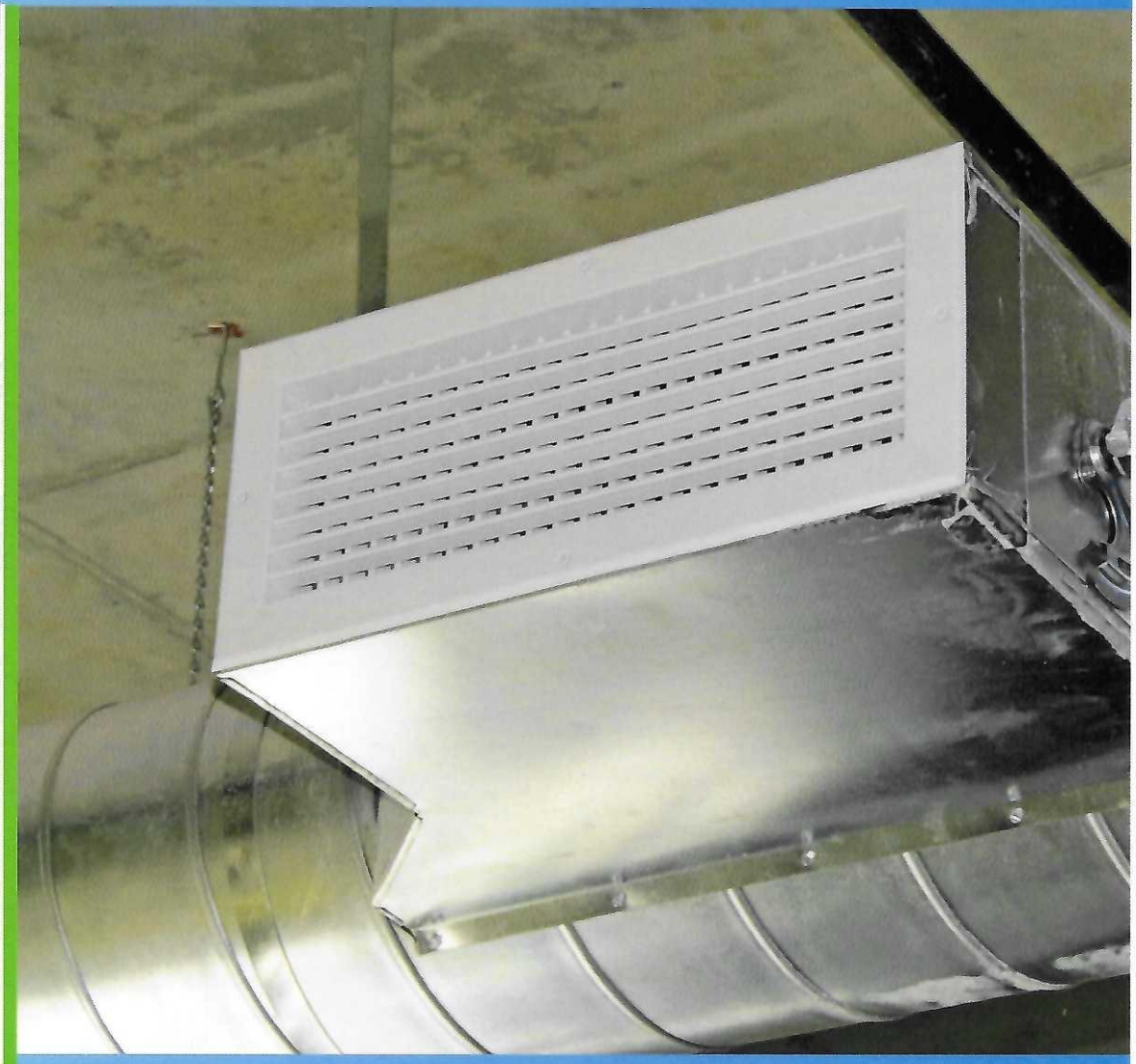
03101-13

Introduction to HVAC



Overview

Virtually all of the millions of homes and businesses in the United States have a heating system. A large percentage of homes and businesses have comfort cooling systems as well. In addition, there are many thousands of stores and restaurants that use refrigeration equipment. Workers trained in the HVAC industry have the opportunity to install systems in new construction, service equipment in existing construction, and replace aging systems.

Module One

Trainees with successful module completions may be eligible for credentialing through NCCER's National Registry. To learn more, go to **www.nccer.org** or contact us at **1.888.622.3720**. Our website has information on the latest product releases and training, as well as online versions of our *Cornerstone* newsletter and Pearson's product catalog.

Your feedback is welcome. You may email your comments to **curriculum@nccer.org**, send general comments and inquiries to **info@nccer.org**, or fill in the User Update form at the back of this module.

This information is general in nature and intended for training purposes only. Actual performance of activities described in this manual requires compliance with all applicable operating, service, maintenance, and safety procedures under the direction of qualified personnel. References in this manual to patented or proprietary devices do not constitute a recommendation of their use.

03101-13
Introduction to HVAC

Objectives

When you have completed this module, you will be able to do the following:

1. Explain the basic principles of heating, ventilation, air conditioning, and refrigeration.
   a. Explain the principles of heating.
   b. Explain the principles of ventilation.
   c. Explain the principles of air conditioning.
   d. Explain the principles of refrigeration.
2. Describe the principles that guide HVAC/R installation and service techniques.
   a. Identify common safety principles and organizations.
   b. Describe the importance of LEED construction and energy management.
   c. Describe trade licensing and certification requirements.
   d. Identify important codes and permits.
3. Identify career paths available in the HVAC/R trade.
   a. Identify the responsibilities and characteristics needed to be a successful HVAC/R technician.
   b. Identify residential, commercial, and industrial career opportunities.
   c. Describe opportunities provided by equipment manufacturers.

Performance Tasks

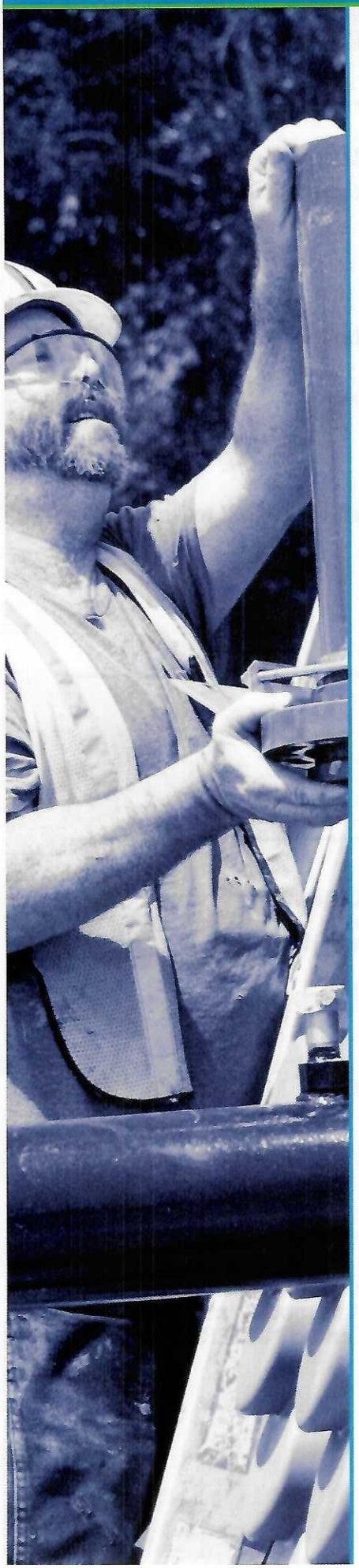
This is a knowledge-based module; there are no performance tasks.

Trade Terms

Bond
Carbon monoxide (CO)
Chiller
Chlorofluorocarbon (CFC) refrigerant
Compressor
Condenser
Easement
Evaporator
Expansion device
Heat pump
Heat transfer
Hydrochlorofluorocarbon (HCFC) refrigerant
Hydronic
International Building Code (IBC)
Mechanical refrigeration
Mechanical refrigeration cycle
Noxious
On the job learning (OJL)
Reclaimed
Recovery
Recycling
Sustainable construction
Toxic

Industry-Recognized Credentials

If you are training through an NCCER-accredited sponsor, you may be eligible for credentials from NCCER's Registry. The ID number for this module is 03101-13. Note that this module may have been used in other NCCER curricula and may apply to other level completions. Contact NCCER's Registry at 888.622.3720 or go to **nccer.org** for more information.



Contents

Topics to be presented in this module include:

Figures and Tables

SECTION ONE

1.0.0 HVAC/R PRINCIPLES

Objective

Explain the basic principles of heating, ventilation, air conditioning, and refrigeration.

a. Explain the principles of heating.
b. Explain the principles of ventilation.
c. Explain the principles of air conditioning.
d. Explain the principles of refrigeration.

Trade Terms

Compressor: In a refrigeration system, the mechanical device that converts low-pressure, low-temperature refrigerant gas into high-temperature, high-pressure refrigerant gas.

Condenser: A heat exchanger that transfers heat from the refrigerant flowing inside it to the air or water flowing over it.

Evaporator: A heat exchanger that transfers heat from the air flowing over it to the cooler refrigerant flowing through it.

Expansion device: Also known as the liquid metering device or metering device. Provides a pressure drop that converts the high-temperature, high-pressure liquid refrigerant from the condenser into the low-temperature, low-pressure liquid refrigerant entering the evaporator.

Heat pump: A comfort air conditioner that is able to produce heat by reversing the mechanical refrigeration cycle.

Heat transfer: The transfer of heat from a warmer substance to a cooler substance.

Hydronic: A heating or air conditioning system that uses water as a heat transfer medium.

Mechanical refrigeration: The use of machinery to provide cooling.

Mechanical refrigeration cycle: The process by which a circulating refrigerant absorbs heat from one location and transfers it to another location.

Noxious: Harmful to health.

Toxic: Poisonous.

Today, the Heating, Ventilating, Air Conditioning, and Refrigeration (HVAC/R) industry provides the means to control the temperature, humidity, and even the cleanliness of the air in our homes, schools, offices, and factories. Comfort air conditioning and product/process refrigeration are based on the same principles, so there are many common elements in the training required for the two areas.

1.1.0 Heating

Early humans burned fuel as a source of heat. That hasn't changed; what's different between then and now is the way it's done. It is no longer necessary to huddle around a wood fire to keep warm. Instead, a central heating source such as a furnace or boiler does the job using the **heat transfer** principle; that is, heat is created in one place and carried to another place by means of air or water.

For example, in a common household furnace, fuel oil, natural gas, or propane gas is burned to create heat, which warms metal plates known as heat exchangers (*Figure 1*). Air from living spaces is circulated over the heat exchangers and returned to the living spaces as heated air. This type of system is known as a forced-air system. It is the most common type of central heating system used in the United States.

Water is also used as a heat exchange medium. The water is heated in a boiler (*Figure 2*), then pumped through pipes to heat exchangers, where the heat it contains is transferred to the surrounding air. The heat exchangers are usually baseboard heating elements located in the space to be heated. Systems that use water or steam as a heat exchange medium are known as **hydronic** heating systems. This type of system is more common in the Northeast and Midwest than in other parts of the United States.

Natural gas and fuel oil are, by far, the most widely used heating fuels. Of the two, natural gas is far more common. Oil heat is more common in the Northeast than in other parts of the country. Propane gas is used in many parts of the country in place of oil or natural gas. Propane fuels are primarily used in rural areas of the country where natural gas pipelines are not readily available. Propane is stored in tanks on the property where the equipment is located.

Electricity is also used as a heat source. In an electric heating system, electricity flows through coils of heavy wire, causing the coils to become hot. Air from the conditioned space is passed over the coils and the heat from the coils is transferred to the air. Because electricity can be expensive, total electric resistance heating is no longer common in cold climates. Total electric heat is more likely to be used in warm climates where heat is seldom required. **Heat pumps** are used in areas with moderate climates, such as the Southeast-

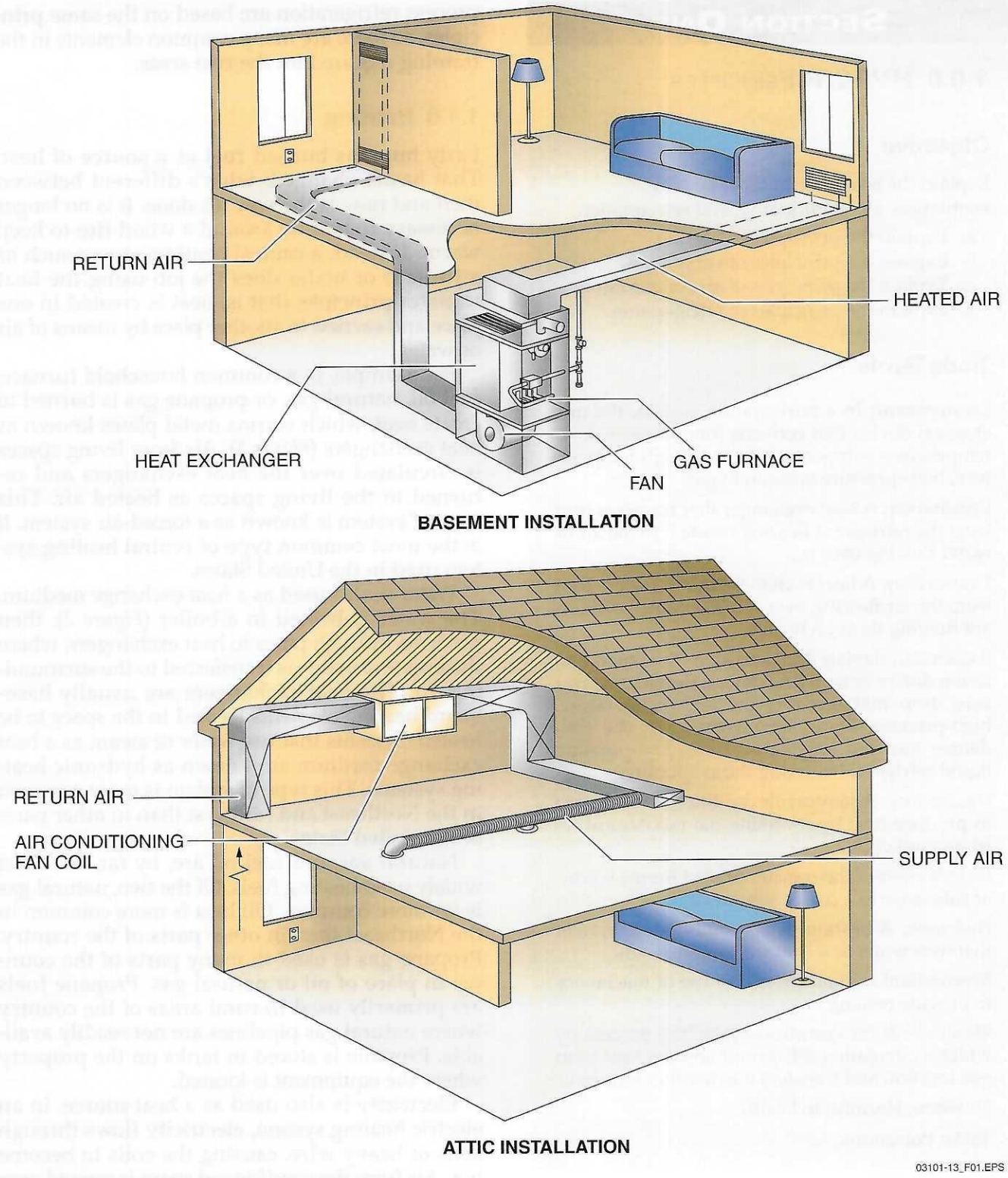


Figure 1 Forced-air heating.

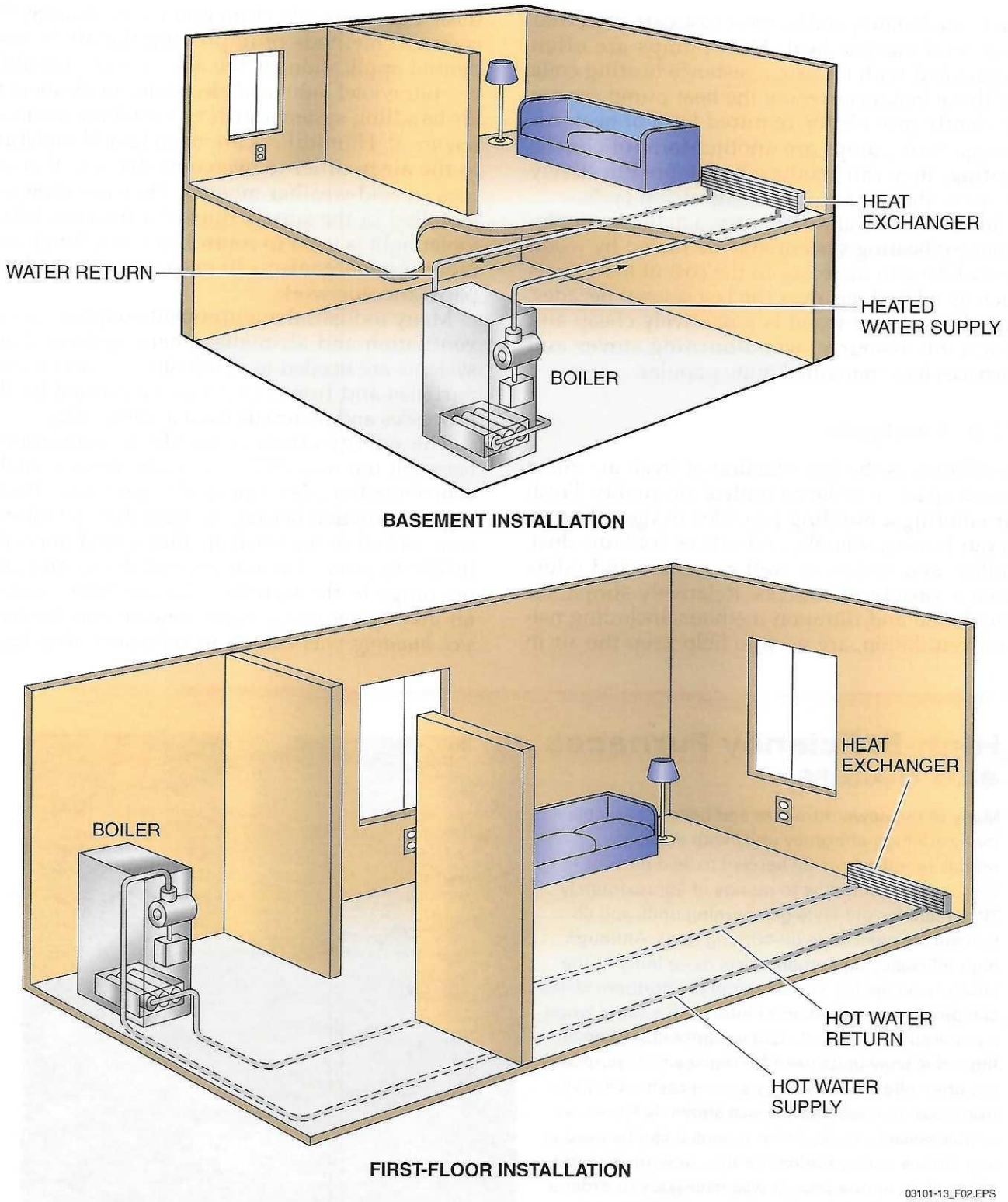


Figure 2 Hot water heating.

ern United States, and in most cases are preferred over total electric heat. Heat pumps are often augmented with electric resistance heating coils for those instances where the heat pump cannot efficiently provide the required level of heat. Although heat pumps are another form of electric heating, they can produce heat more effectively by using the **mechanical refrigeration cycle**.

In some areas of the country, a main or supplementary heating system may be fueled by wood or coal. Due to increases in the cost of fossil fuels such as oil and gas over the last several decades, and the fact that wood is a relatively cheap and renewable resource, wood-burning stoves and furnaces have remained quite popular.

1.2.0 Ventilation

Ventilation is the introduction of fresh air into a closed space in order to control air quality. Fresh air entering a building provides oxygen. The air in our homes, schools, and offices contains dust, pollen, and molds, as well as vapors and odors from a variety of sources. Relatively simple air circulation and filtration methods, including natural ventilation, are used to help keep the air in these environments clean and fresh. Among the common methods of improving the air in residential applications is the addition of humidifiers, ultraviolet light, and electronic air cleaners to air-handling systems such as forced-air furnaces (*Figure 3*). Humidifiers are used to add moisture to the air in order to overcome dryness that occurs in cold-weather months. They are typically installed in the supply duct of a furnace. Ultraviolet light is used to control bacteria, fungi, and other microorganisms in evaporator coils, drain pans, and ductwork.

Many industrial environments require special ventilation and air-management systems. Such systems are needed to eliminate **noxious** or **toxic** particles and fumes that may be created by the processes and materials used at the facility.

The energy-efficient buildings constructed between the mid-1970s and early 1990s actually contributed to indoor air quality problems. Building construction became so tight that the interior was robbed of the fresh air that would normally infiltrate around windows and doors and tiny openings in the structure. In the 1990s, indoor air quality became a major concern and the term *sick building* was coined to represent structures

High-Efficiency Furnaces and Boilers

Many of the newer furnaces and boilers available today are high-efficiency units with efficiency ratings ranging from 90 percent to 96.6 percent for gas. This compares to ratings of approximately 70 percent for old-style gas-burning units and 65 percent for older-style oil-burning units. Although high-efficiency equipment costs more initially, the energy savings for a customer in the northern states can provide a payback in as little as five years when compared with less efficient equipment. Moreover, high-efficiency units used for replacement purposes are often eligible for energy saving cash incentives from local utilities. The furnace shown is known as a multipoise furnace, which means it can be used in any airflow configuration: upflow, downflow, and to either side. At one time, it was necessary to order a furnace specifically for the airflow configuration.

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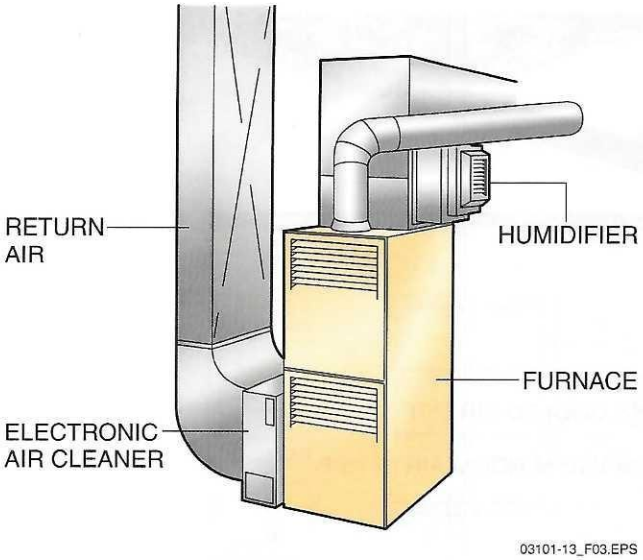

Figure 3 Humidifier and electronic air cleaner in a residential heating system.

in which the air being breathed by the occupants lacked sufficient fresh air and contained excessive amounts of dust, germs, molds, and other pollutants. The recognition of this problem has led to the much wider use of electronic air cleaners, fresh air ventilation, duct cleaning, and other measures aimed at improving the indoor air we breathe. The problem has also created more opportunities in the HVAC/R industry to manufacture, sell, install, and service equipment designed to improve indoor air quality.

The US government has strict regulations governing indoor air quality (IAQ) in both commercial and industrial environments, and the release of toxic materials to the outside air. Where noxious or toxic fumes may be present, the indoor air must be constantly replaced with fresh air. Fans and other ventilating devices are normally used for this purpose. Special filtering devices may also be required. These devices not only protect the health of building occupants, but also prevent the release of toxic materials to the outdoor air.

1.3.0 Air Conditioning

The most common method of cooling indoor spaces is based on what is known as **mechanical refrigeration**. This method, which came into use early in the twentieth century, is based on a principle known as the mechanical refrigeration cycle (*Figure 4*).

Simply stated, the refrigeration cycle relies on the ability of chemical refrigerants to absorb heat. If a cold refrigerant flows through a warm space, it absorbs heat from the space. Having given up heat to the refrigerant, the space becomes cooler. The colder the refrigerant, the more heat it will absorb, and the cooler the space will become. If the super-hot refrigerant flows to a cooler location, the outdoors for example, the refrigerant gives up the heat it absorbed from the indoors and becomes cool again.

A mechanical refrigeration system is a sealed system operating under pressure. The main elements of a mechanical refrigeration system are the:

- **Compressor** – A compressor provides the force that circulates the refrigerant and creates the pressure differential necessary for the refrigeration cycle to work. A special refrigerant compressor is used.
- **Evaporator** – An evaporator is a heat exchanger where the heat in the warm indoor air is transferred to the cold refrigerant.
- **Condenser** – A condenser is also a heat exchanger. In the condenser, the heat absorbed by the refrigerant is transferred to relatively cooler outdoor air. Even though it may be hot outdoors, the temperature of the refrigerant flowing through the condenser will be higher.
- **Expansion device** – The relatively simple expansion device is essential to the refrigeration cycle. It provides a pressure drop that lowers the pressure and boiling point of the refrigerant as it enters the evaporator. This allows the refrigerant to become a cold liquid/gas mixture and absorb heat in the evaporator.

The Mechanical Refrigeration Cycle

Many people think that an air conditioner adds cool air to an indoor space. In reality, the basic principle of air conditioning and the mechanical refrigeration cycle is that heat is extracted from the indoor air and transferred to another location (the outdoors) by the refrigerant that flows through the cycle.

A special type of air conditioner known as a heat pump is widely used in moderate climates to provide both cooling and heating. Heat pumps are extremely efficient; however, they are most effective in climates where the temperature generally does not fall below 25°F or 30°F. In colder areas, heat pumps can be combined with a gas- or oil-fired, forced-air furnace. In such arrangements, the furnace automatically takes over heating duties when the outdoor temperature falls below the efficient range of the heat pump. Like high-efficiency furnaces and boilers, heat pumps are often eligible for energy saving cash incentives from local power companies.

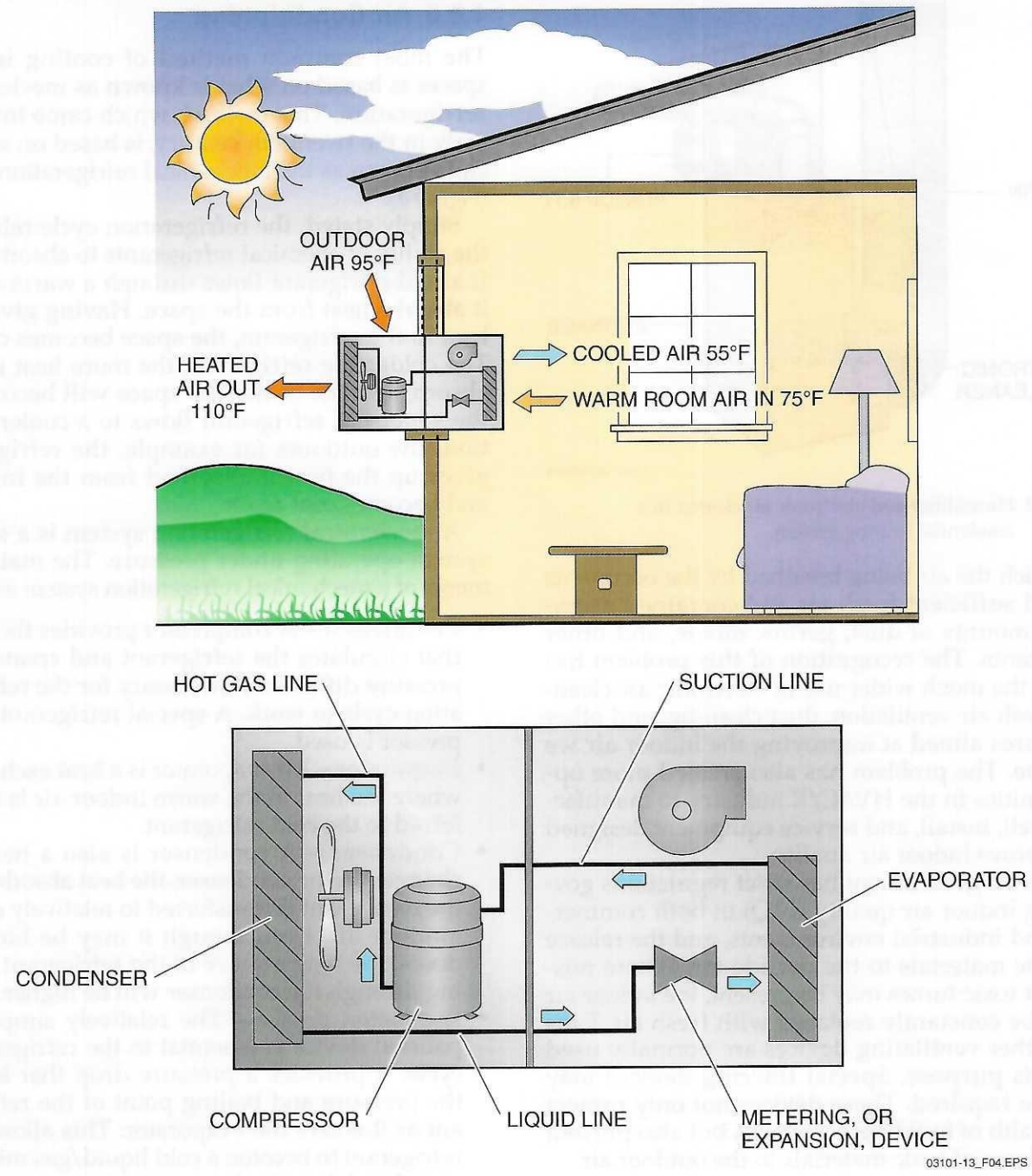

Figure 4 Basic refrigeration cycle for an air conditioner.

Absolute Zero

Absolute zero represents the theoretical point where there is a total absence of heat. It is roughly expressed as –459.67°F or –273.15°C. On another temperature scale that is based on absolute zero, known as the Kelvin scale, it is expressed as 0 K; no degree symbol is used. The Kelvin scale is incrementally the same as the Celsius scale, with 273 K (0°C) being the freezing point of water.

Although the Kelvin scale is by far the most popular in the scientific community, there is yet another scale that also begins at absolute zero. The Rankine scale is a companion to the Fahrenheit scale. Like the Kelvin and Celsius scales, the Rankine and Fahrenheit scales are also the same incrementally. 0°R and –459.76°F are the same temperature point, as is the freezing point of water at 491.67°R and 32°F.

Heat pumps produce heat by reversing the cooling cycle (*Figure 5*). For this reason, heat pumps are sometimes called reverse-cycle air conditioners. The basic operating principle of a heat pump is that there is some heat in the air, even though the air may be very cold. In fact, the temperature would have to be –460°F for a total absence of heat to exist. In the heating mode, a special valve, known as a reversing valve, switches the compressor input and output so that the condenser operates as the evaporator and the evaporator becomes the condenser. Because of this role reversal, the coils in a heat pump are referred to as the outdoor coil and indoor coil instead of the condenser and evaporator.

The relationship between temperature and pressure is critical to mechanical refrigeration. As you study the process, you will learn that the same refrigerant can be very cold at one point in the system (the evaporator input) and very hot at another (the condenser input). These two points are often only inches apart. This is possible because of pressure changes caused by the compressor and expansion device. In addition to the circulation of refrigerant, air must also circulate. Fans at the condenser and evaporator move air across the condenser and evaporator coils.

This is a simple explanation of the refrigeration cycle. It is meant to provide a basic idea of how an air conditioner works. Later in the training program, this subject is explored in greater detail. The relationship between temperature and pressure will also be studied in depth. It is the key to understanding and troubleshooting mechanical refrigeration systems.

The refrigeration cycle is the same in all refrigeration equipment, from the small air conditioner in a car to the system that cools the largest office building. The difference is in the size and construction of the components, piping, and the amount and type of refrigerant.

1.4.0 Refrigeration

The mechanical refrigeration cycle used for comfort cooling is also used in product refrigeration equipment such as the coolers and freezers found in supermarkets and convenience stores (*Figure 6*). The most significant difference between comfort cooling and refrigeration is the operating temperatures (*Figure 7*). Because of the low temperatures at which refrigeration equipment operates, it uses different refrigerants than comfort cooling systems. Moreover, there is a distinction between operating temperatures and refrigerants for coolers and freezers.

Refrigeration equipment based on the mechanical refrigeration cycle is widely used in commercial and industrial applications. Warehouses and distribution centers are often equipped with large coolers and freezers. Food processing plants, such as meat packing plants, dairies, and frozen food processors use refrigeration equipment on a large scale. Refrigeration equipment is also needed to bring perishable food to market in ships and trucks.

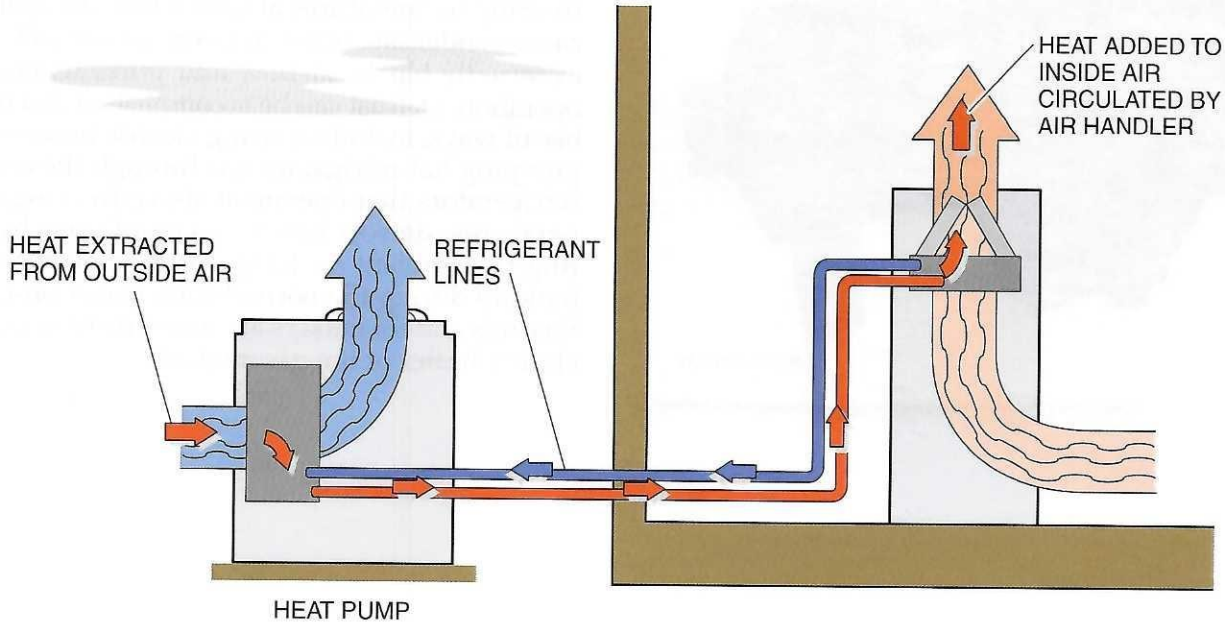

Figure 5 Heat pump heating cycle.

Hermetic and Semi-Hermetic (Serviceable) Compressors

Hermetically sealed compressors are typically used in residential and light commercial air conditioners and heat pumps. Semi-hermetic compressors, also known as serviceable compressors, are used in large-capacity refrigeration or air conditioning chiller units. Semi-hermetic compressors can be partially disassembled for repair in the field. Hermetic compressors are sealed and cannot be repaired in the field.

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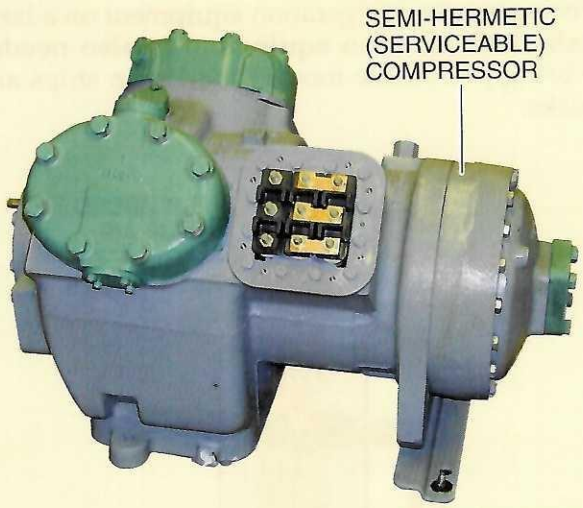

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Figure 6 Retail refrigeration equipment.

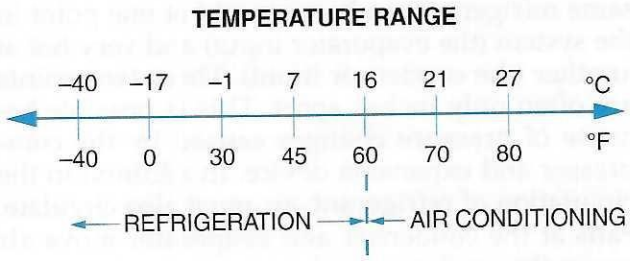

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Figure 7 Comfort cooling and refrigeration temperature ranges.

Another important difference between comfort cooling and refrigeration is the need to defrost the evaporator coil in order to eliminate frost buildup. The buildup occurs because the below-freezing temperatures at which the coil operates cause condensate water to freeze on the coil. This eventually blocks airflow and prevents normal operation. Defrost can be accomplished in a number of ways, including using electric heaters and pumping hot refrigerant gas through the coil. In refrigerators that operate at above-freezing temperatures, defrost can be accomplished by letting the ambient air temperature melt the frost buildup during the normal compressor off-cycle. Freezers and ice makers are more likely to use the electric heater or hot gas method.

Dual-Purpose Systems

It is very common to see a furnace with a cooling coil mounted on it. This approach allows the furnace blower and ductwork to be used for both heating and cooling. The cooling coil on the furnace serves as the evaporator. A condensing unit containing the compressor and condensing coil is installed outdoors to provide the necessary heat transfer. A two-speed blower fan is used in the furnace because cooling requires a higher volume of airflow than heating.

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Additional Resources

ABC's of Air Conditioning. Syracuse, NY: Carrier Corporation.

Refrigeration and Air Conditioning: An Introduction to HVAC/R. Larry Jeffus and David Fearnow. Upper Saddle River, NJ: Pearson Prentice Hall.

Fundamentals of HVAC/R. Carter Stanfield and David Skaves. Upper Saddle River, NJ: Pearson Prentice Hall.

1.0.0 Section Review

1. In a hydronic heating system, the heat transfer medium is _____.
   a. air
   b. water
   c. natural gas
   d. ammonia
2. Ultraviolet light is one method used to _____.
   a. heat residences
   b. control the growth of bacteria
   c. create air movement
   d. produce a cooling effect
3. In the mechanical refrigeration cycle, the purpose of the evaporator is to _____.
   a. convert refrigerant from high pressure to low pressure
   b. transfer heat from the refrigerant to the outdoor air
   c. transfer heat from the indoor air to the refrigerant
   d. provide the pressure difference to circulate refrigerant
4. A defrost cycle is required in _____.
   a. refrigeration systems
   b. gas heating systems
   c. comfort cooling systems
   d. ventilation equipment

Section Two

2.0.0 Guiding Principles for HVAC/R Service Technicians

Objective

Describe the principles that guide HVAC/R installation and service techniques.

a. Identify common safety principles and organizations.
b. Describe the importance of LEED construction and energy management.
c. Describe trade licensing and certification requirements.
d. Identify important codes and permits.

Trade Terms

Bond: Short for surety bond. It is a funded guarantee that a contractor will perform as agreed.

Carbon monoxide (CO): A common byproduct of combustion processes, CO is a colorless, tasteless, and odorless gas that is lighter than air and quite toxic. CO reacts with blood hemoglobin to form a substance that significantly reduces the flow of oxygen to all parts of the body. In some countries, CO is responsible for the majority of fatal air poisoning events.

Chlorofluorocarbon (CFC) refrigerant: A class of refrigerants that contains chlorine, fluorine, and carbon. CFC refrigerants have a very adverse effect on the environment.

Easement: A portion of a property that is set aside for public utilities or municipalities.

Hydrochlorofluorocarbon (HCFC) refrigerant: A class of refrigerants that contains hydrogen, chlorine, fluorine, and carbon.

International Building Code (IBC): A series of model construction codes. These codes set standards that apply across the country. This is an ongoing process led by the International Code Council (ICC).

Reclaimed: Used refrigerant that has been remanufactured to bring it up to the standards required of new refrigerant.

Recovery: The removal and temporary storage of refrigerant in containers approved for that purpose.

Recycling: Circulating recovered refrigerant through filtering devices that remove moisture, acid, and other contaminants.

Sustainable construction: Construction that involves minimum impact on land, natural resources, raw materials, and energy over the building's life cycle. It uses material in a way that preserves natural resources and minimizes pollution.

There is more to becoming a successful HVAC/R service technician than just learning the technical aspects of the systems. The successful technician always follows good safety practices; is conscious of the need to conserve energy and protect the environment; and follows applicable codes and standards.

2.1.0 Safety

The subject of on-the-job safety as defined in OSHA regulations, was covered extensively in the Core module *Basic Safety*. In addition to the general safety practices covered in that module, there are safety concerns specific to HVAC/R work. These concerns include:

- *Working at heights* – HVAC/R installation and service work often require the technician to work from a ladder, install or service equipment on a roof (including sloped roofs), or climb on a cooling tower. In all situations of that type, fall protection and ladder safety regulations must be followed.
- *Working with refrigerants and oils* – There are a number of issues associated with refrigerants and oils:
  - In a confined or enclosed space, refrigerant accidently released from a system can displace oxygen and potentially cause suffocation.
  - Since many common refrigerants boil at temperatures well below 0°F when at atmospheric pressure, serious injuries can result from contact with refrigerants when they are released from their normally pressurized containers or refrigerant circuits.
  - Some rarely used refrigerants contain propane or butane, which are combustible.
  - Exposure to substantial amounts of ammonia refrigerant can cause eye, skin, and mucous membrane irritation.
  - When exposed to an open flame, some refrigerants produce phosgene gas, which can sicken anyone who breathes the fumes. Refrigerant removed from a system after a severe compressor burnout can produce the same result.

– When oil comes into contact with oxygen, an electric arc could cause an explosion under certain conditions. Oxygen must never be used to purge a refrigeration system.

- *Working around gas furnaces* – Natural gas and propane are flammable and explosive. Always check gas supply lines for leaks. In addition, the burning of these gases in the furnace produces deadly **carbon monoxide (CO)**. A cracked heat exchanger or improperly installed vent pipe can cause these gases to be released into the conditioned space.
- *Working around oil furnaces* – Oil is flammable and its fumes are explosive. Each attempt to restart an oil burner will inject a small quantity of oil into the fire pot. A homeowner may try to restart a furnace several times before calling for help. To avoid a possible explosion, always check the fire pot and clean out the accumulated oil before attempting to start the burner.

2.2.0 Energy Conservation and LEED Construction Principles

HVAC/R systems play an important role in efforts to reduce toxic emissions that come from the burning of fossil fuels and to reduce dependence on foreign oil. High-efficiency furnaces, heat pumps, and comfort air conditioning systems are available for both commercial and residential installations.

A number of manufacturers have voluntarily partnered with the Environmental Protection Agency (EPA) in an ENERGY STAR® program to market units that exceed minimum efficiency standards. Building designs may also qualify for this program through the use of high-efficiency HVAC/R systems combined with thermal storage systems.

A high-efficiency system is only effective if it is operating at maximum efficiency. This means performing scheduled maintenance, which includes testing and adjusting for peak performance, as well as replacing defective or underperforming parts.

In an effort to improve energy performance, manufacturers have a number of add-on devices designed to improve the energy efficiency of air conditioning and heating equipment. Some of these devices are designed to recover energy that would otherwise be wasted. The heat recovery ventilator (HRV) shown in *Figure 8* is a good example. In this particular configuration, air drawn from outdoors and exhaust air from the furnace pass through the heat exchanger where heat from the exhaust air is transferred to the incoming cool air before it passes over the furnace heat exchangers. Since the air has been pre-warmed, less energy is needed to raise the air to the temperature needed for heating. Some HRVs work directly through a building ventilation system without going through the heating equipment.

Another example is the ice storage system. Many electric utilities charge a higher rate for electricity during peak-use daytime hours. To reduce the energy costs of air conditioning a building, ice is generated by refrigeration systems at night using low-cost off-peak power. The ice is stored in insulated tanks and is used to aid the building's

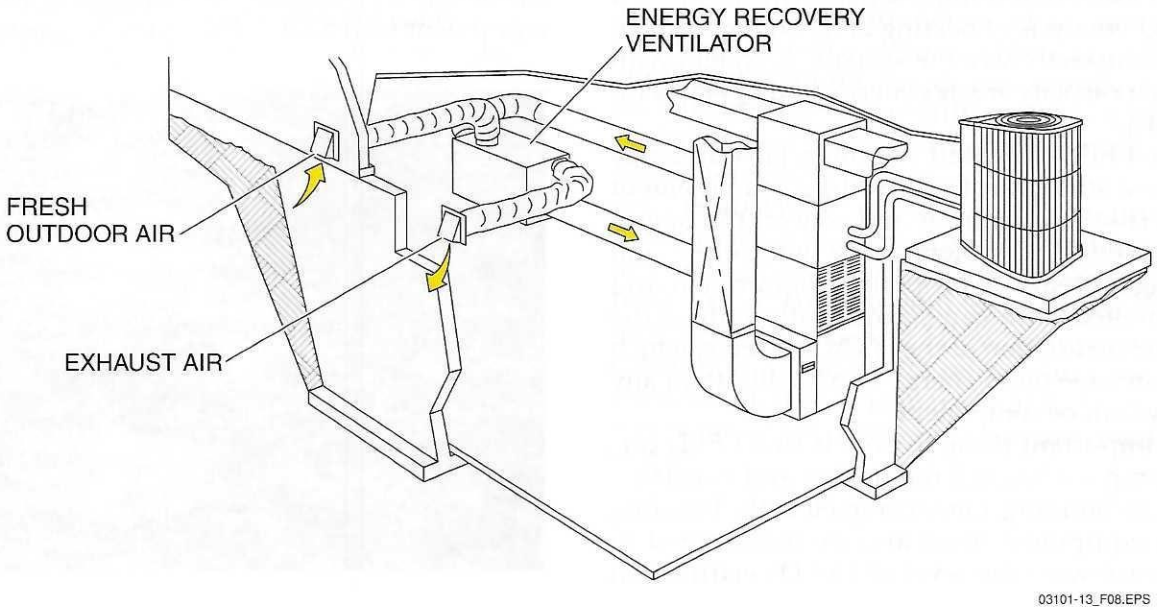

Figure 8 Heat recovery ventilator (HRV).

Table 1 shows the ozone depletion potential (ODP) and the global warming potential (GWP) of various refrigerants. This subject is covered in much greater depth in future training modules. Note that the refrigerants with no atmospheric life recorded are blends of two or more existing refrigerants. This is due to the fact that the various components of the blend separate once they enter the atmosphere. Carbon dioxide, the final entry in the table, has a GWP of 1, and is the basis for the GWP values for all of the others. For example, HCFC-22, with a GWP of 1,700, has 1,700 times the potential to create a greenhouse effect than carbon dioxide. CFC-12 is the basis for the ODP of all other refrigerants in the table.

Refrigerant typically comes in cylinders packaged in boxes like the ones shown in *Figure 10*. They are color-coded to represent the type of refrigerant. For example, the container for R-404A is bright orange.

In the 1980s, many nations of the world made a commitment to phase out these chemicals. Those countries agreed to take steps in the interim to prevent the discharge of refrigerants into the atmosphere. In 1990, the US Congress passed the Clean Air Act, which calls for the phase out of the most toxic refrigerants, the eventual elimination of all CFCs and HCFCs, and the strict control and labeling of refrigerants. As a result of the requirement to phase out CFCs and HCFCs, a number of new, environmentally friendly refrigerants have been developed. The US Environmental Protection Agency (EPA) is responsible for implementing and enforcing this law, which has a significant impact on the HVAC/R trade. For example, it has imposed the following restrictions on refrigerants, regardless of the chlorine content:

- Anyone releasing these refrigerants to the atmosphere is subject to a stiff fine, and possibly a prison term.
- Anyone handling these refrigerants must have EPA-sanctioned certification. Without the EPA-sanctioned card that shows you have completed the training, you cannot even buy refrigerants. The training needed to obtain EPA certification is included in this curriculum. There are four

Table 1 Common Refrigerant Environmental Impact Data

Refrigerant	Ozone Depletion Potential (ODP)	Global Warming Potential (GWP)	Atmospheric Life, in Years
CFC-11 (Trichlorofluoromethane)	1.0	4,000	45
CFC-12 (Dichlorodifluoromethane)	1.0	8,500	100
CFC-13 (Chlorotrifluoromethane)	1.0	11,700	640
HCFC-22 (Chlorodifluoromethane)	0.05	1,700	12
HFC-32 (Difluoromethane)	0	543	4.9
CFC-113 (Trichlorotrifluoroethane)	0.8	5,000	85
CFC-114 (Dichlorotetrafluoroethane)	1.0	9,300	300
HCFC-123 (Dichlorotrifluoroethane)	0.02	93	1.3
HCFC-124 (Chlorotetrafluoroethane)	0.02	480	5.8
HFC-125 (Pentafluoroethane)	0	3,400	29
HFC-134a (Tetrafluoroethane)	0	1,300	14
HFC-143a (Trifluoroethane)	0	4,300	52
HFC-152a (Difluoroethane)	0	120	1.4
HCFC-401A	0.37	1,100	NA
HCFC-402A	0.02	2,600	NA
HFC-404A	0	3,300	NA
HFC-407A	0	2,000	NA
HFC-407C	0	1,600	NA
HFC-410A	0	1,725	NA
R-717 Ammonia	0	0	NA
R-718 Water	0	0	NA
R-729 Air	0	0	NA
R-744 Carbon Dioxide	0	1	50–200

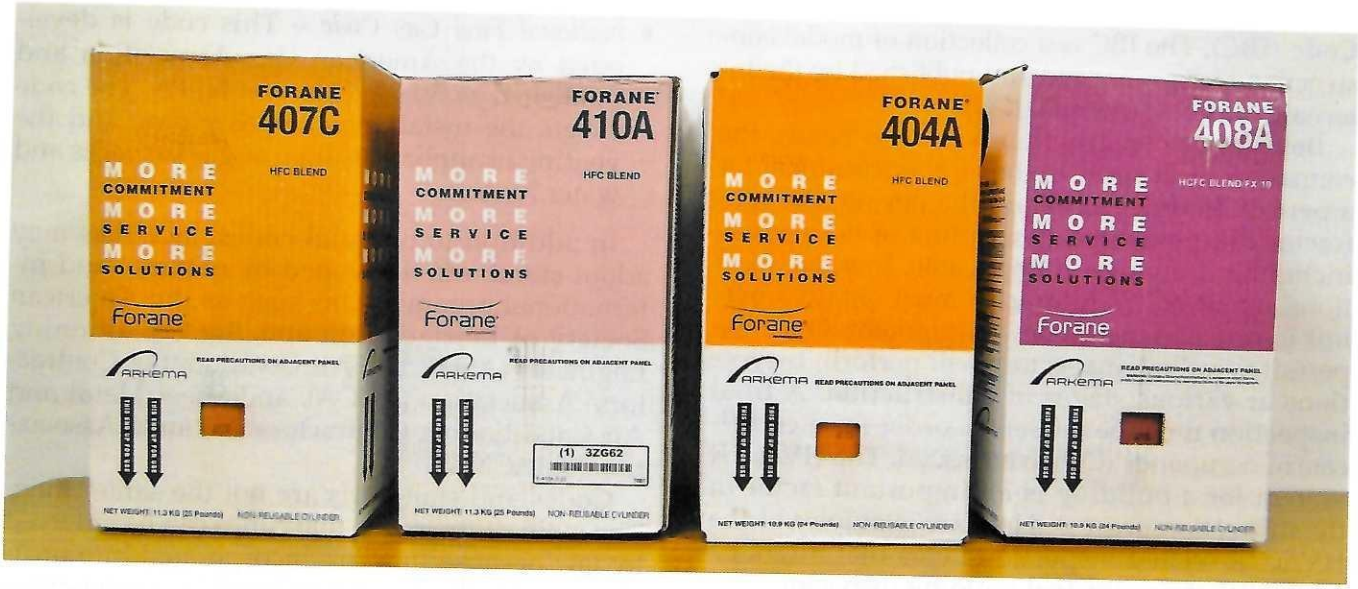

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Figure 10 Refrigerant cylinders.

levels of EPA certification, based on the type of work. The levels range from a Type I certification that allows a person to work on systems containing less than 5 pounds of high-pressure refrigerant, to a Universal certification which allows work on any type of system containing refrigerant.

- Records must be kept on all transactions involving these refrigerants. These records must include purchase, use, reprocessing, and disposal.

Before a sealed refrigeration system can be opened for repair, the refrigerant it contains must be identified. With few exceptions, all refrigerants must be recovered using approved **recovery** equipment, and stored in approved containers. *Figure 11* shows a refrigerant recovery system in use. When the repair is complete and the system is resealed, the same refrigerant may be returned to the system. It may also be used in another system belonging to the same owner. Recovered refrigerant should, however, be recycled before reuse. **Recycling** removes most moisture and impurities that could damage the system. Some refrigerant recovery units have a built-in recycling capability.

If the refrigerant is badly contaminated or no longer needed, it can be reclaimed. This is done at remanufacturing centers where the refrigerant is returned to the standards of purity that govern new refrigerants. Reclaimed refrigerant can be resold on the open market, but cannot be classified as new refrigerant.

In addition to federal regulations, there may be state regulations that apply to refrigerants. State regulations may be stricter. It is critical that everyone in the HVAC/R industry understands and follows the EPA regulations regarding the handling, storage, and labeling of refrigerants. Failure to do so could be very costly to both the worker and the employer.

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Figure 11 Refrigerant recovery equipment.

2.4.0 Codes and Permits

Construction work is governed by building codes, which are enforced by local municipalities. The purpose of a building code is to regulate the health and safety aspects of building construction in a community. Building codes regulate new construction, for example, by establishing limits on the height and floor area of buildings, by specifying the separation between buildings, and by requiring specific setbacks for buildings and equipment from property boundaries and **easements**. Local codes are based on the **International Building**

Code (IBC). The IBC is a collection of model construction codes managed and published by the International Code Council (ICC).

Before any construction work can begin, the contractor must apply to the local government for a permit. In order to obtain the permit, the contractor must submit a description of the project, including drawings, if applicable. In some locations, an HVAC/R contractor must obtain a permit in order to install new equipment. Once the permit is pulled, inspectors will perform inspections at various stages of construction. A final inspection must be passed in order for a certificate of occupancy (CO) to be issued. The HVAC/R system for a building is an important factor in the inspection process. Here are examples of the HVAC/R-related inspection items that might be on the list of a municipal building inspector:

- Furnace venting
- Gas piping for furnaces
- Duct installations
- Pipe supports for refrigerant lines and hydronic system piping
- Condensate drains
- Equipment placement
- Locations of piping for furnace combustion air intake and exhaust.

NOTE

In locations where hurricanes or tornadoes are a threat, proper anchorage of outdoor equipment is a special concern. Areas with earthquake potential also have special requirements.

In addition to building codes, there are other national codes that have been incorporated into state and municipal building codes by adoption. These codes include the following:

- *National Electrical Code (NEC®)* – This code is published by the National Fire Protection Association (NFPA) as *NFPA 70®*. The *NEC®* establishes the minimum standard for electrical wiring. This code is rigidly enforced. For that reason, electrical wiring installations for HVAC/R systems are nearly always performed by a licensed electrician.
- *National Fuel Gas Code* – This code is developed by the American Gas Association and published as *NFPA 54* by the NFPA. The code covers the installation of gas piping and the venting of appliances such as gas furnaces and water heaters.

In addition to national codes, localities may adopt standards developed by national and international organizations such as the American Society of Refrigeration and Air Conditioning Engineers (ASHRAE), Air Conditioning Contractors' Association (ACCA), and Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

Codes and standards are not the same thing. The main difference is that codes can be enforced by law because they are incorporated into ordinances. Standards are produced by associations of engineers, contractors, and manufacturers. Their purpose is to establish criteria for the design, manufacture, and installation of equipment. Standards are often included by reference in contractual documents such as drawings and specifications. If they are so incorporated, it is up to the contractors to make sure their employees are familiar with, and comply with, the referenced standards.

A standard can take on the force of law if it is adopted by state or municipal governments as part of a building code structure. An example is *ASHRAE Standard 62.1*, which deals with indoor air quality. Some states have adopted this standard as part of their building code, which means that the municipal inspector's checklists will include such items as duct sealing, air filter efficiency, use of outdoor air for ventilation, and moisture and humidity control.

The takeaway message is that it is important for HVAC/R installers to become familiar with code requirements for the areas in which they work. Inspectors will not hesitate to order work to be re-done if it does not meet code requirements.

There's an App for Everything

HVAC/R technicians can benefit from applications that are available for smart phones and tablets. Here are a few examples of such apps: duct-sizing calculator; refrigerant temperature-pressure charts; refrigerant charging charts; pipe-sizing charts; and load-calculating aids. Apps like these are available through smart application packages such as HVAC/R Buddy® and HVAC/R Toolkit.

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Additional Resources

Your Role in the Green Environment. Alachua, FL: NCCER.

2.0.0 Section Review

1. Phosgene gas can be produced when some refrigerants are exposed to _____.
   a. air
   b. oil
   c. water
   d. a flame

2. Mastic is a material used to _____.
   a. test for gas leaks
   b. seal ductwork
   c. insulate refrigerant lines
   d. lubricate bearings

3. A mechanical contractor is a company that _____.
   a. services automobile mechanical systems
   b. specializes in the installation and repair of air conditioning systems
   c. manufactures air conditioning equipment
   d. constructs entire buildings

4. Building permits are usually issued by the _____.
   a. local government
   b. state
   c. Federal Government
   d. building architect

SECTION THREE

3.0.0 CAREERS IN HVAC/R

Objective

Identify career paths available in the HVAC/R trade.

a. Identify the responsibilities and characteristics needed to be a successful HVAC/R technician.
b. Identify residential, commercial, and industrial career opportunities.
c. Describe opportunities provided by equipment manufacturers.

Trade Terms

Chiller: A high-volume hydronic cooling unit.

On the job learning (OJL): Learning obtained while working under the supervision of a journeyman.

Since ancient times, people have sought ways to make the buildings in which they live, work, and play more comfortable. The members of the HVAC/R craft are skilled workers who install, maintain, and repair the equipment that makes this possible. Working in the HVAC/R industry is challenging and rewarding because environmental technology is constantly changing. Technical advances in HVAC/R systems are made every day in advanced computerized controls, greater operating efficiency, and improved packaging.

The HVAC/R industry offers many opportunities for advancement. The training you are receiving can qualify you to become an installer, troubleshooter, sales technician, system design specialist, and eventually even the owner of your own HVAC/R service business.

3.1.0 Employee Responsibilities and Characteristics

In order to be successful, the professional must be able to use current trade materials, tools, and equipment to finish the task quickly and efficiently. A technician must be able to adjust methods to meet each situation. The successful technician must keep abreast of technical advancements and continually gain the skills to use them. A professional never takes chances with regard to their personal safety or the safety of others. The sections that follow describe some characteristics that distinguish a professional employee.

3.1.1 Professionalism

The word *professionalism* is a broad term that describes the desired overall behavior and attitude expected in the workplace. Professionalism involves a number of qualities, including honesty; productivity; safety; civility; cooperation; teamwork; clear and concise communication; being on time and prepared for work; and regard for the impact of behavior on co-workers. It can be demonstrated in a variety of ways every minute you are in the workplace.

3.1.2 Honesty

Honesty and personal integrity are important traits of the successful professional. Professionals pride themselves in performing a job well, and in being punctual and dependable. Each job is completed in a professional way, and never by cutting corners or reducing materials. A valued professional maintains work attitudes and ethics that protect property such as tools and materials belonging to employers, customers, and other trades from damage or theft at the shop or job site.

Honesty and success go hand-in-hand. It is not simply a choice between good and bad, but a choice between success and failure. Dishonesty always catches up with you. Whether you are stealing materials, tools, or equipment from the job site or simply lying about your work, it will not take long for your employer to find out. Of course, you can always go and find another employer, but this option will ultimately run out.

Honesty also means giving a fair day's work for a fair day's pay and doing what you say you will do. Employers place a high value on an employee who is strictly honest. Customers also place a high value on honesty, and tend to return to those they can trust when they need help.

3.1.3 Loyalty

Employees expect employers to look out for their interests, to provide them with steady employment, and to promote them to better jobs as openings occur. Employers feel that they, too, have a right to expect their employees to be loyal to them—to keep the company's interests in mind, to speak well of the company to others, to keep any minor troubles strictly within the plant or office, and to keep all matters that pertain to the business absolutely confidential. Both employers and employees should keep in mind that loyalty is not something to be demanded; rather, it is something to be earned. Loyalty between an em-

ployer and an employee requires both parties to work in each other's best interest.

3.1.4 Willingness to Learn

Every business has its own way of doing things. Employers expect their workers to be willing to learn their system. Sometimes, a change in safety regulations or the purchase of new equipment makes it necessary for even experienced employees to learn new methods. Employees often resent having to accept improvements because of the retraining that is involved. However, methods must be kept up to date in order to meet competition and show a profit. It is this profit that enables the owner to continue in business and to provide jobs for the employees.

3.1.5 Willingness to Take Responsibility

Every employee has the responsibility for working safely and must take that responsibility seriously. In addition, employers expect their employees to see what needs to be done, and then do it. It is frustrating for a supervisor to have to ask again and again that a certain job be done. Once the responsibility has been delegated, the employee should continue to perform the duties without further direction.

Regardless of your skill level, everyone makes mistakes from time to time. In fact, the expensive errors are often made by workers with the most experience, since those workers are in a position of higher responsibility. All workers must take responsibility for their mistakes and accept their part in correcting the error. A highly experienced craftworker said that, "one major difference in an amateur and a professional is that the professional knows how to correct his mistakes."

3.1.6 Willingness to Cooperate

To cooperate means to work effectively with others. In the modern business world, cooperation is the key to getting things done. Employees must be able to work as a member of a team with the employer, supervisor, fellow workers, and even customers in a common effort to get the work done efficiently, safely, and on time. People can work well together only if there is some understanding about what work is to be done, when and how it will be done, and who will do it. Rules and regulations are a necessity in the working world and employees must embrace them to function effectively as a member of the team.

3.1.7 Tardiness and Absenteeism

Tardiness means being late for work, and absenteeism means being off the job for one reason or another. Consistent tardiness and frequent absences are an indication of poor work habits, unprofessional conduct, and a lack of commitment.

Failure to get to work on time results in lost time and resentment on the part of those who do come on time. In addition, it may lead to penalties, including dismissal. Although it may be true that a few minutes out of a day are not very important, you must remember that a principle is involved. It is your obligation to be at work at the time indicated. In fact, arriving a little early indicates your interest and enthusiasm for your work,

Ethical Principles for Members of the Construction Trades

- *Honesty* – Be honest and truthful in all dealings. Conduct business according to the highest professional standards. Faithfully fulfill all contracts and commitments. Do not deliberately mislead or deceive others.
- *Integrity* – Demonstrate personal integrity and the courage of your convictions by doing what is right even where there is pressure to do otherwise. Do not sacrifice your principles because it seems easier.
- *Loyalty* – Be worthy of trust. Demonstrate fidelity and loyalty to companies, employers and sponsors, co-workers, and trade institutions and organizations.
- *Fairness* – Be fair and just in all dealings. Do not take undue advantage of another's mistakes or difficulties. Fair people are open-minded and committed to justice, equal treatment of individuals, and tolerance for and acceptance of diversity.
- *Respect for others* – Be courteous and treat all people with equal respect and dignity.
- *Obedience* – Abide by laws, rules, and regulations relating to all personal and business activities.
- *Commitment to excellence* – Pursue excellence in performing your duties, be well informed and prepared, and constantly try to increase your proficiency by gaining new skills and knowledge.
- *Leadership* – By your own conduct, seek to be a positive role model for others.

which is appreciated by employers. The habit of being late is another thing that stands in the way of promotion.

It is sometimes necessary to take time off from work. No one should be expected to work when sick or when there is serious trouble at home. However, workers must not get into the habit of letting unimportant and unnecessary matters keep them from the job. This results in lost production and hardship on those who try to carry on the work with less help. If it is necessary to miss work, at least phone the office early in the morning so they have time to make alternate arrangements. If you do not call, it leaves those at work uncertain about what to expect. They have no way of knowing whether you have merely been held up and will be in later, or whether immediate steps should be taken to assign your work to someone else.

Employers do not tolerate habitual lateness or absenteeism. In order to control it, they resort to docking pay, demotion, and even dismissal. In fairness to the company and to those workers who do show up for work, an employer is sometimes forced to discipline those who do not follow the rules.

3.2.0 Career Opportunities

Career opportunities in the HVAC/R trade are many and varied. There is a large existing base of HVAC/R systems that need service, repair, and replacement. In addition, every time a new residential, commercial, or industrial building is constructed, it contains one or more HVAC/R system elements.

To get an idea of how vast the HVAC/R trade is, picture the town in which you live. Then think about the fact that almost every building in town contains some form of equipment to provide heating and cooling, as well as air circulation and purification. Expand that view to include the entire country and you realize that there are millions of heating, air conditioning, and air management systems. New ones are being added every day; old ones are wearing out and being repaired or replaced. From that perspective, the opportunities in the craft appear limitless.

Figure 12 provides an overview of career opportunities in the HVAC/R trade. For the purposes of this discussion, it is convenient to view the HVAC/R industry as having the following three segments:

- *Residential/light commercial* – Residential/light commercial companies sell, install, and service residential and light commercial equipment and systems such as furnaces and packaged air conditioners.
- *Commercial/industrial* – Commercial/industrial companies are generally mechanical contractors that install and maintain systems for large office buildings, factories, apartment complexes, shopping malls, and so forth.
- *Manufacturing* – Manufacturing companies build and market HVAC/R systems and equipment.

3.2.1 Residential/Light Commercial

At this level, you might find anything from a one-person installation and service business to a firm with 100 or more employees, including heating and air conditioning specialists, installers, sheet metal workers, and sales engineers. In such businesses, HVAC/R specialists may work alone or with a partner. They typically respond to service calls from homes or small businesses. They may also install furnaces and air conditioning equipment sold by their firm's sales engineer. In other firms, one group may do installations while another group handles troubleshooting and maintenance. At this level, a technician is expected to work with a wide variety of products from many different manufacturers. Systems can consist of anything from a window air conditioner to complete, centralized heating/air-conditioning systems with as much as 25 tons of cooling capacity.

Local or regional distributors provide equipment, parts, special tools, and other services for the firms that sell, install, and service HVAC/R equipment. The distributor needs salespeople who know HVAC/R equipment. The distributor may also provide engineering support and service training for its dealers. Distributorships are often affiliated with a single manufacturer.

NOTE

Many community-based firms are subsidiaries of nationwide firms known as consolidators. A consolidator is an umbrella organization that provides centralized management, purchasing, training, and other functions that give small, local companies the power of a large, national company.

3.2.2 Commercial/Industrial

Large commercial and industrial systems have many components and may require thousands of feet of ductwork and piping. Such systems are designed by engineers and architects. Many HVAC/R craftworkers are required for these projects and an individual is more likely to specialize. For example, where a single wall thermostat often controls residential systems, a

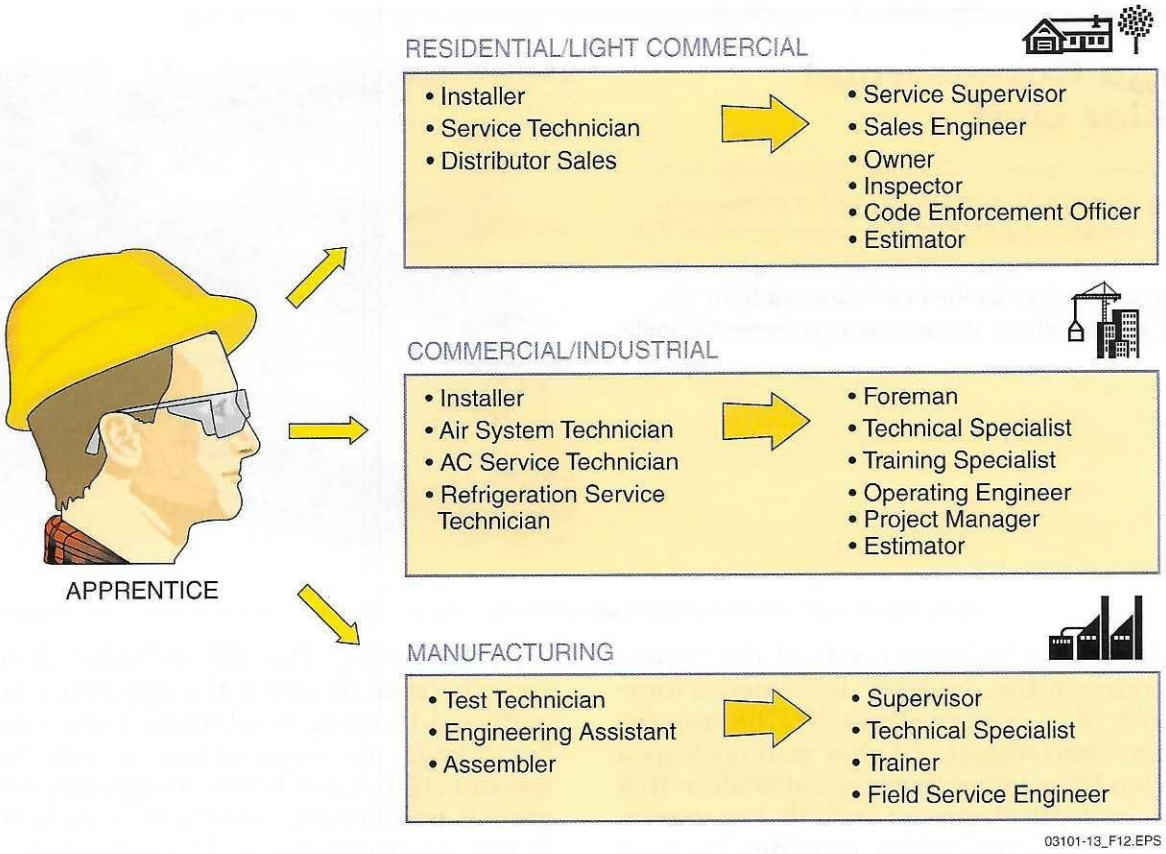

Figure 12 Career opportunities in the HVAC/R trade.

large commercial system often has central computer controls that are installed and serviced by a system control specialist. These systems, commonly known as building management systems (BMS), require specialized skills to program and maintain. In many cases, the technician must be intimately familiar with the specific software package being used. Others may specialize in working with large steam boilers; still others may choose to become experts in installing and servicing large capacity hydronic cooling units known as **chillers**.

Companies that install such equipment are often large construction firms or mechanical contractors that may work anywhere in the world. They are likely to do only the installation and let the building owner contract with another firm for maintenance. Many companies that have large facilities employ their own HVAC/R maintenance people.

3.2.3 HVAC/R Training

The Department of Labor's Office of Apprenticeship sets the minimum standards for training programs across the country. These programs rely on mandatory classroom instruction and **on-the-job learning (OJL)**. They require at least 144 hours of classroom instruction per year and 2,000 hours of OJL per year. In a typical four-year HVAC/R apprenticeship program, trainees spend 576 hours in classroom instruction and 8,000 hours in OJL before receiving certificates issued by registered apprenticeship programs.

Modern Air Conditioning

Dr. Willis Carrier, founder of Carrier Corporation, is credited with the invention of modern air conditioning. In 1902, he developed a system that could control both humidity and temperature using a non-toxic, non-flammable refrigerant. Air conditioning started out as a means of solving a problem in a printing facility where heat and humidity were causing paper shrinkage. Later systems served similar purposes in textile plants. The concept wasn't applied to comfort air conditioning until about 20 years later when Carrier's centrifugal chillers began to be installed in department stores and movie theaters.

Large Commercial Chiller Unit

As the name implies, chillers use chilled water as a cooling medium. The chiller acts as the evaporator. Chillers are often combined with a cooling tower that acts as the condensing unit. Water flowing over the cooling tower absorbs the heat extracted from the indoor air. This photo shows a large commercial chiller unit.

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To address the training needs of the professional communities, NCCER developed a four-year HVAC/R training program. NCCER uses the minimum Department of Labor standards as a foundation for a comprehensive curriculum that provides in-depth classroom and OJL experience.

This NCCER curriculum provides trainees with industry-driven training and education. It adopts a purely competency-based teaching approach. This means that trainees must show the instructor that they possess the knowledge and skills needed to safely perform the hands-on tasks that are covered in each module.

When the instructor is satisfied that a trainee has the required knowledge and skills for a given module, that information is sent to NCCER and recorded in the National Registry. The National Registry can then confirm training and skills for workers as they move from state to state, company to company, or even within a company.

Whether you enroll in an NCCER program or another apprenticeship program, make sure you work for an employer or sponsor who supports a nationally standardized training program that includes credentials to confirm your skill development.

Apprentice training goes back thousands of years. Its basic principles have not changed over time. First, it is a means for a person entering the craft to learn from those who have mastered the craft. Second, it focuses on learning by doing; real skills versus theory. Some theory is presented in the classroom. However, it is always presented in a way that helps the trainee understand the purpose behind the skill that is to be learned.

Apprenticeship Standards – All apprenticeship standards prescribe certain work-related or on-the-job learning. This OJL is broken down into specific tasks in which the apprentice receives hands-on training. In addition, a specified number of hours are required in each task. The total amount of OJL for an HVAC/R apprenticeship program is traditionally 8,000 hours, which amounts to four years of training. In a competency-based program, it may be possible to shorten this time by testing out of specific tasks through a series of performance exams.

In a traditional program, the required OJL may be acquired in increments of 2,000 hours per year. Layoffs or illness may affect the duration. The apprentice must log all work time and turn it in to the apprenticeship committee so that accurate time control can be maintained.

The classroom instruction and work-related training does not always run concurrently due to such reasons as layoffs, type of work needed to be done in the field, etc. Furthermore, apprentices with special job experience or coursework may obtain credit toward their classroom requirements. This reduces the total time required in the classroom while maintaining the total 8,000-hour OJL requirement. These special cases depend on the type of program and the regulations and standards under which it operates.

Informal OJL provided by employers is usually less thorough than that provided through a formal apprenticeship program. The degree of training and supervision in this type of program often depends on the size of the employing firm. A small contractor may provide training in only one area, while a large company may be able to provide training in several areas.

For those entering an apprenticeship program, a high school or technical school education is de-

sirable. Courses in shop, mechanical drawing, and general mathematics are helpful. Manual dexterity, good physical condition, and quick reflexes are important. The ability to solve problems quickly and accurately and to work closely with others is essential. You must also have a high concern for safety.

The prospective apprentice must submit certain information to the apprenticeship committee. This may include the following:

- Aptitude test (General Aptitude Test Battery or GATB Form Test) results (usually administered by the local Employment Security Commission)
- Proof of educational background (candidate should have school transcripts sent to the committee)
- Letters of reference from past employers and friends
- Proof of age
- If the candidate is a veteran, a copy of Form DD214
- A record of technical training received that relates to the construction industry and/or a record of any pre-apprenticeship training
- High school diploma or General Equivalency Diploma (GED)

The apprentice must do the following:

- Wear proper safety equipment on the job
- Purchase and maintain tools of the trade as needed and required by the contractor
- Submit a monthly on-the-job learning report to the committee
- Report to the committee if a change in employment status occurs
- Attend classroom instruction and adhere to all classroom regulations such as attendance requirements

NOTE

Some companies have physical activity requirements that must be met by apprentices. These requirements vary from company to company.

Youth Apprenticeship Programs – A Youth Apprenticeship Program is also available that allows students to begin their apprentice training while still in high school. A student entering the program in eleventh grade may complete as much as two years of an NCCER program by high school graduation. In addition, the program, in cooperation with local craft employers, allows students to work in the trade and earn money while still in school. Upon graduation, the student can enter the industry at a higher level and with more pay than someone just starting the apprenticeship program.

This training program is similar to the one used by NCCER, learning centers, contractors, and colleges across the country. Students are recognized through official transcripts and can enter the next year of the program wherever it is offered. They may also have the option of applying the credits at a two-year or four-year college that offers degree or certification programs in the construction trades.

Apprenticeships in the United States

In 2008, more than 500,000 apprentices received registered apprenticeship training in the United States.

An Ancient Apprenticeship Contract

How did these old apprenticeships work? Here's one example. Historical records include a contract between a young Greek named Heracles and a weaver. In exchange for food, a tunic (a long shirt), and 20 holidays a year, Heracles worked for the weaver for five years. After two and a half years, he was paid 12 drachmas. In his fifth year, his pay was scheduled to double.

In addition to learning to become a journeyman weaver, Heracles most likely worked seven long days each week and had to clean the shop, build fires, pick up supplies, make deliveries, and do whatever other jobs the master weaver needed to have done. It's also likely that any damage he caused came out of his promised pay.

So how much pay is 12 drachmas? There is no way of knowing for certain, but the word *drachma* means handful—not much pay for almost three years of hard work. Yet Heracles was willing to put in the time to become a skilled master in his chosen trade. As a master weaver, Heracles could look forward to a better income and a better life.

3.3.0 Opportunities in Manufacturing

There are thousands of HVAC/R manufacturers. Some of the larger ones cover the entire HVAC/R spectrum, while others focus on a particular product or market. For example, one may make window air conditioners, another gas furnaces, and yet another might make only heavy commercial equipment such as chillers. Some companies work in niche markets, manufacturing specialized equipment such as that used for flash freezing of food products. Regardless of their market, manufacturers employ a variety of HVAC/R specialists such as:

- Test technicians
- Engineering assistants
- Training specialists
- Instruction book writers
- Field service technicians

A major advantage of working in such a company is that the jobs generally pay good salaries, have benefits, and offer opportunities for advancement. Some manufacturers have multiple locations, so the opportunities for advancement are sometimes broad-based. Many manufacturing companies, especially the larger ones, offer a variety of in-house training courses, as well as tuition reimbursement for college courses.

Testing technicians often work in quality control labs. They may test manufactured equipment to make sure it performs to specifications. They may also test equipment returned under warranty to determine what caused it to fail. An engineering assistant works with equipment designers and may help build and test prototypes of new designs. Large manufacturers, and those that manufacture specialized equipment offer training to their distributors and clients. A training specialist develops and delivers the training courses offered by the manufacturer.

New equipment is always accompanied by installation instructions. Many companies provide operation and maintenance handbooks as well. This material is prepared by technical writers who work with engineers to produce the instruction books.

Manufacturers that design and build specialized equipment or large engineered systems generally have a cadre of field service technicians who perform periodic maintenance and are called upon to troubleshoot and repair systems in the event of a failure. Needless to say, if specialized HVAC/R equipment fails, there is usually an urgent need to get it back on line. The technicians who perform this work are highly trained, able to work under stress, and available to travel on short notice.

Child Labor Laws

Federal law establishes the minimum standards for workers under the age of 18. Some municipal jurisdictions may enforce stricter regulations. Employers are required to abide by the laws that apply to them.

The Child Labor Provisions of the Fair Labor Standards Act forbid employers from using illegal child labor, and also forbid companies from doing business with any other business that does. DOL investigates alleged abuses of the law. In such cases, employers have to provide proof of age for their employees.

In addition to the Child Labor Provisions, employers in the construction trades are required to follow DOL's *Child Labor Bulletin No. 101, Child Labor Requirements in Nonagricultural Occupations Under the Fair Labor Standards Act. Bulletin No. 101* does the following:

- Explains the coverage of the Child Labor Provisions
- Identifies minimum age standards
- Lists the exemptions from the Child Labor Provisions
- Sets out employment standards for 14- and 15-year-old workers
- Defines the work that can be performed in hazardous occupations
- Provides penalties for violations of the Child Labor Provisions
- Recommends the use of age certificates for employees

More Than Just Candles

Wax has actually been used for several thousand years to create precise molds and patterns in a process known as investment casting. This process is used to form parts such as titanium turbine blades used in jet engines. Precise copies of turbine blades are first created in wax, and then dipped into a ceramic slurry to apply a coating about ¼" thick. Heat then hardens the ceramic material as the melted wax flows out. The now-hollow ceramic mold is filled with molten titanium.

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A new wax mold must be used for each and every blade. The molds must be stored in an environment maintained at very precise temperature and humidity levels because even the smallest change in the environmental conditions can cause dimensional changes in the wax. Highly specialized HVAC/R systems, such as those manufactured by Kathabar Dehumidification Systems, Inc., are capable of maintaining these critical environments. These units heat, cool, humidify, and dehumidify as necessary to maintain precise set points. Without this unique equipment to maintain the highest level of mold accuracy, the extreme levels of reliability found in jet engines today would not be possible.

3.0.0 Section Review

1. Keeping your employer's interests in mind is an example of _____.
   a. honesty
   b. loyalty
   c. cooperation
   d. taking responsibility

2. The minimum number of annual classroom hours required for an apprentice program is _____.
   a. 50
   b. 75
   c. 112
   d. 144

3. Engineering assistants are most likely to be employed by _____.
   a. residential service companies
   b. mechanical contractors
   c. industrial refrigeration contractors
   d. equipment manufacturers

SUMMARY

The HVAC/R craft involves equipment used for heating, cooling, and purifying indoor air, as well as equipment for preserving food and other perishable products. It covers furnaces and air conditioners used in homes and businesses, as well as the heating and cooling systems used in large office buildings and industrial complexes. It includes equipment used in retail, commercial, and industrial enterprises for the preservation and packaging of food and other perishables.

One of the most serious issues affecting the craft is the damage that can be done to Earth's ozone layer by the improper release of refrigerants into the atmosphere. There are severe penalties for improper refrigerant disposal. HVAC/R technicians form an important line of defense in the fight to improve energy efficiency and reduce emission of harmful chemicals into Earth's atmosphere. Federal regulations govern the handling and disposal of refrigerants used in HVAC/R systems. Technicians are required to receive training and obtain an EPA certificate for this purpose.

Because of the widespread use of HVAC/R equipment, there are many career opportunities in the craft. Jobs are available with small local firms, large industrial and commercial contractors, and the manufacturing firms that build and market HVAC/R equipment. The apprentice program provides an opportunity to learn the trade through a combination of hands-on training and related classroom learning. The Youth Apprentice Program allows students to begin their training while still in high school.

Review Questions

1. In a common household forced-air furnace, heat is transferred from the _____.
   a. heat exchangers to the air
   b. natural gas or oil to the conditioned space
   c. air to the heat exchangers
   d. refrigerant to the outdoor air

2. Water is often used in heating systems as a _____.
   a. fuel
   b. refrigerant
   c. heat exchange medium
   d. heat exchanger

3. Ventilation is concerned with _____.
   a. preventing outdoor air from entering a building
   b. maintaining a constant air temperature
   c. removing moisture from indoor air
   d. the introduction of fresh air to control indoor air quality

4. The growth of bacteria and other harmful organisms can be reduced or eliminated by _____.
   a. humidification
   b. cooling air
   c. ultraviolet light
   d. common air filters

5. The term *mechanical refrigeration cycle* refers to _____.
   a. the process by which circulating refrigerant absorbs heat in one location and moves it to another location
   b. the process by which refrigerant moves through a compressor
   c. mobile refrigeration units
   d. the process by which refrigerant is recycled to remove impurities

6. A device that is able to extract heat from the air through the use of the refrigeration cycle is a(n) _____.
   a. furnace
   b. evaporator
   c. heat pump
   d. expansion device

7. The expansion device in the mechanical refrigeration cycle _____.
   a. raises the refrigerant pressure entering the evaporator
   b. lowers the refrigerant pressure entering the evaporator
   c. raises the refrigerant pressure at the condenser inlet
   d. lowers the refrigerant pressure at the condenser outlet

8. In a refrigeration system, heat is transferred from the indoor air to the refrigerant at the _____.
   a. compressor
   b. furnace
   c. evaporator
   d. condenser

9. A leak in the vent pipe of a gas furnace is a concern because it can _____.
   a. release carbon monoxide
   b. release flammable gas
   c. release carbon dioxide
   d. cause heat loss

10. Which of these companies is likely to install HVAC/R equipment during the construction of a large office building?
    a. Mechanical contractor
    b. Distributor
    c. Manufacturer
    d. General contractor

11. In order to be resold on the open market, a refrigerant must have been _____.
    a. reclaimed
    b. recycled
    c. recovered
    d. refurbished

12. Releasing CFC and HCFC refrigerants or certain substitutes to the atmosphere is _____.
    a. okay, provided that the refrigerant has been recycled
    b. okay, provided that the refrigerant has been reclaimed
    c. prohibited by federal law
    d. prohibited in some states

13. The primary purpose of a building code is to regulate the quality of all mechanical installations on a commercial site.
    a. True
    b. False
14. Which of the following is a function performed by a distributor?
    a. Repair of residential heating systems
    b. Sale of equipment and parts
    c. Manufacture of equipment
    d. Installation of mechanical systems
15. Development and delivery of training programs is typically a function of a _____.
    a. mechanical contractor
    b. distributor
    c. manufacturer
    d. residential service company

Trade Terms Quiz

Fill in the blank with the correct trade term that you learned from your study of this module.

1. A substance that is _____ is considered poisonous.
2. Used refrigerant that has been reprocessed to bring it up to the standards required of new refrigerant is called _____.
3. A class of refrigerants that contains hydrogen, chlorine, fluorine, and carbon is called _____.
4. A(n) _____ is a heat exchanger that transfers heat from the air flowing over it to the cooler refrigerant flowing through it.
5. A class of refrigerants that contains chlorine, fluorine, and carbon is called _____.
6. The removal and temporary storage of refrigerant in containers approved for that purpose is called _____.
7. A liquid metering device is also known as a(n) _____.
8. A(n) _____ is a heat exchanger that transfers heat from the refrigerant flowing inside it to the air or water flowing over it.
9. The process by which a circulating refrigerant absorbs heat from one location and transfers it to another location is called a(n) _____.
10. The movement of heat energy from a warmer substance to a cooler substance is known as _____.
11. The process of circulating recovered refrigerant through filtering devices that remove moisture, acid, and other contaminants is known as _____.
12. The use of machinery to provide cooling is called _____.
13. A substance harmful to your health is said to be _____.
14. A high-volume hydronic cooling unit is called a(n) _____.
15. The _____ is a series of model construction codes that set standards that apply across the country.
16. The mechanical device that converts low-pressure, low-temperature refrigerant gas into high-temperature, high-pressure refrigerant gas in a refrigeration system is a(n) _____.
17. The funded performance guarantee that a contractor puts up is called a _____.
18. A portion of property set aside for use by a utility is called a(n) _____.
19. A device that can produce heat by reversing the mechanical refrigeration cycle is a(n) _____.
20. Systems that use water as a heat transfer medium are known as _____ systems.
21. Documented learning that is obtained while working is called _____.
22. The construction process that focuses on minimizing environmental impact is known as _____.
23. A potentially-deadly, colorless, tasteless, and odorless gas that is a common byproduct of combustion processes is _____.

Trade Terms

Bond
Carbon monoxide (CO)
Chiller
Chlorofluorocarbon (CFC) refrigerant
Compressor
Condenser
Easement
Evaporator
Expansion device
Heat pump
Heat transfer
Hydrochlorofluorocarbon (HCFC) refrigerant
Hydronic
International Building Code (IBC)
Mechanical refrigeration
Mechanical refrigeration cycle
Noxious
On the job learning (OJL)
Reclaimed
Recovery
Recycling
Sustainable construction
Toxic

Joseph Pietrzak

Senior Program Manager
Duke Energy

How did you get started in the construction industry (i.e., took classes in school, a summer job, etc.)?

Getting started in the construction industry came naturally to me as I was always drawn to mechanical systems. When I was young, I would often take things apart to see how they worked and then try to put them back together again (hoping they still worked).

After moving from New York to Florida, I had an opportunity to attend school full-time for six months to learn Air Conditioning and Refrigeration. Upon completing this course, I started a job the very next day. I worked and learned the trade for about five years, and then I decided to take the state exam for my Class A license.

Shortly after this, I was hired by Florida Power's Demand-Side Management Department. The goal was to reduce demand and kilowatt-hour usage by their 1.7 million-customer base. In 2000, I started working in technology development-type programs, which included the development of alternative energy platforms. We built the first two hydrogen-fueling stations in the state to service 18 vehicles. In addition, I did a lot of work with solar power generation and systems. I am currently the Senior Solar Program Manager for the following five SunSense programs: Residential PV Incentives, Commercial PV Incentives, Solar Water Heating, Solar for Schools, and Solar for Low Income Families. The key to my success has always been the determination to never stop learning.

Who or what inspired you to enter the industry (i.e., a family member, school counselor, etc.)? Why?

My initial inspiration to enter the HVAC/R industry came through a desire to provide for my family. After moving to Florida, I noted a great demand for HVAC/R technicians and I thought it would be a great career to pursue. I loved working on mechanical systems, there was always a demand in the job market, and I was confident that I would be able to advance my career as long as I was honest, dependable, and worked hard.

What do you enjoy most about your career?

The thing that I enjoy the most is the diversity and variety that it offers. My career has evolved over the years and I currently work for the largest electric utility in the nation managing all the solar programs in Florida. I love the interaction with the customers and contractors and I thoroughly enjoy the research portion where we are asked to validate information and data.

Why do you think training and education are important in construction?

I think training and education are important because workers must develop and measure their competency so that they can perform at a safe and effective level, for both themselves and the people around them. Technology advances rapidly and constantly, so it is important to continue with education and training in order to provide the best possible service to all consumers.

Why do you think credentials are important in construction?

Credentials validate an individual's level of experience and verify that the skills have been observed by a competent instructor.

How has training/construction impacted your life and career (i.e., advancement opportunities, better wages, etc.)?

I take advantage of every training opportunity available through my employer. Training enhances my skills and level of experience. Certifications are eventually reviewed by potential bosses who may find that they document just the skill set needed, and an opportunity for advancement is created. Training has personally impacted my life by allowing me to advance in my career, earn higher wages, and participate in a variety of new, innovative programs that help others and the environment.