EIGHTH EDITION

REFRIGERATION AND AIR CONDITIONING TECHNOLOGY

JOHN TOMCZYK
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Refrigeration and Air Conditioning Technology, Eighth Edition

John A. Tomczyk, Eugene Silberstein, William C. Whitman, William M. Johnson

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PREFACE

Refrigeration & Air Conditioning Technology is designed and written for students in vocational-technical schools and colleges, community colleges, and apprenticeship programs. The content is in a format appropriate for students who are attending classes full-time while preparing for their first job, for students attending classes part-time while preparing for a career change, or for those working in the field who want to increase their knowledge and skills. Emphasis throughout the text is placed on the practical applications of the knowledge and skills technicians need to be productive in the refrigeration and air-conditioning industry. The contents of this book can be used as a study guide to prepare for the Environmental Protection Agency (EPA) mandatory technician certification examinations. It can be used in the HVAC/R field or closely related fields by students, technicians, installers, contractor employees, service personnel, and owners of businesses.

This text is also an excellent study guide for the Industry Competency Exam (ICE), the North American Technician Excellence (NATE), the HVAC Excellence, the Refrigeration Service Engineers Society (RSES), the United Association (UA) STAR certification, and the Heating, Air Conditioning, and Refrigeration Distributors International (HARDI) voluntary HVAC/R technician certification and home-study examinations.

The book is also written to correspond to the National Skill Standards for HVAC/R technicians. Previous editions of this text are often carried to the job site by technicians and used as a reference for service procedures. "Do-it-yourselfers" will find this text valuable for understanding and maintaining heating and cooling systems.

As general technology has evolved, so has the refrigeration and air-conditioning industry. A greater emphasis is placed on digital electronic controls and system efficiency. At the time of this writing, every central split cooling system manufactured in the United States today must have a Seasonal Energy Efficiency Ratio (SEER) rating of at least 13. This energy requirement was mandated by federal law as of January 23, 2006. SEER is calculated on the basis of the total amount of cooling (in Btus) the system will provide over the entire season, divided by the total number watt-hours it will consume. Higher SEER ratings reflect a more efficient cooling system. Air-conditioning and refrigeration technicians are responsible for following procedures to protect our environment, particularly with regard to the handling of refrigerants. Technician certification has become increasingly important in the industry.

Global warming has become a major environmental issue. When HVAC/R systems are working correctly and efficiently, they will greatly reduce energy consumption and greenhouse gases. Organizations like the Green Mechanical Council (GreenMech) are advocates for the HVAC/R industry and assist the industry in meeting with government, educational, industry, and labor interests to find solutions to the world's global-warming problem. GreenMech has created a scoring system designed to help engineers, contractors, and consumers know the "green value" of each mechanical installation. The "green value" encompasses the system's energy efficiency, pollution output, and sustainability. Realtors, building inspectors, builders, and planning and zoning officials will now have some knowledge about and guidance on how buildings and mechanical systems are performing. Green buildings and green mechanical systems are becoming increasingly popular in today's world as a way to curb global warming.

Energy audits have become an integral part of evaluating and assessing an existing building's energy performance. Higher efficiency standards for the energy performance of new buildings have been established. Higher levels of training and certification have been developed for HVAC/R technicians to meet the needs of more sophisticated, energy-efficient buildings and HVAC/R equipment.

TEXT DEVELOPMENT

This text was developed to provide the technical information necessary for a technician to be able to perform satisfactorily on the job. It is written at a level that most students can easily understand. Practical application of the technology is emphasized. Terms commonly used by technicians and mechanics have been used throughout to make the text easy to read and to present the material in a practical way. Many of these key terms are also defined in the glossary. This text is updated regularly in response to market needs and emerging trends. Refrigeration and air-conditioning instructors have reviewed each unit. A technical review takes place before a revision is started and also during the revision process.

Illustrations and photos are used extensively throughout the text. Full-color treatment of most photos and illustrations helps amplify the concepts presented.

No prerequisites are required for this text. It is designed to be used by beginning students, as well as by those with training and experience.

ORGANIZATION

Considerable thought and study have been devoted to the organization of this text. Difficult decisions had to be made to provide text in a format that would meet the needs of varied institutions. Instructors from different areas of the country and from various institutions were asked for their ideas regarding the organization of the instructional content.

The text is organized so that after completing the first four sections, students may concentrate on courses in refrigeration or air conditioning (heating and/or cooling). If the objective is to complete a whole program, the instruction may proceed until the sequence scheduled by the school's curriculum is completed.

NEW IN THIS EDITION

NEW AND/OR EXPANDED CONTENT HAS BEEN ADDED TO THE TEXT IN THE FOLLOWING AREAS:

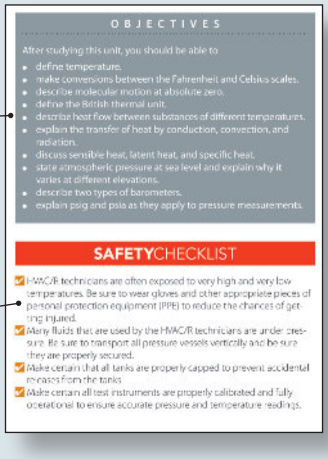
- WiFi and learning thermostats
- Thermostat applications for smart phones and other electronic hand-held devices
- Fossil-fuel furnace technologies
- Intelligent refrigeration case controllers
- Variable air volume (VAV)
- Variable refrigerant flow (VRF)
- Ultraviolet germicidal irradiation
- Natural refrigerants (hydrocarbons), their structure, boiling points, GWP, ODP, applications, charge amounts, serviceability, handling, transportation and safety
- R-22 alternatives
- System efficiencies with respect to EER, SEER, HSPF
- Supermarket refrigeration systems
- Microchannel heat exchangers
- Air-conditioning and heat pump technologies
- Ductless split systems
- Variable frequency drives
- Dry coolers
- Mechanical piping techniques
- Basic electronic theory
- Biofluels
- Blueflame burners
- Boiler setback controls
- Mixed air systems
- Psychrometrics
- Ventilation requirements
- Detailed coverage on crankcase heaters
- Detailed coverage on compressor oil pumps, partition walls, and oil check valves
- New photos on scroll compressor valve plates and other damaged valve plates
- Hydrofluoro-olefin (HFO) refrigerants
- Digital evaporator defrost and efficiency controllers
- Digital "Smart" gauges and manifolds including Bluetooth technologies
- Calculating water usage for water-cooled condensers

HOW TO USE THIS TEXT AND SUPPLEMENTARY MATERIALS

This text may be used as a classroom text, as a learning resource for an individual student, as a reference text for technicians on the job, or as a homeowner's guide. An instructor may want to present the unit objectives, briefly discuss the topics included, and assign the unit to be read. The instructor then may want to discuss the material with students. This can be followed by students completing the review questions, which can later be reviewed in class. The lecture outline provided in the *Instructor's Manual* may be utilized in this process. Lab assignments may be made at this time, followed by the students completing the lab review questions.

The instructor resource DVD may be used to access a computerized test bank for end-of-unit review questions, teaching tips, PowerPoint® presentations, and more.

FEATURES OF THE TEXT



OBJECTIVES

After studying this unit, you should be able to

- define temperature.
- make conversions between the Fahrenheit and Celsius scales.
- describe molecular motion at absolute zero.
- 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 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 measurements.

SAFETYCHECKLIST

- HVAC/R technicians are often exposed to very high and very low temperatures. Be sure to wear gloves and other appropriate pieces of personal protection equipment (PPE) to reduce the chances of getting injured.
- Many fluids that are used by the HVAC/R technicians are under pressure. Be sure to transport all pressure vessels vertically and be sure they are properly secured.
- Make certain that all tanks are properly capped to prevent accidental releases from the tanks.
- Make certain all test instruments are properly calibrated and fully operational to ensure accurate pressure and temperature readings.

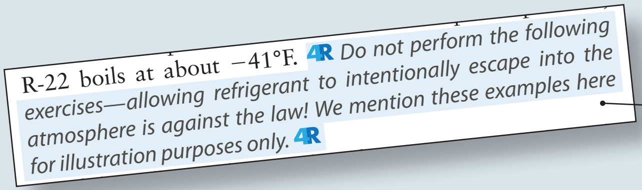
Objectives

Objectives are listed at the beginning of each unit. The objective statements have been stated clearly and simply to give students direction.

Safety Checklists

A Safety Checklist is presented at the beginning of each unit, when applicable, immediately following the Objectives. This checklist emphasizes the importance of safety and is included in units where "hands-on" activities are discussed.

Safety is emphasized throughout the text. In addition to the Safety Checklist at the beginning of most units, safety precautions and techniques are highlighted throughout. It would be impossible to include a safety precaution for every conceivable circumstance that may arise, but an attempt has been made to be as thorough as possible. The overall message is to work safely whether in a school shop, laboratory, or on the job and to use common sense.



R-22 boils at about −41°F. 4R *Do not perform the following exercises—allowing refrigerant to intentionally escape into the atmosphere is against the law! We mention these examples here for illustration purposes only.* 4R

Recovery/Recycling/Reclaiming/Retrofitting

Discussions relating to recovery, recycling, reclaiming, retrofitting, or other environmental issues are highlighted in blue throughout the text. In addition, one complete unit on refrigerant management is included—Unit 9, "Refrigerant and Oil Chemistry and Management—Recovery, Recycling, Reclaiming, and Retrofitting."

Green Awareness

As previously mentioned, global warming stemming from the uncontrolled rate of greenhouse gas emissions is a major global environmental issue. Buildings are important users of energy and materials and so are a major source of the greenhouse gases that are the by-products of energy and materials use. At the time of this writing, there are approximately 5 million commercial buildings and 125 million housing units in the United States. Surprisingly, almost every one of their mechanical systems is obsolete. Discussions relating to the green awareness movement (for example, lowering energy costs, reducing operating and maintenance costs, increasing productivity, and decreasing the amount of pollution generated) are highlighted in green throughout the text.

The correct size, layout, and installation of tubing, piping, and fittings helps to keep a refrigeration or air-conditioning system operating properly and efficiently and prevents refrigerant loss.

HVAC GOLDEN RULES

When making a service call to a business:

- Never park your truck or van in a space reserved for customers.
- Look professional and be professional.
- Before starting troubleshooting procedures, get all the information you can regarding the problem.
- Be extremely careful not to scratch tile floors or to soil carpeting with your tools or by moving equipment.
- Be sure to practice good sanitary and hygiene habits when working in a food preparation area.
- Keep your tools and equipment out of the customers' and employees' way if the equipment you are servicing is located in a normal traffic pattern.
- Be prepared with the correct tools and ensure that they are in good condition.
- Always clean up after you have finished. Try to provide a little extra service by cleaning filters, oiling motors, or providing some other service that will impress the customer.
- Always discuss the results of your service call with the owner or representative of the company. Try to persuade the owner to call if there are any questions as a

HVAC Golden Rules

Golden Rules for the refrigeration and air-conditioning technician give advice and practical hints for developing good customer relations. These "golden rules" appear in appropriate units.

PREVENTIVE MAINTENANCE FOR REFRIGERATION

PACKAGED EQUIPMENT. Packaged equipment is built and designed for minimum maintenance because the owner may be the person that takes care of it until a breakdown occurs. Most of the fan motors are permanently lubricated and will run until they quit, at which time they are replaced with new ones.

The owners should be educated to keep the condensers clean and not to stack inventory so close as to block the condenser airflow. When the unit is a reach-in cooler, the owner should be cautioned to follow the manufacturer's directions in loading the box. The load line on the inside should be observed for proper air distribution.

inspected and cleaned regularly. The technician cannot always tell when a coil is dirty by looking at the evaporator. Grease or dirt may be in the core of the coil. Routine cleaning of the evaporator once a year will usually keep the coil clean. **SAFETY PRECAUTION:** *Use only approved cleaning compounds where food is present. Turn off the power before cleaning any system. Cover the fan motors and all electrical connections when cleaning to prevent water and detergent from getting into them.*•

The motors in the evaporator unit are usually sealed and permanently lubricated. If not, they should be lubricated at recommended intervals, which are often marked on the motor. Observe the fan blade for alignment and look for bearing

Preventive Maintenance

Preventive Maintenance procedures are included in many units and relate specifically to the equipment presented in that unit. Technicians can provide some routine preventive maintenance service when on other types of service calls as well as when on strictly maintenance calls. The preventive maintenance procedures provide valuable information for the new or aspiring technician and homeowner, as well as for those technicians with experience.

Diagnostic Charts

Diagnostic Charts are included at the end of many units. These charts include material on troubleshooting and diagnosis.

Problem	Possible Cause	Possible Repair
No heat—thermostat calling for heat	Open disconnect switch	Close disconnect switch.
	Open fuse or breaker	Replace fuse or reset breaker and determine why it opened.
	High-temperature fuse link open circuit	Tighten loose connection at fuse link causing heat.
	Faulty high-voltage wiring or connections	Repair or replace faulty wiring or connections.
	Control-voltage power supply off	Check control-voltage fuses and safety devices.
	Faulty control-voltage wiring or connections	Repair or replace faulty wiring or connections.
	Heating element burned, open circuit	Replace heating element—check airflow.
Insufficient heat	Portion of heaters or limits open circuit	See above.
	Low voltage	Correct voltage.

SERVICE CALL 1

A customer calls indicating that the boiler in the equipment room at a motel has hot water running out and down the drain all the time. Another service company has been performing service at the motel for the last few months. *The problem is that the water-regulating valve (boiler water feed) is out of adjustment. Water is seeping from the boiler's pressure relief valve,* **Figure 14.66**.

The technician arrives at the motel, parking alongside the building so as not to block the front door or the motel's registration parking areas. When the property manager comes into the office to greet the technician, the technician intro-

Service Technician Calls

In many units, practical examples of service technician calls are presented in a down-to-earth situational format. These are realistic service situations in which technicians may find themselves. In many instances, the solution is provided in the text, and in others the reader must decide what the best solution should be. These solutions are provided in the Instructor's Manual. The Service Technician Calls will now incorporate customer relations and technician soft skills.

SUMMARY

- Thermometers measure temperature. Four temperature scales are Fahrenheit, Celsius, Fahrenheit absolute (Rankine), and Celsius absolute (Kelvin).
- Molecules in matter are constantly moving. The higher the temperature, the faster they move.
- The British thermal unit (Btu) describes the quantity of heat in a substance. One Btu is the amount of heat necessary to raise the temperature of 1 lb of water 1°F.
- The transfer of heat by conduction is the transfer of heat from molecule to molecule.
- The transfer of heat by convection is the actual moving of heat in a fluid (vapor state or liquid state) from one place to another.
- Radiant heat is a form of energy that does not depend on matter as a medium of transfer. Solid objects absorb the energy, become heated, and transfer the heat to the air.
- Sensible heat causes a rise in temperature of a substance.
- Latent (or hidden) heat is heat added to a substance that causes a change of state and does not register on a thermometer.
- Specific heat is the amount of heat (measured in Btu) required to raise the temperature of 1 lb of a substance 1°F. Substances have different specific heats.
- Pressure is the force applied to a specific unit of area. The atmosphere around the earth has weight and therefore exerts pressure.
- Barometers measure atmospheric pressures in inches of mercury. Two of the barometers used are the mercury and the aneroid.
- Gauges have been developed to measure pressures in enclosed systems. Two common gauges used in the air-conditioning, heating, and refrigeration industry are the compound gauge and the high-pressure gauge.

REVIEW QUESTIONS

1. Temperature is defined as
   A. how hot it is.
   B. the level of heat.
   C. how cold it is.
   D. why it is hot.
2. State the standard conditions for water to boil at 212°F.
3. List four types of temperature scales.
4. Under standard conditions, water freezes at _____°C.
5. Molecular motion stops at _____°F.

Summary

The Summary appears at the end of each unit prior to the Review Questions. It can be used to review the unit and to stimulate class discussion.

Review Questions

Review Questions follow the Summary in each unit and can help to measure the student's knowledge of the unit. There are a variety of question types—multiple choice, true/false, short answer, short essay, and fill-in-the-blank.

SUPPORT MATERIALS

INSTRUCTOR'S MANUAL

This manual includes an overview of each text unit, including a summary description, a list of objectives, and important safety notes. The manual provides diagnoses for service technician calls that are not solved in the text. It also includes references to lab exercises associated with each unit. "Special Notes to Instructors" specify how to create an equipment "problem" for students to resolve during certain lab exercises. The manual also provides answers to the review questions in the text and to all questions in the *Lab Manual and Workbook* (review and lab exercises). ISBN: 978-1-305-58326-9.

LAB MANUAL AND WORKBOOK

The *Lab Manual and Workbook* includes a unit overview, key terms, and a unit review test. Each lab provides a general introduction to the lab, including objectives, text references, tools, materials, and safety precautions. The manual then provides a series of practical exercises for the student to complete in a "hands-on" lab environment, including maintenance instructions for the workstation and tools. Cross references to the "Special Notes to Instructors" in the *Instructor's Manual* allow the instructor to create a system "problem" to be solved in the lab. ISBN: 978-1-305-57870-8

INSTRUCTOR RESOURCES DVD

This educational resource creates a truly electronic classroom. It is a DVD containing tools and instructional resources that enrich the classroom and make the instructor's preparation time shorter. The elements of the instructor resource link directly to the text to provide a unified instructional system. With the instructor resource the instructor can spend time teaching, not preparing to teach. ISBN: 978-1-305-58327-6.

Features contained in the instructor resource include the following:

- Syllabus. This is the standard course syllabus for this textbook, providing a summary outline for teaching HVAC/R.
- Teaching Tips. Teaching hints form a basis for presenting concepts and material. Key points and concepts can be highlighted graphically to enhance student retention.
- Lecture Outlines. The key topics and concepts that should be covered for each unit are outlined.
- PowerPoint Presentation. These slides can be used to outline a lecture on the concepts and material. Key points and concepts are highlighted graphically to enhance student retention.
- Image Gallery. This database of key images (all in full color) taken from the text can be used in lecture presentations, as transparencies, for tests and quizzes, and with PowerPoint presentations.
- Test Bank. Over 1000 questions of varying levels of difficulty are provided in true/false, multiple-choice, fill-in-the-blank, and short-answer formats for assessing student comprehension. This versatile tool allows the instructor to manipulate the data to create original tests.

VIDEO DVD SET

A seven-DVD video set addressing over 120 topics covered in the text is available. Each DVD contains four 20-minute videos. To order the seven-DVD set, reference ISBN: 978-1-111-64451-2.

MINDTAP

MindTap is well beyond an eBook, a homework solution or digital supplement, a resource center website, a course delivery platform, or a Learning Management System. MindTap is a new personal learning experience that combines all your digital assets—readings, multimedia, activities, and assessments—into a singular learning path to improve student outcomes.

INSTRUCTOR SITE

An Instructor Companion website containing supplementary material is available. This site contains an Instructor's Manual, teaching tips, syllabus, lecture outline, an image gallery of text figures, unit presentations done in PowerPoint, and testing powered by Cognero.
Cengage Learning Testing Powered by Cognero is a flexible, online system that allows you to:

- author, edit, and manage test bank content from multiple Cengage Learning solutions
- create multiple test versions in an instant
- deliver tests from your LMS, your classroom, or wherever you want

Contact Cengage Learning or your local sales representative to obtain an instructor account. To access an Instructor Companion website from SSO Front Door:

1. Go to http://login.cengage.com and log in using the instructor e-mail address and password.
2. Enter author, title, or ISBN in the **Add a title to your bookshelf** search.
3. Click **Add to my bookshelf** to add instructor resources.
4. At the Product page, click the **Instructor Companion site** link.

DELMAR ONLINE TRAINING SIMULATION: HVAC

Delmar Online Training Simulation: HVAC is a 3D immersive simulation that offers a rich learning experience and mimics field performance. To address the critical area of Electricity, it offers a learning path from basic electrical concepts to real-world electrical troubleshooting. This innovative product includes dynamic interactive wiring diagrams in two modes: an open sand-box mode for exploration and experimentation, and a tutorial mode where the proper sequencing required for sound electrical practice is provided. Both modes are supported by an adaptive question engine. Learning electrical theory, and trying and testing sound electrical practice prepares the student for life-like, simulated exposure to faults with the HVAC equipment that follows. It also challenges learners to master diagnostic and troubleshooting skills across seven pieces of HVAC equipment found in the industry—Gas Furnace, Oil Furnace, Gas Boiler, Split Residential A/C, Commercial A/C, Heat Pumps, and Commercial Walk-in Freezers. Soft skills are also included within the simulation.

To create successful learning outcomes, Delmar Online Training Simulation: HVAC offers approximately 200 scenarios which allow students to troubleshoot and build diagnostic and critical thinking skills. Two modes within the simulation promote incremental learning: Training Mode and Challenge Mode. Training Mode has fixed scenarios to aid in familiarizing the user with the equipment, the problem needing attention, and the capabilities of the simulation. Challenge Mode has randomized scenarios within three levels: Beginner, Intermediate, and Advanced. Both modes require learners to diagnose a fault or faults and perform the repair successfully while materials and labor costs are tracked. An integrated digital badging system helps students track their progress and adds additional engagement and motivation. Simulation-based videos teach students key troubleshooting concepts as well as familiarize them with the simulation. The instructional design allows for full open engagement, so students do not have artificial guardrails leading them to a conclusion.

Combining sound instructional design with top-quality computer immersive technology, learners develop critical thinking skills and apply them to real-world customer service calls in a simulated, 3D, life-like setting. This performance simulation complements live training practice by reinforcing good habits, and even presenting scenarios that are impractical (dangerous, expensive, etc.) to create in labs or in a residence. Available for instant purchase on www.cengagebrain.com.

ABOUT THE AUTHORS

JOHN TOMCZYK

John Tomczyk received his associate's degree in refrigeration, heating, and air-conditioning technology from Ferris State University in Big Rapids, Michigan; his bachelor's degree in mechanical engineering from Michigan State University in East Lansing, Michigan; and his master's degree in education from Ferris State University.

Professor Tomczyk has worked in refrigeration, heating, and air-conditioning service and project engineering and served as a technical writing consultant in both the academic and industrial fields. His technical articles have been featured in the *Refrigeration News, Service and Contracting Journal*, and *Engineered Systems Journal*. He writes monthly for the *Air Conditioning, Heating, Refrigeration News* and is coauthor of an EPA-approved *Technician Certification Program Manual* and a Universal R-410A Safety and Retrofitting Training Manual. Professor Tomczyk also is the author of the book *Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems,* published by ESCO Press. He also is co-owner of Delta Tee Solutions Inc., a Subchapter-S Corporation and sole owner of Technical Writing Services, LLC. Professor Tomczyk has recently retired from his professorship at Ferris State University after 29 years of service with the title of Professor Emeritus. While continuing consulting through his two companies and being a member of many HVAC/R trade organizations, he will be spending his winters in Maui, Hawaii and the remainder of the year living in the quaint beach town of Empire located in the Sleeping Bear National Lakeshore in Michigan.

EUGENE SILBERSTEIN

Over the past 30-plus years, Eugene has been involved in all aspects of the HVAC/R industry from field technician and system designer to company owner, teacher, administrator, consultant, and author. Eugene is presently an Assistant Professor and the lead faculty member in the HVAC/R program at Suffolk County Community College in Brentwood, New York. Eugene has over 20 years of teaching experience and has taught at a number of institutions in the Greater New York area.

Eugene earned his dual Bachelors Degree from The City College of New York and his Masters of Science degree from Stony Brook University, where he specialized in Energy and Environmental Systems, studying renewable and sustainable energy sources such as wind, solar, geothermal, biomass, and hydropower. He presently holds the Certified Master HVAC/R Educator (CMHE) credential from the ESCO Group and the Building Energy Assessment Professional (BEAP) credential issued by ASHRAE.

As an active member of both ASHRAE and RSES, Eugene served as the subject matter expert and wrote the production scripts for over 30 education videos directly relating to our industry. Other book credits include *Residential Construction Academy: HVAC,* 1st and 2nd Edition, *Pressure Enthalpy Without Tears* (2006), *Heat Pumps,* 1st and 2nd Edition, *and Psychrometrics Without Tears* (2014). Eugene has also written a number of articles for industry newspapers and magazines.

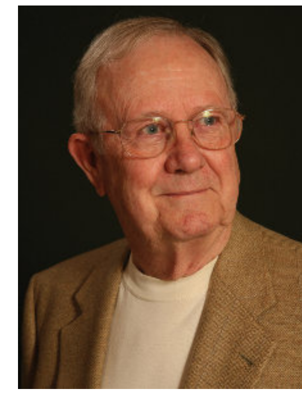
Eugene was selected as one of the top HVAC/R instructors in the country for the 2005/2006, 2006/2007, and 2007/2008 academic school years by the Air Conditioning and Refrigeration Institute (ARI), now AHRI, and the Air Conditioning, Heating and Refrigeration (ACHR) News.

BILL WHITMAN

Bill Whitman graduated from Keene State College in Keene, New Hampshire, with a bachelor's degree in industrial education. He received his master's degree in school administration from St. Michael's College in Winooski, Vermont.

After instructing drafting courses for 3 years, Mr. Whitman became the Director of Vocational Education for the Burlington Public Schools in Burlington, Vermont, a position he held for 8 years. He spent 5 years as the Associate Director of Trident Technical College in Charleston, South Carolina. Mr. Whitman was the head of the Department of Industry for Central Piedmont Community College in Charlotte, North Carolina, for 18 years.

BILL JOHNSON



Bill Johnson graduated from Southern Polytechnic with an associate's degree in gas fuel technology and refrigeration. He worked for the North Carolina's Weights and Measures Department; Coosa Valley Vocational and Technical Institute in Rome, Georgia; and the Trane Company of North Carolina. He also owned and operated an air-conditioning, heating, and refrigeration business for 10 years. He has unlimited North Carolina licenses in heating, air-conditioning, and refrigeration. Mr. Johnson taught heating, air-conditioning, and refrigeration installation, service, and design for 15 years at Central Piedmont Community College in Charlotte, North Carolina, and was instrumental in standardizing the heating, air-conditioning, and refrigeration curriculum for the state community college system. He has written a series of articles for the website of the *Air Conditioning, Heating, Refrigeration News*. These articles, called "BTU Buddy," describe service situation calls for technicians. Mr. Johnson has also authored the *BTU Buddy Notebook* along with two textbooks, *Practical Heating Technology* and *Practical Cooling Technology*, published by Cengage Learning.

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The late **Ed Bottum, Sr.**, President of Refrigeration Research, Inc., in Brighton, Michigan, for supplying much of the history and many photographs for the timeline found in the introduction to this text. Mr. Bottum's historical collection of refrigeration items and artifacts in Brighton, Michigan, has been designated a National Historic Site by the American Society of Mechanical Engineers (ASME).

Ferris State University, Big Rapids, Michigan, for permission to use their building and HVAC/R applications laboratories to take digital photographs. These digital photographs have certainly enhanced many units in this book.

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Danny Moore, Director of Technical Support, Hoshizaki America, Inc., for his technical assistance in Unit 27, "Commercial Ice Machines." His published technical articles on the topics of water and ice quality and water filtration and treatment surely enhanced the quality of this unit.

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John A. Tomczyk
tomczykjohn@gmail.com

Eugene Silberstein
eugene.silberstein@yahoo.com

SECTION 1

THEORY OF HEAT

Units

INTRODUCTION

Refrigeration is a complex topic that covers a wide range of areas. Refrigeration relates to the cooling of substances to

- preserve and transport food products,
- produce ice,
- aid in the manufacturing of many commercial products, and
- aid in medical research.

In addition, refrigeration plays vital roles in many other industrial, commercial, and residential applications. Air-conditioning, a form of refrigeration, refers to space heating, cooling, dehumidifying, humidifying, air filtering, exhausting, ventilating, and improving overall indoor air quality for those in the occupied space.

HISTORY OF REFRIGERATION AND AIR-CONDITIONING (COOLING)

Most evidence indicates that the Chinese, as early as 1000 B.C., were the first to store ice and snow in order to cool wine and other food products. Early Greeks and Romans used underground pits, which were insulated with straw and weeds, to store ice for long periods of time. The ancient people of Egypt and India cooled liquids in porous earthen jars. These jars were set out in the dry night air, and the evaporation of the liquids seeping through the porous walls provided the cooling. Some evidence indicates that ice was even produced from the vaporization of water through the walls of these jars.

In the eighteenth and nineteenth centuries, natural ice was cut from lakes and ponds in the winter in the northern United States and stored underground for use in the warmer months. Some of this ice was packed in sawdust and transported to southern states to be used for preserving food. In the early twentieth century, it was still common in the northern states for ice to be cut from ponds and then stored in open ice houses. Sawdust insulated the ice, which was then delivered to homes and businesses.

In 1823, Michael Faraday discovered that certain gases under constant pressure will condense when they cool. In 1834, Jacob Perkins, an American, developed a closed refrigeration system using liquid expansion and then compression to produce cooling. He used ether as a refrigerant, a hand-operated compressor, a water-cooled condenser, and an evaporator in a liquid cooler. He was awarded a British patent for this system. In Great Britain during the same year, L. W. Wright produced ice by the expansion of compressed air.

TIME LINE

1800

1823
Michael Faraday discovered that certain gases under constant pressure will condense when they cool.

1834
L. W. Wright produced ice by expansion of compressed air. Jacob Perkins developed a closed refrigeration system using expansion of a liquid and compression to produce cooling. David Perkins developed a closed refrigeration system using the expansion and compression of ether.

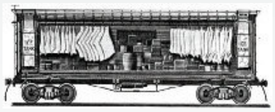
1842
John Gorrie used dripping ammonia to produce cooling.

1850

1858

Ferdinand Carré developed an ammonia mechanical refrigerator. It made blocks of ice.

1875
Raoul Pictet used sulfur dioxide as a refrigerant.

1881

Gustavus Swift was developing refrigeration railcars.

1890
Michael Cudahy improved railcar refrigeration.

In 1842, Florida physician John Gorrie placed a vessel of ammonia atop a stepladder and let the ammonia drip, which then vaporized and produced a cooling effect. This basic principle is still used in air-conditioning and refrigeration today. In 1856, Australian inventor James Harrison, an immigrant to America from Scotland, also used ammonia experimentally, but reverted to an ether compressor in equipment that had been previously constructed. In 1858, a French inventor, Ferdinand Carré, developed a mechanical refrigerator using liquid ammonia in a compression machine that produced blocks of ice. Generally, mechanical refrigeration was first designed to produce ice.

In 1875, Raoul Pictet of Switzerland first used sulfur dioxide as a refrigerant. Sulfur dioxide was not only a good refrigerant, but also served as a good lubricant for the system's compressor. This refrigerant was used frequently after 1890 and on British ships into the 1940s. Refrigeration railcars were developed by Gustavus Swift in 1881, and in 1890, Michael Cudahy had improved their design. Sulfur dioxide was also used in the Audiffren-Singrün refrigeration machine patented in 1894 by a French priest and physicist, Father Marcel Audiffren. It was originally designed to cool liquids, such as wine, for the monks.

In 1902, Willis Carrier, the "father of air-conditioning," designed a humidity control to accompany a new air-cooling system. He pioneered modern air-conditioning. In 1915, he, along with other engineers, founded Carrier Engineering, now known as the Carrier Corporation.

In 1918, the Kelvinator company, originally named the Electro Automatic Refrigeration Corporation, came into being and sold the first Kelvinator household units. The refrigerator was a remote-split type in which the condensing unit was installed in the basement and connected to an evaporator in a converted icebox in the kitchen. The Guardian Refrigerator Company developed a refrigerator they called "the Guardian." General Motors purchased Guardian in 1919 and developed the refrigerator they named Frigidaire. By 1929, refrigerator sales topped 800,000. The average price fell from $600 in 1920 to $169 in 1939. By the 1930s, refrigeration was well on its way to being used extensively in American homes and commercial establishments.

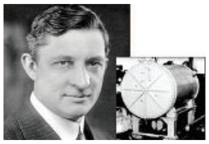
In 1923, Nizer introduced a water-cooled compressor and condensing unit for ice cream cabinets, considered to be the first commercial ice cream unit. Nizer soon merged into the Kelvinator Company. In 1923–1926, units produced by Savage Arms were among the first automatically controlled commercial units. The Savage Arms compressor had no seals, no pistons, and no internal moving parts. A mercury column compressed the refrigerant gas as the entire unit rotated. The compressor was practically noiseless.

In 1928, Paul Crosley introduced an absorption-type refrigeration machine so that people could have refrigeration in rural areas where electricity was scarce. These systems, which used a mixture of ammonia and water, could lower the inside temperature to 43°F or less. Ice cubes actually could be made for a period of about 36 hours, depending on the room temperature. These machines would need periodic "recharging" by heating the system over a kerosene burner.

In 1939, the Copeland Company introduced the first successful semihermetic (Copelametic) field-serviceable

1894
The Audiffren-Singrün refrigerating machine used a hermetically sealed system.

1900

1902

Willis Carrier designed humidity control for a new air-cooling system and pioneered modern air-conditioning. Willis Carrier also originated the Carrier equation upon which the psychrometric chart and all air-conditioning is based.

1918

Kelvinator refrigeration unit introduced.

1919
FRIGIDAIRE
Guardian Refrigerator Company developed a refrigerator they called the Guardian. General Motors purchased Guardian in 1918 and the name was changed to Frigidaire.

1923
Nizer water-cooled compressor and condenser for ice cream cabinets. Nizer made the first ice cream unit for the market. Nizer soon merged into Kelvinator.

1926
Savage Arms ice cream unit introduced. It contained a unique mercury column compressor with no seals, pistons, or lubrication.


1928
Crosley Icy Ball—An absorption-type refrigerator machine provided refrigeration in rural areas without electricity.

compressor. Three engineering changes made these compressors successful:

1. Cloth-insulated motor windings were replaced with Glyptal insulation.
2. Neoprene insulation replaced porcelain enamel in the electric terminals.
3. Valves were redesigned to improve efficiency.

Many different refrigerants have been developed over the years. The refrigerant R-12, a chlorofluorocarbon (CFC), was developed in 1931 by Thomas Midgley of Ethyl Corporation and C. F. Kettering of General Motors. It was produced by DuPont. In 1974, two professors from the University of California, Sherwood Rowland and Mario Molina, presented the "ozone theory." Their hypothesis was that CFC refrigerants released into the atmosphere were depleting the earth's protective ozone layer. Scientists conducted high-altitude studies and concluded that CFCs were indeed linked to ozone depletion. Representatives from the United States, Canada, and more than 30 other countries met in Montreal, Canada, in September, 1987, to try to solve the problem of released refrigerants and the effect they had on ozone depletion. This meeting produced the Montreal Protocol, which by 1989 had been ratified by 100 nations. It mandated a global freeze on the production of CFCs at 1986 levels. The Protocol also froze production of hydrochlorofluorocarbon (HCFC) refrigerants at their 1986 levels, beginning in 1992. In addition, the Protocol set a schedule of taxes on CFC refrigerants. As research on ozone depletion continues today, reassessments and updates to the Montreal Protocol also continue. At the time of this writing, the most current updates are as follows:

- 1990 (November)—President George H. W. Bush signed the Clean Air Act amendments that initiated production freezes and bans on certain refrigerants.
- 1992 (July)—The EPA made it against the law to intentionally vent CFC and HCFC refrigerants into the atmosphere.
- 1993—The EPA mandated the recycling of CFC and HCFC refrigerants.
- 1994 (November)—The EPA mandated a technician certification program deadline. Current HVAC/R technicians had to be EPA-certified by this date.
- 1995 (November)—The EPA made it against the law to intentionally vent alternative refrigerants (HFCs and all refrigerant blends) into the atmosphere.
- 1996—The EPA made it illegal to manufacture or import CFC refrigerants.
- 1996—The EPA put into place a gradual HCFC production phaseout schedule, which will totally phase out the production of HCFC refrigerants by the year 2030.

TIME LINE

1929
Household refrigerator sales topped 800,000.

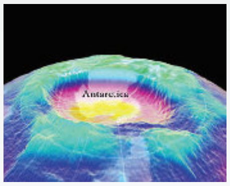
1931
Refrigerant R-12 was developed by Thomas Midgley and C. F. Kettering.

1939
First successful semi-hermetic (Copelametic) compressor introduced by the Copeland Company. Sales started in 1939. It was a field serviceable compressor.

1935–1965
A number of chlorofluorocarbons (CFCs) were developed during this period.

1974
Professors Rowland and Molina presented the "ozone theory" that CFCs were depleting the ozone layer.

1985



Stratospheric ozone hole discovered.

1989
Montreal Protocol ratified by 100 countries.

1990
Clean Air Act amendments. Production freezes and bans on certain refrigerants. Signed by President George H. W. Bush, November, 1990.

1992
EPA
The EPA made it illegal to intentionally vent CFC and HCFC refrigerants into the atmosphere.

1994
Mandatory EPA technician certification required to service refrigeration and A/C equipment or to buy ozone-depleting refrigerants as of November, 1994.

- 1998 (June)—The EPA proposed new regulations on recovery/recycling standards, equipment leak rates, and alternative refrigerants.
- 2004—35% reduction in HCFC refrigerant production.
- 2007—HCFC reduction on production was accelerated from 65% to 75% from the baseline 1989 production year.
- 2010—HCFC-22 is banned in new equipment. No production or importing of HCFC-22 and HCFC-142b, except for use in equipment manufactured before January 1, 2010.
- 2015—90% reduction in HCFC-22 production from the baseline production year of 1989. No production or importing of any HCFC, except for use in equipment manufactured before January 1, 2010.
- 2020—Total ban on HCFC-22 production. No production and no importing of R-22 and R-142b.
- 2030—Total ban on all HCFC production. No production and no importing of any HCFC.

From 1997 to 2000, voluntary HVAC/R technician certification became a major focus of the industry. From 1998 to the present, the major players in voluntary HVAC/R technician certification and home-study examinations were, and continue to be, the AC&R Safety Coalition, the Air Conditioning, Heating, and Refrigeration Institute (AHRI), the Heating, Air Conditioning, and Refrigeration Distributors International (HARDI), the Carbon Monoxide Safety Association (COSA), the Green Mechanical Council, HVAC Excellence, North American Technician Excellence (NATE), the Refrigeration Service Engineers Society (RSES), and the United Association of Journeymen and Apprentices (UA).

By 2008, global warming had become a major environmental issue. A scoring system was designed to help engineers, contractors, and consumers know the "green value" of each mechanical installation. R-410A, an efficient and chlorine-free HFC-based refrigerant blend for residential and light-commercial air-conditioning applications was developed for use with the scroll compressor for greater efficiencies. Also today, every central split cooling system manufactured in the United States must have a Seasonal Energy Efficiency Ratio (SEER) rating of at least 13. This energy requirement was mandated by federal law as of January 23, 2006. The "green value" encompasses the system's energy efficiency, pollution output, and **sustainability**. Green buildings and green mechanical systems are becoming increasingly popular in today's world as a way to curb global warming.

Green awareness, global warming, energy efficiency, energy savings, sustainability, and high-performance buildings are still at the forefront of environmental and energy concerns. Energy audits have become an integral part of evaluating and assessing the energy performance of existing buildings. Higher efficiency standards for the performance of new buildings have been established.

1995

Unlawful to intentionally vent alternative refrigerants (HFCs and all refrigerant blends) into the atmosphere as of November, 1995.

1996

Gradual HCFC production phaseout schedule with the total phaseout of HCFC refrigerants in the year 2030. Phaseout of CFC refrigerants.

1997–2000

Kyoto Protocol introduced, intended to reduce worldwide global warming gases. Global warming has become a major environmental issue.

Voluntary HVAC/R technician certification became a major focus.

2000

1998–2005

Puron

R-410A, an efficient and chlorine-free HFC-based refrigerant blend for residential and light-commercial air-conditioning applications, is used with the scroll compressor for greater efficiencies.

"Green awareness"—Green mechanical systems and green buildings become increasingly popular as a way to curb global warming and conserve energy. Natural refrigerants like carbon dioxide, ammonia, propane, butane, and isobutane are becoming increasingly popular because of their low GWP, zero ODP, low costs, availability, and high efficiencies.

2006

"Minimum 13 SEER" required for 1 1/2- to 5-ton unitary equipment and split/ packaged air conditioners and heat pumps.

2008–2014

Green awareness, global warming, energy efficiency, equipment efficiency, energy savings, sustainability and high performance buildings are still on the environmental and energy forefront. Energy audits have become an integral part of evaluating and assessing existing building's energy performance. Higher efficiency standards for new building's energy performance have been established. Higher levels of training and certification have been developed for HVAC/R technicians to meet the needs of more sophisticated, energy-efficient buildings and HVAC/R equipment. Carbon Dioxide (R-744) is gaining popularity in commercial refrigeration applications. This naturally occurring refrigerant does not deplete ozone and has a low global warming potential (GWP).

2015–2016

The SMART revolution is taking hold where wireless technology, applications (Apps), smart phones, notebooks, and pads, are controlling and monitoring HVACR equipment through wireless networks. Cloud computing is also becoming very popular.

GREEN AWARENESS

As mentioned, global warming stemming from the uncontrolled rate of greenhouse gas emissions is a major global environmental issue. Most of the sun's energy that reaches the earth is in the form of visible light. After passing through the atmosphere, part of this energy is absorbed by the earth's surface and is converted into heat energy. The earth, warmed by the sun, radiates heat energy back into the atmosphere toward space. Naturally occurring gases and lower atmospheric pollutants such as CFCs, HCFCs, HFCs, carbon dioxide, carbon monoxide, water vapor, and many other chemicals absorb, reflect, and/or refract the earth's infrared radiation and prevent it from escaping the lower atmosphere. Carbon dioxide, mainly from the burning of fossil fuels, is a major contributor to global-warming. The gases in the atmosphere slow the earth's heat loss, making the earth's surface warmer than it would be if heat energy had passed unobstructed through the atmosphere into space. The warmer earth's surface then radiates more heat until a balance is established between incoming and outgoing energy. This warming process is called **global warming** or the **greenhouse effect**. Humans are chiefly responsible for producing many of the greenhouse gases that are causing environmental problems.

Over 70% of the earth's fresh water supply is either in ice cap or glacier form. Scientists are concerned that these ice caps or glaciers will melt if the average earth temperature rises too much, thereby increasing ocean water levels. The scientific consensus is that we must limit the rise in global temperatures to less than 3.6°F (2°C) above pre-industrial levels to avoid disastrous impacts. An increase of 2°C will likely displace millions of people from their homes due to rising water levels. Food production will decline, rivers will become too warm to support marine life, coral reefs will die, snow packs will decrease and threaten water supplies, weather will become unpredictable and extreme, and many plant and animal species will die and become extinct.

Nineteen of the hottest 20 years on record have occurred in the past 20 years [this information updated from multiple sources, including http://www.climate.gov/news-features/videos/2014-global-temperature-recap]. Atmospheric carbon dioxide levels are now at their highest. Half of the world's oil is gone and other natural resources are dwindling. The average American uses 142 gallons of water per day, and in some regions of the country, water supplies are drying up. Because of this, slowing, and possibly stopping or even reversing, the growth rate of greenhouse gas emissions has become a global effort.

Buildings are the major source of demand for energy and materials, and they are also the major source of greenhouse gases that are attributed to the by-products of energy use and materials. At the time of this writing, there are over 5 million commercial buildings and over 132 million housing units in the United States. Surprisingly, almost every one of their mechanical systems is obsolete. The global-warming scares, the rising price of fuels, the scarcity of clean water, and the ever-growing waste stream demand improvements in our homes and businesses today. Trained contractors, with the help of the government, installers, builders, manufacturers, and educators, must renovate and improve the efficiency of these buildings and mechanical systems.

In the United States, buildings account for approximately

- 36% of total energy used,
- 65% of electrical consumption,
- 30% of greenhouse gas emissions,
- 30% of raw materials used,
- 30% of waste output (136 millions tons annually), and
- 12% of potable water consumption.

Organizations like the Green Mechanical Council (GreenMech) and the United States Green Building Council (USGBC) are setting goals for the use of fewer fossil fuels in existing and new buildings. Some of these goals are listed here:

- All new buildings, developments, and major renovation projects must be designed to use one-half of the fossil-fuel energy they would typically consume.
- The fossil-fuel reduction standard for all new buildings must be increased to
  - 70% in 2015,
  - 80% in 2020, and
  - 90% in 2025.
- By 2030, new buildings must be carbon-neutral, which means that they cannot use any greenhouse-gas-emitting fossil-fuel energy to operate.
- Joint efforts must be made to change existing building standards and codes to reflect these targets.

Builders can accomplish these goals by choosing proper siting, building forms, glass properties and locations, and materials and by incorporating natural heating, cooling, ventilating, and lighting strategies. Renewable energy sources such as solar, wind, biomass, and other carbon-free methods can operate equipment within the building.

Leadership in Energy and Environmental Design (LEED) is a voluntary internationally recognized green building certification system for developing high-performance, sustainable buildings, which is referred to as the LEED Green Building Rating System. It was established by the USGBC in 1999 and is widely recognized as a third-party verification system and guideline for measuring what constitutes a green building. It was enhanced in 2009 and is currently operating under Version 3 of the rating system. All of the information for LEED ratings is available at http://www.usgbc.org/. Version 4 of the LEED program was scheduled to be put into effect in July 2015 and, at the time of this writing, the implementation of the new version is on schedule.

The USGBC membership, which is composed of every sector of the building industry and consists of over 9,000 organizations, developed and continues to refine LEED. LEED promotes expertise in green building by offering project certification, professional accreditation, and training. LEED emphasizes state-of-the-art strategies for sustainable site development, water savings, energy efficiency, material selection, and indoor environmental quality. According to the United Nations World Commission on Environment and Development, a **sustainable design** "meets the needs of the present without compromising the ability of future generations to meet their own needs." Companies looking to utilize **green** technologies or incorporate sustainable design into their buildings and facilities, are concerned with six areas:

- Optimizing site location
- Optimizing energy use
- Protecting and conserving water
- Using environmentally preferable products
- Enhancing indoor environmental quality
- Optimizing operational and maintenance practices

There are nine possible LEED rating categories, and each is assigned individual points for reaching accreditation. Listed here are the nine categories (separate rating systems) and possible points per categories.

Category	Points Possible
New Construction	110
Existing Buildings (Operation & Maintenance)	92
Commercial Interiors	110
Core & Shell	110
Schools	110
Retail	110
Healthcare	110
Homes	136
Neighborhood Development	110

Points are awarded in each category depending on how well the building meets the category's requirements. For example, the following information is taken from the New Construction (NC) LEED Rating System. Keep in mind that each system has different point-generation possibilities. The LEED NC system requires that a building earn a minimum of 40 points to meet minimum requirements out of a possible 110 points. There are four levels of certification according to the point system:

Certified	40–49
Silver	50–59
Gold	60–79
Platinum	80–110

A LEED NC certified building means that it has achieved at least a minimum standard as judged in the following seven categories prior to any points being awarded toward a LEED rating.

Category	Points Possible
Sustainable Sites	26
Water Efficiency	10
Energy & Atmosphere	35
Materials & Resources	14
Indoor Environmental Quality	15
Innovation & Design Process	6
Regional Priority Credits	4
	110

The Energy & Atmosphere category has a possible 35 points, with potentially 33 of them directly linked to HVAC systems. This category for New Construction (NC) addresses such items as the facility's basic consumption of energy, its optimization of energy consumption, system commissioning and refrigerant management, and use of on-site renewable energy. Optimizing building facilities' performance can equate to a possible 19 out of 35 points. These points would equate to installing an HVAC system that improves efficiency by 48% for new construction or 44% for existing HVAC systems and constitute a large portion of the possible points, which provides opportunities in building renovation.

The Indoor Environmental Quality category has a possible 15 points, with potentially 7 of them directly linked to HVAC systems. This category has multiple possibilities: HVAC systems can affect outdoor air-delivery monitoring of facility ventilation, minimum air changes in buildings for removing harmful volatile organic compounds (VOCs), electronic thermal control systems, and thermal comfort design and verification.

In summary, the purpose of LEED is to provide a third-party certification process using nationally developed and accepted minimum standards for the construction industry. It affects the design, construction, and operation phases of high-performance "green" buildings. LEED systems take into account other ways of increasing efficiencies, such as water conservation, **heat island** reduction in urban areas, incentives for use of locally manufactured materials, site preparation, and maintenance as well as the HVAC efficiencies listed above. To receive a LEED rating, the facility must be built by a team, some of whose members are LEED accredited professionals. LEED-rated projects have a higher cost than similar, non-LEED projects because the enhancements required to increase efficiencies and the certification and documentation required cost more. Many European nations have made LEED-type systems mandatory for all buildings and have instituted existing-building rating systems that monitor yearly energy consumption of all utilities in these buildings. The higher a building's energy usage or "energy utilization index" above a minimum consumption, the higher amount of penalty tax the building owner must pay. This provides an incentive for improving the building's energy footprint.

The green awareness movement isn't just a temporary "buzzword" that will fade away with time. It is one that will be rapidly gaining momentum in the coming years. If contractors want to remain competitive, they must obtain the necessary training with regard to green building and LEED certification.

An alternative to LEED certification is the Green Globes® program, which is offered by the Green Building Initiative. The Green Globes program operates on a 1,000-point scale and certifications range from one to four Green Globes, with four Green Globes being their highest possible rating. Both the LEED and Green Globes programs are nationally accepted.

HISTORY OF HOME AND COMMERCIAL HEATING

Human beings' first exposure to fire was probably when lightning or another natural occurrence, such as a volcanic eruption, ignited forests or grasslands. After overcoming the fear of fire, early humans found that placing a controlled fire in a cave or other shelter could create a more comfortable living environment. Fire was often carried from one place to another. Smoke was always a problem, however, and methods needed to be developed for venting it outside. Native Americans, for example, learned in later years to vent smoke through holes at the peak of their tepees, and some of these vents were constructed with a vane that could be adjusted to prevent downdrafts. The fireplaces common in Europe and North America were vented through chimneys.

Early stoves were found to be more efficient than fireplaces. These early stoves were constructed of a type of firebrick, ceramic materials, or iron. In the mid-eighteenth century, a jacket for the stove and a duct system were developed. The stove could then be located at the lowest place in a structure, and the heated air in the jacket around the stove would rise through a duct system and grates into the living area. This was the beginning of the development of circulating warm-air heating systems.

Boilers that heated water were also developed, and this water was circulated through pipes in duct systems. The water heated the air around the pipes, and the heated air passed into the rooms to be heated. Radiators were then developed. The heated water circulated by convection through the pipes to the radiators, and heat was passed into the room by radiation. These early systems were forerunners of modern hydronic heating systems.

Steam heat became a popular heating option at the beginning of the nineteenth century and coal was the fuel of choice for boilers. Coal was desirable because it burned hot and lasted a long time. But coal was not inexpensive and the coal dust that was ever-present resulted in health, primarily breathing, problems for many people. In the late 1920s, the oil burner was invented and was a very attractive alternative to coal. Oil was less expensive and cleaner than coal and nobody had to keep feeding coal to keep the fire burning.

Oil remained popular, and inexpensive, until the Arab oil embargo of 1973 and the Iranian Revolution in 1979. Oil prices spiked and people had to wait in lines, sometimes for hours, to get their ration of fuel for their cars. As a result, many people switched to natural gas, comprised primarily of methane. Natural gas boilers began to replace the old oil boilers, just as oil had replaced coal.

After the price shocks of the 1970s, oil prices stayed low for most of the 1980s and 1990s, with occasional moderate peaks. Oil prices then rose steadily from the period between September 11, 2001 and 2009, and continue to fluctuate today.

Today, commercial and residential heating needs are being met in a number of ways that include traditional hot water and steam, but new, more efficient technologies are becoming more attractive. These include radiant heating, radiant cooling, and geothermal heat pump systems.

CAREER OPPORTUNITIES

The HVAC/R industry is rapidly changing due to advancements in technology being spurred on by the need for increased energy efficiencies. The career opportunities available in HVAC/R for those who have acquired formal technical training coupled with field experience are unlimited. Schools that provide excellent technical training in the field are becoming easier to identify through HVAC/R program accreditation. As new equipment becomes more technically challenging and the existing workforce continues to age, the employment positions available will continue to outnumber applicants for the foreseeable future. This shortfall in available, competent HVAC/R service technicians is being addressed through the cooperative efforts of educational institutions, labor unions, employers, and manufacturers. Many organizations offer apprenticeship opportunities that can lead to high-income positions. Manufacturers are also teaming up with select educational institutions across North America to help develop the next generation of HVAC/R technicians.

Many newer buildings are constructed so tightly that the quality of the air must be controlled by specialized equipment. The conditions of the air must also be carefully controlled in areas that perform manufacturing processes. Heating and air-conditioning systems control the temperature, humidity, and total air quality in residential, commercial, industrial, and other types of buildings. Refrigeration systems are used to store and transport food, medicine, and other perishable items. Refrigeration and air-conditioning technicians design, sell, install, or maintain these systems. Many contractors and service companies specialize in commercial refrigeration. The installation and service technicians employed by these companies install and service refrigeration equipment in supermarkets, restaurants, hotels/motels, flower shops, and many other types of retail and wholesale commercial businesses.

Other contractors and service companies may specialize in air-conditioning. Many specialize in residential-only or commercial-only installation and service; others may install and service both residential and commercial equipment up to a specific size. Air-conditioning may include cooling, heating, humidifying, dehumidifying, ventilating, exhausting, and air cleaning. Heating equipment may rely on fossils fuels, such as natural gas, liquefied petroleum, or oil, or may be configured as electric-based or heat pump systems. The type and number of installations will vary from one part of the country to another, depending on the climate and availability of the heat source. The heating equipment may be either a furnace (which heats air) or a boiler (which heats water). The boiler heats water and pumps it to the space to be heated, where one of many types of heat exchangers transfers the heat to the air.

Technicians may specialize in installation or service of equipment, or they may be involved with both. Other technicians may design installations or work in the sales area. Sales representatives may be in the field selling equipment to contractors, businesses, or homeowners; others may work in wholesale supply stores. Still other technicians may represent manufacturers, selling equipment to wholesalers and large contractors.

Many opportunities exist for technicians to be employed in the industry or by companies owning large buildings. Technicians may be responsible for the operation of air-conditioning equipment, or they may be involved in the service of this equipment. Opportunities also exist for employment in servicing household refrigeration and room air conditioners, which would include refrigerators, freezers, and window or through-the-wall air conditioners. Opportunities are also available for employment in a field often called transport refrigeration. This includes servicing refrigeration equipment on trucks or on large containers hauled by trucks and ships.

Most modern houses and other buildings are constructed to keep outside air from entering, except through planned ventilation. Consequently, the same air is circulated through the building many times. The quality of this air may eventually cause a health problem for people spending many hours in the building. This indoor air quality (IAQ) presents another opportunity for employment in the air-conditioning field. Technicians clean filters and ducts, take air measurements, check ventilation systems, and perform other tasks to help ensure healthy air quality. Other technicians work for manufacturers of air-conditioning equipment. These technicians may be employed to assist in equipment design, in the manufacturing process, or as equipment salespersons.

Following is a list of many career opportunities in the HVAC/R field:

- Field service technician
- Service manager
- Field supervisor
- Field installer
- Journeyman
- Project manager
- Job foreman
- Application engineer
- Controls technician
- Draftsperson
- Contractor
- Lab technician
- Inspector
- Facilities technician
- Instructor
- Educational administrator
- Inside/outside sales rep
- Sales manager
- New product developer
- Research engineer
- Estimator

TECHNICIAN CERTIFICATION PROGRAMS

HISTORY

Even though mandatory technician certification programs are in place today, the EPA originally did not consider them as its lead option. As a matter of fact, the EPA initially thought private incentives would ensure that technicians were properly trained in refrigerant recycling and recovery. The EPA also stated that it would play an important role through a voluntary technician certification program by recognizing those who provide and participate in voluntary technician training programs that meet certain minimum standards. The EPA also thought that a mandatory certification program would be an administrative burden. The EPA then requested public comments on a mandatory versus voluntary technician certification program. More than 18,000 comments were in favor of a mandatory program, and only 142 were in favor of a voluntary program. Most of the 18,000 in favor of the mandatory certification program were major trade organizations and technicians themselves. Manufacturers of recovery and recycling equipment, along with environmental organizations, also supported mandatory certification. They believed it would increase compliance with venting, recovery, and recycling laws and the general safe handling of refrigerants. The following were reasons given by those favoring mandatory technician certification:

- Improve refrigerant leak detection techniques
- Promote awareness of problems relating to venting, recovery, and recycling of refrigerants
- Improve productivity and cost savings through proper maintenance practices
- Ensure environmentally safe service practices
- Gain more consumer trust
- Receive more liability protection
- Ensure that equipment is properly maintained
- Educate technicians on how to effectively contain and conserve refrigerants
- Create uniform and enforceable laws
- Foster more fair competition in the regulated community

With these comments in mind, the EPA decided that mandatory technician certification would increase fairness by ensuring that all technicians were complying with today's rules. The EPA