CHAPTER

1 Matter, Energy, and Heat Basics

Instructor's Note

In this column, instructors will find a variety of lecture tips to aid student comprehension, notes on when to use PowerPoint slides[PP] to teach concepts, safety cautions for your students, and notes on when your class should view a video segment.

Appendix A lists corresponding numbered PowerPoint Presentation titles (see page 257).

Appendix B lists corresponding numbered video titles and sections as applicable (see page 266).

In order for an air conditioning system to be properly installed, the members of the installation crew should possess at least a basic understanding of matter, energy, and heat theory. Having this knowledge tends to improve the quality of the initial installation, which will lead to an air conditioning system with fewer operational problems in the future. Matter can exist in nature as a solid, liquid, or a vapor and is said to be any substance that occupies space and has mass. Energy is often defined as the potential to do work. Common forms of energy are heat energy, electrical energy, and mechanical energy. Heat is the term used to describe the motion of molecules. If the molecules of a substance are not moving, there is said to be zero heat content. In our study of heat theory, we will also discuss two factors that affect the operation of air conditioning systems: temperature and pressure.

The purpose of an air conditioning system is to transfer heat from inside the occupied space to a remote location where this heat is not objectionable. In order to clarify this concept, we will study heat transfer in this chapter as well as the concepts just described. In order for heat transfer to take place between two substances, there must be a temperature difference between the substances. In the air conditioning industry, the two substances we primarily concern ourselves with are the temperature of the occupied space and the temperature of the outside air. By maintaining desired pressures within an air conditioning system, we can maintain and control the rate and direction of heat transfer.

SLIDES 1-2 to 1-4

OBJECTIVES [PP 1-2, 1-3, 1-4]

After studying this chapter, the student should be able to:

- Define the terms solid, liquid, and gas.
- Explain the three states of matter.
- Explain the law of conservation of energy.
- Explain the three types of heat transfer: conduction, convection, and radiation.
- Relate the concepts of conduction, convection, and radiation to real-life situations.
- Explain the differences between sensible heat and latent heat.
- Relate the concepts of sensible and latent heat to real-life situations.
- Explain the difference between heat content and heat level.
- Convert Fahrenheit temperature readings to the Celsius scale and vice versa.
- Explain the differences between gauge pressure and absolute pressure.
- Convert absolute pressures to their equivalent gauge pressures.

GLOSSARY

Absolute pressure — The pressure scale that takes atmospheric pressure into account.

Atmospheric pressure — The weight of the gases that exert a force on the Earth's surface.

British thermal unit (Btu) — The amount of heat required to raise the temperature of 1 pound of water 1° Fahrenheit.

Conduction — The method of heat transfer by which heat is transferred from molecule to molecule within a substance.

Convection — The method of heat transfer that is facilitated by the flow of a fluid, typically air or water.

Energy — The ability to do work.

Gas laws — Laws of physics that govern the behavior of gases or vapors.

Gauge pressure — The pressure scale that does not take atmospheric pressure into account. At sea level the gauge pressure will be 0 psig.

Heat — Energy that causes molecules within a substance to move more rapidly, increasing the temperature of the substance.

Horsepower — Unit of power equal to 33,000 ft lb / min.

Inches of mercury vacuum — When reading gauge pressure, a reading below atmospheric pressure.

Latent heat — Heat energy that results in a change in state of a substance while maintaining a constant temperature.

Matter — Any substance that has weight and mass and occupies space.

Power — The rate at which work is done. Work per unit time.

Pressure — Force per unit area. Common units are pounds per square inch, psi.

PSIA — Pounds per square inch absolute. This pressure takes into account the pressure of the atmosphere and is approximately equal to the gauge pressure plus 15.

PSIG — Pounds per square inch gauge; ignores the pressure of the atmosphere. Used to measure the pressure in sealed vessels such as car tires and air conditioning systems.

Radiation — The method of heat transfer by which heat travels through the air and heats the first object the rays come in contact with.

Sensible heat — Heat energy that results in the change of temperature of a substance.

Temperature — Term used to describe the level of heat intensity.

Thermal kinetic energy — See Sensible heat.

Thermal potential energy — See Latent heat.

Work — Force exerted on an object times the distance the object is moved, measured in foot-pounds (ft-lb).

OUTLINE

SLIDES 1-5 to 1-7

VIDEO #1
Section 2

A. Matter is anything that has weight and mass and occupies space.[PP 1-5]

1. Solids[PP 1-6, 1-7]
   a. Substances that have definite volume and sufficient mechanical strength to maintain a constant shape
      1) Figure 1-1
      2) Figure 1-2

   b. The weight is a combination of the mass of the object as well as the gravitational force acted on it by the Earth

SLIDE 1-8

2. Liquids[PP 1-8]
   a. Have definite volumes but not definite shapes
   b. The shape depends on the shape of the container that holds it
   c. Because a liquid has a definite volume, it cannot be compressed into a smaller space
   d. Pascal's law
      1) Figure 1-3

SLIDES 1-9 to 1-19

3. Gases[PP 1-9, 1-10]
   a. Gases have neither definite volume nor definite shape[PP 1-9]
   b. Gases exert pressure in all directions against the walls of the container that holds them[PP 1-10]
   c. The pressure, volume, and temperature of a gas are related
   d. Three laws of physics relating to gases
      1) Boyle's Law[PP 1-11]
      2) Charles' Law[PP 1-12]
      3) Dalton's Law[PP 1-13, 1-14]

As an example of Boyle's Law, have students imagine that they are each individual gas molecules. In their present position in the classroom, they are equally spaced from each other and there is little chance of them coming in contact with each other. If the students were then asked to all move to one corner of the room, the volume that they are permitted to occupy is greatly reduced. The chance of them bumping into each other is greatly increased and the "pressure" is increased as well. The number of "molecules" has remained the same, but the volume has decreased, leading to an increase in the pressure.

B. Energy is the ability or capacity to do work.

1. Energy can exist in a number of different forms
   a. Heat or thermal energy
   b. Mechanical energy
   c. Electrical energy
   d. Chemical energy
2. Energy cannot be created or destroyed but can be converted from one form to another[PP 1-15]; heat energy is a byproduct of energy conversion, flows from a warmer substance to a cooler substance[PP1-16]
3. Work is force exerted on an object times the distance the object is moved, measured in foot-pounds (ft-lb)[PP 1-17, 1-18]
4. Power is the rate of doing work[PP 1-19]
   a. Horsepower, hp, measures units of power

As an example of Charles' Law, reference Mylar® balloons that are purchased during the colder months. In the warm store, the balloons are completely inflated, but when they are brought outside, it appears that the balloons have deflated. The reduction in temperature has caused the pressure to drop. When the balloons are once again brought inside, they inflate again.

C. The air conditioning industry concerns itself primarily with the transfer of heat energy from one area to another.

1. Heat content is measured in British Thermal Units, or Btus[PP 1-20, 1-21]
   a. The amount of heat required to raise the temperature of 1 pound of water 1°F
      1) Figure 1-8
      b. Power is expressed in watts where 1 Watt = 3.413 Btu
2. The level, or intensity, of heat is defined as the temperature of a substance
3. Temperature as we know it is measured with a thermometer
   a. Figure 1-9
   b. Figure 1-10
      1) Four temperature scales are used to measure the level of heat intensity[PP 1-22, 1-23]
         a) Fahrenheit
         b) Celsius

As an example, take 1 cup of water and heat it over a burner for 1 minute. Measure the temperature of the water before and after heating. Now repeat the same demonstration with a 2-cup water sample at the same initial temperature. Heat the water for the same 1 minute and measure the final temperature of the water. Have students interpret the results. What relationships can be found?

SLIDES 1-20 to 1-23

VIDEO #1
Sections 3–7

SLIDES 1-24 to 1-40

To illustrate conduction, secure the lead of a thermocouple thermometer to one end of a 24-inch piece of copper tubing. Secure the tubing in a vise, insulating the tubing from the vise. Heat the non-thermocouple end of the pipe with a torch and have students monitor the temperature reading on the thermometer.

As an example of radiation, secure a 100-watt light bulb in a stationary socket base. Secure the lead of a thermocouple thermometer to a short, flattened section of copper tubing. Energize the bulb and hold the flat surface of the copper a distance of 2 inches from the surface of the bulb. Take a temperature reading at that point. Then, move the tubing to a distance of 4 inches from the bulb and once again take a temperature reading. Have students compare the two readings and establish a relationship between temperature and the distance between the bulb and tubing section.

Place a thermometer in a glass filled with ice water (use as much ice as possible) and record the temperature (32°). Leave the cup alone and periodically measure the temperature. Although the ice can be seen to be melting, the temperature of the ice water should remain constant (latent). After the ice has melted, the temperature of the water will begin to increase (sensible).

c) Rankine
d) Kelvin
e) Figure 1-11
f) Figure 1-12

4. Heat is transferred by three common methods
   a. Conduction[PP 1-24, 1-25]
   b. Convection[PP 1-26, 1-27]
   c. Radiation[PP 1-28, 1-29]
      1) Figure 1-13
      2) Figure 1-14
      3) Figure 1-15
      4) Figure 1-16
5. Sensible heat transfers can be measured with a thermometer[PP 1-30]
   a. Example — Raising the temperature of water from 40 to 41°
6. Latent heat transfers are hidden and cannot be measured with a thermometer[PP 1-31, 1-32]
   a. Example — Changing ice at 32° to water at 32°

D. Pressure is the force that is exerted on the walls of a vessel and is measured in force per unit area.[PP 1-33]

1. The units of force are pounds per square inch, or psi
   a. Absolute pressure, psia
   b. Atmospheric pressure
   c. Gauge pressure, psig
      1) Figure 1-18
      2) Figure 1-19
   d. Vacuum pressures
      1) Figure 1-20
      2) Figure 1-22
   e. Vacuum pressure calculations and conversions
      1) Figure 1-23

E. Summary[PP 1-34 – 1-39]

1. Green Checklist[PP 1-40]

F. Review Questions