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 technologies. 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. Decision had to be made to provide text in a format that would meet the needs of different 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

SERVICE TECHNICIAN CALLS

This edition of the book will involve a universal change for units incorporating SERVICE TECHNICIAN CALLS. The SERVICE TECHNICIAN CALLS will now incorporate a customer relations and technician soft skills.

INTRODUCTION

The introduction is now part of Section 1. New and/or expanded topics include:

- New updated timeline
- New topic on Green Awareness
- Expanded coverage on Leadership in Energy and Environmental Design (LEED)
- New topic on Programmatic Accreditation
- Expanded coverage on Customer Relations and Technician Soft Skills

UNIT 1  Heat, Temperature, and Pressure

- Some new images
- Removal of metric terms (joule, gram, etc.)
- Improved specific heat chart
- Additional content on latent heat of vaporization, latent heat of condensation, and heat of fusion
UNIT 3  Refrigeration and Refrigerants
  • Larger, color-coded, and easier to read pressure/temperature charts of refrigerants
  • Expanded coverage of new refrigerants and refrigerant blends

UNIT 4  General Safety Practices
  • New photo and coverage of a new carrying strap for refrigerant cylinders for ladder safety

UNIT 5  Tools and Equipment
  • Over 50 new photos on tools and equipment
  • Ten new photos on residential energy auditing tools and equipment

UNIT 6  Fasteners
  • Addition of many hollow wall fasteners
  • Expanded content on connecting stranded wire under screw terminals
  • Expanded content on power-actuated fastener systems
  • Expanded content on threaded rod and steel channel
  • Over 25 new photos

UNIT 7  Tubing and Piping
  • Over 20 new images and photos
  • Regulatory information on line sets
  • Expanded content on fluxing
  • Information regarding the scrubbing effect that ester-based lubricants have on interior piping surfaces and the importance of using nitrogen during the brazing process

UNIT 8  Leak Detection, System Evacuation, and System Cleanup
Entirely new section on advanced leak detection. Revised sections on evacuation and system clean-up procedures. The following topics are discussed:
  • Over 30 new photos on leak detection and equipment, evacuation, and system clean-up
  • Defining leaks
  • Types of leaks
  • Exposing the leak site
  • Standing leaks
  • Pressure-dependent leaks
  • Temperature-dependent leaks
  • Vibration-dependent leaks
  • Combination-dependent leaks
  • Cumulative micro-leaks
  • Testing for evaporator section leaks
  • Testing for condenser section leaks
  • Spotting oil residue from leaks
  • Testing for suction and liquid line leaks
  • Advanced leak detection
  • Modern evacuation techniques and equipment
  • Modern system clean-up procedures

UNIT 9  Refrigerant and Oil Chemistry and Management—Recovery, Recycling, Reclaiming, and Retrofitting
  • New toxicity and flammability matrix for ASHRAE Standard 34-2010 (Designation and Safety Classifications of Refrigerants)
  • Many new popular refrigerants and refrigerant blends with their compatible oils are discussed
• New calculations on figuring how much refrigerant (maximum cylinder weight) put into a recovery cylinder using the tare weight and water capacity of the cylinder.
• New photos of modern recovery machines and the internals of recovery machines.
• New section on refrigerant and oil retrofitting. This section also includes an expanded refrigerant retrofit guideline from DuPont Fluorochemicals for replacing R-22 (HFC-22) with R-407C (HFC-407C).

UNIT 10 System Charging
• Additional content on using charging charts and tables.
• Examples using charging charts and tables.

UNIT 17 Types of Electric Motors
Many new photos and expanded coverage on shaded pole motors, potential relay temperature coefficient resistors (PTCRs), and Variable Frequency Drives (VFDs) troubleshooting. Topics include:
• New photos and coverage of shaded pole motors.
• New photos of potential relay internals.
• Continuous coil voltage.
• Pick-up voltage.
• Drop-out voltage.
• Potential relay troubleshooting.
• New photos and expanded coverage on Positive Temperature Coefficient Resistors (PTCRs).
• Positive Temperature Coefficient Resistor (PTCR) troubleshooting.
• New photos and expanded coverage on Variable Frequency Drives (VFDs) with troubleshooting.
• Inverter history and operations.
• Motor speed calculations.
• Rectification.
• Filtering.
• Switching.
• Switch or carrier frequency.
• VFD electrical diagrams and sign waves.

UNIT 18 Application of Motors
• New coverage and charts on Service Factor Amperage (SFA).
• New coverage on rated load amperage (RLA) and full load amperage (FLA).
• New and expanded coverage on compressor performance data which include new.

UNIT 19 Motor Controls
• New coverage and photos on compressor overload devices.

UNIT 20 Troubleshooting Electric Motors
• New coverage on megohmmeters (meggers) with photos and charts.
• New coverage and photos of a universal capacitor.

UNIT 21 Evaporators and the Refrigeration System
• New photos of evaporators and fin spacings on evaporators.

UNIT 22 Condensers
• Extended coverage and many new photos on water-cooled condensers and cycling methods.
• Extended coverage on condenser fan cycling for head pressure control.
• New coverage and diagrams on condenser splitting for head pressure control.
UNIT 23 Compressors
• Extended coverage and photos on electronic compressor protection and monitoring

UNIT 24 Expansion Devices
• New photos of electronic expansion valves

UNIT 25 Special Refrigeration System Components
• Extended coverage on defrosting methods
• Many updated photos on special system components

UNIT 26 Applications of Refrigeration Systems
• New coverage on the GreenChill® partnership
• New system diagrams on parallel refrigeration systems for supermarkets
• New coverage on preserving liquid subcooling through use of a surge-type receiver
• Detailed new coverage, photos, graphs, and diagrams on carbon dioxide (CO₂) refrigeration systems including subcritical and transcritical cycles. Cascade and indirect systems are covered.

UNIT 30 Electric Heat
• Expanded content on radiant floor heating
• Expanded content on unit and wall heaters
• Expanded content on electric boilers

UNIT 33 Hydronic Heat
• Addition of solar heat as a supplemental heat source
• Pool heating
• Active and passive solar heating systems
• Direct and diffuse radiation
• Solar constant and the declination angle

UNIT 34 Indoor Air Quality
• Additional information on UV air cleaners
• More information on mold remediation
• New content on bi-polar ionization
• New content on polarized filtration
• New content on photocatalytic oxidation, PCO, filters

UNIT 39 Residential Energy Auditing (New Unit)
Entirely new unit with 69 new photos. This new unit includes:
• Categories of a residential energy audit
• Thermal boundaries
• Base load inspections
• Diagnostic tests for residential energy audits
• Health and safety issues as they relate to indoor air quality
• Infrared scanning using a thermal imaging camera
• Sealing air leaks in a residential structure
• Duct leakage tests
• Blower door tests
• Sealing air leaks for energy conservation
• Combustion efficiency
• Furnace efficiency testing
• Draft as it applies to combustion appliances
• Safety issues of properly venting combustion appliances
• Flame safeguard controls
• High efficiency gas furnace anatomy
• Numerical analysis and reporting
• Base load and seasonal usage of energy
• Home energy indexes

UNIT 42 Heat Gains and Heat Losses in Structures (New Unit)
• Concepts of heat gain and heat loss
• Importance of accurate calculations
• Design heating and cooling temperatures
• Heating and cooling temperature differentials
• R-values and U-values
• Construction elements
• Heat gains and heat losses through construction panels
• Net and gross wall area
• Building orientation
• Above and below grade walls
• Window shading

UNIT 44 Geothermal Heat Pumps
• Detailed new coverage and photos on Direct GeoExchange systems
• New coverage and photographs of slinky loops and their installations for close geothermal systems

UNIT 45 Domestic Refrigerators and Freezers
• Consolidation of original units 45 and 46
• Updated refrigerant information to stress R-134a
• Many artwork changes
• Addition of PTC devices as control devices
• Discussion on solid state defrost timers
• Additional coverage on EPA regulations

UNIT 47 High-Pressure, Low-Pressure, and Absorption Chilled-Water Systems
• New content on chilled water systems with scroll compressors

UNIT 48 Cooling Towers and Pumps
• New coverage and many new photos on chemical-free cooling tower water tre
• Including encapsulation, electroporation, and particle separation
• Many new photos on cooling towers, pumps, and pump cut-aways
• New coverage on calculating the cooling tower load and range

UNIT 50 Commercial Packaged Rooftop, Variable Refrigerant Flow and Variable Air Volume Systems (New Unit)
• Rooftop package units
• Equipment rigging
• Crane components and terminology
• Communicating with the crane operator
• Roof curbs
• Roof safety
• Variable air volume
• Chilled water VAV systems
• Variable refrigerant flow (Variable refrigerant volume)
• Reheat
• Economizers
• ASHRAE Standard 62
• Demand Control Ventilation
• Carbon dioxide sensors
HOW TO USE THE 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 Guide 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 CD 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

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 in red 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.

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.
A customer calls and complains that the compressor for a medium-temperature walk-in cooler with a remote condensing unit is short cycling and not cooling correctly. The evaporator has two fans, and one is burned. The unit is short cycling on the low-pressure control because there is not enough load on the coil. On the way to the job the technician goes over the possible problems. This is where it helps to have some familiarity with the setup. The technician remembers that the unit has a low-pressure control, a high-pressure control, a...
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.

Diagnostic Charts

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

Instructor’s Guide
This guide includes an overview of each text unit, including a summary description of objectives, and important safety notes. The guide provides diagnoses for 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 a “problem” for students to resolve during certain lab exercises. The guide provides answers to the review questions in the text and to all questions in the Guide/Lab Manual (review and lab exercises). ISBN: 1-1116-4449-7.

Study Guide/Lab Manual
The Study Guide/Lab Manual includes a unit overview, key terms, and a unit test. Each lab includes a general introduction to the lab, including objectives, 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 “Special Notes to Instructors” in the Instructor’s Guide allow the instructor to create a system “problem” to be solved in the lab. ISBN: 1-1116-4448-9.

Instructor Resource CD
This educational resource creates a truly electronic classroom. It is a CD containing tools and instructional resources that enrich the classroom and shorten the instructor’s preparation time. 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: 1-1116-4450-0.

Features contained in the instructor resource include the following:

- Syllabus. This is the standard course syllabus for this textbook, providing a suggested 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.
- Optical Image Library. 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 as a starting point for creating PowerPoint presentations.
- Computerized 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 test bank to create original tests.

Video DVD Set
Preface

Audiobook
This is a collection of audio files covering every unit in *Refrigeration & Air Conditioning Technology, Seventh Edition*. The audio files are organized into “A” head groupings (comparable to songs), which allows access to content within the unit. Once downloaded, MP3 audio files can be played on portable MP3 players or on PCs with standard media programs.

Students can listen to content being read while they follow along and look at the illustrations. References to page numbers in the text are included at the beginning of each file. Unit objectives, boxed features, figure and photo captions, and end-of-chapter elements are included as well (but not end-of-chapter questions). The audio files will not replace the book, since the artwork and photos are essential and must be viewed. ISBN: 1-1116-4452-7.

Web Tutor Advantage
Web Tutor Advantage for the Blackboard online course-management system is available. The Web Tutor includes unit presentations in PowerPoint, end-of-unit review questions, tests, discussion springboard topics, and more, all designed to enhance the classroom experience. ISBN: 1-1116-4455-1.

CourseMate
CourseMate complements the text and course content with study and practice materials. Cengage Learning's CourseMate brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook. Watch student comprehension soar as your class works with the printed textbook and the textbook-specific website.

CourseMate includes an integrated eBook, interactive teaching and learning tools including quizzes, flashcards, videos, Engagement Tracker, a first-of-its-kind tool that monitors student engagement in the course, and more.

CourseMate goes beyond the book to deliver what you need!

To access additional course materials, including CourseMate, please visit www.CengageBrain.com. At the CengageBrain.com home page, search for the ISBN (from the back cover of the book) using the search box at the top of the page. This will take you to the product page where these resources can be found.

ONLINE COURSEWARE

ONLINE TRAINING SIMULATION
Similar to a video game, this simulation allows students to engage inside a life-like, 3-D simulated environment mimicking HVAC-R service call scenarios. From the customer interaction “soft skills” to the technical trouble-shooting, students will be challenged with a beginning-to-end, field-like training experience. ISBN: 1-1335-9438-7.

SIMUTECH LAB MANUAL
A lab manual for use with Simutech simulators is also available. Simutech’s third party computer-based simulators provide realistic “hands-on” service training of generic HVAC and refrigeration systems. ISBN: 1-1335-9741-6.