref: 1.16
1-7. The ________ is the amount of heat required to raise the temperature of 1 lb of water 1°F.	1-7. BRITISH THERMAL UNIT (Btu) Ref: 1.25
1-8. A substance with a specific heat of 0.58 requires ________ than 1 Btu to raise 1 lb of the substance 1°F.	1-8. LESS Ref: 1.26

Sensible Heat and Latent Heat

1.27 *Sensible heat* refers to the direct change in temperature as heat is added to a substance. Sensible heat can be sensed or measured with a thermometer. When water is heated from 32°F to 212°F, there is a measurable increase of 180°F in sensible heat. Each degree of temperature increase requires the addition of 1 Btu/lb, and each degree of temperature decrease requires the removal of 1 Btu/lb.

Fig. 1-4. Sensible heat and latent heat



1.28 *Latent heat* refers to the addition or removal of heat from a substance that is undergoing a change of state. There is no temperature change, even though large amounts of heat are involved. This occurs, for example, when water has been heated to 212°F, and then receives additional heat. The water boils, but the temperature remains constant until all the water is changed to steam. About 970 Btu of heat input are needed to change 1 lb of water at 212°F to 1 lb of steam at 212°F. Similarly, removal of 970 Btu of heat from steam at 212°F will result in condensing the 1 lb of steam to water at 212°F. Figure 1-4 compares sensible heat and latent heat.

1.29 Latent heat has two very important aspects—there is always a change in state of the substance, and there is no temperature change while this is happening. Latent heat changes apply not only to water, but to other substances as well. The most common occurrences in the realm of heating equipment are the change of state from a liquid to a vapor and the reverse from a vapor to a liquid.

Heat Transfer

1.30 Two fundamental laws govern the transfer of heat.

- Heat transfer always occurs between objects of different temperatures, and the direction of flow is always from the warmer to the cooler object.
- The rate of heat transfer between the two objects varies directly with the temperature difference between the two objects. The greater the temperature difference, the faster the heat transfer.

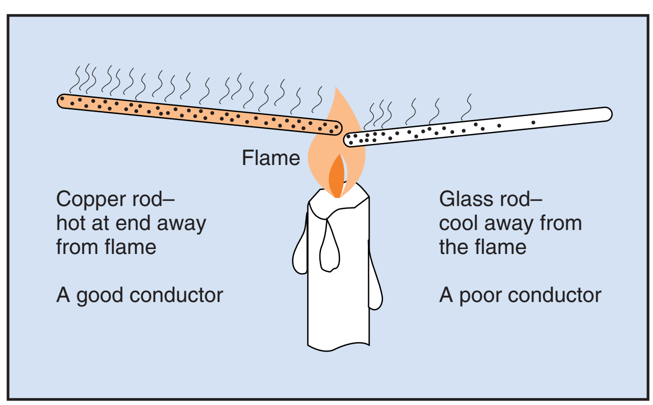
1.31 Heat is transferred or moved from one location to another by one or more of three different methods:

- conduction
- convection
- radiation.

Conduction is the transfer of heat from a region of higher temperature to one of lower temperature, generally within a single solid material. Conduction occurs through direct contact of molecules at a higher temperature (faster vibration) with molecules at a lower temperature (slower vibration). Purely conductive heat transfer occurs only in solid materials. Conduction is illustrated in Fig. 1-5.

1.32 *Convection* is the transfer of heat from one place to another by the movement of one portion of a

Fig. 1-5. Heat transfer by conductance



fluid (liquid or gas) with another portion at a different temperature. For example, air (gas) heated in a furnace is forced through ductwork into rooms where the warm air intermingles with the cooler air, thus warming both the air and the room itself. This system is known as *forced convection*, because a mechanical fan is used to move the air. Another example of an air system is a baseboard heater, as illustrated in Fig. 1-6. In this case, the cooler floor-level air comes in contact with the heater, becomes warmer and thus lighter, rising and making room for more cool air to enter the heater. This arrangement is called *natural convection*, because the air movement is generated by the density difference of the warm and cool air.

1.33 *Radiation* is the transfer of energy by electromagnetic waves. All substances emit radiant energy. The heat transferred from one substance to another is the net flow from the higher temperature source to a substance at a lower temperature. Radiation does not require a transfer medium such as air or water. The sun provides the most obvious example. Its thermal energy reaches the earth by radiation across millions of miles of vacuum space. Radiant energy travels at the speed of light, 186,000 miles per second. In heating systems, this form of heat transfer is important in fireplace and radiant space heater technology.

1.34 In practical heating systems, heat is transferred by a combination of conduction, convection, and radiation processes. In a furnace, the burning fuel contacts the metal surface of the heat exchanger by convection of the flue gases. Heat is transferred through the metal of the heat exchanger by conduction, and then convection warms the air that is forced into the rooms to be heated. By means of convection, heated air in the room warms people and objects and mixes with the cooler air in the room to maintain the desired temperature. In most cases, radiation plays only a minor part except for the technologies noted previously.

Energy Conversions

1.35 As mentioned earlier, energy exists in many forms and can be converted from one form to another. The units that describe energy are unique to each form of energy. It is important to be able to convert the units of one form of energy to the units of another form. When one form of energy is used to generate another form, or when one form is transferred to another form, we must have a system that will permit the interchange of units suitable in each case.

1.36 Electric power is expressed as watts (W) or, in larger quantities, as kilowatts (kW). A kilowatt is equal to 1000 watts. The rate of electric power usage is expressed as watt-hours or kilowatt-hours. It is the amount of work that can be done by 1 kW in 1 hr.

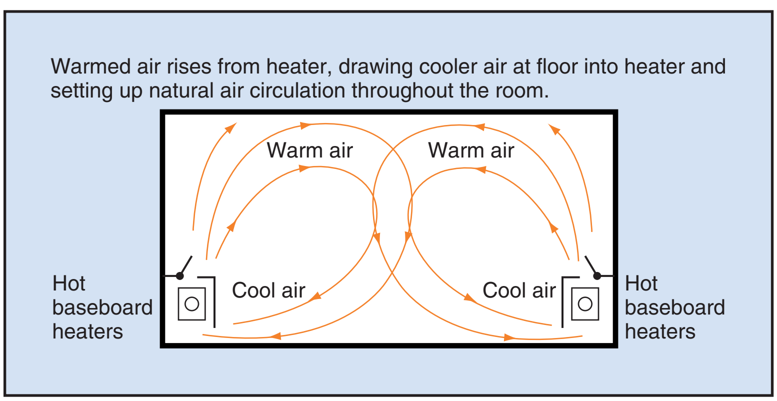
1.37 Electric energy used to drive a motor can produce the power which, in the United States, is called brake horsepower (bhp). The conversions between kW and bhp are as follows:

$$1 \text{ kW} = 1.341 \text{ bhp}$$

$$1 \text{ bhp} = 0.746 \text{ kW}$$

For example, a 3-hp motor requires 3×0.746 kW = 2.24 kW.

Fig. 1-6. Room heating by natural convection



1.38 Heat energy is expressed in Btu, and its equivalent rate of heating is known as Btu per hour (Btu/hr or Btuh). The correlation between electric power and the rate of heating is given in the following equations:

$$1 \text{ kW} = 3415 \text{ Btu/hr}$$

$$1 \text{ Btu/hr} = 0.0002928 \text{ kW}$$

For example, a resistance heater that provides 9000 Btu/hr will require $9000 \div 3415 = 2.64$ kW.

Electric Motors

1.39 Electric motors convert electrical energy to the horsepower of whatever is being driven by the motor. Electric motors turn the primary moving equipment of heating systems. This equipment includes the following:

- fans to move air
- pumps for moving water and fuel oil
- compressors for air conditioning and heat pump applications.

Table 1-3. AC electric power in the United States

Phase	V/Ph/Hz*	Location	Maximum bhp
Single	120/1/60	Residential, commercial	3
Single	208/1/60	Residential, commercial	10
Single	230/1/60	Residential, commercial	10
Three	208/3/60	Commercial, industrial	100
Three	230/3/60	Commercial, industrial	100
Three	460/3/60	Commercial, industrial	500

*Voltage/phase/hertz (frequency in cycles per second)

Typical alternating current (ac) electrical power in the United States operates at 60 Hertz (Hz), although 50 Hz is the standard ac frequency for most countries throughout the world. Power is distributed as single phase or three phase. Table 1-3 lists details about electric power in the United States.

1.40 AC induction motors have two main components—the stator and the rotor. The stator is wound with coils of wire, creating a rotating magnetic field when energized with ac power. The rotor rotates inside the stator and is under the influence of the magnetic field. The stator remains stationary and contains the electrical connections to the power supply. The rotor has no wires and is not electrically connected to the stator or to the power supply. Rotation is induced by the rotor being magnetically linked to the rotating magnetic field of the stator.

1.41 When the rotor turns at exactly the same speed as the rotating magnetic field, it is said to be at *synchronous speed*. The synchronous (no-load) motor speed of an induction motor is determined by the frequency (Hz) of the ac power and the number of poles with which the stator is wound. To find the synchronous speed of an induction motor, use the following formula:

$$\text{speed in rpm} = (120 \times \text{Hz}) \div \text{number of poles}$$

For example, for a 4-pole, 60-Hz motor,

$$\text{rpm} = (120 \times 60) \div 4 = 1800$$

Similarly, a 2-pole, 60-Hz motor has a synchronous speed of $(120 \times 60) \div 2 = 3600$ rpm. A 4-pole, 50-Hz motor has a synchronous speed of $(120 \times 50) \div 4 = 3000$ rpm.

1.42 Synchronous speed is attained only when there is no load on the motor. In use, there is some difference, called *slip*, between the synchronous speed and the actual rotor speed due to the turning load or torque on the motor. The higher the motor load, the greater the slip. Maximum motor horsepower occurs when the slip is approximately at the motor speeds listed in Table 1-4 on the following page.

1.43 Most motors used in smaller heating systems are single-phase motors. For this reason, this lesson will concentrate on this kind of motor. Single-phase motors can operate in either direction of rotation. The rotation is controlled by the connection made to the start-winding terminal. To reverse rotation, change the start-winding connection at the terminal box. Inside the cover of the terminal box, you will see a diagram for that specific motor.

1.44 Single-phase motors are generally known as split-phase induction motors. These motors will not start if only the run windings are energized. The motor will hum and, if the shaft is given a twist in one direction or another, the motor will begin to run in the direction of the twist. For this reason, split-phase motors have two windings. One is a start winding and the other is the run winding.

1.45 The start winding is used only to start the motor turning in the proper direction. When the motor speed is up to about 75% of the full-load speed, the start winding is disconnected and only the run winding remains energized. Most split-phase motors use a centrifugal switch that is mounted on the end of the

Table 1-4. Synchronous and full-load motor speeds

Phase	Hz	Poles	Synchronous rpm	Full-load rpm
Single	60	2	3600	3450
Single	60	4	1800	1725
Single	60	6	1200	1150
Three	60	2	3600	3550
Three	60	4	1800	1770
Three	60	6	1200	1180
Single	50	2	3000	2875
Three	50	2	3000	2960

rotor to disconnect the start winding. This is accomplished by several centrifugal weights that fly out at the proper speed and, in doing so, open the electrical circuit. Because the centrifugal switch causes a spark within the motor, other methods—for example, solid state electronic relays—can be used if sparking is unacceptable.

Fig. 1-7. Split-phase motor

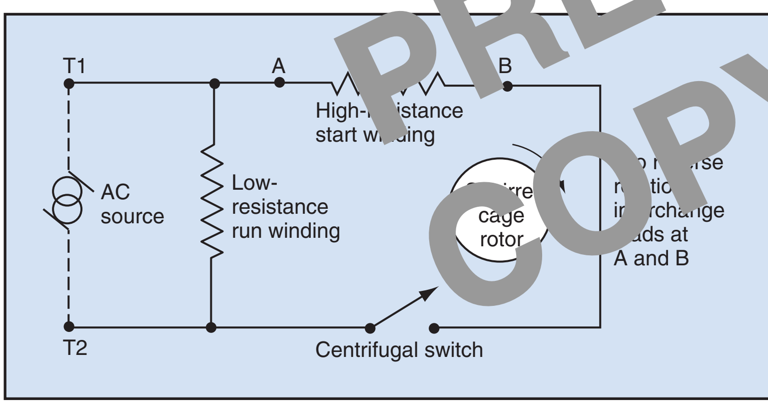
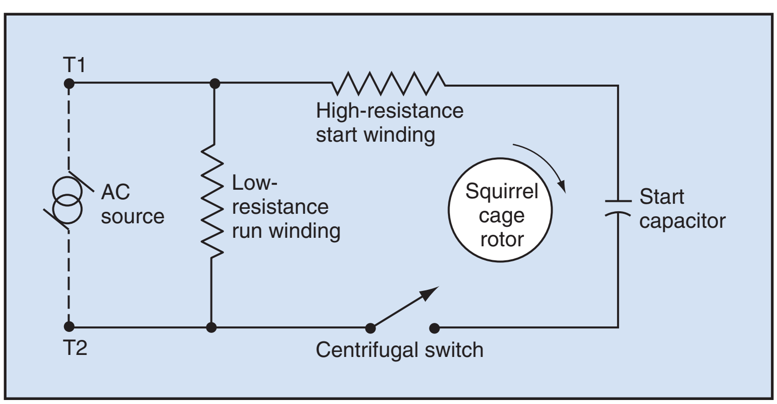


Fig. 1-8. Split phase, capacitor-start motor



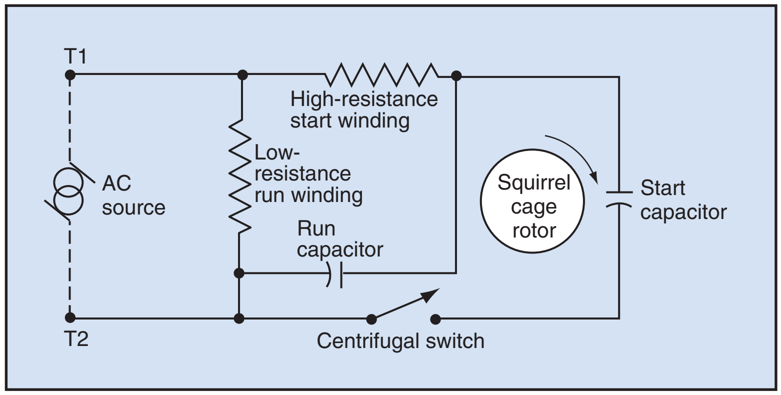
1.46 Several versions of the split-phase motor are in common use. The variations generally are related to the strength of the motor, the strength or starting torque capability, and the efficiency of the motor. As mentioned previously, the basic split-phase motor has two windings—a start winding and a run winding. The motor is started on the start winding, and the centrifugal switch disengages this winding before the motor reaches running speed. The starting torque of the split-phase motor is very light, as is the torque capability of the run winding. These motors are generally used for fan operation where the loads and starting requirements are minimal. Figure 1-7 shows the general connection scheme for split-phase motor windings.

1.47 The split-phase capacitor-start motor provides a more powerful design. This motor has a capacitor on the start winding. The capacitor causes the current in the start winding to lead the voltage, thereby producing a stronger starting torque. These motors are used for pumps and compressors. Figure 1-8 shows the winding arrangement of a split-phase capacitor-start motor.

1.48 The use of capacitors is increased in the split-phase capacitor-start, capacitor-run motor. In this case, a second capacitor is introduced on the run winding to provide a greater torque capability to the motor. The start winding and its capacitor are removed from the circuit after startup, but the run capacitor remains in the run winding circuit as long as the motor is in operation. These motors are typically used for equipment with high torque requirements, such as compressors. Figure 1-9 shows the winding arrangements of a split-phase capacitor-start, capacitor-run motor.

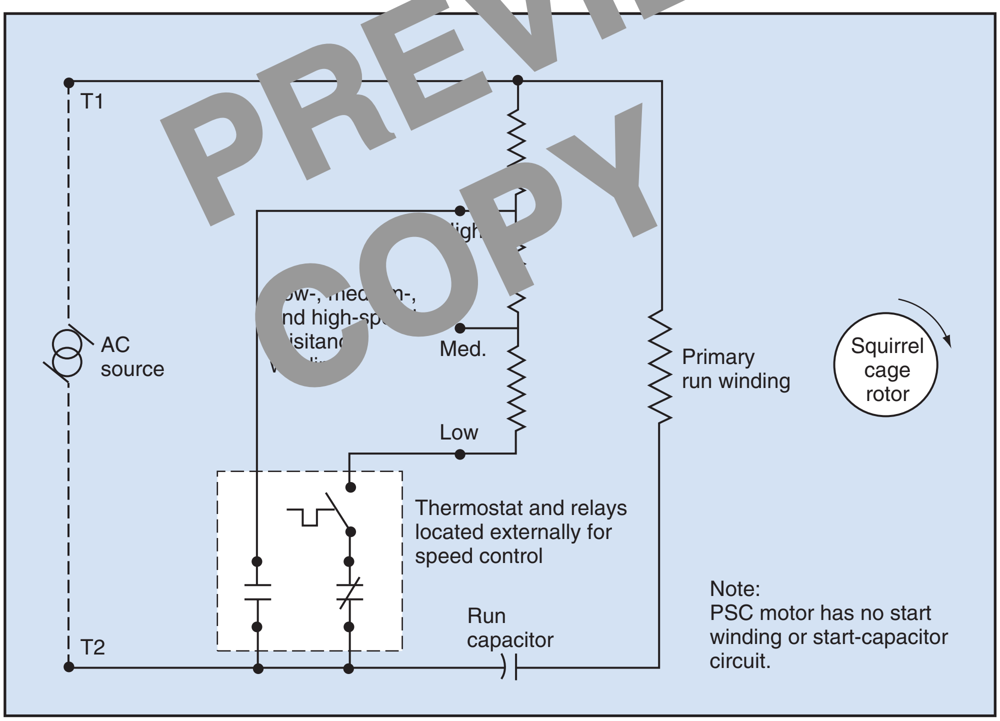
1.49 Another variation is the permanent split capacitor motor (PSC). These motors do not have a start capacitor, but they do have a capacitor permanently connected in the run circuit. The run windings consist of several groupings of windings, which gives the motor the capability of running at several different speeds. A particular speed can be manually chosen and the terminals at the motor connected so that the motor will always run at the same speed. The motor can instead be connected through the system so that the proper motor speed for a particular system requirement will be chosen automatically by means of a relay or switching device. These motors generally have low torque capabilities and are used primarily to drive fans. Figure 1-10 shows the wiring arrangements of a PSC motor.

Fig. 1-9. Split-phase, capacitor-start, capacitor-run motor



1.50 In addition, a relatively inexpensive motor called a shaded-pole motor is available. This motor has some small windings and a shaded pole, which gives it most of its starting torque and also determines the direction the motor will turn. It does not use capacitors for either the start or run circuits. It is a light-duty motor used for fan applications in the fractional horsepower ranges.

Fig. 1-10. Three-speed permanent split capacitor (PSC) motor



1-9. A change in ________ heat can be read on a thermometer, but a change in ________ heat cannot.	1-9. SENSIBLE; LATENT Ref: 1.27, 1.28
1-10. Heat always transfers from the ________ to the ________ object.	1-10. WARMER; COOLER Ref: 1.30
1-11. The greater the temperature difference between two objects, the ________ the heat transfer.	1-11. FASTER Ref: 1.30
1-12. Heat is transferred within a solid material by ________ and from place to place by ________ and/or ________.	1-12. CONDUCTION; CONVECTION; RADIATION Ref: 1.31-1.33
1-13. A 5-hp motor requires ________ kW to operate.	1-13. 3.73 Ref: 1.37
1-14. Each kilowatt of electric power provides ________ Btu/hr of heating.	1-14. 3415 Ref: 1.38
1-15. The speed of an ac induction motor depends on its ________ and number of ________.	1-15. FREQUENCY; POLES Ref: 1.41
1-16. A(n) ________ motor can drive a variable-speed fan.	1-16. PERMANENT SPLIT CAPACITOR (PSC) Ref: 1.49

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Geothermal energy is available from

- ☐ a. an engine's waste heat
- ☐ b. electrons flowing through a conductor
- ☐ c. the ground
- ☐ d. the sun

1-2. The purpose of using a heat exchanger for the heat recovery process is to

- ☐ a. increase the enthalpy of the waste stream
- ☐ b. increase the temperature of the waste stream
- ☐ c. physically mix the two streams
- ☐ d. physically separate the two streams

1-3. A temperature of 70°F is equal to ________°C.

- ☐ a. 21.1
- ☐ b. 42.8
- ☐ c. 45
- ☐ d. 138.6

1-4. Two pounds of water are heated from 32°F to 212°F and vaporized. The heat gain is ________ Btu of sensible heat and ________ Btu of latent heat.

- ☐ a. 180; 970
- ☐ b. 212; 32
- ☐ c. 360; 1940
- ☐ d. 1940; 180

1-5. Which of the following is a common heating system example of natural convection?

- ☐ a. Baseboard heater
- ☐ b. Fireplace technology
- ☐ c. Forced hot air
- ☐ d. Heat exchanger

1-6. Five kilowatts can power a motor with a bhp of about

- ☐ a. 6.7
- ☐ b. 7.4
- ☐ c. 8.1
- ☐ d. 8.7

1-7. A formula that can be used to calculate the power needed to provide a known amount of heat energy is as follows: 1 kW = ________ Btuh.

- ☐ a. 0.0002928
- ☐ b. 0.746
- ☐ c. 1.341
- ☐ d. 3415

1-8. The synchronous speed of a 2-pole, 60-Hz ac induction motor is ________ rpm.

- ☐ a. 1200
- ☐ b. 1800
- ☐ c. 3000
- ☐ d. 3600

1-9. The motor in question 1-7 runs at about ________ rpm when subject to slip.

- ☐ a. 2960
- ☐ b. 3000
- ☐ c. 3450
- ☐ d. 4000

1-10. Unlike other split-phase ac induction motors, the PSC motor can provide variable speeds by means of a

- ☐ a. relay or switching device
- ☐ b. run capacitor
- ☐ c. start capacitor
- ☐ d. start winding

SUMMARY

Heating systems require a heat source, a means of control, and provisions for safety and shutdown. Heating sources include fire, electricity, solar radiation, heat recovery, and others. Heat energy is caused by molecular vibration. Solar energy is transmitted by the sun, and geothermal energy comes from the heat of the earth. Heat recovery transfers heat energy from a waste stream to a useful stream. Energy can be converted from one form to another.

Heat energy has intensity, measured as temperature, and quantity, measured as enthalpy. In the United States, temperature is measured in degrees Fahrenheit (°F), but the Celsius (°C) scale is used throughout most of the rest of the world. The formula °C = (°F - 32) ÷ 1.8 converts from Fahrenheit to Celsius, and the formula °F = (°C × 1.8) + 32 converts from Celsius to Fahrenheit. Enthalpy is measured in Btu/lb. A British thermal unit (Btu) is the amount of heat required to raise the temperature of 1 lb of water 1°F. Specific heat indicates the number of Btu required to raise the temperature of 1 lb of a substance 1°F. Sensible heat is the heat change that can be measured on a thermometer. Latent heat is the heat change that accompanies a change of state without a change in temperature.

Heat always transfers from a warmer to a cooler object. The rate of transfer varies directly with the temperature difference. Heat is transferred by conduction, convection, and/or radiation.

Electric power is expressed in watts (W) or kilowatts (kW). Motors produce brake horsepower (bhp). One kW is equal to 1.341 bhp, and 1 bhp is equal to 0.746 kW. One kW provides 3415 Btu/hr, and 1 Btu/hr requires 0.0002928 kW. Electric motors in heating systems power fans, pumps, and compressors. AC induction motors turn at synchronous speed under no load and exhibit slip under load conditions. Single-phase motors use a start winding and a run winding. Capacitor-start motors are used for pumps and compressors. Compressors with high torque requirements use capacitor-start, capacitor-run motors. Permanent split capacitor (PSC) motors can provide variable speeds.

Answers to Self-Check Quiz

1-1. c. The ground. Ref: 1.11

1-2. d. Physically separate the two streams. Ref: 1.12

1-3. a. 21.1. Ref: 1.19

1-4. c. 360; 1940. Ref: 1.27, 1.28, Fig. 1-4

1-5. a. Baseboard heater. Ref: 1.34

1-6. a. 6.7. Ref: 1.37

1-7. d. 3415. Ref: 1.38

1-8. d. 3600. Ref: 1.41, Table1-4

1-9. c. 3450. Ref: 1.42, Table 1-4

1-10. a. Relay or switching device. Ref: 1.49, Fig. 1-10