AHRI Air-Conditioning, Heating, and Refrigeration Institute

Fundamentals of HVACR

Carter Stanfield and David Skaves

Third Edition

Fundamentals of HVACR

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AHRI Air-Conditioning, Heating, and Refrigeration Institute

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Take the Guided Tour

Fundamentals of HVACR, 3rd 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 edition has been fully updated, including 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. describe the different types of refrigeration service valves.
> 2. explain the operation of gauge manifold valves.
> 3. explain how to properly install and remove a gauge manifold set on manual service valves.
> 4. explain the operation of split-system installation valves.
> 5. explain how to properly install and remove a gauge manifold set on Schrader valves.
> 6. describe how to gain access to systems without ser-

Review Questions

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

> **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?

Unit Introductions and Unit Summaries

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

> **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

> **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.

Caution Tips and Safety Tips

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

> **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 sus-

> **SAFETY TIP**
>
> Proper personal protection equipment should always be used when applying chemical cleaners. Typically this includes safety goggles for eye protection, gloves to protect your hands, and a long-sleeve shirt to protect your arms.

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

Many people find the relationship of fractions with different denominators confusing. To compare two fractional sizes, multiply the bottom number (denominator) of the fraction with the smaller number on the bottom by 2 until it equals the denominator of the other fraction. Then multiply the top number (numerator) by 2 the same number of times. For example, comparing 3/4 inch and 11/16 inch: multiply 4 by 2 twice to get 16 ($2 \times 4 = 8$, $8 \times 2 = 16$). Then multiply 3 by 2 twice get 12 ($3 \times 2 = 6$, $6 \times 2 = 12$). Now you can easily see that 12/16 is larger than 11/16.

SERVICE TIP

To determine how many quarts of oil are required for an oil charge stated in fluid ounces, divide the quantity of fluid ounces by 32. For example, an oil charge of 64 ounces would require 2 quarts: 64 fluid ounces/32 = 2 quarts.

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Supplemental Text

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

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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).

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,

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

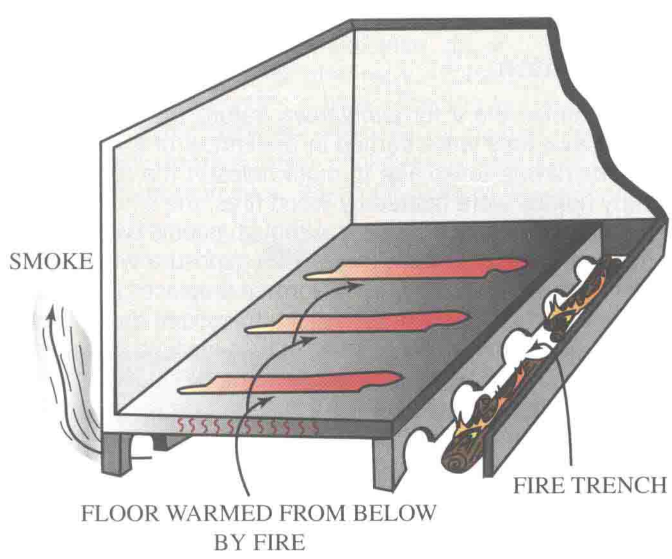


Figure 1-2 Romans used fires channeled below floors as early heating systems.

Figure 1-3 Woodstove.

the next 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, environment-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.

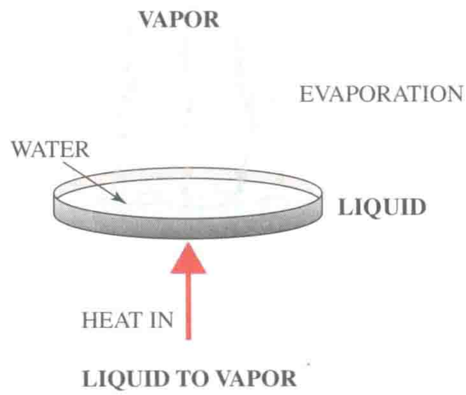


Figure 1-4 When water evaporates, heat is absorbed. This change of state is also referred to as a phase change.

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).

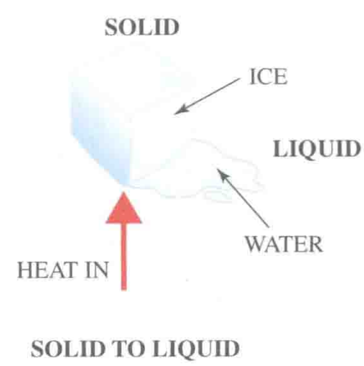


Figure 1-5 When ice melts, heat is absorbed.

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.

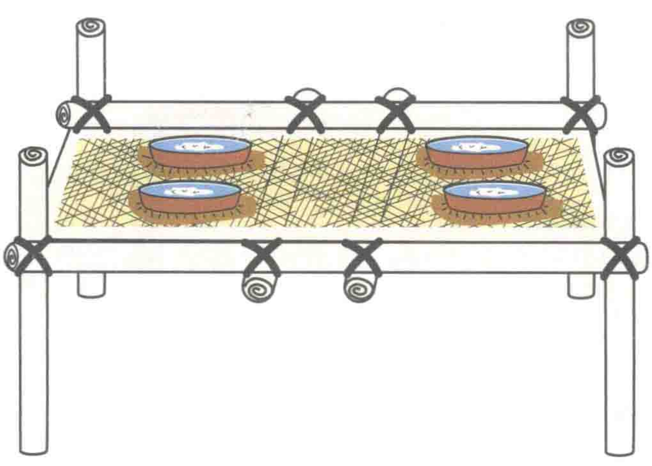


Figure 1-6 Ice was first artificially produced to be used for food preservation more than 3,000 years ago.

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

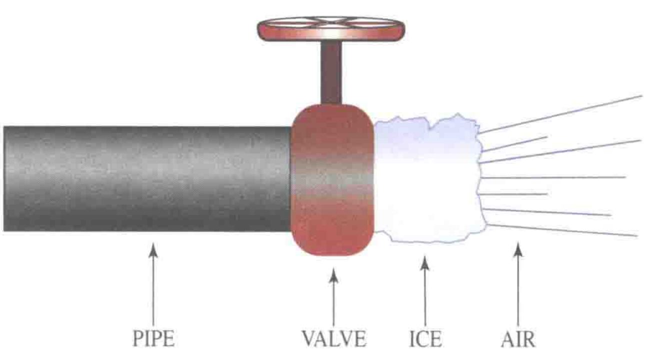


Figure 1-8 Ice forming around an air nozzle.

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.

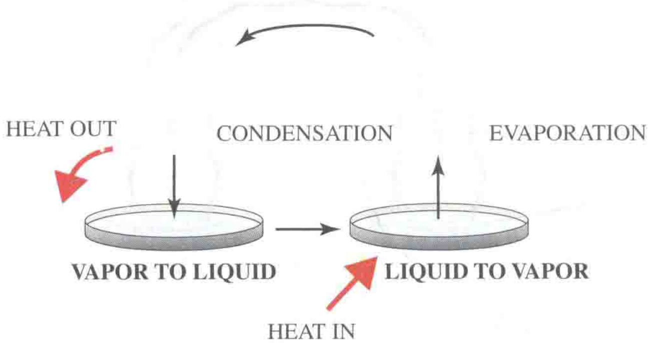
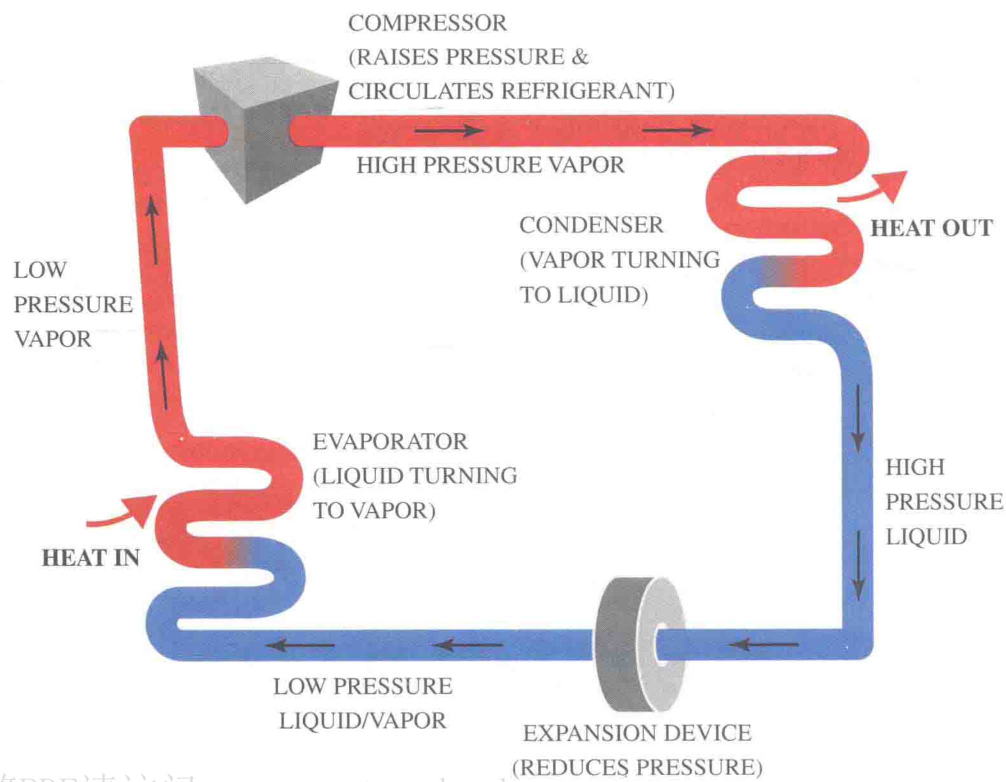


Figure 1-9 Water evaporates to vapor and absorbs heat, and then the vapor is condensed back to water to release its heat.

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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