The Refrigeration Cycle

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THE REFRIGERATION CYCLE

Lesson One

Refrigeration and Air-Conditioning Basics

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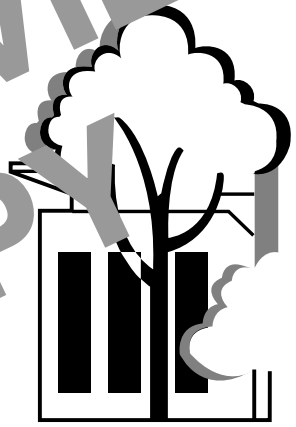

TPC Training Systems

43101

Lesson

1 Refrigeration and Air-Conditioning Basics

TOPICS

Definition of Refrigeration
Definition of Air Conditioning
The Composition of Matter
The States of Matter

OBJECTIVES

After studying this Lesson, you should be able to…

- Define *refrigeration* and *air conditioning* and explain how they differ.
- Describe the two methods of lowering the temperature of a material.
- Name the three physical states of matter.
- Identify what causes matter to change its state.

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KEY TECHNICAL TERMS

Refrigeration 1.02 process of cooling or removing heat
Heat transfer 1.03 process in which heat travels from a warmer substance to a colder substance
Air conditioning 1.07 control of the temperature, humidity, movement, and cleanliness of air in a defined space
Solid 1.21 rigid substance that has a definite size and shape
Liquid 1.21 substance that has a definite volume but no definite shape; it flows and takes the shape of its container
Gas 1.21 substance with no definite shape or volume; it is easily compressed or expanded to fill available space

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Air conditioning and refrigeration systems today are becoming increasingly important in such varied applications as human comfort, food and drug processing and preservation, the proper operation of electronic computers, and the manufacture and/or assembly of many parts and products. In this Lesson, you will learn the definitions of air conditioning and refrigeration and how they differ. You will also learn about methods of heat transfer.

This Lesson also covers the composition of matter and the three states of matter—topics that will be important to your understanding of the behavior of refrigerants and their role in the cooling process. Finally, the Lesson touches on the concept of change of state and how change of state is related to temperature and pressure.

Definition of Refrigeration

1.01 You might think that the logical place to begin a course on air conditioning and refrigeration is with air conditioning. But air conditioning is really a recent application of refrigeration. This Lesson begins at the beginning—with refrigeration.

1.02 *Refrigeration* is the process of cooling—of lowering the temperature of a space or a substance to a level below that of the area around it. You might also think of refrigeration as the process of removing heat. There are two basic methods of lowering temperature: *heat transfer* and *change of state*.

1.03 **Heat transfer.** When heat moves from one substance to another, it always goes from the warmer substance to the cooler substance. As it does, the warm substance becomes cooler and the cool substance becomes warmer. This process is called *heat transfer*. For example, you place an ice cube in a glass of water to cool the water. This process, as illustrated in Fig. 1-1, is refrigeration by *direct* heat transfer. You bring the substance to be cooled in direct contact with the colder substance.

1.04 Now suppose you place a block of ice in front of a fan so that the fan blows air over the ice. The ice cools the air. Of course, what you really want to cool is yourself, so you sit in the path of the air that has been cooled by the ice. This process of *indirect* heat transfer is illustrated in Fig. 1-2. A third substance—in this case, the air—is between the cool substance (ice) and the substance to be cooled (you). Air conditioning is another example of indirect heat transfer.

1.05 **Change of state.** When water or some other liquid changes state by evaporating, its temperature drops. This principle can be put to use for cooling purposes. For example, consider the way in which a breeze cools you off when you perspire on a hot summer day. As the perspiration on your body evaporates into the air, it absorbs heat from your body. Evaporation, heat transfer, and combinations of the two are used in refrigeration applications. You will study more about them in later Lessons.

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Fig. 1-1. Direct heat transfer

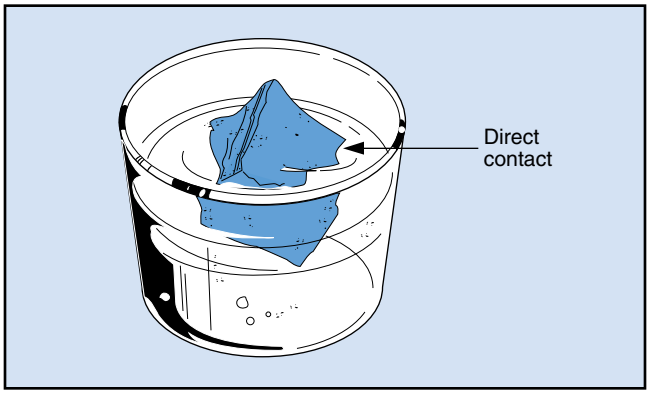
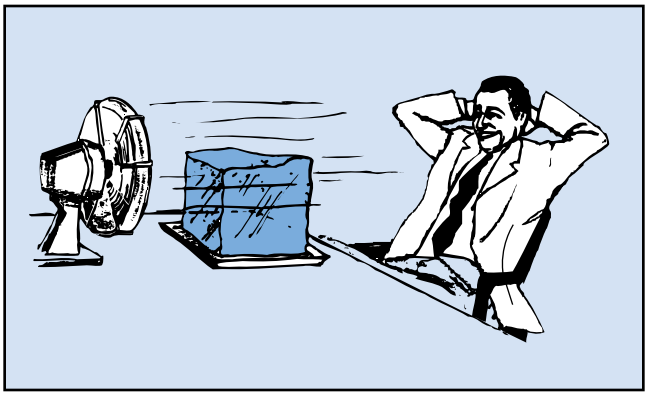


Fig. 1-2. Indirect heat transfer



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1.06 Refrigeration is used for one of three basic reasons. The most obvious reason is to cool something—to cool water for drinking, for instance. The second reason is to change the state of a substance. For example, you might want to change water to ice. The third reason is to maintain the state of a substance—you might want to keep ice from melting, for example.

Definition of Air Conditioning

1.07 You read in the first paragraph that air conditioning is an application of refrigeration. In reality, air conditioning is much more than that. *Air conditioning* is the control of the temperature, moisture content (humidity), movement, and cleanliness of air in a defined space. As you can see, air conditioning involves more than simply cooling the air. In some cases, an air-conditioning system must heat the air to control the air temperature. The system must be able to add or remove moisture from the air to control its moisture content. In addition, an air-conditioning system must move the air and remove dust and pollen from it. The purpose of air conditioning is to maintain a needed or desired atmosphere in an enclosed space.

1.08 There are two reasons for air conditioning. The first is for human comfort and health—*comfort air conditioning*. You can experience comfort air conditioning almost anywhere you go—stores, offices, homes, and cars. The other reason for air conditioning is to provide the atmospheric conditions needed for a manufacturing process to take place—*process air conditioning.*

1.09 **Comfort air conditioning.** People's bodies are always producing heat. They usually produce more heat than they need to maintain their normal temperature. Thus, they constantly give up heat in order to be comfortable. A body gives up much of this heat to the air around it. The temperature, moisture content, and movement of the air all control the rate of heat a body gives up.

1.10 People are also sensitive to impurities in the air. Dust, smoke, and plant pollen irritate people's noses, lungs, and eyes. People require clean, fresh air to stay healthy. In addition to containing the oxygen that the body needs, fresh air also dilutes odors.

1.11 **Process air conditioning.** Many machines and processes used in industry are sensitive to air conditions. Carefully adjusted machines can malfunction if the temperature of the surrounding air is not correct. Too much moisture or even a speck of dust in the air can affect the accuracy of a tiny electronic part. The quality of textiles, foods, and many other products depends on the conditions of the air around them during their processing. A secondary benefit is that often the people working in areas having process air conditioning are more comfortable. In other words, process air conditioning sometimes serves as comfort air conditioning as well.

The Composition of Matter

1.12 *Matter* is any kind of material substance—iron, wood, rock, water, and air are examples. Matter can be defined simply as anything that occupies space and has weight.

1.13 **Atoms.** All matter is made up of very small particles called *atoms*. Atoms are so small that you cannot see them, even with a powerful microscope. Atoms themselves are made up of still smaller particles called *subatomic particles* (protons, neutrons, and electrons). The number of subatomic particles in an atom, and their arrangement, determines what kind of atom it is. Several examples are shown in Fig. 1-3. There are over 100 different kinds of atoms. They are the building blocks of the universe.

1.14 **Elements.** An *element* is a substance made up of only one kind of atom. Since there are over 100 kinds of atoms, there are also over 100 different elements. Some common examples of elements are carbon, hydrogen, iron, lead, oxygen, gold, mercury, and helium. These elements, by themselves and in various chemical combinations, make up all the different forms of matter found in the universe. Wood, for example, contains hydrogen, carbon, oxygen, and traces of numerous other elements. Air contains oxygen, nitrogen, and small amounts of other elements.

1.15 **Molecules.** A *molecule* is a very small particle made up of two or more atoms. The atoms of a molecule are bound to each other in a special way for each kind of molecule. The number of atoms in a molecule, their kind, and the way they are bound together tells you what kind of molecule it is. A water molecule, for exam-

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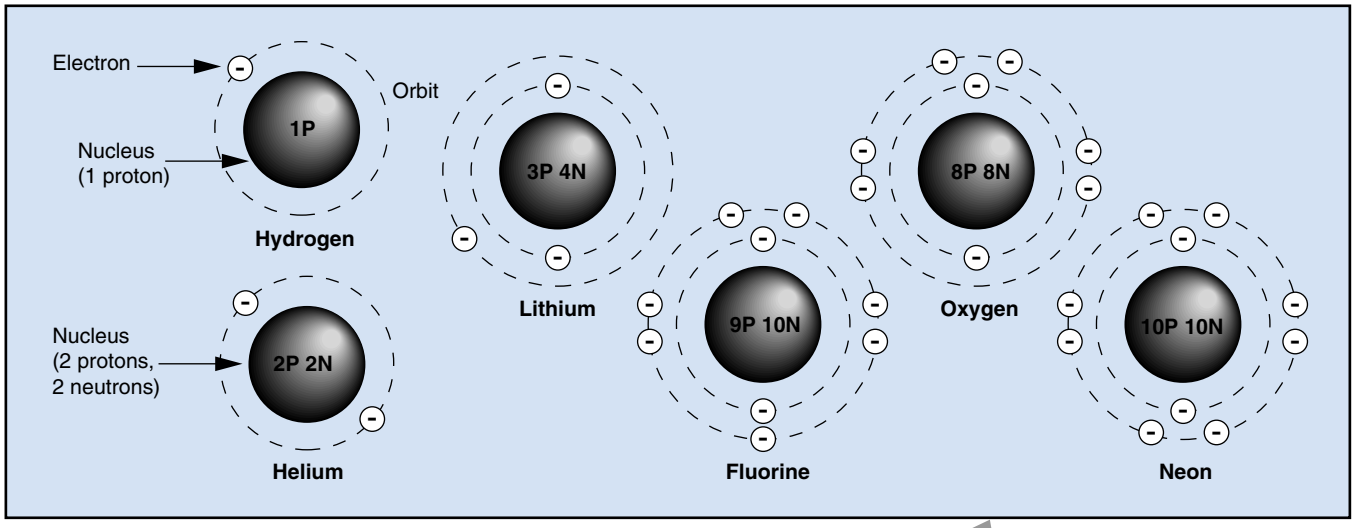
Fig. 1-3. Atomic structure of various elements



ple, contains two atoms of hydrogen and one atom of oxygen (the chemical symbol is H_2O).

1.16 **Compounds.** A *compound* is a substance made up of two or more elements. Elements are substances that cannot be broken down; compounds can be broken down into their individual elements. Water is a compound. It is made of H_2O molecules, each made of the elements hydrogen and oxygen. Other compounds, however, can also be made up of these same two elements. Hydrogen peroxide, for example, contains the same two elements but in slightly different form—it contains two atoms of hydrogen and two atoms of oxygen in each molecule (chemical symbol H_2O_2). It has properties that are very different from water. It is heavier, boils at a higher temperature, and breaks down easily into water or oxygen.

1.17 The number of different compounds that can be found or made from the basic elements is almost limitless. Their molecules can be very simple, like water (H_2O), or they can be complex, like ethylene dibromide (CH_2BrCH_2Br), which is an additive used in high-test gasoline.

1.18 The important things to remember about compounds are:

- They contain two or more elements.
- Different compounds can contain the same elements but in different proportions.
- Their molecules are built from the atoms of the elements they contain.
- The physical properties of a compound (freezing point and boiling point, for example) are quite different from the properties of the individual elements that make up the compound.
- The physical properties of a compound are due to the structure of its molecules—that is, the kinds of atoms in a molecule and the way they are arranged.

1.19 **Mixtures.** A *mixture* is made up of two or more substances. The substances might be elements or compounds, or both. Air, for example, is a mixture of two elements—oxygen and nitrogen. The two elements, however, are not combined into molecules. Their atoms are bound together in pairs (two oxygen atoms or two nitrogen atoms). The oxygen molecules and nitrogen molecules are mixed up like sand and sugar. (Air usually contains other substances such as water vapor and carbon dioxide, but air is basically a mixture of oxygen and nitrogen.) A mixture differs from a compound or element because it is not made up of only one kind of molecule or atom.

1.20 **Solutions.** A *solution* is a mixture formed by dissolving a substance in a liquid or gas. For example, sugar dissolved in water is a solution of two compounds—sugar and water. Other examples are: oxygen dissolved in water and carbon dioxide dissolved in

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water (common soda water). A solution differs from an ordinary mixture in that the substances are dispersed evenly throughout the solution. Also, there are limits to the amount of one substance that you can dissolve into another. In an ordinary mixture, like sand and sugar, there are no limits. As you will see later, solutions and their behavior play an important role in refrigeration systems.

The States of Matter

1.21 Matter exists in three physical states: solid, liquid, and gas. Liquids and gases can both be classified as *fluids*.

- **Solid.** A solid substance is rigid and has a definite shape. A given weight will have a definite volume. It can be cut, sawed, torn, broken apart, or split in two. Some solids can be bent. Liquids and gases do not have these properties.

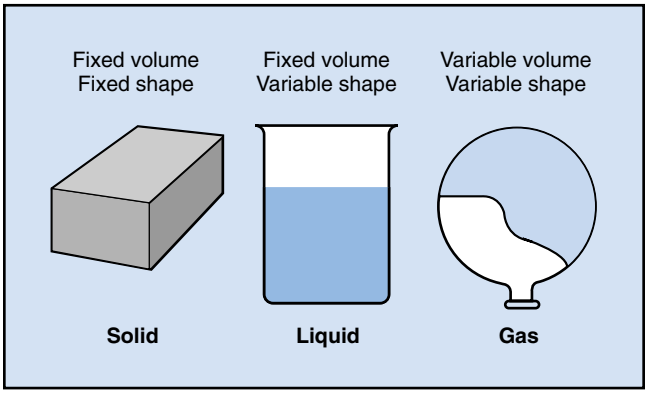
- **Liquid.** A liquid substance has no definite shape—it flows and takes the form of its container. Like a solid, however, a given weight of liquid has a definite volume.

- **Gas.** A gaseous substance, like air, has no definite shape or volume. It is easily compressed, and expands to fill whatever space is available.

Water is an example of a material that is commonly found in all three states of matter—as ice (a solid), as ordinary water (a liquid), and as steam (a gas). The three states of matter are illustrated in Fig. 1-4.

1.22 The state of a substance depends upon its temperature and its pressure. Water, for example, is a liquid at ordinary room temperature and pressure. You can change it to a solid by freezing it, however, or to a gas by boiling it. Other substances like iron, oxygen, and mercury can also be changed from one state to another by raising or lowering the temperature—that is, by heating or cooling the substance you want to change. The process involves the addition or removal of heat. In other words, you must transfer heat to or from the substance in order to change its state.

Fig. 1-4. Three states of matter



1.23 You can also change the state of a substance by changing its pressure. Under normal atmospheric pressure, water boils at a temperature of 212°F (100°C). At that temperature, it changes state from liquid to gas. However, if you place water in a closed container and then pressurize the container, the water will not boil at 212°F (100°C). You will have to raise the temperature higher than 212°F (100°C) to make it boil. The reverse is also true. At pressures lower than normal atmospheric pressure, water will boil at a lower temperature. The lower the pressure, the lower the boiling temperature. The same holds true for other substances as well.

1.24 You will study more about how temperature and pressure affect the states of a substance in Lesson Two. The most important thing to keep in mind for now is that you can change the physical state of a substance by changing the temperature or pressure. When a change of state occurs, heat is transferred in the process. You can, therefore, control the transfer of heat. Refrigeration, remember, is simply the transfer of heat away from the area you want to cool.

The Programmed Exercises on Page 10 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.

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1-1. Refrigeration is the process of _____.	1-1. REMOVING HEAT or COOLING Ref: 1.02
1-2. Heat always travels from a(n) _____ substance to a(n) substance.	1-2. WARMER; COLDER Ref: 1.03
1-3. When water evaporates, its temperature _____.	1-3. DROPS Ref: 1.05
1-4. What are the three reasons for using refrigeration?	1-4. TO COOL A SUBSTANCE, TO CHANGE THE STATE OF A SUBSTANCE, TO MAINTAIN THE STATE OF A SUBSTANCE Ref: 1.06
1-5. In addition to temperature control, air conditioning involves the control of air's _____, _____, and _____.	1-5. HUMIDITY, MOVEMENT, AND CLEANLINESS REF: 1.07
1-6. All matter is made up of very small particles called _____.	1-6. ATOMS Ref: 1.13
1-7. Name the three states of matter.	1-7. SOLID, LIQUID, GAS Ref: 1.21
1-8. The state of a substance depends on its _____ and _____.	1-8. TEMPERATURE and PRESSURE Ref: 1.22

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

1-1. Refrigeration is the process of

- ☐ a. changing the state of a substance
- ☐ b. conditioning the air
- ☐ c. controlling humidity
- ☐ d. removing heat

1-2. What are the two basic methods of removing heat?

- ☐ a. change of state and refrigeration
- ☐ b. refrigeration and pressurization
- ☐ c. pressurization and heat transfer
- ☐ d. heat transfer and change of state

1-3. Heat always travels

- ☐ a. away from a substance under pressure
- ☐ b. between substances with like temperatures
- ☐ c. from a cooler substance to a warmer substance
- ☐ d. from a warmer substance to a cooler substance

1-4. When water evaporates, it

- ☐ a. drops in temperature
- ☐ b. becomes a solid
- ☐ c. maintains its state
- ☐ d. releases heat

1-5. What kind of air conditioning is used to control dust and moisture in an electronic assembly plant?

- ☐ a. Central station
- ☐ b. Comfort
- ☐ c. Evaporative
- ☐ d. Process

1-6. When the atoms of two or more elements combine with each other in a definite pattern they form a

- ☐ a. mixture
- ☐ b. molecule
- ☐ c. solid
- ☐ d. solution

1-7. A substance that consists of only one kind of atom is called a(n)

- ☐ a. compound
- ☐ b. element
- ☐ c. gas
- ☐ d. solution

1-8. Which of the following is a mixture?

- ☐ a. Air
- ☐ b. Hydrogen peroxide
- ☐ c. Oxygen
- ☐ d. Water

1-19. Which of the following involves a change of state?

- ☐ a. Boiling water
- ☐ b. Compressing air
- ☐ c. Dissolving salt in water
- ☐ d. Rolling metal into sheets

1-10. If you attempt to boil water in a pressurized, closed container, what will you discover?

- ☐ a. A temperature higher than 212°F is required
- ☐ b. A temperature lower than 212°F is required
- ☐ c. It will boil at 212°F
- ☐ d. It will not boil

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SUMMARY

Refrigeration **is a cooling process accomplished by either heat transfer or evaporation. Refrigeration is used to cool something, to change the state of a substance, or to maintain the state of a substance. *Air conditioning*, which is an application of refrigeration, involves the control of temperature, humidity, air movement, and air cleanliness in a confined space. Comfort air conditioning is used for human comfort and health purposes. Process air conditioning is used in industry to ensure the manufacture of quality products and the proper operation of electronic equipment.**

Matter **is any kind of material that occupies space and has weight. All matter is made up of small particles called *atoms*. A *solution* is a mixture formed by dissolving a substance in a liquid or gas. You will see in a later Unit the importance of solutions in refrigeration systems. Matter can be solid, liquid, or gaseous in form. The state of matter depends on temperature and pressure and can be changed by changing pressure and temperature, as happens in a refrigeration system.**

Answers to Self-Check Quiz

1-1. d. Removing heat. Ref: 1.02

1-2. d. Heat transfer and change of state. Ref: 1.02

1-3. d. From a warmer substance to a cooler substance. Ref: 1.03

1-4. a. Drops in temperature. Ref: 1.05

1-5. d. Process. Ref. 1.11

1-6. b. Molecule. Ref: 1.15

1-7. b. Element. Ref: 1.14

1-8. a. Air. Ref: 1.19

1-9. a. Boiling water. Ref: 1.22

1-10. a. A temperature higher than 212°F is required. Ref: 1.23

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