AHRI Air-Conditioning, Heating, and Refrigeration Institute

Fundamentals of HVACR

Carter Stanfield and David Skaves

Second Edition



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Letter to Readers

Our goal in writing *Fundamentals of HVACR* is to encourage a high level of professionalism for future and current technicians in the industry by producing a text that is both accessible and thorough. To accomplish this, we followed a few guiding principles:

- Explain why things work.
- Organize material so that it progresses from fundamental concepts to specific applications of those concepts.
- Organize the material so that it progresses in difficulty from easily understood ideas to more challenging concepts and applications.
- Write a text that is accessible to readers while still providing the detailed information necessary to be successful.
- Write a book that HVACR students will want to keep for reference when they become professionals.

The "HVACR Science" section lays the foundation for understanding virtually all the concepts and applications introduced later in the book. Taking the time to understand the science behind HVACR systems is an investment in your future. The specific details of individual units change over time, but the science that governs how they operate stays the same.

The most difficult part of writing a comprehensive text is deciding what material to include. Everything there is to know simply won't fit into a single book. We focused on one simple question: Does the material help the reader understand how to install, maintain, and service HVACR systems?

The presentation of the material is equally important. There is always more than one way to describe or explain something. We chose the most transparent and easily understood explanations possible without leaving out crucial detail. Concepts and applications are reinforced with specific, real-world examples. Our writing style is engaging to draw the students in, as there is really no reason a textbook can't be written in a style that encourages the reader to read out of interest rather than obligation.

HVACR students and technicians are our target audience. Most technicians are visually oriented learners. A good picture or illustration can often explain more than several pages of text, so we have included many pictures, illustrations, graphs, and diagrams to show everything from basic concepts to operational sequences.

One of the great things about teaching is sharing in other people's success. There is nothing more gratifying than seeing students succeed. We hope that this book launches you on a successful HVACR career and finds a permanent place in your library or service truck.

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Fundamentals of HVACR

Second Edition

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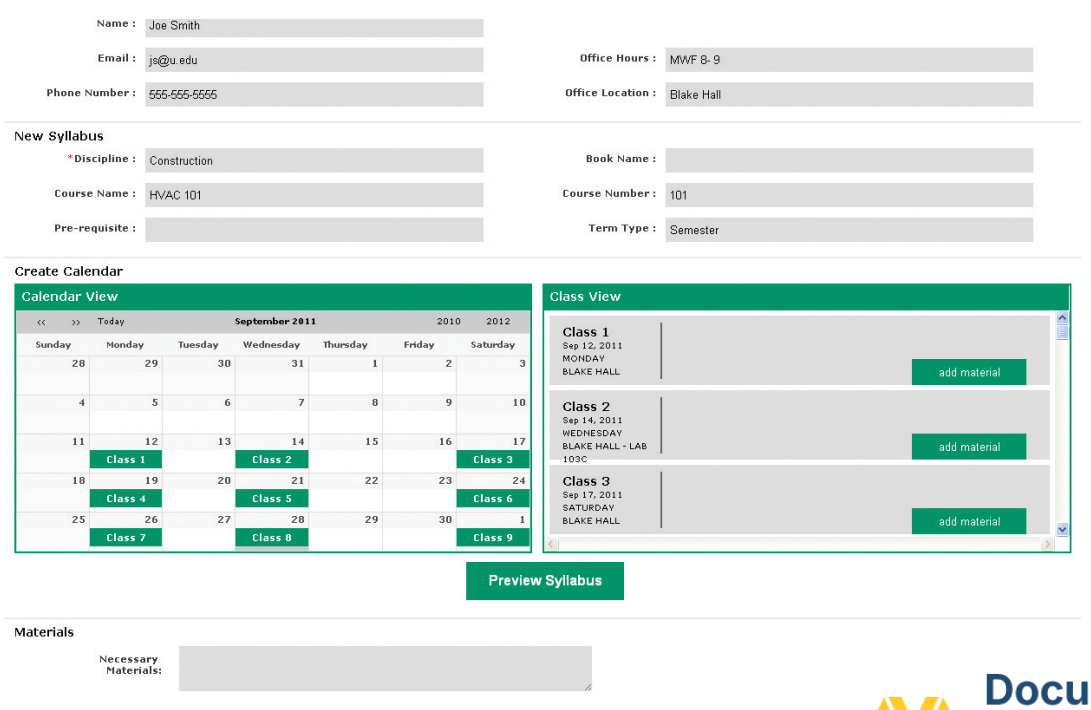
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We didn't just revise this textbook. We rethought the way you use it and the way you teach with it. We revised the entire line of materials for your HVACR program. Every item, from the supplements to the PowerPoints and the media program, was evaluated so that they would all seamlessly cover your entire curriculum. We wanted to save you time and headaches while giving your students a consistent and engaging learning experience for their entire degree or certificate.

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Fundamentals of HVACR, 2nd Edition

Created with a clear-cut vision of what students need, this groundbreaking text provides comprehensive coverage of heating, ventilating, air conditioning, and refrigeration. This fully updated edition includes additional coverage of electrical, commercial, codes, and sustainability.

Learning Objectives

Each unit begins with clearly stated objectives that enable you to focus on what you should achieve by the end of the unit.

OBJECTIVES

After completing this unit, you will be able to:

1. define *refrigerant*.
2. identify the type of refrigerant by its number designation.
3. list the different types of refrigerant chemical composition.
4. explain the difference between compounds, zeotropes, and azeotropes.
5. describe the pressure-temperature relationship of saturated refrigerant.
6. list the different types of refrigerant contaminants.
7. explain the refrigerant safety rating system.
8. match refrigerants with the proper refrigeration oil.

Unit Introductions and Unit Summaries

These pull together the main points of the unit to prepare and remind students of what they should remember.

19.1 INTRODUCTION

Any study of the refrigeration cycle would be incomplete without a look at the refrigerant in the system. The refrigerant is the first component of a refrigeration system that must be determined, since its chemical and physical properties will play a large role in selecting all other components in a refrigeration system. A number of materials have physical and thermodynamic properties that make them suitable for use as refrigerants. In fact, anything that can boil at a low temperature and condense at

UNIT 19—SUMMARY

Refrigerant is the fluid used in a refrigeration system to transfer heat. It does this by absorbing heat while evaporating at a low pressure and temperature and condensing at a high pressure and temperature. Refrigerants may be classified by many characteristics, including the following:

Operating Pressure

Very high pressure
High pressure

Review Questions

Every unit has a set of review questions to help the reader assess his or her understanding of the material.

UNIT 19—REVIEW QUESTIONS

1. Define *refrigerant*.
2. What organization has established the number designation for refrigerants?
3. What are the chemical components of CFC refrigerant?
4. What are the chemical components of HCFC refrigerant?
5. What are the chemical components of HFC refrigerant?
6. What is ozone?
7. Which chemical family of refrigerants has the highest ozone-depletion potential?

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Caution Tips and Safety Tips

These tips contain information students should know to operate equipment properly and protect themselves from harm.

CAUTION

Do not use pliers to tighten or loosen brass fittings. No matter how delicately you use pliers on these fittings, the fitting surface will be damaged. This damage can prevent the next technician from using the proper wrench on the damaged fitting.

SAFETY TIP

Some portable electric tools provide for double-insulated casings and do not need to be grounded. This type of tool may only have a two-prong plug rather than three. If a tool plug has three prongs, never use an adapter to make it fit a two-prong receptacle unless the adapter is properly grounded.

Code Tips

These tips help students provide additional information about codes that technicians will need to know.

CODE TIP

On December 7, 2009, the EPA declared that the current and projected atmospheric concentrations of the six key, well-mixed greenhouse gasses, including HFCs, "threaten the public health and welfare of current and future generations." While no regulations are currently in place in the United States to regulate or phase out HFC refrigerants, the statement does establish the justification for future HFC regulations.

Tech Tips and Service Tips

These tips provide extra detail and information for students who want to go beyond the basics and get practical applications for the information in the unit.

TECH TIP

Air-conditioning and refrigeration hand tools do not get as dirty as most mechanics' tools will. However, it is a good idea to wipe them down with a clean, dry rag after each use. In addition, from time to time they should be rubbed with a lightly oiled cloth to protect them from rusting.

SERVICE TIP

Wrenches should always fit securely over the bolt head or nut before force is applied. If the wrench slips, you will jam your fingers. It is always best to try to pull rather than push on a wrench (Figure 4-39). You will have more control and will be less likely to jam your fingers or rap your knuckles. If you must push, then use an open palm so you're your fingers do not become jammed between the wrench and the work as the wrench begins to turn (Figure 4-40).

Green Tips

These tips provide important details about sustainable practices in the HVAC industry.

GREEN TIP

Blower door readings are useful when performing house tightening. They provide an objective measurement of the degree of improvement achieved.

COMPREHENSIVE TEACHING AND LEARNING PACKAGE

For the Instructor

To access supplementary materials, go online to www.pearsonhighered.com/irc and register. Within forty-eight hours you will receive a code via e-mail and instructions. Within forty-eight hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Prentice Hall textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at http://247pearsoned.custhelp.com/. *Note:* The supplements are also housed in MyHVACLab at www.MyHVACLab.com.

Class Master

You can gain access to the Class Master Web site through the supplements pages referenced above and through MyHVACLab. Once you are at Class Master, you will not need a new password. There is a walk-through to guide you through the system.

HVACR Blog

For teaching tips and more, visit Carter Stanfield's HVACR blog at http://hvacrfundamentals.blogspot.com/

Instructor's Manual with Lecture Notes and Correlation Guides ISBN-10: 0-13-287932-8

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AHRI and HVAC Excellence Correlation Guides

Standards for these two associations have been mapped to our materials.

Supplemental Text

Guide to the NATE/Ice Certification Exams by Featherstone and Riojas, order ISBN-10: 0-13-231970-5

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An asterisk denotes contributors to more than one area of the program.

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UNIT 1

Introduction to Heating, Ventilation, Air Conditioning, and Refrigeration

OBJECTIVES

After completing this unit, you will be able to:

1. give a brief history of HVACR.
2. define environmental heating and air conditioning.
3. give the advantages of freezing foods quickly.
4. explain the importance of having a clean background.
5. list the various types of HVACR jobs and explain what they might do.
6. list the HVACR professional organizations.

1.1 INTRODUCTION

The abbreviation HVACR is certainly a mouthful, and so it is not unusual to ask the question, "What does this mean, and how does it impact me?" However, the answer is not so simple, and a standard definition may not explain very much. This is because the HVACR industry is a complex network that our entire society relies on more today than ever before. Just think how your world would change without refrigeration for your food or drinks and without air conditioning in your car or classroom. Try to visualize how this would affect the greater population, from food distribution networks, to hospital care, to housing for the elderly. As a trained and skilled HVACR technician, you can make a positive impact on society. You can contribute to this growing industry to ensure that systems work efficiently and safely and are environmentally friendly (Figure 1-1).



Figure 1-1 Think green! New innovative technologies will allow some HVACR systems to operate on power supplied by wind turbines.

1.2 HISTORY AND OVERVIEW OF HVACR

Heating

In an attempt to better understand HVACR, let's break it down component by component. The *H* for *heating* seems easy. The history of heating a space by burning wood starts in our earliest times and continues to the present. Elaborate systems using firewood heated Roman buildings. Channels were built underneath the floors to draw heat from a fire, thus warming the building and creating the first central heating systems (Figure 1-2).

Wood, peat, and coal remained the primary heating fuels for centuries. Many early buildings had open fireplaces. But fireplaces are an inefficient way of heating because too much of the heat produced is drawn up the chimney. Although early seventeenth-century European masonry-type stoves burned wood safely at high efficiency, the next

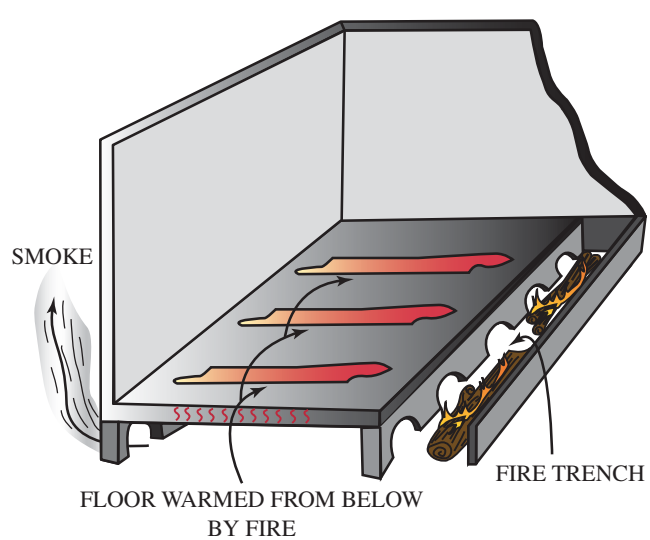


Figure 1-2 Romans used fires channeled below floors as early heating systems.

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Figure 1-3 Woodstove.

major step in heating technology in America was the metal stove. Benjamin Franklin is credited with inventing a cast-iron stove that was several times more efficient than any other stove at that time. Many people still use decorative, efficient stoves to provide much, if not all, of their heating needs (Figure 1-3).

However, wood heat is only one alternative, because today there are many more choices for heating. Gas heat, oil heat, electric heat, and solar heating systems are common. Heat pumps that use a refrigeration system for heating can be very efficient. Geothermal heating systems that utilize the heat from within the earth are becoming more popular. New, environmentally friendly ideas and efficient designs are continually being developed, tested, operated, and maintained by people just like you entering the industry. So you can see that just the *H* alone is a large and important sector.

Ventilation

Next comes the *V* for *ventilation*. Before the invention of chimneys, fires were burned in the center of a room with smoke having to escape through holes in the roof. When early homes were heated by wood fires, the smoke would permeate the entire building. Although people were warm, the health hazards from this smoke exposure were harmful. As an improvement, early Norman fireplaces in England were designed to allow the smoke to escape through two holes in the side of the building. It was obvious that something needed to be done to improve the air quality.

A properly ventilated building allows for the air to flow and exchange so that harmful particulates such as those in smoke are not allowed to accumulate. Fresh air also brings oxygen into the space, but it becomes depleted over time. A simple ventilation system can consist of only a fan and some minor ductwork for transporting the air. More complex systems circulate air throughout entire buildings through a vast network of ducts and blowers.

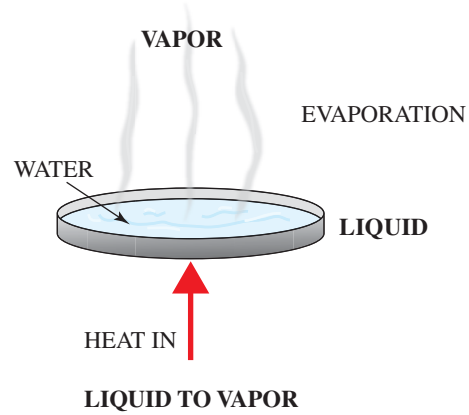


Figure 1-4 When water evaporates, heat is absorbed. This change of state is also referred to as a phase change.

Air Conditioning

The *AC* stands for *air conditioning*. Generally this is considered by most people to be a way to cool a space, but as you will learn, this term encompasses much more. Artificially cooling the air in a living space dates back to the earliest centuries. In ancient Greece, large wet woven tapestries were hung in natural drafts so that the air flowing through and around the tapestries was cooled by the evaporating water. As the water evaporated it would remove heat, just like when you perspire to remain cool (Figure 1-4). Some manufacturers sprayed water in factories for cooling as early as the 1720s. Evaporative cooling is still used extensively in residences and businesses throughout the southwestern United States, where typical summer conditions are very hot and dry.

Ice was the primary means of cooling air for many years. The Romans packed ice and snow between double walls in the emperor's palaces. John Gorrie patented the first mechanical air-conditioning system in 1844. His system was used to cool sick rooms in hospitals in Florida. The United States capitol building in Washington, DC, was first air conditioned using ice in 1909. Rumor has it that when the legislators got really involved in controversial debates, more ice was required to keep the building cool. The phrase "tons of air conditioning" we use today came from this era in history, when tons of ice were used for cooling (Figure 1-5).

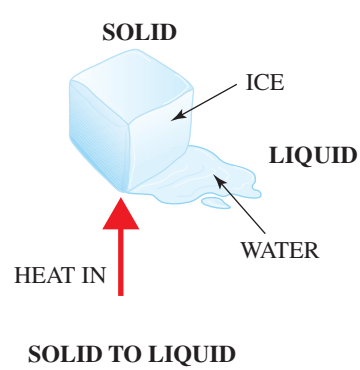


Figure 1-5 When ice melts, heat is absorbed.

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TECH TIP

Refrigerant capacity is measured in tons. One ton of capacity is equivalent to the amount of heat that 2,000 lb of ice can absorb in one day. The amount of latent heat required to change 1 ton of ice into 1 ton of water is 288,000 BTU. If this amount is divided by 24 hr per day, the equivalent is 12,000 BTU/hr.

Refrigeration

Finally, the *R* stands for *refrigeration*, which is a necessary component for most air-conditioning systems; however, refrigeration systems are more commonly considered to be used for keeping food cold. That is why very often you may see the abbreviation HVAC, which implies air conditioning only. The broader term HVACR includes both air conditioning and refrigeration systems.

The first use of refrigeration was for the preservation of food. Ice was harvested from frozen lakes and stored for later use. Sometimes it could be kept all summer long in ice houses. Ice harvesting remained a flourishing industry well into the twentieth century.

Archeologists have discovered that the first evidence of man making ice appeared more than 3,000 years ago, about 1,000 BC. Peoples living in northern Egypt, the Middle East, Pakistan, and India made ice using evaporation. Archeological excavations in these regions have discovered ice-producing fields that covered several acres. The ice was produced in shallow clay plates, about the size of a saucer. The water in these clay plates wept through the clay. This water dampened the small straw mats holding the clay plates in racks a few feet above the ground (Figure 1-6). The straw aided evaporative cooling of the water. Under the right conditions of temperature and humidity, a thin film of ice would form overnight on each clay plate.

Producing ice in this way is also the principle behind modern snow-making equipment. A snow-producing machine like the one in Figure 1-7 can make snow by evaporative cooling even when the temperatures on the ski slopes are above freezing.

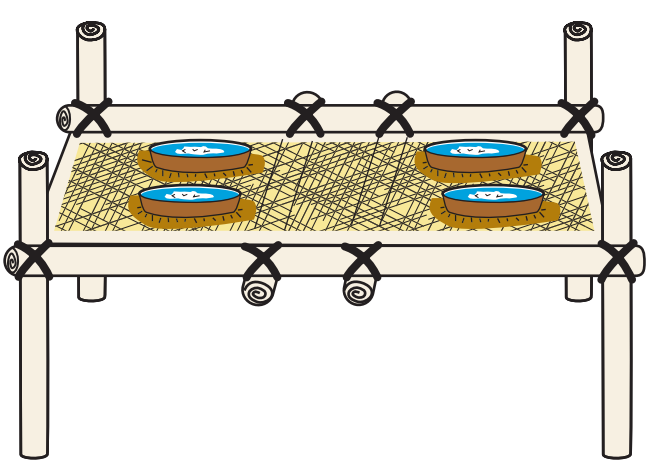


Figure 1-6 Ice was first artificially produced to be used for food preservation more than 3,000 years ago.



Figure 1-7 Snowblowers can produce artificial snow by evaporative cooling. *(Courtesy of Red River Ski Area)*

Today, a majority of refrigeration systems use what is referred to as mechanical vapor compression. The mechanical process of compressing a gas to produce cooling can be traced back to coal mines in England. Large steam-driven or water-powered compressors were used to force air into the deepest mines so miners could work in a safe atmosphere. Over long hours of operation, miners observed the formation of ice around the air nozzles (Figure 1-8). This ice was collected and used for food preservation. The construction of steam-powered compressed-air plants that produced ice soon followed. The first maritime refrigeration units were made by putting steam-powered compressors on sailing ships to make it possible for beef to be shipped from Australia to England, starting in 1876.

HVACR and the Refrigeration Cycle Now that you have a better understanding of what HVACR means, it is easy to see that it encompasses a broad spectrum of needs and applications. Although the methods for heating can vary considerably, the majority of cooling applications are based on the refrigeration cycle. When ice changes to water, heat

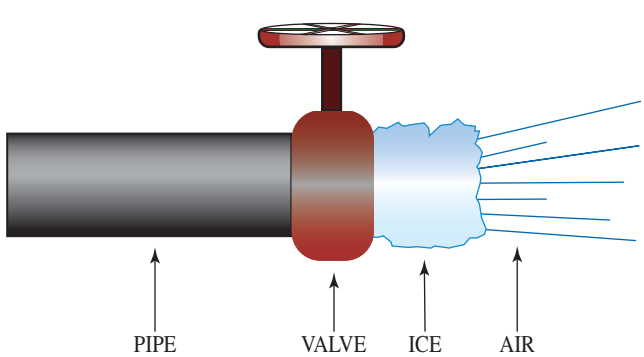


Figure 1-8 Ice forming around an air nozzle.

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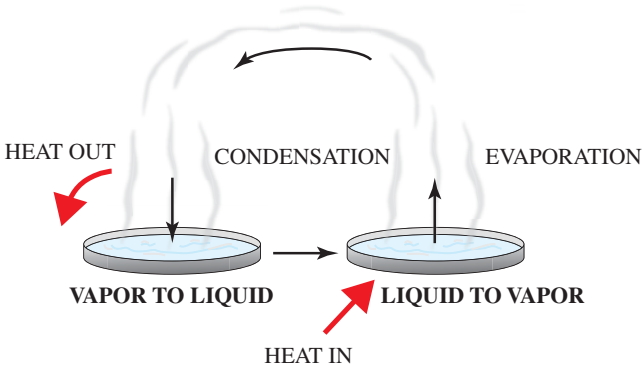


Figure 1-9 Water evaporates to vapor and absorbs heat, and then the vapor is condensed back to water to release its heat.

is absorbed, which makes ice a viable refrigerant. But ice is hard to store and takes up a lot of space. Water is easier to use because it can be pumped and doesn't need the insulation that ice requires. When water evaporates to vapor it also absorbs heat, but then the water needs to be replaced, and this uses up a lot of water over time.

If the vapor can be recovered and turned back into water, then this cycle reduces the total amount of water needed (Figure 1-9). Even so, the major disadvantage with this type of evaporative cooling is that the lowest temperature that can be reached is dependent on the properties of water.

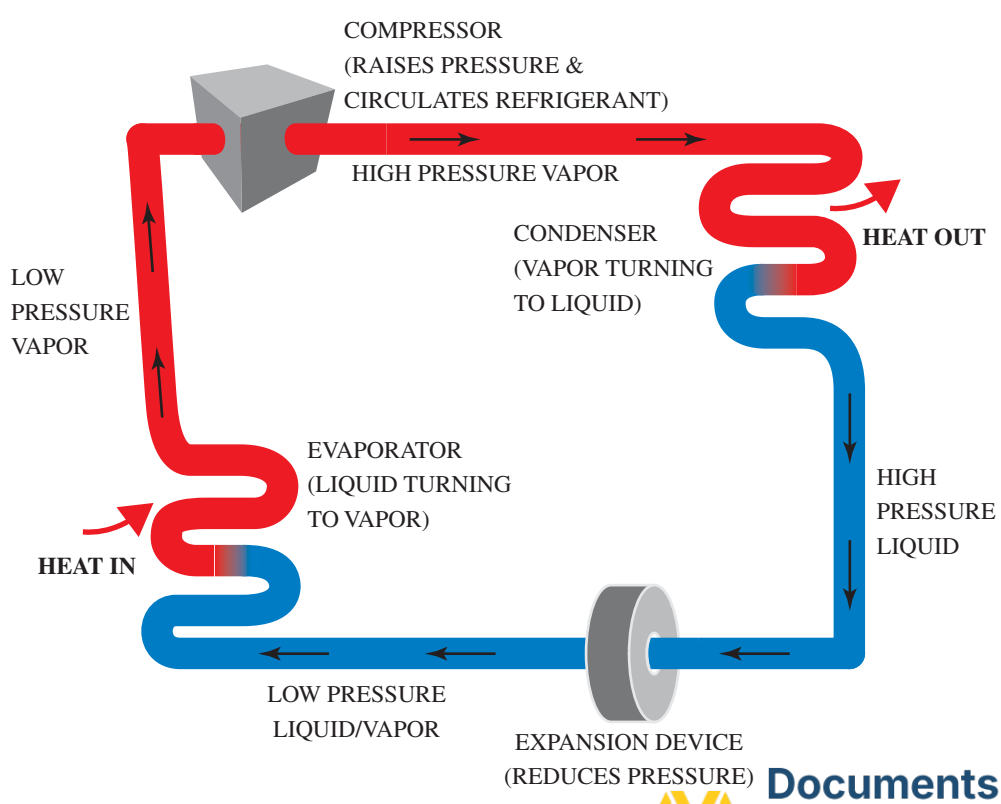
Notice that with both ice and water, it is their change of state that allows for heat to be absorbed. It is this important principle that serves as the basis for most refrigeration systems today, but instead of using water, other fluids with different properties and lower boiling points, called refrigerants, are now used. This allows for much colder temperatures, far below freezing. The "refrigeration cycle" therefore continually evaporates and condenses refrigerants to absorb and then throw away the heat.

A compressor is used like a pump to raise the pressure and circulate the refrigerant through the system (Figure 1-10). A condenser is used to remove heat from the refrigerant as it turns into a liquid. An expansion device drops the pressure to allow the refrigerant to change back from liquid to vapor in the evaporator. Heat is absorbed in the evaporator and then thrown away in the condenser. The refrigerant does not wear out and circulates around and around during operation. Most refrigeration systems in use today operate using this type of cycle.

1.3 TODAY'S HEATING, AIR CONDITIONING, AND REFRIGERATION

"Environmental heating and air conditioning" refers to the control of a space's air temperature, humidity, circulation, cleanliness, and freshness, and it is used to promote the comfort, health, and/or productivity of the inhabitants. Homes, offices, schools, colleges, factories, sporting arenas, hotels, cars, trucks, and other vehicles such as aircraft and spacecraft are heated and cooled. The main purpose of environmental heating or cooling is to help maintain the body temperature within its normal range. Generally, the term *air conditioning* is used when the space temperature is above 60°F (15°C), and *refrigeration* is the term used when the space temperature is below 60°F (15°C).

Figure 1-10 The basic refrigeration cycle consists of four major components: compressor, condenser, expansion device, and evaporator.



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TECH TIP

Without our ability to control the environment, it would be impossible for us to explore space or the bottom of the ocean or even to enjoy the comfort of a transcontinental jet ride at 35,000 ft. So our ability to control our environment has served both to improve the quality of life and to enhance our scientific endeavors.

Process heating and cooling are used to aid in manufacturing or to keep equipment at a desired temperature. An area used to process meat or vegetables may be cooled to help preserve the product. Computer rooms are cooled so the equipment lasts longer and is able to stay online due to the heat being removed from the space. Computers would not operate properly if heat was not absorbed from the space. Remote pumping stations may be heated to prevent pipes from freezing. The main purpose of process heating or cooling is to maintain the temperature of things or processes within their required range.

TECH TIP

An operating room is cooled to aid with the surgery as well as for the comfort of the patient or surgeon. Therefore, an operating room is an example of process cooling even though it may be within the normal air-conditioning temperature range.

Modern Heating

Central heating of homes and businesses dates back to ancient times, but the first commercial warm-air fan-driven system was marketed in the 1860s. By the 1900s a number of different central warm-air systems were available for residential and commercial applications, and in 1908, the essential elements for heating, cooling, humidifying, dehumidifying, and filtering air were defined.

Today central heating systems can use warm air, hot water, steam, electric resistance, or a reverse refrigeration cycle (heat pump). The basic theory for the heat pump dates back to 1852.

Modern Air Conditioning

The development of modern air conditioning is often credited to Dr. Willis Carrier. Dr. Carrier, an engineer, was confronted with a problem facing printers. As paper was printed with one color, the dampness in the ink caused the paper to stretch slightly, and it was nearly impossible for the second color to be printed without being misaligned. Dr. Carrier determined that a means for controlling the humidity was necessary and developed the first air-conditioning system for the printing industry. His invention, called an "Apparatus for Treating Air," was patented in 1906 (Figure 1-11). His invention quickly found favor not only for dehumidifying but also for cooling. Through the 1940s and 1950s, businesses would proudly display signs reading "Air Conditioned." Dr. Carrier designed the psychrometric chart as we know it today. (This chart displays the properties of air, such as temperature, humidity, and volume, and is commonly used for many HVAC applications.)

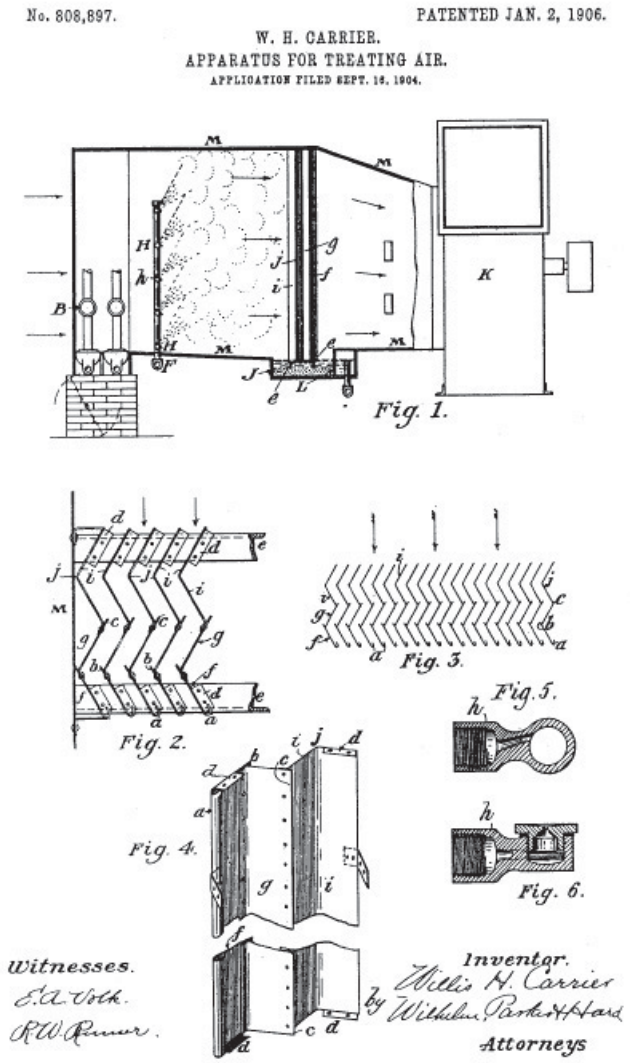


Figure 1-11 The patent for the first apparatus for cooling air, invented by Willis Carrier.

Mass air conditioning of homes began in the late 1950s with window air conditioners. Central residential air conditioning started to become popular in the mid-1960s. Today most of us cannot imagine living in a home anywhere in the country that does not have air conditioning.

Modern Refrigeration

Clarence Birdseye made another major contribution to the industry. He developed the process of freezing foods in 1922. Today, supermarket freezer displays provide us with a variety of food products that would not be possible to preserve any other way (Figure 1-12). In 2006, a new era in eating occurred when the American public purchased more heat-to-eat and thaw-to-eat foods than any other type of food.

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Figure 1-12 Modern refrigeration display cases provide us with a variety of food products that would not be available without refrigeration.

- **Frozen foods** Before Clarence Birdseye began commercially freezing food, people had allowed food to freeze naturally during the winter months as a way of preserving it for later use. Food frozen this way did not always taste that good, so the trick was to come up with a way of freezing food and having it still taste good when it was thawed.
- **Quick freezing** The process of rapidly freezing food using air blast, contact, and/or immersion freezing was the key to improving the quality and taste of thawed frozen foods. The problem with freezing food slowly is that when ice crystals form over time, they become much larger. These large, sharp ice crystals grow through the cell walls of the food, and when the food thaws, all of the nutrients in the food are allowed to drain away. Quick freezing causes the ice crystals to be very small and less likely to penetrate cell walls, so the food retains nutrients and flavor when it is thawed.

1.4 EMPLOYMENT OPPORTUNITIES

The HVACR industry represents one of the largest employment occupations in the country. Our industry, for example, is one of the largest consumers of electric and gas utilities in the nation. More electricity and natural gas is consumed producing heating and cooling than for any other single use. The size of the industry has been growing steadily since the late 1960s, when residential central systems became popular. The installation and servicing of HVACR systems will always be an expanding occupation. No one builds a home or business without some type of heating and/or cooling system, which requires designing, installing, and servicing by skilled and trained technicians.

Residential Air Conditioning and Heating

Most residential heating systems have a heating capacity of 50,000 to 150,000 BTU/hr. The majority of residential air-conditioning systems are 5 tons or less. Both of these sizes will obviously vary greatly, depending on the region of the country you are working in. In addition, there are many very large homes being built, requiring systems that could easily be classified as light commercial because of their size and/or complexity.

TECH TIP

To protect the public from potentially dangerous individuals, some businesses and/or local and state governments require criminal background checks on anyone involved with in-home service work. These checks may go back 25 years or more into an individual's past. Check with your local or state governmental department that regulates in-home service work if you feel there is something in your past that might affect your ability to work in residential service. In most states these checks are only required for in-home service work, so you may still be able to work in new construction or in the commercial or industrial areas.

Commercial Air Conditioning and Heating

The term *commercial* is used to refer to any system that is used in commercial buildings (for business) that provides cooling or heating. These systems may be as small as a fraction of a ton in size to several thousand tons in cooling capacity and/or from 1,000 BTU/hr to hundreds of thousands of BTU/hr.

Commercial systems may be operated independently of any other system or be integrated with a building automation system. Because of the vast differences in the types of equipment and system complexity, commercial technicians often specialize in a single type of system or group of systems.

Commercial and Industrial Refrigeration

The terms *commercial refrigeration* and *industrial refrigeration* are applied to retail food and cold-storage equipment and facilities. Examples of commercial equipment and systems include refrigeration equipment found in supermarkets, convenience stores, restaurants, and other food service establishments. Industrial refrigeration can include long-term storage either as cold storage or medium or low-temperature refrigeration systems that are generally larger-scale operations.

Types of Jobs

There are a variety of occupational specialties offered within the HVACR industry. These occupations range from the basic entry-level helper to the systems designer. Although the work involved with heating, air conditioning, or refrigeration equipment and systems is similar in theory, there is a significant difference between the work done in the areas of residential, light commercial, commercial, and industrial. These areas of heating, air conditioning, and refrigeration generally relate to the size (capacity) and complexity of the system. However, technicians may find the exact same equipment used in one home being used in a commercial shop or factory. In these cases the distinguishing factor is whether you are working in someone's home or in a business.

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- **Entry-level helper** The entry-level helper (first-year apprentice) provides the senior technician with assistance installing and servicing equipment. Most medium and large mechanical contracting companies use a number of helpers to assist with the installation and service of residential and commercial systems. A helper may be expected to assist in lifting, carrying, or placing equipment or components. He or she may also run errands to pick up parts and clean up the area following installation or service. Helpers receive basic safety training, and if they will be driving, they must have good driving records.
- **Rough-in installer** The initial installation process is referred to as rough-in. In this process the technician (first- through third-year apprentice) will install the refrigerant lines, electrical lines, thermostat and control lines, duct boots, and duct run and set the indoor and outdoor units. The rough-in technician must have an understanding of duct layout, blueprint reading, and basic hand tools and good brazing skills.
- **Start-up technician** Once the system has been installed and all of the components are ready for operation, a start-up technician (fourth- and fifth-year apprentice) will go through the manufacturer's recommended procedures to initially start a system. Because much of the HVAC system has been field installed, this checkout procedure is essential to ensure safe and efficient operation. The start-up technician records all of the information requested by the manufacturer's warranty. Start-up technicians must be skilled with electrical troubleshooting and refrigerant charging and have good reading comprehension and writing skills.
- **Service technician** The service technician (fourth-year apprentice to journeyman) is the individual who provides the system owner with repair and maintenance. Service technicians are the people who must be able to diagnose system problems and make the necessary repairs. Service technicians must be skilled in diagnosing electrical problems, refrigerant problems, and air-distribution problems.

TECH TIP

Technology has enabled the field tech to stay in close contact with his service manager. This allows the highly experienced service managers to provide assistance to technicians as they come upon new problems. The technician can also call upon the office to research unique problems to determine the best, most efficient way of making the repair.

- **Sales** HVACR sales are divided into two major categories: inside sales and outside sales. Inside sales deal primarily with system sales to other air-conditioning contractors. Outside sales may be to both contractors and end users. Working in outside sales or consumer sales requires the technician to have a good understanding of cost and value of equipment so that the owner can make an informed choice.
- **Equipment operator** Equipment operators are required by local ordinance and state law to be present anytime large central heating and air-conditioning plants are in operation. Their primary responsibility is to ensure the safe and efficient operation of these large systems. They must have a good working knowledge of the system's mechanical, electrical, and computer control systems to carry out their job. They sometimes need to hold a city or state license to become an operator. Equipment operators generally work by themselves or as part of a small crew. They often are required to have good computer skills when buildings have computerized building-management systems.
- **Facilities maintenance personnel** Facilities-maintenance personnel are responsible for planned maintenance and routine service on systems. They may work at a single location or have responsibilities for multiple locations, such as school systems. Facilities-maintenance personnel typically maintain systems and provide planned maintenance. They may work alone or as part of a crew, depending on the size of the facility. Maintenance personnel may from time to time have duties and responsibilities outside of the HVACR trades, such as doing minor electrical plumbing and carpentry projects for the upkeep of the building.
- **Service manager** A service manager is typically a skilled HVACR technician with several years of experience. This individual oversees the operation of a company or maintenance department. He or she must have good management skills, communication skills, and technical expertise. Service managers typically assign jobs to other technicians and employees. They must then oversee these individuals' jobs.
- **Systems designer** For small buildings, contractors normally size and select HVAC systems and equipment. There are many industry-standard sizing and design guides available from trade associations such as the ACCA (Air Conditioning Contractors of America). For larger buildings, mechanical, architectural, or building services engineers may be required by law to design and specify the HVAC systems. Specialty mechanical contractors will work with the design plans to build and commission these systems.

1.5 TRADE ASSOCIATIONS

With the rapid growth and variety of interests, trade associations naturally evolved to represent specific groups. The list includes manufacturers, wholesalers, contractors, sheet metal workers, and service organizations. Each is important and makes a valuable contribution to the field. Space does not permit a detailed examination of all of these organizations, or all of their activities, but throughout the book many of these associations will be acknowledged as specific subjects are covered.

Certifications

Many trade associations offer training programs and competency examinations for the industry to help ensure a workforce of qualified technicians. In addition, the 1990 Clean

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Air Act passed by the United States Congress requires that anyone who performs maintenance, service, repair, or disposal that could be reasonably expected to release refrigerants must be certified. To become certified, technicians are required to pass an Environmental Protection Agency (EPA)–approved test given by an EPA-approved certifying organization. Four different types of certifications have been developed to address different types of equipment. A person meeting the requirements for all four types is issued a universal certification. This is certification process is further described in Unit 28, Refrigerant Management.

Air-Conditioning, Heating, and Refrigeration Institute (AHRI)

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) is a national trade association representing manufacturers of over 90 percent of U.S.-produced central air-conditioning, gas appliances, and commercial refrigeration equipment. AHRI was formed in 2007/2008 when ARI (Air Conditioning and Refrigeration Institute) merged with GAMA (Gas Appliance Manufacturers Association). ARI, now AHRI, was originally formed in 1954 through a merger of two related trade associations and traces its history back to 1903 when it started as the Ice Machine Builders Association of the United States. Today AHRI has over 180 companies as members.

Many services are provided by AHRI to assist HVACR technicians. Some of these services, which would supplement this text, are listed below:

- ICE is an industry competency exam. This test is made available to students of educational institutions to test their knowledge of fundamental and basic skills necessary for entry-level HVACR technician positions. The information in this text covers the topics in the AHRI curriculum guide and would assist the student in taking this examination. A directory of those who pass the examination is published nationally to assist prospective employers in identifying job candidates.
- Equipment donations to schools participating in the ICE competency exam. AHRI contacts industry sources having no-cost or low-cost equipment available to supply a school's laboratory needs.
- Technician certification program. In accordance with EPA's enforcement of the Clean Air Act, the sale of refrigerants is made only to those technicians who have been certified. AHRI is among the many approved by EPA to administer the test for certification. In addition, AHRI provides study material to prepare for the test.
- Reclaimer certification program. EPA also requires certification of any processor of recovered refrigerant for resale. AHRI is among those assigned by EPA to carry out a certification program for companies that seek to reclaim refrigerants. Technicians handling reclaimed refrigerant should become familiar with the *Directory of Certified Reclaimed Refrigerants*, published every March and September by AHRI.
- Certification program for equipment used to recover and recycle refrigerant. AHRI is one of the companies approved by EPA to certify equipment used to recover and recycle refrigerants. Technicians should become familiar with the *Directory of Certified Refrigerant Recovery/Recycling Equipment*, published every March and September by AHRI.
- HVACR equipment certification program. AHRI maintains a certification service, which tests a wide variety of equipment and products to verify the performance described by the manufacturer. Certified directories for various products are published semiannually and annually.

AHRI has a full program of educational activities geared toward helping the nation's vocational and technical schools improve and expand their education and training programs. Under the direction of AHRI's education director and its Education and Training Committee, AHRI serves as a resource for manufacturers, school instructors, department heads, and guidance counselors. In addition to this textbook and its companion materials, AHRI produces the *Bibliography of Training Aids*, a career brochure, and a promotional video for schools to use to recruit students into HVACR programs. Many schools around the country have adopted the ICE competency exams as final exams for their programs. AHRI's most recent efforts involve participation in developing national HVACR competency standards.

Having students pass the ICE competency exams and training toward national competency standards will improve the quality of installation and service. New HVACR technicians will be better prepared, resulting in three basic advantages:

- Limited training required for contractors
- Limited rework or repeat calls due to error
- Limited warranty/replacement for manufacturers

The cost of repeat service calls, which is borne by contractors, may be reduced substantially by employing properly trained technicians. Every new technician receives training and serves as an apprentice for a period of time. That is essentially a period where contractors pay two people to do one job. A properly trained technician will generally require less training time and function sooner than a poorly trained technician.

In co-sponsorship with AHRI, ASHRAE holds an annual international Air Conditioning Heating Refrigeration Exposition, which may draw 30,000 to 50,000 people in the field. Product exhibits, technical displays, and business seminars highlight the event.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) is an organization started in 1904 as the American Society of Refrigeration Engineers (ASRE) with seventy members. Today its membership is composed of thousands of professional engineers and technicians from all phases of the HVACR industry. ASHRAE also creates equipment standards for the industry. Its most important contribution probably has been a series of our books that have become the reference books of the industry: *HVAC Applications, Refrigeration, Fundamentals,* and *HVAC Systems* and *Equipment.*

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TECH TIP

Becoming an active participating member in a professional trade association will provide you with an opportunity to continue your HVACR education. The HVACR field is such a dynamic and evolving industry that to stay competitive you must continually attend seminars and take classes. This is a field where your success will depend on your continued education.

American Society of Mechanical Engineers (ASME)

The American Society of Mechanical Engineers is an organization composed of engineers in a wide variety of industries. Among other functions, ASME writes standards related to safety aspects of pressure vessels.

Air Conditioning Contractors of America (ACCA)

The Air Conditioning Contractors of America is a service contractor's association concerned with the education of technicians and service managers with business-improvement techniques. ACCA provides technician EPA certification.

Refrigeration Service Engineers Society (RSES)

The Refrigeration Service Engineers Society is the international professional association for all HVACR workers and is dedicated to education and certification of technicians in the HVACR industry. RSES offers Specialist Certification for senior technicians in eight HVACR areas and has a technician EPA certification program. RSES chapters conduct classroom training in technical areas and are a source for educational printed material and books.

HVAC Excellence

HVAC Excellence is a not-for-profit organization that has been serving the HVACR industry since 1994. The organization's goal is to improve competency through validation of the technical education process by offering progressive levels of technician certification through its HVAC Excellence programs.

SERVICE TIP

The AHRI list of certified equipment is available to anyone through the Internet. This material is very helpful when trying to make a determination of the best equipment to recommend for customers and their specific application needs. On the Web, very often all of the various pieces of equipment are available.

UNIT 1—SUMMARY

Since the beginning of time, people have had a desire to control their environment to live and work more comfortably. That trend will not stop, and that is the good news for anyone entering this ever-growing, financially rewarding, and personally satisfying field. HVACR technicians are required to understand the theories behind designing, installing, and servicing a wide range of systems. This diversity ensures that each day on the job will be new and unique, ever changing, and challenging.

UNIT 1—REVIEW QUESTIONS

1. List some of the different ways that homes and buildings may be heated.
2. What were some of the primary heating fuels that early civilizations used?
3. When is it believed that ice was first artificially made for food storage?
4. How did early man make ice?
5. Why did some manufacturers spray water in factories in the early 1700s?
6. How did early Romans cool palaces?
7. What do the terms *environmental heating* and *air conditioning* refer to?
8. What does the term *process heating and cooling* refer to?
9. When did central warm-air systems for residential and commercial applications become well defined?
10. Who developed what is referred to as modern air conditioning?
11. When did mass air conditioning of homes with window units begin?
12. Why is it important to freeze foods quickly?
13. Why do some businesses and/or local and state governments require criminal background checks for HVACR workers?
14. What size range might a commercial air conditioner fit into?
15. Give an example of some of the types of equipment that a commercial refrigeration technician might work on.
16. What type of things might an entry-level helper do?
17. Whose job is it to do the initial installation process, such as install the refrigerant lines, electrical lines, thermostat and control lines, duct boots, and duct run, as well as setting the indoor and outdoor units?
18. What skills must a service technician have?
19. What are some of the things that a service manager must be able to do?
20. What is the ICE exam, and who might take it?
21. What are some of the RSES's activities?

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UNIT 2

Being a Professional HVACR Technician

OBJECTIVES

After completing this unit, you will be able to:

1. list some of the most popular HVACR publications.
2. explain the importance of professional certifications.
3. list the seven specialty areas of NATE specialty certification.
4. explain the value of taking the Industry Competency Exam (ICE).
5. list the items that help make for a professional appearance while on the job.
6. describe how to develop good communication with the customer.

2.1 INTRODUCTION

The air-conditioning and refrigeration industry has more professional organizations, trade associations, publications, and other related organizations than most any other technical field. As a student, you should consider becoming involved with a student organization such as the student clubs of ACCA, RSES, or ASHRAE. These will give you an opportunity to begin developing extremely important business and technical contacts in the local HVACR industry, and these contacts will serve you very well as you enter the profession.

As a professional in the trade, it is to your advantage to maintain a close relationship with one or more of these professional organizations. Each group provides its members with the latest trends and most current technical information. This gives members a significant edge. Most of the organizations provide ongoing technical and business training classes. Many of the classes cover the latest trends in equipment, regulations, codes and standards, local building regulations, and business practices. Being able as a member to participate in these ongoing educational opportunities will keep you at the leading edge of your new profession.

Each of these professional organizations has publications, and many provide the industry with codes and standards. These publications would be an excellent addition to your technical library. Having an up-to-date library will help you provide your employer and customers with the best possible service while making you significantly more valuable as an employee. HVACR is an ongoing learning process for even the most skilled technician.

Figure 2-1 lists a number of these professional associations. Most have Web sites, and many have local, regional, and state chapters that you can become affiliated with.

Many of the HVACR professional organizations have industrial trade shows. These shows provide excellent opportunities for you to see the various manufacturers' latest equipment, tools, supplies, and services. Some of the trade shows are local, others may be regional, some are national, and a few are international (Figure 2-2).

TECH TIP

Once you enter the profession as an HVACR technician, all costs associated with taking additional classes, purchasing books, and membership dues may be tax deductible.

2.2 PUBLICATIONS

Another excellent way of keeping up with the latest information in the HVACR field is by subscribing to one or more of the HVACR publications (Figure 2-3). Some of these publications are weekly, while others are monthly. They all contain well-written articles specifically addressing HVACR industry concerns. Many of them are written to teach their readers troubleshooting skills. Their articles are very valuable even to the skilled technician.

Some of the professional organizations have their own newsletters that are published and provided to their members. Some local and state chapters of these organizations have additional newsletters that are provided to their members.

2.3 PROFESSIONAL CERTIFICATION

Every HVACR technician must become certified under the EPA Section 608 regulations. Compliance with these regulations regarding the management of refrigerants is mandatory for everyone in the trade. Following your successful completion of any and all of the appropriate levels, it remains your responsibility to stay current with any changes in these regulations . As unfair as it may seem, you can be fined significantly for violating an EPA regulation pertaining to refrigerants even if that regulation took effect after your successful completion of the certification. In addition, it is your sole responsibility to remember and follow all of the

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ACCA—Air Conditioning Contractors of America
AFEAS—Alternative Fluorocarbons Environmental Acceptability Study
AGA—American Gas Association
AHAM—Association of Home Appliance Manufacturers
AMCA—Air Movement & Control Association
ANSI—American National Standards Institute
AHRI—Air-Conditioning, Heating, and Refrigeration Institute
ARWI—Air-Conditioning & Refrigeration Wholesalers International
ASAE—American Society of Association Executives
ASHRAE—American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ABC—Associated Builders & Contractors
BOMA International—Building Owners and Managers Association
COBRA—The Association of Cogeneration
CDA—Copper Development Association
COSA—Carbon Monoxide Safety Association
EEI—Edison Electric Institute
EPRI—Electrical Power Research Institute
EHCC—Eastern Heating & Cooling Council
Envirosense Consortium Inc.
EPEE—European Partnership for Energy and the Environment
FMI—The Food Marketing Institute
GEO—Geothermal Exchange Organization
GMA—Grocery Manufacturers of America
Green Mechanical Council
HARDI—Heating, Airconditioning, and Refrigeration Distributors International
HPBA—Hearth, Patio and Barbeque Association
HI—Hydraulic Institute
HRAI—Heating, Refrigerating, & Air-Conditioning Institute of Canada
HVAC Excellence
IDDBA—International Dairy, Deli, Bakery Association
IFPA—International Fresh-Cut Produce Association
IGSHPA—International Ground Source Heat Pump Association
IIAR—International Institute of Ammonia Refrigeration
IHACI—Institute of Heating and Air Conditioning Industries
ISA—The Instrumentation, Systems, and Automation Society
MCAA—Mechanical Contractors Association of America
MSCA—Mechanical Service Contractors of America
NACS—National Association of Convenience Stores
NADCA—National Air Duct Cleaners Association
NAHB—National Association of Home Builders
NAFEM—National Association of Food Equipment Manufacturers
NAM—National Association of Manufacturers
NATE—North American Technician Excellence Program
NRA—National Restaurant Association
NEMA—National Electrical Manufacturers Association
NFFS—Non-Ferrous Founders' Society
NIPC—National Inhalant Prevention Coalition
PHCC—Plumbing Heating Cooling Contractors Association
PIMA—Polyisocyanurate Insulation Manufacturers Association
PMA—Produce Marketing Association
RACCA—Refrigeration & Air Conditioning Contractors Association
RSES—Refrigeration Service Engineers Society
SMACNA—Sheet Metal and Air Conditioning Contractors' National Association
SMWIA—Sheet Metal Workers International Association
UL—Underwriters Laboratories Inc.
UA—United Association

Figure 2-1 U.S. organizations.

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CANMET—Canadian Centre for Mineral and Energy Technology
EPEE—European Partnership for Energy and the Environment
EUROVENT—European Committee of Air Handling & Refrigerating Equipment
ICARMA—International Council of Air-Conditioning and Refrigeration Manufacturers' Association
globalEDGE
IEA—International Energy Agency
IIAR—International Institute of Ammonia Refrigeration
IIR—International Institute of Refrigeration
JRAIA—Japan Refrigeration and Air-Conditioning Industry Association
LATCO's Tools of the Trade (Latin American international trade sites)
Trade Compass
UNEP—United Nations Environment Programme
USA*Engage
World Bank
WTPF—World Trade Point Federation

Figure 2-2 International Organizations.

The Air-Conditioning, Heating & Refrigeration (ACHR) News
American School & University (AS&U)
APPLIANCE magazine
Appliance Manufacturer
ASHRAE Journal
Buildings
Building Design and Construction
Consulting-Specifying Engineer
Contracting Business
Contractor magazine
Energy User News
Engineered Systems
Facilities Net
Heating/Piping/AirConditioning (HPAC)
Japan Air Conditioning, Heating & Refrigeration News (JARN)
Plant Engineering
RSES Journal
SchoolDesigns.com
Skylines
Supply House Times
Western HVACR News

Figure 2-3 Publications.

EPA regulations pertaining to refrigerant management. For that reason, it would be a good business practice to occasionally take a refresher course in EPA rules and regulations.

2.4 INDUSTRY COMPETENCY EXAM (ICE)

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the Air Conditioning Contractors of America (ACCA); Heating, Airconditioning, and Refrigeration Distributors International (HARDI); the Plumbing, Heating, Cooling Contractors Association (PHCC); North American Technician Excellence (NATE); the Partnership for Air-Conditioning, Heating, Refrigeration Accreditation (PAHRA); and the Refrigeration Service Engineers Society (RSES) have established a competency examination that is designed for students who have completed or nearly completed a technical training program. This examination is voluntary, but it does provide students leaving a training program, whether from high school, trade school, or community college, with an opportunity to evaluate their knowledge with an industry standardized test.

The ICE has been developed over the years with input from manufacturers, trade associations, instructors, and other industry experts. This exam can also provide your institution with an overall evaluation of its training program. Upon your successful completion of the ICE, your name, along with your school's name, is published and made available to area contractors who might be looking for new skilled employees. In short, the successful completion of the ICE can put you well ahead of other graduates from programs not participating in the ICE. The ICE is in three parts—Residential Heating and Air Conditioning, Light Commercial Heating and Air Conditioning, and Commercial Refrigeration. A good student will make testing and certification achievement a challenge for him- or herself, always setting goals high.

AHRI and its affiliates provide training institutions with incentives as encouragement to participate in the ICE by directing many of its manufacturing members' equipment donation programs toward the schools, institutes, and colleges that participate in the ICE program. These equipment donations can become an excellent source of the latest equipment you will be seeing in the field.

2.5 SKILLS USA

Skills USA is a vocational industrial club for students in high schools, trade schools, and community colleges. Skills USA clubs are open to students in all areas of specialty, including HVACR. The national organization provides local chapters and students with many opportunities to develop leadership, citizenship, and interpersonal skills that are invaluable to the success of individuals in any profession. The Skills USA logo is shown in Figure 2-4a.

In addition to the opportunities for individual professional growth, Skills USA sponsors regional, state, national, and international skills competitions. The contestants for the HVACR competitions will be tested in the following areas: written

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(a)



(b)



(c)

Figure 2-4 (a) Skills USA logo; (b,c) Students competing in the National Skills Olympics.

exam, brazing skills, refrigerant component service, air measurement and troubleshooting, refrigerant recovery, and electrical troubleshooting. Various industry equipment used may include ice machines, refrigerated display cases, small package HVAC units, furnaces, and split-system air-conditioning units. These skills competitions are available on the secondary and post-secondary levels. By participating in the competition, students are given the opportunity to demonstrate their troubleshooting skills in diagnosing real-world problems under the supervision of highly skilled individuals serving as judges.

The winners of local, state, and national competitions move on to the international skills competition held in a different country each year. At the international competition, the best and brightest students from around the world compete to see who has the greatest knowledge and expertise in each of the technical areas, including HVACR. Every student who participates in these skills Olympics at any level receives recognition. Students involved in this program are shown in Figure 2-4b, c. This recognition is invaluable to the students because prospective employers value such recognition.

2.6 COUNCIL OF AIR CONDITIONING AND REFRIGERATION EDUCATORS (CARE)

The Council of Air Conditioning and Refrigeration Educators (CARE) is an organization that was founded in the late 1990s by a group of air-conditioning educators, counselors, and administrators responsible for the various aspects of HVACR training. This group is made up of individuals from secondary schools, post-secondary schools, and colleges, representing institutions from various regions of the country.

The purpose of CARE is to educate to meet or exceed the needs of the industry.

CARE membership is open to instructors, counselors, and administrators who are involved in some aspect of HVACR training. Through this organization, individuals can come together to learn and share experiences for the betterment of the HVACR students and program.

2.7 NORTH AMERICAN TECHNICAL EXCELLENCE (NATE)

NATE is an independent, third-party certification body formed in 1997 as a result of a concern expressed by many in the industry that there was not a way of distinguishing quality, highly skilled HVACR technicians from every other person working in the field. NATE is supported by all of the major equipment manufacturers, major component manufacturers, professional and trade associations, and the National Skills Standard Board. Figure 2-5 shows a technician with a patch showing NATE certification working on a system. You can earn installation, service or senior certification in one or more of the following specialty areas:

1. Air conditioning
2. Air distribution
3. Air-to-air heat pumps
4. Gas furnaces
5. Oil furnaces
6. Hydronics gas
7. Hydronics oil
8. Light commercial refrigeration
9. Commercial refrigeration
10. Ground source heat pump loop installer
11. HVAC efficiency analyst (Senior Level)

Installation certification is primarily designed for the technician who is involved with the installation or removal of HVAC equipment. Installers assemble the system and fabricate the necessary connections to complete an efficient system. They also set up the operational controls under the supervision of a service technician. After the system is started, the installation technician records the readings for temperature, pressure, voltage, current, and any other

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Figure 2-5 NATE-certified air-conditioning technician checking the refrigerant charge in a residential system.

measurements required by the manufacturer or service company for the completion of the warranty paperwork.

The service technician must have all of the skills of the installation technician plus be able to work independently. Service technicians must be able to perform field diagnostics to determine the cause of system failures and to make the needed repairs.

In addition to having the technical skills required to pass the various areas of specialization, each technician must take a core exam as part of the exam process. The core test covers basic math, customer relations, comfort, heat transfer, and the fundamentals of electricity. A well-trained, experienced technician should be able to take and pass both the core and area specialty exams. A number of organizations provide NATE pretest tutorial classes to bring technicians' skill levels up to pass the exam. The exam passing score is 70 percent or better. Certification lasts for five years, after which time a technician must recertify. There are many classes that qualify for credits that can be used toward recertification. If a technician receives 60 hours of credit, the technician does not have to take a test at five years. If the technician obtains 30 credit hours, he or she will only be required to take a fifty-question specialty test instead of a hundred questions.

NATE recommends that you have at least one year of field experience before taking an installation series test and at least two years of experience before taking a service series test. It is further recommended that you have some instruction from an educational institution or trade association.

NATE has provided technicians with Knowledge Areas of Technician Expertise (KATEs), which give detailed outlines of all of the material that a technician can expect to be questioned about on an exam. These KATEs represent all of the knowledge and skills that a quality HVACR technician should have. The KATEs also help the prospective test candidate to focus on those areas that the industry feels are most important.

2.8 HVAC EXCELLENCE

HVAC Excellence established the national standards for HVACR programs in the summer of 1999, becoming the industry's first accrediting body. Programmatic accreditation is an independent third-party review of an educational program. This begins with experienced auditors conducting an on-site visit at each school applying for accreditation. The process validates that established standards of excellence for HVACR educational programs are met. Standards require a thorough examination of mission of the program, administrative responsibilities, finances and funds, curriculum, plan of instructions, facilities, equipment and tools, cooperative training, and instructor's qualifications.

2.9 CODES AND STANDARDS

There are many organizations and agencies that provide codes that are used throughout the HVACR industry, and Figure 2-6 lists many of them. In addition to codes, these groups provide standards. The difference between a code and a standard is that codes often carry with them the force of law, and standards do not. Organizations providing standards to the HVACR industry are listed in Figure 2-7.

International Association of Plumbing and Mechanical Officials (IAMPO)
International Code Council (ICC)
International Fire Code Institute (IFCI)
National Conference of States on Building Codes and Standards (NCS/BCS)
National Fire Protection Association (NFPA)

Figure 2-6 Code groups.

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AFNOR—Association Francaise de Normalisation
ANSI—American National Standards Institute
BSI—British Standards Institution
CSA International—Canadian Standards Association
DIN—Deutches Institut für Normunge. V.
CEN—The European Committee for Standardization
CENELEC—The European Committee for Electrotechnical Standardization
EU—European Union
IEC—International Electrotechnical Commission
ISO—International Organization for Standardization
JIS—Japanese Industrial Standards
NSSN—National Standards Systems Network
SASO—Saudi Arabian Standards Organization
SES—Standards Engineering Society

Figure 2-7 Standards associations.

DOE-EERE—Department of Energy, Energy Efficiency and Renewable Energy
FCIC—Federal Citizen Information Center
NATE—North American Technician Excellence Program
CEE—Consortium for Energy Efficiency

Figure 2-8 Consumer information.

Many consumer groups over the years have worked with HVACR industry leaders to help the industry provide consumers with the most efficient and effective service. Some of these consumer information groups are listed in Figure 2-8.

2.10 THE PROFESSIONAL TECHNICIAN'S APPEARANCE

As a service technician you are seen by the customer as a representative of your company. Customers often assume the appearance and professionalism of the technician is a reflection on the technician and company's technical skills. It is therefore important that you present yourself professionally, in a very clean and neat manner, to the customer. In some cases you might find during the course of the day that your uniform becomes soiled. It is therefore a good idea to carry at least an extra clean shirt in the service van so that you can change if necessary.

If your company does not provide uniforms, you should dress appropriately. In some cases, blue jeans and a jersey or denim shirt are acceptable. In other cases, where you might be working in an office building, slacks and a shirt would be appropriate. Check with your employer to see what the company dress code is. In addition to your clothing, you must have a clean and neat personal appearance. That means clean, well-kept hair and either being clean shaven or having a well-kept beard for men, and clean hands for everyone.

You must keep your service vehicle clean and neat. It is a rolling billboard for your company, and it is important that it look sharp. A clean service van provides a better, more efficient work area, making it easier to find tools and supplies, and it also makes a better impression on the customer. Unless you have permission from residential customers, you should not park your service vehicle in their driveway. Always make it a habit to park your vehicle on the street. You do not want to be responsible for cleaning up an oil spill, and your vehicle can obstruct their access, which to some customers is very aggravating.

When you present yourself to a customer's door, you should have your hands in plain sight either at your side or holding your tools and clipboard. When the customer opens the door, if you take one step back, it will give the customer a greater sense of comfort. Many companies provide photo ID badges, and you must have yours clearly displayed. If it is necessary for you to enter a dwelling for service, ask permission from the homeowner before entering.

2.11 WORKING NEAT

Some companies provide technicians with paper shoe covers to prevent tracking dirt into residences. If you suspect your shoes are dirty, either remove them or use the covers. You and your company can be responsible for cleaning the carpet if it becomes soiled. When working on an indoor furnace, place a drop cloth on the floor in front of the furnace so that any debris will be contained. When you are finished working in the furnace area, a small battery-powered vacuum cleaner can be used to pick up loose dirt and debris in the area. Use a damp rag to wipe down any fingerprints that are on the equipment or that may be on the door or woodwork.

TECH TIP

Cleaning up the equipment area in a residence is an excellent PR move. You should vacuum up all of the debris in the area. Many customers judge your work by appearance, and all they may understand is neat and clean. When changing out a unit, electricians or plumbers may also be involved. You should clean up any mess even if you did not make it. Leaving behind a mess will reflect on you, since the final repair is still your responsibility.

In many residences, the air handler is located in an attic. If access to the unit is through a pulldown staircase, make certain that any dirt or debris that falls from the

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stairs when it is pulled down is cleaned up. If you are going to be going in and out of the attic a number of times during the service, place a drop cloth on the floor below the stairs to catch any insulation or other debris that might fall on the floor. Do not attempt to carry a large number of tools up and down the stairs. This can cause you to be caught off balance and possibly drop your toolbox. In addition, most attic stairs have a weight limit that could be exceeded by you and a large toolbox. Attic stair treads, like any ladder, are strongest next to the side rail. For that reason, when you ascend and descend the stairs, place your foot as close as possible to the side next to the side rail to reduce the possibility of breaking the stairs. Always be careful in an attic so that you do not step through the homeowner's ceiling.

Many customers have extensively landscaped their homes, including the area around an outdoor condensing unit. Even though their landscaping may encroach within the manufacturer's recommended free air space around the unit, do not remove this landscaping. Notify the homeowner as to how it should be trimmed so that they or their landscaper can remove the vegetation. When working around vegetation, it is important that you be as careful as possible so as not to damage any plants. On very soft, wet ground your repeated trips to the service van can wear a path. To avoid this, each time you have to cross soft, wet ground, take a slightly different route when possible.

It is considered bad practice to leave packaging and boxes left over from the installation of new equipment in the customer's trash receptacles. This material should be taken with you so as not to overload their receptacle.

TECH TIP

Working in air conditioning and refrigeration is often a very hot job. From time to time customers may offer you a glass of water, tea, or cold drink. Use your discretion on accepting these offers. However, it is never appropriate for you to accept a beer or other alcoholic beverage from a customer. Even if you do not open the drink but take it with you, you have significantly damaged your credibility with the customer and your boss. If you take a beer, even though you do not drink it, and there is a problem with the service you provided the customer, the first thing the customer is going to tell your boss and everyone else is that you were drinking on the job, in spite of the fact that they gave you the beer. *Do not take any alcoholic beverages that are offered by customers.*

2.12 TECHNICIAN AND CUSTOMER COMMUNICATION

A large part of the technician's job is to educate the customer as to the problem that was found and the available options for its repair. Tell the customer what failed, why it failed, and the options to fix the problem. Do not simply tell the customer that they need a part and that you are going to replace it.

Many customers would like an estimate of the job's cost. In some municipalities you are obligated under consumer protection laws to provide customers with such a quote. In some cases the quote must be in writing. If, however, as part of your service you uncover a situation that could not have been foreseen or was not visible in your initial evaluation that will require additional work, immediately stop and inform the customer of the new problem. Do not simply make the repairs and expect the customer to accept the higher charge at the conclusion of the job.

TECH TIP

If you locate an additional problem or pending problem with a customer's system and, after notifying the customer of your concerns, they choose not to have you provide that repair, you should note that on the customer's invoice as part of your service call recordkeeping and get them to sign the acknowledgment.

Under no circumstance should you tell a customer that the previous technician messed up their system when they did the last service. All that will result from such statements is the loss of faith the customer may have in you and your professionalism; but, more important, you might find out that one of your colleagues who works for your company did the last service job.

TECH TIP

Good professional technicians never knock the competition. Their skill and knowledge will set them apart from everyone else without the need to brag.

One of the primary complaints customers have on any service call is punctuality. It is not always possible to be at a job exactly when you anticipated being there, as earlier service calls may take more time than you initially estimated. However, as soon as you realize you are not going to make the schedule, and as early as possible, let the customer know and give them an opportunity, if they so choose, to reschedule. If you do reschedule, you must be at the next scheduled appointment on time.

It is also extremely important that you provide a very clear, clean, and legible invoice or bill to the customer. If it is necessary for you to get prices, look up information, or check your spelling, you should do all of that in your service vehicle and not in front of the customer. Even though you may not be a literary expert, customers do expect you to provide them with clear, concise, well-written statements. If you have a problem writing clear and concise statements, you may want to invest in a PDA (personal digital assistant) device. There are many of these devices on the market, and many can have spell-check and writing programs installed.

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TECH TIP

Some air-conditioning and refrigeration work in the summer requires that the technician work in relatively hot environments such as attics or buildings without working air-conditioning systems. To prevent heat stress injury, it is important that you guard against dehydration by drinking large quantities of water or sports drinks. You must drink enough so that you have to use the restroom at least once every couple of hours throughout the day. In addition to dehydration, you may also develop kidney and bladder problems if you do not drink enough fluids while working in hot environments.

Carbonated beverages, milk, fruit juice, beer, and many other beverages do not replace the body's electrolytes. Without replacing the electrolytes, you can feel fatigue and may experience cramps. For that reason, only sports drinks with the essential electrolytes and water are recommended as your primary drinks when working in the heat.

UNIT 2—SUMMARY

You should become familiar with the various professional organizations and trade associations that support the air-conditioning and refrigeration industry and consider joining those that are suitable to your career goals. Read the many available publications so that you may keep up-to-date with the latest changes in industry practices and standards.

As a refrigerant technician, you must become certified under EPA Section 608 regulations. To further demonstrate your ability as a service technician, you may also consider taking an industry standardized test such as the Industry Competency Exam (ICE). There are also certification programs such as North American Technical Excellence (NATE) that allow you to focus on specialty areas.

Always remember to present yourself to the customer as a neat and clean professional. Carry an extra set of clothes in the event you need to change because your uniform becomes soiled. Think of using paper shoe covers rather than tracking dirt across the customer's carpet. Finally, always be polite to the customer and make sure that you communicate clearly. A large part of your job is to provide guidance for the customer by explaining the nature of the equipment-related problem. Be prepared to tell the customer what failed, why it failed, and the options to fix the problem.

UNIT 2—REVIEW QUESTIONS

1. List three student organization clubs.
2. What does RSES stand for?
3. What does ACCA stand for?
4. What does AHRI stand for?
5. What does ASHRAE stand for?
6. What does NATE stand for?
7. What section of the EPA regulations requires technician certification?
8. The _____ has been developed over the years with input from manufacturers, trade associations, instructors, and other industry experts.
9. What is the name of the vocational industrial club for students in high schools, trade schools, and community colleges?
10. What organization was founded in the late 1990s by a group of air-conditioning educators, counselors, and administrators responsible for the various aspects of HVACR training?
11. List the seven specialty areas for the NATE service technician certification program.
12. The core exam for the NATE certification program covers what topics?
13. What is the difference between a code and a standard?
14. What precaution should be taken if you find that during the course of the day your uniform becomes soiled?
15. When might it be necessary for you to use a drop cloth?
16. When making a repair, what information should you relay to the customer?
17. If you locate an additional problem or pending problem with a customer's system and they choose not to have you provide that repair, what should you do?
18. What is one of the primary complaints that customers have regarding service calls?
19. Why are many common drinks, such as sodas, not adequate for your protection against heat stress injury?
20. When would it be appropriate to tell the customer that the previous technician messed up their system when performing the last service call?

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UNIT 3
Safety

OBJECTIVES

After completing this unit, you will be able to:

1. explain how to work safely to avoid accidents.
2. discuss the material that appears on all Material Safety Data Sheets (MSDS).
3. discuss how to safely use hand and power tools.
4. discuss how to practice safety in the shop.
5. describe four types of fire extinguishers.
6. demonstrate a safe method of lifting heavy objects.
7. discuss safe welding and cutting practices.
8. discuss electrical safety rules.
9. discuss the safe use of refrigerants, their storage, and proper disposal.
10. tell how to safely handle refrigerant cylinders.
11. discuss refrigerant system safety.
12. name three major hazards of pressure vessels.
13. discuss how a technician's driving record can affect employability.
14. tell what steps should be followed in case of an accident.

3.1 INTRODUCTION

In every trade, safety is a major concern, and safety is everyone's first job responsibility. Accidents, no matter how minor, can cost the technician, the company, and the customer unnecessary losses of time and money. There is no reason to feel that accidents are inevitable and something you must just accept. Good working habits, good tools, and being vigilant to potential hazards can virtually eliminate accidents. Never do anything you feel is unsafe. When working with new equipment or tools, read all the safety instructions and follow them.

Most companies require some type of safety training for all their employees. In addition, some of the businesses where you may be asked to do HVACR work at may have their own safety program that you must pass before beginning work at their site.

Most accidents are caused by carelessness, as well as lack of awareness of proper safety procedures. This unit deals with some of the basic safety tips and procedures the installer and service technician should follow—whether on the job site or at related locations where hazards could exist; additional specific safety facts are covered in each unit. Read and follow all safety rules.

3.2 PERSONAL PROTECTIVE EQUIPMENT

Personal protection equipment (PPE) is designed to reduce your exposure to hazards that cannot be eliminated or controlled. PPE may include equipment or devices to protect your head, face, eyes, ears, respiratory system, hands, and feet. Some devices, such as safety glasses, are commonly used, while others, such as respiratory protection, may be less frequently used.

If PPE is required for any job, OSHA (Occupational Safety and Health Administration) recommends that all employees be trained. This training may be as short as a few minutes or as long as several hours or more. The length of the training time depends on the level of hazard and the complexity of the PPE to be used.

Keeping all PPE clean and in good working condition is essential to ensure that, when needed, it will work properly.

Head Protection

An approved hard hat (Figure 3-1) should be worn whenever there is a danger of things dropping on the head or where the head may be bumped. On a construction site, proper safety head gear is a must.

Eye and Face Protection

The majority of eye injuries are the result of flying or falling objects. Most of these objects are smaller than the head of a pin but can cause serious injury. Approved eye or face protectors (Figure 3-2) must be worn whenever there is



Figure 3-1 Hard hats are required to be worn on many job sites.

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(a) (b)

Figure 3-2 Eye protection equipment: (a) these safety goggles can be worn over glasses; (b) safety glasses with side protection.

a danger of objects striking the eyes or face. Side shields must be part of any safety glasses worn, even if they are prescription eyeglasses. Safety glasses or goggles must be worn over prescription eyeglasses if they do not have side shields. Eye and face protectors come in various shapes and sizes, and some of them are very specialized.

Special eye protectors must be worn when arc welding, spot welding, and burning to cut out harmful light radiation. These special face visors come with various shades of viewing eyepieces that filter out the harmful emissions. Take time to identify the right one for the job. For example, never wear oxyacetylene welding goggles when an arc welding face shield is needed.

Confine long hair and loose clothing before operating rotating equipment.

TECH TIP

To control insurance costs, many air-conditioning companies have adopted very stringent policies on personal protection equipment. Unlike your shop teacher, who may have reminded you each day about safety glasses, ear protection, and so on, many employers may terminate you with a single safety infraction. Others may warn you once or twice about wearing proper safety equipment while working. But no HVACR companies are going to give you unlimited warnings before your employment with them is terminated. These policies are good for you and the company, because they reduce the likelihood of your being injured on the job.

Ear Protection

Hearing protection devices (Figure 3-3) must be worn whenever there is exposure to high noise levels of any duration. These devices are of two types: (1) ear plugs, which are inserted in the ear, and (2) headphones, which cover the ear. Either one must be properly selected on the basis of how much protection is required.

Respiratory Protection

There are two main types of respirators, as shown in Figure 3-4: (1) *air-purifying respirators* are ones that purify the air by filtering out harmful dust, mist, metal, fumes, gas, and vapor; and (2) *atmosphere-supplying respirators* are



(a) (b) (c) (d)

Figure 3-3 Ear protection equipment: (a) disposable earplugs on a lanyard (that fits around the neck) allow for easy removal and reuse; (b) headphones protect both ears and hearing; (c, d) disposable, one-time-use earplugs.



(a) (b) (c)

Figure 3-4 Filtration masks: (a, b) light-duty filter; (c) respirator with replaceable filters.

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ones that supply clean breathing air from a compressed air source. The second type should always be worn when working in a confined space where concentrations of harmful substances are very high or where the concentration is unknown. Remember that most refrigerants are odorless, tasteless, and invisible and can cause asphyxiation in a very short time.

Respirators must fit tightly against the skin so that there is no leakage from the outside into the face. Workers who are required to use respirators at any time must be instructed in their use, care, maintenance, and limitations.

TECH TIP

Respirators are required to be located in all equipment rooms where that equipment contains large quantities of refrigerant. These respirators are provided in case there is a massive refrigerant leak. If you work in one of these areas, you must familiarize yourself with where the respirators are located and how to quickly put them on. You may have only a matter of seconds once a refrigerant leak alarm is sounded to safely put on this equipment.

Hand, Foot, and Back Protection

There are many different kinds of gloves used for hand protection, as shown in Figure 3-5. Some are made for special uses, such as gloves of steel mesh or Kevlar to protect against cuts and puncture wounds. Different glove materials are needed to protect against a variety of different chemicals. Choose the right kind from a dependable supplier who can supply information to lead you to the right gloves. Discard any damaged ones.



Figure 3-5 (a) Gauntlet-type work gloves; (b) work gloves; (c) welding gloves; (d) open-tipped gloves.



Figure 3-6 High-top work boots.

Lifting heavy objects improperly can lead to back injury. Always bend at the knees and lift straight upward rather than bending over, which will place undue stress on the spine. There are a number of different types of back-support belts available. These should be used if heavy lifting is expected to be performed on a regular basis.

When choosing foot protection, as shown in Figure 3-6, use the following guidelines:

1. All footwear must be well constructed to support the foot and to provide secure footing.
2. Where there is danger of injury to the toes or top of the foot or from electrical shock, the proper shoe or boot, such as steel toe, must have Construction Safety Approval (CSA) indicated.
3. Where there is danger of injury to the ankle, footwear must cover the ankle and have a built-in protective element/support.
4. If there is danger of harmful liquids spilling on the foot, the top of the shoe must be completely covered with an impervious material or treated to keep the dripped substance from contacting the skin.

3.3 LADDERS AND SCAFFOLDS

Access equipment refers to ladders and scaffolds that are used to reach locations not accessible by other means. The following precautions should be practiced in the use of ladders.

1. Only use CSA- or ANSI-approved ladders. Maintain ladders in good condition, and inspect ladders before each use. Discard ladders needing frequent repairs or showing signs of deterioration.
2. All portable ladders must have no-slip feet.
3. Place ladders on a firm footing, no farther out from the wall than one quarter of the height required, as shown in Figure 3-7.
4. Ladders must be tied, blocked, or otherwise secured at the top where the ladder meets the building to prevent them from slipping sideways.

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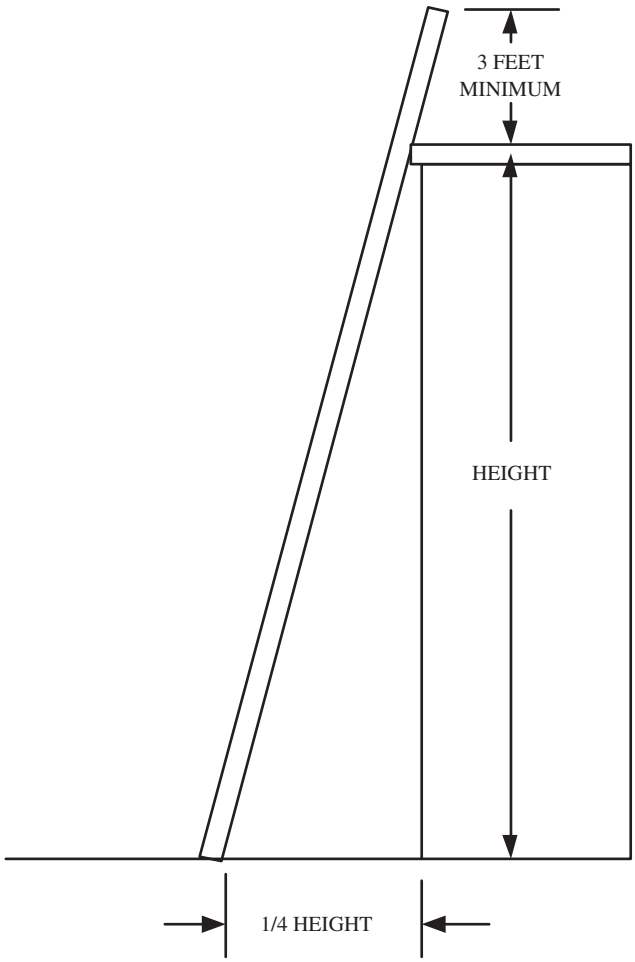


Figure 3-7 A ladder must be placed so the top is at least 3 ft above the roof and at an angle in which the distance from the building is one-fourth the height of the building.

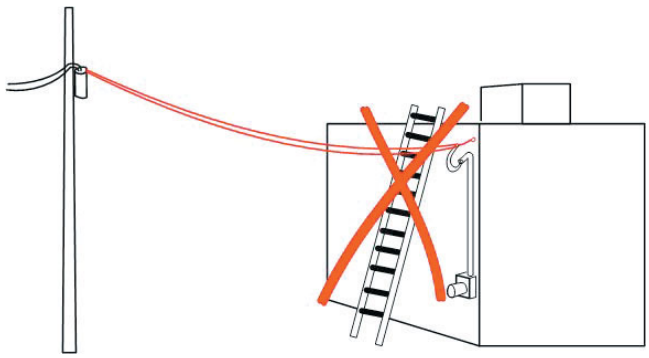


Figure 3-8 Never use a metal ladder near electrical wires!

CAUTION

Ladders must be inspected from time to time to ensure their safety. Some companies will require that a company safety official inspect the ladders you carry on your service van. Damaged or worn ladders must be repaired or removed from service.

The following recommendations apply to scaffolds.

1. Scaffolds must be supported by solid footings.
2. A scaffold having a height exceeding three times its base dimension must be secured to the structure.
3. When rolling scaffolds are used, the wheels must be locked when there are workers on the scaffold.
4. No worker is to remain on the scaffold while it is being moved. All equipment should also be removed before moving a scaffold.
5. Access to the work platform must be a fixed vertical ladder or other approved means.

5. Never overload a ladder. Follow the maximum carrying capacity of the ladder, including the person and equipment. The American National Standards Institute (ANSI) sets the standard for ladders.
6. Only one person should be on a ladder, unless the ladder is designed to carry more people. Follow maximum load rating.
7. Never use a broken ladder. Never place a ladder for use on top of scaffolding, and never use a borrowed ladder on someone's property. Always use your own ladder even if you need to leave the job site to go get it.
8. Always face the ladder and use both hands when climbing or descending a ladder.
9. Use fiberglass or wood ladders when doing any work around electrical lines (Figure 3-8).
10. Ladders should be long enough so you can perform the work comfortably, without leaning or having to go beyond the two rungs below the top rung safety barrier.
11. Stepladders should only be used in the fully open position.

3.4 FALL PROTECTION

Two types of equipment for preventing injury from falling are (1) fall-prevention equipment and (2) fall-arresting equipment. Either of these methods is required when working at heights over 10 ft above grade when no other means has been provided for preventing falls. Figure 3-9 illustrates a safety belt.

In fall prevention, a worker is prevented from getting into a situation where a fall can occur. For example, a safety belt attached to a securely anchored lanyard will limit the distance a worker can move.

In fall arresting, the worker must wear a safety harness attached to a securely anchored lanyard, which will limit the fall to a safe distance above impact. The harness helps prevent the worker from suffering internal damage. Belts should not be used to arrest a fall because they do not provide the measure of safety that harnesses do. Where a fall-arresting system is not practicable, a safety net should be suspended below the work activity. The worker should be secured separately from the tools and equipment.

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Figure 3-9 Safety equipment for heights over 10 ft above grade—a safety lanyard would be attached to this safety belt.

CAUTION

Fall-protection harnesses are designed to suspend you in a vertical position if you accidentally slip and fall from a height. These harnesses, however, are not designed to suspend you for long periods of time. In recent years, workers have survived a fall, only to die in the safety harness. The safety harness can constrict blood flow to your legs as you dangle at the end of the safety line. The restriction of blood flow to your legs can cause enough blood to pool in your legs so that you might pass out or even die if allowed to dangle motionless for a long period of time. If you are the victim of a fall and are suspended on your safety line, you should remember to move your legs to help keep the blood flowing until you are rescued.

3.5 HOT AND COLD

HVACR technicians often work with extremely hot or extremely cold vapors, liquids, and solid objects. Similar PPE is required for both extremely hot and extremely cold work because of the potential for burns. Burns can occur on your skin from accidentally contacting either extremely hot or extremely cold material. It is easy to see how a hot material can cause a burn but more difficult to see how something that is cold can burn your skin.

When you touch something that is extremely cold, your body heat is drawn out so quickly that it causes the surface of your skin to burn and blister. Remember that refrigerant will cause frostbite, so be careful.

3.6 HARMFUL SUBSTANCES

Workers in the mechanical trades can be exposed to a variety of harmful substances, such as dust, asbestos, carbon monoxide, refrigerants, resins, adhesives, and solvents.

All dust can be harmful. Where dust cannot be controlled by engineering methods, an approved respirator designed to filter out specific dust must be worn.

When asbestos-containing material (insulation) is being cut or shaped, the particles must be removed by a ventilation system that discharges the particulate matter through a high-efficiency particulate air (HEPA) filter. All waste materials that contain asbestos must be placed in impervious bags for transfer to an approved disposal site. These fibers, when inhaled, are considered carcinogenic. If you are asked to remove asbestos from, for instance, a piece of equipment such as an old boiler, do not attempt this. You do not want to put anyone's life at risk, so do not be forced into improperly removing asbestos. Improper removal of asbestos can also lead to serious fines.

Engine-driven mobile equipment operating in an enclosed area can produce dangerous levels of carbon monoxide (CO). Oil-fired or gas-fired space heaters without suitable vents can also produce carbon monoxide. Areas must be well ventilated while being heated with these devices.

TECH TIP

Read and follow all label safety and user instructions on any materials you use in the HVACR field. Some of these materials can be hazardous to your health if you do not follow the label's directions.

Some refrigerants are more dangerous than others, but all refrigerants are dangerous if they are allowed to replace the oxygen in the air. Even the so-called safe refrigerants can produce a poisonous phosgene gas when heated to high temperatures, and refrigerants sprayed on any part of the body can quickly freeze tissue.

Resins, adhesives, and solvents can be dangerous if not properly handled. Ensure that the workspace is continuously ventilated with large amounts of fresh air.

Never use carbon tetrachloride for any purpose, because it is extremely toxic, either inhaled or on the skin. Even slight encounters with it can cause chronic problems.

To provide workers and health-care professionals with specific reactions and treatments for exposure to materials on the job, all manufacturers must provide, on request, a Material Safety Data Sheet (MSDS) on all of their products. It is your responsibility to request a MSDS for all of the products you work with or carry on your service vehicle. Some site safety officers, building inspectors, or job managers may even ask to see the MSDS before you are allowed to start or continue work.

3.7 MATERIAL SAFETY DATA SHEETS (MSDS)

Material safety data sheets are required by law and have specific important information listed in specific areas so that emergency personnel can easily read them. If an area does not apply to the product, the manufacturer must mark the space as being nonapplicable. No blank spaces are allowed on a MSDS. This is done so that there will not be any confusion regarding the safety or reactions to any products. You should read the MSDS on any material before you use it so you know how to use it properly and safely and know what to do if there is an accident involving the material.

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Figure 3-10 is an example of an MSDS for a coil cleaner. The following material will appear on every MSDS:

1. **Identity.** This section gives the name of the product.
2. **Section I.** This section gives the manufacturer's name and address and contains the emergency contact phone number and company phone number.
3. **Section II: Hazardous Ingredients/Identity Information.** A list of the hazardous ingredients by chemical name is given here. If a material has a secret ingredient, the company must either list it or provide it to a health worker on request. The item listed as OSHA PEL indicates the *personal exposure limit*. This is the maximum safe amount of contact or exposure time that is allowed. The ACGIH TLV is the time weighted average exposure over an 8-hr period of time. It is the maximum amount of contact or exposure allowed during an 8-hr working day. Any other specific limitations are given in this section.
4. **HMIS Information.** The information in this section refers to the hazardous material identification system (HMIS). This information provides health-care workers with a relative number according to how significantly the material will affect health, how reactive it is, and its flammability.
5. **Section III: Physical/Chemical Characteristics.** This section gives the properties of the material, such as its boiling point, vapor pressure, solubility in water, specific gravity, melting point, evaporation rate, and its appearance or odor.
6. **Section IV: Fire and Explosion Hazard Data.** Gives the flammability of the material and lists its flash point, flammability limits, extinguishing media, any special firefighting procedures, and any unusual fire or explosion hazards.

In addition to the information on the MSDS, you must read and follow all manufacturers' listed instructions for

Material Safety Data Sheet
May be used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200. Standard must be
consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

(1) IDENTITY *(As Used on Label and List)* Coil Master Non Acid Coil Cleaner CMD-2A

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

(2) **Section I**

Manufacturer's Name Crow Marketing & Distribution, Inc.	Emergency Telephone Number 800-255-3924
Address *(Number, Street, City, State, and ZIP Code)* P. O. Box 29171, Dallas, TX 75229	Telephone Number for Information 214-241-3049
	Date Prepared 08-23-95 reviewed 12/01/99
	Signature of Preparer *(Optional)*

(3) **Section II -- Hazardous Ingredients/Identity Information**

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recomended	% (optional)
NaOH Sodium Hydroxide 50%	2mg/m^3	2mg/m^3		
CAS#1310-73-2 NA1824 Corrosive				

(4) **HMIS INFORMATION**

Health	2
Reactivity	1
Flammability	0

(5) **Section III -- Physical/Chemical Characteristics**

Boiling Point	180°F	Specific Gravity (H_2O = 1)	1.01
Vapor Pressure (mm Hg.)	760	Melting Point	N/A
Vapor Density (AIR = 1)	1	Evaporation Rate (Butyl Acetate = 1)	N/A

Solubility in Water
Complete - 100%

Appearance and Odor
Yellow to gold liquid, characteristic odor

(6) **Section IV -- Fire and Explosion Hazard Data**

Flash Point (Method Used)	Flammable Limits	LEL	UEL
None	None		

Extinguishing Media
N/A

Special Fire Fighting Procedures
Will react with metals to produce flammable hydrogen gas

Unusual Fire and Explosion Hazards
None known. Contents under pressure. Exposure to temperatures above 120°F may cause bursting.

Figure 3-10 Sample of a completed Material Safety Data Sheet (MSDS).

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proper use and handling of every material you use on the job. Many companies have policies that require that you be fired if you do not follow these instructions. These policies are both for your protection and for the protection of the company and the customers. Handle all material properly according to the manufacturer's instructions.

SERVICE TIP

It is a good work practice to request a MSDS on all products that you get from the supply house. Some job site safety officials require that you have a MSDS on all of the products you will be using at their job site. An easy way of maintaining these documents is to put them all in a large manila envelope that is labeled MSDS and keep this envelope in your service vehicle.

3.8 SAFE WORK PRACTICES

The installer and service technician works in many areas: in the shop, in various types of buildings, in equipment rooms, on rooftops, under houses, and on the ground outside buildings. Each location requires different activities where safe performance is essential.

In addition, the worker deals with many potentially dangerous conditions, such as handling pressurized liquids and gases, moving equipment and machines, working with electricity and chemicals, and being exposed to heat and cold. It is important, therefore, that the technician practice good safety procedures wherever or whatever the work is.

Confined Space Entry

A confined space is an area that has been closed off from any outside source of ventilation and is a space large enough for a person to enter and perform work. Entering a storage tank through a manhole opening would be an example of this. Never enter such a space unless the atmosphere has been checked to ensure that no hazardous vapors exist. Even without the presence of hazardous vapors, the space could be potentially deadly due to a lack of oxygen. A person entering an oxygen-deficient space may not realize it until too late and suddenly pass out unconscious. Never enter a confined space until the air quality in the space has been verified as acceptable. Even then, always leave someone standing outside the space with emergency breathing apparatus available and ready.

3.9 TOOLS

All tools come with safety instructions. Do not assume you know how to use a tool; read and follow the manufacturer's safety instructions. These instructions have been developed and tested to ensure that, when followed, you are not likely to be injured.

Part of the manufacturer's literature may include instructions on how to service or repair the tool. Make sure to follow these instructions so that your tools will last longer and you can use them safely.

Hand Tools

1. Keep all hand tools sharp, clean, and in safe working order.
2. Defective tools should be repaired or replaced.
3. Use correct, proper fitting wrenches for nuts, bolts, and objects to be turned or held.
4. Do not work in the dark; use plenty of light.
5. Do not leave tools on the floor. Keep them properly put away neatly in your vehicle.

Power Tools

1. Only use power tools that are properly grounded.
2. Stand on dry, nonconductive surfaces when using electrical tools.
3. Use only properly sized electrical cords in good condition with a GFI or GFCI.
4. Turn on the power only after checking to see that there is no obstruction to proper operation.
5. Disconnect the power from an electrical tool (or motor) before performing any maintenance.
6. Disconnect the power supply when equipment is not in use.

CAUTION

Never use portable electrical equipment unless it is connected to a ground fault circuit interrupter (GFCI) or ground fault interrupter (GFI). GFI is the term that is sometimes used when referring to a GFCI. A GFCI is a safety device that cuts off electric current to a circuit when a short or ground is detected. These devices are designed to prevent burns and electrocution if a portable electric tool is being used. OSHA requires that all extension cords used for outside service work be equipped with GFCIs. Some extension cords now come with these devices built into the plug. If your extension cords do not have GFCIs built in, one can be purchased and added to the end.

3.10 SHOP SAFETY

1. Keep the shop or laboratory floor clear of scraps, litter, and spilled liquid.
2. Store oily shop towels or oily waste in metal containers in an open, airy place.
3. Clean the chips from a machine with a brush; do not use a towel, bare hands, or compressed air.
4. Keep safety glasses and gloves in a prominent location adjacent to machinery used for grinding, buffing, or hammering and where material with sharp edges is handled.
5. Establish cleaning periods regularly, at least on a daily basis. Make sure everyone is clear when using compressed air to clean.

Maintaining an Orderly Shop

Proper organization of machinery and equipment in the shop helps to promote safety. In addition, there will be

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less wasted time searching for the required tools or materials. Organizing and preparing is often as important as doing the job itself.

1. Arrange machinery and equipment to permit safe, efficient work practices and ease in cleaning.
2. Materials, supplies, tools, and accessories should be safely stored in cabinets, on racks, or in other readily available locations.
3. Working areas and workbenches should be clear. Floors should be cleaned on a daily or more frequent basis. Keep aisles, traffic areas, and exits free of materials and obstructions.
4. Combustible materials should be properly disposed of or stored in approved containers.
5. Drinking fountains and wash facilities should be clean and in good working order at all times.
6. Eyewash stations should be periodically tested to make sure that they work properly, and they should not be blocked and should always be readily accessible.

Fire Extinguishers

The danger of fire is always present. Rags soaked in oil, grease, or paint can ignite spontaneously. Keep used rags in tightly closed approved metal containers.

Sparks, open flames, and hot metal can ignite many materials. Always have a fire extinguisher close at hand when welding or burning.

Extreme caution should be taken with highly flammable and volatile solvents. Due to its low flash point (the temperature at which vapors will ignite), gasoline should never be used as a cleaning solvent.

Fire extinguishers should be readily accessible, properly maintained, regularly inspected, and promptly refilled after use. Fire extinguishers are classified according to their capacity for handling specific types of fires (Figure 3-11).

1. **Class A extinguishers.** These are used for fires involving ordinary combustible materials such as wood, paper, and textiles, where a quenching, cooling action is required.

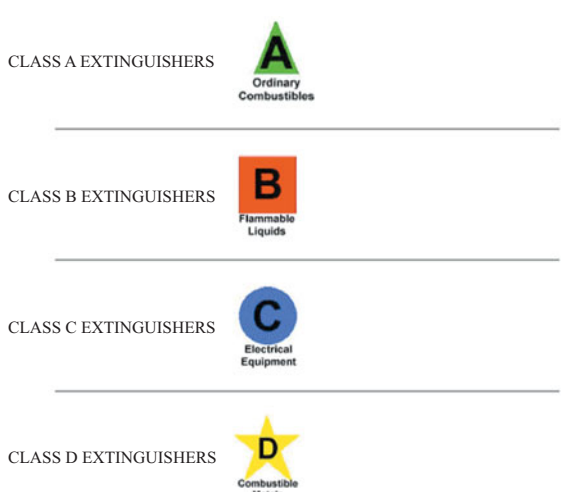


Figure 3-11 Fire extinguisher classification symbols.

2. **Class B extinguishers.** These are for flammable liquid and gas fires involving oil, gas, paint, and grease, where oxygen exclusion or flame interruption is essential.
3. **Class C extinguishers.** These are for fires involving electrical wiring and equipment where nonconductivity of the extinguishing agent is critical. This type of extinguisher should be present whenever functional testing and system energizing take place.
4. **Class D extinguishers.** Some metals, such as magnesium, can actually catch fire. Class D extinguishers are used to put out combustible metal fires.

CAUTION

Having the proper fire extinguisher is not enough if it is not large enough to do the job. Make sure that your fire extinguisher is large enough to handle the size of fire that might occur in your work area. If there are a lot of combustible materials, you need a bigger fire extinguisher. In some cases you may want to have more than one fire extinguisher available.

Material Handling

Use mechanical lifting devices whenever possible. Use a hoist when lifting tools or equipment to a roof. If you are required to lift a heavy object, get help. To avoid straining your back, the following procedures should be observed when lifting heavy objects.

1. Bend your knees and pick up the object, keeping your back straight.
2. Gradually lift the weight using your leg muscles, continuing to keep your back vertical.

3.11 WELDING AND CUTTING

Welding and cutting are specialized skills that require special training. Many refrigeration and air-conditioning technicians require this training due to the need to perform some of these operations as part of their work. It must be recognized, strictly from a safety standpoint, that this work should not be attempted without adequate knowledge and instruction.

Acetylene

Acetylene gas under high pressure is unstable, so to make it safe to use it is absorbed in acetone inside the acetylene cylinder. However, an acetylene cylinder can explode if it is struck or jarred severely, so keep the cylinders secured so they cannot be accidentally knocked over or fall. Because acetylene can explode at high pressures, it is illegal to operate a torch with an acetylene pressure greater than 15 psi. For HVACR work, we generally use pressure less than 5 psi. Most acetylene gauges have a red mark indicating 15 psi (Figure 3-12).

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Figure 3-12 Acetylene regulator with gauges.

CAUTION

The acetone used to stabilize the acetylene is absent in the neck of the tank. For this reason, never store or transport an acetylene cylinder in the horizontal position. Storage in this manner even for short periods is *very* dangerous.

Oxygen

Oxygen is provided in highly pressurized cylinders. A full oxygen cylinder contains approximately 2,000 lb/psi of oxygen. Because the oxygen is under such great pressure, care must be taken to ensure that the oxygen cylinder valve is not damaged or knocked off. If the oxygen cylinder valve were to be broken off of a full oxygen cylinder, the cylinder could fly around the room much like a child's balloon. To prevent possible damage to the valves and regulators on oxygen and acetylene cylinders, the cylinders should be securely attached to a frame or cart when they are in use (Figure 3-13).

CAUTION

Certain materials react explosively if exposed to high-pressure pure oxygen. Never use oil or grease on any part of the oxygen or acetylene regulator, hoses, or torch and tips. Ensure that all fittings are clean and dry when assembling. Repair using only manufacturer-approved replacement parts.

Air acetylene torches are used by HVACR technicians to produce sufficient heat for silver (hard) soldering brazing. These torches use a mixture of air and acetylene as a fuel.



Figure 3-13 Portable oxyacetylene welding and cutting rig. *(Courtesy of Victor, a Brand of Thermadyne Industries, Inc.)*

Oxyacetylene torches are used for brazing, welding, and cutting. These torches mix oxygen and acetylene gases to produce a very intense, hot flame.

The following safety rules should be practiced when using this equipment.

1. Always use a welding regulator on acetylene and oxygen cylinders.
2. Never use oil or grease on a regulator, as this could cause a violent explosion with compressed oxygen.
3. Always secure the cylinder to something solid to prevent it from being accidentally knocked over.
4. Wear the proper colored safety glasses.
5. Open the valve on the acetylene cylinder only one and one-quarter turns.
6. Light the torch with a striker.

SAFETY TIP

Always remove regulators from oxygen and acetylene cylinders before you put them back in your service vehicle. In many states and cities it is against the law to transport oxygen and acetylene cylinders in a motor vehicle with the regulators attached. The danger is that in an accident the regulators could be broken off, causing a fire or explosion.

CAUTION

All oxygen and acetylene cylinders should be stored and used in secure racks or carts. Federal safety regulations (OSHA) require 55-ft^3 cylinders and larger to be safety chained to carts or structures anytime the cylinder is being used with its safety cap removed. There are no exceptions to these OSHA regulations regarding cylinders.

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3.12 FIRST AID

Refrigeration and air-conditioning workers are advised to enroll in an approved first-aid course. Some vocational programs and technical colleges offer first aid as an elective course. Be sure to talk to your adviser about taking a first-aid course. Prompt and correct treatment of injuries not only reduces pain but could also save lives. A classification of accidents that occur to HVACR personnel, related to the hazards described, include the following:

1. Injuries due to mechanical causes
2. Injuries due to electrical shocks
3. Injuries due to high pressure
4. Injuries due to burns and scalds
5. Injuries due to explosions
6. Injuries due to breathing toxic gases
7. Injuries due to negligence when working with electricity (Always pay strict attention to the work, and never allow any horseplay, as this could cause you or someone you are with to receive serious injury or die.)
8. Heat exhaustion or heat stress

3.13 ELECTRICITY SAFETY

All possible precautions must be practiced to prevent electrical shock—that is, current passing through the body. Very few realize the damage that can be done by even a small amount of current.

The following information applies to low-voltage circuits where current is measured in milliamps (mA). One amp (A) is equal to 1,000 mA.

The illustration in Figure 3-14 indicates the effect on the body when various amounts of current pass through the body at 100 mA or less.

Noncontact voltage (NCV) testers should be a standard tool for all HVACR service technicians. Some digital multimeters incorporate an NCV feature.

Electrical Safety Rules

1. Check all circuits for voltage before doing any service work. Tag and lock out all electrical disconnects when working on live circuits.
2. Stand on dry, nonconductive surfaces when working on live circuits.
3. Work on live circuits only when absolutely necessary.
4. Use only properly insulated tools to work on electrical circuits.
5. Never bypass an electrical protective device.
6. Properly fuse all electrical lines.
7. Properly insulate all electrical wiring.
8. Use ground fault circuit interrupters whenever using power tools.

3.14 REFRIGERATION SAFETY

The hazards associated with refrigeration service are principally associated with the proper use of refrigerants and their storage in closed containers and systems. A large improvement was made when the HVAC industry started using the so-called safe refrigerants (Class I, or fluorocarbons),

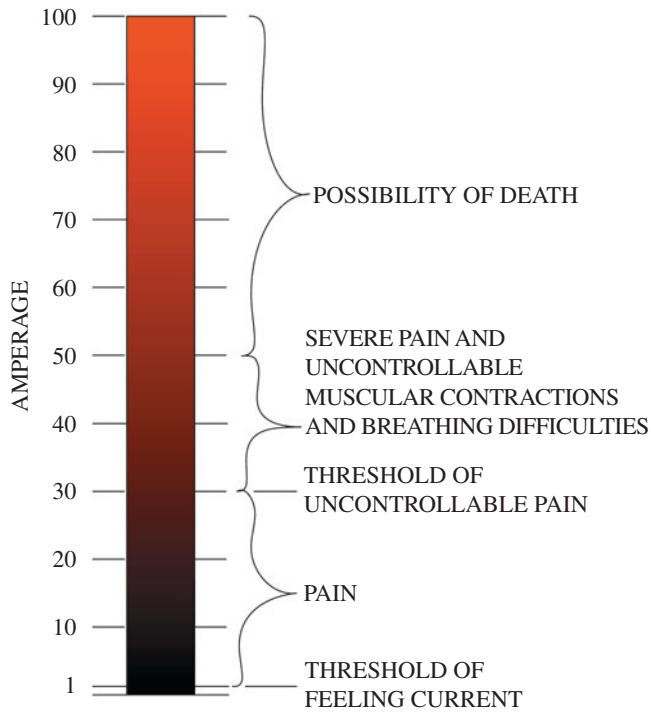


Figure 3-14 Amperage rating of electric current creating various shock effects from 1 mA up to 100 mA. *(© WorkSafeBC. Used with permission from* Working Safely Around Electricity*.)*

which were nontoxic and nonflammable. Dangers now relate to the use of pressurized gas or liquid and the fact that these chemicals, when released accidentally, can replace oxygen in a confined space without sensory detection.

CAUTION

From time to time it may be necessary to warm a refrigerant cylinder so that system charging can proceed. Never heat a refrigerant cylinder with an open flame. This could cause two problems: the open flame could cause a rapid rise in cylinder pressure above the rupture point of the cylinder, and the high heat can cause the refrigerant to decompose. Three safe ways of warming cylinders are to place the cylinder in a warm bath of water, place the cylinder in the warm discharge air from the condenser fan, or wrap an electrical cylinder heater around the cylinder (Figure 3-15).

Used Refrigerants and Refrigerant Oils

The EPA classifies all used refrigerants and used refrigerant oils as hazardous waste that must be disposed of properly. They must be taken to a state or locally approved recycler that specializes in used refrigerants and used refrigerant oils. Often these recyclers have local or state certifications that you can obtain copies of for your records. It is a good idea to keep accurate and complete records showing how and where all of the used refrigerant and used oil you collect was disposed. Although these records are not required

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Figure 3-15 An electrical cylinder heater can be used to safely raise cylinder temperature. *(Courtesy of Airserco Manufacturing Company)*

by the EPA, you may be asked to prove that you are complying with all disposal requirements. Having good documentation can help show the EPA, if your records are audited, that you are complying with all the laws and regulations regarding disposal of hazardous waste.

Used refrigerant oil and used automotive oils are not compatible and cannot be mixed for disposal. That is why used refrigerant oil cannot be disposed of at an automotive oil recycler unless they have special containers just for used refrigerant oil.

CAUTION

It is illegal to sell any used CFC (chlorofluorocarbon) or HCFC (hydrochlorofluorocarbon) refrigerants that have not been reclaimed by an EPA-certified reclaimer.

Handling Refrigerant Cylinders

1. Do not fill a cylinder with liquid refrigerant to more than 80 percent of its volume. Heat can expand the liquid enough so that it fills the cylinder. Once that occurs, the cylinder will rupture. Space must be available inside the cylinder for proper expansion of the liquid to take place. In recovering refrigerants, this is particularly important. Special cylinders with an automatic volume-limiting device have been designed for recovery.
2. In using a cylinder or transporting it, the cylinder must be secured with a chain or a rope in an upright position. Do not drop a cylinder.
3. Mixing refrigerants is dangerous. Cylinders are color coded to help identify each refrigerant. Each system has an identifying label. Do not mix refrigerants. Maintain the identification system.
4. Never apply a torch to a system containing refrigerant. If heat is needed to vaporize refrigerant, use hot water at a temperature not to exceed 125°F (52°C).
5. Do not refill disposable refrigerant cylinders.
6. Replace the cylinder cap when not using a cylinder. The cap protects the valve. Do not lift or carry a cylinder by the valve.

SERVICE TIP

Most refrigerant cylinders come in cardboard boxes. These boxes contain important safety information. Some industrial plant safety officers will require that you maintain these cardboard containers with the safety material listed whenever you are working on their job site.

Refrigerant System Safety

1. Never use oxygen or acetylene to pressurize a system, because an explosion can occur. Use dry nitrogen or carbon dioxide from a tank properly fitted with a pressure regulator.
2. When isolating a section of piping or component of a system, exercise caution to prevent damage and potential hazard from liquid expansion.
3. Always charge refrigerant vapor into the low side of the system. Liquid refrigerant entering the compressor could damage the compressor or cause it to burst.
4. Never service a refrigeration system where an open flame is present. The flame must be enclosed and vented outdoors. If a fluorocarbon refrigerant comes in contact with intense heat, it can produce poisonous phosgene gas.

3.15 PRESSURE VESSEL SAFETY

Pressure vessels pose three major hazards if they rupture: The blast from the sudden explosion can cause serious internal injury. The pressurized liquid can cause severe burns. And fragments of metal thrown from the exploding vessel can cause lacerations and punctures. All pressure vessels pose some degree of hazard to individuals working in the area, so they must be inspected for flaws that might weaken their integrity.

There are a number of pressure vessels used in the HVACR field. These include accumulators, receivers, refrigerant cylinders, low-pressure boilers, high-pressure boilers, and hot water tanks. Both low- and high-pressure boilers and many commercial hot-water tanks are required to be inspected periodically. The type and frequency of inspection varies depending on the type of pressure vessel. There must be a placard displayed on or near the pressure vessel showing when it was inspected and giving the date when it needs to be reinspected.

Some pressure vessels, such as accumulators and receivers, may not have to be inspected. It is, however, a good idea to inspect them for rust, corrosion, cracks, and

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other signs of physical damage that may render them unfit for service.

Refillable refrigerant cylinders, such as those that are used for refrigerant recovery, must be inspected every five years. The inspection date must be stamped on the top of the cylinder. Cylinders that have not been inspected within five years cannot be used.

3.16 DRIVING SAFETY

A good driving record is essential for any job that requires that you drive. Almost all HVACR work requires that you do some driving as part of your job. Outside service technicians may spend much of their day driving from one job to another.

Your driving record will affect the insurance rate the company must pay. In some cases a very bad driving record could make you unemployable due to the high insurance rates your employer would have to pay so you could drive their service vans.

You cannot speed or drive recklessly or aggressively in a service vehicle. To do so could result in bad public relations for your company. In addition, with almost everyone having a cell phone, the chance that someone would call your boss and report your actions is very high. Even worse would be if they use their cell phone to take a picture or video of your driving and send that to your boss. You might be the best technician the company has, but you can still lose your job because of your actions behind the service vehicle's wheel.

If you are involved in an accident, make sure to get all of the other driver's information. You should also get any contact information from anyone who may have witnessed the accident.

TECH TIP

Carrying a disposable camera in the vehicle glove box will let you take photos of the accident and of any cars in the area. Make sure to get photos of the license plates of potential witnesses to the accident. A few photos taken shortly after the accident can help you prove your side of the story, if necessary.

3.17 STEPS TO BE FOLLOWED IN CASE OF AN ACCIDENT

1. If the injuries appear to be serious, call 911 or your local emergency number.
2. First aid should be administered, if needed, only by those qualified to do so.
3. All accidents, injuries, and illnesses should be reported to your boss or supervisor no matter how minor the injuries may seem.
4. An accident report form should be filled out and turned in to your company office.
5. An investigation of the accident may be done to determine the cause of the accident.
6. Clean up the area before resuming work.

UNIT 3—SUMMARY

Schools provide a safe environment in which to *learn*, but it is your responsibility to always *work* safely. You must follow all of the rules and standards, because electricity, compressed gases, and other potential hazards do not know you are a student; you may not get to make a safety mistake more than once.

If you have not been trained on the safe operation of any tool, equipment, or device, do not attempt to use it.

Safe working habits can last a lifetime. Start now and learn everything you can to make your HVACR career a long and safe one.

UNIT 3—REVIEW QUESTIONS

1. What causes accidents, and how they can be eliminated on the job site?
2. What is PPE?
3. Discuss ladder safety.
4. Discuss scaffold safety.
5. What is the difference between fall-prevention equipment and fall-arresting equipment?
6. Describe how cold can cause a burn on skin.
7. List harmful respiratory substances.
8. Explain some of the dangers of refrigerants.
9. Explain what material appears on every Material Safety Data Sheets (MSDS).
10. Discuss how to safely use hand tools.
11. Discuss how to safely use power tools.
12. Discuss how to practice safety in the shop.
13. List four types of fire extinguishers.
14. Tell how to safely lift heavy objects.
15. Discuss safe welding cylinder practices.
16. Discuss electrical safety rules.
17. When a refrigerant cylinder needs to be warmed, how should it be done?
18. How should used refrigerants and refrigerant oils be disposed of?
19. Discuss refrigerant system safety.
20. List three major hazards of pressure vessels.
21. Discuss how a technician's driving record can affect employability.
22. Tell what steps should be followed in case of an accident.

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UNIT 4

Hand and Power Tools

OBJECTIVES

After completing this unit, you will be able to:

1. identify the major tools used in HVACR work.
2. describe how the major HVACR tools are used.
3. explain the safety procedures required for using different types of tools.
4. demonstrate how to care for tools.

4.1 INTRODUCTION

The care and use of tools are important considerations for the technician. The customer often judges a technician on the appearance of his tools. They often assume that a technician that has a dirty, poorly maintained, and disorderly tool bag will provide the same type of service. To a large extent this is true, because it is harder to work with poorly maintained tools, and a tool bag that is not well organized makes it take longer to locate the tools for the job. The way you maintain your tools reflects on your quality of workmanship. In addition, injury can frequently be traced to a lack of, or improper use of, hand tools. Clean, sharp tools are better to work with and safer to use. This unit describes the purpose and use of some of the most basic hand and power tools needed by the HVACR technician. Specialty instruments, electrical meters, gauge manifold sets, and tubing/piping tools are described in other follow-on units of the text.

4.2 TOOL KITS

Tool manufacturers package tools in kits (see Figure 4-1), and tool kits are available for most types of HVACR jobs. They are easier to store and have greater convenience than loose tools. Kits come in many sizes and price ranges. A complete kit includes wrenches, hex keys, screwdrivers, nut drivers, pliers, knives and cutters, measurement tools, electrical repair tools, flaring/swaging/cutting tools, a multimeter, a gauge manifold set, and a clamp-on ammeter.

The basic tool kit should include varying sizes of combination, adjustable, refrigeration service, and hex key (Allen) wrenches. There should be an assortment of slotted and Phillips screwdrivers along with nut drivers. Pliers are an essential tool for the technician, and different types—such as lineman's side cutting pliers, needle-nose (long-nose) pliers, diagonal cutting pliers, tongue-and-groove pliers, slip-joint pliers, and multipurpose wire strippers—will be necessary.

Specialty tools can be added to the tool kit over time, and because all tools are expensive, they should be maintained properly. It is recommended that you keep your tool kit locked and placed in a secure location when not in use. Keep an inventory list so that you can check it after each job. Good quality tools will provide for many years of service if you take care of them.



Figure 4-1 Prepackaged tool kit.

4.3 TOOL CARE AND USE

Keep tools in a safe place. Never carry tools in your pockets or leave them lying around. A ripped car seat caused by a screwdriver left in your back pocket spoils a good day on the job. A round screwdriver lying on the ground is an accident waiting to happen because someone will step on it, slip, and fall. Other accidents can occur from using damaged tools. Pieces of metal will fly from a chisel that has a mushroomed head when struck with a hammer (Figure 4-2). That is why safety glasses must be worn whenever using hammers and chisels. Don't keep damaged tools. Throw them away and make sure to dispose of them properly.

You not only need to have the right tool, but it must be used properly. As an example, pliers are not made for tightening or loosening nuts (Figure 4-3). This will round off the corners of the nut and make it increasingly more difficult to



Figure 4-2 Chisel with mushroomed end.

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