AUTOMOTIVE AIR CONDITIONING

7th Edition

Boyce H. Dwiggins

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PREFACE

Automotive Air-Conditioning, 7th edition, continues in the best-selling tradition established in 1967 by the first edition. The most up-to-date automotive air-conditioning technology has been included: electronic temperature controls, new domestic and foreign compressors, and cycling clutch and variable displacement orifice tube systems.

The information given in this text is a balanced introduction to automotive air-conditioning. The student will develop a basic understanding of the theory, diagnostic practices, and service procedures essential to automotive air-conditioning. At the same time, the student will develop habits of sound practice and good judgment in the performance of all automotive air-conditioning diagnostic and repair procedures. The instructional units can be regarded as entry level for those who immediately apply the basic skills developed in the class and shop. The units are preparatory for those who plan to continue studies in advanced phases of refrigeration and air-conditioning, including systems not related to automotive applications. The text contains three basic sections. Section 1 is arranged in the natural order of dependence of one principle, law, or set of conditions upon another. The material within a unit follows an organized pattern that helps the student to see relationships. Section 2 guides the student in the performance of system diagnostic procedures. This is accomplished by stressing diagnosis through the use of a manifold and gauge set. Fifteen color plates are included for interpretation of various system functions and malfunctions. Section 3 presents step-by-step instructions for the application of specific service procedures. A Glossary is provided to aid in identifying component parts and phrases relevant to automotive air-conditioning.

It is suggested that each topic in this text be considered as an assignment to be carried out by the student.

An Instructor's Guide provides solutions to all of the objective questions and problems. Suggested answers are given wherever there may be variations in the responses given by the students. Lesson plans are provided for each unit of the text.

ABOUT THE AUTHOR

Over thirty years ago, Boyce H. Dwiggins organized one of the first courses for vocational education for Automotive Air Conditioning. This course has run continuously since 1965. He was in charge of automotive classes as a county-level administrator and was a consultant for the writing of educational specifications for a five-shop automotive complex in an area vocational center.

Mr. Dwiggins has served as an examiner, administering the "Automotive Excellence" test for the International Garage Owner's Association (IGOA) for the certification of auto mechanics. He has served on the automotive air-conditioning writing committee of the National Institute for Automotive Service Excellence (ASE) to revise the certification test for automotive air-conditioning. ASE's Blue Seal of Excellence was awarded for his efforts in 1994.

Mr. Dwiggins holds patents on teaching devices and copyrights on teaching material in the automotive and refrigeration fields. He has conducted workshops for automotive and refrigeration teachers throughout the eastern United States. Until his retirement in 1994, he was chairperson of the industrial department of a large vocational-technical center in South Florida.

This text would not have been possible without the generous cooperation of many manufacturers of automotive air-conditioning equipment and components. Their contributions, for over twenty-five years since the first edition, have been most helpful in providing the latest information available. They include:

Chrysler Motors Corporation
Controls Company of America
Everhot Products Company
Ford Motor Company
General Electric Company
General Motors Corporation: Buick Motor Division,
Cadillac Motor Car Division, Chevrolet Motor
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Mapco
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Robinair Manufacturing Company
Sankyo
Sears, Roebuck and Company
Tecumseh Products Company
Thermal Industries
T.I.F. Instruments
Uniweld Products

A special thanks to the instructors who reviewed the revised manuscript for this seventh edition. A very special thanks to the memory of Mr. Richard G. Herd, former associate, Vocational-Industrial Education, State of New York, for his initial assistance and encouragement. Last, but by no means least, thanks to the great team at Delmar Publishers for steering this text through all seven editions.

. . . and, to Edward and Judith, this book is dedicated.

B. H. Dwiggins

CONTENTS

SECTION 1 BASIC THEORY

SECTION 2 SYSTEM DIAGNOSIS

SECTION 3 SERVICE PROCEDURES

SECTION 1:

BASIC THEORY

UNIT 1: Introduction

Refrigeration and air-conditioning are not twentieth-century discoveries. Simple forms of refrigeration and air-conditioning were in use more than twelve thousand years ago. Although these early systems were crude by today's standards, they served the same purpose as modern units.

Many aspects of modern life became possible only after sophisticated air-conditioning systems were developed. Some components vital to the National Aeronautics and Space Administration (NASA) space exploration programs could not have been manufactured without the use of air-conditioning. For example, many precision mechanical and electrical parts must be manufactured and assembled under very strict tolerances. These tolerances require that temperature and humidity be controlled within a range of a few degrees. For example, this microprocessor chip shown in figure 1-1, only about 1/16 inch (1.59 mm) square, is a miniaturized electronic circuit etched into a base of silicon. It was manufactured in a temperature- and humidity-controlled environment made possible by modern refrigeration techniques.

Automotive air-conditioning was available in 1940, but it did not become popular until about 1960. Since that time, interest in automotive air-conditioning has continued to increase. Air-conditioning is now one of the most popular automotive accessories.

In 1962, slightly more than 11% of all cars sold were equipped with air-conditioners. This accounted for 756,781 units, including both factory-installed systems and those added after the purchase of the automobile, referred to as "aftermarket." Just five years later, in 1967, the total number of installed air-conditioning units rose to 3,546,255. At the present time, nearly 90% of all automobiles sold in the United States are equipped with air-conditioning units. Sales of these units are expected to remain at approximately 90%. This means that 90 out of every 100 cars on the road will be equipped with a factory- or dealer-installed air-conditioning system. Air-conditioning, in trucks, how-

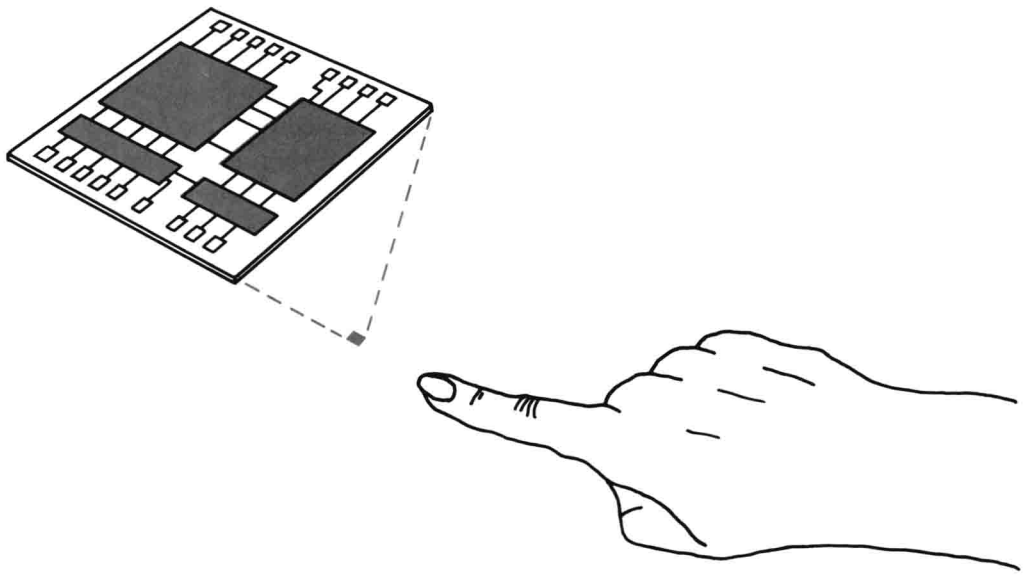

Fig. 1-1 This microprocessor, only about 1/16-inch (1.59 mm) square is a miniaturized electronic circuit etched into a base of silicon. It was manufactured in a temperature- and humidity-controlled environment made possible by modern refrigeration techniques.

ever, did not become popular until around 1970. Percentages of factory- and dealer-installed truck systems are rising at about the same rate as for cars. In Europe, the popularity of mobile air-conditioning is now at about the level it was at in the late 1970s in the United States and is expected to increase at about the same rate as it has in the United States. Mobile air-conditioning was first introduced as a luxury. Its usefulness, however, soon made it a necessity.

Air-conditioning, by definition, is the process by which air is cooled or heated, cleaned or filtered, and circulated or recirculated. The quantity and quality of the conditioned air is also controlled. This means that the temperature, humidity, and volume of air can be controlled at any time in any given situation. Under ideal conditions, air-conditioning can be expected to accomplish all of these tasks at the same time. The learner should recognize that the air-conditioning process includes the process of refrigeration (cooling by removing heat).

HISTORICAL DEVELOPMENT OF AIR-CONDITIONING

Refrigeration as we know it today, is just over ninety years old. Some of its principles, however, were known as long as ten thousand years before Christ (B.C.). For Example, the Egyptians developed a method for removing the heat from the Pharaoh's palace. The walls of the palace, weighing over a thousand tons, were constructed of huge stone blocks. Every night, three thousand slaves dismantled the walls and moved the heavy stones to the Sahara Desert. Since the temperature in the desert is cool during the night, the stones gave up the heat they had absorbed during the day. Before daybreak, the slaves would move the stones back to the site and reassemble the walls, as shown in figure 1-2.

As a result of this crude form of refrigeration, it is believed that the Pharaoh enjoyed temperatures of about 80°F (26.6°C) inside the palace while the temperature outside soared to about 130°F (54.4°C). Modern refrigeration easily handles a job that once took three thousand men working all night. Less work effort is required today, but both systems apply the same principle of refrigeration. That is, heat is removed from one space and is transferred to another space.

Shortly after the beginning of the twentieth century, T. C. Northcott of Luray, Virginia, became the first man in history to have a home with central heating and air-conditioning. Northcott, who was a heating and ventilating engineer, built his house on a hill above the famous Caverns of Luray. He knew that air filtered through limestone was free of dust and pollen. This fact was important because both Northcott and his family suffered from hay fever.

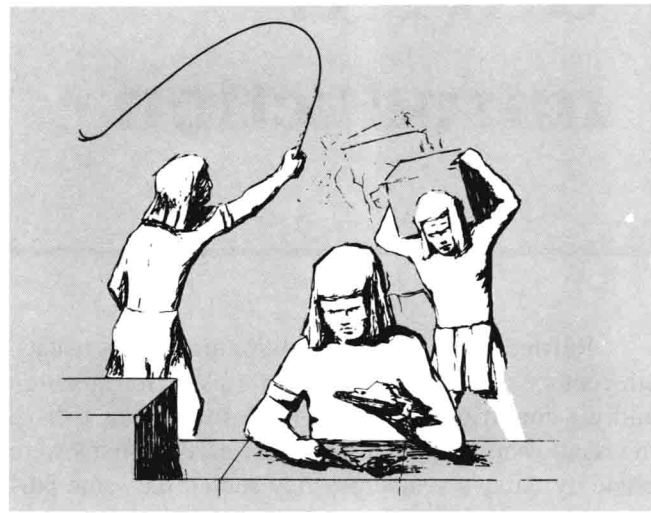

Fig. 1-2 Moving stones of Paroah's palace back in place

Northcott drilled a 5-foot (1.5 m) shaft through the ceiling of the cavern some distance behind his house. He installed a 42-inch (1.07 m) fan in the shaft to pull 8,000 cubic feet (2,265 m^3) of air per minute through the shaft. He then constructed a shed over the shaft and a duct system to the house. The duct was divided into two chambers, one above the other. The upper chamber carried air from the cavern and was heated by the sun. It provided air to warm the house on cool days. The lower chamber carried cool air from the cavern which was used to cool the house on warm days.

The humidity (moisture content) of the air from the cavern was controlled in a chamber in Northcott's basement where air from both ducts was mixed. Warm air contains a greater amount of moisture than cool air. Northcott was able to direct conditioned air from the mixing chamber of the air system to any or all of the rooms in his house through a network of smaller ducts. During the winter season, auxiliary heat was provided by steam coils located in the base of each of the branch ducts.

Each year more than 350,000 people visit the Caverns of Luray, where the temperature is a constant 54°F (12.22°C) and the air is always free of dust and pollen. Visitors are impressed by Northcott's ingenuity in providing central heating and air-conditioning long before these conveniences were widely available.

Domestic Refrigeration

Domestic refrigeration systems did not appear until 1910, even though ice has been made artificially since 1820. In 1896, the Sears, Roebuck and Company catalog offered the *refrigerators* pictured in figure 1-3. The refrigeration, however, was provided by ice. The first ice box shown in figure 1-3 held 25 pounds of ice and was useful only for short-term food storage. Incidentally, the selling price was $5.65.

The first manually operated refrigerator was produced by J. L. Larsen in 1913. The Kelvinator Company produced the first automatic refrigerator in 1918. The acceptance of this new refrigerator was slow. By 1920,

Fig. 1-3 The early refrigerator was actually an icebox (1896). ***Courtesy of Sears Roebuck and Co.***

only about two hundred units had been sold.

In 1926, the first hermetic (sealed) refrigerator was introduced by General Electric. The following year, Electrolux introduced an automatic absorption unit. A 4-cubic-foot refrigerator was introduced by Sears, Roebuck and Company in 1931. The refrigerator cabinet, shown in figure 1-4, and the refrigeration unit were shipped separately and required assembly. This unit cost $137.50. In terms of the cost per cubic foot, the 1931 refrigerator is comparable to today's models.

Mobile Air-Conditioning

The first automotive air-conditioning unit appeared on the market in 1927. True air-conditioning did not appear in cars for another thirteen years. However, air-conditioning was advertised as an option in some cars in 1927. At that time, air-conditioning meant the car could be equipped with a heater, a ventilation system, and a means of filtering the air. In 1938, Nash introduced "air-conditioning" heating and ventilation. Fresh outside air was heated, filtered, and then circulated around inside the car by a fan.

By 1940, heaters and defrosters were standard equipment on many models. That same year Packard offered the first method of cooling a car by means of refrigeration. Actually, these first units were commercial air-conditioners, usually located in the trunk, adapted for automotive use. A few passenger buses had been air-conditioned by the same method in 1938.

Accurate records were not kept in the early days of automotive air-conditioning. However, it is known that before World War II between three thousand and four thousand units were installed in Packards. Defense priorities for materials and manufacturing prevented the improvement of automotive air-conditioning until the early 1950s. At that time, there was a demand for air-conditioned vehicles in the Southwest.

The first of today's modern automotive air-conditioning systems was introduced by Cadillac in 1960. Cadillac's two-level system could cool the top level while heating the lower level of the car. This provided a method of controlling humidity.

Air-conditioning has had a positive affect on businesses too. Many large firms have reported increased sales revenue after air-conditioning was installed in the cars driven by their salespeople. Most commercial passenger-carrying vehicles are now air-conditioned, which makes riding in them more comfortable. Truck lines have increased their profits because drivers with air-conditioned cabs average more mileage than those who do not.

Fig. 1-4 Early refrigerator (1931). *Courtesy of Sears, Roebuck and Co.*

In 1967, Florida Turnpike state police cars were air-conditioned. Since then, most U.S. law enforcement agencies across the nation have added air-conditioning to their vehicles.

Mobile air-conditioning is not only found in cars, trucks, and buses. In recent years, mobile air-conditioning application has been installed in farm equipment such as tractors, harvesters, and thrashers. In addition, systems have been developed for use in other off-the-road equipment, such as backhoes, bulldozers, and graders. Actually, mobile air-conditioning may be found in almost any kind of domestic, farm, or commercial equipment with an enclosed cab and an onboard operator.

Yesterday and Today

Thus, although air-conditioning and refrigeration systems were in use thousands of years ago, the refrigeration industry did not experience rapid growth until the latter twentieth century.

Modern technology has been aided by air-conditioning systems. Submarines are able to remain submerged indefinitely due, in part, to air-conditioning. Modern medicine and delicate machine components are perfected in scientifically controlled atmospheres. Computer centers are able to function properly because they are maintained within a specific range of temperature and humidity levels.

THE INDUSTRY

Automobile air-conditioning today is no longer a luxury; it has become a necessity. Millions enjoy its benefits. Businesspeople are able to drive to appointments in comfort and arrive fresh and alert. People with allergies are able to travel without suffering from the effects of excessive dust, airborne pollen, and pollution. Automobile air-conditioning also plays an important role in promoting the comfort, health, and safety of travelers throughout the world. Today over 90% of all cars produced in the United States are equipped with air-conditioners.

The number of cars, trucks, and recreational vehicles (RVs) equipped with air-conditioning systems has increased rapidly during the past thirty or so years. Although that number is expected to level off in the United States, it is still rapidly growing in Europe and Asia.

It is easy to understand how automotive air-conditioning has become the industry's most sought-after product. In the South and Southwest, many specialty auto repair shops base their year-round trade on selling, installing, and servicing automotive air-conditioners.

COST OF OPERATION

Many people believed that the ever-increasing cost of fossil fuel would put an early end to the luxury of automotive air-conditioning. After all, the air-conditioning system does place an extra load on the engine. Because any engine load requires fuel it seems that the use of an air-conditioner would reduce gasoline mileage. This is true, but only for stop-and-go driving. At highway speeds, cars with their windows closed and the air-conditioning operating actually average 2% to 3% better mileage than do cars with their windows down. The aerodynamic design considerations of the car body are based on having the windows closed. So it seems that reduced wind resistance offsets the demand load of the air-conditioning system on the engine.

For example, as EXXON published in its *Happy Motoring News*® (Vol. 19), "At 40 miles per hour (mph), or faster, you'll use more gasoline by driving with your windows open than you will by operating an air-conditioner with all the windows closed. Open windows cause that much 'drag.'"

The number of annual new car sales has decreased slightly in recent years. However, the number of new cars sold with air-conditioning systems has increased by about the same percentage. Moreover, aftermarket sales, service, and repairs on automotive air-conditioners have increased. Car owners are therefore keeping their cars longer and in better repair.

THE AUTOMOBILE AND THE ENVIRONMENT

In recent years, concerns for the environment have resulted in some strict federal regulations relating to the automobile heating and cooling system. One concern important to the automotive air-conditioning technician is the depletion of the Ozone (O_3). There is significant evidence that Ozone (O_3) depletion is partially brought on by the release of certain man-made chemicals into the atmosphere. Unfortunately, it has been determined that the biggest offender is a group of chemicals known as CFCs.

Chlorofluorocarbons (CFCs), are a family of "Group I" refrigerant chemicals. These chemicals contain a mixture of chlorine (Cl), fluorine (F), and carbon (C). One CFC, dichlorodifluoromethane (Refrigerant-12), has always (with a few exceptions in the early days) been used as the refrigerant for automotive air-conditioning.

Unfortunately, the biggest offender by far is Refrigerant-12 (R-12). Worldwide use of R-12 for automotive applications is on the order of 20%. In the United States, however, over 34% of R-12 consumption has been for automotive use. Accordingly, the automotive air-conditioning industry was first to be regulated. Florida was among the first states to enact a state law. Many other states are now following Florida's example.

Florida Law

Florida's Department of Environmental Regulations (DER) law simply states that "this law was promulgated to prevent the release of motor vehicle air-conditioning refrigerants through the use of approved refrigerant recycling equipment and the proper training of personnel in the use of such equipment." The law is based on sections of the Federal Clean Air Act (CAA) amendments of 1990, Section 609, which specifically address servicing of motor vehicles. It is unlawful for anyone to intentionally release CFCs into the atmosphere, as outlined in Section 608, which addresses, in general, the heating,

air-conditioning, refrigeration, and ventilation (HARV) industry. The following is an excerpt from that section:

> **Federal Clean Air Act**
> Section 608 (c) PROHIBITIONS. — (1)
> Effective July 1, 1992, it shall be unlawful for any person, in the course of maintaining, servicing, repairing, or disposing of any appliance or industrial process refrigeration, to knowingly vent or otherwise knowingly release or dispose of any class I or class II substance used as a refrigerant in such appliance (or industrial process refrigeration) in a manner which permits such substance to enter the environment.

A New Refrigerant

Virgin Refrigerant-12 will no longer be available to any but the medical industry. The industry will have to rely on recovered and recycled R-12 or to retrofit present systems in order to use a new refrigerant.

The new refrigerant, Refrigerant-134a (R-134a), is in an environmentally friendly group known as HFCs. The halofluorocarbon (HFC) group of refrigerants contains hydrogen (H), fluorine (F), and carbon (C). This group does not contain chlorine (Cl).

Several refrigerants have been suggested as "drop in" replacements for R-12. R-134a is not a drop-in substitute for R-12, but it is the only suitable replacement recommended by the automotive industry. Certain system modifications must be made, however. Although there are those who claim to have a direct replacement refrigerant, all automobile manufacturers warn that these alternate refrigerants are not approved for automotive use.

THE SERVICE TECHNICIAN

How does all this affect the student of automotive air-conditioning? As the popularity of vehicle air-conditioning increases, it is obvious that the need for installation, maintenance, and service technicians will also increase. Many shops that initially added air-conditioning service as a sideline now find it to be their primary business.

The air-conditioning technician must have a thorough working knowledge and understanding of the operation and function of the mechanical and electrical circuits and controls of the automotive air-conditioner. A good knowledge of the equipment, special tools, techniques, and skills of the trade is also essential.

Federal and state laws now mandate that automotive air-conditioning systems be serviced in licensed shops by certified technicians. Class I refrigerants can no longer be purchased over-the-counter in "pound" cans. This means that the do-it-yourselfer can no longer service automotive air-conditioning systems.

Air-conditioning has helped us realize the Space Age in the twentieth century. What was a dream at the turn of the nineteenth century is commonplace today. The service technician's contribution to the industry may help turn today's dreams into reality in the twenty-first century.

SAFETY

Procedures used by the technicians performing automotive service vary greatly. It is not possible to anticipate all ways or conditions under which service may be performed. Therefore, it is not possible to provide precautions for every conceivable hazard. For example, air bags may be inadvertently inflated while working on the air duct system under the dash if specific precautions are not taken by the technician. Always consult the manufacturer's reference and repair manuals before attempting a specific repair. The following basic precautions apply to any type of automotive service and are not intended to supersede any instructions or precautions given by the manufacturer for any procedure:

1. Wear safety glasses or goggles for eye protection.
2. Set the parking brake. Place the gear select in *park* if automatic transmission (*neutral* if manual transmission).
3. Be sure the ignition switch is in the OFF position, unless otherwise required for the procedure.
4. When required for the procedure, operate the engine only in a well-ventilated area.
5. Keep clear of all moving parts when the engine is running.
6. Remove rings, watches, and loose-hanging jewelry.
7. Avoid loose clothing.
8. Tie long hair securely behind the head.
9. Keep hands, clothing, tools, and test leads away from the radiator cooling fan. Electric cooling fans can start without warning even when the ignition switch is in the OFF position.
10. Avoid contact with hot parts such as radiator, exhaust manifold, and high-side refrigeration lines.

11. Follow procedures outlined in manufacturer's service manuals when disconnecting the battery. Sensitive computer circuits may be interrupted if specific procedures are not followed.
12. When in doubt, ask your instructor. Do not take chances.

Review

Select the appropriate answer from the choices given.

1. How did moving the stones of Pharaoh's palace into the desert help to keep the palace cool?
   a. The palace was given a chance to air out.
   b. The stones gave up heat during the day.
   c. The stones gave up heat during the night.
   d. The stones could be easily rotated for reassembly.

2. The first advertised air conditioning for a car was:
   a. in 1940, by Packard.
   b. in 1927, consisting of a heater, a ventilation system, and a filter.
   c. in 1926, by General Electric.
   d. after the war, in the 1950s.

3. What is the greatest technical accomplishment that was made possible, at least in part, by air conditioning?
   a. The space program
   b. Modern medicine
   c. Computer electronics
   d. All of the choices are perhaps equally as great.

4. What percent of the total domestic car production will be equipped with air conditioning this year?
   a. About 80%
   b. Between 70% and 80%
   c. 70%, or less
   d. 90%, or more

5. Generally, at a speed of 40 mph or faster, less fuel will be used with the air conditioner:
   a. off and the windows open.
   b. on and the windows closed.
   c. off and the windows closed.
   d. on and the windows open.

6. What underhood part(s) becomes hot when the engine is running?
   a. Radiator
   b. Exhaust manifold
   c. Radiator hoses
   d. All of the answers are correct.

7. Technician A says when disconnecting the battery it is necessary to disconnect the ground (negative) cable. Technician B says to consult the manufacturer's manual first. Who is correct?
   a. Technician A is correct.
   b. Technician B is correct.
   c. Both technicians are correct.
   d. Both technicians are wrong.

8. When working under the hood of a car:
   a. securely tie back long hair.
   b. avoid loose clothing.
   c. remove jewelry.
   d. All of the answers are correct.

9. Before working under a hood of a car:
   a. set the parking brake.
   b. place the automatic transmission in neutral.
   c. chock the rear wheels.
   d. All the answers are correct.

10. Technician A says that the greatest underhood hazard is the belts. Technician B says the greatest underhood hazard is fans and fan blades. Who is correct?
    a. Technician A
    b. Technician B
    c. Both technicians are correct.
    d. Neither technician is correct.