

**R**efrigeration & 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. Difficult decisions had to be made to provide text in a format that would meet the needs of various 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 in the school's curriculum is completed.

## NEW IN THIS EDITION

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### 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 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
- New toxicity and flammability matrix for ASHRAE Standard 34-2010 (Designation and Safety Classifications of Refrigerants). Includes new A2L and B2L categories for lower flammability refrigerants.

### 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 oil and refrigerant retrofit guideline from DuPont Fluorochemicals for replacing R-22 (HCFC) 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, positive 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 cleaning 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 (CO<sub>2</sub>) 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 closed 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 treatment 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.

#### OBJECTIVES

After studying this unit, you should be able to

- discuss applications for high-, medium-, and low temperature refrigeration.
- describe the terms ton of refrigeration.
- describe the basic refrigeration cycle.
- explain the relationship between pressure and the boiling point of water or other liquids.
- describe the function of the evaporator or cooling coil.
- explain the purpose of the compressor.
- list the compression normally used in residential and light commercial buildings.
- discuss the function of the condensing coil.
- state the purpose of the metering device.
- list four characteristics to consider when choosing a refrigerant for a system.
- list the designated colors for refrigerant cylinders for various types of refrigerants.
- describe how refrigerants can be stored or processed while refrigeration systems are being serviced.
- plot a refrigeration cycle for refrigerants (R-22, R-12, R-134a, and R-502) on a pressure/enthalpy diagram.
- plot a refrigeration cycle on a pressure/enthalpy diagram for refrigerant blends R-404A and R-410A.

### 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.

#### SAFETY CHECKLIST

- Areas in which there is the potential for refrigerant leaks should be properly ventilated.
- Extra precautions should be taken to ensure that no refrigerant leaks occur near an open flame.
- Refrigerants are stored in pressurized containers and should be handled with care. Goggles with side shields and gloves should be worn when checking pressures and when transferring refrigerants from the container to a system or from the system to an approved container.

### PREVENTIVE MAINTENANCE

Preventive maintenance for air-conditioning equipment involves the indoor airside, the outdoor airside (air-cooled and water-cooled), and electrical circuits.

The indoor airside maintenance is much the same for air-conditioning as for electric heat, where motor and filter maintenance is involved. The only difference is that the evaporator coil operates below the dew point temperature of the air and is wet. It will become a superfilter for any dust particles that may pass through the filter or leak in around loose panel compartment doors. Many air handlers have

a steam cleaner. Approved cleaners may be purchased at any air-conditioning supply house. **SAFETY PRECAUTION:** Follow the directions. Make sure no water can enter the coil through the piping connections.

The outdoor unit may be either air-cooled or water-cooled. Air-cooled units have fan motors that must be lubricated. Some motors require lubrication only after several years of operation. At that time, a recommended amount of approved oil is added to the oil cup. Some motors require more frequent lubrication.

### 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.

## SERVICE CALL 1

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

## 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 Guide. The Service Technician Calls will now incorporate customer relations and technician soft skills.

As mentioned earlier, environmental issues like ozone depletion and global warming have forced manufacturing phaseout dates for many refrigerants. However, these refrigerants can still be used if recovered or recycled, or if they are in an operating refrigeration or air-conditioning system. Environmental issues and phaseout dates have made many refrigerants very expensive due to the heavy taxes imposed, and so alternative (environmentally friendly) refrigerants have entered the market. It is now illegal to intentionally vent any refrigerant into the atmosphere. Stiff fines of up to \$32,500 and/or imprisonment can follow. Because of this, mandatory technician certification programs have educated HVAC/R personnel on environmental issues, alternative refrigerants, and legislation issues.

## 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.

## 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 damage 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 customer's 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 result of the service call.

## 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.

## Recovery/Recycling/Reclaiming/Retrofitting

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

The more efficient the HVAC/R equipment is, the less energy needed, but even refrigeration or air-conditioning equipment with a relatively small charge of refrigerant that never runs out may have a great impact on global warming if the equipment is undercharged or overcharged. The equipment would be very inefficient under these conditions, and the carbon dioxide generated from the longer run times created by these inefficiencies would contribute to global warming more than the leakage of refrigerant because the longer run times would require more electricity, resulting in more carbon dioxide from the combustion of more fossil fuels. In the United States, fossil-fuel combustion is used for much of the generation of electricity. This is an example of an indirect effect of global warming.



**SUMMARY**

- Matter takes up space, has mass, and can be in the form of a solid, a liquid, or a gas.
- The weight of a substance at rest on the earth is proportional to its mass.
- In the British system of units, density is the weight of a substance per cubic foot.
- Specific gravity is the term used to compare the density of various substances.
- Specific volume is the amount of space a pound of a vapor or a gas will occupy.
- Boyle's Law states that the volume of a gas varies inversely with the absolute pressure, provided the temperature remains constant.
- Charles' Law states that at a constant pressure, the volume of a gas varies directly as to the absolute temperature, and at a constant volume the pressure of a gas varies directly with the absolute temperature.
- Dalton's Law states that the total pressure of a confined mixture of gases is the sum of the pressures of each of the gases in the mixture.
- Electrical energy and heat energy are two forms of energy used in this industry.
- Fossil fuels are purchased by the unit. Natural gas is metered by the cubic foot; oil is purchased by the gallon; and coal is purchased by the ton. Electricity is purchased from the electric utility company by the kilowatt-hour (kWh).
- Work is the amount of force necessary to move an object: Work = Force Distance.
- Horsepower is the equivalent of lifting 33,000 lb to a height of 1 ft in 1 min or some combination totaling the same.
- Watts are a measurement of electrical power. One horsepower equals 746 W.
- 3.413 Btu = 1 W = 1 kW (1000 W) = 3413 Btu.

**REVIEW QUESTIONS**

1. Name three reasons why ice melts in an icebox:
  - B. 21°F
  - C. 10°F
  - D. 20°F
2. What are the approximate temperature ranges for low-, medium-, and high-temperature refrigeration applications?
  - A. 1200 Btu.
  - B. 12,000 Btu/h.
  - C. 120,000 Btu.
  - D. 120,000 Btu/h.
3. One ton of refrigeration is
  - A. 1200 Btu.
  - B. 12,000 Btu/h.
  - C. 120,000 Btu.
  - D. 120,000 Btu/h.
11. Define a subcooled liquid.
12. The condensing pressure is 260 psig, and the condenser outlet temperature is 108°F for R-22. By how many degrees is the liquid subcooled in the condenser?
  - A. 12°F
  - B. 42°F
  - C. 7°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**

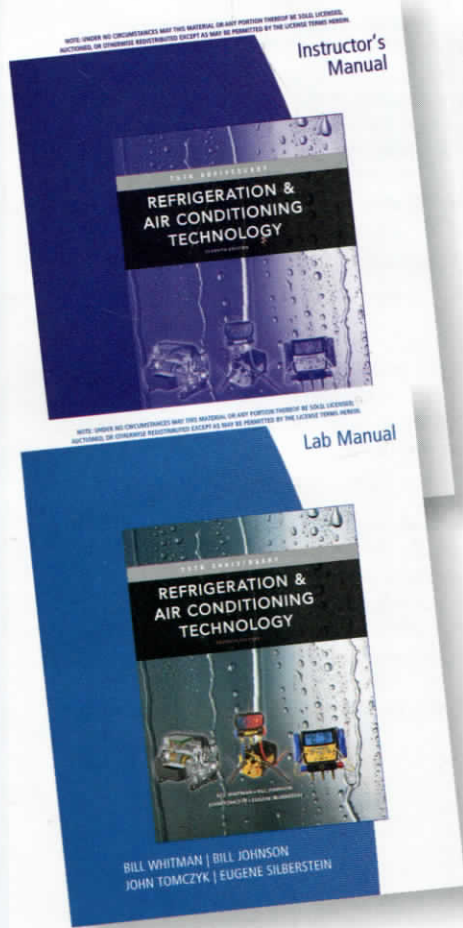
Review Questions follow the Summary in each unit and can help to measure the student's knowledge of the unit. There are a variety of question types—multiple choice, true/false, short answer, short essay, and fill-in-the-blank.

**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
Furnace will not start—no heat	Open disconnect switch Open fuse or breaker Faulty wiring Defective low-voltage transformer Primary safety control off—needs reset	Close disconnect switch. Replace fuse or reset breaker and determine why it opened. Repair or replace faulty wiring or connections. Replace transformer and look for possible overload condition Check for oil accumulation in the combustion chamber; if none, reset the control and observe fire and flame characteristics.
Furnace starts after reset but shuts off after 90 sec	Tripped burner motor reset Cad cell may be out of alignment or dirty	Press reset button, check amperage; if too much, check motor or pump for binding. Check cad cell for alignment and smoke on lens—if there are smoke deposits on the lens, adjust the burner for correct fire.
Furnace starts but no ignition occurs	Defective cad cell Defective primary control No fuel	Replace cad cell and reset. Change primary control. Fill fuel tank.
	Electrodes out of alignment Defective ignition transformer Defective oil pump Restricted fuel filter Defective coupling between pump and motor	Align electrodes. Replace transformer. Replace oil pump. Replace filter. Replace coupling.

## 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-ROM 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 text. 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 complete outline for teaching HVAC/R.
- **Teaching Tips.** Teaching hints form a basis for presenting concepts and materials. 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 of the 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 in PowerPoint presentations.
- **Computerized Test Bank.** Over 1000 questions of varying levels of difficulty are available in true/false, multiple-choice, fill-in-the-blank, and short-answer formats for assessment of student comprehension. This versatile tool allows the instructor to manipulate the questions to create original tests.

### Video DVD Set

A six-DVD video set addressing over 120 topics covered in the text is available. Each DVD contains four 20-minute videos. To order the six-DVD set, reference ISBN: 1-1116-6445-5. A new, seventh DVD containing video of content new to the seventh edition text is available separately. ISBN: 1-111-64453-5.

### 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](http://www.CengageBrain.com). At the [CengageBrain.com](http://www.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 courseware developed from the contents of the core text is available on two platforms, Web Angel and Blackboard. Web Tutor Advantage on Angel ISBN: 1-1116-4456-X, Blackboard ISBN: 1-1116-4455-1.

## 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.