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FOURTH EDITION

COMMERCIAL REFRIGERATION

FOR AIR CONDITIONING TECHNICIANS

DICK WIRZ

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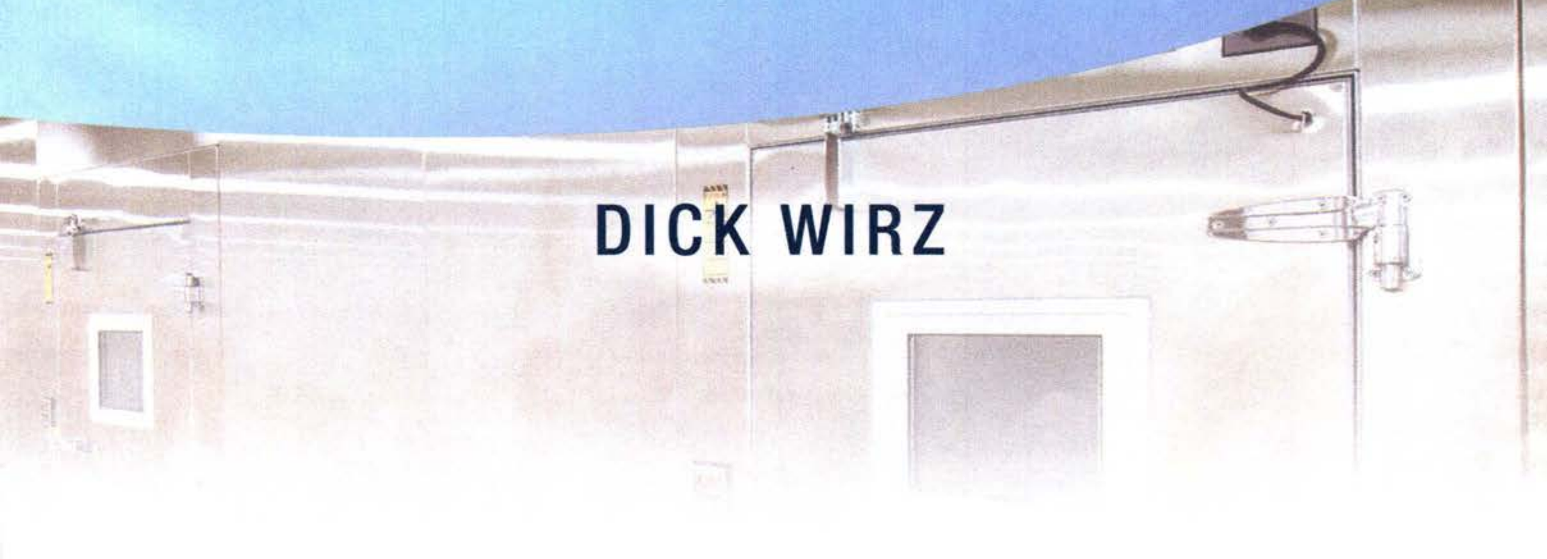

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Commercial Refrigeration for Air Conditioning Technicians,
4th Edition

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PREFACE

COMMERCIAL REFRIGERATION FOR AIR CONDITIONING TECHNICIANS

by Dick Wirz

This book is written for refrigeration technicians, air conditioning (A/C) technicians and advanced A/C students. Commercial refrigeration as a specific subject is taught in only about 10 percent of the schools that have HVACR programs. As a result, there are very few A/C students and technicians exposed to this related technology. The industry certainly needs technicians trained in A/C. However, if A/C technicians also understand commercial refrigeration, they will be more valuable to their companies and their customers.

ORGANIZATION

The first six of the fourteen chapters combine a review of refrigeration theory and an introduction to how those principles are specifically applied to commercial refrigeration equipment. Wherever possible, refrigeration concepts are compared with those of A/C. This makes it easier for HVACR students and technicians to relate what they already know about A/C to the field of commercial refrigeration.

Chapter 7 applies the information in the first six chapters to the troubleshooting of nine common refrigeration system problems. It also includes a diagnostic chart for the reader to use in class, as well as on the job. Chapters 4 and 8, on compressors and motor controls, also have their share of troubleshooting instructions. Chapter 9 covers retrofitting, recovery, evacuation, and charging in greater detail and with more practical applications than found in other HVACR textbooks.

Chapter 10 is an introduction to the fascinating world of supermarket refrigeration. It provides insights into the multicompressor rack systems, the various temperature applications, electronic controllers, and the supermarket equipment manufacturers' pursuit of providing optimum efficiency while addressing global environmental concerns.

Chapter 11 covers walk-ins and reach-ins, while Chapter 12 deals with the basics of ice machines. Chapter 13 is a short but important look at the role of the refrigeration technician in food preservation and health issues.

Chapter 14 looks at the business side of this industry. Many HVACR technicians eventually become part of management or even start their own companies. This chapter provides a glimpse of what their employers deal with on a daily basis. By gaining these insights, technicians can become a more supportive and vital part of their organizations.

FEATURES

Chapters 6 through 11 have Service Scenarios, which are real-life situations that exemplify concepts described in those chapters.

Throughout the book, there are tips called Technician's Rules of Thumb (TROT). These practical bits of information are a collection of practices that experienced technicians use to help them service equipment better and more quickly. There is a complete list of these rules of thumb included in the appendix. The appendix also contains pressure/temperature (P/T) charts for the refrigerants mentioned in the book as well as those currently used in most refrigeration applications.

SUPPLEMENTS

Most HVACR technicians are very visual learners. Therefore, both the print and digital versions of this text include many pictures and drawings to illustrate what has been written in the text. The supplements include PowerPoints for instructors to use in their classroom, MindTap to provide assessments of student learning and the answers to the Chapter Review Questions on the Instructor Companion Site.

We have made significant advancements in the digital offerings of this product. We continue to provide instructors with more online teaching opportunities through products such as MindTap, which integrate well in learning management systems.

WHAT IS NEW IN THE FOURTH EDITION

Of course, there were some corrections that needed to be made. It takes many skilled people to produce a technical book such as this, and extensive editing is done to prevent errors. Unfortunately, errors do occur. Thanks so much to all of you who took the time to email your comments and suggestions to me at teacherwirz@cox.net. Once notified, necessary updates can be made.

Key Terms have been added at the beginning of each chapter to provide students with a convenient list of terms introduced in that chapter. The Glossary provides definitions of the Key Terms. The review questions are a mix of multiple-choice and essay questions with rationales included.

MindTap includes electronic Flash Cards, Video links to service scenarios, and HVAC Simulations for the user.

Chapter 7, Refrigeration System Troubleshooting, has been completely revised and simplified. There is less emphasis on evaporator TD and condenser split in diagnosing and more on determining the proper evaporator and condensing temperatures. The examples utilize more current refrigerants. The diagnostic chart has combined similar problems in order to add three additional problem areas, yet still maintain a total of nine diagnoses.

Chapter 9, Retrofitting, Recovery, Evacuation, and Charging. The outdated sections about retrofitting R12 and R502 systems have been eliminated. Wherever possible throughout the book, discussion of R22 in commercial refrigeration examples has been replaced by R404A. High-glide refrigerants such as R448A are discussed at great length in Chapter 9. The reader will learn how to properly determine superheat, subcooling, and condensing and evaporator temperatures, and how to set operating controls on equipment with high-glide refrigerants. An overview of propane (R290) as a refrigerant is also included. Because of safety and liability concerns, the reader is directed to the equipment manufacturer for the specifics of proper handling of flammable refrigerants.

Chapter 11, Walk-in Refrigerators and Freezers. Two more insightful and interesting Service Scenarios have been added.

ABOUT THE AUTHOR

My career in HVACR started with a summer job in 1963. For the first eight years, I installed ductwork and serviced residential A/C and heating equipment. Over the next thirty years, I enjoyed the world of commercial refrigeration. I am a licensed Master HVACR Technician and Master Electrician in several states. I am certified by RSES (Refrigeration Service Engineers Society), North American Training Excellence (NATE), and ESCO (HVAC Excellence). For more than twenty-five years, I was president and co-owner of a successful commercial refrigeration company. After retiring in 2000, I enjoyed teaching HVACR and producing animated PowerPoints for HVACR instructors. In this way, I was able to repay some of the many benefits I have received from a very rewarding career in the HVACR industry.

I graduated from Virginia Tech with a degree in business management and a minor in mechanical engineering. Twenty years later, I returned to school to earn my master's in business administration in order to qualify as a community college professor upon retiring from my refrigeration company. To help me become a more effective instructor, I spent two years in a postgraduate program at George Mason University, where I earned a certificate in community college teaching. In 2014, I retired from full-time teaching after nearly fifteen years at Northern Virginia Community College, Woodbridge Campus. My wife and I continue to produce teaching aids under the corporate name of Refrigeration Training Services (www.hvacteaching.com) for HVACR programs in the form of animated PowerPoints.

ACKNOWLEDGMENTS

I would like to thank my wife, Irene, for her tremendous help in this project. She provided all the graphics used in the book and in the instructor PowerPoints. Without her editing, graphics, software expertise, and support, this book never would have become a reality.

I would also like to thank the many people who have contacted me since the first edition of the book was published. Your appreciation has enforced my belief that the tremendous amount of work that goes into this project has been beneficial to thousands of students, teachers, and technicians. Your comments helped shape the changes and updates in each edition.

A special thanks goes out to Holly Villarreal for her technical expertise and writing, and to Jess Lukin for so many service scenarios and pictures. Also to Gary Purdue, Bill McDonald, Manolo, and Mike Hynes for their service scenarios. Their real-life service situations have made the material in the book come alive and become more relevant. I hope some of you reading this will contribute for the next edition. Andre Patenaude of Emerson provided expert information and editing of the section about CO_2 in supermarket applications. I learned much from John Whithouse, Parker/Sporlan, who wrote an enlightening paper on high-glide refrigerants. Dave Demma, formerly with Sporlan and currently with United Refrigeration, Inc., provided me with on-the-job training with supermarket refrigeration many years ago. I have included his insights on properly checking for leaks on large supermarket systems. And finally Andy Shoen, formerly with Sporlan and currently with Sanhua, has been my go-to source for control valve questions for nearly twenty years. Networking with industry contacts such as these has helped make my writing relevant, accurate, and informative.

The information in this book has provided thousands of techs with a firm understanding of commercial refrigeration, which is so important to those who wish to progress and prosper in this industry. However, I will be 77 in 2021 when the fourth edition is published, and I am asking for the help of instructors and technicians who have used this book to provide me with comments as to what current information is needed.

This book is essential to providing a step-by-step learning experience upon which to build knowledge of commercial refrigeration. Cengage is doing all it can to make that learning accessible. In addition, I am especially impressed by those emerging in this digital age to make learning easy and fun. Bryan Orr of Kalos Services in Clermont, Florida, started HVAC School to provide free online training in HVACR "for techs by techs." Chris Stephans is a tech who has developed a vast collection of service scenarios under HVACR Videos on YouTube. Bryan and Chris are two fine examples of how additional training is readily available within our industry to supplement this book.

Teaching and training have been a rewarding, yet humbling, experience for me. Although I thought I knew HVACR well, I soon realized that there was much more I

needed to master in order to teach the subjects. Someone once told me, "You can never know everything about anything, but you have to keep trying." Now I realize how true those words are. I have become a lifelong student, and I encourage the same thirst for knowledge in those I teach. I believe you must agree because you have taken the time to pick up this book and read at least this much of it. Thank you.

FEEDBACK

Please use the email below to contact me. I enjoy hearing from techs all over the world who like this industry and have benefitted from what I have written. In addition, I appreciate the wealth of insightful comments made by instructors such as Jon Hamel of Truckee Meadows Community College and Joe Owens of Antelope Valley Community College.

Thank you for using this book. I am sure what you learn will be of great benefit to your success in this industry. I also hope this text will become an important part of your technical library. As you gain knowledge and experience, I encourage you to share it with others. If those you work with are doing a better job, it not only makes it easier for you but helps you progress higher in your organization. It is not a matter of *if* we will become teachers, but *when* we will become teachers.

Dick Wirz
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1 REFRIGERATION

CHAPTER OVERVIEW

This chapter begins by explaining what this book is about and for whom it is written. This is followed by a thorough review of the refrigeration cycle. Next, air conditioning is compared with commercial refrigeration; both their similarities and their differences are explained. The newer refrigerants used in commercial refrigeration are also covered. Finally, the four basic components of a refrigeration system are discussed.

OBJECTIVES

After completing this chapter, you should be able to

- Describe temperature ranges of refrigeration
- Describe the refrigeration cycle
- Relate refrigeration to air conditioning
- Describe the relationship between a refrigerant's pressure and temperature
- Describe the newer refrigerants used in commercial refrigeration systems
- Describe the relationship among the four basic components of a refrigeration system

KEY TERMS

Subcooling
Ambient
Superheat
Latent heat
Saturated
Sensible heat
Condenser split
De-superheat
Zeotropes
Glide
Dew point
Bubble point
TROT (Technician's Rules of Thumb)
Mirror image

INTRODUCTION

Most technicians tend to specialize in a single type of air conditioning (AC) application, such as residential, light commercial, or heavy commercial systems. However, very often, opportunities arise outside a technician's primary area of expertise, so it is smart to be knowledgeable in more than one specialty. For instance, a company that provides good service on a restaurant's AC may be asked to service its commercial refrigeration equipment. Likewise, a building engineer who competently handles the large chillers of a commercial building may have their responsibility expanded to include maintaining refrigeration and ice machines in the building's cafeteria.

The primary objective of this book is to help AC technicians understand commercial refrigeration. Someone once said, "Luck is preparation meeting opportunity." The more knowledge areas technicians master, the better they can take advantage of any opportunities that arise.

Therefore, *Commercial Refrigeration for Air Conditioning Technicians* is written for both experienced AC technicians and students who have a firm basis in AC theory. This first chapter is intended to be a review of basic refrigeration as well as an introduction to the similarities and differences between AC and commercial refrigeration.

Throughout this book, a key word or phrase used for the first time that may not be familiar to all readers will be in **blue** font type. A list of key words is on the first page of each chapter beside Chapter Overview and Objectives. These words and phrases will also be included in the glossary.

TEMPERATURE RANGES OF REFRIGERATION

The following is a list of the space temperatures of the more common ranges of refrigeration discussed in this book:

- 75°F, AC (comfort cooling)
- 55°F, high-temperature refrigeration
- 35°F, medium-temperature refrigeration
- –10°F, low-temperature refrigeration
- –25°F, extra-low-temperature refrigeration

Most of the examples in the next few chapters are concerned with medium- and low-temperature applications. Medium-temperature walk-in refrigerators (aka walk-in coolers) usually operate at a range of 35°F to 37°F, whereas reach-in refrigerators run at slightly higher temperatures, from 38°F to 40°F. Walk-in freezers normally run at –10°F, and reach-in freezers operate at about 0°F.

The difference between the temperatures in walk-ins and reach-ins is mainly due to how the box is used and how the equipment is designed. The lower temperatures of walk-ins allow them to keep large amounts of product fresh for relatively longer periods of time.

Reach-ins, on the other hand, are used more for convenience. Because they are smaller than walk-ins, reach-ins can be located closer to where they are needed. A reach-in is usually restocked from a walk-in at least once a day. Therefore, the slightly higher storage temperature of a reach-in is acceptable because the product is in the box for a relatively shorter period of time.

THE REFRIGERATION CYCLE

Figure 1-1 is an illustration of a very simple AC system showing a compressor and an expansion valve; cylindrical tanks represent the condenser and evaporator. The pressures and temperatures represent those of a standard-efficiency R22 AC system on a 95°F day.

NOTE: At one time, R22 was used in both AC and medium-temperature walk-ins. Therefore, it is used in this chapter to help the reader focus on temperature differences between AC and commercial refrigeration rather than the different refrigerant pressures currently used for the two types of equipment.

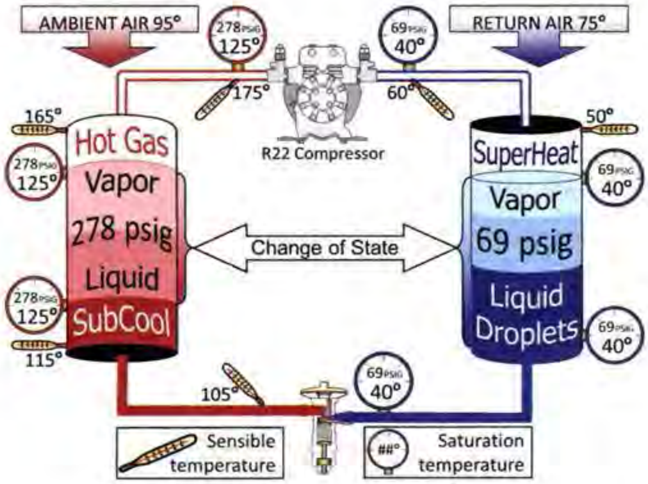
The compressor develops a pressure of 278 pounds per square inch gauge (psig) and discharges superheated vapor at 175°F. The vapor drops to 165°F when it enters the condenser and continues to be cooled by the air around the cylinder. When the vapor temperature falls to 125°F, the gases start to condense into droplets of liquid—the vapor has reached its condensing temperature, which is the saturation temperature of R22 refrigerant at a pressure of 278 psig (refer to the pressure/temperature [P/T] chart in the appendix). The condensing continues at 125°F until all the vapor turns to liquid at the bottom of the tank. Additional cooling, called **subcooling**, of that liquid by the 95°F **ambient** air reduces the temperature of the liquid to 115°F as it leaves the bottom of the condenser. By the time the liquid enters the expansion valve, it has been further subcooled to 105°F.

During this process, the pressure in the high side of the system, between the compressor outlet and the expansion valve inlet, remains constant at 278 psig. However, the refrigerant changes temperature when the hot discharge gas cools, then subcools, as it flows through the condenser. The significance of these different temperatures is important in understanding the refrigeration process.

Low-Pressure Side of the System

As the 278-psig liquid refrigerant goes through the thermostatic expansion valve (TEV), its pressure drops to 69 psig. The 209-psig decrease in pressure, from one side of the valve to the other, is accompanied by a decrease in temperature. The TEV acts like a garden-hose nozzle, changing the solid stream of liquid from the condenser to a spray mixture of vapor and liquid refrigerant droplets. Small droplets are more easily boiled off in the evaporator than a solid stream of liquid is. The R22 refrigerant boils, or evaporates, at 40°F when its pressure is reduced to 69 psig (refer to the P/T chart in the appendix).

FIGURE 1-1 **Simple R22 AC system.** *Courtesy of Refrigeration Training Services.*



The heat from the 75°F air blowing across the tank is absorbed into the refrigerant, causing the refrigerant droplets to boil. The refrigerant temperature remains at 40°F until all of it has vaporized. Only then will its temperature rise as it absorbs more heat from the surrounding air. By the time the suction vapor leaves the tank, the refrigerant temperature will be raised to 50°F. The temperature of the refrigerant above its 40°F boiling point (saturation temperature) is called **superheat.**

How Is Heat Absorbed into the Evaporator?

Starting at the TEV, a fog of liquid droplets is sprayed into the tank. The warm air blowing over the evaporator tank is cooled as its heat is absorbed into the boiling refrigerant. Much more heat is absorbed in the refrigerant as it boils off than is absorbed before or after it has boiled. Boiling, or the change of state from a liquid to a vapor, absorbs heat without a change in temperature. Strange as it may sound, this temperature change cannot be measured with a thermometer. Almost all the refrigerating effect achieved in the evaporator is accomplished as the refrigerant boils. The type of heat absorbed during the evaporation process is called **latent heat**. The ability to remove tremendous amounts of heat in a small area makes it possible for manufacturers to design refrigeration systems small enough to be used in both homes and businesses.

When the refrigerant is fully vaporized, it is totally **saturated** with all the latent heat it can absorb. The 40°F saturated vapor can raise its temperature only by absorbing **sensible heat.** This sensible heat can be measured with a thermometer, and any temperature rise above the refrigerant's saturation temperature is called superheat.

How Does the Condenser Get Rid of the Heat Absorbed by the Evaporator?

To reject the heat absorbed by the evaporator, as shown in Figure 1-1, the cool suction vapor must be raised to a temperature higher than the 95°F outside air. In Figure 1-1, the refrigerant temperature is increased to 125°F. The 30°F difference between the condensing temperature and the outdoor air is great enough to easily transfer heat from the hot condenser to the warm outdoor air.

NOTE: The greater the difference in temperature between two substances, the faster the transfer of heat from one to the other.

Compressing the 69-psig suction vapor to 278 psig increases its boiling point from 40°F to 125°F (see the P/T chart in the appendix). Raised to 125°F, the vapor from the evaporator releases latent heat to the cooler ambient air as the refrigerant condenses to a liquid.

NOTE: The difference between the condensing temperature of a refrigerant and the ambient temperature is called the condenser split.

EXAMPLE: 1

125°F condensing temperature – 95°F ambient = 30°F condenser split

In fact, the discharge vapor leaving the compressor is above 125°F. In addition to the evaporator's latent heat, the discharge vapor also contains the following sensible heat:

- Evaporator superheat
- Suction line superheat
- Compressor motor heat
- Heat of compression

In Figure 1-1, the 175°F hot gas leaving the compressor must **de-superheat,** or get rid of its superheat, before it can start condensing at its saturation temperature of 125°F. The condensing process continues at 125°F, rejecting latent heat into the ambient. Cooling the fully condensed liquid below its saturation temperature is called subcooling. To calculate subcooling, determine the condensing temperature from the head pressure and then subtract the temperature of the liquid line leaving the condenser.

EXAMPLE: 2

The head pressure is 278 psig, and the temperature of the liquid line at the condenser outlet is measured at 115°F. Therefore, 125°F condensing temperature – 115°F liquid line temperature = 10°F subcooling.

The liquid travels out of the condenser to the TEV, where the process starts again. This cycle removes heat from where it is not wanted (cooled space) and rejects it somewhere else (outdoors). This is the basic definition of the refrigeration process.

This section on the basic refrigeration cycle is nothing new for most readers. However, the review is still important to form a basis for much of what is discussed in the following chapters.

COMPARING COMMERCIAL REFRIGERATION WITH AC

What is the difference between the medium-temperature refrigeration system in Figure 1-2 and the AC system in Figure 1-1?

The pressures and temperatures on the condenser side are the same because they both use R22 refrigerant and reject evaporator heat into 95°F ambient air. However, the return air blowing over the evaporator in the medium-temperature system is only 35°F. Because the space temperature is lower, the evaporator temperature had to be lowered. In Figure 1-2, the evaporator was lowered to 25°F by reducing the pressure of the R22 refrigerant to 49 psig.

Therefore, a refrigeration system metering device drops the evaporator pressure and temperature to a level lower than that achieved by a metering device designed for an AC system. Similarly, a refrigeration compressor should be capable of increasing the lower evaporator pressure up to a level high enough to reject the heat into 95°F ambient air.

Figure 1-3 is a more elaborate diagram of an AC system, with labels to identify what is happening in the refrigerant circuit.

Figure 1-4 is similar to Figure 1-3, except that it shows the different temperatures and low side pressures of a typical walk-in cooler using R22.

Newer Refrigerants in Commercial Refrigeration

With the vast number of refrigerants available today, there are many different pressures relating to a single saturation temperature. Therefore, this book concentrates on using system temperatures so that the reader will better understand all refrigeration systems, no matter what refrigerant is used.

EXAMPLE: 3

The condensing and evaporator temperatures in Figure 1-4 will be the same regardless of the refrigerant the system uses: R22, R12, R502, R134a, or R404A.

Until about 2018, the following refrigerants were being used in new equipment:

- R404A—walk-in refrigerators and freezers
- R134a and R404A—reach-in refrigerators
- R404A—reach-in freezers

These refrigerants have a consistent temperature–pressure relationship. For each pressure (in psig) there is a specific saturation temperature, no matter whether the refrigerant was in a vapor state or a liquid state. An example of this is R410A, which is used in AC.

However, these refrigerants have been phased out and replaced by those having a high glide such as R448A. All 400 series refrigerants are **zeotropes** or blends of different refrigerants. Some have a low glide, some a high glide. **Glide** refers to the range of temperature between the refrigerant's vapor state and its liquid state. In a vapor state, the saturation temperature is the dew point. **Dew point** is used to calculate superheat. In a liquid state, the saturation temperature is the bubble point.

FIGURE 1-2 **Simple R22 refrigeration system.** *Courtesy of Refrigeration Training Services.*

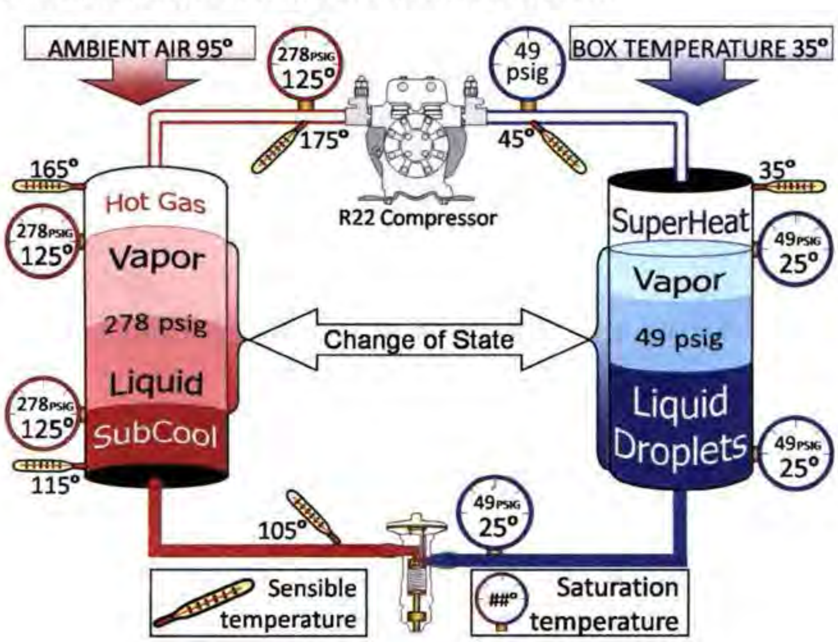


FIGURE 1-3 **Basic R22 AC system.** *Courtesy of Refrigeration Training Services.*

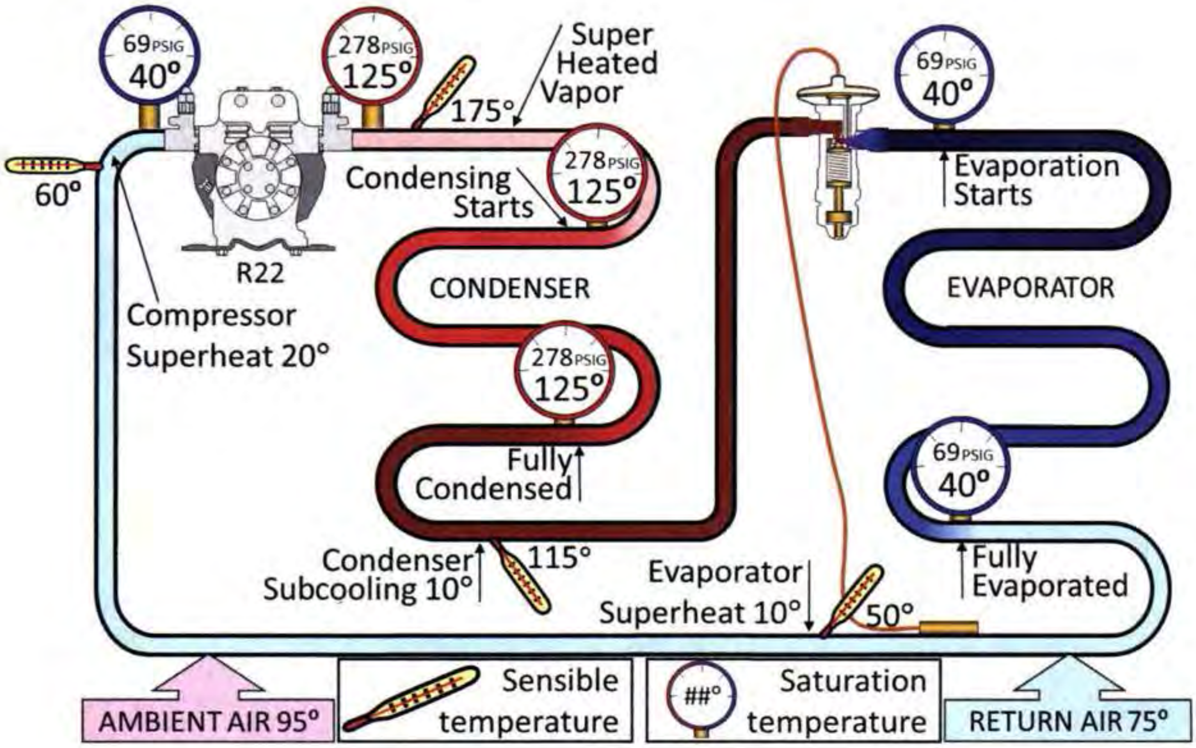
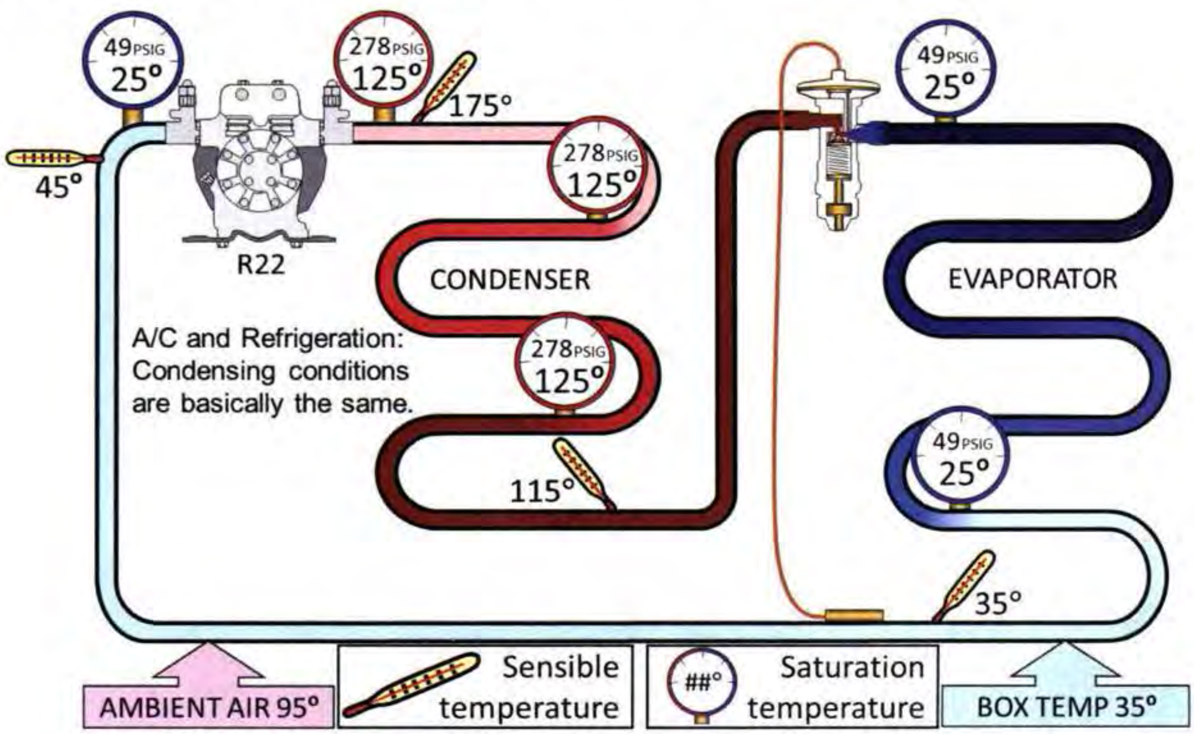


FIGURE 1-4 **Basic R22 walk-in cooler.** *Courtesy of Refrigeration Training Services.*



Bubble point is used to calculate subcooling. These terms will be more fully explained in later chapters. Although glide is a factor to contend with when diagnosing a system, technicians with a good understanding of how it applies will have nothing to fear. The intent of this book is to make sure of that.

THE FOUR BASIC COMPONENTS OF A REFRIGERATION SYSTEM

Chapters 2 through 5 cover in detail each of the four basic components of a refrigeration system. The following is a brief overview of the part each component plays in the refrigeration cycle (Figure 1-5).

Evaporator

Warm air from the space is blown over the evaporator. Heat from the air is absorbed into the refrigerant as it boils within the evaporator tubing. The heat remains in the refrigerant, which flows to another area and is ejected.

TROT

Sometimes when technicians are not able to obtain the exact information needed to solve a problem, they must rely on past experience with similar equipment under similar conditions. The technician has subconsciously determined approximate values for certain conditions. Although they may not be easy to put into words, every technician has developed certain rules of thumb that can be used to diagnose equipment problems.

The New Dictionary of Cultural Literacy defines the term *rules of thumb* as "a practical principle that comes from the wisdom of experience and is usually but not always valid."

Most experienced service and installation technicians use rules of thumb every day on the job. When used in this book, they will be referred to as **TROT (Technician's Rules of Thumb)**. The acronym TROT is easy to remember if one thinks of a horse breaking into a trot when it wants to move faster. Likewise, a technician can both learn and work faster by using some rules of thumb. There will be a special notation in the text when TROT are relevant. In addition, the appendix has a complete list of all the TROT used in this book.

NOTE: Factory specifications and guidelines always take precedence over TROT. These rules of thumb should be used only when factory information is not available.

Condenser

The condenser is a **mirror image** of the evaporator. Instead of absorbing heat, it rejects heat. There is tremendous heat transfer as the refrigerant changes state. Latent heat is released as the vapor condenses into a liquid within the condenser.

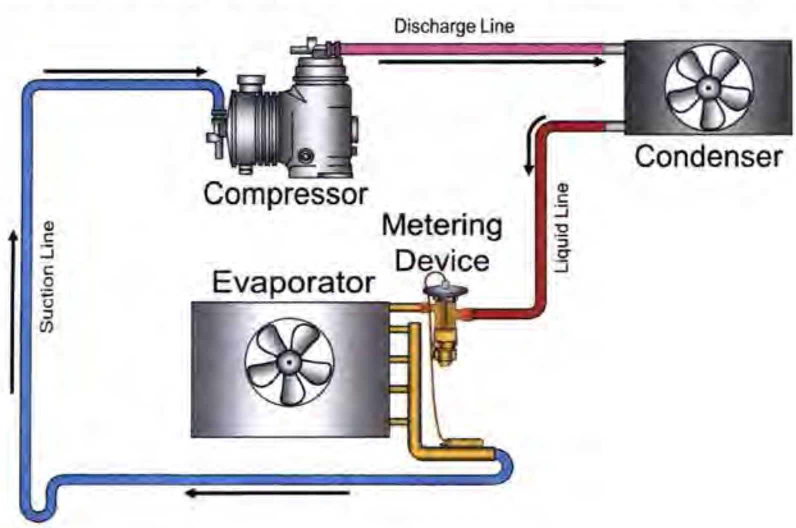
Compressor

The heat in the refrigerant can be removed only if it is exposed to relatively cooler ambient temperatures. Since the outside air can be 95°F or higher, the refrigerant temperature must be raised much higher. The compressor can raise the refrigerant temperature by raising its pressure. Therefore, the hotter it gets outside, the higher the compressor pressures become.

Metering Device

The metering device, either expansion valve or capillary tube, reduces the liquid pressure by forcing it through a nozzle or other small opening. Lowering the pressure of the refrigerant allows it to boil at a lower temperature. To make the refrigerant boil more easily, the metering device changes the stream of liquid into a dense fog of liquid droplets before it enters the evaporator.

FIGURE 1-5 **The four basic components of a refrigeration system.** *Courtesy of Refrigeration Training Services.*



SUMMARY

Most of the commercial refrigeration applications in this book operate at a range of 35°F to 40°F for medium-temperature units and 0°F to –10°F for low-temperature units. Whenever possible, explanations of how these systems operate will be in terms of evaporator and condensing temperatures, rather than suction and head pressures.

There are four basic components of the refrigeration system. The evaporator, condenser, compressor, and metering device are covered in greater detail in the next four chapters. A thorough understanding of these components is necessary before moving on to the many accessories, operating controls, and safety controls covered in later chapters.

Technicians should always follow factory specifications and recommendations. However, there are times when a Technician's Rules of Thumb (TROT) can help speed up the diagnostic process.

In commercial refrigeration, as in any service business, time is money. The quicker a technician can diagnose a problem, the more efficient they are. Better efficiency means more success for the technician and their company. Just as important to success is a technician's positive attitude as a result of working at something they enjoy. The goal of this book is to help the reader become a better technician, one who enjoys what they do and make a good living doing it.

There are some very talented female technicians in this trade, and many more are needed. In this book, gender neutral pronouns will be used to describe technicians. Not only is this fairer, but it is less cumbersome than to keep using *him/her*, *he/she*, and so on.

REVIEW QUESTIONS

1. What is considered the "normal" box temperature of a walk-in refrigerator?
   a. 35°F to 37°F
   b. 38°F to 40°F
   c. –10°F
   d. 0°F
2. What is considered the "normal" box temperature of a reach-in refrigerator?
   a. 35°F to 37°F
   b. 38°F to 40°F
   c. –10°F
   d. 0°F
3. What is considered the "normal" box temperature of a walk-in freezer?
   a. 35°F to 37°F
   b. 38°F to 40°F
   c. –10°F
   d. 0°F
4. What is considered the "normal" box temperature of a reach-in freezer?
   a. 35°F to 37°F
   b. 38°F to 40°F
   c. –10°F
   d. 0°F
5. Why is the temperature of walk-ins usually lower than the temperature of reach-ins?
   a. Walk-ins are designed for long-term storage and lower temperatures.
   b. Reach-ins are designed for long-term storage and lower temperatures.
   c. Reach-ins are small and cannot hold low temperatures.

Refer to figures 1-1, 1-2, 1-3, 1-4 to answer the question.

6. What is the pressure throughout the high side of the system?
   a. 229 psig
   b. 278 psig
   c. 49 psig
   d. 69 psig
7. Refer to figures 1-1, 1-2, 1-3, 1-4 to answer the question. At what temperature does the refrigerant condense?
   a. 125°F
   b. 115°F
   c. 100°F
   d. 95°F

8. Refer to figures 1-1, 1-2, 1-3, 1-4 to answer the question. What is the temperature of the subcooled liquid in the condenser?
   a. 125°F
   b. 115°F
   c. 95°F
   d. 10°F

Refer to Figure 1-4 for questions 9–11.

9. Refer to figure 1-4 to answer the question. What is the pressure drop across the TEV?
   a. 229 psig
   b. 278 psig
   c. 49 psig
   d. 69 psig

10. Refer to figure 1-4 to answer the question. R22 refrigerant at 49 psig boils at what temperature?
    a. 75°F
    b. 35°F
    c. 25°F
    d. 10°F

11. Refer to figure 1-4 to answer the question. What is the temperature of the superheated vapor at the outlet of the evaporator?
    a. 75°F
    b. 35°F
    c. 25°F
    d. 10°F

12. How can the latent heat in a cold suction line be transferred to higher outdoor air temperatures?
    a. Add heat to the suction vapor until it is higher than the ambient
    b. Compress the suction vapor until its condensing temperature is higher than the ambient
    c. Cool the discharge vapor until it condenses just above the ambient

13. What is the primary difference between the AC system in Figure 1-1 and the refrigeration system in Figure 1-2?
    a. The AC unit has to raise the head pressure higher.
    b. The refrigeration unit has to lower the evaporator temperature.
    c. The AC unit cannot use a TEV.

Questions 14–16 refer to refrigerants used up to 2018.

14. Which refrigerant is used most in recently installed walk-in refrigerators?
    a. R12
    b. R502
    c. R404A
    d. R134a

15. Which refrigerant is used in recently installed reach-in refrigerators?
    a. R12
    b. R502
    c. R123
    d. R134a

16. Which refrigerant is used most in recently installed walk-in freezers and reach-in freezers?
    a. R12
    b. R502
    c. R404A
    d. R134a

17. Why do zeotropic blends have temperature glide?
    a. The component refrigerants boil off at different rates.
    b. The refrigerants are so new they have not had time to stabilize.
    c. Glide makes the refrigerant blends more efficient.

18. Under what circumstances should a technician use TROT?
    a. When the technician is too rushed to look up the correct information
    b. When the factory information is not available
    c. When the technician has not had enough training

19. If the condensing temperature is 125°F and the evaporator temperature is 25°F, which refrigerants are being used?
    a. R22: 278 psig head, 49 psig suction
    b. R404A: 332 psig head, 63 psig suction
    c. R134a: 185 psig head, 22 psig suction
    d. all of these answer choices

2

EVAPORATORS

CHAPTER OVERVIEW

This chapter begins with an explanation of what an evaporator does and how it is designed to accomplish its functions. The concepts of evaporator temperature and temperature difference (TD) are introduced to help explain the function and performance of an evaporator.

The practice of superheat measurement is shown as the only reliable means of determining whether an evaporator has too much or too little refrigerant. Understanding these key concepts and conditions is essential to solving the complex system troubleshooting problems in later chapters.

Humidity is discussed as a function of TD, and moisture plays an important role in most commercial refrigeration applications. Because refrigeration evaporators operate below freezing point, the practice of defrosting both medium-temperature and low-temperature evaporators is covered in detail.

OBJECTIVES

After completing this chapter, you should be able to

- Describe evaporator defrost methodology
- Describe evaporator temperature
- Explain the significance of humidity in a walk-in
- Describe types of evaporators
- Calculate evaporator superheat and TD
- Describe hot pull-down
- Explain how airflow affects evaporator operation
- Describe types of evaporator problems
- Describe evaporator defrost methodology

KEY TERMS

Evaporator temperature

Temperature difference (TD)

Delta *T* (ΔT)

Hot pull-down

Design conditions

Dehumidifying

Benchmark

Low-velocity coils

DX (direct expansion) coil

Header

Saturated

Superheat

Flooding

Starving

Random defrost or off-cycle defrost

Differential

Cut-in

Cut-out

Planned air defrost

Pump-down solenoid

Hot gas defrost

Fail-safe

Defrost termination switch

Fan delay switch

DTFD