

**EIGHTH EDITION**



**JOHN TOMCZYK**  
**EUGENE SILBERSTEIN**  
**BILL WHITMAN**  
**BILL JOHNSON**

**REFRIGERATION AND AIR CONDITIONING TECHNOLOGY**

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**Refrigeration and Air Conditioning Technology,  
Eighth Edition**

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# PREFACE

**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 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

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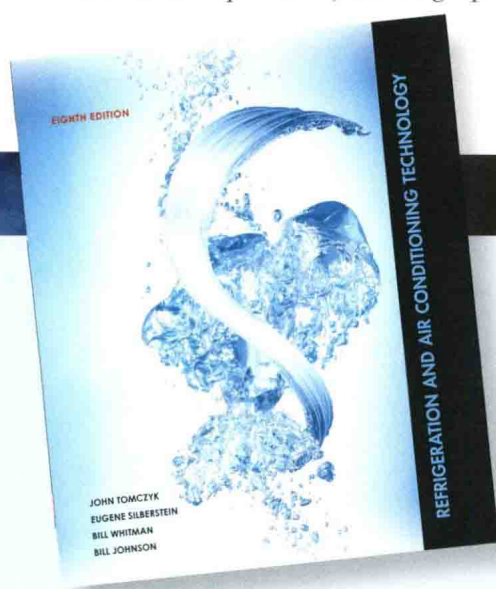
### NEW AND/OR EXPANDED CONTENT HAS BEEN ADDED TO THE TEXT IN THE FOLLOWING AREAS:

- 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
- Biofuels
- 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

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:
<ul style="list-style-type: none"> <li>define temperature.</li> <li>make conversions between the Fahrenheit and Celsius scales.</li> <li>describe molecular motion at absolute zero.</li> <li>define the British thermal unit.</li> <li>describe heat flow between substances at different temperatures.</li> <li>explain the transfer of heat by conduction, convection, and radiation.</li> <li>discuss sensible heat, latent heat, and specific heat.</li> <li>state atmospheric pressure at sea level and explain why it varies at different elevations.</li> <li>describe two types of barometers.</li> <li>explain psig and psia as they apply to pressure measurements.</li> </ul>

### 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.

SAFETYCHECKLIST
<ul style="list-style-type: none"> <li>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.</li> <li>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.</li> <li>Make certain that all tanks are properly capped to prevent accidental releases from the tanks.</li> <li>Make certain all test instruments are properly calibrated and fully operational to ensure accurate pressure and temperature readings.</li> </ul>

R-22 boils at about  $-41^{\circ}\text{F}$ .  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. 

### 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 Open fuse or breaker High-temperature fuse link open circuit Faulty high-voltage wiring or connections Control-voltage power supply off Faulty control-voltage wiring or connections	Close disconnect switch. Replace fuse or reset breaker and determine why it opened. Tighten loose connection at fuse link causing heat. Repair or replace faulty wiring or connections. Check control-voltage fuses and safety devices. Repair or replace faulty wiring or connections.
Insufficient heat	Heating element burned, open circuit Portion of heaters or limits open circuit Low voltage	Replace heating element—check airflow. See above. 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

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### 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
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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](http://www.cengagebrain.com).



## ABOUT THE AUTHORS

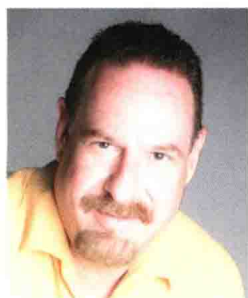
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### JOHN TOMCZYK

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

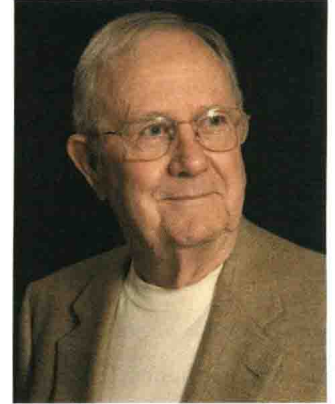
Bill Whitman graduated from Keene State College in Keene, New Hampshire, with a bachelor's degree in industrial education. He received his master's degree in school administration from St. Michael's College in Winooski, Vermont.



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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