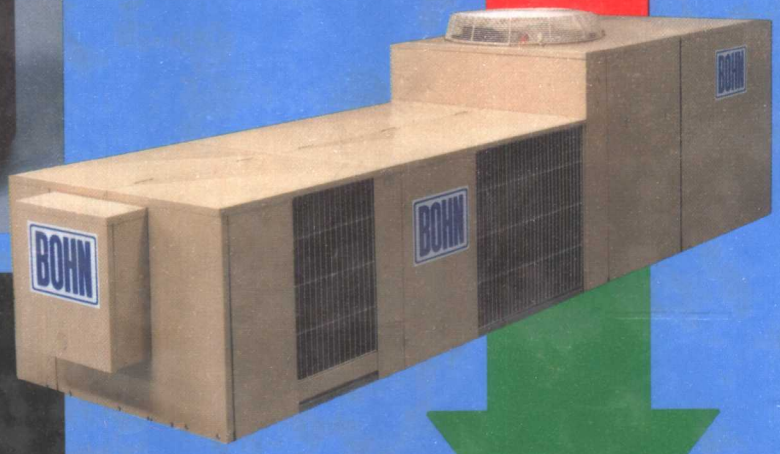
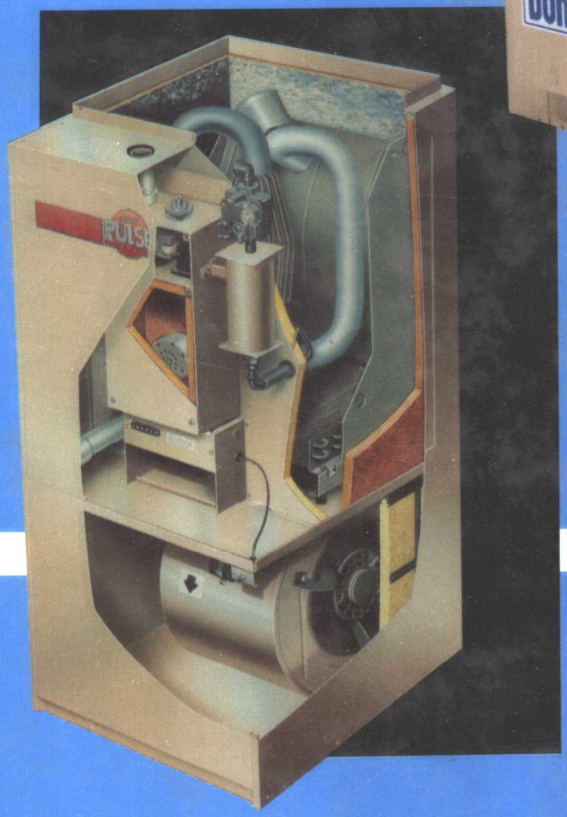
REFRIGERATION & AIR CONDITIONING TECHNOLOGY





WILLIAM C. WHITMAN
WILLIAM M. JOHNSON

REVISED

REFRIGERATION AND AIR CONDITIONING TECHNOLOGY

Concepts, Procedures, and Troubleshooting Techniques

WILLIAM C. WHITMAN
WILLIAM M. JOHNSON

Central Piedmont Community College
Charlotte, North Carolina

delmar publishers inc.

Revised to Include Three Units on Domestic Appliances

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PREFACE

Refrigeration and Air Conditioning Technology was written because we felt that a text was needed to better suit the students and instructional staff in the Air Conditioning and Refrigeration Technology program at our institution.

The text is flexible enough to meet the needs of most readers. After completing the first three sections, you may concentrate on courses in refrigeration or air conditioning (heating and/or cooling). If your objective is to complete a whole curriculum, you may proceed until you have finished the sequence scheduled by your school's curriculum.

We have tried to make the text easy to read and to present the material in a practical way, using everyday language and occasionally using terms more commonly used by mechanics and technicians. Our approach to electrical application, for instance, differs from standard treatments—we classify components as "power passing" or "power consuming."

Objectives are listed at the beginning of each unit. A summary and review questions are provided at the end of each unit. Students should answer the questions while reviewing what they have read; instructors can use the questions to stimulate class discussion and for classroom unit review. The questions are not necessarily designed for testing.

Practical troubleshooting procedures are a main feature of this text. There are practical component and system troubleshooting suggestions and techniques. In many units practical examples of service technician calls are presented in a down-to-earth situational format.

One unit is dedicated to general safety precautions. This includes general safety procedures and describes tools and equipment that can be used to prevent injury. Specific safety techniques and tips are highlighted throughout the text.

A significant feature of this text is the section on heating. We tried to include heating systems found throughout the country. Obviously some of these heating systems are more appropriate for some geographical areas than others. These heating systems are presented separately by unit so that a unit can easily be skipped if the instructional program does not include it. At the suggestion of several people, we have included a unit on wood heat.

Another section is devoted to all-weather systems and heat pumps. The number of heat pump installations in temperate climates have risen dramatically. Some increase has also occurred in the colder areas.

This text covers some older systems of heating and cooling as well as newer designs since there are thousands of older systems still existing that need servicing.

Refrigeration and Air Conditioning Technology can be used by students as a general reference after completing their program of study. Salespeople, suppliers, contractors, installers, and service technicians can also benefit from the use of this text.

We would like to thank the following reviewers for their help in developing this text. Bill Abernathy, formerly of Orange Coast College; Herschael Blitz, Wayne County Community College; Harvey Castelaz, Milwaukee Area Technical College; Walter Hilmes, Indiana Vocational Technical College; and Henry Puzio, Lincoln Technical Institute.

BRIEF CONTENTS

CONTENTS

Section One
Theory of Heat

1

THEORY

OBJECTIVES

After studying this unit, you should be able to

- **define temperature.**
- **make general comparisons between Fahrenheit and Celsius scales.**
- **describe molecular motion at absolute 0.**
- **define the British thermal unit.**
- **describe heat flow between substances of different temperatures.**
- **explain the transfer of heat by conduction, convection, and radiation.**
- **discuss sensible heat, latent heat, and specific heat.**
- **state the atmospheric pressure at sea level and explain why it varies at different elevations.**
- **describe two types of barometers.**
- **explain psig and psia as they apply to pressure gages.**

1.1 TEMPERATURE

The word "temperature" is used in everyday discussions or descriptions about comfort, weather, and food preparation. It is used in many conversations and decision-making processes by people who still do not know exactly how far-reaching the word is or what it really means.

Temperature can be thought of as a description of the level of heat. For now, heat can be thought of as energy in the form of molecules in motion. The starting point of temperature is, therefore, the starting point of molecular motion. To describe this in more usable terms, we will describe some more familiar points of reference.

Most people know that the freezing point of water is 32 degrees Fahrenheit (32°F) and that the boiling point is 212 degrees Fahrenheit (212°F). These points are commonly indicated on a thermometer.

Early thermometers were of glass-stem types operating on the theory that when the substance in the bulb was heated it would expand and rise up in the tube, Figure 1–1. Mercury and alcohol are still commonly used today for this application. More information

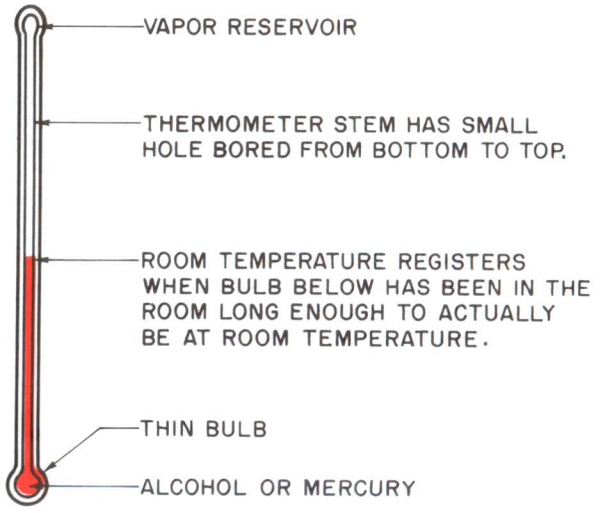

Figure 1–1. Thermometer.

about temperature measurement is found in the section on automatic controls.

We must qualify the statement that water boils at 212°F. Pure water boils at precisely 212°F at sea level when the atmosphere is 68°F. This qualification concerns the relationship of the earth's atmosphere to the boiling point and will be covered in detail later in this section in the discussion on pressure. The statement that water boils at 212°F at sea level when the atmosphere is 68°F is important because these are standard conditions that will be applied to actual practice in later units.

Pure water has a freezing point of 32°F. Obviously the temperature can go lower than 32°F, but the question is, how much lower?

The theory is that molecular motion stops at −460°F. See Figure 1-2 for an illustration of the levels of heat or molecular motion shown on a thermometer scale. This is theoretical because molecular motion has never been totally stopped. The complete stopping of molecular motion will be recorded as absolute zero. This has been calculated to be −460°F. Scientists have actually come within a few degrees of reaching absolute zero.

Temperature can also be expressed in degrees Centigrade or, more commonly, Celsius. The weather forecaster often uses the term "Celsius." Celsius and Fahrenheit both express the level of heat, but they do it in different terms, Figure 1-2.

Temperature has been expressed in everyday terms up to this point. It is equally important in the air conditioning, heating, and refrigeration industry to describe temperature in terms engineers and scientists use. Performance ratings of equipment are established

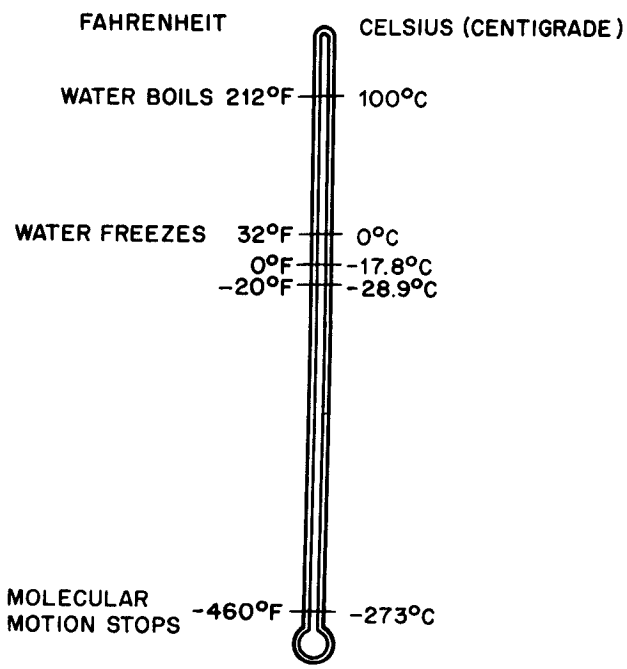

Figure 1-2. Fahrenheit scale compared to Celsius scale.

in terms of *absolute* temperature. Equipment is rated to establish criteria for comparing equipment performance. In other words, different manufacturers make similar claims about their products. We can use the equipment rating to evaluate these claims. The Fahrenheit absolute scale is called the *Rankine* scale (named for its inventor W. J. M. Rankine), and the Celsius absolute scale is known as the *Kelvin* scale (named for the scientist, Lord Kelvin). Absolute temperature scales begin where molecular motion starts; they use 0 as the starting point. For instance, 0 on the Fahrenheit absolute scale is called absolute zero or 0° Rankine (0°R). Similarly, 0 on the Celsius absolute scale is called absolute zero or 0° Kelvin (0 K). See Figure 1-3.

The Fahrenheit, Celsius and the Rankine, Kelvin scales are used interchangeably to describe equipment and fundamentals of this industry. Memorization is not very important. To be able to work back and forth from degrees Fahrenheit to degrees Rankin, with Celsius and Kelvin surfacing from time to time, is too much to ask. A working knowledge of these scales and a ready reference table are more practical. Figure 1-3 shows how these four scales are related. The world that we live in accounts for only a small portion of the total temperature spectrum. The thermometer scale illustrated in Figure 1-4 shows some examples of how typical temperatures compare.

Our earlier statement that temperature describes the level of heat or molecular motion can now be explained. As a substance becomes warmer, the molecular motion, and therefore the temperature, increases, Figure 1-5.

1.2 INTRODUCTION TO HEAT

The laws of thermodynamics can help us to understand what heat is all about. One of these laws states that heat can neither be created nor destroyed. This means that all of the heat that the world experiences is not created but is merely converted to usable heat from something that is already here. This heat can also be accounted for when it is transferred from one substance to another.

Heat can now be more fully explored by using temperature as one of the describing factors. Remember, temperature describes the level of heat with reference to no heat. The term used to describe the quantity of heat is known as the *British thermal unit* (Btu). This term explains how much heat is contained in a substance. The rate of heat consumption can be determined by adding time to the picture, but more on this later.

The Btu is defined as the amount of heat required to raise the temperature of 1 lb of water 1°F. For example, when 1 lb of water (about 1 pint) is heated from 68° to 69°F, 1 Btu of heat energy is absorbed into the water, Figure 1-6. To actually measure how much heat is absorbed in a process like this, we need

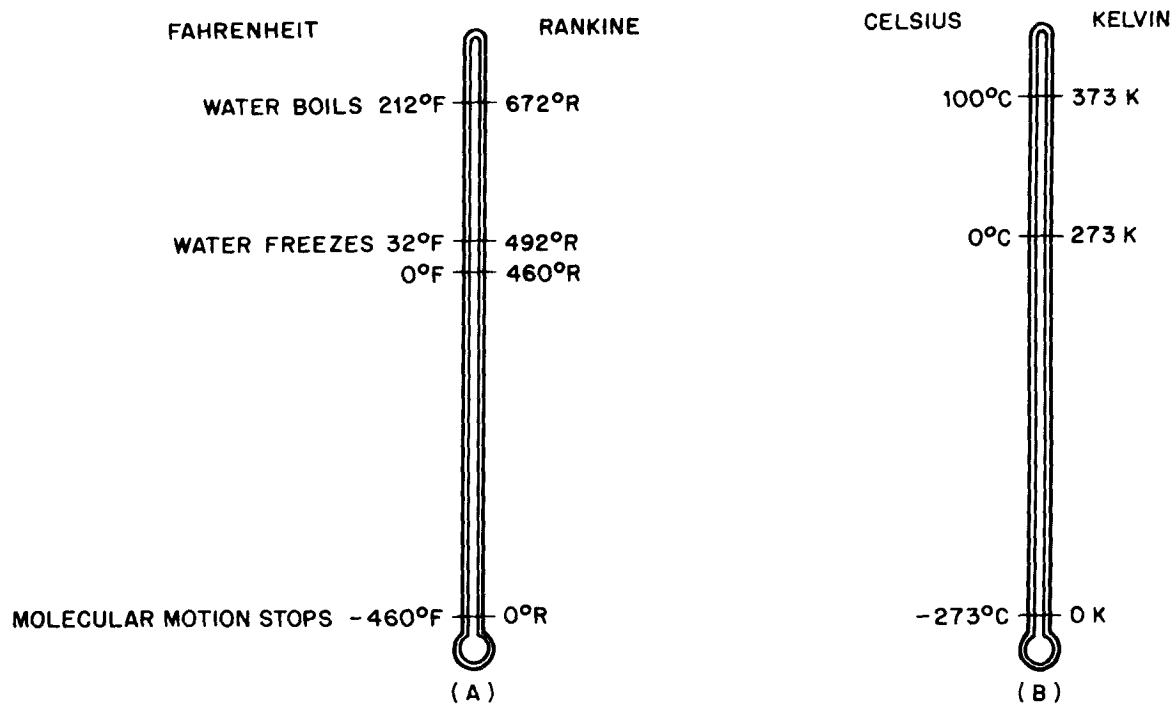

Figure 1-3. (A) Fahrenheit and Rankine thermometer. (B) Celsius and Kelvin thermometer.

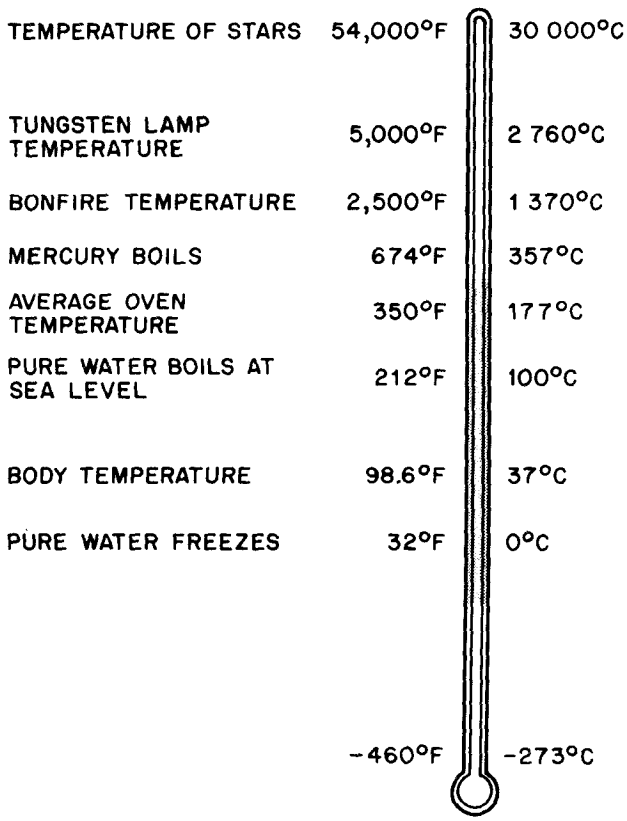

Figure 1-4. Civilization is generally exposed to a comparatively small range of temperatures.

an instrument of laboratory quality. This instrument is called a *calorimeter*. Notice the similarity to the word "calorie," the food word for energy.

Heat flows naturally from a warmer substance to a cooler substance. Rapidly moving molecules in the warmer substance give up some of their energy to the slower-moving molecules in the cooler substance. The warmer substance cools because the molecules have slowed. The cooler substance becomes warmer because the molecules are moving somewhat faster.

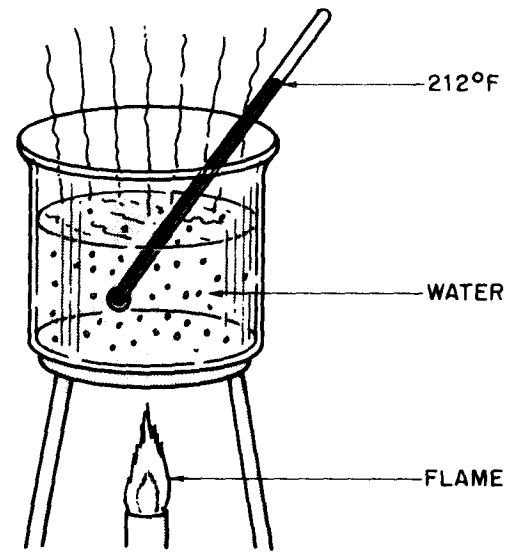

Figure 1-5. The water in the pot boils because the molecules move faster when heat is applied.

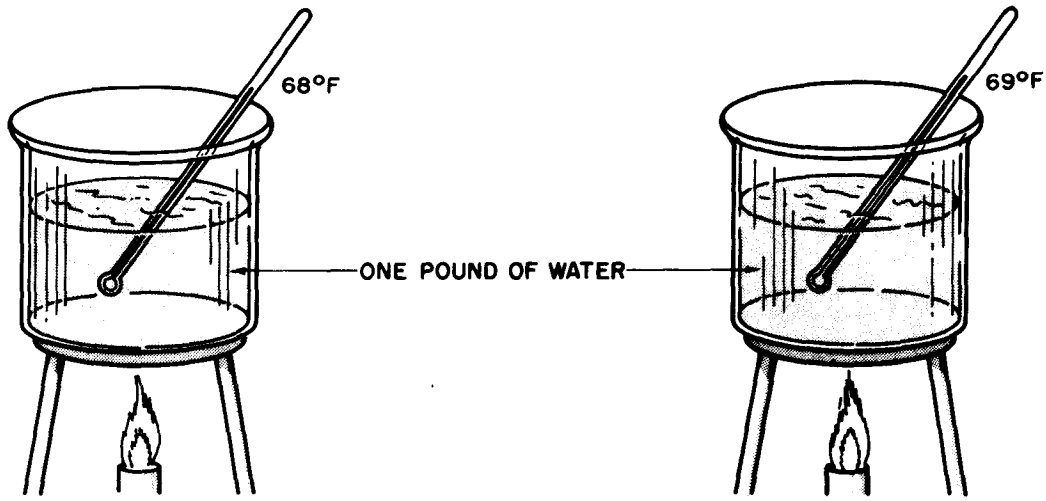

Figure 1-6. 1 British thermal unit (Btu) of heat energy is required to heat 1 lb of water from 68°F to 69°F.

The following example will illustrate the difference in the amount or quantity of heat compared to the level of heat. One tank of water weighing 10 lb (slightly more than 1 gallon) is heated to a temperature level of 200°F. A second tank of water weighing 100,000 lb (slightly more than 12,000 gallons) is heated to 175°F. It is easy to imagine that the 10-lb tank will cool to room temperature much faster than the 100,000-lb tank. The temperature difference of 25°F is not very much, but the cool-down time is much longer for the 100,000-lb tank, Figure 1-7.

A comparison using water is always helpful in showing the level verses the quantity of heat. A well with 200 ft of water would not have nearly as much water as a large lake with 25 ft of water. The depth of water (in feet) tells us the level of water, but it in no way expresses the quantity (gallons) of water.

In practical terms, each piece of heating equipment is rated according to the amount of heat it will produce. If the equipment had no such rating, it would be difficult for a buyer to intelligently choose the correct appliance.

A gas or oil furnace used to heat a home has the rating permanently printed on a nameplate. Either furnace would be rated in Btu per hour, which is a *rate* of energy consumption. Later, this rate will be used to calculate the amount of fuel required to heat a house or a structure. For now, it is sufficient to say that if one needs a 75,000-Btu/h furnace to heat a house on the coldest day, a furnace rated at 75,000 Btu/h should be chosen. If not, the house will begin to get cold on any day the temperature falls below the capacity of the furnace.

1.3 CONDUCTION

Conduction heat transfer can be explained as the energy actually traveling from one molecule to another.

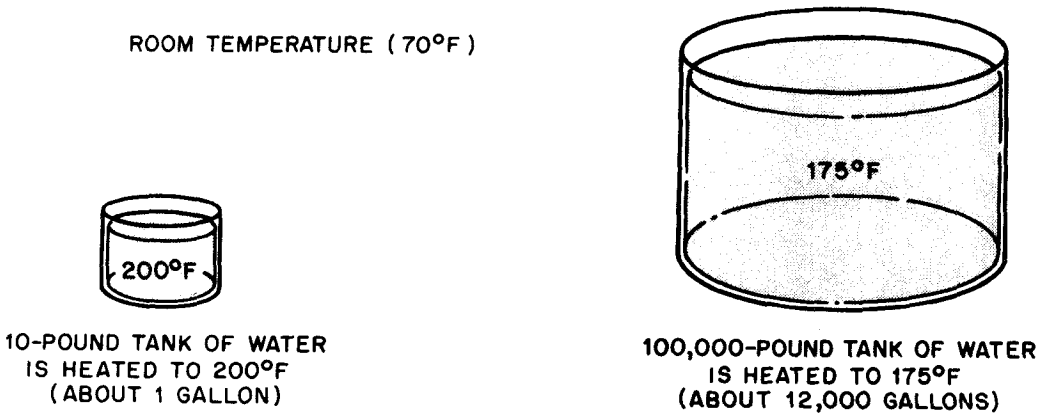

Figure 1-7. The smaller tank will cool to room temperature first because there is a smaller quantity of heat.