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AUTOMOTIVE HEATING & AIR CONDITIONING

7

Classroom Manual

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Mark Schnubel

TODAY'S TECHNICIAN™

CLASSROOM MANUAL

For Automotive Heating & Air Conditioning

SEVENTH EDITION

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For Automotive Heating & Air Conditioning

SEVENTH EDITION

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CENGAGE

Australia • Brazil • Canada • Mexico • Singapore • United Kingdom • United States

***Today's Technician™: Classroom Manual for Automotive Heating & Air Conditioning,* Seventh Edition**

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Library of Congress Control Number: 2020920712
Book Only ISBN: 978-0-3573-5868-9
Package ISBN: 978-0-3573-5867-2

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200 Pier 4 Boulevard
Boston, MA 02210
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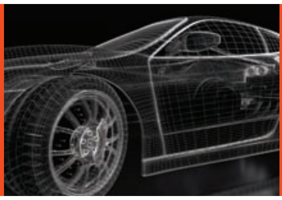
Printed in the United States of America
Print Number: 01 Print Year: 2020



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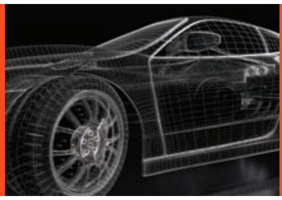


PREFACE

Thanks to the support the *Today's Technician*™ series has received from those who teach automotive technology, Cengage, the leader in automotive-related textbooks, is able to live up to its promise to regularly provide new editions of texts of this series. We have listened and responded to our critics and our fans and present this new updated and revised seventh edition. By revising this series on a regular basis, we can respond to changes in the industry, changes in technology, changes in the accreditation process, and to the ever-changing needs of those who teach automotive technology.

The *Today's Technician*™ series features textbooks that cover all mechanical and electrical systems of automobiles and light trucks. Principally, the individual titles correspond to the areas for National Institute for Automotive Service Excellence (ASE) certification.

All titles in the *Today's Technician*™ series include remedial skills and theories common to all of the certification areas and advanced or specific subject areas that reflect the latest technological trends.

Today's Technician™*: Automotive Heating & Air Conditioning, 7*e, is designed to give students a chance to develop the same skills and gain the same knowledge that today's successful technician has. This edition also reflects the changes in the guidelines established by the ASE Education Foundation in 2017.

The purpose of the ASE Education Foundation is to evaluate technician training programs against standards developed by the automotive industry and recommend qualifying programs for accreditation by ASE. Programs can earn ASE accreditation upon the recommendation of the ASE Education Foundation. ASE Education Foundation's national standards reflect the skills that students must master. ASE Education Foundation accreditation ensures that the training programs meet or exceed industry-recognized, uniform standards of excellence.

The technician of today and for the future must know the underlying theory of all automotive systems and be able to service and maintain those systems. Dividing the material into two volumes, a Classroom Manual and a Shop Manual, provides the reader with the information needed to begin a successful career as an automotive technician without interrupting the learning process by mixing cognitive and performance learning objectives into one volume.

The design of Cengage Learning's *Today's Technician*™ series was based on features known to promote improved student learning. The design was further enhanced by a careful study of survey results in which the respondents were asked to value particular features. Some of these features can be found in other textbooks, whereas others are unique to this series.

Each Classroom Manual contains the principles of operation for each system and subsystem. The Classroom Manual also discusses design variations in key components used by the different vehicle manufacturers and considers emerging technologies that will be standard or optional features in the near future. This volume is organized to build upon basic facts and theories. Its primary objective is to help the reader gain an understanding of how each system and subsystem operates. This understanding is necessary to diagnose the complex automobiles of today and tomorrow. Although the basics contained in the Classroom Manual provide the knowledge needed for diagnostics, diagnostic procedures appear only in the Shop Manual. An understanding of the underlying theories is also a requirement for competence in the skill areas covered in the Shop Manual.

A spiral-bound Shop Manual delivers hands-on learning experiences with step-by-step instructions for diagnostic and repair procedures. Photo Sequences are used to illustrate some of the common service procedures. Other common procedures are listed and accompanied with fine-line drawings and photos that let the reader visualize and conceptualize the finest details of the procedure. This volume explains the reasons for performing the procedures, as well as the circumstances when each particular service is appropriate.

The two volumes are designed to be used together and are arranged in corresponding chapters. Not only are the chapters in the volumes linked together, the contents of the chapters are also linked. The linked content is indicated by marginal callouts that refer the reader to the chapter and page where the same topic is addressed in the companion volume. This valuable feature saves users the time and trouble of searching the index or table of contents to locate supporting information in the other volume. Instructors will find this feature especially helpful when planning the presentation of material and when making reading assignments.

Both volumes contain clear and thoughtfully selected illustrations, many of which are original drawings or photos specially prepared for inclusion in this series. This means that the art is a vital part of each textbook and not merely inserted to increase the number of illustrations.

The page design of this series uses available margin space to deliver helpful information efficiently without interrupting the pedagogical lesson material. This information includes examples of concepts just introduced in the text, explanations or definitions of terms that are not defined in the text, examples of common trade jargon used to describe a part or operation, and unique applications of the system or service described in the text. Many textbooks also include this information but insert it in the main body of text; this tends to interrupt the reader's thought process. By placing this information to the side of the main text, students can read through the text uninterrupted and refer to the additional information when it is best for them.

Jack Erjavec
Series Advisor

HIGHLIGHTS OF THIS EDITION—CLASSROOM MANUAL

The Classroom Manual of this edition has been updated to include new technology used in the automotive heating and air-conditioning systems of today's vehicles while still retaining information on systems used in older vehicles that are still in use. In addition, an emphasis has been placed on updating images throughout the text with full-color photos. Charts, graphs, and line drawings are also in full color to be more visually appealing and improve the content comprehension by the reader. Expanded coverage of R-1234yf has been added throughout the text. Chapter 2 covers the basic theories required to fully understand the operation and diagnosis of the complete HVAC system. The chapter on electricity and electronic fundamentals has been added covering the application and use of digital multimeters for those readers that have a limited background in electrical applications. This is intended to improve their understanding of electrical applications material covered in later chapters and prepare them with the electrical knowledge needed to complete future job sheets. Chapter 4 covers the automotive heating system and engine cooling system, including systems used on today's hybrid electric vehicles. The electronic thermostat used on some of today's vehicles is thoroughly explained along with the rationale behind its use.

The rest of the text is laid out in a logical order, beginning with basic air-conditioning system operating principles and progressing to diagnosis of the refrigerant system. The end-of-chapter questions in all chapters have been revised and updated. Updated coverage on advanced electronics has been included, from the operation of electronic variable compressors and electric motor–driven compressors to advanced sensors such as the airborne pollutants sensor. Chapter 11 on HVAC system controls has been updated to include more information on advanced climate control systems and tablet scan tool use, while still including a thorough description of CAN system operation.

HIGHLIGHTS OF THIS EDITION—SHOP MANUAL

Safety information remains the first chapter of the Shop Manual and covers general safety issues as well as topics specific to automotive HVAC service. This chapter includes an in-depth discussion on high-voltage safety on today's hybrid and electric vehicles and the equipment necessary to service these vehicles. As with the Classroom Manual, an emphasis has been placed on updating Shop Manual images and photo sequences throughout the text with full-color photos and line art. Chapter 3, "Electricity and Electronic Fundamentals," has been added. This chapter contains detailed information on digital multimeter usage for electrical system diagnosis and troubleshooting.

Chapter 4 and later chapters cover service information related to the system information covered in the corresponding Classroom Manual chapters. Many new job sheets have been added and existing job sheets have been updated with 100 percent of the ASE Education Foundation tasks covered. The latest use of tools and technology has been integrated into the text, including hybrid electric compressors and the operation and use of SAE standard J2788 refrigerant recovery/recycling/recharging equipment needed to service today's small-capacity refrigerant systems. Added coverage of today's automatic climate control system service and diagnosis has been updated and includes specific examples. Enhanced tablet-based scanner usage for the diagnosis of climate control systems is fully explained in the shop manual. Photo sequences have been added showing how to use an enhanced tablet-based diagnostic scanner, including bi-directional control features to aid the technician in system diagnosis.

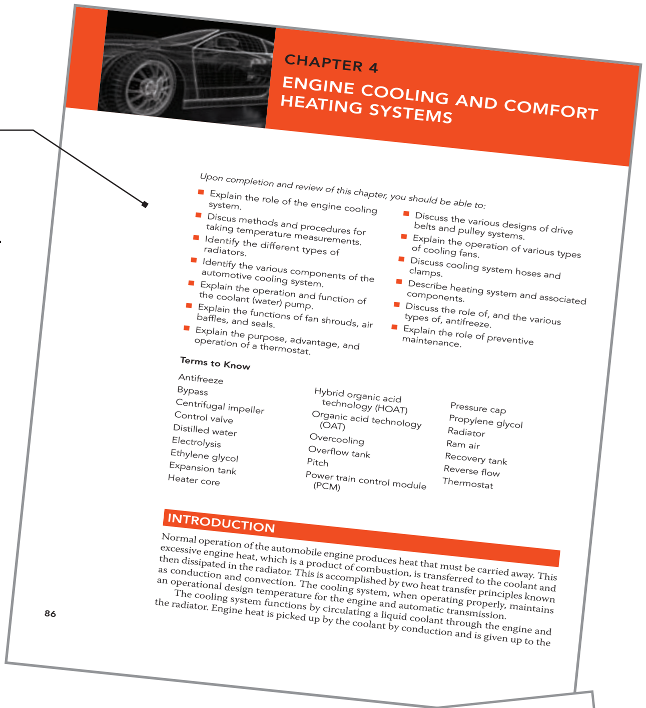
This edition of the Shop Manual will guide the student/technician through all the basic tasks related to automotive heating and air-conditioning service and repair.

CLASSROOM MANUAL

Features of the Classroom Manual include the following:

Cognitive Objectives

These objectives outline the chapter's contents and identify what students should know and be able to do upon completion of the chapter. Each topic is divided into small units to promote easier understanding and learning.



CHAPTER 4

ENGINE COOLING AND COMFORT HEATING SYSTEMS

Upon completion and review of this chapter, you should be able to:

- Explain the role of the engine cooling system.
- Discuss methods and procedures for taking temperature measurements.
- Identify the different types of radiators.
- Identify the various components of the automotive cooling system.
- Explain the operation and function of the coolant (water) pump.
- Explain the functions of fan shrouds, air baffles, and seals.
- Explain the purpose, advantage, and operation of a thermostat.
- Discuss the various designs of drive belts and pulley systems.
- Explain the operation of various types of cooling fans.
- Discuss cooling system hoses and clamps.
- Describe heating system and associated components.
- Discuss the role of, and the various types of, antifreeze.
- Explain the role of preventive maintenance.

Terms to Know

Antifreeze	Hybrid organic acid technology (HOAT)	Pressure cap
Bypass	Organic acid technology (OAT)	Propylene glycol
Centrifugal impeller	Overcooling	Radiator
Control valve	Overflow tank	Ram air
Distilled water	Pitch	Recovery tank
Electrolysis	Power train control module (PCM)	Reverse flow
Ethylene glycol		Thermostat
Expansion tank		
Heater core		

INTRODUCTION

Normal operation of the automobile engine produces heat that must be carried away. This excessive engine heat, which is a product of combustion, is transferred to the coolant and then dissipated in the radiator. This is accomplished by two heat transfer principles known as conduction and convection. The cooling system, when operating properly, maintains an operational design temperature for the engine and automatic transmission.

The cooling system functions by circulating a liquid coolant through the engine and the radiator. Engine heat is picked up by the coolant by conduction and is given up to the

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Margin Notes

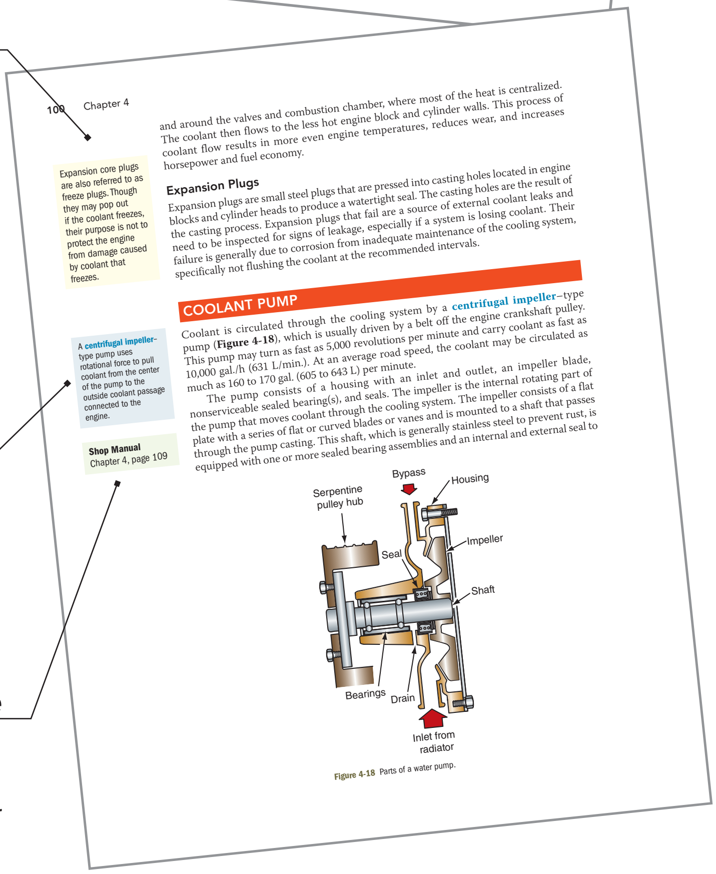
The most important terms to know are highlighted and defined in the margin. Common trade jargon also appears in the margin and gives some of the common terms used for components. This helps students understand and speak the language of the trade, especially when conversing with an experienced technician.

Terms to Know List

A list of key terms appears immediately after the Objectives. Students will see these terms discussed in the chapter. Definitions can also be found in the Glossary at the end of the manual.

Cross-References to the Shop Manual

References to the appropriate page in the Shop Manual appear whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Shop Manual may be fundamental to the topic discussed in the Classroom Manual.



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and around the valves and combustion chamber, where most of the heat is centralized. The coolant then flows to the less hot engine block and cylinder walls. This process of coolant flow results in more even engine temperatures, reduces wear, and increases horsepower and fuel economy.

Expansion core plugs are also referred to as freeze plugs. Though they may pop out if the coolant freezes, their purpose is not to protect the engine from damage caused by coolant that freezes.

Expansion Plugs

Expansion plugs are small steel plugs that are pressed into casting holes located in engine blocks and cylinder heads to produce a watertight seal. The casting holes are the result of the casting process. Expansion plugs that fail are a source of external coolant leaks and need to be inspected for signs of leakage, especially if a system is losing coolant. Their failure is generally due to corrosion from inadequate maintenance of the cooling system, specifically not flushing the coolant at the recommended intervals.

COOLANT PUMP

A **centrifugal impeller**–type pump uses rotational force to pull coolant from the center of the pump to the outside coolant passage connected to the engine.

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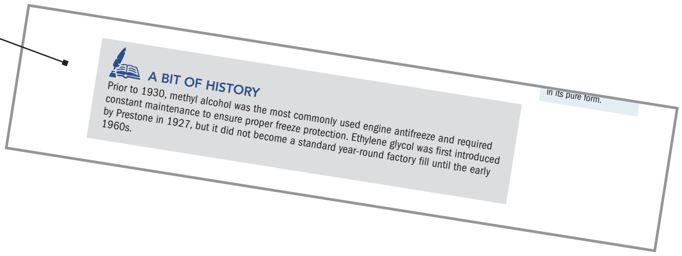
Coolant is circulated through the cooling system by a **centrifugal impeller**–type pump (**Figure 4-18**), which is usually driven by a belt off the engine crankshaft pulley. This pump may turn as fast as 5,000 revolutions per minute and carry coolant as fast as 10,000 gal./h (631 L/min.). At an average road speed, the coolant may be circulated as much as 160 to 170 gal. (605 to 643 L) per minute.

The pump consists of a housing with an inlet and outlet, an impeller blade, nonserviceable sealed bearing(s), and seals. The impeller is the internal rotating part of the pump that moves coolant through the cooling system. The impeller consists of a flat plate with a series of flat or curved blades or vanes and is mounted to a shaft that passes through the pump casting. This shaft, which is generally stainless steel to prevent rust, is equipped with one or more sealed bearing assemblies and an internal and external seal to

Figure 4-18 Parts of a water pump.

A Bit of History

This feature gives the student a sense of the evolution of the automobile. This feature not only contains nice-to-know information, but also should spark some interest in the subject matter.


A BIT OF HISTORY
Prior to 1930, methyl alcohol was the most commonly used engine antifreeze and required constant maintenance to ensure proper freeze protection. Ethylene glycol was first introduced by Prestone in 1927, but it did not become a standard year-round factory fill until the early 1960s.

Summary

Each chapter concludes with summary statements that contain the important topics of the chapter. These are designed to help the reader review the contents.

Review Questions

Short-answer essay, fill in the blank, and multiple-choice questions follow each chapter. These questions are designed to accurately assess the student's competence in the stated objectives at the beginning of the chapter.

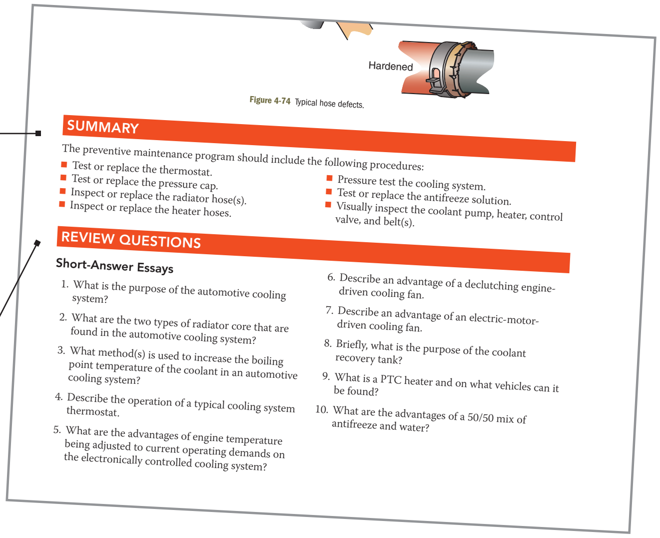


Figure 4-74 Typical hose defects.

SUMMARY

The preventive maintenance program should include the following procedures:

- Test or replace the thermostat.
- Test or replace the pressure cap.
- Inspect or replace the radiator hose(s).
- Inspect or replace the heater hoses.
- Pressure test the cooling system.
- Test or replace the antifreeze solution.
- Visually inspect the coolant pump, heater, control valve, and belt(s).

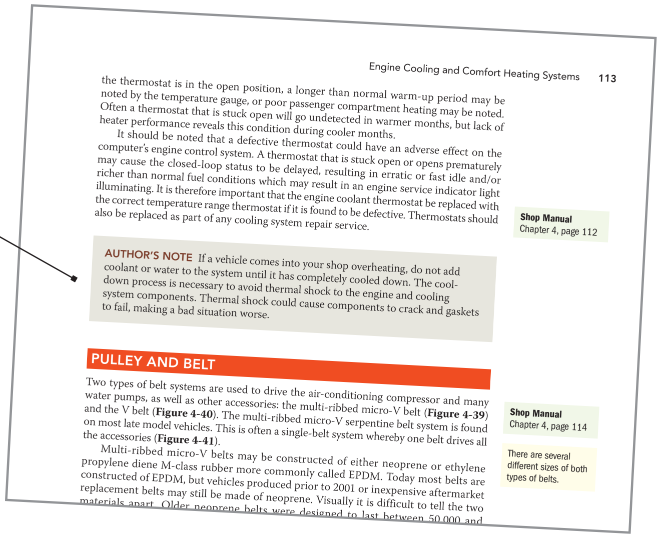
REVIEW QUESTIONS

Short-Answer Essays

1. What is the purpose of the automotive cooling system?
2. What are the two types of radiator core that are found in the automotive cooling system?
3. What method(s) is used to increase the boiling point temperature of the coolant in an automotive cooling system?
4. Describe the operation of a typical cooling system thermostat.
5. What are the advantages of engine temperature being adjusted to current operating demands on the electronically controlled cooling system?
6. Describe an advantage of a declutching engine-driven cooling fan.
7. Describe an advantage of an electric-motor-driven cooling fan.
8. Briefly, what is the purpose of the coolant recovery tank?
9. What is a PTC heater and on what vehicles can it be found?
10. What are the advantages of a 50/50 mix of antifreeze and water?

Author's Note

This feature includes simple explanations, stories, or examples of complex topics. These are included to help students understand difficult concepts.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the thermostat is in the open position, a longer than normal warm-up period may be noted by the temperature gauge, or poor passenger compartment heating may be noted. Often a thermostat that is stuck open will go undetected in warmer months, but lack of heater performance reveals this condition during cooler months.

It should be noted that a defective thermostat could have an adverse effect on the computer's engine control system. A thermostat that is stuck open or opens prematurely may cause the closed-loop status to be delayed, resulting in erratic or fast idle and/or richer than normal fuel conditions which may result in an engine service indicator light illuminating. It is therefore important that the engine coolant thermostat be replaced with the correct temperature range thermostat if it is found to be defective. Thermostats should also be replaced as part of any cooling system repair service.

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AUTHOR'S NOTE If a vehicle comes into your shop overheating, do not add coolant or water to the system until it has completely cooled down. The cool-down process is necessary to avoid thermal shock to the engine and cooling system components. Thermal shock could cause components to crack and gaskets to fail, making a bad situation worse.

PULLEY AND BELT

Two types of belt systems are used to drive the air-conditioning compressor and many water pumps, as well as other accessories: the multi-ribbed micro-V belt (**Figure 4-39**) and the V belt (**Figure 4-40**). The multi-ribbed micro-V serpentine belt system is found on most late model vehicles. This is often a single-belt system whereby one belt drives all the accessories (**Figure 4-41**).

Multi-ribbed micro-V belts may be constructed of either neoprene or ethylene propylene diene M-class rubber more commonly called EPDM. Today most belts are constructed of EPDM, but vehicles produced prior to 2001 or inexpensive aftermarket replacement belts may still be made of neoprene. Visually it is difficult to tell the two materials apart. Older neoprene belts were designed to last between 50,000 and

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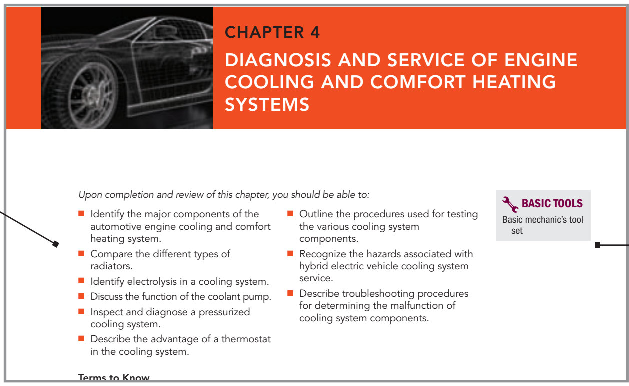
There are several different sizes of both types of belts.

SHOP MANUAL

To stress the importance of safe work habits, the Shop Manual also dedicates one full chapter to safety. Other important features of this manual include the following:

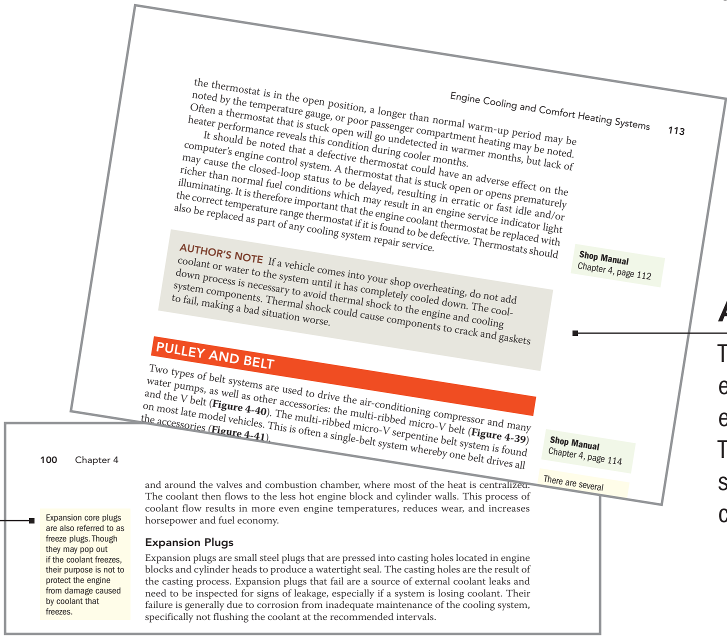


Performance-Based Objectives

These objectives define the contents of the chapter and define what the student should have learned on completion of the chapter.

Basic Tools Lists

Each chapter begins with a list of the basic tools needed to perform the tasks included in the chapter.



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Margin Notes

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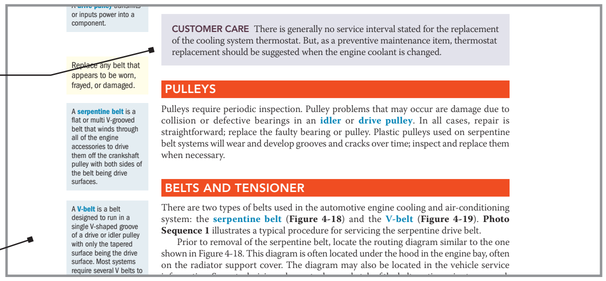

Customer Care

This feature highlights those little things a technician can do or say to enhance customer relations.

Terms to Know List

Terms in this list are also defined in the Glossary at the end of the manual.

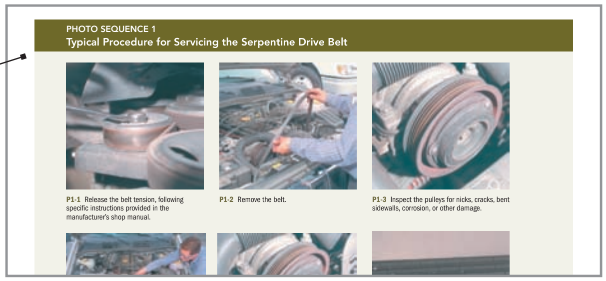

Photo Sequences

Many procedures are illustrated in detailed Photo Sequences. These photographs show the students what to expect when they perform particular procedures. They also familiarize students with a system or type of equipment that the school might not have.

Caution
For reassembly, note the size and length of the bolts removed. The bolts may be both English and metric and all may not be the same length.

Cautions and Warnings

Cautions appear throughout the text to alert the reader to potentially hazardous materials or unsafe conditions. Warnings advise the student of things that can go wrong if instructions are not followed or if an incorrect part or tool is used.

Flexible Fans

Flexible fans are covered in detail in the Classroom Manual. They are subject to the same problems and are tested in basically the same manner as rigid fans.

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Electric Fans

Electric cooling fans (**Figure 4-32**) are used because there is more precise control over their operation. They may be turned on and off by temperature- and pressure-actuated switches, thereby regulating engine coolant and air conditioning refrigerant temperatures at a more precise level.

WARNING **Electric engine cooling fans may start and operate at any time and without warning. This may occur with the ignition switch off or on.**

Follow the schematic in **Figure 4-33** for testing and troubleshooting a typical engine cooling fan system.

If in doubt, replace the fan clutch.

The **fan relay** is an electromagnetic switch that controls the cooling and auxiliary fan motors.

The **fan relay** is an electromagnetic switch that controls the cooling and/or auxiliary fan motors.

1. Start the engine and bring the coolant up to operating temperature.
2. Turn on the air conditioner.
3. Disconnect the cooling fan motor electrical lead connector (**Figure 4-34**). Verify fan spins freely.
4. Make sure that the ground wire is not disturbed. If the ground wire is a part of the electrical connector, establish a ground connection with a jumper wire (**Figure 4-35**).

The ground connection must be established to a metal part of the

References to the Classroom Manual

References to the appropriate page in the Classroom Manual appear whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Classroom Manual may be fundamental to the topic discussed in the Shop Manual.

CASE STUDY

A customer brings his car into the shop because the temperature gauge does not operate. It remains on cold all of the time, regardless of engine heat conditions.

The lead wire to the sending unit is disconnected, and a test light is used to probe for voltage. The test light comes on when the ignition switch is placed in the ON position. When the lead is connected to ground (−) through a 100 Ω resistor, the dash unit needle moves to the full hot position. This is a normal operation according to the service manual.

The diagnosis is that the sending unit is defective. It is replaced after approval by the customer and the temperature gauge system is returned to normal operation.

Case Studies

Each chapter ends with a Case Study describing a particular vehicle problem and the logical steps a technician might use to solve the problem. These studies focus on system diagnosis skills and help students gain familiarity with the process.

Service Tips

Whenever a short-cut or special procedure is appropriate, it is described in the text. Generally, these tips describe common procedures used by experienced technicians.

SERVICE TIP If the coolant is to be reused, drain it into a clean container. If, however, it is not to be reused, it must be disposed of or recycled in a manner considered to be environmentally safe.

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Name ______________________ **Date** ____________

JOB SHEET 10

DRAIN AND FILL COOLANT

Upon completion of this job sheet, you should be able to remove and replace cooling system coolant.

ASE Education Foundation Correlation

This job sheet addresses the following **MLR** task:

C.1. Inspect engine cooling and heater system's hoses and pipes; determine necessary action. **(P-1)**

This job sheet addresses the following **AST** task:

Job Sheets

Located at the end of each chapter, the Job Sheets provide a format for students to perform procedures covered in the chapter. A reference to the ASE Task addressed by the procedure is included on the Job Sheet.

WARNING **Be sure to use the proper safety equipment when working on any high-voltage system. Failure to do so may result in a serious or fatal injury.**

- Follow the service information diagnostic procedures.
- Never open high-voltage components.
- Before touching any of the high-voltage system wires or components, put on insulating gloves, make sure that the high-voltage service plug is removed, and disconnect the auxiliary battery.
- Remove the service disconnect prior to performing a resistance check.
- Remove the service plug prior to disconnecting or reconnecting any HV connections or components.
- Isolate any high-voltage wires that have been removed with insulation tape.
- Properly torque the high-voltage terminals.

WARNING **When the vehicle has been left unattended, recheck that the service disconnect has not been reinstalled by a well-meaning associate.**

When working on an HEV, always assume the HV system is live until you have proven

Special Tools
DMM capable of reading 400 volts AC/DC
Insulating gloves
Insulating tape

Special Tools Lists

Whenever a special tool is required to complete a task, it is listed in the margin next to the procedure.

ASE-Style Review Questions

Each chapter contains ASE-style review questions that reflect the performance objectives listed at the beginning of the chapter. These questions can be used to review the chapter as well as to prepare for the ASE certification exam.

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ASE-STYLE REVIEW QUESTIONS

1. Engine overcooling is being discussed:
   Technician A says that a thermostat stuck open could be the cause of this condition.
   Technician B says that a missing thermostat could be the cause of this condition.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
2. *Technician A* says that when pressure testing a cooling system, it should hold pressure for 5 minutes.
   Technician B says that a wet carpet may indicate a heater core leak.

6. *Technician A* says that antifreeze should be changed every year.
   Technician B says that extended-life coolant may last 5 years or longer.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
7. An overheating condition is being discussed:
   Technician A says that replacing the thermostat with one of a lower temperature rating will reduce the coolant temperature.
   Technician B says that a faulty water pump will reduce the coolant temperature.

ASE Challenge Questions

Each technical chapter ends with five ASE challenge questions. These are not mere review questions; rather, they test the students' ability to apply general knowledge to the contents of the chapter.

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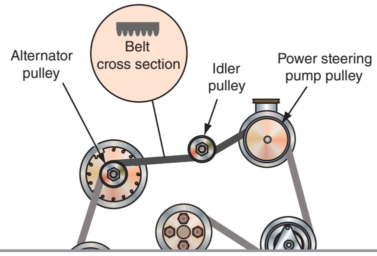
ASE CHALLENGE QUESTIONS

1. The tank on a radiator has ruptured:
   Technician A says that a thermostat that is stuck in the open position could be the cause.
   Technician B says that a faulty radiator cap could be the cause.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
2. A vehicle is in for repair with a complaint of poor heat output. During testing and diagnosis air is found to be trapped in the heater core. Which of the following is the most likely cause?
   A. A faulty head gasket
   B. A stuck open thermostat
   C. A radiator cap with a failed pressure relief valve
   D. A faulty water pump
3. The least likely problem associated with a cooling system that had the thermostat removed is:
   A. Poor heater performance

5. If the crankshaft pulley turns clockwise (cw), all of the following statements about the illustration below are true, except:
   A. The compressor turns clockwise (cw)
   B. The idler pulley turns counterclockwise (ccw)
   C. The water pump turns clockwise (cw)
   D. The alternator pulley turns clockwise (cw)



ASE Practice Examination

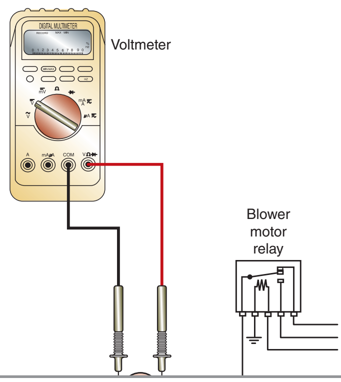
A 50-question ASE practice exam, located in the Appendix, is included to test students on the content of the complete Shop Manual.

APPENDIX A
ASE PRACTICE EXAMINATION

Final Exam Automotive Heating and Air Conditioning A7

1. What component part of the air-conditioning system causes the refrigerant to change from a liquid to a vapor?
   A. Evaporator
   B. Compressor
   C. Condenser
   D. Metering device
2. How does the air-conditioning system remove excess humidity from the air entering the passenger compartment?
   A. Moisture collects on the duct walls.
   B. Moisture condenses on the condenser.
   C. Moisture condenses on the evaporator.
   D. Moisture is separated by the blower motor.
3. During a system performance test of the air-conditioning system operation both the high-side and low-side pressure readings are about the same and the compressor clutch is engaged. Which of the following is the most likely cause?
   A. A restriction in the low pressure line
   B. A faulty compressor valve plate
   C. Moisture contamination of the system

6. All of the following may cause a compressor clutch to slip, *except*:
   A. Overcharge of refrigerant
   B. Loose drive belt
   C. Improper air gap
   D. Low voltage



SUPPLEMENTS

Instructor Resources

The *Today's Technician*™ series offers a robust set of instructor resources, available online at Cengage's Instructor Resource Center (http://login.cengage.com). The following tools have been provided to meet any instructor's classroom preparation needs:

- Lesson Plans provide lecture outlines, teaching tips, and complete answers to end-of-chapter questions.
- Power Point presentations include images, videos, and animations that coincide with each chapter's content coverage.
- Cengage Learning Testing Powered by Cognero® delivers hundreds of test questions in a flexible, online system. You can choose to author, edit, and manage test bank content from multiple Cengage Learning solutions and deliver tests from your LMS, or you can simply download editable Word documents.
- An Image Gallery includes photos and illustrations from the text.
- The Job Sheets from the Shop Manual are provided in Word format.
- End-of-Chapter Review Questions are also provided in Word format.
- To complete this powerful suite of planning tools, a pair of correlation guides map this edition's content to the ASE Education Foundation tasks and to the previous edition.

Mindtap

MindTap for ***c™: Automotive Heating & Air Conditioning, 7th edition***, is a personalized teaching experience with relevant assignments that guide students to analyze, apply, and improve thinking, allowing you to measure skills and outcomes with ease.

- Personalized Teaching: Becomes yours with a Learning Path that is built with key student objectives. Control what students see and when they see it. Use it as-is or match to your syllabus exactly—hide, rearrange, add, and create your own content.
- Guide Students: A unique learning path of relevant readings, multimedia, and activities that move students up the learning taxonomy from basic knowledge and comprehension to analysis and application.
- Promote Better Outcomes: Empower instructors and motivate students with analytics and reports that provide a snapshot of class progress, time in course, engagement, and completion rates.

MindTap for ***Today's Technician™: Automotive Heating & Air Conditioning, 7th edition***, meets the needs of today's automotive classroom, shop, and student. Within the MindTap, faculty and students will find editable and submittable job sheets based on ASE Education Foundation tasks. MindTap also offers students engaging activities that include videos and assessments.

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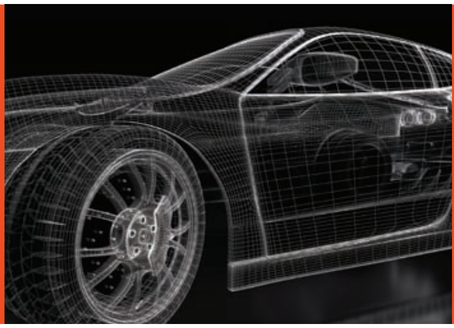

CHAPTER 1

HEATING AND AIR CONDITIONING—HISTORY AND THE ENVIRONMENT

Upon completion and review of this chapter, you should be able to:

- Define the term air conditioning.
- Discuss the historic developments of modern refrigeration.
- Explain the importance of the ozone layer.
- Discuss what industry is doing about the ozone depletion problem.
- Discuss what government is doing about the ozone depletion problem.
- Describe how ozone is created.
- Describe how ozone is destroyed.
- Discuss the Clean Air Act.
- Discuss ozone protection regulations.
- Discuss global warming potential (GWP) of refrigerant gases.
- Discuss CFC-12 (R-12), HFC-134a (R-134a), and the introduction of HFO-1234yf (R-1234yf) as an automotive refrigerant.
- Describe technician certification.
- Explain special safety precautions.
- Discuss the types of antifreeze/coolant used.
- Discuss the hazardous materials used.
- Describe toxic gases.

Terms to Know

Air conditioning	Global warming	Nitrogen (N)
Allotropes	Global warming potential (GWP)	Oxygen (O)
Atmosphere	Greenhouse effect	Ozone (O_3)
Chlorine (Cl)	Halogens	Ozone depletion
chlorofluorocarbons (CFCs)	Hydrofluorocarbons (HFCs)	Price leader
Clean Air Act (CAA)	Hydrostatic pressure	Refrigeration
Dobson Unit (DU)	Infrared	Toxicity
Evaporators		Ultraviolet (UV) radiation

INTRODUCTION

Since the dawn of time, humans have been trying to control their environment. It was natural that after the automobile became popular, a passenger comfort heating and cooling system would be required. And so began the quest for vehicle passenger compartment temperature control.

The first year that automotive air conditioning (A/C) was offered on a production vehicle was 1940, by the Packard Motor Car Company. Cadillac soon followed in 1941. After its initial introduction in the early 1940s, it did not become a popular option until the early 1960s. Since then the popularity of air conditioning has increased annually.

In 1962, just over 11 percent of all cars sold were equipped with air conditioners. This accounted for 756,781 units, including both factory-installed systems and those with add-on systems installed after the purchase, which are referred to as "aftermarket" systems. Just 5 years later, in 1967, the total number had increased an astounding 469 percent—to 3,546,255 units. Air conditioning is now one of the most popular selections in the entire list of automotive accessories and is often standard equipment on many vehicle models today. At the present time, over 93 percent of all automobiles sold in the United States are equipped with air conditioning units. It is expected that this percentage will remain at approximately 93 percent into the future.

When mobile air conditioning was first introduced, it was considered a luxury. Its usefulness, however, has made it a necessity.

Millions enjoy the benefits it produces. Businesspeople are able to drive to appointments in comfort and arrive fresh and alert. People with allergies are able to travel without the fear of coming into contact with excessive dust and airborne pollen and pollution. Because of the extensive use of the automobile, automobile air conditioning is playing an important role in promoting the comfort, health, and safety of travelers throughout the world. In the South and Southwest, many specialty auto repair shops base their entire trade on selling, installing, and servicing automotive air conditioners throughout the year. If a vehicle is not equipped with air conditioning, or if the A/C system is not functioning, its value is dramatically reduced on the resale market.

This text concentrates on the heating and air-conditioning system's function and operation as employed by various automotive manufacturers and the methods they use to improve passenger comfort levels.

AIR CONDITIONING DEFINED

Air conditioning is the process of adjusting and regulating by heating or refrigerating; the quality, quantity, temperature, humidity, and circulation of air in a space or enclosure; to condition the air.

Temperature and *humidity* refer to the quality of the conditioned air.

Volume refers to the quantity of the conditioned air.

The definition of air conditioning should be reviewed before tracing its history and its application to the automobile. **Air conditioning**, by definition, is the process by which air is:

- Cooled
- Heated
- Cleaned or filtered
- Humidified or dehumidified
- Circulated or recirculated

In addition, the quantity and quality of the conditioned air are controlled. This means that the temperature, humidity, and volume of air can be controlled at any time in any given situation. Under ideal situations, air conditioning can be expected to accomplish all of these tasks at the same time. It is important to recognize that the air conditioning process includes the process of refrigeration (cooling by removing heat).

REFRIGERATION

Refrigeration is the term given to a process by which heat is removed from matter—solid, liquid, or vapor. It is the process of lowering the temperature of an enclosure or area by natural, chemical, electrical, or mechanical means. The fluid that circulates through an air-conditioning system is referred to generically as refrigerant. The refrigerants used in automotive air conditioning systems today are commonly referred to as R134a, R1234yf, and R12 for pre-1995 systems. These refrigerants will be discussed further in this chapter and in Chapter 5.

HISTORICAL DEVELOPMENT OF REFRIGERATION

Refrigeration, as we know it today, is less than one hundred years old. Some of its principles, however, were known as long ago as 10,000 BCE.

Harvested ice, usually cut from frozen ponds, contained many impurities, dirt, and debris.

The Egyptians developed a method for cooling water. They found that water could be cooled by placing it in porous jugs on the rooftop at sundown. The night breeze evaporated the moisture seeping through the jugs and, in turn, cooled the contents. The Greeks and Romans had snow brought down from mountaintops. They preserved it by placing it in cone-shaped pits lined with straw and covered with a thatched roof. Even earlier, the Chinese learned that ice improved the taste of drinks. They cut it from frozen ponds and lakes in the winter, preserved it in straw, and sold it in the summer.

Domestic Refrigeration

Dr. John Gorrie (1803–1855) of Abbeville, South Carolina, was issued the first U.S. patent for a mechanical refrigeration system in 1851. Gorrie correctly theorized that if air were highly compressed, it would be heated by the energy of compression. If this compressed air were then run through metal pipes that were cooled with water, the air could be cooled to the water temperature. If this air were then expanded back to atmospheric pressure, low temperatures of about 26°F (−33°C—low enough to freeze water in pans in a refrigerator box—could be obtained. The compressor of this system could be powered by horse, water, wind, or steam. Gorrie's original system was installed in the U.S. Marine Hospital in Apalachicola, Florida, where he used it to treat patients suffering from yellow fever. A replica of his system is on display at the John Gorrie State Museum in Apalachicola.

While Dr. Gorrie's mechanism produced ice in quantities, leakage and irregular performance often impaired its operation. Gorrie's basic principle, however, is the one most often used in today's modern refrigeration: cooling caused by the rapid expansion of gases.

Domestic refrigeration systems first appeared in 1910, although in 1896 the Sears, Roebuck and Company catalog offered several refrigerators. Refrigeration, however, was provided by ice. The refrigerator held 25 pounds (11.34 kilograms) of ice and was useful only for short-term storage for the preservation of foods.

In 1899, the first household refrigeration patent was awarded to Albert T. Marshall of Brockton, Massachusetts. A 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 technology was slow. By 1920, only about 200 refrigerators 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 and the refrigeration unit were shipped separately and required assembly.

In terms of the cost per cubic foot of refrigeration, the early refrigerator compares favorably to today's modern machines. In terms of the economy, one worked about four times longer to pay for the 4-cubic-foot refrigerator than one works for today's 16-cubic-foot refrigerator, which is four times larger.

Shortly after the beginning of the 20th century, T. C. Northcott of Luray, Virginia, became the first person known in history to have a home with central heating and air conditioning. A heating and ventilating engineer, Northcott built his house on a hill above the famous Caverns of Luray. Because of his work, he knew that air filtered through limestone was free of dust and pollen. This fact was important because Northcott and his family suffered from hay fever.

Some distance behind his house he drilled a shaft through the ceiling of the cavern and installed a fan to pull cavern air through the shaft. He then constructed a shed over the shaft and a duct system to the house. The duct system was divided into two chambers, Cooling accomplished by humidification is only effective in arid (dry) areas of the country.

Humidity refers to the amount of moisture in the air.

one above the other. The upper duct, which carried air from the cavern, was heated by the sun, providing air to warm the house on cool days. The lower duct, which was unheated, carried air from the cavern to cool the house on warm days.

The moisture content (humidity) of the air was controlled in a chamber in Northcott's basement. Here, air from both ducts could be mixed. Because it is known that warm air contains more moisture than cool air, Northcott was able to direct conditioned air from the mixing chamber 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.

Mobile Air Conditioning

The first automotive air conditioning unit appeared on the market in 1927. True air conditioning was not to appear in cars for another 13 years. However, air conditioning was advertised as an option in some cars in 1927. At that time, air conditioning meant only that 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 and filtered, then circulated around inside the car by fan.

Early studies of the effectiveness of vehicles equipped with automotive air conditioning proved that sales and production increased significantly.

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

Accurate records were not kept in the early days of automotive air conditioning. However, it is known that before World War II between 3,000 and 4,000 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, the demand for air-conditioned vehicles began in the Southwest.

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

Many large firms reported increased sales after air conditioning was installed in the cars of their salespeople. Most commercial passenger-carrying vehicles are now air conditioned. Truck lines realize larger profits because drivers who have air-conditioned cabs average more miles per day than those who do not.

In 1967, all of the state police cars on the Florida Turnpike were air conditioned. Since that time, most governmental and law enforcement agencies across the nation have added air conditioning to their vehicles.

Other Applications

Mobile air conditioning is not only found in cars, trucks, and buses. Mobile air conditioning application expanded for use in farm equipment such as tractors, harvesters, and threshers over the last 5 decades. Additionally, mobile air-conditioning systems have been developed for use in other off-road equipment, such as backhoes, bulldozers, and graders. Air conditioning may be found in almost any kind of domestic, farm, or commercial equipment that has an enclosed cab and requires an onboard operator.

REFRIGERANT AND THE ENVIRONMENT

In 1985, scientists with the British Antarctic Survey announced their discovery of a huge hole in the ozone layer over Antarctica. Since that time, ozone depletion, together with global warming resulting from the greenhouse effect, has attracted widespread media attention and well-founded concern for human health and for the environment. This section will explain:

- The importance of the ozone layer
- How the ozone layer is formed
- How the ozone layer is being depleted
- What is causing ozone depletion
- What industry is doing to correct the damage
- What government is doing to correct the damage, including:
  - The 1990 Clean Air Act Amendment
  - The Montreal Protocol

The Earth's Atmosphere

The earth's **atmosphere** is composed of a thin covering of gases that surround the globe and comprise an enormous mass. This mass is equivalent to about one million tons for every person living on earth. The atmosphere extends skyward for hundreds of miles (**Figure 1-1**). The lowest part of the atmosphere is the troposphere, which extends from ground level to about seven miles (11 kilometers) depending on the time of year and region of the globe. The troposphere has clouds, wind, storms, and a weather system. Above the troposphere is the stratosphere which extends to an altitude of about 30 miles (48 kilometers). The next time you see a very large, anvil-shaped thundercloud (cumulonimbus) with a flat top, look at it carefully. This flat top is caused by the top of the cloud reaching the highest level of the troposphere and flattening out just below the stratosphere as it is sheared off by high-level winds.

The major gases in the atmosphere are **nitrogen (N)**, an inert gas that comprises 78 percent of the atmosphere by volume, and **oxygen (O)**, which is vital for life and comprises 21 percent. The composition of atmospheric gases is shown in **Table 1-1**.

The remaining 1 percent of the earth's atmosphere is made up of several trace gases. Though very small in volume, these gases play critical roles in regulating the earth's atmosphere. Carbon dioxide (CO_2), for example, is a trace gas with a concentration of only 350 parts per million by volume (ppmv). CO_2 accounts for less than 0.04 percent of atmospheric gases, but it absorbs infrared radiation, thus warming the atmosphere through the phenomenon of the greenhouse effect.

Atmosphere is a general term used to describe the gaseous envelope surrounding the earth to a height of 621 miles (1,000 km); it is 21 percent oxygen, 78 percent nitrogen, and 1 percent other gases.

Nitrogen (N) is an odorless, colorless, tasteless element that forms 78 percent of our atmosphere. It is an essential element for plant and animal life.

Oxygen (O) is an odorless, colorless, tasteless element that forms 21 percent of our atmosphere. It is an essential element for plant and animal life.

The air we breathe contains 1 percent rare gases, such as krypton (Kr).

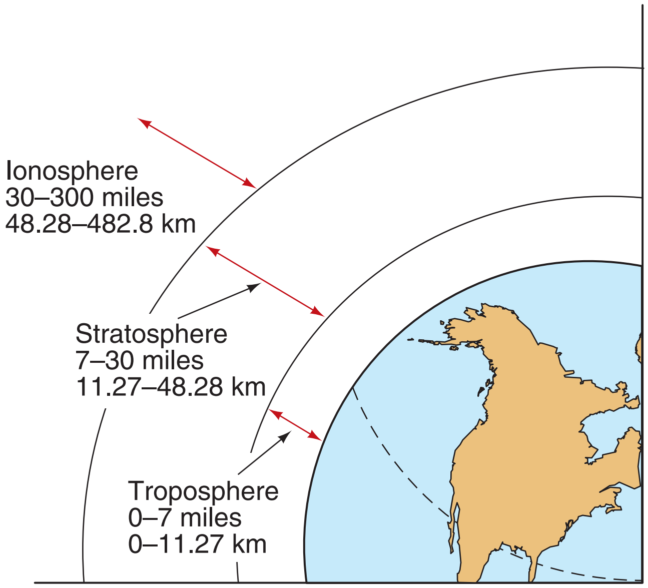

Figure 1-1 The atmosphere extends skyward for hundreds of miles.

Gas	PPM by Volume	Percentage
Nitrogen (N)	780,840	78
Oxygen (O)	209,460	21
Argon (Ar)	9,340	0.0934
Carbon dioxide (CO_2)	350	0.0035
Neon (Ne)	18.18	0.0002
Helium (He)	5.24	0.00005
Methane CH_4	2.00	0.00002
Krypton (Kr)	1.14	0.00001
Hydrogen (H)	0.50	0.000005
Nitrous oxide N_2O	0.50	0.000005
Ozone O_3	0.40	0.000004
Xenon (Xe)	0.09	0.0000009

Table 1-1 Composition of the Earth's Atmosphere

Ozone (O_3) is a form of oxygen.

Ozone (O_3) is an unstable, pale blue gas with a penetrating odor; it is an allotropic form of oxygen (O) that is usually formed by electrical discharge in the air.

Allotropes are structurally different from elements. For example, though different in structure, the properties of charcoal and diamond are the same as the element carbon; they are both made up of the same element in differing combinations.

Ultraviolet (UV) radiation consists of invisible rays from the sun that have damaging effects on the earth. Ultraviolet radiation causes sunburns.

Without its ability to retain this heat, the earth would be about 60°F (33°C) colder and could not support life as we know it. An increase of 25 percent in the concentration of carbon dioxide over the past century is one of the primary causes of global warming.

Ozone (O_3) is another trace gas and occurs at concentrations of only about 0.4 ppmv (0.000004 percent). Ozone is an **allotrope** of oxygen with different chemical and physical properties. In high concentrations, it is considered to be a poisonous gas, exhibiting a pale blue color and a pungent odor that some people describe as irritating. (This is in contrast with oxygen (O), which is colorless, tasteless, and has no odor.) But ozone is also essential for absorbing UV radiation from the sun. Excessive UV radiation is very damaging to life on earth.

Ozone Formation in the Atmosphere

Unlike other gases that are concentrated in the troposphere, about 90 percent of the ozone occurs in the stratosphere, from an altitude of about 9–22 miles (15–35 km). Even at its highest concentration, ozone does not exceed 10 ppmv—equivalent to one ozone molecule in every 100,000 molecules. If all the ozone in the atmosphere were concentrated at sea level, it would form a layer less than 0.125 in. (3 mm) thick. There are about 3,000 million tons of ozone in the atmosphere, equivalent to about 1,600 lb. (726 kg) per person on earth. Compared with the total mass of the atmosphere, however, the amount of ozone is negligible.

Ozone is formed by the action of electrical discharges. For this reason, it is sometimes detected by odor near electrical equipment or just after a thunderstorm. More frequently, however, ozone is formed by the action of **ultraviolet (UV) radiation** on oxygen in the stratosphere. The atoms in the oxygen molecules split apart, and the separated atoms recombine with other oxygen molecules to form the triatomic allotrope ozone (O_3).

Because sunlight is essential for the formation of stratospheric ozone, it is formed mainly over the equatorial region, where solar radiation is highest. From there, it is distributed throughout the stratosphere by the slight global wind circulation. Stratospheric ozone levels vary throughout the world, being highest at the equator and lowest toward the poles.

Absorption of Ultraviolet Radiation

Incoming radiation from the sun is of various wavelengths, ranging from invisible ultraviolet (UV) radiation, to visible light, to infrared light. UV radiation can cause sunburn, skin cancer, and damage to eyes, including cataracts. It can also cause premature aging and wrinkling of the skin. Ultraviolet radiation breaks down the food chain by destroying minute organisms such as plankton in the ocean, thereby depriving certain species of their natural food. Plant life and crops can also be devastated by excessive UV radiation.

Ultraviolet (UV) radiation is to be avoided whenever possible.

Fortunately, the damaging forms of UV radiation are absorbed by ozone in the atmosphere and do not reach the earth. The minute percentage of atmospheric ozone is sufficient to absorb this radiation. The ozone layer, then, acts as a giant sunscreen or umbrella, enveloping the earth and protecting life from the dangerous UV radiation. **Ozone depletion** weakens this protective shield and allows more UV radiation to strike the earth and living organisms, as shown in **Figure 1-2**.

Ozone depletion is the reduction of the ozone layer due to contamination, such as the release of chlorofluorocarbon (CFC) refrigerants into the atmosphere.

Another benefit of the absorption of solar energy by ozone is that the upper stratosphere is somewhat warmer than at lower altitudes, which helps to regulate the earth's temperature. Stratospheric ozone absorbs about 3 percent of incoming solar radiation, thus serving as a heat sink. Loss of this ozone will decrease the temperature of the stratosphere, which will, in turn, affect the troposphere and consequently the weather and climate on the earth's surface.

THE OZONE HOLE

The term *ozone hole* refers to large areas of thinning in the ozone barrier. This "hole" allows a much greater amount of UV radiation to penetrate to the earth's surface.

Ozone measurements were first recorded at the British base at Halley Bay in the Antarctic in 1956. Levels were found to fall drastically in September and October to 150 **Dobson units (DU)**—half the normal level. This is also half the levels measured in the northern hemisphere in the spring. Levels again rose in November to the expected pattern, confirming that the atmosphere over Antarctica differs from elsewhere in the world.

In 1984, British Antarctic Survey scientists, Joseph Farman, Brian Gardiner, and Jonathan Shanklin, discovered a recurring springtime Antarctic ozone hole. They found

The standard term for measuring ozone levels is the **Dobson Unit (DU)**, named after the British meteorologist Gordon Dobson, who was the first to use a spectrophotometer. This device is used to determine the intensity of various wavelengths in a spectrum of light and can thereby measure the density of the ozone layer.

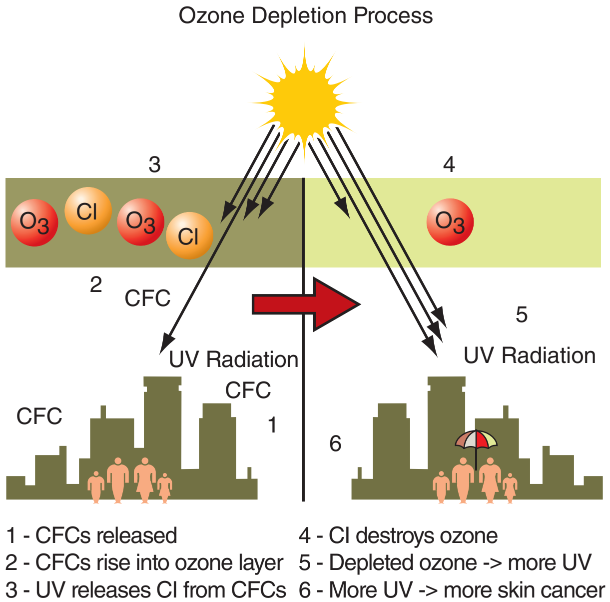

Figure 1-2 Ozone depletion process.

that in October 1984 ozone levels were about 35 percent lower than the average for the 1960s. At the center of the depleted area, almost all of the ozone had disappeared. Annually at Halley Bay between mid-August and early October, ozone levels fall by 97 percent at a height of 10.25 miles (16.5 km). The hole occurs between 10.6 and 13.7 miles (17 and 22 km) above the earth.

How Ozone Is Destroyed

Chlorine (Cl) is a poisonous, greenish-yellow gas used in some refrigerants and known to be harmful to the ozone layer.

CFC stands for chlorofluorocarbon, a man-made compound used in refrigerants such as CFC-12 (R-12).

Toxicity refers to the toxic or poisonous quality of a substance.

Ozone is both created and destroyed by the action of UV radiation on oxygen molecules. **Chlorine (Cl)** is the major gas causing the destruction of ozone and starts chain reactions in which a single molecule of chlorine can destroy 100,000 ozone molecules. Such reactions can continue for many years, even a century or more, until the chlorine drifts down into the troposphere or is chemically bound into another compound.

The main sources of chlorine are **chlorofluorocarbons (CFCs)**. CFCs (**Figure 1-3**) are artificially made chemicals first developed in 1928 and are comprised of:

- Chlorine (Cl)
- Fluorine (F)
- Carbon (C)
- (Often) hydrogen (H)

CFCs are very stable chemicals and are nonflammable, nonirritating, nonexplosive, noncorrosive, odorless, and relatively low in **toxicity**. They vaporize at low temperatures, which makes them very desirable for use as refrigerants in air conditioners and refrigerators. CFCs were also used as solvents for cleaning electronic components, for blowing bubbles in certain types of foam-blown plastics such as sponges and food packaging, in dry cleaning solvent, and as an aerosol propellant. **Figure 1-4** depicts the consumption rates in the United States where CFCs were used to produce goods and services prior to the restriction in production under the Clean Air Act. As can be seen, refrigerant made up a large portion of the overall use of CFCs.

During the 1960s and 1970s, aerosol use was widespread due to the stable nature and nonflammability of CFCs. Peak worldwide use of CFCs in the 1970s was on the order of about 700,000 tons (635,460 metric tons) each year. The scheduled phaseout caused drastic reductions, however, and with the decline in the use of aerosols, nonaerosol use has risen.

The consumption of CFCs on a per capita basis in the United States was among the highest in the world (**Figure 1-5**), a reflection of our affluence and the popularity and use of air conditioners. Although industrialized nations were the major consumers of CFCs,

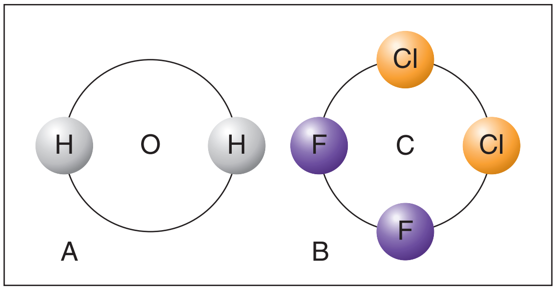

Figure 1-3 Chemical structure of (A) water; (B) CFC-12.

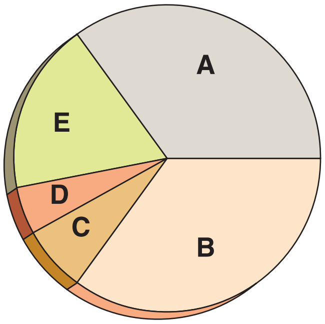

Figure 1-4 United States' consumption rates prior to CFC use being restricted by the Clean Air Act: (A) A/C-Ref 35%, (B) Foam blowing 35%, (C) Other 7%, (D) Sterilants 5%, (E) Solvents 18%. (Consumption rates are prior to CFC being restricted.)

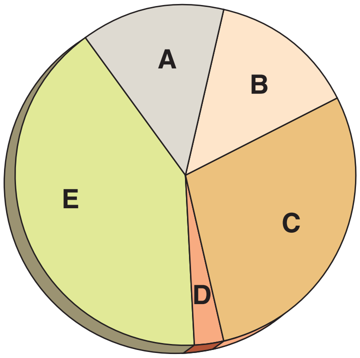

Figure 1-5 Consumption of CFCs at the time of the signing of the Montreal Protocol, by country/region: (A) The former Soviet Republics 14%, (B) Developing nations 14%, (C) United States 29%, (D) China and India 2%, (E) Other developed nations 41%.

developing nations such as China and India, because of their large populations, had an enormous potential to require CFCs for refrigerators and other uses.

In 1974, two chemists at the University of California, Mario Molina and Sherwood Rowland, asked the simple question: "What has happened to the millions of tons of CFCs released over the previous four decades?" The only "sink" they could suggest was the stratosphere. They hypothesized that the chemical stability of CFCs would enable them to reach the stratosphere, be broken apart by the intense UV radiation, and release chlorine by a process known as photolysis. The chlorine would then react with the ozone, causing its depletion.

It is not the CFCs, as such, that cause the destruction, but rather the chlorine released by the CFCs. The research of the British scientists at Halley Bay, together with international research programs in which samples of stratospheric air are obtained by high-altitude flights over Antarctica, have proven the link between CFCs and ozone destruction. A further factor identified as contributing to the loss of ozone is the polar stratospheric clouds that form during the Antarctic winter in the very cold stratospheric air. These comprise tiny particles of frozen water vapor, which condense and form clouds in spring. The clouds act as reservoirs of frozen chlorine during winter until thawed in spring. At that time, the chlorine is released and begins to react with the ozone over the following five to six weeks, then the vortex breaks up and the stratosphere becomes less stable.

The chlorine atoms in CFCs are hazardous to the ozone layer.

A chlorine atom reacts with an ozone molecule by splitting it apart and attaching itself to one of the oxygen atoms to form chlorine monoxide. A free oxygen atom splits the chlorine monoxide molecule to reform a molecule of oxygen (O_2), and the chlorine atom is free to attack another ozone molecule (**Figure 1-6**).

Chlorine atoms split ozone molecules to form chlorine monoxide.

The CFCs take 6 to 8 years to rise up through the atmosphere. Chlorine as used in swimming pools and bleach is unstable and breaks down rapidly without rising into the atmosphere. The concern is that the current hole and depletion that have resulted from CFCs released in early years will only worsen as their full effects are manifested over time in the stratosphere.

EFFECTS OF OZONE DEPLETION ON HUMAN HEALTH

As we have seen, ozone protects life on earth from damaging UV radiation. It acts as a giant sunscreen absorbing the UV rays, preventing a certain percentage of them from reaching the earth. As already noted, loss of ozone will only allow more UV radiation to penetrate to the earth and adversely affect human health and the environment. The three areas of our bodies that are adversely affected are the skin, eyes, and the immune system.

Exposure of skin to UV radiation can initially result in sunburn and suntan. If the exposure continues over a long period, as with those who work outdoors, the skin protects itself from UV radiation by gradually thickening and darkening as a pigment called melanin is released in the skin. Continuous exposure of the skin to UV radiation results in its aging and wrinkling and increases the risk of skin cancer.

Excessive UV exposure to the eyes will increase the risk of cataracts, which cause cloudiness in the lens of the eye, limiting vision. Other eye problems such as retina damage, tumors on the cornea, and "snow blindness" may also be caused by exposure to increased levels of UV radiation.

The body's immune system protects it from foreign chemicals and infections. If damaged, the immune system cannot protect the body and infections spread more rapidly. Ultraviolet radiation reduces the ability of the immune system to reject cancers, although not much is known about why this happens. Overall, increased UV radiation resulting from ozone depletion has the potential to significantly increase human skin cancers and cataracts and damage the human immune system. It also adversely affects marine and terrestrial plants and animals.

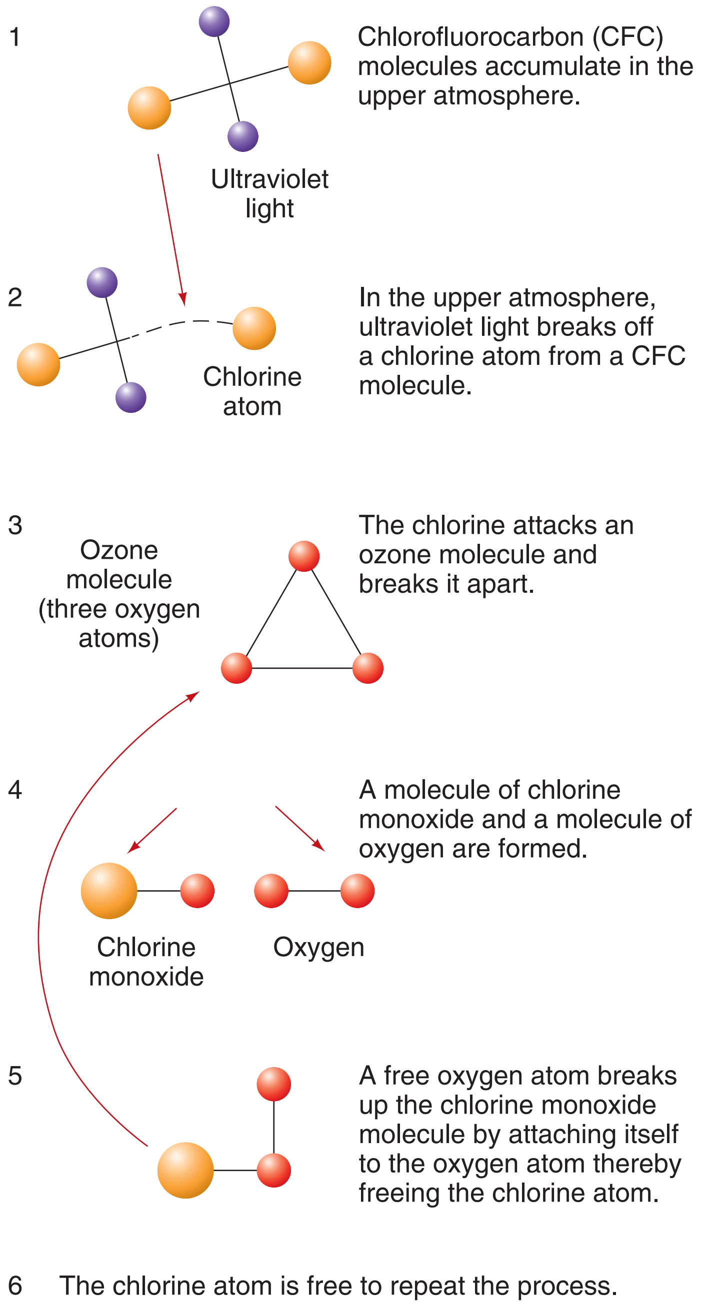

Figure 1-6 How CFCs destroy the ozone.

The extent of the damage will depend on the degree to which the earth's ozone layer is depleted. To date, it has been reduced by about 2.5 percent, and it remains to be seen whether the actions taken to control the release of ozone-depleting substances will be sufficient. Even though most industrialized nations have signed international agreements to ban them, the CFCs once used in the production of refrigerant and other commercial applications will last for decades in the upper stratosphere.

Computer modeling indicated that the hole in the ozone layer was the largest ever observed by NASA on September 21–30, 2006. But, between 2005 and 2018, we have seen a 20 percent decrease in ozone depletion during the winter months (**Figure 1-7**). Another study indicates that, as the level of CFCs decline and their effect on the ozone layer is taken by itself, the ozone layer will make a full recovery by the year 2065. Unfortunately, the

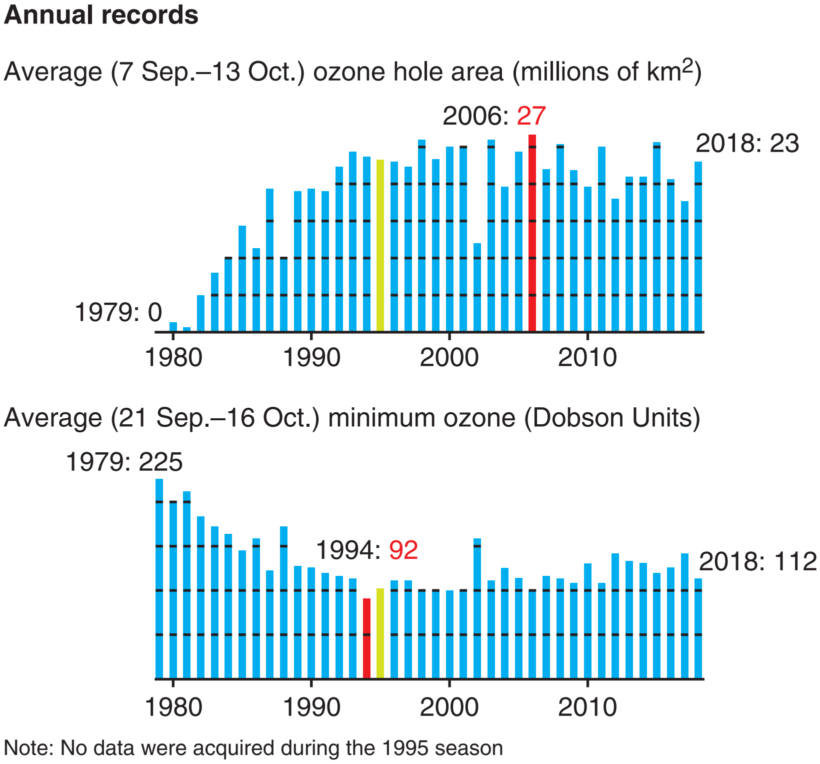

Figure 1-7 The graphs show the variations of ozone layer from year to year. The red bars indicate the largest ozone hole area and the lowest minimum thickness value.

same study indicates that when the other variables such as the greenhouse effect and water vapor in the stratosphere are added back into the equation, the ozone layer will only make a slight improvement by 2040 and a full recovery may not be achieved before 2080. There is still hope, but CFC reduction is only one piece of the puzzle.

CLIMATE CHANGE AND THE GREENHOUSE EFFECT

NASA studies indicate that by the 2030s, climate change may surpass chlorofluorocarbons as the main cause of ozone depletion. Greenhouse gases such as methane and carbon dioxide are changing the earth's climate. Methane emissions that migrate to the stratosphere are transformed into water vapor. At these high altitudes, water vapor can be broken down into molecules that attack the ozone molecules and thin the protective layer. The greenhouse effect also heats up the lower stratosphere where most of the ozone is concentrated. As it heats up, the chemical reactions that destroy ozone are also accelerated.

How the Greenhouse Effect Works

The loss of ozone and the greenhouse effect are separate phenomena, although CFCs are a common agent in both. Ideally, the heat energy (infrared radiation) sent from the sun to heat the earth is radiated back into space, thus leaving the earth's temperature relatively constant over time. Greenhouse gases in effect work as a blanket to trap infrared radiation and warm the lower atmosphere.

The earth's atmosphere contains many chemical compounds that act as "greenhouse" gases, and these gases allow sunlight to enter the earth's atmosphere freely. As this solar radiation passes through the atmosphere it then strikes and warms the earth. But some

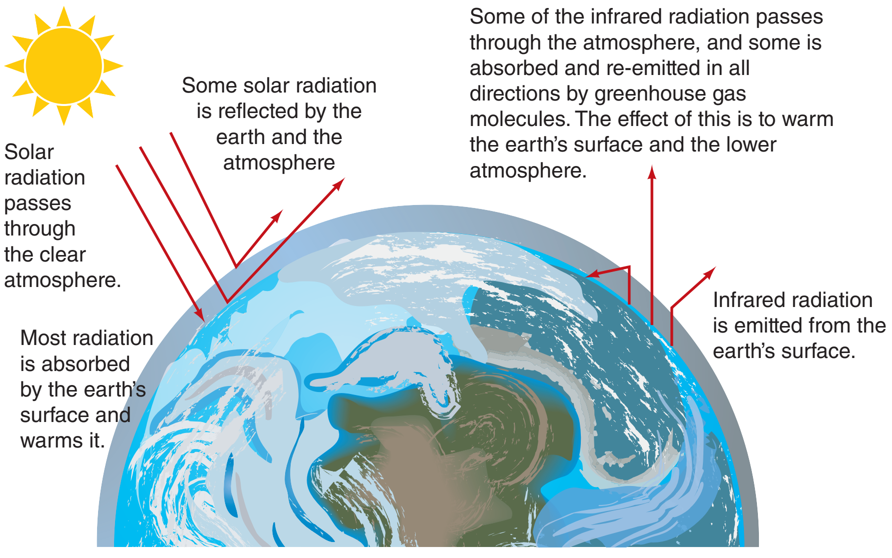

Figure 1-8 The greenhouse effect.

Infrared is the invisible light rays just beyond the red end of the visible spectrum that have a penetrating heating effect.

of this **infrared** radiation (heat) is re-emitted by the earth's surface and is absorbed and reflected by greenhouse gas molecules in the atmosphere, in all directions (**Figure 1-8**). The effect of this is to warm the earth's surface and lower atmosphere even further. It is similar to how a greenhouse is warmed by sunlight passing through the glass warming the interior and not allowing the heat to escape unless the vents are open. Think of the glass as the greenhouse gas molecules. Also, think of the interior of a car in the sun on a hot summer day with the windows rolled up. The interior will become much hotter than the outside temperature. Over time the amount of heat energy (infrared radiation) sent from the sun to heat the earth is radiated back into space, thus leaving the earth's temperature relatively constant ideally, if nature is left alone.

Greenhouse Gas Emissions and the Environment

Greenhouse effect is a term based on the fact that a greenhouse is warmed because glass allows the sun's radiant heat to enter, but prevents radiant heat from leaving. Likewise, global warming is caused by some gases in the atmosphere that act like greenhouse glass.

Global warming is the gradual warming of the earth's atmosphere due to the greenhouse effect.

Many gases exhibit greenhouse gas properties, and some, such as water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide, occur naturally. Others are man-made or increased by human activities. The **greenhouse effect** or **global warming** is the result of the release of increasing amounts of so-called "greenhouse gases" into the atmosphere, gases such as CO_2, CH_4, and man-made gases such as CFCs and HFCs. This blanket of greenhouse gases keeps the earth's average surface temperature at 59°F (15°C). Without any greenhouse effect, the earth's average surface temperature would be 0°F (−18°C), too cold to support life as we know it.

Greenhouse gas emissions have increased by about 25 percent over the last 150 years (**Figure 1-9**). This is also the time period of large-scale industrialization in the United States and Europe. In addition, 75 percent of the carbon dioxide emissions produced in the last 20 years was from the burning of fossil fuels. Gross U.S. greenhouse gas emissions have increased by about 2 percent between 1990 and 2016 (**Figure 1-10**). U.S. greenhouse emissions in 2016 decreased as compared to 2015 levels. Fluctuations in year-to-year greenhouse emissions can be a result of changes in the economy, fuel costs, as well as other factors. In 2016, the largest source of greenhouse gas emissions in the United States was burning fossil fuels. Electricity generation contributed the largest share, followed by transportation (**Figure 1-11**). Between 1990 and 2015, the warming effect from greenhouse gases added by human activity to the earth's atmosphere increased by 37 percent. Carbon dioxide emissions alone increased the warming effect by 30 percent.

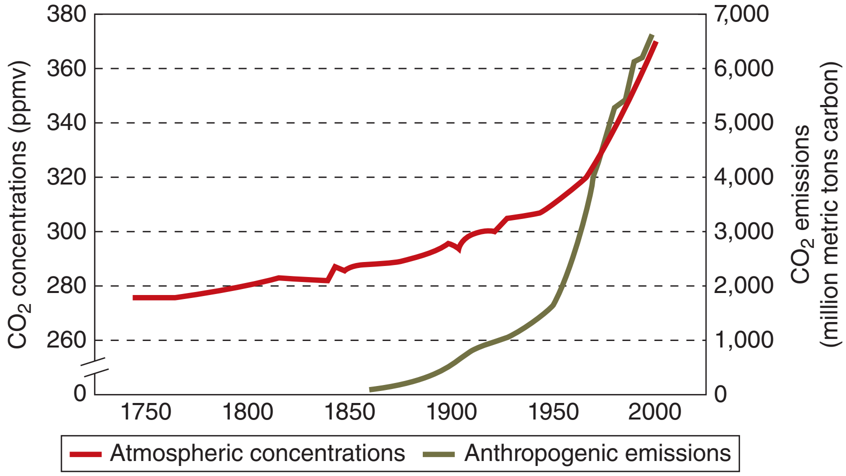

Figure 1-9 Trends in atmospheric concentrations and man-made (anthropogenic) emissions of carbon dioxide.

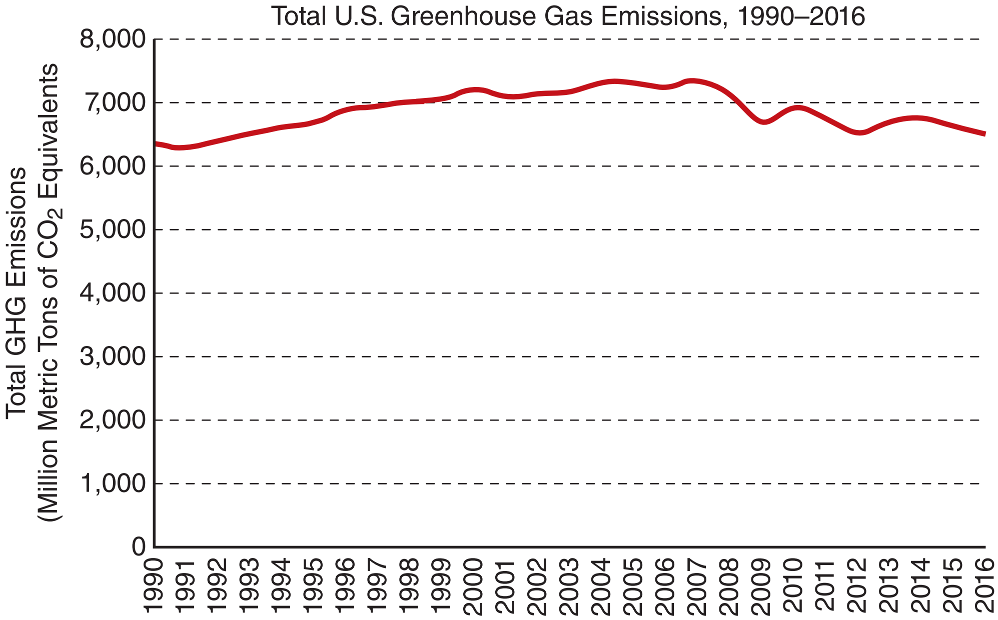

Figure 1-10 U.S. greenhouse emissions.

The earth has a natural process by which concentrations of carbon dioxide in the atmosphere are regulated, known as the "carbon cycle" (**Figure 1-12**). Through processes like plant photosynthesis, carbon is moved from the atmosphere to the land and oceans of the earth. These natural processes are responsible for removing approximately 6.1 billion metric tons of man-made carbon dioxide emissions each year. But this leaves an additional 3.1 billion metric tons of man-made carbon dioxide emissions that are not removed by the carbon cycle and are added to the atmosphere each year. This results in an ever-increasing amount of greenhouse gases accumulating in our atmosphere that are not absorbed naturally.

Because the earth's climate is naturally variable, it is difficult to determine the exact extent of the effect that human activity has had. Computer analysis has shown that increases in greenhouse gases have been correlated to increases in the earth's temperature.

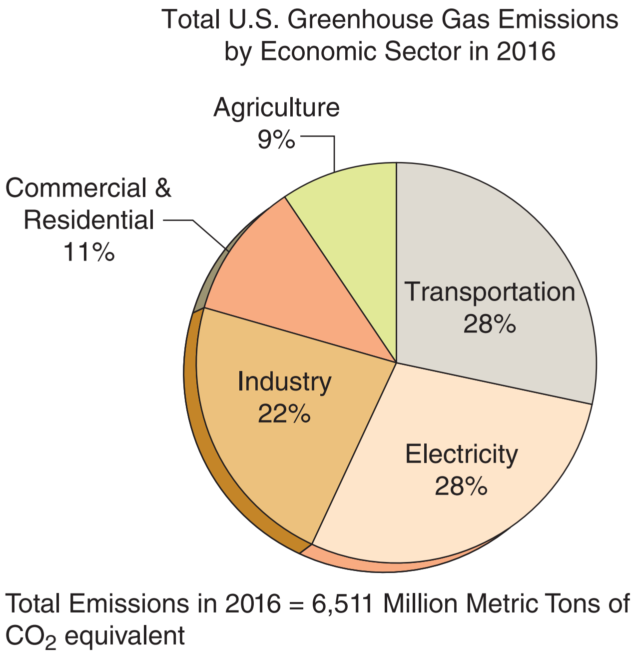

Figure 1-11 U.S. greenhouse emissions by sector.

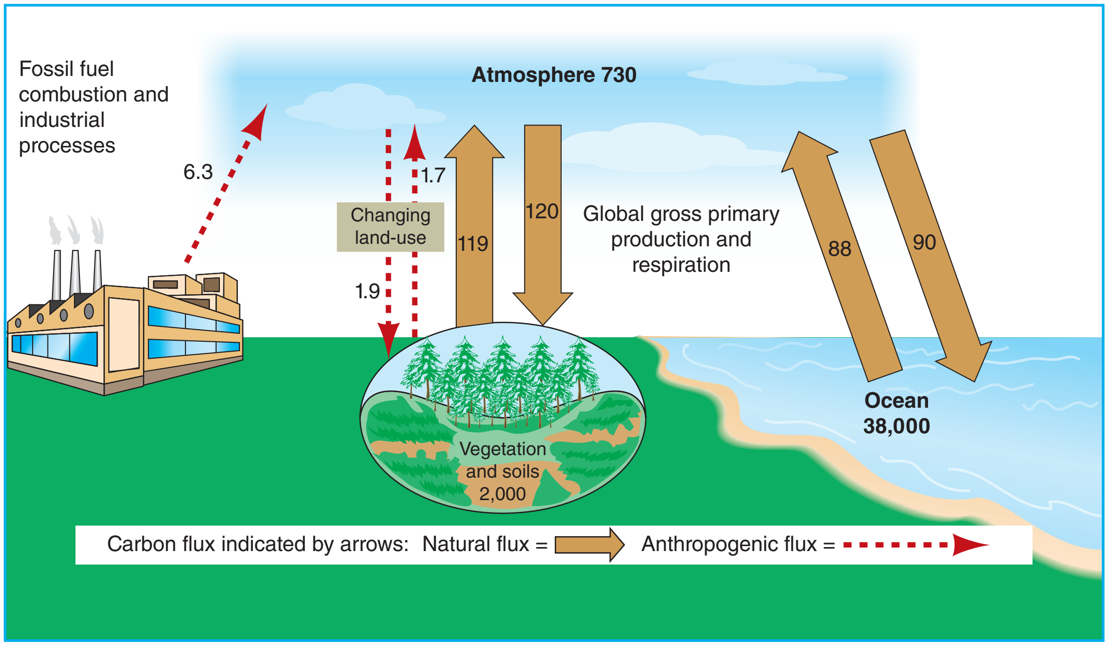

Figure 1-12 The global carbon cycle in billions of metric tons.

This analysis also indicates that rising temperatures may produce changes in sea level and weather commonly referred to as "climate change." A National Research Council study stated:

> *Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and sub-surface ocean temperatures to rise. Temperatures are, in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability.*

In 1992, the National Climate Data Center (NCDC) declared that the winter of 1991–1992 was the warmest U.S. winter in the 97 years that the federal government had kept a record of climatic conditions. The average temperature was 36.87°F (2.7°C). The previous high average temperature of 36°F (2.22°C) was recorded in 1953–1954. Then in 1999, the NCDC declared that 1998 was the warmest year on record. This record was broken once again when the winter of 2016–2017 was declared as the warmest winter in the lower 48, averaging about 4.6 degrees Fahrenheit warmer than the 20th century average. In North America, seven of the eight warmest years have occurred since 2001 with the ten warmest years occurring since 1995 (**Figure 1-13**). This increase in global warming has also increased worldwide rainfall amounts by about 1 percent. Some scientists predict that global surface temperatures could rise 1–4.5 percent over the next 15 years and by 2–10 percent during this century. This could result in sea levels rising by as much as 2 feet along most of the U.S. coastline.

The United States is responsible for producing approximately 16 percent of the global CO_2 emissions by burning fossil fuels (**Figure 1-14**). Our economy is the largest in the world and 80 percent of our energy needs (i.e., electricity generation and transportation) are derived from the burning of petroleum and natural gas (**Figure 1-15**). Unfortunately, both hybrid electric and battery electric vehicles in the United States still ultimately rely on fossil fuels for the majority of their energy. Man-made gases, which include hydro fluorocarbons (HFCs) used as refrigerants, represent two percent of total emissions. The good news is that the United States is predicted to lower its carbon intensity between 2001 and 2025 by 25 percent (**Figure 1-16**). The bad news is that worldwide CO_2 emissions levels are expected to increase by 1.9 percent annually over the same time period, primarily due to increased levels of emissions by developing countries such as China and India. Developing countries' CO_2 emissions levels are expected to increase by 2.7 percent annually between 2001 and 2025 causing industrialized countries' gains to be negatively offset.

According to recent statistics, automobiles in the United States have leaked approximately 51 thousand tons of R134a refrigerant gas into the atmosphere, which is equivalent to 72.8 million metric tons of greenhouse gases. Though this number seems large, it is a very small percentage when compared to the CO_2 emissions generated from the burning of fossil fuels as was noted in Figure 1-15.

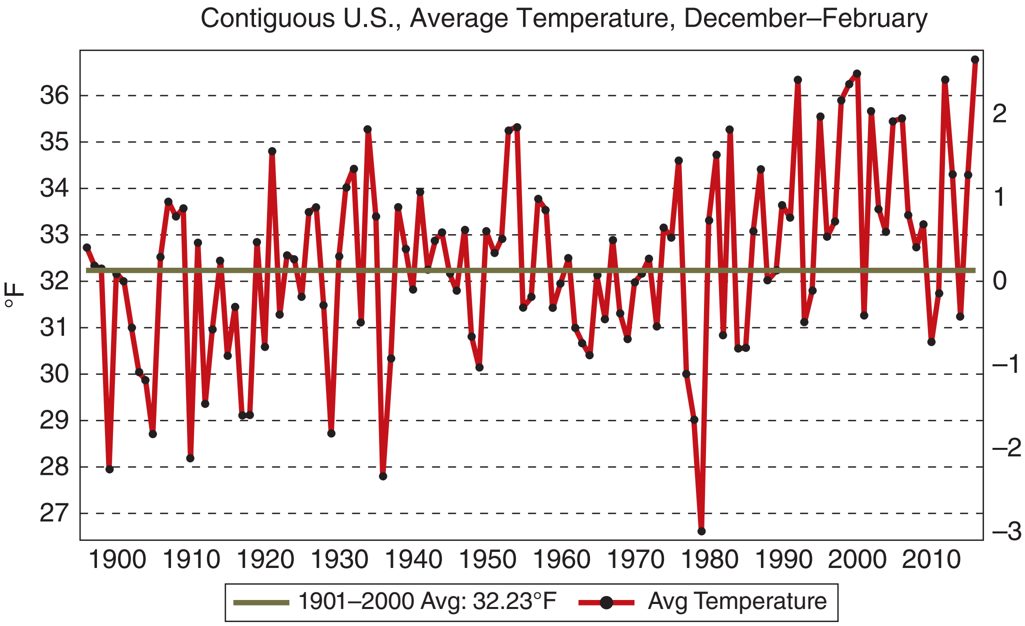

Figure 1-13 U.S. National Climate Data Center 2017 showing an increase in contiguous U.S. temperature.

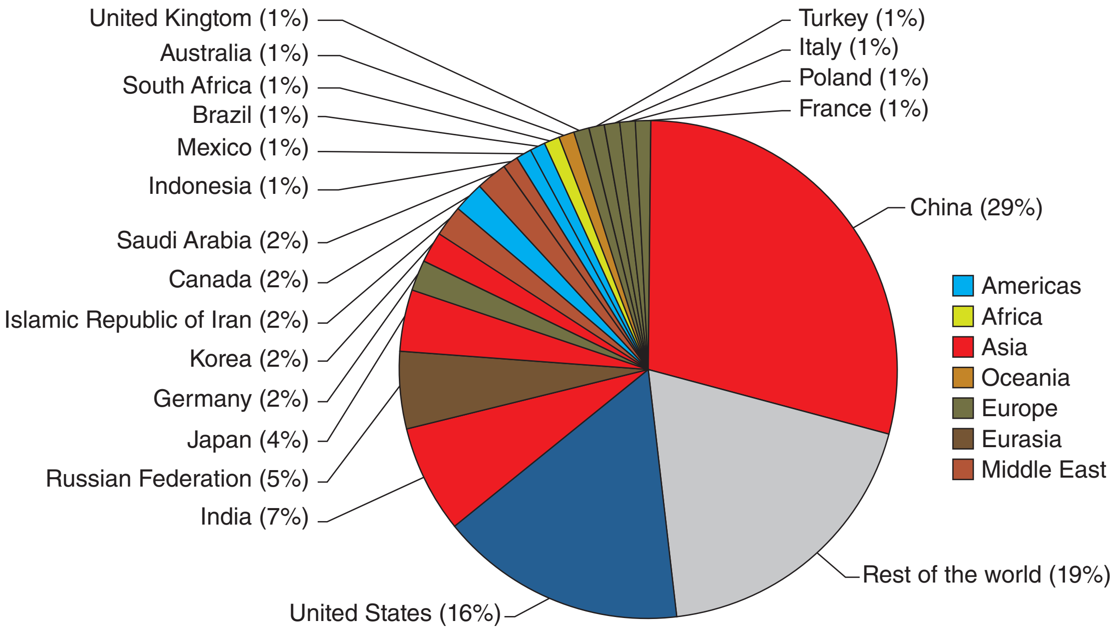

Figure 1-14 CO_2 by country.

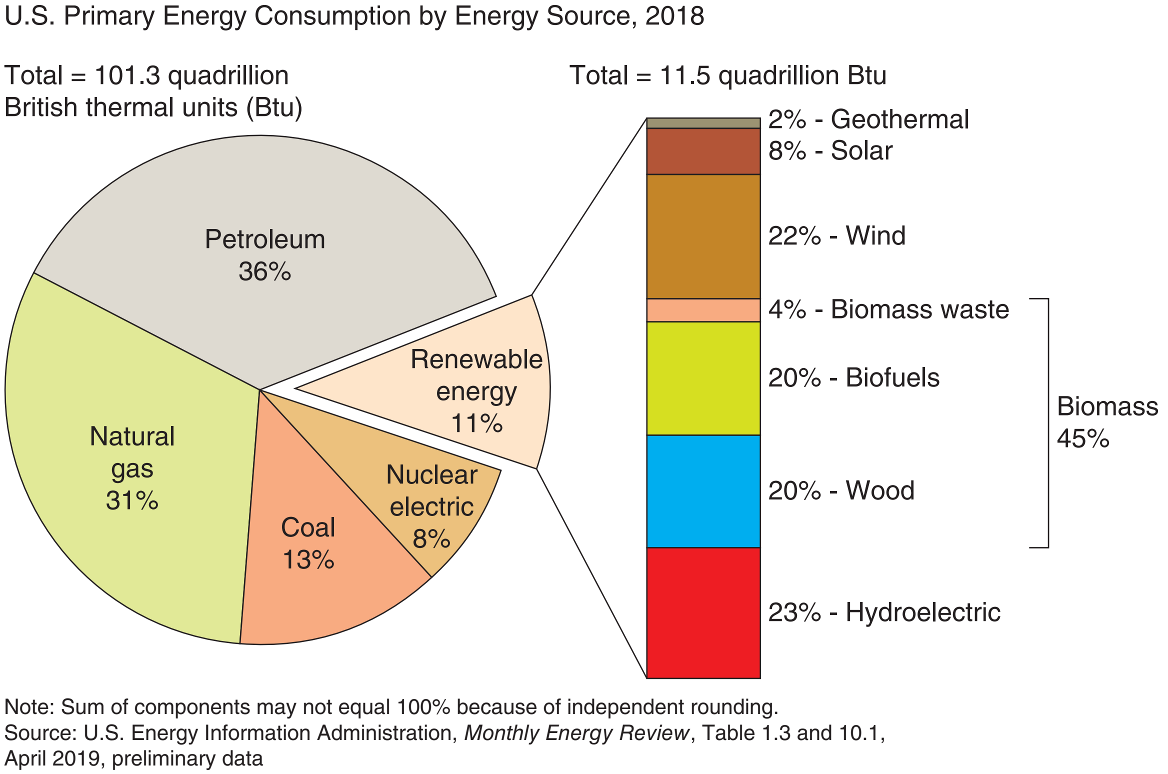

Figure 1-15 United States' greenhouse gas emissions by gas.

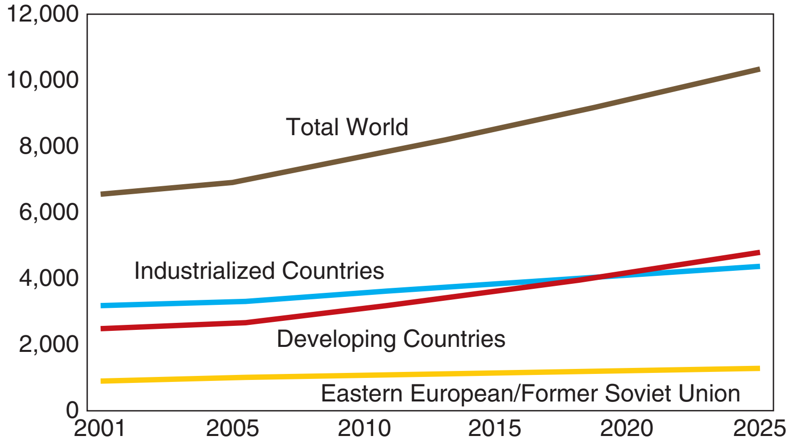

Figure 1-16 Predicted world carbon dioxide emissions by region 2001–2025.

REGULATIONS REDUCING GREENHOUSE GASES

Beginning on January 1, 2011, the European Union EU 2006/40/EC Act provisions went into effect, though the deadline was extended to January 1, 2013, due to the lack of a readily available supply of a new refrigerant. This law was designed to phase out global warming refrigerants with complete phaseout of R134a in Europe by January 1, 2017, for new vehicles sold in EU member countries. The act requires all new automotive platform refrigerant systems to use a refrigerant with a **global warming potential (GWP)** that is not to exceed 150. The GWP number is an index number that is an estimate of how much a given mass of a gas will contribute to global warming compared to the same mass of carbon dioxide, where carbon dioxide is given the number 1.

Global warming potential (GWP) Global warming potential is an index number which is an estimate of how much a given mass of a gas will contribute to global warming compared to the same mass of carbon dioxide, where carbon dioxide is given the number 1.

The refrigerant R134a has a GWP number of 1430, meaning it has 1400 times the greenhouse effect of carbon dioxide. The refrigerant that has been chosen to replace R-134A in Europe is R-1234yf, which has a GWP of less than 1. The environmental life span of CFC refrigerants like R-12 was over 100 years, whereas HFC refrigerants like R-134A have an environmental life span of 13 years compared to R1234yf, which has a much shorter atmospheric life span of only 11 days. Currently the United States has no plan to regulate the use of R134a as a refrigerant gas but is incentivizing manufacturers to choose a lower GWP refrigerant. Many automotive manufacturers began to phase in the use of R-1234yf, which has a lower GWP number beginning in 2013 on some platforms, and other manufacturers began to follow, offering R1234yf on some new platforms. Although higher costs and lack of federal regulation may deter some automotive manufacturers from adopting alternative refrigerants in the U.S. market completely, it is predicted that by 2020s, R-134A may be phased out in the United States (**Figure 1-17**).

Officially R-134a is not going away as far as the United States and the Environmental Protection Agency (EPA) are concerned, at least for the near future, and R-134a will continue to be manufactured and installed in new and existing systems. Europe, on the other hand, as was stated earlier, has required the phaseout of R-134a by 2017. The European Union (EU) has enacted some very stiff environmental rules that are now driving the worldwide mobile HVAC industry to adopt low GWP refrigerants. The European Community mandated that beginning January 1, 2011, any "new type" vehicle platform must change over to a low-GWP refrigerant with a GWP number of 150 or below. R-134a's GWP number is 1430. This does not mean a full-scale changeover was required to a new refrigerant, only on completely "new type" platforms. Existing platforms were allowed to continue to be produced using R-134a until full phaseout in 2017 in the EU. In the United States and Asia, manufacturers are not required to phase out R-134a, although many

OEM	Total # of Models	R-134a %	R-1234yf %
Acura	5	100.00%	0.00%
Audi	9	77.70%	22.20%
BMW	11	0.00%	100.00%
Buick	8	50.00%	50.00%
Chevrolet	17	35.29%	64.70%
FCA	8	12.50%	87.50%
Ford	14	57.14%	42.89%
Genesis	3	33.33%	66.66%
GMC	6	16.66%	83.33%
Honda	9	22.22%	77.77%
Hyundai	8	75.00%	25.00%
Infinity	6	100.00%	0.00%
JLR	7	0.00%	100.00%
Kia	10	30.00%	70.00%
Lexus	9	88.88%	11.11%
Lincoln	5	60.00%	40.00%
Mazda	6	100.00%	0.00%
Mini	2	0.00%	100.00%
Mitsubishi	4	50.00%	50.00%
Nissan	12	100.00%	0.00%
Ram	2	50.00%	50.00%
Subaru	7	71.42%	28.57%
Toyota	14	71.42%	28.57%
Volvo	6	100.00%	0.00%
VW	7	28.57%	71.42%

Figure 1-17 Percentage of vehicles using R-1234yf.

manufacturers that sell vehicles in the United States and elsewhere have chosen to switch to a refrigerant with a lower GWP number in an effort to receive EPA "carbon credits" on some of their platforms. A "carbon credit" is a credit that can be used to offset carbon dioxide (CO_2) production (emissions) above the EPA limit of 250 grams per mile (g/mi.) vehicle fleet average beginning in 2016, which also coincides with more stringent corporate average fuel economy (CAFE) regulations. Like many EPA regulations, the agency does not tell the industry how to achieve these limits, only what they are. The industry has many options on how they will meet these requirements. As an example, think about vehicle tailpipe emission requirements. The EPA did not tell the industry to abandon carburetors; the EPA set emission limits that required the industry to develop new technology in order to meet more stringent emission regulations. In the early stages, the industry developed electronic ignition systems and electronic feedback carburetors and later implemented more sophisticated fuel injection and computer-controlled subsystems. And today when you open the hood, it is almost unrecognizable from the engine compartments of the 1960s. This is the road we are taking once again, but this time the emission gas that is being regulated is CO_2, and if you remember from basic internal combustion engine theory, the higher the CO_2 levels produced after combustion, the more efficient the engine is running. But these CO_2 limits are not just related to tailpipe emissions, they apply to the entire vehicle. Now the industry must decide how they want to meet these new regulations. If a manufacturer decides to switch over to a low-GWP refrigerant, the EPA will issue carbon credits for a reduced carbon footprint. However, if R-134a systems are improved to provide greater fuel efficiency and reduce lifetime leakage, they may also receive carbon offset credits. Beginning in the 2009 model year, improvements in R-134a systems received carbon credits that could be carried forward to when the new regulations are implemented, which in turn reduces the urgency of needing to switch to a new refrigerant. The EPA formula is based, in part, on the SAE J2727 standard for calculating system improvements. As an example of carbon credits, an R-134a system with system improvements and an electric compressor can receive 9.5 g/mi. credit for cars and 11.7 g/mi. credit for trucks compared to the carbon credit received for switching over to R-1234yf of 13.8 g/mi. credit.

So the question in many automotive manufacturer boardrooms is, "Do we need to switch to a new refrigerant to receive carbon credits or can we improve our current R-134a system in order to meet new EPA requirements?" Like many questions, there will be more than one answer and not every manufacturer will make the same choices. But with a global marketplace and economies of scale, the long-term choices will probably be similar.

The Clean Air Act

The most significant legislation to affect the automotive air conditioning industry in the United States is the **Clean Air Act (CAA)**. The CAA was signed into law by U.S. President George H. W. Bush on November 15, 1990. Most of the rules and regulations of the CAA were a result of the recommendations made at the Montreal Protocol. Under the CCA, the EPA mandated the phaseout of refrigerant CFC-12 (R-12). By the 1994 model year, automotive manufacturers had completed the phaseout from R-12 and transitioned to HFC-134a (R-134a).

Clean Air Act (CAA) is a Title 6 Amendment signed into law in 1990 that established national policy relative to the reduction and elimination of ozone-depleting substances.

The Montreal Protocol 1987 and later amendments deal with the environmental problems and issues created by certain refrigerants depleting the ozone on an international level. The CAA deals with this problem on a national level. The Montreal Protocol is structured so that periodic meetings must take place in order to reassess the ozone problem. As new facts about the impact of refrigerants are brought to light, the protocol will be modified accordingly. The majority of protocol modifications will also result in the CAA being modified accordingly.

Language exists in the CAA stating that the Environmental Protection Agency (EPA) can accelerate schedules for the phaseout of refrigerants if it is deemed necessary and practical. The CAA also mandates that phaseout may be accelerated if required by the Montreal Protocol. The Montreal Protocol declared that R-12 has to be completely phased out worldwide by the year 2021.

The CAA is somewhat more specific than the Montreal Protocol in addressing the ozone depletion problem. The act gives the EPA the authority to establish environmentally safe procedures with respect to the use and reuse of refrigerants. In addition, the EPA will establish standards for certifying those who service refrigeration equipment and for that service itself. These standards will be derived from the information furnished mainly by private sector organizations.

Stratospheric Ozone Protection—Title VI

Title VI of the CAA concerns stratospheric ozone protection. It establishes regulations for the production, use, and phaseout of CFCs, halons, and HCFCs. Other chemicals such as carbon tetrachloride (CCI_4), also covered by Title VI, are not covered in this text. Title VI divides the substances to be regulated into two classes: Class I and Class II.

The chemical that we are primarily concerned with in the automotive industry is CFC-12, a Class I refrigerant. Manufacture of this refrigerant ended in the United States on December 31, 1995.

Hydrofluorocarbons (HFCs) are an alternative to ozone-damaging CFCs in refrigeration systems. The refrigerant currently used in automotive air-conditioning systems is HFC-134a, better known as R-134a. HFCs have been designated greenhouse gases, and HFC-134a has an atmospheric lifetime of about 13 years.

Ozone Protection Regulations

For decades, R-12, or Freon, more properly known as CFC-12, was used as the refrigerant in motor vehicle air-conditioning systems. However, since the discovery that CFCs damage the ozone layer, the production of ozone-depleting substances has ended. To help ensure that existing R-12 is used and reused rather than being wasted and released to the atmosphere, the EPA has issued regulations under Section 609 of the CAA to require that automotive shop technicians use special machines to recover and recycle R-12.

On December 31, 1995, the production of R-12 in the United States essentially ceased. It is legal, however, to use existing stockpiles of R-12, and several companies have also developed several new substitutes. These substitute refrigerants have been reviewed by the EPA's Significant New Alternatives Policy (SNAP) program. It is also illegal to release these substitutes to the atmosphere. As of June 1, 1998, the EPA has allowed refrigerant blends used in motor vehicle air-conditioning systems to be recycled. The EPA stipulates that the equipment used must meet Underwriters Laboratories (UL) standards, and the refrigerant must be returned only to the vehicle from which it was removed.

The California Automotive Repair Bureau (CARB) passed a law that went into effect on January 19, 2001, requiring that every shop in the state that performs mobile air conditioning service have a minimum set of diagnostic equipment.

REFRIGERANTS USED IN MOBILE AIR CONDITIONING SYSTEMS

Refrigerant R-12 (CFC-12)

Refrigerant R-12 (CFC-12) was introduced in 1930 and was broadly accepted as the primary refrigerant used in automotive air conditioning systems until it was phased out in 1995 as part of the Clean Air Act Amendment. All CFCs, including R-12, were phased out of production on January 1, 1996. Replacement R-12 refrigerant is only available from stockpiles produced before January 1, 1996 or if recovered from existing equipment. Those who wish to service or repair motor vehicle air conditioners (MVACs) using R-12 as a refrigerant must be trained and certified by an EPA-approved organization. The training program must include pertinent information on the proper care and use of equipment, the regulatory requirements, the importance of refrigerant recovery, and the environmental effects of ozone depletion. To be certified, a technician must pass a test designed to demonstrate his or her knowledge in all of these areas. The supply tank for R-12 is white in color, which applies to both disposable and reusable tanks.

Refrigerant R-134a (HFC-134a)

As the phaseout of R-12 approached, R-134a was selected as the automotive industry's choice as a replacement refrigerant gas for automotive air conditioning systems. Any automotive technician who wishes to repair or service HFC-134a MVACs must also be trained and certified by an EPA-approved agency. If, however, a technician is already trained and certified to repair and service R-12 systems, he or she does not have to be recertified to service R-134a systems.

Characteristics of R-134a (HFC134a). The automotive industry chose R-134a as the replacement refrigerant for R-12. R-134a is an HFC and does not contribute to the depletion of the ozone layer. R-134a is classified as a contributor to global warming and has a GWP of 1430 though, and as such, is regulated. HFC refrigerants replace the chlorine atom with hydrogen atoms. It is a single-composition refrigerant that changes state at a specified temperature and pressure and has similar performance and vapor pressure characteristics to that of R-12. The power consumption is slightly higher for R-134a, and it has a slightly lower refrigeration capacity of between 3 and 5 percent compared to R-12. The properties of R-134a also require the use of different refrigerant oils to provide proper compressor lubrication, which are not compatible with R-12. Components have been redesigned for the different characteristics of R-134a. The supply tank for R-134a is sky blue in color, which applies to both disposable and reusable tanks. Vehicles with R-134a have unique low- and high-side quick-connect coupler service fittings to avoid system contamination by another refrigerant.

Refrigerant R-1234yf (HFO-1234yf)

The refrigerant that is the preferred replacement for R-134a today is R-1234yf, pronounced R twelve thirty four yf. The new refrigerant was developed by Honeywell and DuPont and is classified as HFO-1234yf (R-1234yf); HFO stands for hydrofluoro olefin and has a chemical structure of CF3CF 5 CH2 2,3,3,3-tetrafluoropropene. The refrigerant has been determined to be mildly flammable gas. R-1234yf is an environmentally friendly refrigerant that has no ozone depletion potential; a global warming potential (GWP) of less than 1, which is 99.7% lower than R-134a; and has a vapor pressure of 583 kPa absolute at 20°C and a boiling point of −29.2°C. This new refrigerant received final EPA approval under the Significant New Alternatives Program (SNAP) for use in mobile air-conditioning (MAC) systems in early 2011. But the changeover to this new refrigerant may be very slow. General Motors began rolling out a few platforms equipped with R-1234yf in the United States on a very limited basis beginning in 2013. Vehicles with R-1234yf have unique low- and high-side service fittings to avoid system contamination by another refrigerant. The fittings are similar to R-134a fittings, but smaller.

Honeywell developed the commercially viable R-1234yf as a low-cost, low-GWP drop-in refrigerant replacement for R134a refrigerant. This new refrigerant is expected to significantly reduce the global warming footprint associated with air-conditioning systems. The GWP of R-1234yf is 4 compared to R-134a, which has a GWP of 1430. Many environmental groups still favor other refrigerant options such as CO_2 (R744), which has a GWP of 1, but for now the higher production costs of these systems has stalled development and production for automotive applications. R-1234yf has an atmospheric lifetime of 11 days and the atmospheric breakdown products are the same as R-134a, trifluoroacetic acid (TFA), which does not pose a threat to the environment, based on industry evaluations that took place in the 1990s. In fact, TFA is found in large amounts in the oceans of the world and it has been suggested that TFA is a natural component of saltwater.

On August 8, 2017, the U.S. District Court of Appeals reversed a 2015 EPA rule which would have removed R-134a from their SNAP list of acceptable substitute refrigerants for newly manufactured passenger cars and light trucks beginning with the 2021 model year (MY). As of October 2018, the Supreme Court decided not to review the case, leaving in place the 2017 ruling, which means that the use of high-GWP refrigerants, such as R-134A, remains legal and there is no plan for mandatory phaseout as of the time of this writing. Because it does not appear that the United States is going to regulate R-134a out of existence, manufacturers do not have to stop using R-134a in new vehicle platforms as they did with R-12. One incentive for automotive manufacturers to switch to R-1234yf is that the EPA does grant fuel economy credits for the use of R-1234yf. Because R-134a will still be produced and available, there will be some manufacturers that will incorporate production R-1234yf systems along with R-134a. In addition, retrofitting from R-134a to R-1234yf has not been approved or allowed by the EPA. In the end, what may keep the U.S. automotive industry from changing over to R-1234yf on all vehicle platforms may be economic—higher product costs and a single supplier. Honeywell-DuPont is retaining sole patent and production rights and ultimately that may be too large an issue for the automotive industry to overlook. The supply tank for R-1234yf is white with a red band to denote flammability, which applies to both disposable and reusable tanks.

Blend Refrigerants

Automotive technicians who service or repair MVACs that use a blend refrigerant must be trained and certified by an EPA-approved agency. However, a technician that is already trained and certified to handle CFC-12 or HFC-134a does not have to be recertified to handle a blend refrigerant.

REFRIGERANT CYLINDERS

It is a violation of federal law to reuse a disposable refrigerant cylinder.

Refrigerant cylinders (**Figure 1-18**) are designed and constructed for definite maximum pressures and for definite quantities of refrigerant that are based on specified maximum temperatures, usually 130°F (54°C). The color of the cylinder indicates the type of refrigerant gas that it contains. A white cylinder indicates R-12, sky blue identifies R-134a, and a white cylinder with a red band around the top indicates R-1234yf refrigerant (**Figure 1-19**). If the cylinders are subjected to temperatures above those specified, the liquid expands to entirely fill the cylinder; extremely high hydrostatic pressures develop, and the cylinder may burst.

If the cylinders are filled with a greater amount of refrigerant than specified, hydrostatic pressures may develop at ordinary room temperatures, and the cylinder may burst.

Figure 1-18 Refrigerant cylinders are designated for a particular type refrigerant; (A) 30-pound (12.08 kg) cylinder R-12; and (B) 30-pound (12.08 kg) cylinder R-134a.

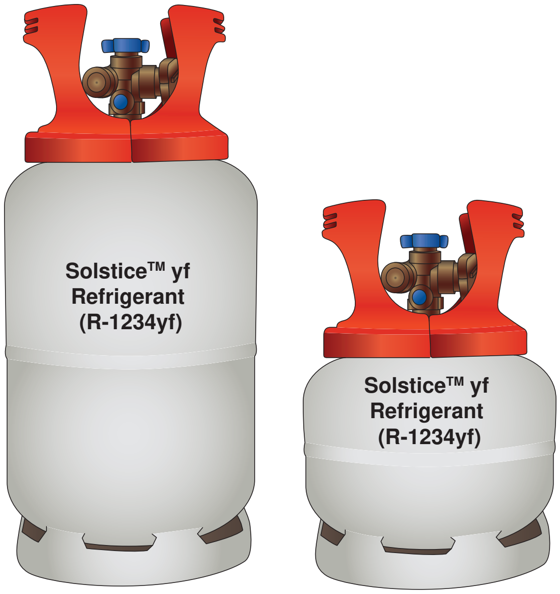

Figure 1-19 The R1234yf refrigerant tank is white with an identifying red band because it is a mildly flammable refrigerant.

Flying pieces of the cylinder may travel at bullet velocity, or in the case of small cylinders or light containers, the container itself may travel like a rocket at projectile speed. Sometimes of equal or greater danger, the refrigerant itself may burst from the cylinder; technicians have been blinded or suffered freezing injuries from being sprayed with refrigerant.

Many factory cylinders are equipped only with fusible plugs, which offer no protection against overfilling; nor do they offer adequate protection on most cylinders against excessive temperatures. Fusible plugs melt at about 160°F (71°C) and most cylinders are liquid-full at 130°F (54°C), so the fusible plug gives no protection between 130°F and 160°F.

All refrigerant cylinders should be protected by means of pressure-activated relief valves, especially service cylinders, because they are more often abused by overfilling than are factory-filled cylinders. Small combination service valves, with built-in pressure-relief safety valves, were developed by valve manufacturers in cooperation with the Refrigeration Service Engineers Society (RSES) safety and educational department and are available at moderate prices from refrigeration supply wholesalers. Every service cylinder should be equipped with one of the safety valves.

Pressure relief valves are provided to release excess pressure.

Even with the best of care, cylinders become rusted, damaged, or otherwise weakened after several years of use and should be retested by a hydraulic test approved by the Interstate Commerce Commission (ICC). The ICC requires a retest of all service cylinders and most factory cylinders once every 5 years (**Figure 1-20**). Do not use cylinders beyond the 5-year period without having them retested. It may save your life or prevent serious injury. Your refrigerant supplier should be able to suggest a laboratory for retesting refrigerant cylinders. If not, consult the Yellow Pages of your local telephone directory under Hydrostatic Testing for the nearest facility.

Do not refill disposable cylinders.

Corrosion may occur inside a refrigerating system and may also affect external parts. It is commonly due to rusting in damp atmospheres or in areas in which there is a great deal of acidity in the air. As a rule, the parts most likely to be seriously affected are bolts, screws, nuts and rivets, or comparatively thin-walled vessels or tubes, especially those made of iron or steel. Particularly in damp or acidic atmospheres, these parts should be inspected occasionally and repaired or replaced if necessary. Keeping parts subject to corrosion properly painted will greatly extend their useful life and lessen the possibility that they will suddenly give way, causing an accident. Using protective paints and greases is an inexpensive preventative maintenance that guards against the dangerous and costly

Figure 1-20 Service cylinders must be reinspected every 5 years.

breakage of corroded and weakened parts. Water supply lines, gate valves, fittings, and automatic pressure and control valves should be inspected periodically; badly corroded or weakened parts should be replaced.

EPA TECHNICIAN TRAINING CERTIFICATION

Automotive technicians who wish to service mobile air-conditioning systems and refrigeration equipment must be certified by an appropriate testing agency approved by the EPA and receive an EPA section 609 Technician Training Certification. This includes all who work with R-12, R-134a, and R1234yf, or any of the blend refrigerants available and approved for automotive use. As of January 1, 2018, a Section 609 certification card is required to purchase R-134a, or R-1234yf cylinders of 2 pounds or greater and any size container of R-12.

Certificating Agency

If there is any doubt about the integrity of the agency offering training and certification, check with the EPA. The EPA maintains an updated list of all of the approved agencies. The EPA has little mercy for anyone issuing bogus technician certificates to those who have not taken the required exam and can impose prison sentences and fines.

INJURIES AS A RESULT OF HIGH PRESSURE

A basic characteristic of a mechanical refrigeration system is the use of a fluid, both gas and liquid, that is at pressures above atmospheric pressure. The fluid must, therefore, be maintained and transmitted in tanks, pipes, and other vessels that do not allow the fluids to leak and that are strong enough to withstand maximum pressures without splitting or bursting under extreme conditions of use.

It is also a basic characteristic of mechanical refrigeration that these pressures change with fluctuations in temperature or are increased by compressors or pumps. We must,

Figure 1-21 An accumulator is a pressure vessel designed to withstand the normal pressures of an air-conditioning system.

therefore, guard against extra pressures caused by compressors and pumps, as well as the pressures existing in the system because of variations of temperature.

Pressure-containing vessels (**Figure 1-21**) and tubes are designed and constructed to withstand normal pressures caused by normal temperatures, by normal degrees of compression, and normal filling of the vessels. If the vessel or tube is overheated, if an attempt is made to put too much fluid in it, or if the fluid is compressed above the pressure for which the vessel is designed or constructed, the vessel will "give" somewhat until it reaches its limit of elasticity; then the vessel will burst, often with explosive violence.

Overpressure may cause large parts to be blown out, such as the welded ends of dryers or of receivers. Overpressure may also drive plugs or other small parts out with projectile speed and force.

Explosions or bursting of vessels from overpressure sometimes start with overfilling the vessels with liquids at lower temperature. Then when the completely filled vessel warms up, the liquid expands and exerts tremendous pressure, known as **hydrostatic pressure**. In other words, hydrostatic pressure occurs when a cylinder is full of a liquid and there is no room for expansion as it heats up. As a result, something has to give, and it is the weakest part that gives. Oftentimes it is a hose or hose connection. Sometimes it is the compressor head gasket or a head, which may be most dangerous.

Hydrostatic pressure is the pressure exerted by a fluid.

SPECIAL SAFETY PRECAUTIONS

Because it is very important that the student be aware of the hazards involved in the use of any refrigerant, the following safety procedures must be observed at all times. Recall that refrigerant is:

- Odorless
- Undetectable in small quantities
- Colorless
- Nonstaining

However, refrigerant is dangerous because of the damage it can cause if allowed to strike the human eye or come into contact with the skin. Suitable eye protection must be worn to protect the eyes from splashing refrigerant (**Figure 1-22**). If refrigerant does enter

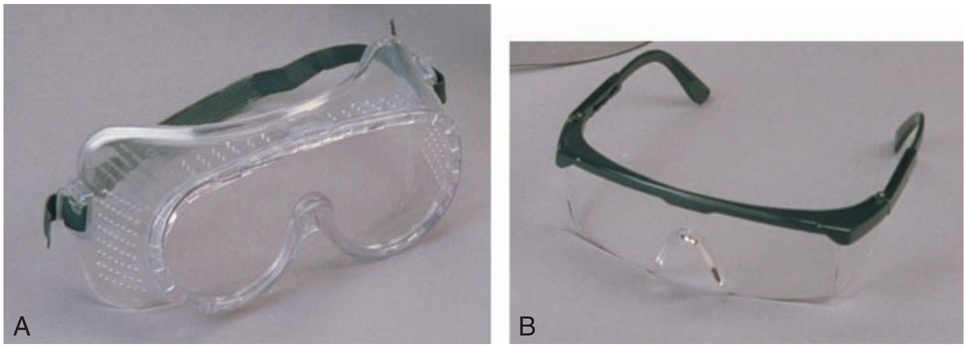

Figure 1-22 Wear suitable eye protection: (A) monogoggle; (B) safety glasses.

Do not attempt self-treatment for injury.

the eye, freezing of the eye can occur with resultant blindness. The following procedure is suggested if refrigerant enters the eye(s):

1. Do not rub the eye.
2. Splash large quantities of cool (not hot) water into the eye to raise the temperature.
3. Tape a sterile eye patch over the eye to prevent dirt from entering. Do not use salves or ointments.
4. Go immediately to a doctor or hospital for professional care.

If liquid refrigerant strikes the skin, frostbite can occur. The same procedure outlined for emergency eye care can be used to combat the effects of refrigerant contact with the skin. Refrigerant in the air is harmless unless it is released in a confined space. In a refrigerated trailer with an evaporator leak, it is possible that the refrigerant could displace the oxygen, resulting in an oxygen-depleted environment. Always exercise caution when a refrigerant leak is suspected in a sealed or confined space and allow for adequate ventilation before performing services. Under these conditions, refrigerant displaces oxygen in the air and may cause drowsiness or unconsciousness—even death. However, the automobile owner and the service technician need not be overly concerned about the safety of the automotive air-conditioning system under normal conditions. The small capacity of the system compared to the large area of the car interior or work area minimizes the concentration of any contamination.

Refrigerant must not, however, be allowed to come into contact with an open flame or a very hot metal. Tests made by UL in 1933, shortly after the development of CFC-12, indicated that it produced a highly toxic gas known as phosgene during decomposition. Tests in recent years, however, prove that phosgene gas is not a product of decomposition in this manner. Decomposition does, however, result in the formation of carbonyl fluoride (COF_2) and carbonyl chlorofluoride (COClF) with small amounts of free chlorine (CI_2).

Though 20–50 times less toxic than phosgene, as discussed earlier, the decomposed gases of CFC-12 must be avoided. At high concentrations, the lack of oxygen, which results in asphyxiation, is the real hazard. A primary rule, then, is to avoid breathing these or any other fumes. The human body requires oxygen in the quantity found in noncontaminated air. Diluting air with any foreign gas can reduce the available oxygen to a level that may be harmful or, in some cases, fatal.

The following rules must always be observed when handling refrigerants:

1. Never heat a refrigerant cylinder above 125°F (51.7°C) or allow it to reach this temperature. Above 130°F (54.44°C), expanding liquid refrigerant completely fills the container, and hydrostatic pressure builds up rapidly with each degree of temperature rise.
2. Never apply a direct flame to a refrigerant cylinder or container. Never place an electrical resistance heater near or in direct contact with a container of refrigerant.

3. Do not abuse a refrigerant cylinder or container. To avoid damage, use an approved valve wrench for opening and closing the valves. Secure all cylinders in an upright position for storing and withdrawing refrigerant. Carefully invert a refrigerant cylinder to dispense liquid refrigerant (first ensuring that the compressor is not running). Recovery cylinders are not to be inverted; use the liquid valve for dispensing liquid refrigerant (again ensuring that the compressor is not running).
4. Do not handle refrigerant without suitable eye protection.
5. Do not discharge (vent) refrigerant into the atmosphere. Remove refrigerant from a system using approved recovery equipment only.
6. Use only Department of Transportation (DOT) approved refrigerant recovery cylinders (**Figure 1-23**). Do not fill recovery cylinders beyond 80 percent of their rated capacity.
7. Do not mix refrigerants. Cross-contaminated refrigerants must be destroyed or separated by an approved reclamation center.
8. For an automotive air-conditioning system, do not introduce anything but refrigerant acceptable under EPA's SNAP program into the system.
9. Use only lubricant recommended for the refrigerant type. Properly identify, by label and fittings, refrigerant used.
10. Keep refrigerant containers out of direct sunlight.
11. Always work in a well-ventilated area. DO NOT work in a confined area.

It is a violation of federal law to intentionally vent refrigerant to the atmosphere.

ENGINE ANTIFREEZE/COOLANT

There are four key areas of engine protection. These are:

- Freeze protection
- Boil-over protection
- Corrosion prevention
- Adequate heat transfer

The term engine coolant is widely used in the automotive industry when referring to antifreeze. This is especially true in warmer climates where the temperature never drops below freezing.

Ethylene Glycol–Based Antifreeze

Ethylene glycol (EG) is the main ingredient of all major antifreeze brands and has long been known to be poisonous. When ingested, EG converts to oxalic acid, which damages the kidneys and may cause kidney failure and death.

Just 2 ounces of undiluted EG antifreeze (**Figure 1-24**) can kill a dog; 1 teaspoon can be lethal to a cat; and 2 tablespoons can be hazardous to children.

Figure 1-23 Use only DOT-approved recovery cylinders.

Figure 1-24 Ethylene glycol antifreeze.

Data compiled by the American Association of Poison Control Centers showed that about 3,400 poisonings related to EG occur annually. About 20 percent of these incidents are reported among children under 6 years of age. Due to public pressure, antifreeze manufacturers voluntarily agreed to add a bitter flavoring agent beginning January 2013.

Propylene Glycol–Based Antifreeze

A "new" antifreeze, formulated with propylene glycol (PG), is less toxic than EG antifreeze. Therefore, PG antifreeze (**Figure 1-25**) is much safer for children and animals. Actually, PG is used in specific amounts in the formulation of many consumer products. These products include, but are not limited to, cosmetics, pet food, and certain over-the-counter medications. Nonetheless, PG-based antifreeze should be considered toxic and handled as a hazardous substance.

In areas where recycling antifreeze is required, one may locate a facility through a local automotive parts house or in the telephone book's Yellow Pages under *Recycling Centers* or *Hazardous Materials and Waste Contractors*.

Mixing EG and PG

It should be noted that EG-based antifreeze should not be mixed with PG-based antifreeze. Most antifreeze manufacturers caution against mixing the various types and suggest recovery and storage of the different types in separate containers. Also, most vehicle manufacturers require the same type antifreeze be used for top-off or refill that was originally installed in the factory fill to avoid warranty problems. It should be noted that there may be different formulations of antifreeze specified by some vehicle manufacturers. Always refer to manufacturer's specifications before changing or adding antifreeze to a cooling system.

Vehicle Engine Protection

Either EG- or PG-based antifreeze offers excellent protection for vehicle engines against corrosion, freezing, and overheating. A 50/50 blend of ethylene glycol antifreeze and water has a freezing point of −34°F (−36.7°C). If a lower temperature protection is required, it can be attained by increasing the concentration of antifreeze. A 60/40 blend, for example, gives antifreeze protection to −54°F (−47.8°C). It also helps to prevent corrosion in all metals used in automotive cooling systems, including aluminum, brass, copper, cast iron, steel, and the elements contained in solder.

Figure 1-25 Propylene glycol antifreeze.

Disposal

Used coolant must be properly disposed of in compliance with local rules and regulations. In areas where recycling is available, both used EG and PG coolants should be offered to recyclers for recycling and reuse.

HAZARDOUS MATERIALS

Refrigerants, refrigeration lubricants, solvents, and other chemicals used in an automotive repair facility may be considered hazardous materials and will include warning and caution labels that should be read and understood by everyone who uses them.

All hazardous materials should be properly labeled, indicating what health, fire, or reactive hazard they pose and what protective equipment is necessary when handling each chemical. The manufacturer of the hazardous material must also provide all warnings and precautionary information that must be read and understood by all users before the material is used. One should pay particular attention to the label information. Using the product according to label directions helps to ensure proper and safe methods, thereby preventing a hazardous condition.

A list of all hazardous materials used in the shop should be posted for all employees to see. Shops must also maintain documented records of the hazardous chemicals in the workplace, training programs, accidents, and spill incidents.

Material Data Sheets

Every employee in a shop is protected by "right-to-know" laws concerning hazardous materials and wastes. The general intent of the law is to ensure that the employer provide a safe work environment. All employees must be trained about their rights under the legislation, the nature of the hazardous chemicals in their workplace, the labeling of chemicals, and the information about each chemical listed and described on Material Data Sheets (MDS). These sheets (**Figure 1-26**) are available from the manufacturers and suppliers of the chemicals. They detail the chemical composition and precautionary information for all products that can pose health or safety hazards.

Employees must be familiar with the contents of the MDS that contain information relative to the intended purposes of the substance, the recommended protective equipment, accident and spill procedures, and any other information regarding safe handling. Training must be provided by the employer annually, and new employees must be trained as a part of their job orientation. When handling any hazardous material, always wear the

Figure 1-26 Typical Material Data Sheet (MDS) manual.

appropriate safety protection. Always follow the correct procedures while using the material, and be familiar with the information given in the MDS for that material.

Hazardous Waste

Waste is considered hazardous if it is on the EPA list of known harmful materials. Those materials generally have one or more of the following characteristics:

- Ignitable
- Corrosive
- Reactive
- Toxic

Many service procedures also generate products that may be considered hazardous wastes. Contaminated refrigerants or antifreezes are typical examples of hazardous waste.

Safety Precautions

The following safety precautions in working with hazardous materials should always be observed:

- Do not overfill refrigerant cylinders.
- Do not allow pressure-containing vessels to become overheated.
- Do not put a flame on a refrigerant cylinder, accumulator, receiver, or any other vessel that may contain refrigerant.
- Do not steam clean any vessels that may contain refrigerant.
- Do not change or add refrigerant to any system without first determining system compatibility.
- Always connect both low- and high-pressure gauges before servicing a system. Observe these gauges frequently.
- Before loosening bolts or screws, see that the pressure in the part has been relieved. Gaskets may hold the pressure temporarily, then release suddenly, throwing a full charge of refrigerant in the technician's face.
- Use pressure relief valves on all refrigerant cylinders and other vessels that may be subject to excessive pressures.
- Do not allow a compressor to pump liquid or "slug oil."
- Wear suitable protective gear when handling any materials that may be considered toxic.
- Keep your mind on what you are doing.
- Be vigilant.
- If you are tired, take a break.
- Read and heed all caution labels. Those warning of high pressures, as in the antilock brake systems, and the dangers of unexpected air bag deployment are most important.
- Be aware of under-hood hazards and avoid their danger.

AUTHOR'S NOTE When you first begin a new job in an automotive shop, you will have many concerns on your first day. Pay particular attention to the location of all exits from the building, fire extinguishers, eye wash stations, the emergency shower, and where the MDS data book is located in case of emergency. An emergency situation is not the time to try to locate safety equipment or exits.

BREATHING TOXIC GASES

Literally the word *toxic* means "poisonous," so "toxicity" is the condition of being "poisonous." In refrigeration terms, "toxic" is more frequently used with gases that we may breathe in and that poison us by being taken into our blood by means of the lungs.

Refrigerants vary a great deal in their degrees of toxicity. Some refrigerants, such as ammonia (NH_3), are so highly toxic that it is dangerous, as well as unpleasant, to breathe air that has only a few parts per million of these gases. Others, such as R-12, may be breathed in large percentages with air without noticeably harmful effects.

It must be remembered, however, that the gas we as humans are suited to breathe is air, which is approximately 21 percent oxygen, 78 percent nitrogen, and 1 percent other inert gases. Any other gas, especially in large concentrations, may be harmful or fatal. Harmful effects depend upon:

- The nature of the gas itself,
- Its concentration in air, and
- How long a time it is breathed.

Decomposition of Gases

Some gases that may have a high safety rating or moderate safety ratings in their natural state become highly toxic if they are exposed to flames or hot surfaces. The heat "decomposes" these relatively safe gases and causes them to form other gases that are very toxic.

The refrigerants thus decomposed are those that contain one or more of the **halogens**, a group of elements that includes chlorine (Cl), fluorine (F), bromine (Br), and iodine (I). Any of the refrigerants that have the symbols "Cl" or "F" in their chemical structure may be subject to hazardous decomposition.

Halogen refers to any of the five chemical elements that may be found in some refrigerants: astatine (At), bromine (Br), chlorine (Cl), fluorine (F), and iodine (I).

Refrigerants should not be allowed to come into contact with an open flame or a very hot metal. Until recently, it was believed that fluorocarbon refrigerants, such as R-12, produce phosgene gas when exposed to hot metal or an open flame. The original tests, made by UL shortly after the development of R-12, indicated that it produced this highly toxic gas during decomposition. Recent tests, however, have shown that phosgene gas is not produced in this manner.

According to a technical specialist for SUVA® Refrigerants at DuPont Chemicals, which was one of the major manufacturers of R-12, commonly known as Freon®, the only products of decomposition of R-12 when in contact with an open flame or glowing metal surface, are hydrofluoric and hydrochloric acids.

Though as much as 50 times less toxic than phosgene gas, the decomposed gases of R-12 must be avoided. At high concentrations, lack of oxygen, which results in asphyxiation, is the real hazard. Avoid breathing these or any other fumes. The human body requires oxygen in the quantity found in noncontaminated air. Diluting air with any foreign gas can reduce the available oxygen to a level that may be harmful or, in some cases, fatal.

These gases of decomposition may not noticeably affect the person breathing them for several hours, so you should vacate the area contaminated by them as soon as you detect them by smell. Also, beware of the gases from burning plastics; one of these is the extremely dangerous phosgene ($COCI_2$).

Precautions. If the nature of the various refrigerants and other gases and fumes are understood and if reasonable care is exercised, a refrigeration service technician need have no fear of possible toxic hazards from refrigerants. One must use care, however, and in particular observe the following:

- Do not breathe any gas any more than is absolutely necessary. None of them is harmless under all conditions.
- Do not ignore the possible danger of a gas just because it has very little odor. The odor of a gas is no indication of its toxicity. Do not discharge any gas into any unventilated area.
- Do not discharge any of the hydrocarbon gases into a room in which there is a fire, flame, or electric heating element.

- Do not hesitate to use a gas mask if it is necessary to enter a room that you know or suspect has any of the toxic gases in it.
- Do not leave leaks in refrigerating equipment that may fill the room with gas and pose a danger to someone.
- Do not run an automobile engine in a closed garage; do not sit in a closed car with the engine running.
- Do not allow liquids to boil over on a gas stove; they may put out the flame, but the gas continues to escape.
- Do not use questionable tubing, flexible hose, or connectors.
- Do not work in an unventilated room with a heater having an open flame.
- Do not vent refrigerant. The EPA requires that all refrigerant be recovered.
- Do not breathe fumes from acids, caustics, carbontetrachloride, benzol, ketone, xylene, or other toxic cleaning materials. Always keep rooms well ventilated when using cleaning solvents.
- Do not breathe fumes from broken fluorescent lamps; they are poisonous.

ASE CERTIFICATION

The National Institute for Automotive Service Excellence (ASE) has established a certification program for the automotive heating and air conditioning technician (**Figure 1-27**). This is one of the eight automotive certification areas that lead to certification as a Master Auto Technician (**Figure 1-28**). ASE also offers other certification programs in other areas, such as heavy-duty truck, collision repair, school bus, engine machine shop technician, parts specialist, alternate fuels, and advanced engine performance.

ASE's voluntary certification system combines on-the-job experience and tests to confirm that technicians have the necessary skills to work on today's vehicles. The ASE Master Auto Technician status certification is awarded when a technician passes all eight tests that address diagnostic and repair problems in the following areas:

1. Engine repair
2. Automatic transmission/transaxle

Figure 1-27 A typical ASE certificate.

Figure 1-28 A certified Master Auto Technician.

3. Manual transmissions and drive axles
4. Suspension and steering
5. Brakes
6. Electrical/electronic systems
7. Heating and air conditioning
8. Engine performance (drivability)

After passing at least one ASE-administered exam and providing proof of 2 years of hands-on work experience, the technician becomes ASE certified in that particular area. The ASE certification is valid for 5 years. Retesting is necessary every 5 years to renew certification.

Work Experience Credit

The technician may be given credit for one of the 2 years of work experience by substituting relevant formal training in one, or a combination, of the following:

- Secondary training: 3 years of high school training in automotive repair may be substituted for 1 year of work experience.
- Postsecondary training: 2 full years of training after high school in a public or private trade school, vocational-technical institute, community college, or 4-year college may be counted as 1 year of work experience.
- An apprenticeship program: The completion of a state-approved apprenticeship program may be counted as 1 year of work experience. Full credit for the experience requirement is given for satisfactorily completing a 3- or 4-year apprenticeship program. Specialty and short courses: For shorter periods of postsecondary training, one may substitute 1 month of work experience for every 2 months of training.

Test Content

The current heating and air conditioning test consists of 50 multiple-choice questions as follows:

Content Area	Questions	Percent of Test
A/C system diagnosis and repair	17	34
Refrigeration system components diagnosis and repair Compressor and clutch (5) Evaporator, condenser, and related components (5)	10	20
Heating and engine cooling systems diagnosis and repair	4	8
Operating systems and related controls diagnosis and repair Electrical (10) Vacuum/mechanical (2) Automatic and semiautomatic heating, ventilating, and A/C systems (7)	19	38
Total	50	100%

Additional Questions

The test could contain up to ten additional questions for statistical research purposes that will not affect your score. The 5-year recertification test covers the same content areas as those listed above; however, the number of questions in each content area will be reduced by about 50 percent.

The Questions

The questions are written by a panel of technical service experts, including domestic and import vehicle manufacturers, repair and test equipment and parts manufacturers, working automotive technicians, and automotive instructors. All questions are pretested by a national sample of technicians before they are included in the actual test. Many test questions force the student to choose between two distinct repair methods. Questions similar to the *Technician A, Technician B* format are included in the review questions at the end of each chapter in this text as well as in the Shop Manual.

Why Certify with ASE?

In a word, "recognition." Being an ASE-certified technician provides credentials that attest to your professional abilities to your peers as well as to your prospective employer. As a matter of practice, although ASE certification is voluntary, many employers ask for certified applicants when advertising for employment, or they state "ASE certification preferred." In no small part, certification demonstrates to the employer one's ability to read—an important requirement for technicians of the future.

EPA CERTIFICATION

To purchase refrigerant or service air conditioning and refrigeration (ACR) systems, one must be certified under section 608 or 609 of the CAA through an agency approved by the EPA. A "609-certified technician" is someone certified by an EPA-approved agency for servicing MVAC and MVAC-like air-conditioning systems. The exam for this certification is open book and is generally available by mail from professional organizations, such as Mobile Air Conditioning Society (MACS), ASE, and others. Testing may also be available in an instructor-led classroom setting.

Under the CAA, a 609-certified technician is not permitted to service domestic or commercial air conditioning or refrigeration equipment, even though the equipment may be similar to an automotive air-conditioning system. A small domestic air conditioner, for example, contains far less refrigerant than the average MVAC; however, a 609-certified technician cannot legally service it. This service requires a 608-certified technician.

A 608-certified technician is someone certified by an EPA-approved agency for servicing particular types of ACR systems. The exam for this certification, with one exception, is closed book and is proctored at an approved test site. There are actually four classes of certification, as follows:

1. Type I: One who services high-pressure ACR systems with a capacity of up to 5 pounds of refrigerant.
2. Type II: One who services high-pressure ACR systems with a capacity over 5 pounds of refrigerant.
3. Type III: One who services low-pressure systems, such as centrifugal systems, with up to hundreds of tons of refrigerating capacity.
4. UNIVERSAL: One who is certified in all three types.

The exception to the above is that one may be certified for "small appliances" by taking an open-book exam that is generally administered by mail. This certification, equivalent to Type I, is much more convenient. It is available from trade organizations listed in the Appendix.

For simplicity, some automotive technicians are certified under both sections 608 and 609. For example, one may purchase refrigerant and other supplies at either an automotive parts or refrigeration supply store. When purchasing HFC-134a, for example, the automotive supplier only has cylinders with the "unique" fitting required by EPA. The refrigeration supply store, on the other hand, can supply the cylinder with either fitting: ½-in. Acme for automotive use or ¼-in. SAE for commercial use.

Depending on geographical location, refrigerants may often be less expensive if purchased at a refrigeration supply store. Generally, refrigerant is a "**price leader**" to a refrigeration supply store as engine oil is to an automotive parts store.

Price leader is an item that a merchant may sell at cost or near cost to attract customers.

COST OF OPERATION

Because the air-conditioning system places an extra load on the engine, it seems apparent that the use of an air conditioner will reduce gasoline mileage. This is only true for stop-and-go driving.

At highway speeds, air conditioned cars, with their windows closed and the air conditioning operating, actually average 2–3 percent better mileage than do cars without air conditioning that have their windows down. The aerodynamic design considerations of today's cars are based upon having the windows closed. When the windows are closed, reduced wind resistance offsets the demand load of the air-conditioning system on the engine.

The modern automobile is designed so it will offer less wind resistance with the windows closed.

SUMMARY

- Refrigeration is the term given to a process by which heat is removed.
- Although the principles were known as long ago as 10,000 BCE, air conditioning and refrigeration were developments of the 20th century.
- Automotive air conditioning has played a significant and important role in the comfort, health, and safety of the modern motorist.
- The ozone layer protects all life on earth from excess UV radiation.
- Ozone depletion seems to be the greatest during the early winter months.
- The mandatory phaseout in the manufacture and the eventual reduction of use of CFCs has had a positive effect on the ozone layer.
- Increased UV radiation affects the eyes, skin, and the immune system.
- The greenhouse effect is also affected by the release of pollutants.
- Solar radiation passes through the clear atmosphere.
- Most of the radiation is absorbed by the earth's surface to warm it.
- Some of the solar radiation is reflected by the earth and the atmosphere.
- Some of the infrared radiation that passed through the atmosphere is absorbed and some re-emitted in all directions to be absorbed by *greenhouse gas* molecules. The effect of this is to warm the lower atmosphere.
- All areas of safety should be practiced at all times.
- Antifreeze is either ethylene glycol or propylene glycol based.

REVIEW QUESTIONS

Short-Answer Essays

1. What EPA certification is required to purchase R-134a and R-1234yf refrigerant in containers larger than 2 pounds?
2. What is the general intent of the "right-to-know" law?
3. Define the term air conditioning.
4. What is the greenhouse effect?
5. What is the main ingredient of all major antifreeze brands and what health hazard does ingestion pose?
6. What does the term "ozone hole" refer to?
7. Compare the ozone layer to an umbrella.
8. What is the intent of Title VI of the Clean Air Act?
9. Briefly describe the term hydrostatic pressure.
10. What are some of the factors that contribute to the greenhouse effect and global warming?

Fill in the Blanks

1. Most of the earth's protective ozone is found in the _______________.
2. The refrigerant R-1234yf is not considered a greenhouse gas and has a significantly lower _______________ than R-134a which has a number of 1430.
3. Increased UV radiation is damaging to the eyes, skin, and _______________.
4. The common name or number used for the hydrofluorocarbon (HFC) refrigerant used in automotive refrigerant systems today is _______________.
5. The chemical symbol O_3 stands for _______________.
6. The Clean Air Act was signed into law by _______________.
7. The fluid in an air-conditioning system is called _______________.
8. Factory cylinders are equipped with _______________ plugs.
9. Over _______________ percent of all cars produced today are equipped with an air-conditioning system.
10. In the late 1920s and early 1930s, an "air conditioning" option meant that the car was equipped with a(n) _______________ and _______________ system.

Multiple Choice

1. What is the air we breathe made up of?
   A. 21 percent nitrogen and 78 percent oxygen
   B. 12 percent oxygen and 88 percent oxygen
   C. 98 percent oxygen and 2 percent nitrogen
   D. 21 percent oxygen and 78 percent nitrogen
2. What is the main source of ozone-depleting chlorine in the stratosphere?
   A. Chlorine used in swimming pools
   B. Chlorine used in laundry detergent
   C. Chlorine contained in chlorofluorocarbons
   D. All of the above
3. Air conditioning is the process by which air is:
   A. Heated.
   B. Cooled.
   C. Cleaned or filtered.
   D. All of the above.
4. What is the global warming potential (GWP) of R-1234yf?
   A. Less than 1
   B. 10
   C. 1234
   D. 1430
5. We are concerned about ozone depletion in what layer of the atmosphere?
   A. Ionosphere
   B. Stratosphere
   C. Troposphere
   D. Ozonosphere
6. Because sunlight is essential for the formation of stratospheric ozone, it is formed mainly over what region of the globe?
   A. The south pole
   B. The north pole
   C. The equator
   D. The United States
7. What can ultraviolet radiation cause?
   A. Skin cancer
   B. Damage to the eyes
   C. Heart disease
   D. Both A and B
8. The hole in the ozone layer was detected over what region of the globe?
   A. The south pole
   B. The north pole
   C. The equator
   D. The United States
9. R-134a was chosen as the replacement refrigerant for R-12 because it does not contribute to the depletion of the ozone layer, but it does have a high:
   A. Working pressure.
   B. Global warming potential.
   C. Cost.
   D. Global cooling effect.
10. In the greenhouse effect what type of radiation is re-emitted by the earth's surface and is absorbed and reflected by greenhouse gas molecules in the atmosphere, warming the earth's surface and lower atmosphere?
    A. Gama
    B. Ultraviolet
    C. Infrared
    D. Nuclear