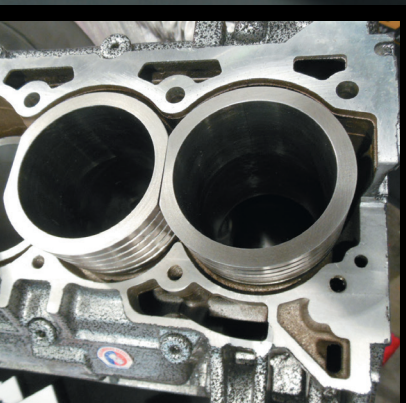
Automotive Engines

Theory and Servicing

Ninth Edition

James D. Halderman



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NINTH EDITION

James D. Halderman

330 Hudson Street, NY NY 10013

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PREFACE

PROFESSIONAL TECHNICIAN SERIES Part of Pearson Automotive's Professional Technician Series, the ninth edition of *Automotive Engines: Theory and Servicing* represents the future of automotive textbooks. The series is a full-color, media-integrated solution for today's students and instructors. The series includes textbooks that cover all 8 areas of ASE certification, plus additional titles covering common courses.

The series is also peer reviewed for technical accuracy.

UPDATES TO THE NINTH EDITION

- All content is correlated to the latest NATEF/ASE tasks.
- Over 165 new or greatly enhanced full-color line drawings and photos have been added to help bring the subject to life.
- Case studies have been added to many chapters and all include the "Three C's" (complaint, cause and correction).
- Updated vehicle identification information and tier 3 emission standards have been added to Chapter 9.
- New content on high pressure common rail (HPCR) diesel engines has been added to Chapter 11.
- Additional information on top tier gasoline has been added to Chapter 12.
- Additional information on cooling system hose clamps has been added to Chapter 14.
- The latest oil ratings and specifications for gasoline and diesel engines have been added to Chapter 15.
- Oxides of nitrogen (NO_x) controlled by variable valve timing (VVT) has been added to Chapter 19.
- Using a scan tool for engine condition diagnosis has been added to Chapter 22.
- "Torque paint" information has been added to Chapter 34.
- Content has been streamlined for easier reading and comprehension.

NATEF CORRELATED NATEF certified programs need to demonstrate that they use course material that covers NATEF tasks. All Professional Technician textbooks have been correlated to the appropriate NATEF task lists. These correlations can be found in an appendix to the book.

A COMPLETE INSTRUCTOR AND STUDENT SUPPLEMENTS PACKAGE All Professional Technician textbooks are accompanied by a full set of instructor and student supplements. Please see page vi for a detailed list of supplements.

A FOCUS ON DIAGNOSIS AND PROBLEM SOLVING The Professional Technician Series has been developed to satisfy the need for a greater emphasis on problem diagnosis. Automotive instructors and service managers agree that students and beginning technicians need more training in diagnostic procedures and skill development. To meet this need and demonstrate how real-world problems are solved, "Real World Fix" features are included throughout and highlight how real-life problems are diagnosed and repaired.

The following pages highlight the unique core features that set the Professional Technician Series book apart from other automotive textbooks.

IN-TEXT FEATURES

chapter 1

SHOP SAFETY

LEARNING OBJECTIVES: **After studying this chapter, the reader should be able to:** • Describe the personal protective equipment used by technicians. • Explain the safety tips for technicians and the cleaning methods and processes used in vehicle service. • Discuss shop safety procedures. • Discuss the purpose of fire extinguishers, fire blankets, and first aid and eye wash stations.

KEY TERMS: ANSI 1 • Bump cap 2 • Decibel (dB) 2 • Eye wash station 7 • Fire blankets 6 • Microbes 4 • "PASS" 5 • Personal protective equipment (PPE) 1 • Spontaneous combustion 3

PERSONAL PROTECTIVE EQUIPMENT

Safety is not just a buzzword on a poster in the work area. Safe work habits can reduce accidents and injuries, ease the workload, and keep employees pain free.

SAFETY GLASSES The most important **personal protective equipment (PPE)** a technician should wear all the time are safety glasses, which meet standard **ANSI** Z87.1. ● **SEE FIGURE 1–1.**

STEEL-TOED SHOES Steel-toed safety shoes are also a good investment. ● **SEE FIGURE 1–2.** If safety shoes are not available, then leather-topped shoes offer more protection than canvas or cloth covered shoes.

GLOVES Wear gloves to protect your hands from rough or sharp surfaces. Thin rubber gloves are recommended when working around automotive liquids such as engine oil, antifreeze, transmission fluid, or any other liquids that may be hazardous. Several types of gloves and their characteristics include:

- **Latex surgical gloves.** These gloves are relatively inexpensive, but tend to stretch, swell, and weaken when exposed to gas, oil, or solvents.
- **Vinyl gloves.** These gloves are also inexpensive and are not affected by gas, oil, or solvents. ● **SEE FIGURE 1–3.**
- **Polyurethane gloves.** These gloves are more expensive, yet very strong. Even though these gloves are also not affected by gas, oil, or solvents, they tend to be slippery.
- **Nitrile gloves.** These gloves are exactly like latex gloves, but are not affected by gas, oil, or solvents, yet they tend to be expensive.

FIGURE 1–1 Safety glasses should be worn at all times when working on or around any vehicle or servicing any component.

FIGURE 1–2 Steel-toed shoes are a worthwhile investment to help prevent foot injury due to falling objects. Even these well-worn shoes can protect the feet of this service technician.

SHOP SAFETY 1

OBJECTIVES AND KEY TERMS appear at the beginning of each chapter to help students and instructors focus on the most important material in each chapter. The chapter objectives are based on specific ASE and NATEF tasks.

TECH TIP

It Just Takes a Second

Whenever removing any automotive component, it is wise to screw the bolts back into the holes a couple of threads by hand. This ensures that the right bolt will be used in its original location when the component or part is put back on the vehicle.

TECH TIPS feature real-world advice and "tricks of the trade" from ASE-certified master technicians.

SAFETY TIP

Shop Cloth Disposal

Always dispose of oily shop cloths in an enclosed container to prevent a fire. ● **SEE FIGURE 1–69.** Whenever oily cloths are thrown together on the floor or workbench, a chemical reaction can occur, which can ignite the cloth even without an open flame. This process of ignition without an open flame is called **spontaneous combustion**.

SAFETY TIPS alert students to possible hazards on the job and how to avoid them.

Case Study

Valve Springs Can Vary

A technician was building a small block Chevrolet V-8 engine at home and was doing the final detailed checks, and found that many of the valve springs did not have the same tension. Using a borrowed valve spring tester, the technician visited a local parts store and measured all of the valve springs that the store had in stock. The technician selected and purchased the 16 valve springs that were within specification and within a very narrow range of tension. Although having all valve springs equal may or may not affect engine operation, the technician was pleased that all of the valve springs were equal.

Summary:

Complaint—A technician discovered that valve springs did not all have the same tension.

Cause—Due to manufacturing tolerances, valve springs can vary in tension.

Correction—The technician tested all available springs and selected those that were the most equal in tension.

CASE STUDIES present students with actual automotive scenarios and shows how these common (and sometimes uncommon) problems were diagnosed and repaired.

FREQUENTLY ASKED QUESTIONS are based on the author's own experience and provide answers to many of the most common questions asked by students and beginning service technicians.

FREQUENTLY ASKED QUESTION

How Many Types of Screw Heads Are Used in Automotive Applications?

There are many, including Torx, hex (also called Allen), plus many others used in custom vans and motor homes. ● **SEE FIGURE 1–9.**

NOTE: Most of these "locking nuts" are grouped together and are commonly referred to as *prevailing torque nuts*. This means that the nut will hold its tightness or torque and not loosen with movement or vibration.

NOTES provide students with additional technical information to give them a greater understanding of a specific task or procedure.

WARNING

Do not use incandescent trouble lights around gasoline or other flammable liquids. The liquids can cause the bulb to break and the hot filament can ignite the flammable liquid which can cause personal injury or even death.

SUMMARY

1. All service technicians should wear safety glasses that meet standard ANSI Z87.1.
2. Ear protection should be worn anytime the noise level is at 90 decibels (dB) or higher.
3. Safety should be exercised when working with electrical cords or when jump-starting another vehicle.
4. If a fire extinguisher is needed, remember: Pull the safety pin, aim the nozzle, squeeze the lever, and sweep the nozzle from side-to-side.

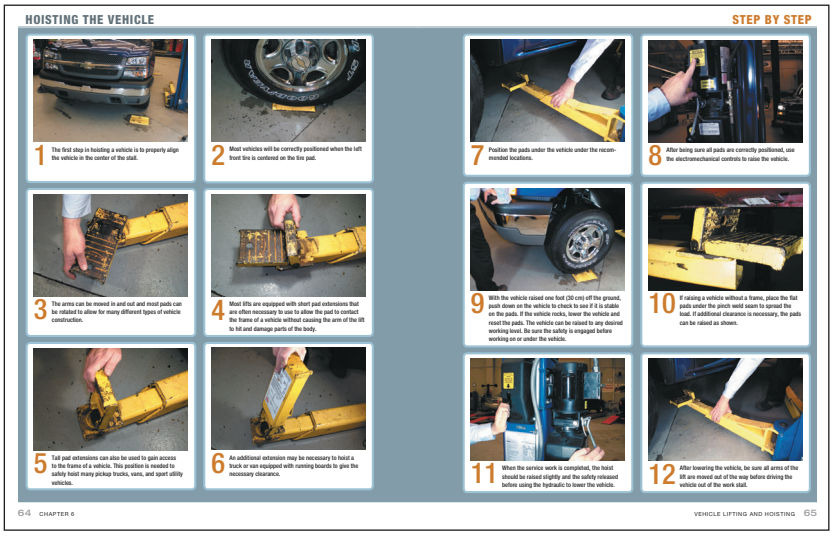
REVIEW QUESTIONS

1. List four items that are personal protective equipment (PPE).
2. What are the types of fire extinguishers and their usage?
3. What items are included in a typical first aid box?

CHAPTER QUIZ

1. What do you call the service technician's protective head cover?
   a. Cap c. Bump cap
   b. Hat d. Helmet
2. All safety glasses should meet the standards set by _____.
   a. ANSI c. ASE
   b. SAE d. DOT
3. When washing hands, the water should be at what temperature?
   a. 98°F (37°C) c. 125°F (52°C)
   b. 110°F (43°C) d. 135°F (57°C)
4. Hearing protection should be worn anytime the noise level exceeds _____.
   a. 60 dB c. 80 dB
   b. 70 dB d. 90 dB
5. Two technicians are discussing the safe use of a wrench. Technician A says that a wrench should be pulled toward you. Technician B says that a wrench should be pushed away from you. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
6. Exhaust hoses should be used because one of the exhaust gases is deadly in high concentration. This gas is _____.
   a. Carbon monoxide (CO)
   b. Carbon dioxide (CO_2)
   c. Hydrocarbons (HC)
   d. Oxides of nitrogen (NO_x)
7. The process of combustion occurring without an open flame is called _____.
   a. Direct ignition
   b. Non-open flame combustion
   c. Spontaneous combustion
   d. Cold fusion
8. When using a fire extinguisher, what word can be used to remember what to do?
   a. PASS c. RED
   b. FIRE d. LEVER
9. Which type of fire extinguisher can create a corrosive compound when discharged?
   a. CO_2 c. Water
   b. Dry chemical d. CO
10. Which item is usually *not* included in a first aid kit?
    a. Eye wash solution c. Fire blanket
    b. Antibiotic cream d. Bandages

CAUTION: *Never* use hardware store (nongraded) bolts, studs, or nuts on any vehicle steering, suspension, or brake component. Always use the exact size and grade of hardware that is specified and used by the vehicle manufacturer.



CAUTIONS alert students about potential damage to the vehicle that can occur during a specific task or service procedure.

WARNINGS alert students to potential dangers to themselves during a specific task or service procedure.

THE SUMMARY, REVIEW QUESTIONS, AND CHAPTER QUIZ at the end of each chapter help students review the material presented in the chapter and test themselves to see how much they've learned.

STEP BY STEP photo sequences show in detail the steps involved in performing a specific task or service procedure.

SUPPLEMENTS

RESOURCES IN PRINT AND ONLINE

Automotive Engines

Name of Supplement	Print	Online	Audience	Description
Instructor Resource Manual 0-13-465401-3		✔	Instructors	NEW! The Ultimate teaching aid: Chapter summaries, key terms, chapter learning objectives, lecture resources, discuss/ demonstrate classroom activities, and answers to the in text review and quiz questions.
TestBank 0-13-465413-7		✔	Instructors	Test generation software and test bank for the text.
PowerPoint Presentation 0-13-465411-0		✔	Instructors	Slides include chapter learning objectives, lecture outline of the text, and graphics from the book.
Image Bank 0-13-465409-9		✔	Instructors	All of the images and graphs from the text-book to create customized lecture slides.
NATEF Correlated Task Sheets – for instructors 0-13-465404-8		✔	Instructors	Downloadable NATEF task sheets for easy customization and development of unique task sheets.
NATEF Task Sheets – For Students 0-13-465403-X	✔		Students	Study activity manual that correlates NATEF Automobile Standards to chapters and pages numbers in the text. Available to students at a discounted price when packaged with the text.
VitalSource eBook 0-13-465414-5		✔	Students	An alternative to purchasing the print text-book, students can subscribe to the same content online and save up to 50% off the suggested list price of the print text. Visit **www.vitalsource.com**

All online resources can be downloaded from the Instructor's Resource Center: **www.pearsonighered.com/irc**

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TECHNICAL AND CONTENT REVIEWERS The following people reviewed the manuscript before production and checked it for technical accuracy and clarity of presentation. Their suggestions and recommendations were included in the final draft of the manuscript. Their input helped make this textbook clear and technically accurate while maintaining the easy-to-read style that has made other books from the same author so popular.

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—James D. Halderman

ABOUT THE AUTHOR

JIM HALDERMAN brings a world of experience, knowledge, and talent to his work. His automotive service experience includes working as a flat-rate technician, a business owner, and a Professor of Automotive Technology at a leading U.S. community college for more than 20 years.

He has a Bachelor of Science Degree from Ohio Northern University and a Masters Degree in Education from Miami University in Oxford, Ohio. Jim also holds a U.S. Patent for an electronic transmission control device. He is an ASE certified Master Automotive Technician and Advanced Engine Performance (L1) ASE certified.

Jim is the author of many Automotive textbooks all published by Pearson.

Jim has presented numerous technical seminars to national audiences including the California Automotive Teachers (CAT) and the Illinois College Automotive Instructor Association (ICAIA). He is also a member and presenter at the North American Council of Automotive Teachers (NACAT). Jim was also named Regional Teacher of the Year by General Motors Corporation and a member of the advisory board for Technological Studies department at Ohio Northern University.

Jim and his wife, Michelle, live in Dayton, Ohio. They have two children. You can reach Jim at:

jim@jameshalderman.com

BRIEF CONTENTS

CONTENTS

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chapter 1

SHOP SAFETY

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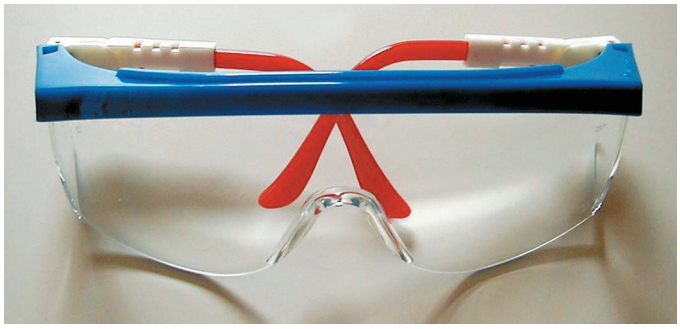


FIGURE 1–1 Safety glasses should be worn at all times when working on or around any vehicle or servicing any component.

FIGURE 1–2 Steel-toed shoes are a worthwhile investment to help prevent foot injury due to falling objects. Even these well-worn shoes can protect the feet of this service technician.

FIGURE 1–3 Protective gloves such as these vinyl gloves are available in several sizes. Select the size that allows the gloves to fit snugly. Vinyl gloves last a long time and often can be worn all day to help protect your hands from dirt and possible hazardous materials.

FIGURE 1–4 One version of a bump cap is this padded plastic insert that is worn inside a regular cloth cap.

- **Mechanic's gloves.** These gloves are usually made of synthetic leather and spandex and provide thermo protection, as well as protection from dirt and grime.

BUMP CAP Service technicians working under a vehicle should wear a **bump cap** to protect the head against under-vehicle objects and the pads of the lift. ● **SEE FIGURE 1–4.**

HANDS, JEWELRY, AND CLOTHING Remove jewelry that may get caught on something or act as a conductor to an exposed electrical circuit. ● **SEE FIGURE 1–5.**

Take care of your hands. Keep your hands clean by washing with soap and hot water that is at least 110°F (43°C). Avoid loose or dangling clothing. Also, ear protection should be worn if the sound around you requires that you raise your voice (sound level higher than 90 **decibels [dB]**).

NOTE: A typical lawnmower produces noise at a level of about 110 dB. This means that everyone who uses a lawnmower or other lawn or garden equipment should wear ear protection.

FIGURE 1–5 Remove all jewelry before performing service work on any vehicle.

TECH TIP

Professional Behavior in the Shop Is a Must

To be respected as a professional service technician and for safety, always behave in a professional manner. These behaviors include, but are not limited to the following:

- Show respect to other technicians and employees. For example, the shop owner or service manager may not always be right, but they are always the boss.
- Avoid horseplay or practical jokes.
- Act as if a customer is observing your behavior at all times because this is often the case.

SAFETY TIPS FOR TECHNICIANS

- When lifting any object, get a secure grip with solid footing. Keep the load close to your body to minimize the strain. Lift with your legs and arms, not your back.
- Do not twist your body when carrying a load. Instead, pivot your feet to help prevent strain on the spine.

FIGURE 1–6 Always connect an exhaust hose to the tailpipe of the engine of a vehicle to be run inside a building.

FIGURE 1–7 A magnetic tray is a helpful item to keep tools needed up where they can be easily reached without having to bend over saving time and energy over the course of a long day in the shop.

- Ask for help when moving or lifting heavy objects.
- Push a heavy object rather than pull it. (This is opposite to the way you should work with tools—never push a wrench! If you do and a bolt or nut loosens, your entire weight is used to propel your hand(s) forward. This usually results in cuts, bruises, or other painful injury.)
- Always connect an exhaust hose to the tailpipe of any running vehicle to help prevent the buildup of carbon monoxide (CO) inside a closed garage space. ● **SEE FIGURE 1–6.**
- When standing, keep objects, parts, and tools with which you are working between chest height and waist height. If seated, work at tasks that are at elbow height. ● **SEE FIGURE 1–7.**

FIGURE 1–8 An electric pusher used to push vehicles into or around the shop.

FIGURE 1–9 All oily shop cloths should be stored in a metal container equipped with a lid to help prevent spontaneous combustion.

- Always be sure the hood is securely held open.
- Ask for help when pushing a vehicle or use a motorized pusher. ● **SEE FIGURE 1–8.**

SAFETY TIP

Shop Cloth Disposal

Always dispose of oily shop cloths in an enclosed container to prevent a fire. ● **SEE FIGURE 1–9.** Whenever oily cloths are thrown together on the floor or workbench, a chemical reaction can occur which can ignite the cloth even without an open flame. This process of ignition without an open flame is called **spontaneous combustion.**

TECH TIP

Pound with Something Softer

If you must pound on something, be sure to use a tool that is softer than what you are about to pound on to avoid damage. Examples are given in the following table.

The Material Being Pounded	What to Pound With
Steel or cast iron	Brass or aluminum hammer or punch
Aluminum	Plastic or rawhide mallet or plastic-covered dead-blow hammer
Plastic	Rawhide mallet or plastic dead-blow hammer

CLEANING METHODS AND PROCESSES

There are four basic types of cleaning methods and processes used in vehicle service.

POWER WASHING Power washing uses an electric- or gasoline-powered compressor to increase the pressure of water and force it out of a nozzle. The pressure of the water itself is usually enough to remove dirt, grease, and grime from vehicle components. Sometimes a chemical cleaner, such as a detergent, is added to the water to help with cleaning.

SAFE USE OF POWER WASHERS. Because water is being sprayed at high pressure, a face shield should be worn when using a power washer to protect not only the eyes but also the face in the event of the spray being splashed back toward the technician. Also use a pressure washer in an area where the runoff from the cleaning will not contaminate local groundwater or cause harm to plants or animals.

CHEMICAL/MICROBE CLEANING Chemical cleaning involves one of several cleaning solutions, including detergent, solvents, or small, living microorganisms called **microbes** that eat oil and grease. The microbes live in water and eat the hydrocarbons that are the basis of grease and oil.

SAFE USE OF CHEMICAL CLEANING. A face shield should be worn when cleaning parts using a chemical cleaner. Avoid spilling the cleaner on the floor to help prevent slipping accidents. Clean and replace the chemical cleaner regularly.

ABRASIVE CLEANING Abrasive cleaning is used to clean disassembled parts, such as engine blocks. The abrasives used include steel shot, ground walnut shells, or in the case of cleaning paint from a vehicle body, baking soda can be used.

SAFE USE OF ABRASIVE CLEANERS. Always wear a protective face shield and protective clothing, including gloves, long sleeves, and long pants.

THERMAL OVENS Thermal cleaning uses heat to bake off grease and dirt with special high-temperature ovens. This method of cleaning requires the use of expensive equipment but does not use any hazardous chemicals and is environmentally safe.

SAFE USE OF THERMAL OVENS. Because thermal ovens operate at high temperatures, often exceeding 600°F (315°C), the oven should be turned off and allowed to cool overnight before removing the parts from the oven to avoid being exposed to the high temperature.

ELECTRICAL CORD SAFETY

Use correctly grounded three-prong sockets and extension cords to operate power tools. Some tools use only two-prong plugs. Make sure these are double insulated and repair or replace any electrical cords that are cut or damaged to prevent the possibility of an electrical shock. When not in use, keep electrical cords off the floor to prevent tripping over them. Tape the cords down if they are placed in high foot traffic areas.

JUMP-STARTING AND BATTERY SAFETY

To jump-start another vehicle with a dead battery, connect good-quality copper jumper cables as indicated in **FIGURE 1–10** or use a jump box. The last connection made should always be on the engine block or an engine bracket as far from the battery as possible. It is normal for a spark to be created when the jumper cables finally complete the jumper cable connections, and this spark could cause an explosion of the gases around the battery. Many newer vehicles have special ground connections built away from the battery just for the purpose of jump-starting. Check the owner manual or service information for the exact location.

Batteries contain acid and should be handled with care to avoid tipping them greater than a 45-degree angle. Always remove jewelry when working around a battery to avoid the possibility of electrical shock or burns, which can occur when the metal comes in contact with a 12 volt circuit and ground, such as the body of the vehicle.

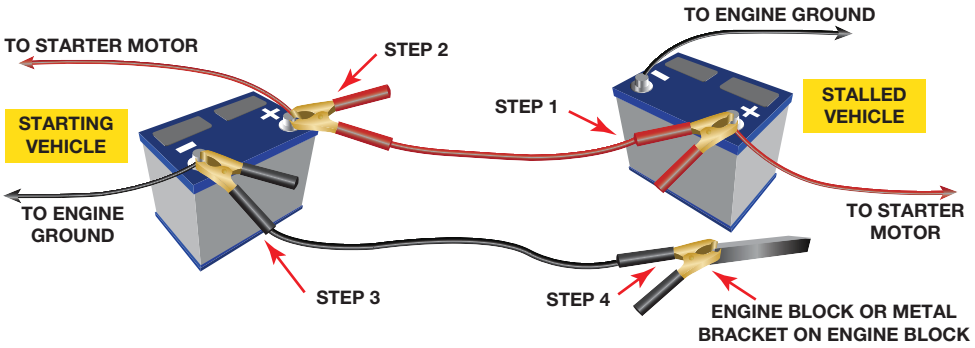


FIGURE 1–10 Jumper cable usage guide. Follow the same connections if using a portable jump box.

FIGURE 1–11 The air pressure going to the nozzle should be reduced to 30 PSI or less.

FIGURE 1–12 A typical fire extinguisher designed to be used on type class A, B, or C fires.

SAFETY TIP

Compressed Air Safety

Improper use of an air nozzle can cause blindness or deafness. Compressed air must be reduced to less than 30 PSI (206 kPa). ● **SEE FIGURE 1–11.** If an air nozzle is used to dry and clean parts, make sure the air stream is directed away from anyone else in the immediate area. Always use an OSHA-approved nozzle with side slits that limit the maximum pressure at the nozzle to 30 PSI. Coil and store air hoses when they are not in use.

FIRE EXTINGUISHERS

There are four classes of fire extinguishers. Each class should be used on specific fires only.

- *Class A* is designed for use on general combustibles, such as cloth, paper, and wood.
- *Class B* is designed for use on flammable liquids and greases, including gasoline, oil, thinners, and solvents.
- *Class C* is used only on electrical fires.
- *Class D* is effective only on combustible metals such as powdered aluminum, sodium, or magnesium.

The class rating is clearly marked on the side of every fire extinguisher. Many extinguishers are good for multiple types of fires. ● **SEE FIGURE 1–12.**

When using a fire extinguisher, remember the word **"PASS."**

P = Pull the safety pin.

A = Aim the nozzle of the extinguisher at the base of the fire.

S = Squeeze the lever to actuate the extinguisher.

S = Sweep the nozzle from side to side.

● **SEE FIGURE 1–13.**

TYPES OF FIRE EXTINGUISHERS Types of fire extinguishers include the following:

- **Water.** A water fire extinguisher, usually in a pressurized container, is good to use on Class A fires by reducing the temperature to the point where a fire cannot be sustained.

FIGURE 1–13 A CO_2 fire extinguisher being used on a fire set in an open steel drum during a demonstration at a fire department training center.

FIGURE 1–14 A treated wool blanket is kept in this easy-to-open wall-mounted holder and should be placed in a centralized location in the shop.

- **Carbon dioxide (CO_2).** A carbon dioxide fire extinguisher is good for almost any type of fire, especially Class B or Class C materials. A CO_2 fire extinguisher works by removing the oxygen from the fire and the cold CO_2 also helps reduce the temperature of the fire.
- **Dry chemical (yellow).** A dry chemical fire extinguisher is good for Class A, B, or C fires by coating the flammable materials, which eliminates the oxygen from the fire. A dry chemical fire extinguisher tends to be very corrosive and will cause damage to electronic devices.

FIRE BLANKETS

Fire blankets are required to be available in the shop areas. If a person is on fire, a fire blanket should be removed from its storage bag and thrown over and around the victim to smother the fire. ● **SEE FIGURE 1–14** showing a typical fire blanket.

FIGURE 1–15 A first aid box should be centrally located in the shop and kept stocked with the recommended supplies.

FIRST AID AND EYE WASH STATIONS

All shop areas must be equipped with a first aid kit and an eye wash station centrally located and kept stocked with emergency supplies.

FIRST AID KIT

A first aid kit should include:

- Bandages (variety)
- Gauze pads
- Roll gauze
- Iodine swab sticks
- Antibiotic ointment
- Hydrocortisone cream
- Burn gel packets
- Eye wash solution
- Scissors
- Tweezers
- Gloves
- First aid guide

● **SEE FIGURE 1–15.** Every shop should have a person trained in first aid. If there is an accident, call for help immediately.

FIGURE 1–16 A typical eye wash station. Often a thorough flushing of the eyes with water is the best treatment in the event of eye contamination.

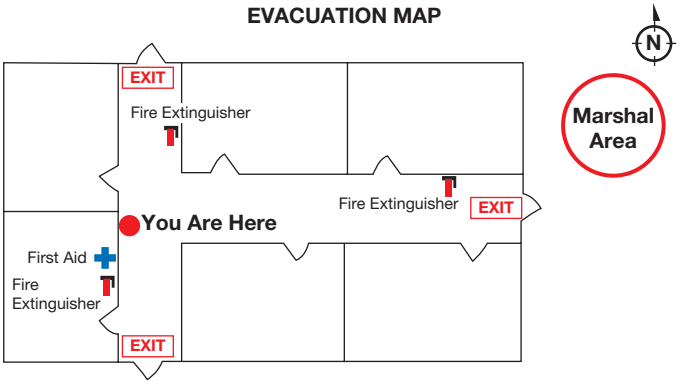


FIGURE 1–17 The evacuation routes from where you are in the building is shown on maps that are attached to the walls in schools and commercial buildings.

EYE WASH STATION An **eye wash station** should be centrally located and used whenever any liquid or chemical gets into the eyes. If such an emergency does occur, keep eyes in a constant stream of water and call for professional assistance. ● **SEE FIGURE 1–16.**

FIGURE 1–18 A properly marked aisle using yellow paint strips leading to an exit.

EVACUATION ROUTES

POSTED MAPS Check the location of posted evacuation routes and be sure to read, understand, and follow the instructions for evacuating the area in case of an emergency. The evacuation routes are commonly posted throughout the building and often include the location of the nearest fire extinguisher and other safety related items. ● **SEE FIGURE 1–17.**

AISLE MARKINGS Aisles leading to the emergency exist must be marked with yellow paint or tape at least 2 inches (5 cm) wide. The aisles should also be 40 to 48 inches (102 to 122 cm) wide. Aisles should lead to exits as directly as possible. ● **SEE FIGURE 1–18.**

SAFETY TIP

Infection Control Precautions

Working on a vehicle can result in personal injury including the possibility of being cut or hurt enough to cause bleeding. Some infections such as hepatitis B, HIV (which can cause acquired immunodeficiency syndrome, or AIDS), and hepatitis C virus are transmitted through blood. These infections are commonly called blood-borne pathogens. Report any injury that involves blood to your supervisor and take the necessary precautions to avoid coming in contact with blood from another person.

SUMMARY

1. All service technicians should wear safety glasses that meet standard ANSI Z87.1.
2. Ear protection should be worn anytime the noise level is at 90 decibels (dB) or higher.
3. Safety should be exercised when working with electrical cords or when jump-starting another vehicle.
4. If a fire extinguisher is needed, remember: Pull the safety pin, aim the nozzle, squeeze the lever, and sweep the nozzle from side-to-side.

REVIEW QUESTIONS

1. List four items that are personal protective equipment (PPE).
2. What are the types of fire extinguishers and their usage?
3. What items are included in a typical first aid box?

CHAPTER QUIZ

1. What do you call the service technician's protective head cover?
   a. Cap **c.** Bump cap
   b. Hat **d.** Helmet
2. All safety glasses should meet the standards set by _____.
   a. ANSI **c.** ASE
   b. SAE **d.** DOT
3. When washing hands, the water should be at what temperature?
   a. 98°F (37°C) **c.** 125°F (52°C)
   b. 110°F (43°C) **d.** 135°F (57°C)
4. Hearing protection should be worn anytime the noise level exceeds _____.
   a. 60 dB **c.** 80 dB
   b. 70 dB **d.** 90 dB
5. Two technicians are discussing the safe use of a wrench. Technician A says that a wrench should be pulled toward you. Technician B says that a wrench should be pushed away from you. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
6. Exhaust hoses should be used because one of the exhaust gases is deadly in high concentration. This gas is _____.
   a. Carbon monoxide (CO)
   b. Carbon dioxide (CO_2)
   c. Hydrocarbons (HC)
   d. Oxides of nitrogen (NO_X)
7. The process of combustion occurring without an open flame is called _____.
   a. Direct ignition
   b. Non-open flame combustion
   c. Spontaneous combustion
   d. Cold fusion
8. When using a fire extinguisher, what word can be used to remember what to do?
   a. PASS **c.** RED
   b. FIRE **d.** LEVER
9. Which type of fire extinguisher can create a corrosive compound when discharged?
   a. CO_2 **c.** Water
   b. Dry chemical **d.** CO
10. Which item is usually *not* included in a first aid kit?
    a. Eye wash solution **c.** Fire blanket
    b. Antibiotic cream **d.** Bandages

chapter 2 ENVIRONMENTAL AND HAZARDOUS MATERIALS

LEARNING OBJECTIVES: **After studying this chapter, the reader should be able to:** • Identify hazardous waste materials in accordance with federal and state laws. • Discuss asbestos hazards and asbestos handling guidelines. • Explain the storage and disposal of brake fluid, used oil, coolants, lead-acid batteries, used tires, and air-conditioning refrigerant oil. • Explain the characteristics of hazardous solvents, fuel safety and storage, and airbag handling.

KEY TERMS: Aboveground storage tank (AGST) 12 • Asbestosis 11 • BCI 15 • CAA 10 • CFR 9 • EPA 9 • Hazardous waste material 9 • HEPA vacuum 11 • Mercury 17 • SDS 10 • OSHA 9 • RCRA 10 • Right-to-know laws 10 • Solvent 11 • Underground storage tank (UST) 12 • Used oil 12 • WHMIS 10

HAZARDOUS WASTE

DEFINITION OF HAZARDOUS WASTE

Hazardous waste materials are chemicals, or components, that the shop no longer needs that pose a danger to the environment and people if they are disposed of in ordinary garbage cans or sewers. However, no material is considered hazardous waste until the shop has finished using it and is ready to dispose of it.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

When handling hazardous waste material, one must always wear the proper protective clothing and equipment detailed in the right-to-know laws. This includes respirator equipment. All recommended procedures must be followed accurately. Personal injury may result from improper clothing, equipment, and procedures when handling hazardous materials.

FEDERAL AND STATE LAWS

OCCUPATIONAL SAFETY AND HEALTH ACT

The United States Congress passed the **Occupational Safety and Health Act (OSHA)** in 1970. This legislation was designed to assist and encourage the citizens of the United States in their efforts to assure:

- Safe and healthful working conditions by providing research, information, education, and training in the field of occupational safety and health.
- Safe and healthful working conditions for working men and women by authorizing enforcement of the standards developed under the Act.

Because about 25% of workers are exposed to health and safety hazards on the job, the OSHA standards are necessary to monitor, control, and educate workers regarding health and safety in the workplace.

EPA

The **Environmental Protection Agency (EPA)** publishes a list of hazardous materials that is included in the **Code of Federal Regulations (CFR)**. The EPA considers waste hazardous if it is included on the EPA list of hazardous materials, or it has one or more of the following characteristics:

- **Reactive.** Any material that reacts violently with water or other chemicals is considered hazardous.
- **Corrosive.** If a material burns the skin, or dissolves metals and other materials, a technician should consider it hazardous. A pH scale is used, with the number 7 indicating neutral. Pure water has a pH of 7. Lower numbers indicate an acidic solution and higher numbers indicate a caustic solution. If a material releases cyanide gas, hydrogen sulfide gas, or similar gases when exposed to low pH acid solutions, it is considered hazardous.
- **Toxic.** Materials are hazardous if they leak one or more of eight different heavy metals in concentrations greater than 100 times the primary drinking water standard.
- **Ignitable.** A liquid is hazardous if it has a flash point below 140°F (60°C), and a solid is hazardous if it ignites spontaneously.

WARNING

Hazardous waste disposal laws include serious penalties for anyone responsible for breaking these laws.

- **Radioactive.** Any substance that emits measurable levels of radiation is radioactive. When individuals bring containers of a highly radioactive substance into the shop environment, qualified personnel with the appropriate equipment must test them.

RIGHT-TO-KNOW LAWS

The **right-to-know laws** state that employees have a right to know when the materials they use at work are hazardous. Under the right-to-know laws, the employer has responsibilities regarding the handling of hazardous materials by their employees. All employees must be trained about the types of hazardous materials they will encounter in the workplace.

SAFETY DATA SHEETS (SDS). All hazardous materials must be properly labeled, and information about each hazardous material must be posted on **safety data sheets (SDS)**, formally called *material safety data sheets* (MSDS) available from the manufacturer. In Canada, MSDS information is called **Workplace Hazardous Materials Information Systems (WHMIS)**.

The employer has a responsibility to place MSDS information where they are easily accessible by all employees.

The manufacturer must supply all warning and precautionary information about hazardous materials. This information must be read and understood by the employee before handling the material. ● **SEE FIGURE 2–1.**

FIGURE 2–1 Safety Data Sheets (SDS) should be readily available for use by anyone in the area who may come into contact with hazardous materials.

RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

Federal and state laws control the disposal of hazardous waste materials and every shop employee must be familiar with these laws. Hazardous waste disposal laws include the **Resource Conservation and Recovery Act (RCRA)**. This law states that hazardous material users are responsible for hazardous materials from the time they become a waste until the proper waste disposal is completed. Many shops hire an independent hazardous waste hauler to dispose of hazardous waste material. The shop owner, or manager, should have a written contract with the hazardous waste hauler. The RCRA controls the following types of automotive waste:

- Paint and body repair products waste
- Solvents for parts and equipment cleaning
- Batteries and battery acid
- Mild acids used for metal cleaning and preparation
- Waste oil, and engine coolants or antifreeze
- Air-conditioning refrigerants and oils
- Engine oil filters

FIGURE 2–2 Tag that identifies the electrical power has been removed and service work is being done.

LOCKOUT/TAGOUT

According to OSHA Title 29, code of Federal Regulations (CPR), part 1910.147, machinery must be locked out to prevent injury to employees when maintenance or repair work is being performed. Any piece of equipment that should not be used must be tagged and the electrical power disconnected to prevent it from being used. Always read, understand, and follow all safety warning tags. ● **SEE FIGURE 2–2.**

CLEAN AIR ACT

Air-conditioning (A/C) systems and refrigerants are regulated by the **Clean Air Act (CAA)**, Title VI, Section 609. Technician certification and service equipment is also regulated. Any technician working on automotive A/C systems must be certified. A/C refrigerants must not be released or vented into the atmosphere, and used refrigerants must be recovered.

ASBESTOS HAZARDS

Friction materials such as brake and clutch linings often contain asbestos. While asbestos has been eliminated from most original equipment friction materials, the automotive service technician cannot know whether the vehicle being serviced is or is not equipped with friction materials containing asbestos. It is important that all friction materials be handled as if they do contain asbestos.

Asbestos exposure can cause scar tissue to form in the lungs. This condition is called **asbestosis**. It gradually causes increasing shortness of breath, and the scarring to the lungs is permanent.

Even low exposures to asbestos can cause *mesothelioma*, a type of fatal cancer of the lining of the chest or abdominal cavity. Asbestos exposure can also increase the risk of *lung cancer* as well as cancer of the voice box, stomach, and large intestine. It usually takes 15 to 30 years or more for cancer or asbestos lung scarring to show up after exposure. Scientists call this the *latency period*.

Government agencies recommend that asbestos exposure be eliminated or controlled to the lowest level possible. These agencies have developed recommendations and standards that the automotive service technician and equipment manufacturer should follow. These U.S. federal agencies include the National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), and Environmental Protection Agency (EPA).

ASBESTOS OSHA STANDARDS The Occupational Safety and Health Administration (OSHA) has established three levels of asbestos exposure. Any vehicle service establishment that does either brake or clutch work must limit employee exposure to asbestos to less than 0.2 fibers per cubic centimeter (cc) as determined by an air sample.

If the level of exposure to employees is greater than specified, corrective measures must be performed and a large fine may be imposed.

NOTE: Research has found that worn asbestos fibers such as those from automotive brakes or clutches may not be as hazardous as first believed. Worn asbestos fibers do not have sharp flared ends that can latch onto tissue, but rather are worn down to a dust form that resembles talc. Grinding or sawing operations on unworn brake shoes or clutch discs *will* contain *harmful* asbestos fibers. To limit health damage, always use proper handling procedures while working around any component that may contain asbestos.

ASBESTOS EPA REGULATIONS The federal Environmental Protection Agency (EPA) has established procedures for the removal and disposal of asbestos. The EPA procedures require that products containing asbestos

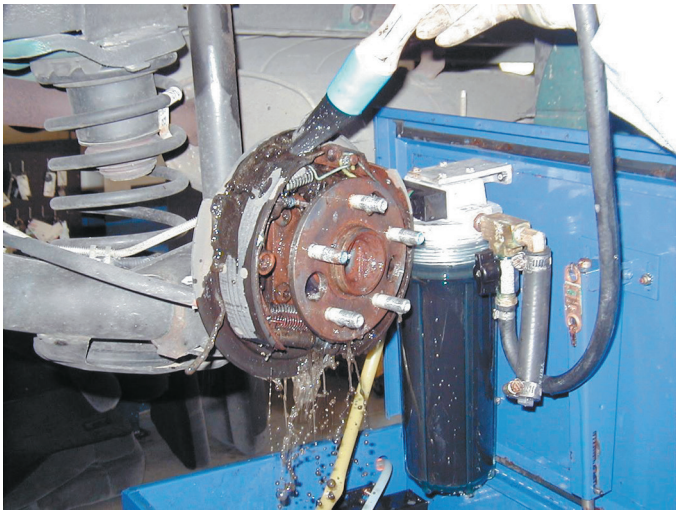


FIGURE 2–3 All brakes should be moistened with water or solvent to help prevent brake dust from becoming airborne.

be "wetted" to prevent the asbestos fibers from becoming airborne. According to the EPA, asbestos-containing materials can be disposed of as regular waste. Only when asbestos becomes airborne is it considered to be hazardous.

ASBESTOS HANDLING GUIDELINES The air in the shop area can be tested by a testing laboratory, but this can be expensive. Tests have determined that asbestos levels can easily be kept below the recommended levels by using a liquid, like water, or a special vacuum.

NOTE: The service technician cannot tell whether the old brake pads, shoes, or clutch discs contain asbestos. Therefore, to be safe, the technician should assume that all brake pads, shoes, or clutch discs contain asbestos.

HEPA VACUUM. A special **high-efficiency particulate air (HEPA)** vacuum system has been proven to be effective in keeping asbestos exposure levels below 0.1 fibers per cubic centimeter.

SOLVENT SPRAY. Many technicians use an aerosol can of brake cleaning solvent to wet the brake dust and prevent it from becoming airborne. A **solvent** is a liquid that is used to dissolve dirt, grime, or solid particles. Commercial brake cleaners are available that use a concentrated cleaner that is mixed with water. ● **SEE FIGURE 2–3.** The waste liquid is filtered, and when dry, the filter can be disposed of as solid waste.

DISPOSAL OF BRAKE DUST AND BRAKE SHOES. The hazard of asbestos occurs when asbestos fibers are airborne. Once the asbestos has been wetted down, it is then considered to be solid waste, rather than hazardous waste. Old brake shoes and pads should be enclosed, preferably in a plastic bag, to help prevent any of the brake material from becoming airborne. *Always follow current federal and local laws concerning disposal of all waste.*

WARNING

Never use compressed air to blow brake dust. The fine talc-like brake dust can create a health hazard even if asbestos is not present or is present in dust rather than fiber form.

USED BRAKE FLUID

Most brake fluid is made from polyglycol, is water soluble, and can be considered hazardous if it has absorbed metals from the brake system.

STORAGE AND DISPOSAL OF BRAKE FLUID

- Collect brake fluid in a container clearly marked to indicate that it is designated for that purpose.
- If the waste brake fluid is hazardous, be sure to manage it appropriately and use only an authorized waste receiver for its disposal.
- If the waste brake fluid is nonhazardous (such as old, but unused), determine from your local solid waste collection provider what should be done for its proper disposal.
- Do not mix brake fluid with used engine oil.
- Do not pour brake fluid down drains or onto the ground.
- Recycle brake fluid through a registered recycler.

USED OIL

Used oil is any petroleum-based or synthetic oil that has been used. During normal use, impurities such as dirt, metal scrapings, water, or chemicals can get mixed in with the oil. Eventually, this used oil must be replaced with virgin or re-refined oil. The EPA's used oil management standards include a three-pronged approach to determine if a substance meets the definition of *used oil*. To meet the EPA's definition of used oil, a substance must meet each of the following three criteria.

- **Origin.** The first criterion for identifying used oil is based on the oil's origin. Used oil must have been refined from crude oil or made from synthetic materials. Animal and vegetable oils are excluded from the EPA's definition of used oil.
- **Use.** The second criterion is based on whether and how the oil is used. Oils used as lubricants, hydraulic fluids, heat transfer fluids, and for other similar purposes are considered used oil. The EPA's definition also excludes products used as cleaning agents, as well as certain petroleum-derived products like antifreeze and kerosene.

FIGURE 2–4 A typical aboveground oil storage tank.

- **Contaminants.** The third criterion is based on whether the oil is contaminated with either physical or chemical impurities. In other words, to meet the EPA's definition, used oil must become contaminated as a result of being used. This aspect of the EPA's definition includes residues and contaminants generated from handling, storing, and processing used oil.

NOTE: The release of only 1 gallon of used oil (a typical oil change) can make 1 million gallons of fresh water undrinkable.

If used oil is dumped down the drain and enters a sewage treatment plant, concentrations as small as 50 to 100 parts per million (ppm) in the wastewater can foul sewage treatment processes. Never mix a listed hazardous waste, gasoline, wastewater, halogenated solvent, antifreeze, or an unknown waste material with used oil. Adding any of these substances will cause the used oil to become contaminated, which classifies it as hazardous waste.

STORAGE AND DISPOSAL OF USED OIL Once oil has been used, it can be collected, recycled, and used over and over again. An estimated 380 million gallons of used oil are recycled each year. Recycled used oil can sometimes be used again for the same job or can take on a completely different task. For example, used engine oil can be re-refined and sold at some discount stores as engine oil or processed for furnace fuel oil. After collecting used oil in an appropriate container such as a 55 gallon steel drum, the material must be disposed of in one of two ways.

- Shipped offsite for recycling
- Burned in an onsite or offsite EPA-approved heater for energy recovery

Used oil must be stored in compliance with an existing **underground storage tank (UST)** or an **aboveground storage tank (AGST)** standard, or kept in separate containers. ● **SEE FIGURE 2–4.** Containers are portable receptacles, such as a 55 gallon steel drum.

KEEP USED OIL STORAGE DRUMS IN GOOD CONDITION. This means that they should be covered, secured from vandals, properly labeled, and maintained in compliance with local fire codes. Frequent inspections for leaks, corrosion, and spillage are an essential part of container maintenance.

NEVER STORE USED OIL IN ANYTHING OTHER THAN TANKS AND STORAGE CONTAINERS. Used oil may also be stored in units that are permitted to store regulated hazardous waste.

USED OIL FILTER DISPOSAL REGULATIONS. Used oil filters contain used engine oil that may be hazardous. Before an oil filter is placed into the trash or sent to be recycled, it must be drained using one of the following hot-draining methods approved by the EPA.

- Puncture the filter antidrainback valve or filter dome end and hot drain for at least 12 hours
- Hot draining and crushing
- Dismantling and hot draining
- Any other hot-draining method, which will remove all the used oil from the filter

After the oil has been drained from the oil filter, the filter housing can be disposed of in any of the following ways.

- Sent for recycling
- Picked up by a service contract company
- Disposed of in regular trash

FIGURE 2–5 Washing hands and removing jewelry are two important safety habits all service technicians should practice.

SAFETY TIP

Hand Safety

Service technicians should wash their hands with soap and water after handling engine oil, differential oil, or transmission fluids or wear protective rubber gloves. Another safety hint is that the service technician should not wear watches, rings, or other jewelry that could come in contact with electrical or moving parts of a vehicle. **SEE FIGURE 2–5.**

SOLVENTS

The major sources of chemical danger are liquid and aerosol brake cleaning fluids that contain chlorinated hydrocarbon solvents. Several other chemicals that do not deplete the ozone, such as heptane, hexane, and xylene, are now being used in nonchlorinated brake cleaning solvents. Some manufacturers are also producing solvents they describe as environmentally responsible, which are biodegradable and noncarcinogenic (not cancer causing).

There is no specific standard for physical contact with chlorinated hydrocarbon solvents or the chemicals replacing them. All contact should be avoided whenever possible. The law requires an employer to provide appropriate protective equipment and ensure proper work practices by an employee handling these chemicals.

EFFECTS OF CHEMICAL POISONING

The effects of exposure to chlorinated hydrocarbon and other types of solvents can take many forms. Short-term exposure at low levels can cause symptoms such as:

- Headache
- Nausea
- Drowsiness
- Dizziness
- Lack of coordination
- Unconsciousness

It may also cause irritation of the eyes, nose, and throat, and flushing of the face and neck. Short-term exposure to higher concentrations can cause liver damage with symptoms such as yellow jaundice or dark urine. Liver damage may not become evident until several weeks after the exposure.

HAZARDOUS SOLVENTS AND REGULATORY STATUS

Most solvents are classified as hazardous wastes. Other characteristics of solvents include the following:

- Solvents with flash points below 140°F (60°C) are considered flammable and, like gasoline, are federally regulated by the Department of Transportation (DOT).
- Solvents and oils with flash points above 140°F (60°C) are considered combustible and, like engine oil, are also regulated by the DOT. All flammable items must be stored in a fireproof container. **SEE FIGURE 2–6.**

FIGURE 2–6 Typical fireproof flammable storage cabinet.

FREQUENTLY ASKED QUESTION

How Can You Tell If a Solvent Is Hazardous?

If a solvent or any of the ingredients of a product contains "fluor" or "chlor" then it is likely to be hazardous. Check the instructions on the label for proper use and disposal procedures.

It is the responsibility of the repair shop to determine if its spent solvent is hazardous waste. Solvent reclaimers are available that clean and restore the solvent so it lasts indefinitely.

USED SOLVENTS Used or spent solvents are liquid materials that have been generated as waste and may contain xylene, methanol, ethyl ether, and methyl isobutyl ketone (MIBK). These materials must be stored in OSHA-approved safety containers with the lids or caps closed tightly. Additional requirements include the following:

- Containers should be clearly labeled "Hazardous Waste" and the date the material was first placed into the storage receptacle should be noted.
- Labeling is not required for solvents being used in a parts washer.
- Used solvents will not be counted toward a facility's monthly output of hazardous waste if the vendor under contract removes the material.
- Used solvents may be disposed of by recycling with a local vendor, such as SafetyKleen®, to have the used solvent removed according to specific terms in the vendor agreement.

FIGURE 2–7 Using a water-based cleaning system helps reduce the hazards from using strong chemicals.

- Use aqueous-based (nonsolvent) cleaning systems to help avoid the problems associated with chemical solvents. **SEE FIGURE 2–7.**

COOLANT DISPOSAL

Coolant is a mixture of antifreeze and water. New antifreeze is not considered to be hazardous even though it can cause death if ingested. Used antifreeze may be hazardous due to dissolved metals from the engine and other components of the cooling system. These metals can include iron, steel, aluminum, copper, brass, and lead (from older radiators and heater cores). Coolant should be disposed of in one of the following ways:

- Coolant should be recycled either onsite or offsite.
- Used coolant should be stored in a sealed and labeled container. **SEE FIGURE 2–8.**
- Used coolant can often be disposed of into municipal sewers with a permit. Check with local authorities and obtain a permit before discharging used coolant into sanitary sewers.

LEAD-ACID BATTERY WASTE

About 70 million spent lead-acid batteries are generated each year in the United States alone. Lead is classified as a toxic metal and the acid used in lead-acid batteries is highly corrosive. The vast majority (95% to 98%) of these batteries are recycled through lead reclamation operations and secondary lead smelters for use in the manufacture of new batteries.

FIGURE 2–8 Used antifreeze coolant should be kept separate and stored in a leakproof container until it can be recycled or disposed of according to federal, state, and local laws. Note that the storage barrel is placed inside another container to catch any coolant that may spill out of the inside barrel.

BATTERY DISPOSAL Used lead-acid batteries must be reclaimed or recycled in order to be exempt from hazardous waste regulations. Leaking batteries must be stored and transported as hazardous waste. Some states have more strict regulations, which require special handling procedures and transportation. According to the **Battery Council International (BCI)**, battery laws usually include the following rules.

1. Lead-acid battery disposal is prohibited in landfills or incinerators. Batteries are required to be delivered to a battery retailer, wholesaler, recycling center, or lead smelter.
2. All retailers of automotive batteries are required to post a sign that displays the universal recycling symbol and indicates the retailer's specific requirements for accepting used batteries.
3. Battery electrolyte contains sulfuric acid, which is a very corrosive substance capable of causing serious personal injury, such as skin burns and eye damage. In addition, the battery plates contain lead, which is highly poisonous. For this reason, disposing of batteries improperly can cause environmental contamination and lead to severe health problems.

BATTERY HANDLING AND STORAGE Batteries, whether new or used, should be kept indoors if possible. The storage location should be an area specifically designated for battery storage and must be well ventilated (to the outside). If outdoor storage is the only alternative, a sheltered and secured area with acid-resistant secondary containment is strongly recommended. It is also advisable that acid-resistant secondary containment be used for indoor storage. In addition, batteries should be placed on acid-resistant pallets and never stacked.

FIGURE 2–9 This red gasoline container holds about 30 gallons of gasoline and is used to fill vehicles used for training.

FUEL SAFETY AND STORAGE

Gasoline is a very explosive liquid. The expanding vapors that come from gasoline are extremely dangerous. These vapors are present even in cold temperatures. Vapors formed in gasoline tanks on many vehicles are controlled, but vapors from gasoline storage may escape from the can, resulting in a hazardous situation. Therefore, place gasoline storage containers in a well-ventilated space. Although diesel fuel is not as volatile as gasoline, the same basic rules apply to diesel fuel and gasoline storage. These rules include the following:

1. Use storage cans that have a flash-arresting screen at the outlet. These screens prevent external ignition sources from igniting the gasoline within the can when someone pours the gasoline or diesel fuel.
2. Use only a red approved gasoline container to allow for proper hazardous substance identification. ● **SEE FIGURE 2–9.**
3. Do not fill gasoline containers completely full. Always leave the level of gasoline at least 1 inch from the top of the container. This action allows expansion of the gasoline at higher temperatures. If gasoline containers are completely full, the gasoline will expand when the temperature increases. This expansion forces gasoline from the can and creates a dangerous spill. If gasoline or diesel fuel

containers must be stored, place them in a designated storage locker or facility.

4. Never leave gasoline containers open, except while filling or pouring gasoline from the container.
5. Never use gasoline as a cleaning agent.
6. Always connect a ground strap to containers when filling or transferring fuel or other flammable products from one container to another to prevent static electricity that could result in explosion and fire. These ground wires prevent the buildup of a static electric charge, which could result in a spark and disastrous explosion.

AIRBAG HANDLING

Airbag modules are pyrotechnic devices that can be ignited if exposed to an electrical charge or if the body of the vehicle is subjected to a shock. Airbag safety should include the following precautions.

1. Disarm the airbag(s) if you will be working in the area where a discharged bag could make contact with any part of your body. Consult service information for the exact procedure to follow for the vehicle being serviced.
2. If disposing of an airbag, the usual procedure is to deploy the airbag using a 12 volt power supply, such as a jump-start box, using long wires to connect to the module to ensure a safe deployment.
3. Do not expose an airbag to extreme heat or fire.
4. Always carry an airbag pointing away from your body.
5. Place an airbag module facing upward.
6. Always follow the manufacturer's recommended procedure for airbag disposal or recycling, including the proper packaging to use during shipment.
7. Wear protective gloves if handling a deployed airbag.
8. Always wash your hands or body well if exposed to a deployed airbag. The chemicals involved can cause skin irritation and possible rash development.

USED TIRE DISPOSAL

Used tires are an environmental concern because of several reasons, including the following:

1. In a landfill, they tend to "float" up through the other trash and rise to the surface.
2. The inside of tires traps and holds rainwater, which is a breeding ground for mosquitoes. Mosquito-borne diseases include encephalitis, malaria and dengue fever.
3. Used tires present a fire hazard and, when burned, create a large amount of black smoke that contaminates the air.

Used tires should be disposed of in one of the following ways.

1. Used tires can be reused until the end of their useful life.
2. Tires can be retreaded.
3. Tires can be recycled or shredded for use in asphalt.
4. Unmounted tires can be sent to a landfill (most landfill operators will shred the tires because it is illegal in many states to landfill whole tires).
5. Tires can be burned in cement kilns or other power plants where the smoke can be controlled.
6. A registered scrap tire handler should be used to transport tires for disposal or recycling.

AIR-CONDITIONING REFRIGERANT OIL DISPOSAL

Air-conditioning refrigerant oil contains dissolved refrigerant and is therefore considered to be hazardous waste. This oil must be kept separated from other waste oil or the entire amount of oil must be treated as hazardous. Used refrigerant oil must be sent to a licensed hazardous waste disposal company for recycling or disposal. ● **SEE FIGURE 2–10.**

WASTE CHART All automotive service facilities create some waste and while most of it is handled properly, it is important that all hazardous and nonhazardous waste be accounted for and properly disposed. ● **SEE CHART 2–1** for a list of typical wastes generated at automotive shops, plus a checklist for keeping track of how these wastes are handled.

FIGURE 2–10 Air-conditioning refrigerant oil must be kept separated from other oils because it contains traces of refrigerant and must be treated as hazardous waste.

WASTE STREAM	TYPICAL CATEGORY IF NOT MIXED WITH OTHER HAZARDOUS WASTE	IF DISPOSED IN LANDFILL AND NOT MIXED WITH A HAZARDOUS WASTE	IF RECYCLED
Used oil	Used oil	Hazardous waste	Used oil
Used oil filters	Nonhazardous solid waste, if completely drained	Nonhazardous solid waste, if completely drained	Used oil, if not drained
Used transmission fluid	Used oil	Hazardous waste	Used oil
Used brake fluid	Used oil	Hazardous waste	Used oil
Used antifreeze	Depends on characterization	Depends on characterization	Depends on characterization
Used solvents	Hazardous waste	Hazardous waste	Hazardous waste
Used citric solvents	Nonhazardous solid waste	Nonhazardous solid waste	Hazardous waste
Lead-acid automotive batteries	Not a solid waste if returned to supplier	Hazardous waste	Hazardous waste
Shop rags used for oil	Used oil	Depends on used oil characterization	Used oil
Shop rags used for solvent or gasoline spills	Hazardous waste	Hazardous waste	Hazardous waste
Oil spill absorbent material	Used oil	Depends on used oil characterization	Used oil
Spill material for solvent and gasoline	Hazardous waste	Hazardous waste	Hazardous waste
Catalytic converter	Not a solid waste if returned to supplier	Nonhazardous solid waste	Nonhazardous solid waste
Spilled or unused fuels	Hazardous waste	Hazardous waste	Hazardous waste
Spilled or unusable paints and thinners	Hazardous waste	Hazardous waste	Hazardous waste
Used tires	Nonhazardous solid waste	Nonhazardous solid waste	Nonhazardous solid waste

CHART 2–1

Typical waste materials generated at auto repair shops and typical category (hazardous or nonhazardous) by disposal method.

TECH TIP

Remove Components That Contain Mercury

Some vehicles have a placard near the driver's side door that lists the components that contain the heavy metal, mercury. **Mercury** can be absorbed through the skin and is a heavy metal that once absorbed by the body does not leave. ● **SEE FIGURE 2–11.**

These components should be removed from the vehicle before the rest of the body is sent to be recycled to help prevent releasing mercury into the environment.

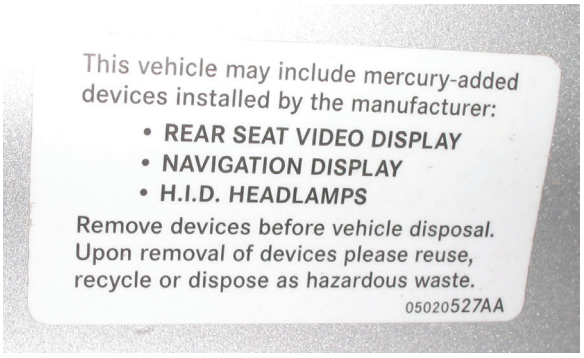


FIGURE 2–11 Placard near driver's door, including what devices in the vehicle contain mercury.

HEALTH HAZARD	FLAME	EXCLAMATION MARK
		
• CARCINOGEN • MUTAGENICITY • REPRODUCTIVE TOXICITY • RESPIRATORY SENSITIZER • TARGET ORGAN TOXICITY • ASPIRATION TOXICITY	• FLAMMABLES • PYROPHORICS • SELF-HEATING • EMITS FLAMMABLE GAS • SELF-REACTIVES • ORGANIC PEROXIDES	• IRRITANT (SKIN AND EYE) • SKIN SENSITIZER • ACUTE TOXICITY • NARCOTIC EFFECTS • RESPIRATORY TRACT IRRITANT • HAZARDOUS TO OZONE LAYER (NON-MANDATORY)
GAS CYLINDER	**CORROSION**	**EXPLODING BOMB**
		
• GASES UNDER PRESSURE	• SKIN CORROSION/BURNS • EYE DAMAGE • CORROSIVE TO METALS	• EXPLOSIVES • SELF-REACTIVES • ORGANIC PEROXIDES
FLAME OVER CIRCLE	**ENVIRONMENT (NON-MANDATORY)**	**SKULL AND CROSSBONES**
		
• OXIDIZERS	• AQUATIC TOXICITY	• ACUTE TOXICITY (FATAL OR TOXIC)

FIGURE 2–12 The OSHA global hazardous materials labels.

TECH TIP

What Every Technician Should Know

OSHA has adopted new hazardous chemical labeling requirements making it agree with global labeling standards established by the United Nations. As a result, workers will have better information available on the safe handling and use of hazardous chemicals, allowing them to avoid injuries and possible illnesses related to exposures to hazardous chemicals.
SEE FIGURE 2–12.

SUMMARY

1. Hazardous materials include common automotive chemicals, liquids, and lubricants, especially those whose ingredients contain *chlor* or *fluor* in their name.
2. Right-to-know laws require that all workers have access to safety data sheets (SDS).
3. Asbestos fibers should be avoided and removed according to current laws and regulations.
4. Used engine oil contains metals worn from parts and should be handled and disposed of properly.
5. Solvents represent a serious health risk and should be avoided as much as possible.
6. Coolant should be disposed of properly or recycled.
7. Batteries are considered to be hazardous waste and should be discarded to a recycling facility.

REVIEW QUESTIONS

1. List five common automotive chemicals or products that may be considered hazardous materials.
2. The Resource Conservation and Recovery Act (RCRA) controls what types of automotive waste?

CHAPTER QUIZ

1. Hazardous materials include all of the following *except* _____.
   a. Engine oil **c.** Water
   b. Asbestos **d.** Brake cleaner
2. To determine if a product or substance being used is hazardous, consult _____.
   a. A dictionary **c.** SAE standards
   b. SDS **d.** EPA guidelines
3. Exposure to asbestos dust can cause what condition?
   a. Asbestosis
   b. Mesothelioma
   c. Lung cancer
   d. All of the above
4. Wetted asbestos dust is considered to be _____.
   a. Solid waste **c.** Toxic
   b. Hazardous waste **d.** Poisonous
5. An oil filter should be hot drained for how long before disposing of the filter?
   a. 30 to 60 minutes **c.** 8 hours
   b. 4 hours **d.** 12 hours
6. Used engine oil should be disposed of by all *except* the following methods.
   a. Disposed of in regular trash
   b. Shipped offsite for recycling
   c. Burned onsite in a waste oil-approved heater
   d. Burned offsite in a waste oil-approved heater
7. All of the following are the proper ways to dispose of a drained oil filter *except* _____.
   a. Sent for recycling
   b. Picked up by a service contract company
   c. Disposed of in regular trash
   d. Considered to be hazardous waste and disposed of accordingly
8. Which act or organization regulates air-conditioning refrigerant?
   a. Clean Air Act (CAA)
   b. SDS
   c. WHMIS
   d. Code of Federal Regulations (CFR)
9. Gasoline should be stored in approved containers that include what color(s)?
   a. A red container with yellow lettering
   b. A red container
   c. A yellow container
   d. A yellow container with red lettering
10. What automotive devices may contain mercury?
    a. Rear seat video displays
    b. Navigation displays
    c. HID headlights
    d. All of the above

chapter 3

FASTENERS AND THREAD REPAIR

LEARNING OBJECTIVES: **After studying this chapter, the reader should be able to:** • Identify bolts and explain the strength ratings of threaded fasteners. • Discuss the purpose of nuts, taps, dies, and washers. • Discuss how snap rings and clips are used. • Explain how to avoid broken fasteners. • Compare the different types of thread repair inserts.

KEY TERMS: Bolts 20 • Cap screws 20 • Capillary action 28 • Christmas tree clips 26 • Cotter pins 26 • Crest 20 • Die 23 • Grade 21 • Helical insert 28 • Heli-Coil® 28 • Jam nut 27 • Metric bolts 21 • Pal nut 27 • Penetrating oil 28 • Pitch 20 • Pop rivet 27 • Prevailing torque nuts 23 • Self-tapping screw 25 • Snap ring 26 • Stud 20 • Tap 23 • Tensile strength 22 • Threaded insert 29 • UNC (Unified National Coarse) 20 • UNF (Unified National Fine) 20 • Washers 25

THREADED FASTENERS

Most of the threaded fasteners used on vehicles are cap screws. They are called **cap screws** when they are threaded into a casting. Automotive service technicians usually refer to these fasteners as **bolts**, regardless of how they are used. In this chapter, they are called bolts. Sometimes, studs are used for threaded fasteners. A **stud** is a short rod with threads on both ends. Often, a stud will have coarse threads on one end and fine threads on the other end. The end of the stud with coarse threads is screwed into the casting. A nut is used on the opposite end to hold the parts together.

The fastener threads *must* match the threads in the casting or nut. The threads may be measured either in fractions of an inch (called fractional) or in metric units. The size is measured across the outside of the threads, called the **crest** of the thread. ● **SEE FIGURE 3–1.**

Fractional threads are either coarse or fine. The coarse threads are called **Unified National Coarse (UNC)**, and the fine threads are called **Unified National Fine (UNF)**. Standard combinations of sizes and number of threads per inch (called **pitch**) are used. Pitch can be measured with a thread pitch gauge as shown in ● **FIGURE 3–2.**

Bolts are identified by their diameter and length as measured from below the head, and not by the size of the head or the size of the wrench used to remove or install the bolt. Bolts and screws have many different-shaped heads. ● **SEE FIGURE 3–3.**

Fractional thread sizes are specified by the diameter in fractions of an inch and the number of threads per inch. Typical UNC thread sizes would be 5/16-18 and 1/2-13. Similar UNF thread sizes would be 5/16-24 and1/2-20. ● **SEE CHART 3–1.**

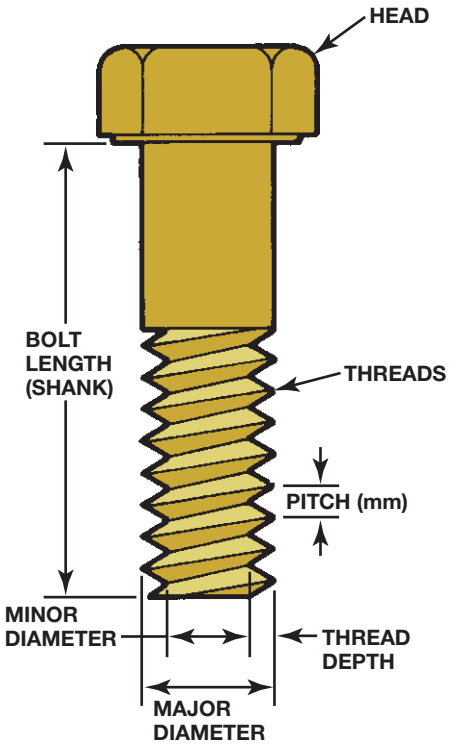


FIGURE 3–1 The dimensions of a typical bolt showing where sizes are measured. The major diameter is called the crest.

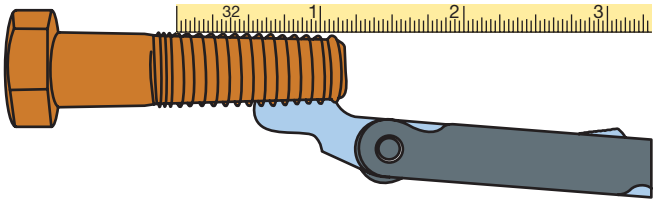


FIGURE 3–2 Thread pitch gauge used to measure the pitch of the thread. This bolt has 13 threads to the inch.

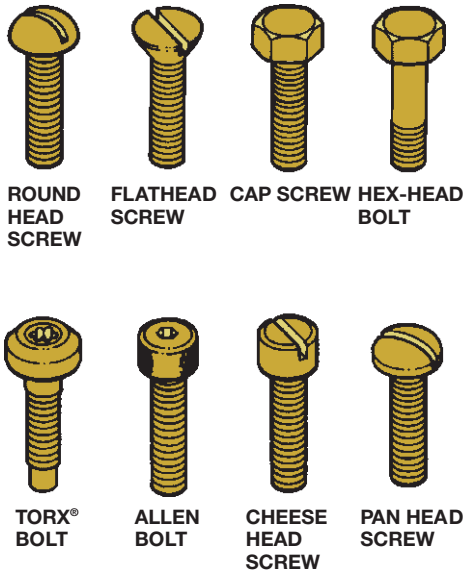


FIGURE 3–3 Bolts and screws have many different heads which determine what tool must be used.

METRIC BOLTS

The size of a **metric bolt** is specified by the letter *M* followed by the diameter in millimeters (mm) across the outside (crest) of the threads. Typical metric sizes would be M8 and M12. Fine metric threads are specified by the thread diameter followed by *X* and the distance between the threads measured in millimeters (M8 × 1.5). ● **SEE FIGURE 3–4.**

GRADES OF BOLTS

Bolts are made from many different types of steel, and for this reason some are stronger than others. The strength or classification of a bolt is called the **grade**. The bolt heads are marked to indicate their grade strength. Graded bolts are commonly used in the suspension parts of the vehicle but can be used almost anywhere in the vehicle.

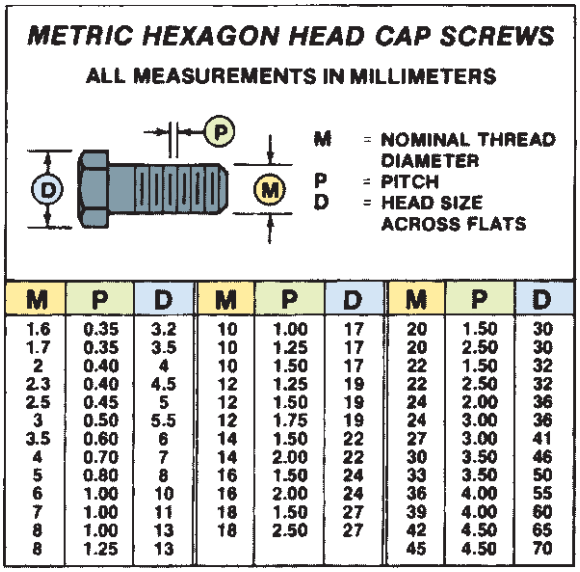
SIZE	THREADS PER INCH NC UNC	THREADS PER INCH NF UNF	OUTSIDE DIAMETER INCHES
0	. .	80	0.0600
1	64	. .	0.0730
1	. .	72	0.0730
2	56	. .	0.0860
2	. .	64	0.0860
3	48	. .	0.0990
3	. .	56	0.0990
4	40	. .	0.1120
4	. .	48	0.1120
5	40	. .	0.1250
5	. .	44	0.1250
6	32	. .	0.1380
6	. .	40	0.1380
8	32	. .	0.1640
8	. .	36	0.1640
10	24	. .	0.1900
10	. .	32	0.1900
12	24	. .	0.2160
12	. .	28	0.2160
1/4	20	. .	0.2500
1/4	. .	28	0.2500
5/16	18	. .	0.3125
5/16	. .	24	0.3125
3/8	16	. .	0.3750
3/8	. .	24	0.3750
7/16	14	. .	0.4375
7/16	. .	20	0.4375
1/2	13	. .	0.5000
1/2	. .	20	0.5000

CHART 3–1

The American national system is one method of sizing fasteners.

The actual grade of bolts is two more than the number of lines on the bolt head. Metric bolts have a decimal number to indicate the grade. More lines or a higher grade number indicate a stronger bolt. Higher grade bolts usually have threads that are rolled rather than cut, which also makes them stronger. ● **SEE FIGURE 3–5.** In some cases, nuts and machine screws have similar grade markings.

CAUTION: *Never* use hardware store (nongraded) bolts, studs, or nuts on any vehicle steering, suspension, or brake component. Always use the exact size and grade of hardware that is specified and used by the vehicle manufacturer.



M	P	D	M	P	D	M	P	D
1.6	0.35	3.2	10	1.00	17	20	1.50	30
1.7	0.35	3.5	10	1.25	17	20	2.50	30
2	0.40	4	10	1.50	17	22	1.50	32
2.3	0.40	4.5	12	1.25	19	22	2.50	32
2.5	0.45	5	12	1.50	19	24	2.00	36
3	0.50	5.5	12	1.75	19	24	3.00	36
3.5	0.60	6	14	1.50	22	27	3.00	41
4	0.70	7	14	2.00	22	30	3.50	46
5	0.80	8	16	1.50	24	33	3.50	50
6	1.00	10	16	2.00	24	36	4.00	55
7	1.00	11	18	1.50	27	39	4.00	60
8	1.00	13	18	2.50	27	42	4.50	65
8	1.25	13				45	4.50	70

FIGURE 3–4 The metric system specifies fasteners by diameter, length, and pitch.

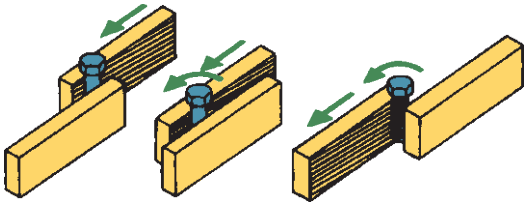


FIGURE 3–5 Stronger threads are created by cold-rolling a heat-treated bolt blank instead of cutting the threads using a die.

TENSILE STRENGTH

Graded fasteners have a higher tensile strength than non-graded fasteners. **Tensile strength** is the maximum stress used under tension (lengthwise force) without causing failure of the fastener. Tensile strength is specified in pounds per square inch (PSI). See the following chart that shows the grade and specified tensile strength.

The strength and type of steel used in a bolt is supposed to be indicated by a raised mark on the head of the bolt. The type of mark depends on the standard to which the bolt was manufactured. Most often, bolts used in machinery are made to SAE Standard J429.

Metric bolt tensile strength property class is shown on the head of the bolt as a number, such as 4.6, 8.8, 9.8, and 10.9; the higher the number, the stronger the bolt. ● **SEE FIGURE 3–6.**

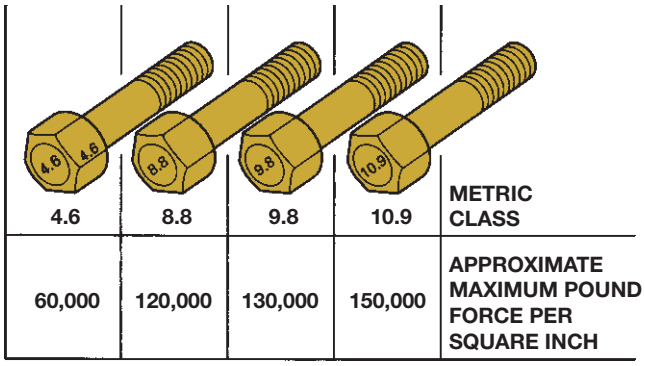


FIGURE 3–6 Metric bolt (cap screw) grade markings and approximate tensile strength.

TECH TIP

A 1/2 Inch Wrench Does Not Fit a 1/2 Inch Bolt

A common mistake made by persons new to the automotive field is to think that the size of a bolt or nut is the size of the head. The size of the bolt or nut (outside diameter of the threads) is usually smaller than the size of the wrench or socket that fits the head of the bolt or nut. Examples are given in the following table.

Wrench Size	Thread Size
7/16 inch	1/4 inch
1/2 inch	5/16 inch
9/16 inch	3/8 inch
5/8 inch	7/16 inch
3/4 inch	1/2 inch
10 mm	6 mm
12 mm or 13 mm*	8 mm
14 mm or 17 mm*	10 mm

*European (Système International d'Unités-SI) metric.

NOTE: An open-end wrench can be used to gauge bolt sizes. A 3/8 inch wrench will fit the threads of a 3/8 inch bolt.

NUTS

Most nuts used on cap screws have the same hex size as the cap screw head. Some inexpensive nuts use a hex size larger than the cap screw head. Metric nuts are often marked with dimples to show their strength. More dimples indicate stronger nuts. Some nuts and cap screws use interference fit threads

SAE Bolt Designations

SAE Grade No.	Size Range	Tensile Strength, PSI	Material	Head Marking
1	1/4 through 1-1/2	60,000	Low or medium carbon steel	
2	1/4 through 3/4	74,000		
	7/8 through 1-1/2	60,000		
5	1/4 through 1	120,000	Medium carbon steel, quenched & tempered	
	1-1/8 through 1-1/2	105,000		
5.2	1/4 through 1	120,000	Low carbon martensite steel*, quenched & tempered	
7	1/4 through 1-1/2	133,000	Medium carbon alloy steel, quenched & tempered	
8	1/4 through 1-1/2	150,000	Medium carbon alloy steel, quenched & tempered	
8.2	1/4 through 1	150,000	Low carbon Martensite steel*, quenched & tempered	

*Martensite steel is steel that has been cooled rapidly, thereby increasing its hardness. It is named after a German metallurgist, Adolf Martens.

to keep them from accidentally loosening. This means that the shape of the nut is slightly distorted or that a section of the threads is deformed. Nuts can also be kept from loosening with a nylon washer fastened in the nut or with a nylon patch or strip on the threads. ● **SEE FIGURE 3–7.**

NOTE: Most of these "locking nuts" are grouped together and are commonly referred to as prevailing torque nuts. This means that the nut will hold its tightness or torque and not loosen with movement or vibration. Most prevailing torque nuts should be replaced whenever removed to ensure that the nut will not loosen during service. Always follow the manufacturer's recommendations. Anaerobic sealers, such as Loctite®, are used on the threads where the nut or cap screw must be both locked and sealed.

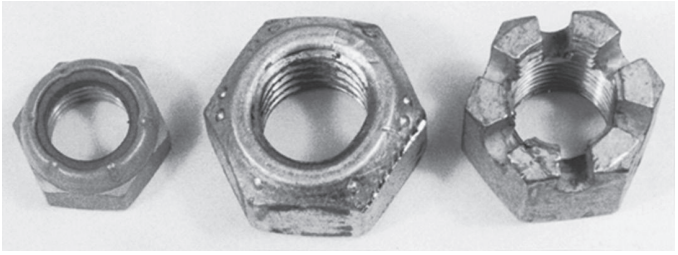


FIGURE 3–7 Types of lock nuts. On the left, a nylon ring; in the center, a distorted shape; and on the right, a castle for use with a cotter key.

TAPS AND DIES

Taps and dies are used to cut threads. **Taps** are used to cut threads in holes drilled to an exact size depending on the size of the tap. A **die** is used to cut threads on round rods or studs. Most taps and dies come as a complete set for the most commonly used fractional and metric threads.

TAPS

There are two commonly used types of taps, including:

- **Taper tap.** This is the most commonly used tap and is designed to cut threads by gradually enlarging the threaded hole.
- **Bottoming tap.** This tap has a flat bottom instead of a tapered tip to allow it to cut threads to the bottom of a drilled hole. ● **SEE FIGURE 3–8.**

All taps must be used in the proper size hole called a "tap drill size." This information is often stamped on the tap itself or in a chart that is included with a tap and die tool set. ● **SEE FIGURE 3–9.**

DIES

A die is a hardened steel round cutter with teeth on the inside of the center hole. ● **SEE FIGURE 3–10.** A die is rotated using a die handle over a rod to create threads.

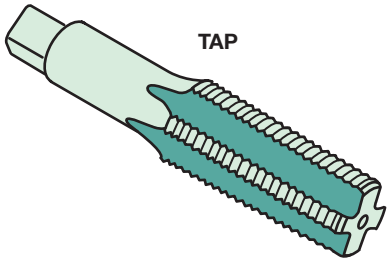


FIGURE 3–8 A typical bottoming tap used to create threads in holes that are not open, but stop in a casting, such as an engine block.

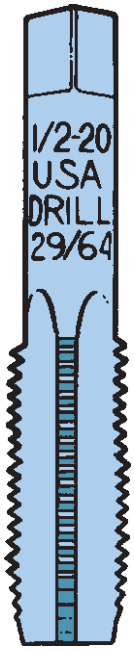


FIGURE 3–9 Many taps, especially larger ones, have the tap drill size printed on the top.

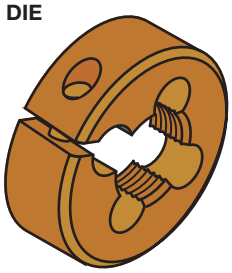


FIGURE 3–10 A die is used to cut threads on a metal rod.

PROPER USE OF TAPS AND DIES

Taps and dies are used to cut threads on rods in the case of a die or in a hole for a tap. A small tap can be held using a T-handle tap wrench but for larger taps a tap handle is needed to apply the needed force to cut threads. ● **SEE FIGURES 3–11A AND 3–11B.**

TAP USAGE. Be sure that the hole is the correct size for the tap and start by inserting the tap straight into the hole. Lubricate the tap using tapping lubricant. Rotate the tap about one full turn clockwise, then reverse the direction of the tap one-half turn to break the chip that was created. Repeat the procedure until the hole is completely threaded.

DIE USAGE. A die should be used on the specified diameter rod for the size of the thread. Install the die securely into the die handle. ● **SEE FIGURE 3–12.**

Lubricate the die and the rod and place the die onto the end of the rod to be threaded. Rotate the die handle one full turn clockwise, then reverse the direction and rotate the die handle about a half turn counterclockwise to break the chip that was created. Repeat the process until the threaded portion has been completed.

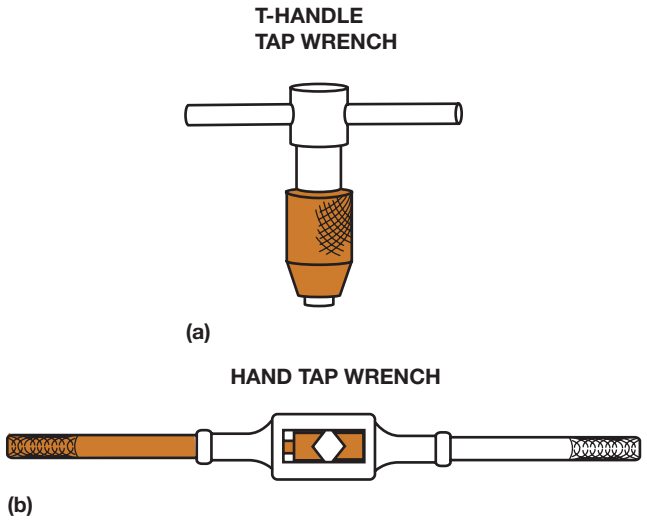


FIGURE 3–11 (a) A T-handle is used to hold and rotate small taps. (b) A tap wrench is used to hold and drive larger taps.

FIGURE 3–12 A die handle used to rotate a die while cutting threads on a metal rod.

THREAD PITCH GAUGE

A thread pitch gauge is a hand tool that has the outline of various thread sizes machined on stamped blades. To determine the thread pitch size of a fastener, the technician matches the thread of the thread pitch gauge to the threads of the fastener. ● **SEE FIGURE 3–13.**

? FREQUENTLY ASKED QUESTION

What Is the Difference Between a Tap and a Thread Chaser?

A tap is a cutting tool and is designed to cut new threads. A thread chaser has more rounded threads and is designed to clean dirty threads without removing metal. Therefore, when cleaning threads, it is best to use a thread chaser rather than a tap to prevent the possibility of removing metal, which would affect the fit of the bolt being installed. ● **SEE FIGURE 3–14.**

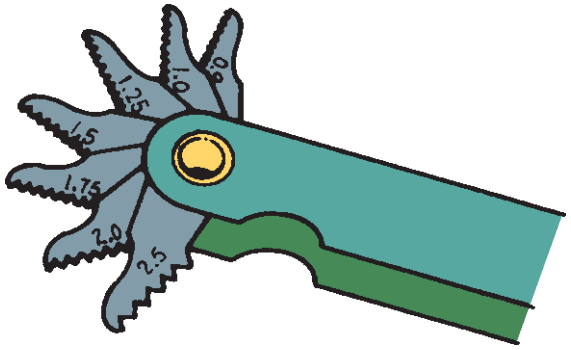


FIGURE 3–13 A typical metric thread pitch gauge.

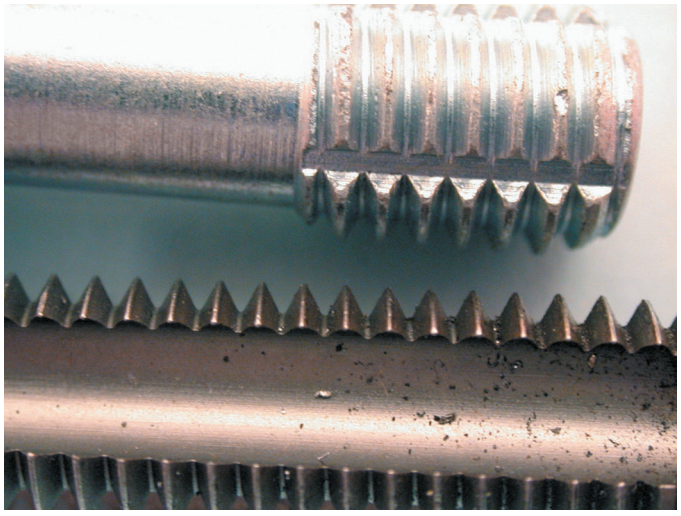


FIGURE 3–14 A thread chaser is shown at the top compared to a tap on the bottom. A thread chaser is used to clean threads without removing metal.

SHEET METAL SCREWS

Sheet metal screws are fully threaded screws with a point for use in sheet metal. Also called **self-tapping screws**, they are used in many places on the vehicle, including fenders, trim, and door panels. ● **SEE FIGURE 3–15.**

These screws are used in unthreaded holes and the sharp threads cut threads as they are installed. This makes for a quick and easy installation when installing new parts, but the sheet metal screw can easily strip out the threads when used on the same part over and over, so care is needed.

When reinstalling self-tapping screws, first turn the screw lightly backwards until you feel the thread drop into the existing thread in the screw hole. Then, turn the screw in; if it threads in easily, continue to tighten the screw. If the screw seems to turn hard, stop and turn it backwards about another half turn to locate the existing thread and try again. This technique can help prevent stripped holes in sheet metal and plastic parts.

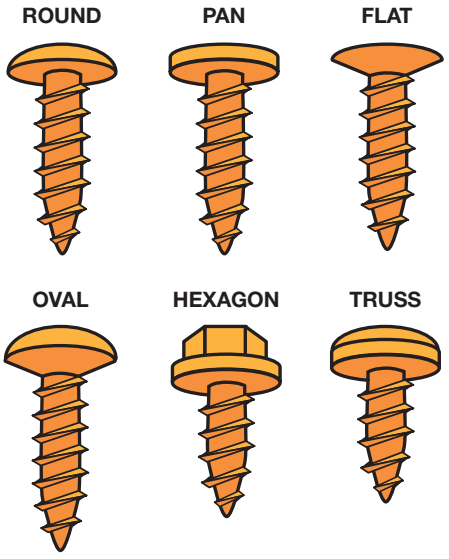


FIGURE 3–15 Sheet metal screws come with many head types.

Sheet metal screws are sized according to their major thread diameter.

Size	Diameter Decimal (inch)	Diameter Nearest Fraction Inch
4	0.11	7/64
6	0.14	9/64
8	0.17	11/64
10	0.19	3/16
12	0.22	7/32
14	0.25	1/4

WASHERS

Washers are often used under cap screw heads and under nuts. ● **SEE FIGURE 3–16.**

Plain flat washers are used to provide an even clamping load around the fastener. Lock washers are added to prevent accidental loosening. In some accessories, the washers are locked onto the nut to provide easy assembly.

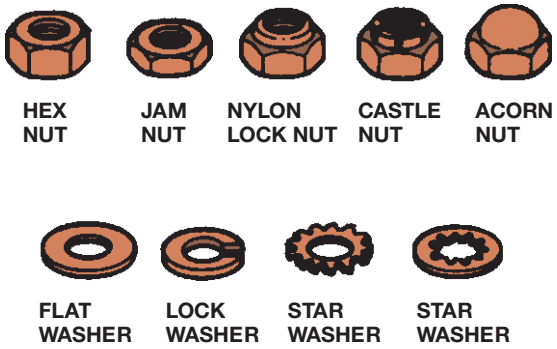


FIGURE 3–16 Various types of nuts (top) and washers (bottom) serve different purposes and all are used to secure bolts or cap screws.

Flat washers are placed underneath a nut to spread the load over a wide area and prevent gouging of the material. However, flat washers do not prevent a nut from loosening.

Lock washers are designed to prevent a nut from loosening. Spring-type lock washers resemble a loop out of a coil spring. As the nut or bolt is tightened, the washer is compressed. The tension of the compressed washer holds the fastener firmly against the threads to prevent it from loosening. Lock washers should not be used on soft metal such as aluminum. The sharp ends of the steel washers would gouge the aluminum badly, especially if they are removed and replaced often.

Another type of locking washer is the star washer. The teeth on a star washer can be external or internal, and they bite into the metal because they are twisted to expose their edges. Star washers are used often on sheet metal or body parts. They are seldom used on engines. The spring steel lock washer also uses the tension of the compressed washer to prevent the fastener from loosening. The waves in this washer make it look like a distorted flat washer.

SNAP RINGS AND CLIPS

SNAP RINGS

Snap rings are not threaded fasteners, but instead attach with a spring-like action. Snap rings are constructed of spring steel and are used to attach parts without using a threaded fastener. There are several different types of snap rings and most require the use of a special pair of pliers, called snap ring pliers, to release or install. The types of snap rings include:

- Expanding (internal)
- Contracting (external)
- E-clip
- C-clip
- Holeless snap rings in both expanding and contracting styles

● **SEE FIGURE 3–17.**

DOOR PANEL CLIPS

Interior door panels and other trim pieces are usually held in place with plastic clips. Due to the tapered and fluted shape, these clips are often called **Christmas tree clips**. ● **SEE FIGURE 3–18.**

FIGURE 3–17 Some different types of snap rings. An internal snap ring fits inside of a housing or bore, into a groove. An external snap ring fits into a groove on the outside of a shaft or axle. An E-clip fits into a groove in the outside of a shaft. A C-clip shown is used to retain a window regulator handle on its shaft.

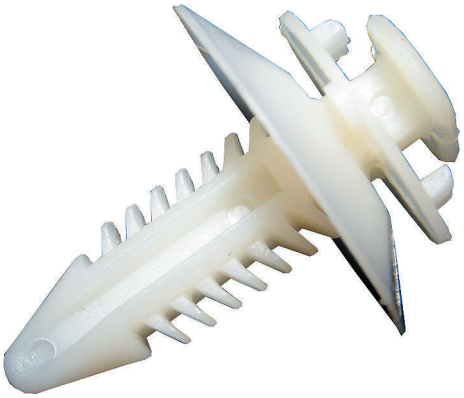


FIGURE 3–18 A typical door panel retaining clip.

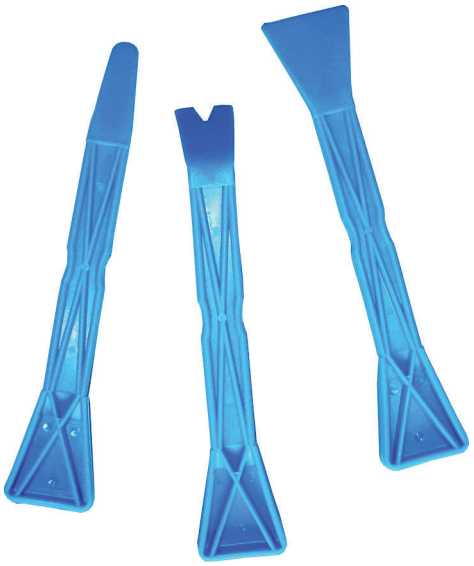


FIGURE 3–19 Plastic or metal trim tools are available to help the technician remove interior door panels and other trim without causing harm.

A special tool is often used to remove interior door panels without causing any harm. ● **SEE FIGURE 3–19.**

CAUTION: Use extreme care when removing panels that use plastic or nylon clips. It is very easy to damage the door panel or clip during removal.

PINS

Cotter pins, also called a cotter key, are used to keep linkage or a threaded nut in place or to keep it retained. The word *cotter* is an Old English verb meaning "to close or fasten." There are many other types of pins used in vehicles, including clevis pins, roll pins, and hair pins. ● **SEE FIGURE 3–20.**

Pins are used to hold together shafts and linkages, such as shift linkages and cable linkages. The clevis pin is held in place with a cotter pin, while the taper and roll pins are driven in and held by friction. The hair pin snaps into a groove on a shaft.

RIVETS

Rivets are used in many locations to retain components, such as window mechanisms, that do not require

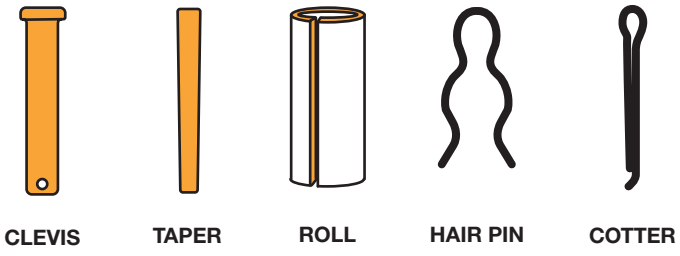


FIGURE 3–20 Pins come in various types.

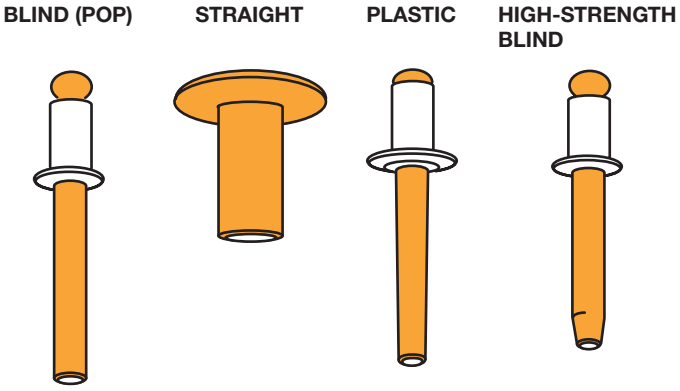


FIGURE 3–21 Various types of rivets.

routine removal and/or do not have access to the back side for a nut. A drill is usually used to remove a rivet and a rivet gun is needed to properly install a rivet. Some rivets are plastic and are used to hold some body trim pieces. The most common type of rivet is called a **pop rivet** because as the rivet tool applies a force to the shaft of the pop rivet, it causes the rivet to expand and tighten the two pieces together. When the shaft of the rivet, which looks like a nail, is pulled to its maximum, the shaft breaks, causing a "pop" sound.

Rivets may be used in areas of the vehicle where a semi-permanent attachment is needed and in places where there is no access to the back side of the workpiece. They are installed using a rivet gun or by peening with a ball-peen hammer. ● **SEE FIGURE 3–21.**

Both types of blind rivets require the use of a rivet gun to install. The straight rivet is placed through the workpieces and then peened over with a ball-peen hammer or an air-operated tool. The plastic rivet is used with a rivet gun to install some body trim parts.

LOCKING NUTS Some nuts, called jam nuts, are used to keep bolts and screws from loosening. **Jam nuts** screw on top of a regular nut and jam against the regular nut to prevent loosening. A jam nut is so called because of its intended use, rather than a special design. Some jam nuts are thinner than a standard nut. Jam nuts are also called **pal nuts**. ● **SEE FIGURE 3–22.**

There are also self-locking nuts of various types. Some have threads that are bent inward to grip the threads of the bolt. Some are oval-shaped at one end to fit tightly on a bolt. Fiber lock nuts have a fiber insert near the top of the nut or inside it; this type of nut is also made with a plastic or nylon insert. When the bolt turns through the nut, it cuts threads in

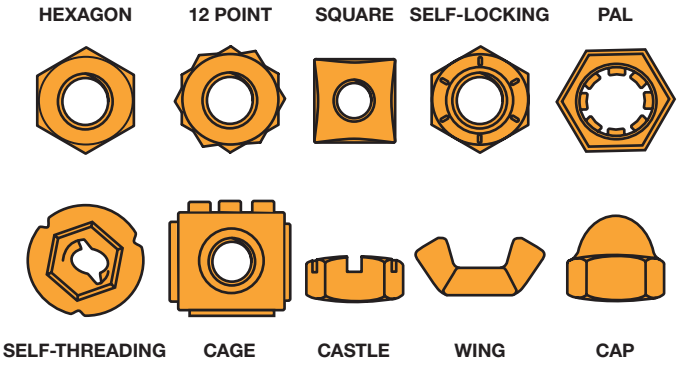


FIGURE 3–22 All of the nuts shown are used by themselves except for the pal nut, which is used to lock another nut to a threaded fastener so they will not be loosened by vibration.

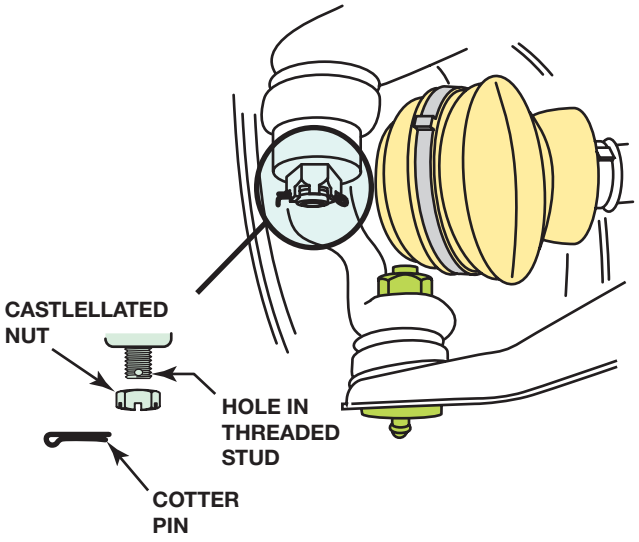


FIGURE 3–23 A castellated nut is locked in place with a cotter pin.

the fiber or plastic. This puts a drag on the threads that prevents the bolt from loosening.

One of the oldest types of retaining nuts is the castle nut. It looks like a small castle, with slots for a cotter pin. A castellated nut is used on a bolt that has a hole for the cotter pin. ● **SEE FIGURE 3–23.**

BROKEN FASTENER REMOVAL

Try not to break, strip, or round off fasteners in the first place. There are several ways that you can minimize the number of fasteners you damage. First, never force fasteners loose during disassembly. Taking a few precautionary steps will often prevent damage. If a bolt or nut will not come loose with normal force, try tightening it in slightly and then backing it out. Sometimes turning the fastener the other way will break corrosion loose, and the fastener will then come out easily. Another method that works well is to rest a punch on the head of a

stubborn bolt and strike it a sharp blow with a hammer. Often this method will break the corrosion loose.

LEFT-HANDED THREADS Although rare, left-handed fasteners are occasionally found on engine assemblies. These fasteners will loosen when you turn them clockwise, and tighten when you turn them counterclockwise. Left-handed fasteners are used to fasten parts to the ends of rotating assemblies that turn counterclockwise, such as crankshafts and camshafts. Most automobile engines do not use left-handed threads; however, they will be found on many older motorcycle engines. Some left-handed fasteners are marked with an "L" on the bolt head for easy identification, others are not. Left-handed threads are also found inside some transaxles.

PENETRATING OIL **Penetrating oil** is a lightweight lubricant similar to kerosene, which soaks into small crevices in the threads by **capillary action**. The chemical action of penetrating oils helps to break up and dissolve rust and corrosion. The oil forms a layer of boundary lubrication on the threads to reduce friction and make the fastener easier to turn.

For best results, allow the oil time to soak in before removing the nuts and bolts. To increase the effectiveness of penetrating oil, tap on the bolt head or nut with a hammer, or alternately work the fastener back and forth with a wrench. This movement weakens the bond of the corrosion and lets more of the lubricant work down into the threads.

PROPER TIGHTENING Proper tightening of bolts and nuts is critical for proper clamping force, as well as to prevent breakage. All fasteners should be tightened using a torque wrench. A torque wrench allows the technician to exert a known amount of torque to the fasteners. However, rotating torque on a fastener does not mean clamping force because up to 80% of the torque used to rotate a bolt or nut is absorbed by friction by the threads. Therefore, for accurate tightening, two things must be performed:

- The threads must be clean and lubricated if service information specifies that they be lubricated.
- Always use a torque wrench to not only ensure proper clamping force, but also to ensure that all fasteners are tightened the same.

THREAD REPAIR INSERTS

Thread repair inserts are used to replace the original threaded hole when it has become damaged beyond use. The original threaded hole is enlarged and tapped for threads and a threaded insert is installed to restore the threads to the original size.

HELICAL INSERTS A **helical insert** looks like a small, stainless-steel spring. **SEE FIGURE 3–24.**

FIGURE 3–24 Helical inserts look like small, coiled springs. The outside is a thread to hold the coil in the hole, and the inside is threaded to fit the desired fastener.

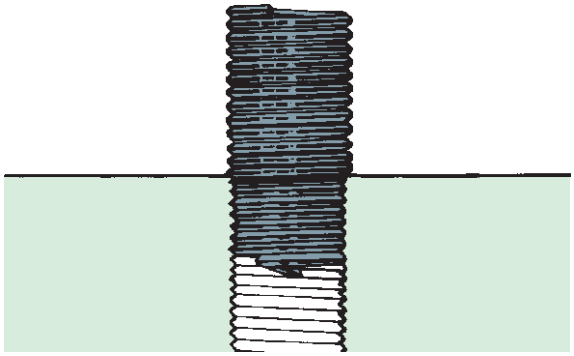


FIGURE 3–25 The insert provides new, stock-size threads inside an oversize hole so that the original fastener can be used.

To install a helical insert, a hole must be drilled to a specified oversize, and then it is tapped with a special tap designed for the thread inserts. The insert is then screwed into the hole. **SEE FIGURE 3–25.**

The insert stays in the casting as a permanent repair and bolts can be removed and replaced without disturbing the insert. One advantage of a helical insert is that the original bolt can be used because the internal threads are the same size. When correctly installed, an insert is often stronger than the original threads, especially in aluminum castings. Some vehicle manufacturers, such as BMW, specify that the threads be renewed using an insert if the cylinder head has to be removed and reinstalled. Plus many high-performance engine rebuilders install inserts in blocks, manifolds, and cylinder heads as a precaution.

One of the best known of the helical fasteners is the **Heli-Coil®**, manufactured by Heli-Coil® Products. To install Heli-Coil® inserts, you will need to have a thread repair kit. The kit includes a drill bit, tap, installation mandrel, and inserts. Repair kits are available for a wide variety of diameters and pitch to fit both American Standard and metric threads. A simple kit contains the tooling for one specific thread size. Master kits that cover a range of sizes are also available. Installing an insert is similar to tapping new threads. A summary of the procedures includes:

1. Select the Heli-Coil® kit designed for the specific diameter and thread pitch of the hole to be repaired. **SEE FIGURE 3–26.**

FIGURE 3–26 Heli-Coil® kits, available in a wide variety of sizes, contain everything needed to repair a damaged hole back to its original size.

2. Use the drill bit supplied with the kit. The drill size is also specified on the Heli-Coil® tap, to open up the hole to the necessary diameter and depth.
3. Tap the hole with the Heli-Coil® tap, being sure to lubricate the tap. Turn it in slowly and rotate counterclockwise occasionally to break the chip that is formed.
4. Thread an insert onto the installation mandrel until it seats firmly. Apply a light coating of the recommended thread locking compound to the external threads of the insert.
5. Use the mandrel to screw the insert into the tapped hole. Once started, spring tension prevents the insert from unscrewing. Stop when the top of the insert is 1/4 to 1/2 turn below the surface.
6. Remove the mandrel by unscrewing it from the insert, and then use a small punch or needle-nose pliers to break off the tang at the base of the insert. Never leave the tang in the bore. The finished thread is ready for use immediately.

THREADED INSERTS

Threaded inserts are tubular, case-hardened, solid steel wall pieces that are threaded inside and outside. The inner thread of the insert is sized to fit the original fastener of the hole to be repaired. The outer thread design will vary. These may be self-tapping threads that are installed in a blank hole, or machine threads that require the hole to be tapped. Threaded inserts return a damaged hole to original size by replacing part of the surrounding casting so drilling is required. Most inserts fit into three categories.

- Self-tapping
- Solid-bushing
- Key-locking

SELF-TAPPING INSERTS

The external threads of a self-tapping insert are designed to cut their own way into a casting. This eliminates the need of running a tap down the hole. To install a typical self-tapping insert, follow this procedure.

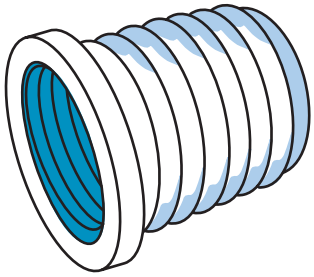


FIGURE 3–27 This solid-bushing insert is threaded on the outside, to grip the workpiece. The inner threads match the desired bolt size.

1. Drill out the damaged threads to open the hole to the proper size, using the specified size drill bit.
2. Select the proper insert and mandrel. As with Heli-Coils®, the drill bit, inserts, and mandrel are usually available as a kit.
3. Thread the insert onto the mandrel. Use a tap handle or wrench to drive the insert into the hole. Because the insert will cut its own path into the hole, it may require a considerable amount of force to drive the insert in.
4. Thread the insert in until the nut or flange at the bottom of the mandrel touches the surface of the workpiece. This is the depth stop to indicate the insert is seated.
5. Hold the nut or flange with a wrench, and turn the mandrel out of the insert. The threads are ready for immediate use.

SOLID-BUSHING INSERTS

The external threads of solid-bushing inserts are ground to a specific thread pitch, so you will have to run a tap into the hole. ● **SEE FIGURE 3–27.**

Some inserts use a machine thread so a standard tap can be used; others have a unique thread and you have to use a special tap. The thread inserts come with a matching installation kit. ● **SEE FIGURE 3–28.**

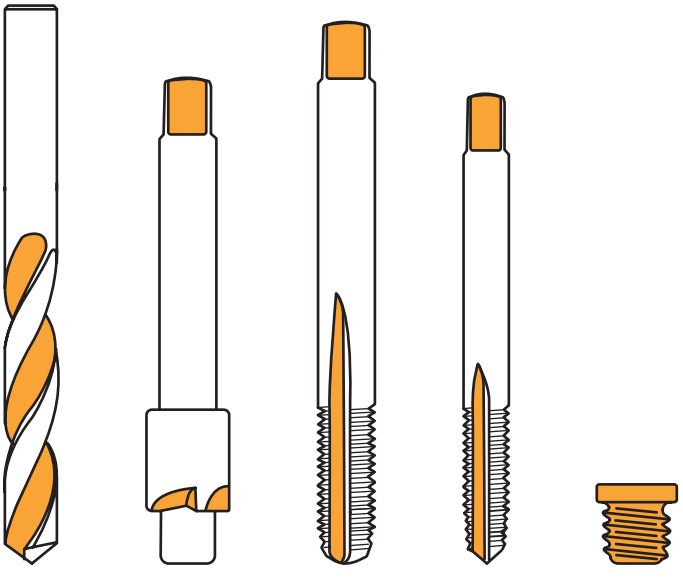


FIGURE 3–28 A Timesert® kit includes the drill (a), the recess cutter (b), a special tap (c), the installer (d), and the Timesert® threaded bushing (e).

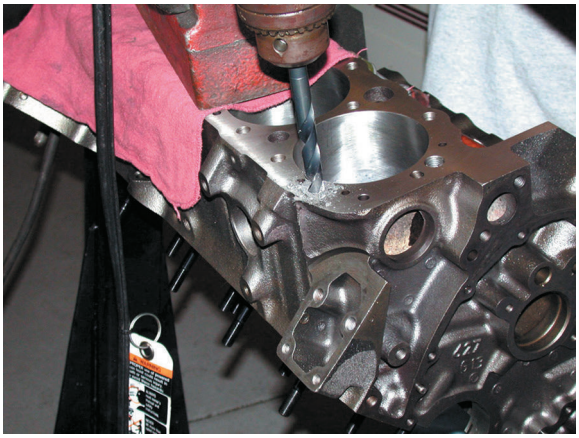


FIGURE 3–29 Drill out the damaged threads with the correct bit.

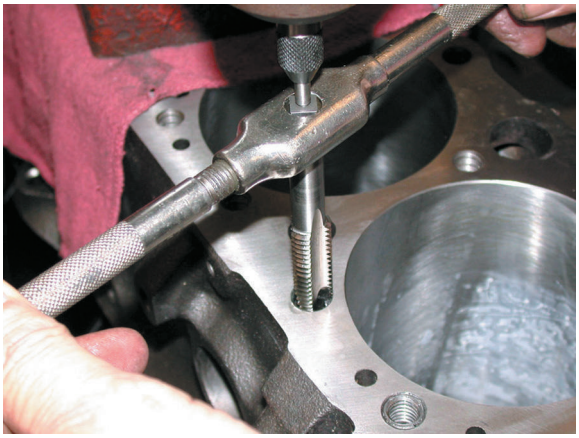


FIGURE 3–30 Use a special tap for the insert.

To install threaded inserts, follow this procedure.

1. Drill out the damaged threads to open the hole to the proper size. The drill bit supplied with the kit must be the one used because it is properly sized to the tap. **SEE FIGURE 3–29.**
2. Cut the recess in the top of the hole with the special tool, then clean the hole with a brush or compressed air.
3. Use the previously detailed tapping procedures to thread the hole. **SEE FIGURE 3–30.** Be sure to tap deep enough; the top of the insert must be flush with the casting surface.
4. Thread the insert onto the installation driver, using the driver to screw the insert into the hole. Some inserts require that a thread-locking compound be applied; others go in dry.
5. Remove the installation driver, and the new threads are ready for service with the original fastener.

KEY-LOCKING INSERTS Key-locking inserts are similar to solid-bushing inserts, but are held in place by small keys. After the insert has been installed, the keys are driven into place—perpendicular to the threads—to keep the insert from turning out. A typical installation procedure includes the following steps.

1. Drill out the damaged thread with the specified drill size.
2. Tap the drilled hole with the specified tap.

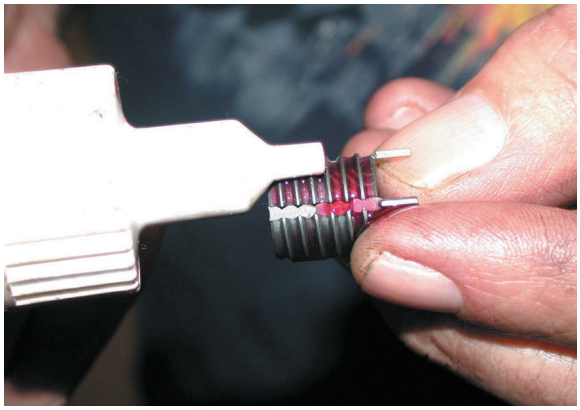


FIGURE 3–31 Put some thread-locking compound on the insert.

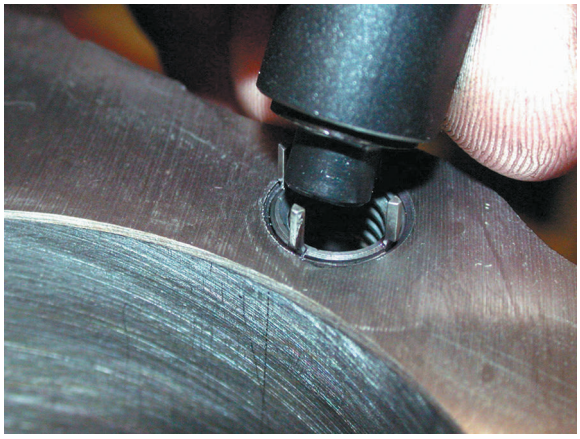


FIGURE 3–32 Use the driver to drive the keys down flush with the surface of the workpiece.

FIGURE 3–33 The insert and insert locks should be below the surface of the workpiece.

3. After putting thread locking compound on the insert, use the mandrel to screw the insert into the tapped hole until it is slightly below the surface. **SEE FIGURE 3–31.** The keys act as a depth stop and prevent the insert from turning.
4. Drive the keys down using the driver supplied with the insert kit. Be sure the keys are flush with the top of the insert. **SEE FIGURES 3–32 AND 3–33.**

SUMMARY

1. The most common type of fastener is a threaded one often referred to as a bolt. A nut or threaded hole is used at the end of a bolt to fasten two parts together.
2. The size of threaded fasteners includes the diameter, length, and pitch of the threads, as well as the shape of the head of the bolt.
3. Metric bolts are labeled with an "M," and the diameter across the threads is in millimeters followed by the distance between the threads measured in millimeters, such as M8 × 1.5.
4. Graded bolts are hardened and are capable of providing more holding force than nongraded bolts.
5. Many nuts are capable of remaining attached to the bolt regardless of vibration. These types of nuts are often called prevailing torque nuts.
6. Other commonly used fasteners in the automotive service industry include sheet metal screws, snap rings and clips, door panel clips, cotter pins, and rivets.
7. Threads can be repaired using a Heli-Coil® or threaded insert.

REVIEW QUESTIONS

1. What is the difference between a bolt and a stud?
2. How is the size of a metric bolt expressed?
3. What is meant by the grade of a threaded fastener?
4. How do prevailing torque nuts work?
5. How are threaded inserts installed?

CHAPTER QUIZ

1. The thread pitch of a bolt is measured in what units?
   a. Millimeters
   b. Threads per inch
   c. Fractions of an inch
   d. Both a and b
2. Technician A says that the diameter of a bolt is the same as the wrench size used to remove or install the fastener. Technician B says that the length is measured from the top of the head of the bolt to the end of the bolt. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
3. The grade of a fastener, such as a bolt, is a measure of its _____.
   a. Tensile strength
   b. Hardness
   c. Finish
   d. Color
4. Which of the following is a metric bolt?
   a. 5/16 − 18
   b. 1/2 − 20
   c. M12 × 1.5
   d. 8 millimeter
5. A bolt that is threaded into a casting is often called a _____.
   a. Stud
   b. Cap screw
   c. Block bolt
   d. Crest bolt
6. The marks (lines) on the heads of bolts indicate _____.
   a. Size
   b. Grade
   c. Tensile strength
   d. Both b and c
7. A bolt that requires a 1/2 inch wrench to rotate is usually what size when measured across the threads?
   a. 1/2 inch
   b. 5/16 inch
   c. 3/8 inch
   d. 7/16 inch
8. A screw that can make its own threads when installed is called a _____ screw.
   a. Sheet metal
   b. Tapered
   c. Self-tapping
   d. Both a and c
9. All of the following are types of clips *except* _____.
   a. E-clip
   b. Cotter
   c. C-clip
   d. Internal
10. What type of fastener is commonly used to retain interior door panels?
    a. Christmas tree clips
    b. E-clips
    c. External clips
    d. Internal clips

chapter 4

HAND TOOLS

LEARNING OBJECTIVES: **After studying this chapter, the reader should be able to:** • Compare the different types of wrenches. • Discuss the purpose of ratchets, sockets, and extensions, and screwdrivers. • Discuss the purpose of hammers, mallets, and pliers. • Explain the characteristics of cutters, punches, chisels, removers, and hacksaws. • Identify the different types of electrical hand tools. • Discuss the safety tips for using hand tools and hand tool maintenance.

KEY TERMS: Adjustable wrench 33 • Aviation tin snips 40 • Beam-type torque wrench 35 • Box-end wrench 32 • Breaker bar (flex handle) 34 • Cheater bar 46 • Chisel 41 • Clicker-type torque wrench 34 • Cold chisel 41 • Combination wrench 32 • Crowfoot socket 34 • Dead-blow hammer 38 • Diagonal (side-cut or dikes) pliers 39 • Double-cut file 40 • Drive size 34 • Easy out 42 • Extension 34 • Files 40 • Fitting wrench 33 • Flare-nut wrench 33 • Flat-tip (straight blade) screwdriver 36 • Hacksaw 43 • Locking pliers 39 • Multigroove adjustable pliers 38 • Needle-nose pliers 39 • Nut splitter 42 • Open-end wrench 32 • Punch 41 • Ratchet 34 • Removers 41 • Screwdriver 36 • Seal driver 45 • Seal puller 45 • Single-cut file 40 • Slip-joint pliers 38 • Snap-ring pliers 39 • Socket 34 • Socket adapter 36 • Straight cut aviation snip 40 • Stud removal tool 41 • Stud remover 41 • Tin snips 40 • Torque wrench 34 • Tube-nut wrench 33 • Universal joint 34 • Utility knife 40 • Vise-Grip® 39 • Water pump pliers 38 • Wrench 32

WRENCHES

Wrenches are the most used hand tool by service technicians. Most wrenches are constructed of forged alloy steel, usually chrome-vanadium steel. ● **SEE FIGURE 4–1.**

After the wrench is formed, it is hardened, tempered to reduce brittleness, and then chrome plated. Wrenches are available in both fractional and metric sizes. There are several types of wrenches.

OPEN-END WRENCH

An **open-end wrench** is often used to loosen or tighten bolts or nuts that do not require a lot of torque. An open-end wrench can be easily placed on a bolt or nut with an angle of 15 degrees, which allows the wrench to be flipped over and used again to continue to rotate the fastener. The major disadvantage of an open-end wrench is the lack of torque that can be applied due to the fact that the open jaws of the wrench only contact two flat surfaces of the fastener. An open-end wrench has two different sizes, one at each end. ● **SEE FIGURE 4–2.**

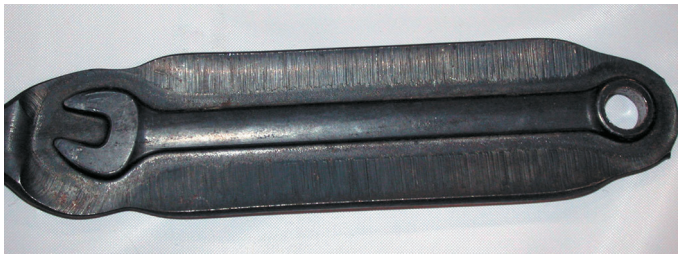


FIGURE 4–1 A forged wrench after it has been forged but before the flashing, extra material around the wrench, has been removed.

BOX-END WRENCH

A **box-end wrench** is placed over the top of the fastener and grips the points of the fastener. A box-end wrench is angled 15 degrees to allow it to clear nearby objects. ● **SEE FIGURE 4–3.**

Therefore, a box-end wrench should be used to loosen or to tighten fasteners. A box-end wrench is also called a **close-end** wrench. A box-end wrench has two different sizes, one at each end. ● **SEE FIGURE 4–4.**

COMBINATION WRENCH

Most service technicians purchase **combination wrenches**, which have the open end at one end and the same size box end on the other. ● **SEE FIGURE 4–5.**

A combination wrench allows the technician to loosen or tighten a fastener using the box end of the wrench, turn it around, and use the open end to increase the speed of rotating the fastener.

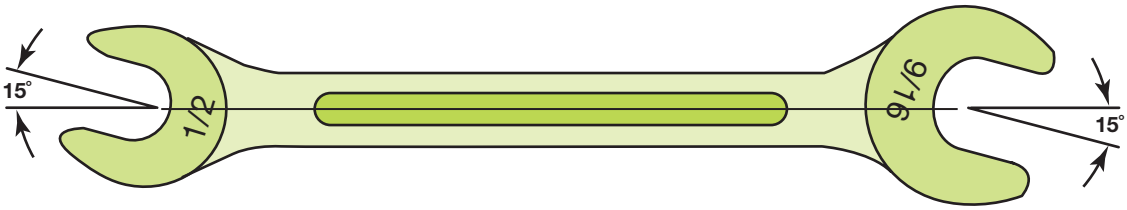


FIGURE 4–2 A typical open-end wrench. The size is different on each end and notice that the head is angled 15 degrees at each end.

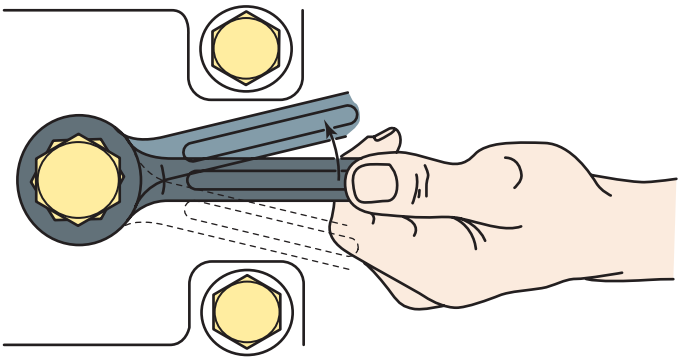


FIGURE 4–3 A typical box-end wrench is able to grip the bolt or nut at points completely around the fastener. Each end is a different size.

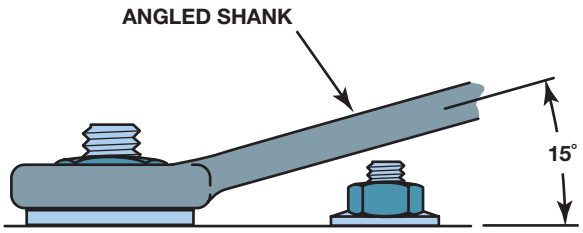


FIGURE 4–4 The end of a box-end wrench is angled 15 degrees to allow clearance for nearby objects or other fasteners.

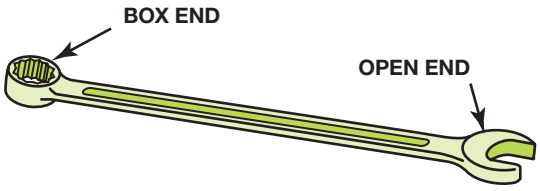


FIGURE 4–5 A combination wrench has an open end at one end and a box end at the other with the same size at each end.

ADJUSTABLE WRENCH

An **adjustable wrench** is often used where the exact size wrench is not available or when a large nut, such as a wheel spindle nut, needs to be rotated but not tightened. An adjustable wrench should not be used to loosen or tighten fasteners because the torque applied to the wrench can cause the movable jaws to loosen their grip on the fastener, causing it to become rounded. ● **SEE FIGURE 4–6.**

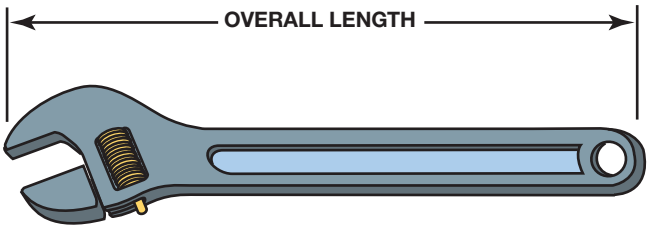


FIGURE 4–6 An adjustable wrench. Adjustable wrenches are sized by the overall length of the wrench and not by how far the jaws open. Common sizes of adjustable wrenches include 8, 10, and 12 inch.

FIGURE 4–7 The end of a typical line wrench, which shows that it is capable of grasping most of the head of the fitting.

LINE WRENCHES

Line wrenches are also called **flare-nut wrenches**, **fitting wrenches**, or **tube-nut wrenches** and are designed to grip almost all the way around a nut used to retain a fuel or refrigerant line, and yet be able to be installed over the line. ● **SEE FIGURE 4–7.**

SAFE USE OF WRENCHES. Wrenches should be inspected before use to be sure they are not cracked, bent, or damaged. All wrenches should be cleaned after use before being returned to the toolbox. Always use the correct size of wrench for the fastener being loosened or tightened to help prevent the rounding of the flats of the fastener. When attempting to loosen a fastener, pull a wrench-do not push a wrench. If a wrench is pushed, your knuckles can be hurt when forced into another object if the fastener breaks loose.

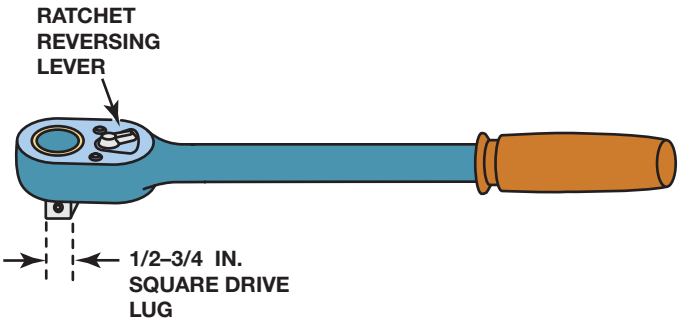


FIGURE 4–8 A typical ratchet used to rotate a socket. A ratchet makes a ratcheting noise when it is being rotated in the opposite direction from loosening or tightening. A knob or lever on the ratchet allows the user to switch directions.

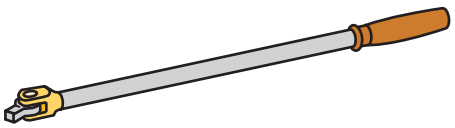


FIGURE 4–9 A typical flex handle used to rotate a socket, also called a breaker bar because it usually has a longer handle than a ratchet and, therefore, can be used to apply more torque to a fastener than a ratchet.

RATCHETS, SOCKETS, AND EXTENSIONS

A **socket** fits over the fastener and grips the points and/or flats of the bolt or nut. The socket is rotated (driven) using either a long bar called a **breaker bar (flex handle)** or a **ratchet**. ● **SEE FIGURES 4–8 AND 4–9.**

A ratchet turns the socket in only one direction and allows the rotating of the ratchet handle back and forth in a narrow space. Socket **extensions** and **universal joints** are also used with sockets to allow access to fasteners in restricted locations.

Sockets are available in various **drive sizes**, including 1/4 inch, 3/8 inch, and 1/2 inch sizes for most automotive use. ● **SEE FIGURES 4–10 AND 4–11.**

Many heavy-duty truck and/or industrial applications use 3/4 inch and 1 inch sizes. The drive size is the distance of each side of the square drive. Sockets and ratchets of the same size are designed to work together.

CROWFOOT SOCKETS

A **crowfoot socket** is a socket that is an open-end or line wrench to allow access to fasteners that cannot be reached using a conventional wrench. ● **SEE FIGURE 4–12.**

Crowfoot sockets are available in the following categories.

- Fractional inch open-end wrench
- Metric open-end wrench
- Fractional line wrench
- Metric line wrench

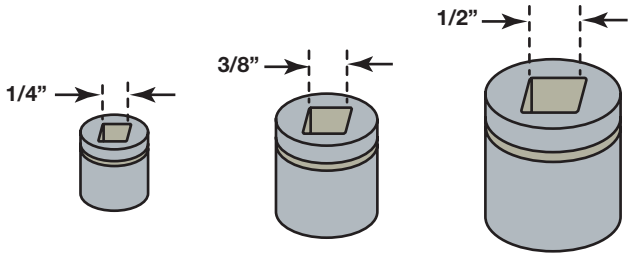


FIGURE 4–10 The most commonly used socket drive sizes include 1/4 inch, 3/8 inch, and 1/2 inch drive.

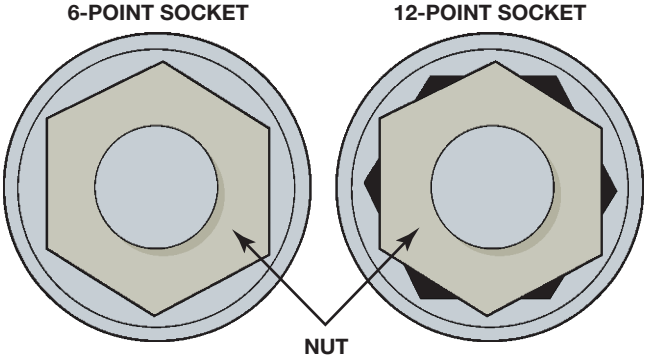


FIGURE 4–11 A 6-point socket fits the head of the bolt or nut on all sides. A 12-point socket can round off the head of a bolt or nut if a lot of force is applied.

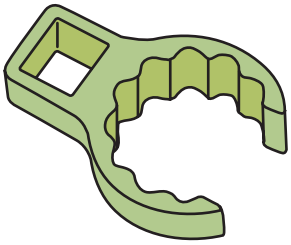


FIGURE 4–12 A crowfoot socket is designed to reach fasteners using a ratchet or breaker bar with an extension.

TORQUE WRENCHES

Torque wrenches are socket turning handles that are designed to apply a known amount of force to the fastener. There are two basic types of torque wrenches.

1. A **clicker-type torque wrench** is first set to the specified torque and then it “clicks” when the set torque value has been reached. When force is removed from the torque wrench handle, another click is heard. The setting on a clicker-type torque wrench should be set back to zero after use and checked for proper calibration regularly. ● **SEE FIGURE 4–13.**