

chapter 1

HEATING AND AIR-CONDITIONING PRINCIPLES

LEARNING OBJECTIVES

After studying this chapter, the reader should be able to:

1. Prepare for the ASE Heating and Air Conditioning (A7) certification test content area “A” (A/C System Service, Diagnosis and Repair).
2. Discuss the changes of states of matter.
3. Discuss the effect of heat and temperature on matter.
4. Discuss the two types of humidity.
5. Explain heating and cooling load.
6. Explain the three ways in which heat flows.
7. Describe the air-conditioning process.
8. Explain the purpose of an HVAC system.

KEY TERMS

Absolute humidity	4	Heating load	5
British thermal unit (BTU)	2	Heating, ventilation, and air conditioning (HVAC)	2
Cabin filter	10	Latent heat	3
Calorie	2	Mechanical refrigeration	6
Cooling load	5	Relative humidity (RH)	4
Comfort zone	3	Temperature	2
Evaporative cooling	6		
Heat	2		
Heater core	5		

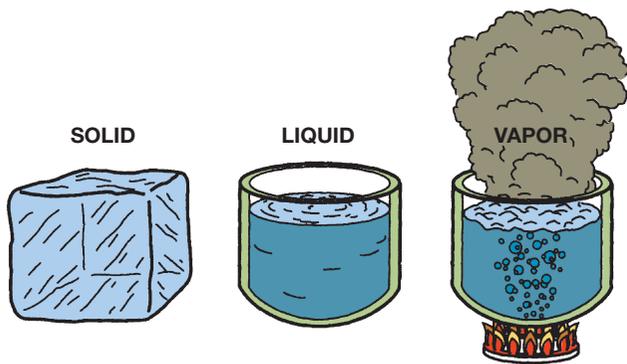


FIGURE 1-1 Water is a substance that can be found naturally in solid, liquid, and vapor states.

INTRODUCTION

PURPOSE AND FUNCTION The **heating, ventilation, and air-conditioning (HVAC)** system of an automobile is designed to provide comfort for the driver and passengers. It is intended to maintain in-vehicle temperature and humidity within a range that is comfortable for the people inside and provide fresh, clean air. The air-conditioning system transfers the heat from inside the vehicle and moves it to the outside of the vehicle. The heater is needed in cold climates to prevent freezing or death.

PRINCIPLES INVOLVED On earth, matter is found in one of three different phases or states:

1. Solid
2. Liquid
3. Vapor (gas)

The state depends upon the nature of the substance, the temperature, and the pressure or force exerted on it. Water occurs naturally in all three states: solid ice, liquid water, and water vapor, depending upon the temperature and pressure.

● **SEE FIGURE 1-1.**

CHANGES OF STATE A solid is a substance that cannot be compressed and has strong resistance to flow. The molecules of a solid attract each other strongly, and resist changes in volume and shape.

- A substance is solid at any temperature below its melting point. Melting point is a characteristic of the substance, and is related to the temperature at which a solid turns to liquid. For water, the melting point is 32°F (0°C), which



FREQUENTLY ASKED QUESTION

Why Is Liquid Sprayed from a Can Cold?

If a pressurized can of liquid is sprayed continuously, the can becomes cold, and so does the liquid being sprayed. The can becomes cold because the pressure in the can is reduced while spraying, allowing the liquid propellant inside the can to boil and absorb heat. The propellant vapor is further cooled as it decompresses when it hits the open air. Rapid decompression results in a rapid temperature drop.

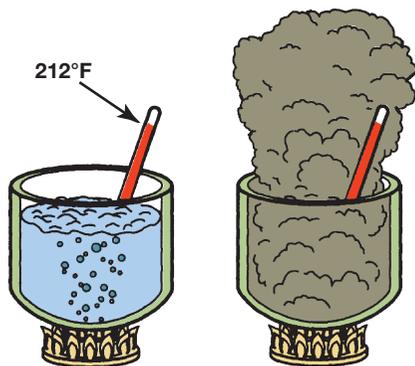
means that changes can be observed between liquid water and ice under normal weather conditions.

- A liquid is a substance that cannot be compressed. A substance in a liquid state has a fixed volume, but no definite shape.
- The boiling point is the temperature at which a liquid substance turns to vapor. For water at normal sea level conditions, the boiling point is 212°F (100°C). A vapor is a substance that can be easily compressed, has no resistance to flow, and no fixed volume. Since a vapor flows, it is considered a fluid just like liquids are.

A vapor condenses to liquid if the temperature falls below the vaporizing temperature. Again, the difference is simply whether heat is being added or taken away. Boiling point and condensation point temperatures are not fixed because they vary with pressure.

HEAT AND TEMPERATURE Molecules in a substance tend to vibrate rapidly in all directions, and this disorganized energy is called heat. The intensity of vibration depends on how much kinetic energy, or energy of motion, the atom or molecule contains. Heat and temperature are not the same.

- **Temperature** is the measure of the level of energy. Temperature is measured in degrees.
- **Heat** is measured in the metric unit called **calorie** and expresses the amount of heat needed to raise the temperature of one gram of water one degree Celsius. Heat is also measured in **British Thermal Units (BTU)**. One BTU is the heat required to raise the temperature of one pound of water 1°F at sea level. One BTU equals 252 calories.



1 GRAM WATER + 540 CALORIES = 1 GRAM VAPOR
1 POUND WATER + 970 BTUs = 1 POUND VAPOR

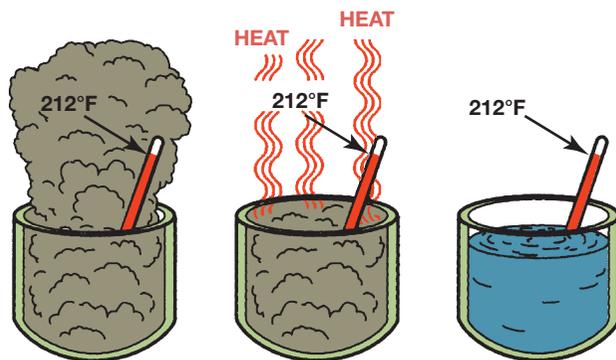
FIGURE 1-2 The extra heat required to change a standard amount of water at its boiling point to vapor is called latent heat of vaporization.

SENSIBLE HEAT Sensible heat makes sense because it can be felt and measured on a thermometer. If there is 1 lb. of water at 40°F and 1 BTU of heat is added to it, the temperature will increase to 41°F. Adding another BTU of heat will increase the temperature to 42°F and adding another 170 BTU (212–42) will increase the temperature to 212°F, the boiling point.

LATENT HEAT Latent heat is the “extra” heat that is needed to transform a substance from one state to another. Imagine that a solid or a liquid is being heated on a stove. When the solid reaches its melting point, or the liquid reaches its boiling point, their temperatures stop rising. The solid begins to melt, and the liquid begins to boil. This occurs without any sensible change in temperature, even though heat is still being applied from the burner. The water in the container on the stove boils at a temperature of 212°F (100°C) at sea level, for as long as any liquid water remains. As heat is further added to the water, heat will be used in changing the state of the liquid to a vapor. This extra, hidden amount of energy necessary to change the state of a substance is called latent heat. ● **SEE FIGURES 1-2 AND 1-3.**

Latent heat is important in the operation of an air-conditioning system because the cooling effect is derived from changing the state of liquid refrigerant to vapor. The liquid refrigerant absorbs the latent heat of vaporization, making the air cooler. The cooler air is then blown into the passenger compartment.

TEMPERATURE, VOLUME, AND PRESSURE OF A VAPOR Unlike a solid, vapor has no fixed volume. Increasing the temperature of a vapor, while keeping the volume confined in the same space, increases the pressure. This happens as the vibrating vapor molecules collide more and



1 GRAM OF VAPOR – 540 CALORIES = 1 GRAM WATER
1 POUND OF VAPOR – 970 BTUs = 1 POUND WATER

FIGURE 1-3 The latent heat of vaporization that water vapor stores is released when the vapor condenses to a liquid. The temperature stays the same.

more energetically with the walls of the container. Conversely, decreasing the temperature decreases the pressure. This relationship between temperature and pressure in vapor is why a can of nonflammable refrigerant can explode when heated by a flame—the pressure buildup inside the can will eventually exceed the can's ability to contain the pressure. Increasing the pressure by compressing vapor increases the temperature. Decreasing the pressure by permitting the vapor to expand decreases the temperature.

HEAT INTENSITY Intensity of heat is important to us because if it is too cold, humans feel uncomfortable and is measured in degrees. Extremely cold temperatures can cause frostbite and hypothermia. The other end of the scale can also be uncomfortable and may cause heat stress and dehydration. Humans have a temperature **comfort zone** somewhere between 68°F and 78°F (20°C and 26°C). This comfort zone varies among individuals. ● **SEE FIGURE 1-4.**

RULES OF HEAT TRANSFER Heating and air conditioning must follow the basic rules of heat transfer. An understanding of these rules helps greatly in understanding the systems.

- Heat always flows from hot to cold. (From higher level of energy to lower level of energy.) ● **SEE FIGURE 1-5.**
- To warm a person or item, heat must be added.
- To cool a person or item, heat must be removed.
- A large amount of heat is absorbed when a liquid changes state to vapor.

TEMPERATURE COMPARISON

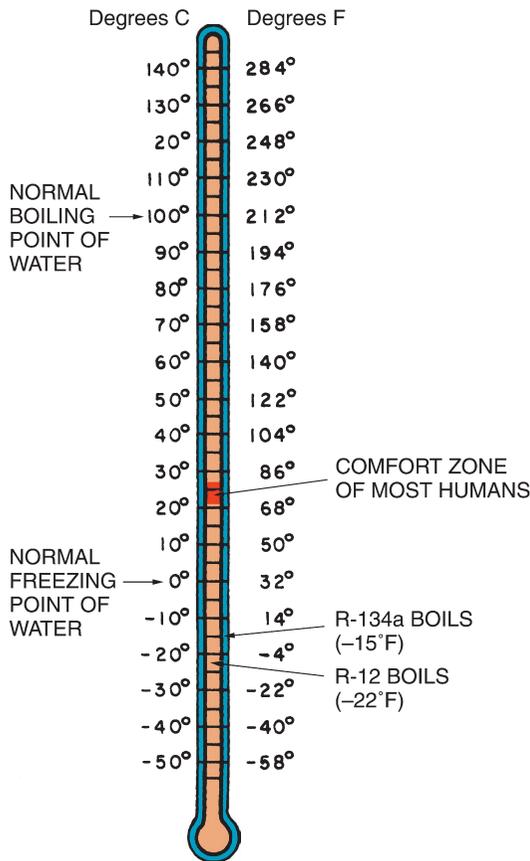
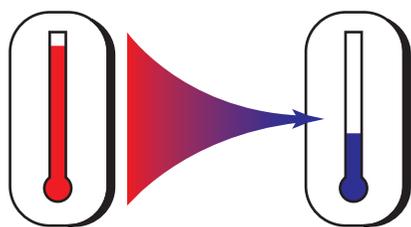


FIGURE 1-4 Heat intensity is measured using a thermometer. The two common measuring scales, Celsius and Fahrenheit, are shown here. This thermometer is also marked with water freezing and boiling and refrigerant boiling temperatures.



HOT TRAVELS TO COLD UNTIL THE TEMPERATURES EQUAL.

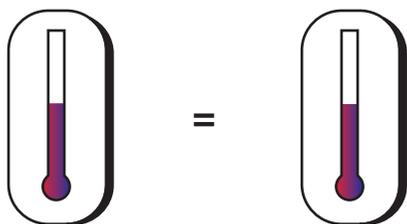


FIGURE 1-5 Heat travels from higher temperature (higher energy level), to lower temperature (lower energy level).



TECH TIP

Quick and Easy Temperature Conversion

Temperature in service information and on scan tools is often expressed in degrees Celsius, which is often confusing to those used to temperature expressed in Fahrenheit degrees. A quick and easy way to get an *approximate* conversion is to take the degrees in Celsius, double it, and add 25.

For example,

Celsius × 2 + 25 = approximate Fahrenheit

degrees:

$$0^{\circ}\text{C} \times 2 = 0 + 25 = 25^{\circ}\text{F} \text{ (actual} = 32^{\circ}\text{F)}$$

$$10^{\circ}\text{C} \times 2 = 20 + 25 = 45^{\circ}\text{F} \text{ (actual} = 50^{\circ}\text{F)}$$

$$15^{\circ}\text{C} \times 2 = 30 + 25 = 55^{\circ}\text{F} \text{ (actual} = 59^{\circ}\text{F)}$$

$$20^{\circ}\text{C} \times 2 = 40 + 25 = 65^{\circ}\text{F} \text{ (actual} = 68^{\circ}\text{F)}$$

$$25^{\circ}\text{C} \times 2 = 50 + 25 = 75^{\circ}\text{F} \text{ (actual} = 77^{\circ}\text{F)}$$

$$30^{\circ}\text{C} \times 2 = 60 + 25 = 85^{\circ}\text{F} \text{ (actual} = 86^{\circ}\text{F)}$$

$$35^{\circ}\text{C} \times 2 = 70 + 25 = 95^{\circ}\text{F} \text{ (actual} = 95^{\circ}\text{F)}$$

$$40^{\circ}\text{C} \times 2 = 80 + 25 = 105^{\circ}\text{F} \text{ (actual} = 104^{\circ}\text{F)}$$

$$45^{\circ}\text{C} \times 2 = 90 + 25 = 115^{\circ}\text{F} \text{ (actual} = 113^{\circ}\text{F)}$$

$$50^{\circ}\text{C} \times 2 = 100 + 25 = 125^{\circ}\text{F} \text{ (actual} = 122^{\circ}\text{F)}$$

The simplest way to convert between the Fahrenheit and Celsius scales accurately is to use a conversion chart or use an app on a smart phone.

- A large amount of heat is released when a vapor changes state to a liquid.
- Compressing a gas concentrates the heat and increases the temperature.

HUMIDITY Humidity refers to water vapor present in the air. The level of humidity depends upon the amount of water vapor present and the temperature of the air. The amount of water vapor in the air tends to be higher near lakes or the ocean, because more water is available to evaporate from their surfaces. In desert areas with little open water, the amount of water vapor in the air tends to be low.

- **Absolute humidity** is the measure of the amount of moisture (water vapor) in the air regardless of the temperature.
- **Relative humidity (RH)** is the percentage of how much moisture is present in the air compared to how much moisture the air is capable of holding at that temperature.

Relative humidity is commonly measured with a *hygrometer* or a *psychrometer*. A hygrometer depends on a sensitive



FIGURE 1-6 A combination meter that measures and displays both the temperature and the humidity is useful to use when working on air-conditioning systems.

element that expands and contracts, based on the humidity. Hygrometers typically resemble a clock, with the scale reading from 0% to 100% relative humidity. ● **SEE FIGURE 1-6.**

HEATING AND COOLING LOAD

HEATING LOAD Heating load is the term used when additional heat is needed. The actual load is the number of BTUs or calories of heat energy that must be added. In a home or office, burning fuel is the usual way to generate heat using coal, gas, or oil as a fuel. In most vehicles, the heat is provided by the heated coolant from the engine cooling system. This coolant is typically at a temperature of 190°F to 205°F (88°C to 98°C) when the engine reaches its normal operating temperature. ● **SEE FIGURE 1-8.**

In most vehicles, heated coolant is circulated through a heat exchanger, called a **heater core**. Air is circulated through the heater core, where it absorbs heat. Then it is blown into the passenger compartment, where the heat travels on to warm the car interior and occupants. The air from the blower motor moves the heat from the heater core to the passengers.

COOLING WITH ICE One way to move heat, called **cooling load**, is with a block of ice. A substantial amount of



FREQUENTLY ASKED QUESTION

What Is a Sling Psychrometer?

A psychrometer is a measuring instrument used to measure relative humidity. It uses two thermometers, one of which has the bulb covered in a cotton wick soaked in distilled water from a built-in reservoir. The wick keeps the bulb of the “wet thermometer” wet so that it can be cooled by evaporation. Sling psychrometers are spun round in the air a certain number of times. Water evaporates from the cotton wick at a rate inversely proportional to the relative humidity of the air.

- Faster if the humidity is low.
- Slower if the humidity is high.

The “dry thermometer” measures the air temperature.

- The higher the relative humidity, the closer the readings of the two thermometers.
- The lower the humidity, the greater the difference in temperature of the two thermometers.

The different temperatures indicated by the wet and dry thermometers are compared to values given in a chart, which gives the relative humidity. While a sling psychrometer is still used, most technicians use an electronic instrument to measure relative humidity. ● **SEE FIGURE 1-7.**

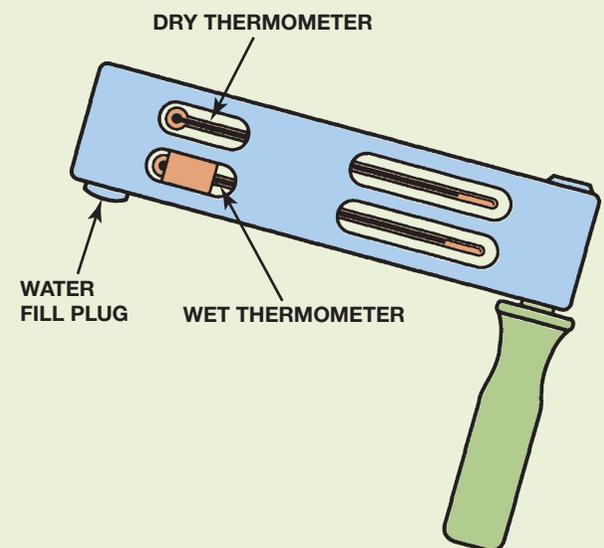


FIGURE 1-7 A sling psychrometer is used to measure relative humidity.

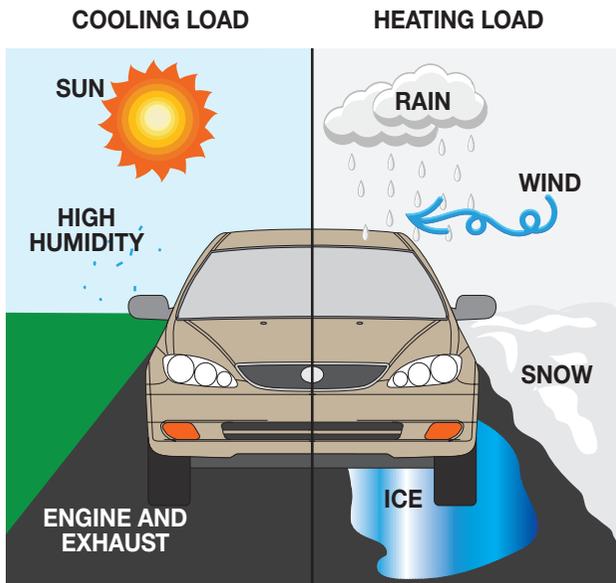


FIGURE 1-8 Winter presents a heat load where heat must be added for comfort (right). Summer presents a cooling load.

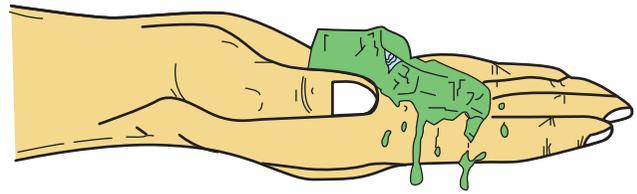


FIGURE 1-9 Ice has a cooling effect because of latent heat of fusion which means that it absorbs heat as it melts.



FIGURE 1-10 At one time, evaporative coolers were used to cool car interiors. Air forced through a water-wetted mesh produces evaporation and a cooling effect.

latent heat is required to change the state of the solid ice into a liquid:

- 144 BTU per lb. (80 calories per gram).
- A 50-lb. block of ice represents 50×144 , or 7,200 BTU, of cooling power when it changes from 50 lb. of solid at 32°F to 50 lb. of liquid at 32°F.

In the early days of air conditioning, the term *ton* was commonly used. A ton of air conditioning was the amount of heat it took to melt a ton of ice: $2,000 \times 144$, or 288,000 BTU.

● **SEE FIGURE 1-9.**

EVAPORATIVE COOLING A method of cooling that works well in areas of low humidity is evaporation of water, commonly called **evaporative cooling**. If water is spread thinly over the extremely large area of a meshed cooler pad and air is blown across it, the water evaporates. For every pound of water that evaporates, 970 BTU (540 calories per gram) of heat is absorbed. This is the latent heat of evaporation, just as when it is boiled. This is a natural process and uses only the energy required by the blower to circulate the air through the cooler pads and on to the space to be

cooled. Disadvantages of evaporative coolers, often called “swamp coolers” includes:

- increases the relative humidity
- not effective in areas of high humidity because the water does not evaporate rapidly enough to be efficient.

At one time, window-mounted evaporative coolers were used in cars. They were not very popular because they were unattractive and worked well only in dry areas. ● **SEE FIGURE 1-10.**

MECHANICAL COOLING A third way to handle a cooling load is by the use of **mechanical refrigeration**, which is called air conditioning. This system also uses evaporation of a liquid and the large amount of heat required for evaporation. The refrigerant boils so that it changes from liquid to gas, but it is condensed back to gas using an engine or electrically powered compressor to move the refrigerant and to increase its pressure in the system. ● **SEE FIGURE 1-11.**

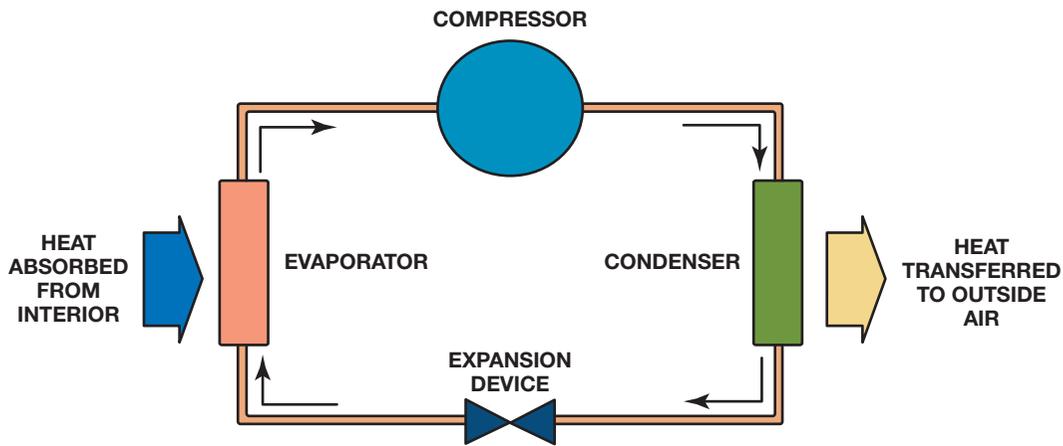


FIGURE 1-11 Heat, from in-vehicle cabin air, causes the refrigerant to boil in the evaporator (left). The compressor increases the pressure and moves refrigerant vapor to the condenser, where the heat is transferred to ambient air. This also causes the vapor to return to liquid form.

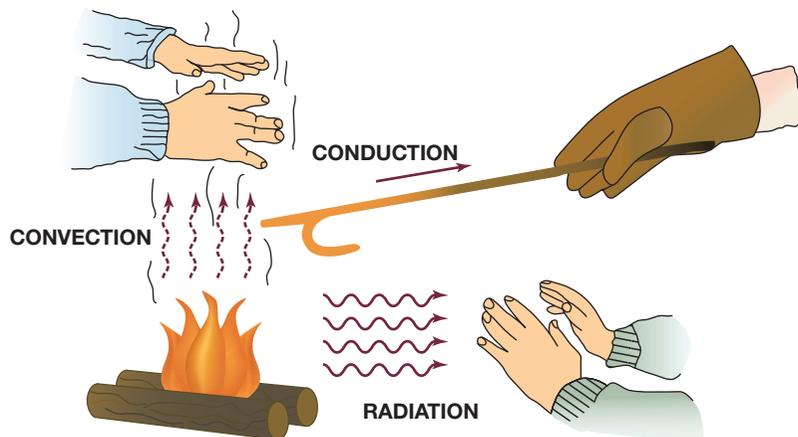


FIGURE 1-12 Heat can be moved from the source by convection, conduction, or radiation.

HEAT MOVEMENT

Heat can travel through one or more of three paths as it moves from hot to cold:

1. conduction
2. convection
3. radiation ● SEE FIGURE 1-12.

CONDUCTION The simplest heat movement method is conduction, by which heat travels through a medium such as a solid or liquid, moving from one molecule of the material to the next. For example, if one end of wire is heated, the heat will travel through the material itself and will be transferred through to the other end of the wire. Some materials (most of the metals) are good heat conductors. Copper and aluminum are among the best of the commonly used metals, so most

heat exchangers (radiators, evaporators, and condensers) use copper or aluminum.

- Some materials, such as wood, are poor heat conductors.
- Some materials, such as Styrofoam, conduct heat so poorly that they are called insulators. Most good insulators incorporate a lot of air or gaseous material in their structure because air is a poor conductor of heat.

CONVECTION Convection is a process of transferring heat by moving the heated medium, usually air or a liquid. An example of convection is the engine cooling system. Coolant is heated in the water jackets next to the cylinders and combustion chambers. Then the coolant is pumped to the radiator, where the heat is transferred to the air traveling through the radiator. Convection also occurs in the interior of the vehicle when air is circulated past the driver and passengers

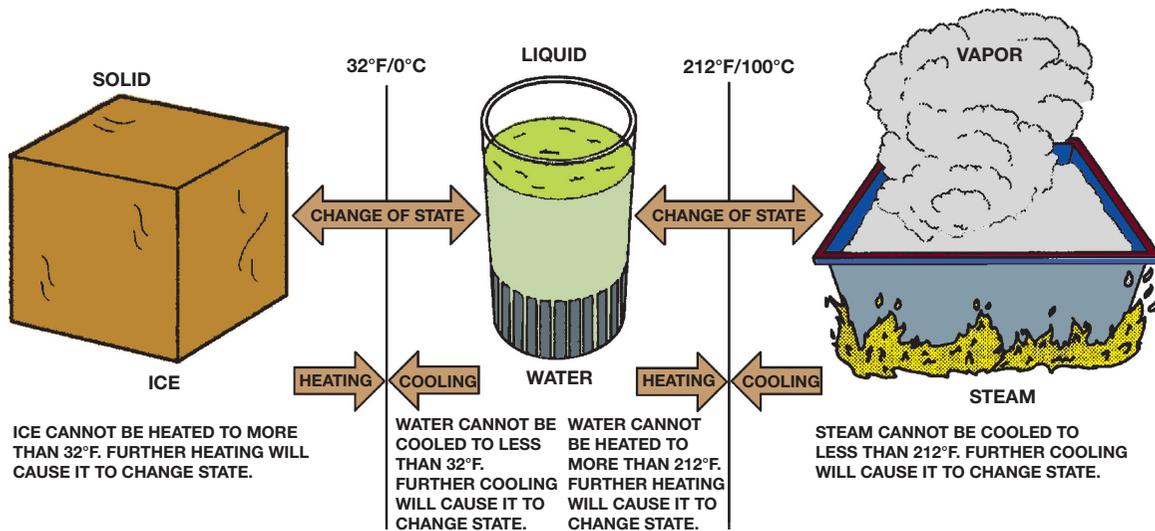


FIGURE 1-13 Matter can change state by adding or removing heat.

to pick up heat and moved to the evaporator, where the heat is transferred to the evaporator fins. The evaporator fins are cooler, so heat is transferred easily.

RADIATION Heat can travel through heat rays and pass from one location to another without warming the air through which it passes. The best example of this is the heat from the sun, which passes through cold space and warms our planet and everything it shines on. Radiant heat can pass from any warmer object through air to any cooler object. It is affected by the color and texture of the heat emitter, where the heat leaves, and the collector, where the heat is absorbed. Dark, rough surfaces make better heat emitters and collectors than light-colored, smooth surfaces.

NOTE: At one time, California Highway Patrol cars were painted all black. Painting the tops white benefited the patrol officers by lowering the in-vehicle temperature significantly.

are in turn made up of electrons, neutrons, and protons. The protons are in the center, or nucleus, of the atom and the electrons travel in an orbit around them. There are about 100 basic elements or atoms, each having a different atomic number, that combine with other elements to make the many, varied molecules. The atomic number of an element is based on the number of electrons and protons in that element. The periodic table of elements seen in most chemistry laboratories shows the relationship of these elements.

Water molecules, for example, are called H₂O. This is a combination of a single oxygen atom and two hydrogen atoms. Hydrogen has an atomic number of 1 (1 proton and 1 electron), and oxygen has an atomic number of 8 (8 electrons and 8 protons). ● **SEE FIGURE 1-14.** The three states of water are well known and include:

1. Solid ice
2. Liquid water
3. Vapor (gaseous)

SOLID Solid matter has a definite shape and substance. Solids exert pressure in only one direction, and that is downward because of gravity. For example, ice is the solid form of water, and will hold its shape, and is cold. Water is normally a solid at temperatures below 32°F (0°C), which is the normal freezing point. The electrons in the molecule's atoms are still orbiting around the protons, but the movement has been slowed because much of the heat energy has been removed. ● **SEE FIGURE 1-15.**

LIQUID Adding heat to most solids causes them to reach their melting point. It is the same material, but heat energy has broken the molecular bond and the matter becomes fluid. Fluid

AIR-CONDITIONING PROCESS

CHANGING THE STATE OF THE REFRIGERANT The air-conditioning process works using a fluid, called *refrigerant*, which continuously changes state from liquid to gas and back to liquid.

Most states of matter can be changed from one state to another by adding or removing heat. ● **SEE FIGURE 1-13.**

Molecules are the building blocks for all things that can be seen or felt. Molecules are combinations of atoms, which

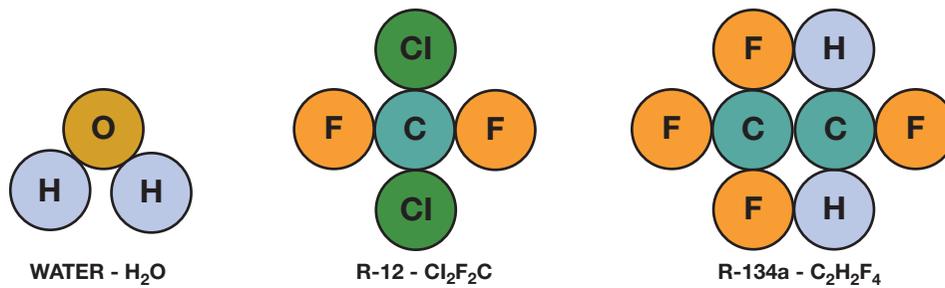
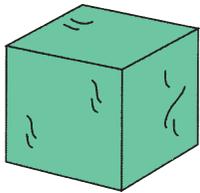


FIGURE 1-14 A water molecule contains two oxygen atoms and one hydrogen atom. R-12 is a combination of one carbon, two chlorine, and two fluorine atoms. R-134a is a combination of two carbon, four fluorine, and two hydrogen atoms.



ICE

SOLID:
H₂O AT TEMPERATURES BELOW 32°F, 0°C:
SOLID, HAS DEFINITE SHAPE
EXERTS PRESSURE DOWNWARD

FIGURE 1-15 Ice is a solid form of water with a low temperature and slow molecular action.



WATER

LIQUID:
H₂O AT TEMPERATURES BETWEEN 32° AND
212°F (0° AND 100°C):
LIQUID/FLUID, TAKES SHAPE OF CONTAINER
EXERTS PRESSURE DOWNWARD AND TO SIDES

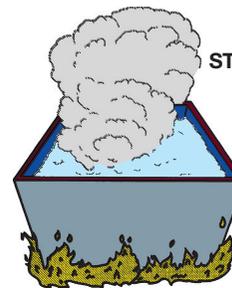
FIGURE 1-16 Water is warmer than ice and can flow to take the shape of any container.

has no shape and it takes the shape of its container. Liquids can flow through a pipe or hose and can be pumped such as by the air-conditioning compressor.

Water is normally a liquid between 32°F and 212°F (0°C and 100°C). The molecules are the same as ice, but heat energy has increased the movement of the electrons. ● **SEE FIGURE 1-16.**

GAS When heat is added to most liquids, it produces gas as the liquids boil. It is the same material, but the heat energy has broken the molecular bonds still further so that the molecules have no shape at all and have expanded so much that they have very little weight. A gas molecule exerts pressure in every direction. Gases can also be pumped through hoses and pipes, making them easy to move through the air-conditioning (A/C) system.

At temperatures above 212°F (100°C), water normally boils to become a gas, called *steam*. Again, the molecules are the same as water or ice, but heat energy has greatly increased molecular movement. ● **SEE FIGURE 1-17.**



STEAM

GAS:
H₂O AT TEMPERATURES ABOVE 212°F,
100°C: GAS HAS NO SHAPE
CAN EXERT PRESSURE IN ALL
DIRECTIONS

FIGURE 1-17 Adding heat to water produces steam, the gas state, with a much freer molecular action.

vehicle by moving the heat from inside the vehicle to outside the vehicle. The internal body temperature of humans is about 98.6°F (37°C), which seems odd when our most comfortable temperature is 68°F to 78°F (20°C to 26°C). This means that in the summer heat must be continually given off to be comfortable, but in the winter suitable clothing is needed to maintain warmth. Body comfort is also affected by radiant heat. In the winter, the sun warms the body.

The velocity of air past our bodies is another factor in human comfort. Air movement is an important part of heating and air-conditioning systems.

CONTROL OF HUMIDITY Humid cold air feels much colder than dry air at the same temperature.

PURPOSE OF AN HVAC SYSTEM

CONTROL OF TEMPERATURE The goal in heating and air conditioning is to maintain a comfortable in-vehicle temperature and humidity. An air-conditioning system cools the interior of the

- Humid hot air slows down our natural body cooling system (evaporation of perspiration), so it can make a day feel much hotter.
- Air that is too dry also tends to make people feel uncomfortable.
- As with temperature, a range of humidity that most people feel comfortable in a relative humidity of about 45% to 55%.

As the air-conditioning system operates, it dehumidifies (removes moisture) from the air. Water vapor condenses on the cold evaporator fins just as it would on a glass holding a cold drink. This condensed water then drops off the evaporator and runs out the drain at the bottom of the evaporator case. In-vehicle humidity is reduced to about 40% to 45% on even the most humid days if the A/C is operated long enough. A good example of this dehumidification process occurs when a vehicle's A/C is operated on cold days when the windows are fogged up. It usually takes only a short time to dry the air and remove the fog from the windows. ● **SEE FIGURE 1-18.**

CLEANLINESS A side effect of air conditioning is the cleaning of the air coming into the vehicle as it passes through the cooling ductwork. The act of cooling and dehumidifying air at the A/C evaporator causes water droplets to form on

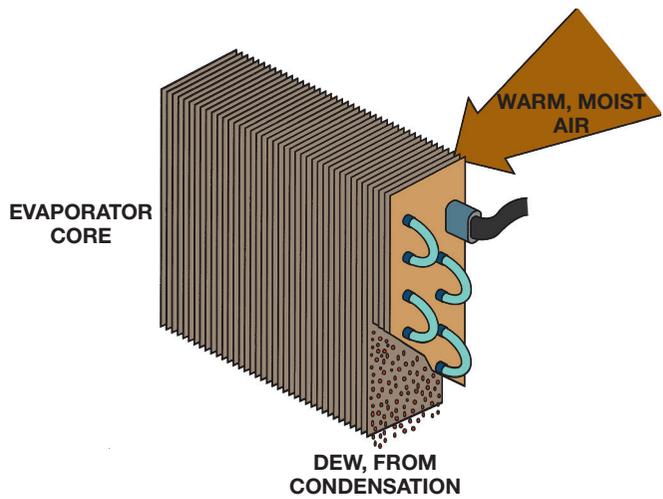


FIGURE 1-18 When air comes into contact with the cold evaporator, excess moisture forms dew. This condensed moisture leaves the car through the evaporator drain.

the evaporator fins. Dust and other contaminants in the air that come into contact with these droplets become trapped and are flushed out of the system as the water drops drain from the evaporator. Most recent vehicles use a **cabin filter** in the A/C and heating systems to clean the air by trapping dust and pollen particles before they enter the passenger compartment.

SUMMARY

1. Heat is moved into or out of the passenger compartment to obtain a good comfort level.
2. Heat intensity is measured using the Fahrenheit or Celsius scales, and heat quantity is measured using calories and BTU.
3. The comfort zone of most humans is between 68°F and 78°F (20°C and 26°C) and 45% to 50% humidity.
4. A/C systems reduce humidity by removing moisture (water) from the air.
5. HVAC systems clean air because particles are caught by moisture on the evaporator and by filters.

REVIEW QUESTIONS

1. Is it possible for heat to be added to water without causing the temperature to increase?
2. What are the three states of matter?
3. What is the difference between heat and temperature?
4. How is relative humidity measured?
5. How does heat move?

CHAPTER QUIZ

- The three different phases or states of matter include _____.
 - Solid, water, and steam
 - Ice, liquid, and gas
 - Solid, liquid, and gas
 - Liquid, water, and steam
- An air-conditioning system cools the interior of the vehicle by _____.
 - Moving the heat from inside the vehicle to outside the vehicle
 - Blowing cold air into the interior
 - Moving heat from inside of the vehicle to the engine cooling system
 - Using the engine to move air
- Twenty degrees Celsius is about how many degrees Fahrenheit?
 - 25
 - 45
 - 65
 - 85
- Heat intensity is measured in _____.
 - BTUs
 - Degrees
 - RH
 - Calories
- A psychrometer measures _____.
 - Temperature
 - Relative humidity
 - Amount of heat
 - Radiation
- A BTU is a measure of _____.
 - Temperature
 - Relative humidity
 - Amount of heat
 - Radiation
- Heat transferred through the air is called _____.
 - Radiation
 - Insulation
 - Convection
 - Conduction
- Air-conditioning process works through a fluid, called a _____ that continuously changes state from liquid to gas and back to liquid.
 - Element
 - Conductor
 - Insulator
 - Refrigerant
- Humans prefer temperatures that are between _____ and _____.
 - 55°F; 65°F
 - 60°F; 70°F
 - 68°F; 78°F
 - 76°F; 86°F
- Humans prefer relative humidity that is between _____ and _____.
 - 10%; 20%
 - 20%; 30%
 - 30%; 40%
 - 45%; 55%