INSTRUCTOR'S RESOURCE GUIDE
to Accompany

RESIDENTIAL CONSTRUCTION ACADEMY

HVAC

Second Edition

EUGENE SILBERSTEIN

Table of Contents

SECTION 2

Answers to Chapter Review Questions . . 179

SECTION 3

Workbook Answers 225

SECTION 4

Appendices 255

Standards Summary

National Association of Home Builders and Home Builders Institute

Residential HVAC Standards Overview

Working with many industry experts, the Home Builders Institute has established national standards for the residential construction industry that reflect industry skill requirements. These standards provide a basis for the certification and training of workers, and provide employers with objective benchmarks for selecting employee and evaluating training needs. In addition, educators will find the standards useful for designing curriculum and evaluating individual training outcomes.

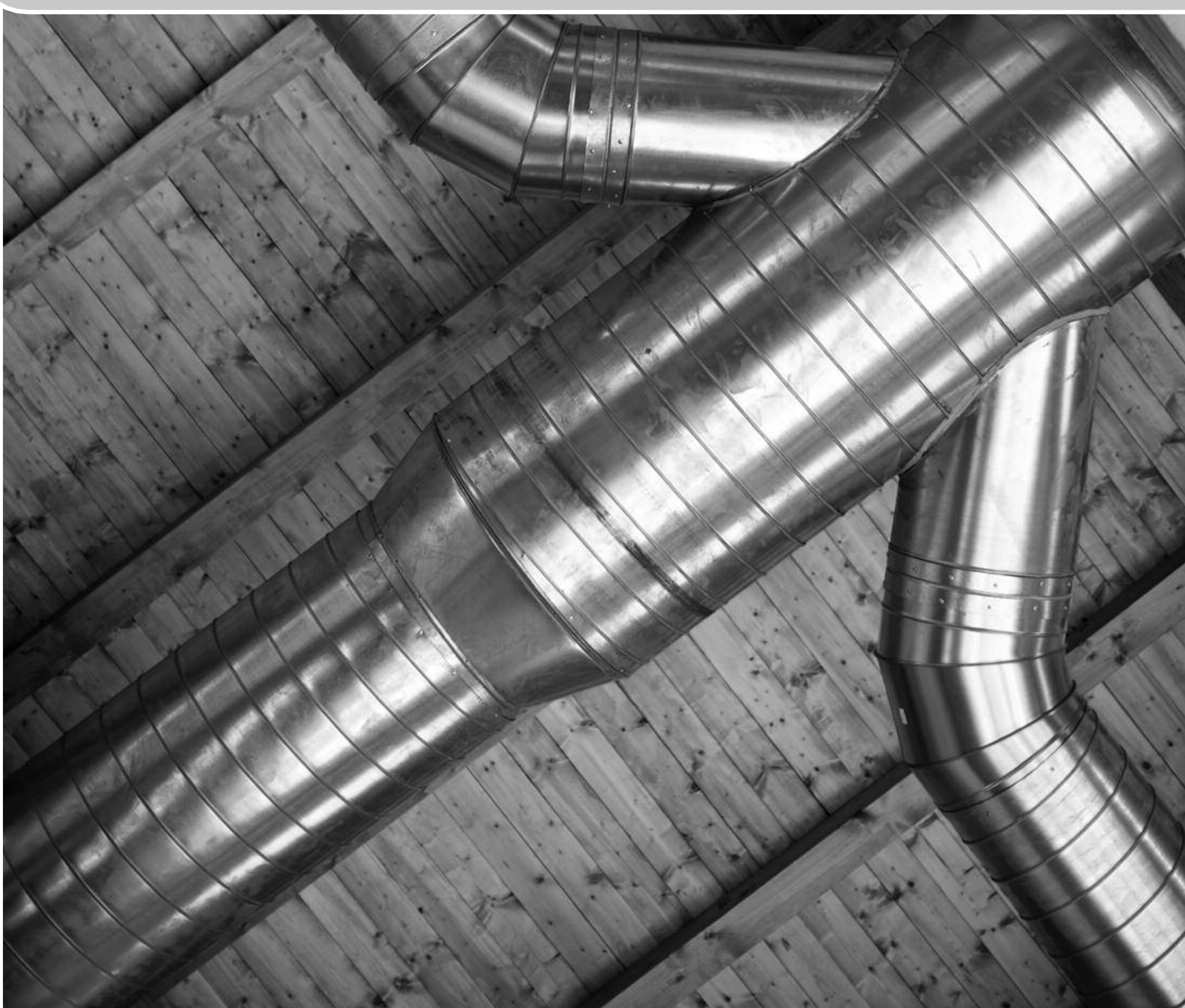
These standards in and by themselves do not represent a model-training program; they are designed to be a source for developing program and curriculum and evaluating the outcomes of residential HVAC technician training programs.

The Residential HVAC Standards were developed by a committee of NAHB industry leaders from various areas within residential HVAC services. The initial group of industry leaders reviewed and rated the importance of many critical work functions, key activities, applied academic skills, tools, and safety requirements needed by residential HVAC technicians. A second group of industry leaders validated the work and determinations of the original team, and produced a list of standards that includes main work functions and key activities.

- *Critical work functions* describe the major tasks and content areas of work within each specialty.
- *Key activities* or major tasks and knowledge involved in completing critical work functions are also provided.
- *Performance Indicators*, which help determine when critical work functions and key activities are being performed competently and referenced to critical work functions where applicable.
- *Applied academic skills* required to perform key activities are provided. These include measurement, arithmetic, layout, algebra, communications, and use of materials.
- *Safety requirements* involved in completing key activities have also been identified.
- *Tools* required for performing key activities are also identified.

These HVAC Skill Standards were developed, and are applicable to, the *Residential Construction Academy HVAC* text, and can be viewed and printed from the Instructor Resources that accompanies the each text, or downloaded at www.residentialacademy.com.

SECTION 1 Chapter Outlines



Chapter Outlines

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

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.

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]

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

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.

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

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

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?

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

SLIDES 1-20 to 1-23

      1) Four temperature scales are used to measure the level of heat intensity[PP 1-22, 1-23]
         a) Fahrenheit
         b) Celsius

VIDEO #1
Sections 3–7

SLIDES 1-24 to 1-40

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°

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).

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

CHAPTER

2 The Refrigeration Process

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).

SLIDE 2-2

In today's society, it is the knowledgeable, well-trained technician who helps to ensure the continued satisfactory operation of air-conditioning equipment. To do this, the HVAC technician needs to fully understand the fundamental concepts of the vapor-compression refrigeration system and the four key components that, together, allow the system to operate effectively and efficiently: the compressor, the condenser, the metering device, and the evaporator.

Having studied heat theory, temperature, and pressure, as well as the relationship that exists among them in the previous chapter, we can now begin our discussion of the basic refrigeration cycle on which these concepts are based. One important factor that must be considered is that the vapor-compression refrigeration process is a repeating cycle. This means that when one cycle has been completed, the system and its refrigerant are in the proper configuration and state to begin another cycle. This repeating process will continue indefinitely as long as the system is in operation. The components in the refrigeration system are intended to facilitate this process and the supply of refrigerant contained within the system will not deplete as long as the system remains leak free.

OBJECTIVES [PP 2-2]

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

- Describe the basic vapor-compression refrigeration cycle.
- List the basic components that make up a vapor-compression refrigeration system.
- Describe the function of a compressor.
- List various types of compressors.
- Describe the function of the condenser.
- Describe the function of the metering device.
- List three commonly used metering devices.
- Describe the function of the evaporator.

GLOSSARY

Automatic expansion valve (AEV) — Metering device that maintains a constant evaporator pressure.

Bubble point — For blended refrigerants, the temperature used to calculate condenser subcooling.

Bulb pressure — The pressure that facilitates the opening of the thermostatic expansion valve.

Capillary tube — A fixed bore metering device.

Compression — The portion of the compression process in which the refrigerant is compressed.

Compressor — The component of an air conditioning system that pumps refrigerant through the system by increasing the pressure of the vapor refrigerant.

Condenser — A heat transfer surface in an air conditioning system that rejects heat.

Condenser saturation temperature — The temperature at which system refrigerant will condense in the condenser. This temperature corresponds to the high side pressure in the system on a pressure/temperature chart.

Condensing medium — The medium, usually air or water, that absorbs the heat that is rejected by the system condenser.

Critically charged system — A system that requires an exact quantity of refrigerant. All of the refrigerant is moving through the system at all times.

Cylinder — The component part of a reciprocating compressor that houses the piston.

Dehumidifying — The process of removing humidity from the air.

Desuperheating — The process by which the discharge refrigerant from the compressor is cooled down to the condenser saturation temperature.

Dew point — The temperature at which air reaches 100 percent humidity.

Discharge — The portion of the compression process when the refrigerant is discharged from the compressor.

Discharge line — The refrigerant line that carries the discharge refrigerant from the compressor to the condenser.

Discharge pressure — The pressure of the refrigerant in the high pressure side of the air conditioning system. Also referred to as the high-side or head pressure.

Discharge valve — The component part of a reciprocating compressor that opens to discharge refrigerant from the compressor into the discharge line.

Dry-type evaporator — An evaporator that is designed to have all of the refrigerant boil off into a vapor before leaving the coil.

Evaporator — The component part of an air conditioning system that is responsible for absorbing heat from the space to be cooled.

Evaporator pressure — The pressure that corresponds to the temperature at which refrigerant vaporizes in the evaporator on a pressure/temperature chart.

Externally equalized TEV — A thermostatic expansion valve that measures the evaporator pressure at the outlet of the coil.

Fixed bore metering device — A metering device that does not open or close in response to changes in the load on the system. Examples of the fixed bore metering device are the capillary tube and the piston.

Flash gas — The process by which some of the liquid refrigerant instantly vaporizes upon entering the evaporator.

Internally equalized TEV — A thermostatic expansion valve that measures the evaporator pressure at the inlet of the coil.

Liquid line — The refrigerant carrying line that connects the condenser to the metering device.

Metering device — The component of an air conditioning system that controls the flow of refrigerant to the evaporator.

Outside ambient temperature — The temperature of the air that surrounds the outdoor coil of an air conditioning system.

Piston — The component part of the reciprocating compressor that moves back and forth within the cylinder to compress or expand the refrigerant in the cylinder.

Pounds per square inch gauge (psig) — Pressure readings taken from a gauge manifold.

Pressure/temperature chart — Chart that provides the relationship that exists between the temperatures and pressures of saturated refrigerants.

Reexpansion — In a reciprocating compressor, the process by which the refrigerant trapped in the cylinder at the end of a cycle is expanded to reduce the pressure in the cylinder.

Repeating cycle — A process that is able to repeat itself indefinitely without depleting resources.

Return air — Air that is brought from the conditioned space to the evaporator.

Saturated — Refrigerant that is a mixture of liquid and vapor. Saturated refrigerants follow a pressure/temperature relationship.

Spring pressure — One of the closing pressures on the thermostatic expansion valve. Also the opening pressure on the automatic expansion valve.

Subcooling — The process by which the refrigerant in the condenser is cooled below the condenser saturation temperature.

Suction — In a reciprocating compressor, the process by which refrigerant in the suction line is pulled into the compression chamber prior to being compressed.

Suction line — The refrigerant carrying line that connects the outlet of the evaporator to the compressor.

Suction pressure — The pressure of the low side of the system. Also called low-side or back pressure.

Suction valve — The component part of a reciprocating compressor that opens to pull refrigerant from the evaporator into the compressor for compression.

Superheat — The process by which vapor refrigerant is heated above its evaporator saturation temperature.

Supply air — The air that is returned to the conditioned space after it has passed through the evaporator.

Thermal bulb — TEV component that senses the temperature at the outlet of the evaporator and converts this temperature to the valve's opening pressure.

Thermostatic expansion valve (TEV) — Metering device that is designed to maintain a constant evaporator superheat.

Total system charge — The amount of refrigerant that a system contains.

Transmission line — The small diameter tube that connects the thermal bulb to the body of a thermostatic expansion valve.

SLIDES 2-2 to 2-4

Referring to the sponge/evaporator analogy, the larger the sponge/evaporator, the more water/heat can be absorbed.

The example of a car accident is a very simple way to illustrate the function of the metering device. Just as a car accident creates a restriction to traffic flow, the metering device creates a restriction to refrigerant flow. (Refer to Figure 2-19.)

OUTLINE

A. The Refrigeration Process

1. Transfer of heat from one place to another
2. Four major components enable heat transfer[PP 2-3]
   a. Evaporator
   b. Compressor
   c. Condenser
   d. Metering device
3. Four components are connected by a piping arrangement that carries a fluid called refrigerant

a. Figure 2-1[PP 2-4]

VIDEO #1
Sections 8 and 9

B. Pressure/Temperature Relationship

1. A saturated refrigerant behaves in a predictable manner[PP 2-5, 2-6]
    a. An increase in the pressure increases the temperature
    b. A decrease in the pressure decreases the temperature
        1) Figure 2-2[PP 2-7]

SLIDES 2-5 to 2-7

VIDEO #1
Section 8

C. Evaporators[PP 2-10]

1. Perform the actual cooling or refrigerating
    a. Figure 2-3[PP 2-11]
    b. Figure 2-4
2. Absorb heat from the space to be cooled
3. Dehumidify or remove humidity from the air
    a. Operate at temperatures below the dew point temperature
4. Transfer heat from the air passing over the coil to the refrigerant flowing inside the coil
    a. Latent heat (hidden heat)
    b. Superheat[PP 2-8]

SLIDES 2-10 and 2-11

SLIDE 2-8

D. Compressors[PP 2-12]

1. Raise the pressure and temperature of the vapor refrigerant that leaves the evaporator
    a. Figure 2-5[PP 2-13]
2. Condensing medium absorbs the heat that the system must reject in order to remain functional
3. Reciprocating compressors[PP 2-14]
    a. Utilize pistons, cylinders, and valves to accomplish the compression of the refrigerant
        1) Figure 2-6
        2) Figure 2-7[PP 2-15]
    b. Vary in size and capacity
4. Reciprocating compressor operation (Figure 2-8)
    a. Reexpansion
        1) Suction valve is closed
        2) Discharge valve is closed
    b. Suction or intake
        1) Suction valve is open
        2) Discharge valve is closed
    c. Compression
        1) Suction valve is closed
        2) Discharge valve is closed
    d. Discharge
        1) Suction valve is closed
        2) Discharge valve is open
5. Rotary compressors[PP 2-14]
    a. Figure 2-9
    b. Figure 2-10
    c. Figure 2-11[PP 2-16]

SLIDES 2-12 to 2-15

Make certain to point out that the suction and discharge valves on a reciprocating compressor cannot be open at the same time.

Have a cutaway of a semi-hermetic reciprocating compressor so that students can see the motion of the piston in the cylinder.

SLIDE 2-14
SLIDE 2-16

Have students identify the differences between the appearance of reciprocating, rotary and scroll compressors.

6. Rotary compressor operation
   a. Introduces suction gas into the compression chamber
   b. Seals off the suction chamber, trapping refrigerant inside
   c. Compresses the refrigerant
   d. Discharges high-pressure refrigerant from the compressor
      1) Figure 2-13

SLIDE 2-14

7. Scroll compressors[PP 2-14]
   a. Use nested scrolls to compress refrigerant
   b. Figure 2-12
   c. Figure 2-13
8. Scroll compressor operation
   a. All chambers are filled with refrigerant
   b. Refrigerant in each chamber is at a different stage of compression

SLIDES 2-17 to 2-19

   c. Figure 2-14[PP 2-17]
9. Condensers[PP 2-18]
   a. Figure 2-15[PP 2-19]
   b. Three processes in the condenser
      1) Desuperheating
      2) Condensing

SLIDE 2-9

      3) Subcooling[PP 2-9]
10. The condensing process
   a. Figure 2-16

VIDEO #1
Section 8

   b. Figure 2-17
11. Air-cooled condensers
12. Metering device (expansion device)[PP 2-20]
   a. Feeds the proper amount of refrigerant to the evaporator
      1) Figure 2-18

SLIDES 2-20 to 2-22

   b. Capillary tube[PP 2-21]
      1) Fixed-bore device
      2) Capillary tubes on critically charged systems
      3) Figure 2-20[PP 2-22]
   c. Automatic expansion valve (AEV)[PP 2-21]
      1) Modulates the flow of refrigerant into the evaporator
      2) Maintains a constant evaporator pressure in the evaporator
      3) Opens and closes to either increase or decrease the amount of refrigerant feeding into the evaporator
      4) Operates on a needle-and-seat mechanism
         a) The spring pressure opens the valve
         b) The evaporator pressure closes the valve

SLIDE 2-23
SLIDE 2-21

            - Figure 2-21[PP 2-23]
   d. Thermostatic expansion valve (TEV)[PP 2-21]
      1) Modulating valve that opens and closes
      2) Designed to maintain a constant evaporator superheat
      3) Operates on a needle-and-seat concept
         a) Figure 2-23

Hand tight sample TEVs can be used effectively to show the students the component parts of the valve.

SLIDE 2-24

b) Figure 2-24

c) Figure 2-25[PP 2-24]

4) Evaporator pressure

a) Pushes to help close the valve

b) Can be taken from either the inlet or the outlet of the coil

- Figure 2-26

5) Spring pressure

a) Pushes to help close the valve

b) Known as the superheat spring pressure

c) Determines how much superheat with which the evaporator will operate

- Figure 2-27

6) Bulb pressure

a) Only pressure that pushes to open the valve

- Figure 2-28
- Figure 2-29
- Figure 2-30
- Figure 2-31
- Figure 2-32

e. Evaporator pressure drops and the TEV

1) Figure 2-33

2) Figure 2-34

3) Figure 2-35

E. Refrigerants in the Residential System

1. Rated by their Ozone Depletion Potential, ODP

SLIDE 2-25

a. R-22[PP 2-25]

1) Very popular in residential air conditioning systems; although no longer used in new air conditioning systems, number of existing systems using it is large, so technicians will encounter it for years to come

2) HCFC refrigerant

3) ODP of 0.05

4) GWP of 1,700

5) Government regulations

6) At present, HFC-410A will be accepted replacement for R-22 in new equipment; R-407C a popular choice for retrofitting existing systems

SLIDE 2-26

b. R-410A[PP 2-26]

1) ODP of zero

2) GWP of 0.42

3) Operating pressures 40 to 70% higher than operating pressures on an equivalent R-22 system

4) Approximate 5% increase in operating efficiency

SLIDE 2-27

c. R-407C[PP 2-27]

1) A ternary HFC refrigerant blend, made up of R-32, R-125 and R-134a

2) ODP of zero
3) GWP of 0.34
4) Pressure/temperature chart for R-407C looks a little different than that of R-22 and R-410A because there are bubble point values and dewpoint values
    a) Figure 2-36

F. The Vapor-Compression Refrigeration Cycle: Putting it Together

1. Figure 2-37
2. Figure 2-38
3. Figure 2-39
4. Figure 2-40
5. Figure 2-41
6. Figure 2-42
7. Figure 2-43
8. Figure 2-44

SLIDES 2-28 to 2-33

G. Summary[PP 2-28, 2-29, 2-30]

1. Green Checklist[PP 2-31, 2-32, 2-33]

H. Review Questions

CHAPTER

3 General Safety Practices

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).

Air conditioning system installers and technicians are faced with a number of potential hazards on a daily basis. Working with open flames, electricity, and pressurized vessels creates the potential for serious injury and equipment damage. Quite often, the service technician works in confined spaces, which leads to an increase in the chances of sustaining injuries related to the inhalation of fumes and gases from refrigerants, adhesives, acetylene, and other materials commonly used in the service and installation of air conditioning systems. In addition, when servicing or installing air conditioning systems, the installers and technicians often work under hot conditions, which lead to perspiration, which in turn, can increase the severity of electric shocks.

Knowing that there are a number of potentially hazardous situations awaiting the service personnel, it is in their best interest to do everything possible to reduce these risks. Most accidents result from carelessness. Being aware of the immediate surroundings and potential safety hazards is the single most important thing that individuals can do to help ensure their safety. Knowing how to use a fire extinguisher and how to administer first aid and cardiopulmonary resuscitation, CPR, are skills that have proven invaluable in times of emergency. This chapter will address a number of safety issues and practices that can help reduce the chances of sustaining injuries while working in the field.

OBJECTIVES [PP 3-2, 3-3]

SLIDE 3-2
SLIDE 3-3

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

- Describe acceptable dress for air conditioning system installers and technicians.
- Dress appropriately to work in the field.
- Explain acceptable tool and equipment safety practices.
- Describe the factors that affect the severity of electric shock.
- Properly ground tools and equipment for use in the field.
- Explain and demonstrate proper fire extinguisher use.
- Explain the importance of knowing proper first aid procedures.
- List the agencies that have an effect on safety-related issues.

GLOSSARY

American National Standards Institute (ANSI) — Organization that coordinates the voluntary formation of standards that ensure the uniformity of products, processes, and systems.

Asphyxiation — Loss of consciousness that is caused by a lack of oxygen or excessive carbon dioxide in the blood.

Carbon dioxide (CO2) extinguisher — Fire extinguisher that uses vaporizing liquid carbon dioxide to remove heat from a fire.

Cardiopulmonary resuscitation (CPR) — Emergency first aid procedure to maintain circulation of blood to the brain.

Class A fire extinguishers — Fire extinguishers intended for use on fires that result from burning wood, paper, or other ordinary combustibles.

Class B fire extinguishers — Fire extinguishers intended for use on fires that involve flammable liquids such as grease, gasoline, or oil.

Class C fire extinguishers — Fire extinguishers intended for use on electrically energized fires.

Class D fire extinguishers — Fire extinguisher typically used on flammable metals.

Dry chemical extinguisher — Fire extinguisher that contains an extinguishing agent and a compressed, non-flammable gas, which is used as the propellant.

Frostbite — Injury to the skin resulting from prolonged exposure to freezing temperatures.

Frostnip — The first stage of frostbite.

Ground — Term used to describe an electrical connection between the casing of equipment or tools and the Earth.

Ground Fault Circuit Interrupter (GFCI) — Electrical device designed to sense small current leaks to ground and deenergize the circuit before injury can result.

Halon extinguisher — Fire extinguisher that contains a gas that interrupts the chemical reaction when fuel burns.

Material Safety Data Sheets (MSDS) — Forms that provide storage, transport, and first aid information regarding chemicals used in the field.

National Fire Protection Agency (NFPA) — Agency that provides codes, standards, research, training, and education regarding safety- and fire-related issues.

Occupational Safety and Health Administration (OSHA) — Branch of the U.S. Department of Labor that strives to reduce injuries and deaths in the work place.

PASS — Acronym used to describe fire extinguisher use (Pull, Aim, Squeeze, Sweep).

Service wrench — Tool designed to turn square stems on valves.

OUTLINE

VIDEO #1
Sections 1 and 2

SLIDE 3-4
SLIDE 3-5

A. **Personal Safety**[PP 3-4]
   1. Personal behavior
      a. Do not run
      b. Clean all spills immediately
      c. Walk from one place to another
      d. Wear rubber-soled shoes to reduce the chances of falling
      e. Be aware of potential dangers

Conduct a role play exercise where students are to dress in both safe and unsafe manners. Divide students into small groups and have them make lists of appropriate and inappropriate dress-related issues that they notice. Then discuss these lists as a class.

   2. Clothing[PP 3-5]
      a. Do not wear baggy clothing
      b. Tuck shirts into pants
      c. Wear long-sleeved shirts
      d. Never wear short pants when working in the field

   e. Tie long hair back and/or place inside the shirt to prevent it from getting caught in rotating parts or getting burned while soldering or brazing
3. Jewelry
   a. Metallic watches, rings, and necklaces are good conductors of electricity and can result in electric shock
   b. If a watch must be worn, make certain that it is made of plastic or other non-conductive material and has a leather or plastic strap
   c. Metal rings are good conductors of electricity but they can also get caught on nails or other objects that may protrude from a work surface
   d. Reduce the possibility of electric shock by wrapping a piece of electrical tape around a ring
   e. Make every effort to avoid wearing metal while working

SLIDE 3-6

4. Safety glasses and goggles[PP 3-6]
   a. One of the most important pieces of safety equipment
   b. When choosing safety glasses consider the style of the glasses and comfort
      1) Figure 3-1
      2) Figure 3-2

SLIDE 3-7

5. Work boots[PP 3-7]
   a. Protect the feet from falling objects
   b. Rubber-soled work boots made of heavy leather provide protection from electric shock and from falling objects
   c. Steel toes are often desirable
   d. Do not wear sneakers in the field
      1) Figure 3-3
6. Ear protection
   a. Wear ear plugs or earmuffs when working with tools that can generate potentially dangerous noise levels
      1) Figure 3-4
7. Gloves
   a. Heavy duty work gloves provide protection for the hands
   b. Gloves can help prevent cuts
   c. Gloves help give a better grasp on the object, reducing the chances of dropping it
   d. Gloves can prevent frostbite that can result when released refrigerant comes in contact with the skin
      1) Figure 3-5

SLIDES 3-8 to 3-10

Demonstrate proper and improper lifting methods for students using an empty box as an example. Have students demonstrate lifting techniques in front of the class and have the other students comment on the methods used.

8. Lifting objects and back support belts[PP 3-8]
   a. Lift objects with the legs, not the back
   b. Do not bend over with straight legs to lift the object
   c. Always bend at the knees, and, once the object is supported, straighten the legs to complete the lift
   d. To provide additional back support, wear a back brace[PP 3-9]
      1) Figure 3-6
      2) Figure 3-7[PP 3-10]

9. Knee pads
    a. Knee pads provide a cushioned surface between the hard surface of ground or attic and the patella (the triangular bone that covers the knee joint)
        1) Figure 3-8

SLIDE 3-11

VIDEO #2
Section 4

B. Electrical Safety[PP 3-11]

1. Electric shock
    a. Occurs when a portion of the body becomes part of an active, or energized, electric circuit
    b. Severity depends on the amount of current flowing in the circuit and the path the current takes though the body
    c. Resistance of the body is greatly reduced when perspiration forms on the skin
    d. As the resistance of the body decreases, the amount of current flow increases
    e. Electric shocks can range in severity, from minor discomfort and tingling to electrocution
    f. The best way to avoid receiving an electric shock is to work on circuits that are deenergized
    g. Wear rubber-soled shoes, avoid metallic jewelry, and be aware that the possibility of shock exists
    h. Do not touch metallic surfaces while working on electric circuits or while using power tools
        1) Figure 3-9
        2) Figure 3-10
        3) Figure 3-11
        4) Figure 3-12
2. Ground wires
    a. All equipment should be properly grounded
    b. Ground is used to describe an electrical connection between the casing of equipment or tools and the Earth
    c. The ground wire should NEVER be disconnected from the equipment
        1) Figure 3-13[PP 3-12]
        2) Figure 3-14[PP 3-13]

SLIDES 3-12 to 3-14

3. Extension cords and ground prongs[PP 3-14]
    a. Power tools and extension cords are often manufactured with three-pronged plugs
    b. Two of these prongs provide power to the tool, while the rounded prong at the bottom of the plug is the ground prong
    c. This prong should never be cut off as doing so will eliminate the protection that the ground is designed to provide
    d. In the event that a receptacle or outlet has only two slots, an approved adapter must be used
    e. The adapter is manufactured with a green wire that extends from the device that must be screwed to a ground in order for the circuit to be protected
        1) Figure 3-15
        2) Figure 3-16

4. Ground Fault Circuit Interrupters (GFCI)
    a. Designed to sense small current leaks to ground and deenergize the circuit before injury can result
    b. Electric codes require the installation of a GFI on any circuit that is located close to a wet location
        1) Figure 3-17[PP 3-15]

SLIDE 3-15
SLIDE 3-16

C. Lockout/Tagout[PP 3-16]

1. Lockout devices are devices that, when in place, prevent the accidental energizing of equipment
    a. Figure 3-18
2. Tagouts are clearly visible warning devices, such as tags, that are securely fastened to a device or piece of equipment; indicate that the equipment may not be operated until the tagout device is removed
    a. Figure 3-19

SLIDE 3-17

D. Fire Safety[PP 3-17]

As an exercise, have students perform a visual inspection of the classroom/institution areas, making notes about fire extinguisher locations, types, and inspection tags. Also have students examine the gauges on the extinguishers to establish that they are properly charged.

1. A fire extinguisher should be carried on the truck and brought along as a tool to the work location
    a. Figure 3-20
2. Class A fire extinguishers[PP 3-17]
    a. Designed to be used on fires that result from burning wood, paper, or other ordinary combustibles
    b. Contain water and compressed gas
        1) Figure 3-21
3. Class B fire extinguishers[PP 3-17]
    a. Dry chemical extinguishers contain an extinguishing agent and a compressed, non-flammable gas, which is used as the propellant
    b. Halon extinguishers contain a gas that interrupts the chemical reaction when fuel burns
    c. In carbon dioxide, CO_2, extinguishers, the CO_2 is stored as a compressed liquid in the extinguisher. As it is released from the cylinder of the extinguisher it expands, vaporizes, and cools the air surrounding the fire
        1) Figure 3-22

SLIDE 3-18

4. Class C fire extinguishers[PP 3-18]
    a. Designed for use on electrically energized fires
    b. Contain an extinguishing agent that is non-conductive to prevent the fire from spreading
    c. Carbon dioxide extinguishers are typically the best choice for class C fires
        1) Figure 3-23
5. Class D fire extinguishers[PP 3-18]
    a. Used on flammable metals and designed for specific metals and materials
    b. This type of extinguisher is typically not found in the residential air conditioning setting
        1) Figure 3-24[PP 3-19]

SLIDE 3-19

6. Multiple purpose fire extinguishers
   a. Designed to be used on A-B fires, B-C fires, or A-B-C fires

SLIDE 3-19
SLIDE 3-20

      1) Figure 3-25[PP 3-19]
      2) Figure 3-26[PP 3-20]
7. Fire extinguisher use
   a. PASS
      1) **P —** Pull the pin at the top of the extinguisher to enable the handle to be squeezed
      2) **A —** Aim the nozzle of the fire extinguisher at the base of the fire
      3) **S —** Squeeze the handle to discharge the extinguisher. You should be at a distance of 6 to 8 feet from the fire
      4) **S —** Sweep the nozzle back and forth at the base of the fire until it is put out

SLIDE 3-20

         a) Figure 3-27[PP 3-20]
8. Fire extinguisher maintenance
   a. Inspect periodically to ensure that the indicator arrow is in the green, or safe, region of the dial
   b. Store in a location that is easily accessible and never lock it away

SLIDE 3-21

      1) Figure 3-28[PP 3-21]

E. Tool, Equipment, and Material Safety

1. Wrenches
   a. Pull on the wrench, don't push it
   b. Specialty wrenches are designed to perform specific tasks and should be used accordingly
   c. The acetylene tank, used in the soldering and brazing processes, is opened and closed by turning a square-shaped stem on the tank

SLIDE 3-22
SLIDE 3-23

      1) Figure 3-29[PP 3-22]
      2) Figure 3-30[PP 3-23]
   d. Use properly-sized pipe wrenches
      1) Figure 3-31[PP 3-23]
   e. When using adjustable, or crescent, wrenches be sure to tighten the wrench around the object as tightly as possible to prevent slippage
      1) Figure 3-32[PP 3-23]
2. Screwdrivers
   a. Screwdrivers are intended to be used to drive screws
   b. Do not use screwdrivers as chisels, crowbars, pry bars, or any other non-screw task
   c. Commonly used screwdrivers are the straight slot screwdriver and the Phillips screwdriver
      1) Figure 3-33
      2) Figure 3-34
      3) Figure 3-35

SLIDE 3-24

3. Ladders[PP 3-24]
   a. Use ladders made of non-conducting material
   b. Commonly used materials in non-conducting ladders are fiberglass and wood
      1) Figure 3-36

c. Avoid standing on or above the top rung of the ladder
    1) Figure 3-37
d. Avoid working overhead whenever possible
e. Always make certain that the ladder is used on a level surface to help prevent it from falling over
f. Make certain that the metal spreaders/locking devices are in place and not damaged
    1) Figure 3-38

4. Soldering and brazing equipment
    a. Make certain that there is ample ventilation
    b. When using the torch always be sure to secure the tank in the vertical position to prevent it from tipping over
5. Pressurized gas tanks and cylinders
    a. Nitrogen, as well as other gases including refrigerant, often comes supplied in 125 pound cylinders and contain high-pressure fluid
    b. These tanks should not be moved unless the cap is screwed securely in place
    c. When moving large tanks, they should be chained securely to a cart and rolled from place to place
        1) Figure 3-39
6. Chemical and material safety
    a. When handling chemicals be sure to follow the manufacturer's directions for use and heed the warnings on the product labels
    b. Many chemicals can cause skin irritation or burns if they come in contact with the bare skin
    c. Vapors from chemicals can cause respiratory inflammation, unconsciousness, irregular heartbeats, or death
        1) Figure 3-40
    d. When purchasing chemicals, obtain Material Safety Data Sheets
        1) Figure 3-41

Have students inspect the contents of a first aid kit, and make sure they are aware of the items in it as well as the use for each item.

F. First Aid

1. All service vehicles should be equipped with a first aid kit containing the basic medical supplies such as burn cream, bandages, alcohol pads, eye wash, eye pads, tweezers, antiseptic spray, gauze bandages, and CPR shields
    a. Figure 3-42

SLIDE 3-25

2. Frostbite[PP 3-25]
    a. Frostbite can occur any time there is prolonged exposure to freezing temperatures
    b. Frostnip results in the whitening of the skin, itching, tingling, and loss of feeling
    c. Frostbite results in the skin turning purple and the formation of blisters on the skin
    d. The third stage is rare and results in gangrene and requires amputation of the affected area
    e. Cover the area with something warm and dry and then obtain professional medical attention
    f. Never rub, massage, poke, or squeeze the affected area

   g. Place a warm bottle of water gently against the affected area to warm it slightly
3. Bleeding
   a. Place a clean folded cloth over the area and apply firm pressure
   b. If blood soaks through the cloth, cover the cloth with another and continue to apply pressure until the bleeding stops
   c. Elevate the cut area to a level above the heart
   d. If the cut is relatively small, wash the injury with soap and warm water and then bandage

SLIDE 3-25

4. Asphyxiation[PP 3-25]
   a. An oxygen level below 19% may result in unconsciousness
   b. As a result of electric shock or inhalation of refrigerant, the victim may stop breathing
   c. If a victim's respiratory system fails, the flow of oxygen through the body may stop within a matter of minutes
   d. In the event the victim stops breathing, administer cardiopulmonary resuscitation (CPR)

SLIDE 3-26

5. Chemical burns[PP 3-26]
   a. Remove the clothing on or near the burn area
   b. Under no circumstances should clothing be pulled off over the head as residual chemical may enter the eyes
   c. If necessary, cut the clothing from the body
   d. Wash the affected area with low pressure water for at least twenty minutes and apply a clean bandage to the wound. Seek medical attention immediately

SLIDE 3-26

6. Electric shock[PP 3-26]
   a. DO NOT TOUCH THE SHOCK VICTIM!
   b. Disconnect the power at the main disconnect switch
   c. Once the power is off, use a non-conducting object such as a wooden stick to move the wires from the victim or, if possible, move the victim from the area
   d. If the victim is conscious, place a pillow or rolled jacket under his or her head and await medical attention
   e. If the victim is not breathing, administer CPR

G. Agencies

1. Occupational Safety and Health Administration (OSHA)
2. National Fire Protection Agency (NFPA)
3. American National Standards Institute (ANSI)

SLIDES 3-27 to 3-29

H. Summary[PP 3-27, 3-28, 3-29]

I. Review Questions

J. Know Your Codes

K. What's Wrong with This Picture?

1. Figure 3-43
2. Figure 3-44