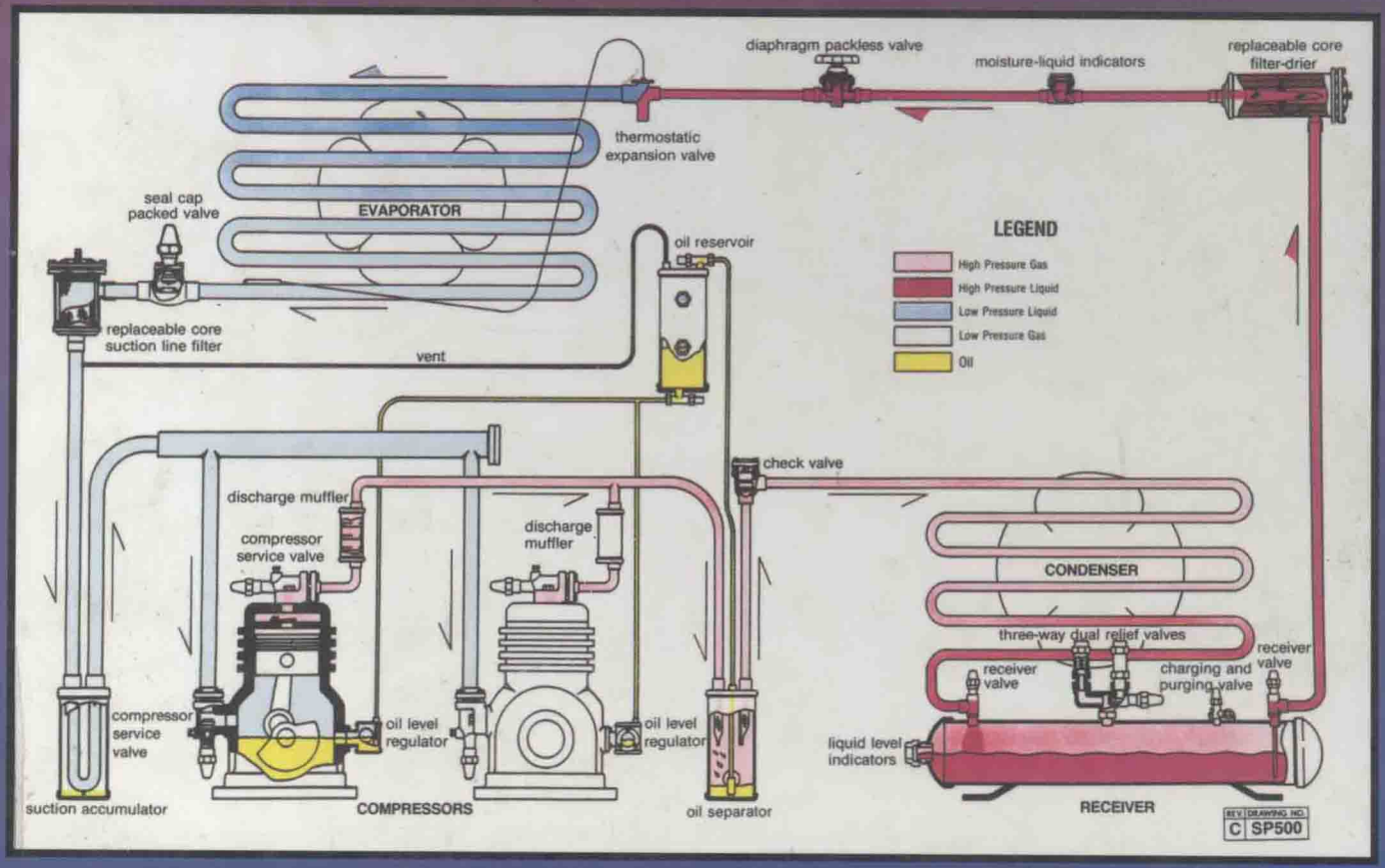
Fundamentals of Refrigeration

Billy C. Langley



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Delmar Staff
Administrative Editor: Vernon Anthony
Project Editor: Eleanor Isenhart
Production Coordinator: Karen Smith
Art Coordinator: Cheri Plasse

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For more information, contact:

Delmar Publishers
3 Columbia Circle, Box 15015
Albany, New York 12212–5015

International Thomson Publishing Europe
Berkshire House 168–173
High Holborn
London WC1V 7 AA
England

Thomas Nelson Australia
102 Dodds Street
South Melbourne, 3205
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PREFACE

Fundamentals of Refrigeration is a basic text written to aid the student in learning the underlying fundamentals of this industry. It should also be helpful to the instructor in planning the class schedule and in making reading assignments. The text will be of benefit to those who are currently working in the industry at the beginning level, as well as those that are studying to learn this industry.

Fundamentals of Refrigeration was written in a manner that allows it to be used as an instructor's curriculum guide, as a textbook for classroom study, or for independent study. The text presents the practical fundamentals and service procedures and safety instructions with which the learner should become familiar. The material in this text is organized to be used in short survey courses or in comprehensive course study in high schools, two-year technical programs, and trade schools.

ORGANIZATION

Fundamentals of Refrigeration presents the material in chapters that deal with specific topics. Each chapter is divided into numbered sections that present smaller parts of the topic covered in the chapter. Every chapter begins with objectives indicating the things that the reader should gain from that study and an introduction. At the end of each numbered topic are a summary and review questions. The review questions usually require thought-provoking answers. There are safety procedures introduced at the appropriate point of study. There are also troubleshooting and service procedures introduced in areas that allow this type of activity. The language used is as close as possible to that typically used in the field. The text is supported by the generous use of photos, line drawings, tables, and charts. There are examples used to aid in the understanding of the material presented.

Chapter Organization

Chapter 1 introduces the reader to the fundamentals of refrigeration which must be learned before success is possible. Chapter 2 presents heat and is divided into sixteen separate units. Temperature and its importance to refrigeration and air conditioning work are discussed in Chapter 3. Pressure and its various aspects are covered in Chapter 4. Vapor compression refrigeration systems are presented in Chapter 5. Chapter 6 discusses tools and test instruments that are commonly used in refrigeration and air conditioning work. Refrigeration materials which include piping, fittings, working with tubing, and how to determine the equivalent length of pipe are presented in Chapter 7. Chapter 8 presents

compressors and lubricants and how they are used in the system. Chapter 9 discusses condensers and receivers and their importance to the operation of the system. Evaporator styles, heat transfer, and temperature difference are discussed in Chapter 10. The various flow control valves and capillary tubes that are popular for use on refrigeration systems are the topics of Chapter 11. Accessories and how they fit into the overall system are presented in Chapter 12. Chapter 13 discusses both old and new refrigerants and their purpose and safe working procedures in overall system operation. Refrigerant recovery, recycling, and reclaim procedures are presented in Chapter 14. Chapter 15 is an introduction to electricity, how it works, and how it is used in refrigeration and air conditioning systems. Electric motors, their controls, and purpose in refrigeration and air conditioning systems are presented in Chapter 16.

TO THE READER

Study this material with assurance that you are being exposed to a very comprehensive presentation. I wish you the very best in your endeavors in this exciting industry.

Billy C. Langley

BRIEF CONTENTS

CONTENTS

CHAPTER

1

REFRIGERATION FUNDAMENTALS

OBJECTIVES

Upon completion of this chapter, you should be able to:

- Understand the fundamentals of refrigeration
- Define refrigeration
- Describe the theories of molecular motion
- Explain how chemical compounds exist
- Describe the three states of matter

INTRODUCTION

Cooling of some kind has been used since the beginning of time. In the early years, water and ice were used to provide cooling. It is only in the last century that mechanical refrigeration has been used on a wide basis. One of the earliest methods of providing cooling was with the ice box. Movie houses and department stores were the only places that used air conditioning in the early years.

The modern way of living requires that refrigeration equipment be used for the proper preservation of food and for human comfort. Many of the modern industrial and commercial processes, such as food storage, textile manufacturing, and printing, depend on the proper operation of air conditioning and refrigeration equipment for efficient, economical operation of the manufacturing processes and equipment.

There are many fields included in the refrigeration and air conditioning industry, such as physics and chemistry. Having good mechanical ability is very important to those who design, install, or service these systems. Customer relations is a very important aspect that must be practiced faithfully for success in this industry.

For those who are interested in selling, designing, manufacturing, servicing, and installing air conditioning and refrigeration equipment there are many opportunities available. Anyone who becomes proficient in any of the areas encompassed by this industry will be in great demand. However, before one can become proficient in this industry, it is necessary to thoroughly understand the basic principles of refrigeration.

1–1 FUNDAMENTALS

The fundamentals of refrigeration must be understood before any success can be achieved in this industry. There is a great desire by many beginners to bypass learning and understanding the underlying fundamentals necessary. When this step is taken, the learner is not going to have the foundation upon which to build a secure future.

Brief History of Refrigeration

As stated before, since the beginning of time people have used some means of food preservation. In the beginning, the food was lowered into a well or was stored in caves that were cooler than the surrounding temperatures. Then, natural ice was used. The ice was cut from rivers and lakes during the winter and stored until it was needed during the warmer weather.

When the harvesting of natural ice became efficient and plentiful, the ice box was more widely used. However, transporting the ice from the cooler to the warmer climates was a problem. Because of this, natural ice was considered a luxury. In some instances, ice frozen from dirty water and containing germs could not be safely used.

More than a century ago, an English scientist used pressure and a lower temperature to successfully change ammonia gas to a liquid. This was done by increasing the pressure and reducing the temperature. When the pressure was released, the ammonia liquid boiled off very rapidly and changed back to a gas. When the liquid changed to a gas, heat was absorbed from the objects surrounding the ammonia. This was an important discovery that eventually led to the development of the refrigeration equipment used today.

The first commercial ice machine was used around 1825. The ice machine produced ice that was purer than that made by nature. Also, the ice-making process did not depend on atmospheric conditions.

As time passed, the demand for more cooling was increased. The need for refrigeration became more apparent. This led to a varied and interesting industry. It

was discovered that when foods were stored below 50°F and above 32°F they lasted longer. The spoilage resulting from microbic growth or freezing was prevented. Today, this temperature range is known as the food safety zone, and is commonly known as safety zone refrigeration.

SUMMARY 1–1

- The fundamentals of refrigeration must be understood before success in the refrigeration industry can be achieved.
- Since the beginning of time people have used some means of food preservation.
- Natural ice was used for cooling foods but it sometimes contained germs and could not be safely used. Natural ice was considered to be a luxury.
- An experiment proved that adding pressure and lowering the temperature of ammonia gas could change it to a liquid.
- Safety zone refrigeration is between 50°F and 32°F, which is the most satisfactory storage temperature for food.

REVIEW QUESTIONS 1–1

1. Name two things that are very important for success in the refrigeration industry.
2. What are some of the early uses for air conditioning?
3. What is the major use of refrigeration in modern times?
4. What were the first methods used for cooling purposes?
5. Why does textile manufacturing depend on air conditioning?
6. For what health reason was natural ice not used?
7. What happens to a gas when its temperature is lowered and its pressure is raised?
8. What is the correct storage temperature range for foods?
9. What foundation is necessary before success in the refrigeration and air conditioning industry can be achieved?
10. What happens to a liquid when the pressure applied to it is released?

1–2 REFRIGERATION

Refrigeration is commonly defined as the process of removing heat from a space or material and maintaining that space or material at a temperature lower than its surroundings. Normally, a closed refrigerant circuit (system) is used to move the heat from inside the space or material and deposit it where it is not objectionable. As the refrigeration system continues to operate, more heat is removed from inside the space and both the space and its contents are further cooled. The more heat removed from a space the colder the objects inside that space become.

Refrigeration is the process used for cooling perishable foods, vegetables, and other products so that they remain usable for a longer period of time. Other processes such as air-conditioning and process cooling use refrigeration equipment to remove some of the moisture from the air and at the same time cool the air to a desirable temperature.

Refrigeration is made possible by the circulation of a fluid, called the refrigerant, through a series of pipes and devices, known as the system. During the circulation process, the refrigerant is compressed, cooled, and evaporated (changed to a vapor). The compressor causes the refrigerant to circulate through the system by causing an increase in pressure on one side of the system and a reduction of pressure on the other side. See Figure 1–1.

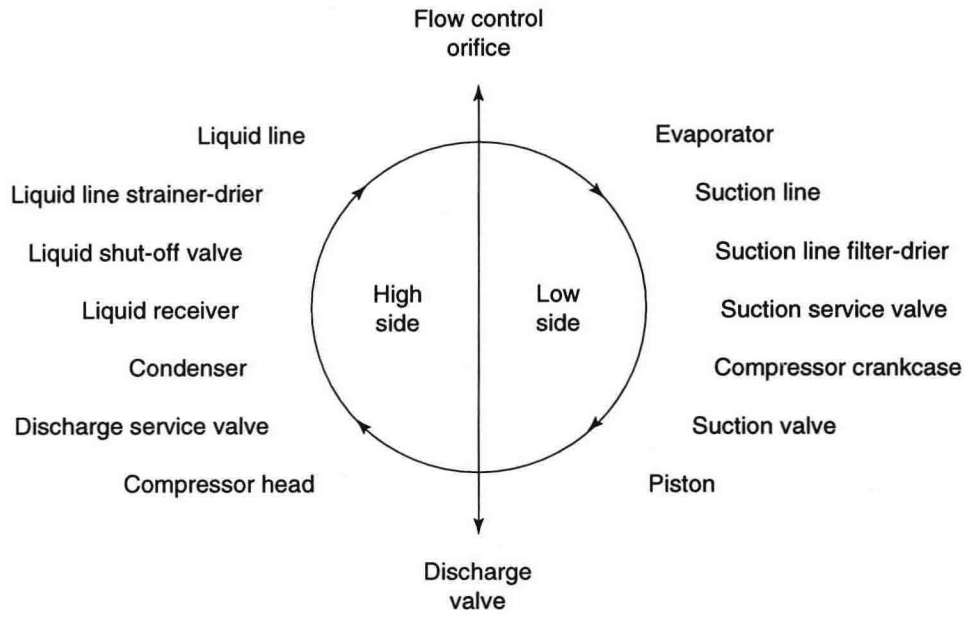

Figure 1–1 Refrigerant circuit diagram

During the operating cycle, the compressor discharges the compressed refrigerant into a device called the condenser. Here the refrigerant is cooled and liquefied. The liquid then flows through the piping to the flow control device, where the flow is metered and the pressure reduced. The refrigerant under lower pressure then flows into the evaporator where it evaporates, absorbing heat from the evaporator and its surroundings. In this process, the refrigerant absorbs heat and changes to a low pressure vapor. The compressor then pumps the refrigerant vapor from the evaporator through the suction line to the compressor, where the cycle is started over again.

This is a very brief explanation of the refrigeration system. However, for any degree of success in this industry, it should be apparent that people involved will need a basic understanding of physics and mechanics. The following sections in this book will provide more theories upon which to build your knowledge and help with advancement in your career.

SUMMARY 1–2

- Refrigeration is defined as the process of removing heat from a space or material and maintaining that space or material at a temperature lower than its surroundings.
- Normally a closed refrigerant circuit (system) is used to move this heat.
- Processes such as air conditioning and process cooling use refrigeration equipment to remove some of the moisture from the air and at the same time cool the air to some desirable temperature.
- As refrigerant flows through the circuit it is compressed, cooled, and evaporated.
- The compressor discharges the compressed refrigerant gas into the condenser.
- The gas is cooled and liquefied in the condenser.
- The flow control device meters the refrigerant into the evaporator.
- The compressor then pumps the refrigerant from the evaporator through the suction line to the compressor.
- People involved in this industry will need a basic understanding of physics and mechanics.

REVIEW QUESTIONS 1–2

1. What is the name of the closed circuit that is used to move heat from one place to another?
2. What is the name of the fluid that is circulated inside a closed system?
3. What must be done to a refrigerant when changing it from a gas to a liquid?
4. What happens to the refrigerant as it passes through the flow control device?
5. Briefly, what happens to the refrigerant in the evaporator?

1–3 COMMON ELEMENTS

There are currently more than 100 basic elements known to mankind. Of these, 92 of them are natural elements, with the remaining being synthetic, or manmade. Most substances are a combination of more than one element. The following is a discussion of the most common elements.

Aluminum, Cadmium, Chromium, Copper, Gold, Iron, Nickel, Silver, Tin, Tungsten, and Zinc. These elements are generally considered to be metals and are most often used alone in objects. There are, however, some found in mixtures, or compounds, commonly known as alloys. These elements are usually present in the solid form.

Calcium, Potassium, Silicon, Sodium, and Sulphur. These elements are found in many materials; however, they are almost always found in chemical combination with other elements. They are generally found in the solid form.

Carbon. This is the major element found in coal, cloth, gasoline, natural gas, oil, and paper. It may also be found in carbon dioxide, methyl chloride, and the fluorocarbon refrigerant that is presently used in refrigeration and air conditioning systems. It exists as a solid at atmospheric pressures and temperatures.

Nitrogen. Nitrogen constitutes about 78 percent of the air around us. It is very important in the growth and life of plants and it is found in nature as a gas.

Oxygen. The atmosphere is made up of about 21 percent oxygen. Oxygen is essential to all animal and human life. Oxygen is an active element that combines readily with most other chemicals to form oxides or more complex chemicals. It is found in nature as a gas.

Air. Air is made up of about 21% oxygen and 78% nitrogen. The other 1% is made up of other gases, namely argon, carbon dioxide, helium, hydrogen, krypton, ozone, and xenon.

Hydrogen. Hydrogen is commonly found in many compounds. It is especially important in the structure of acids, fuels, and oils. It is seldom found alone in nature. It is an extremely light gas form. When it is burned, water is formed. Burning is the process of properly combining hydrogen and oxygen. It is the process used in combustion furnaces and boilers.

SUMMARY 1–3

- Nitrogen constitutes about 78% of the air around us.
- The atmosphere is made up of about 21% oxygen. Oxygen is essential to all animal and human life.
- Air is made up of about 21% oxygen and 78% nitrogen. The other 1% is made up of other gases.
- Hydrogen is especially important in the structure of acids, fuels, and oils.

REVIEW QUESTIONS 1–3

1. What percentage of the air around us is nitrogen?
2. What component in the atmosphere is about 21%?
3. What element in the atmosphere combines with other chemicals to form more complex chemicals?
4. What atmospheric element is important in the structure of acids, fuels, and oils?
5. What is formed when hydrogen is burned?

1–4 ATOMS, MOLECULES, CHEMICAL COMPOUNDS, AND MOLECULAR MOTION ATOMS

Atoms are the particles that form to make up each element. They number into the millions in each element. An atom is the smallest particle that makes up an element. An atom is so small it cannot be seen even with a very strong microscope. For the purposes of this text we will consider an atom as invisible and unchangeable. It cannot be divided by ordinary means. The atoms that make up all elements in the universe are different; thus, iron is made up of iron atoms, and hydrogen is made up of hydrogen atoms.

Scientific study has revealed many things about atoms. However, how they are known is beyond the scope of this text. We must accept some things as being true if we are to understand the fundamentals of refrigeration.

Molecules. The molecule is just larger than an atom and is the next larger particle of a substance. A molecule is made up of one or more of only one kind of atom. They are generally referred to as a molecule of that element. It is possible for a molecule to contain more than one kind of atom. It must be remembered, however, that a molecule can contain several of the same type of atom. As an example, a molecule of iron contains only one iron atom, while a molecule of sulphur will contain eight sulphur atoms.

A very small piece of any element is made up of billions of molecules. Each of these molecules is made up of one or more atoms of that same element.

Chemical Compounds. The molecules that combine to form a chemical compound are made up of two or more atoms from different elements. This combining of the different elements causes the substance to become something entirely different. The new substance probably has none of the characteristics of either of the other elements that combine to make it. For example, a molecule of water is made up of two atoms of hydrogen and one atom of oxygen, both of which are a gas.

The refrigerants that are used in refrigeration systems are prime examples of some of the chemical compounds that are found in this industry.

Many of the common substances that we use in our everyday lives are chemical compounds, such as table salt, baking soda, and calcium.

Molecular Motion. From the previous information it should be understood that all matter is made up of very small particles known as molecules. These molecules may exist in one or a combination of three states. These three states are solids, liquids, and gases. Molecules can be broken down into their components, which are known as atoms. The chapter on basic electricity will discuss atoms in much more detail.

However, in this unit we will discuss the theory of molecular motion and its action as it is used in refrigeration and air conditioning. The amount of movement or vibration of the molecules is what determines the amount of heat present in any given body, or substance. This heat is produced through the friction of the molecules