Automotive Electricity and Electronics

Fifth Edition

James D. Halderman

AUTOMOTIVE ELECTRICITY AND ELECTRONICS

FIFTH EDITION

James D. Halderman

PEARSON

Boston Columbus Indianapolis New York San Francisco Amsterdam
Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto Delhi
Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editor-in-Chief: Andrew Gilfillan
Product Manager: Anthony T. Webster
Program Manager: Holly Shufeldt
Project Manager: Rex Davidson
Editorial Assistant: Nancy Kesterson
Team Lead Project Manager: Bryan Pirrmann
Team Lead Program Manager: Laura Weaver
Director of Marketing: David Gesell
Senior Product Marketing Manager: Darcy Betts
Field Marketing Manager: Thomas Hayward
Procurement Specialist: Deidra M. Skahill
Creative Director: Andrea Nix
Art Director: Diane Y. Ernsberger
Cover Designer: Cenveo
Full-Service Project Management: Abinaya Rajendran, Integra Software Services Pvt. Ltd.
Composition: Integra Software Services Pvt. Ltd.
Printer/Binder: R.R. Donnelley & Sons
Cover Printer: Phoenix Color
Text Font: Helvetica Neue LT Pro

Library of Congress Cataloging-in-Publication Data

Halderman, James D.
Automotive electricity and electronics/James D. Halderman.—Fifth edition.
pages cm
Includes index.
ISBN 978-0-13-407364-4 (alk. paper)—ISBN 0-13-407364-9 (alk. paper) 1. Automobiles—Electric equipment. 2. Automobiles—Electronic equipment. 3. Automobiles—Electronic equipment—Maintenance and repair. 4. Automobiles—Electric equipment—Maintenance and repair. I. Title.
TL272.H22256 2017
629.25'4—dc23

2015025861

10 9 8 7 6 5 4 3 2 1

PEARSON

ISBN 10: 0-13-407364-9
ISBN 13: 978-0-13-407364-4

PREFACE

PROFESSIONAL TECHNICIAN SERIES Part of Pearson Automotive's Professional Technician Series, the fifth edition of *Automotive Electricity and Electronics* 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 FIFTH EDITION

- Over 60 new full-color photos and line drawings to make the subject come alive.
- Updated throughout and correlated to the latest ASE/NATEF tasks.
- New Case Studies included in this edition that includes the "three Cs" (Complaint, cause and correction).
- New OSHA hazardous chemical labeling requirements added to Chapter 2.
- Additional explanations added to Chapter 4 about electrical circuits to make learning this important topic easier to understand.
- New content on three-legged and low profile fuses plus smart junction boxes added to Chapter 10.
- New content on immobilizer systems added to Chapter 26.
- Unlike other textbooks, this book is written so that the theory, construction, diagnosis, and service of a particular component or system is presented in one location. There is no need to search through the entire book for other references to the same topic.

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 two locations:

- As an appendix to each book.
- At the beginning of each chapter in the *Instructor's Manual*.

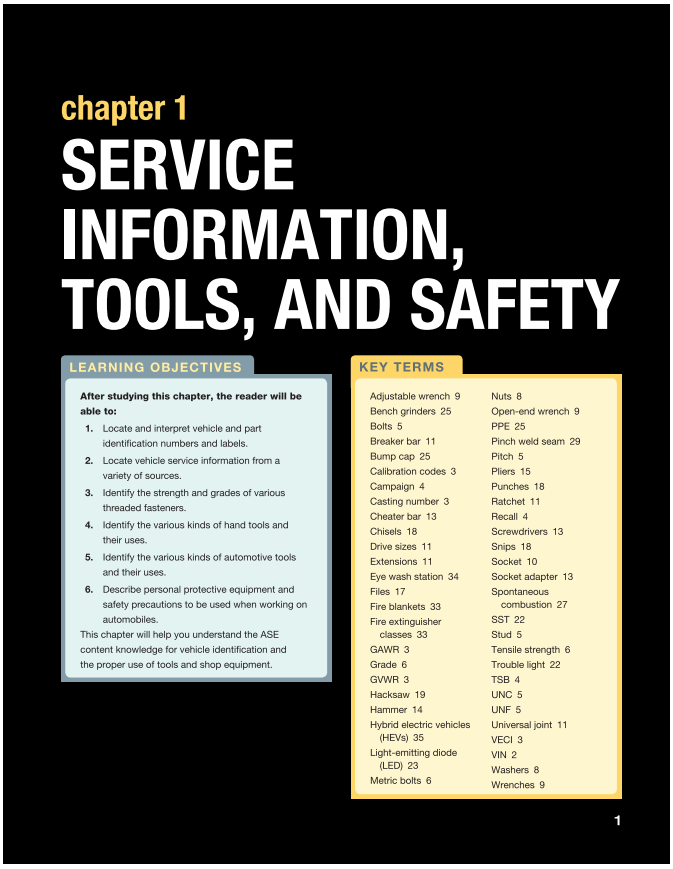
A COMPLETE INSTRUCTOR AND STUDENT SUPPLEMENTS PACKAGE All *Professional Technician* textbooks are accompanied by a full set of instructor and student supplements. Please see page vi for a detailed list of supplements.

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

SERVICE INFORMATION, TOOLS, AND SAFETY

LEARNING OBJECTIVES

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

1. Locate and interpret vehicle and part identification numbers and labels.
2. Locate vehicle service information from a variety of sources.
3. Identify the strength and grades of various threaded fasteners.
4. Identify the various kinds of hand tools and their uses.
5. Identify the various kinds of automotive tools and their uses.
6. Describe personal protective equipment and safety precautions to be used when working on automobiles.

This chapter will help you understand the ASE content knowledge for vehicle identification and the proper use of tools and shop equipment.

KEY TERMS

Adjustable wrench 9
Bench grinders 25
Bolts 5
Breaker bar 11
Bump cap 25
Calibration codes 3
Campaign 4
Casting number 3
Cheater bar 13
Chisels 18
Drive sizes 11
Extensions 11
Eye wash station 34
Files 17
Fire blankets 33
Fire extinguisher classes 33
GAWR 3
Grade 6
GVWR 3
Hacksaw 19
Hammer 14
Hybrid electric vehicles (HEVs) 35
Light-emitting diode (LED) 23
Metric bolts 6
Nuts 8
Open-end wrench 9
PPE 25
Pinch weld seam 29
Pitch 5
Pliers 15
Punches 18
Ratchet 11
Recall 4
Screwdrivers 13
Snips 18
Socket 10
Socket adapter 13
Spontaneous combustion 27
SST 22
Stud 5
Tensile strength 6
Trouble light 22
TSB 4
UNC 5
UNF 5
Universal joint 11
VECI 3
VIN 2
Washers 8
Wrenches 9

1

LEARNING 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.

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

Lightning Damage

A radio failed to work in a vehicle that was outside during a thunderstorm. The technician checked the fuses and verified that power was reaching the radio. Both the radio and the antenna were replaced to correct the problem. **SEE FIGURE 28–26.**

Summary:

- **Complaint**—Customer stated that the radio did not work.
- **Cause**—Visual inspection showed an antenna that had been stuck by lightning.
- **Correction**—Replacing the radio and the antenna restored proper operation.

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

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.

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.**

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.

NOTE: Claw hammer has a claw used to remove nails; therefore, it is not for automotive service.

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

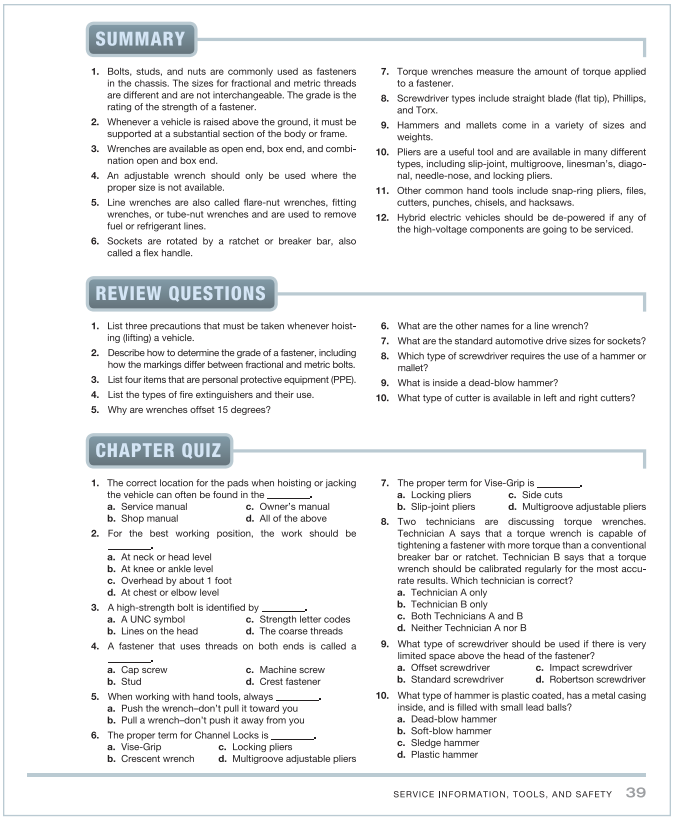
CAUTION: Do not use a screwdriver as a pry tool or chisel. Screwdrivers use hardened steel only at the tip and are not designed to be pounded on or used for prying because they could bend easily. Always use the proper tool for each application.

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

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



SUMMARY

1. Bolts, studs, and nuts are commonly used as fasteners in the chassis. The sizes for fractional and metric threads are different and are not interchangeable. The grade is the rating of the strength of a fastener.
2. Whenever a vehicle is raised above the ground, it must be supported at a substantial section of the body or frame.
3. Wrenches are available as open end, box end, and combination open and box end.
4. An adjustable wrench should only be used where the proper size is not available.
5. Line wrenches are also called flare-nut wrenches, fitting wrenches, or tube-nut wrenches and are used to remove fuel or refrigerant lines.
6. Sockets are rotated by a ratchet or breaker bar, also called a flex handle.
7. Torque wrenches measure the amount of torque applied to a fastener.
8. Screwdriver types include straight blade (flat tip), Phillips, and Torx.
9. Hammers and mallets come in a variety of sizes and weights.
10. Pliers are a useful tool and are available in many different types, including slip-joint, multigroove, linesman's, diagonal, needle-nose, and locking pliers.
11. Other common hand tools include snap-ring pliers, files, cutters, punches, chisels, and hacksaws.
12. Hybrid electric vehicles should be de-powered if any of the high-voltage components are going to be serviced.

REVIEW QUESTIONS

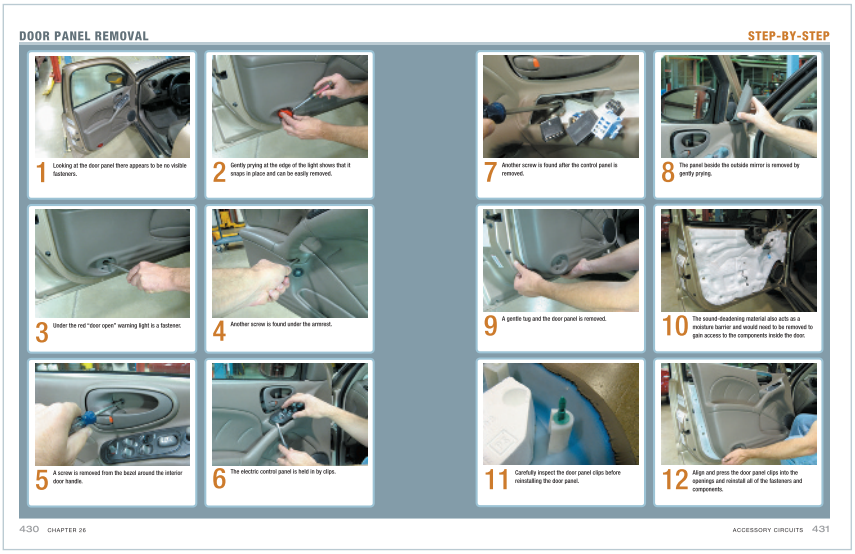
1. List three precautions that must be taken whenever hoisting (lifting) a vehicle.
2. Describe how to determine the grade of a fastener, including how the markings differ between fractional and metric bolts.
3. List four items that are personal protective equipment (PPE).
4. List the types of fire extinguishers and their use.
5. Why are wrenches offset 15 degrees?
6. What are the other names for a line wrench?
7. What are the standard automotive drive sizes for sockets?
8. Which type of screwdriver requires the use of a hammer or mallet?
9. What is inside a dead-blow hammer?
10. What type of cutter is available in left and right cutters?

CHAPTER QUIZ

1. The correct location for the pads when hoisting or jacking the vehicle can often be found in the _____.
   a. Service manual c. Owner's manual
   b. Shop manual d. All of the above
2. For the best working position, the work should be _____.
   a. At neck or head level
   b. At knee or ankle level
   c. Overhead by about 1 foot
   d. At chest or elbow level
3. A high-strength bolt is identified by _____.
   a. A UNC symbol c. Strength letter codes
   b. Lines on the head d. The coarse threads
4. A fastener that uses threads on both ends is called a _____.
   a. Cap screw c. Machine screw
   b. Stud d. Crest fastener
5. When working with hand tools, always _____.
   a. Push the wrench–don't pull it toward you
   b. Pull a wrench–don't push it away from you
6. The proper term for Channel Locks is _____.
   a. Vise-Grip c. Locking pliers
   b. Crescent wrench d. Multigroove adjustable pliers
7. The proper term for Vise-Grip is _____.
   a. Locking pliers c. Side cuts
   b. Slip-joint pliers d. Multigroove adjustable pliers
8. Two technicians are discussing torque wrenches. Technician A says that a torque wrench is capable of tightening a fastener with more torque than a conventional breaker bar or ratchet. Technician B says that a torque wrench should be calibrated regularly for the most accurate results. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
9. What type of screwdriver should be used if there is very limited space above the head of the fastener?
   a. Offset screwdriver c. Impact screwdriver
   b. Standard screwdriver d. Robertson screwdriver
10. What type of hammer is plastic coated, has a metal casing inside, and is filled with small lead balls?
    a. Dead-blow hammer
    b. Soft-blow hammer
    c. Sledge hammer
    d. Plastic hammer

SERVICE INFORMATION, TOOLS, AND SAFETY 39

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 Electricity and Electronics

NAME OF SUPPLEMENT	PRINT	ONLINE	AUDIENCE	DESCRIPTION
Instructor Resource Manual 0134066774		✔	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.
TestGen 0134074742		✔	Instructors	Test generation software and test bank for the text.
PowerPoint Presentation 013407484X		✔	Instructors	Slides include chapter learning objectives, lecture outline of the text, and graphics from the book.
Image Bank 0134074858		✔	Instructors	All of the images and graphs from the text-book to create customized lecture slides.
NATEF Correlated Task Sheets – for instructors 0134074718		✔	Instructors	Downloadable NATEF task sheets for easy customization and development of unique task sheets.
NATEF Correlated Task Sheets – for Students 0134074769	✔		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.
CourseSmart eText 0134074890		✔	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.coursesmart.com**

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

ACKNOWLEDGMENTS

A large number of people and organizations have cooperated in providing the reference material and technical information used in this text. The author wishes to express sincere thanks to the following for their special contributions:

ASE

Automotion, Inc.

Automotive Parts Rebuilders Association (APRA)

Dr. John Kershaw, Criterion Technical Education Consultants

Dave Scaler, Mechanics Education Association

Graphic Home

John Thornton, Autotrain Inc.

Mark Warren

Society of Automotive Engineers (SAE)

Tom Birch

Toyota Motor Sales, USA, Inc.

Wurth USA, Inc.

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.

Jim Anderson
Greenville High School

Brett Baird
Salt Lake Community College

Victor Bridges
Umpqua Community College

Matt Dixon
Southern Illinois University

Dr. Roger Donovan
Illinois Central College

A. C. Durdin
Moraine Park Technical College

Al Engledahl
College of Dupage

Aaron Gregory
Merced College

Larry Hagelberger
Upper Valley Joint Vocational School

Oldrick Hajzler
Red River College

Betsy Hoffman
Vermont Technical College

Richard Krieger
Michigan Institute of Technology

Steven T. Lee
Lincoln Technical Institute

Carlton H. Mabe, Sr.
Virginia Western Community College

Roy Marks
Owens Community College

Tony Martin
University of Alaska Southeast

Kerry Meier
San Juan College

Jim Morton
Automotive Training Center (ATC)

Fritz Peacock
Indiana Vocational Technical College

Greg Pfahl
Miami-Jacobs Career College

Dennis Peter
NAIT (Canada)

Kenneth Redick
Hudson Valley Community College

Douglas Redman
College of the Desert

Jeff Rehkopf
Florida State College

Omar Trinidad
Southern Illinois University

Mitchell Walker
St. Louis Community College at Forest Park

Jennifer Wise
Sinclair Community College

Special thanks to instructional designer **Alexis I. Skriloff James.**

PHOTO SEQUENCES The author wishes to thank Chuck Taylor of Sinclair Community College in Dayton, Ohio, and James (Mike) Watson, who helped with many of the photos. A special thanks to Carl Borsani for his help with many of the new figures used in this edition.

Most of all, I wish to thank Michelle Halderman for her assistance in all phases of manuscript preparation.

—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 (A1-A8), plus A9, F1, G1, L1 and L3).

Jim is the author of many automotive textbooks, all published by Pearson Education.

He 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 an outstanding alumnus of 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

This page intentionally left blank

chapter 1

SERVICE INFORMATION, TOOLS, AND SAFETY

LEARNING OBJECTIVES

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

1. Locate and interpret vehicle and part identification numbers and labels.
2. Locate vehicle service information from a variety of sources.
3. Identify the strength and grades of various threaded fasteners.
4. Identify the various kinds of hand tools and their uses.
5. Identify the various kinds of automotive tools and their uses.
6. Describe personal protective equipment and safety precautions to be used when working on automobiles.

This chapter will help you understand the ASE content knowledge for vehicle identification and the proper use of tools and shop equipment.

KEY TERMS

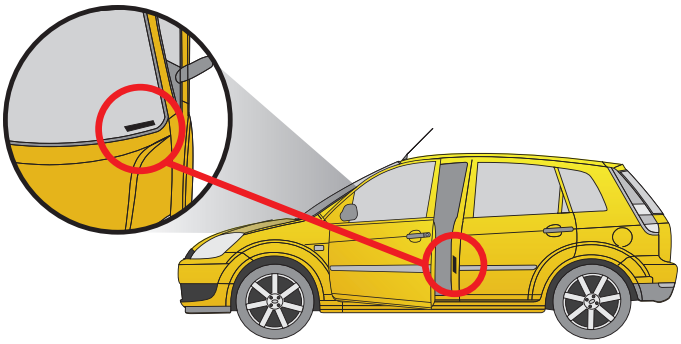


FIGURE 1–1 The vehicle identification number (VIN) is visible through the base of the windshield and on a decal inside the driver's door.

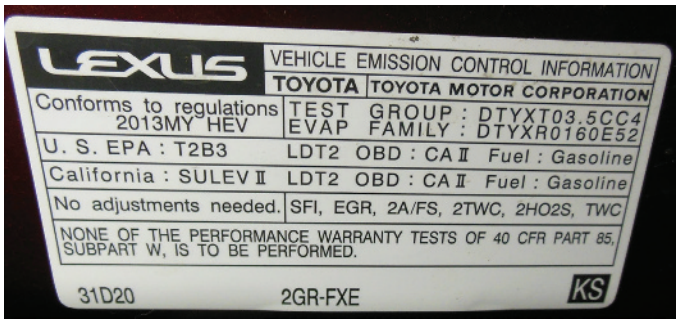


FIGURE 1–2 The vehicle emissions control information (VECI) sticker is placed under the hood.

VEHICLE IDENTIFICATION

MAKE, MODEL, AND YEAR

All service work requires that the vehicle and its components be properly identified. The most common identification is the make, model, and year of manufacture of the vehicle.

Make: e.g., Chevrolet

Model: e.g., Impala

Year: e.g., 2008

VEHICLE IDENTIFICATION NUMBER

The year of the vehicle is often difficult to determine exactly. A model may be introduced as the next year's model as soon as January of the previous year. Typically, a new model year starts in September or October of the year prior to the actual new year, but not always. This is why the **vehicle identification number,** usually abbreviated **VIN,** is so important. ● **SEE FIGURE 1–1**.

Since 1981, all vehicle manufacturers have used a VIN that is 17 characters long. Although every vehicle manufacturer assigns various letters or numbers within these 17 characters, there are some constants, including:

- The first number or letter designates the country of origin. ● **SEE CHART 1–1**.
- The fourth and fifth characters represent the vehicle line/series.
- The sixth character is the body style.
- The seventh character is the restraint system.
- The eighth character is often the engine code. (Some engines cannot be determined by the VIN.)
- The tenth character represents the year on all vehicles. ● **SEE CHART 1–2**.

1 = United States	J = Japan	T = Czechoslovakia
2 = Canada	K = Korea	U = Romania
3 = Mexico	L = China	V = France
4 = United States	M = India	W = Germany
5 = United States	N = Turkey	X = Russia
6 = Australia	P = Philippines	Y = Sweden
8 = Argentina	R = Taiwan	Z = Italy
9 = Brazil	S = England	

CHART 1–1

The first number or letter in the VIN identifies the country where the vehicle was made.

A = 1980/2010	L = 1990/2020	Y = 2000/2030
B = 1981/2011	M = 1991/2021	1 = 2001/2031
C = 1982/2012	N = 1992/2022	2 = 2002/2032
D = 1983/2013	P = 1993/2023	3 = 2003/2033
E = 1984/2014	R = 1994/2024	4 = 2004/2034
F = 1985/2015	S = 1995/2025	5 = 2005/2035
G = 1986/2016	T = 1996/2026	6 = 2006/2036
H = 1987/2017	V = 1997/2027	7 = 2007/2037
J = 1988/2018	W = 1998/2028	8 = 2008/2038
K = 1989/2019	X = 1999/2029	9 = 2009/2039

CHART 1–2

The pattern repeats every 30 years for the year of manufacture.

FIGURE 1–3 A typical calibration code sticker on the case of a controller. The information on the sticker is often required when ordering parts or a replacement controller.

FIGURE 1–4 Casting numbers on major components can be either cast or stamped.

VEHICLE SAFETY CERTIFICATION LABEL A vehicle safety certification label is attached to the left side pillar post on the rearward-facing section of the left front door. This label indicates the month and year of manufacture as well as the **gross vehicle weight rating (GVWR),** the **gross axle weight rating (GAWR),** and the VIN.

VECI LABEL The **vehicle emissions control information (VECI)** label under the hood of the vehicle shows informative settings and emission hose routing information. ● **SEE FIGURE 1–2**.

The VECI label (sticker) can be located on the bottom side of the hood, the radiator fan shroud, the radiator core support, or on the strut towers. The VECI label usually includes the following information.

- Engine identification
- Emissions standard that the vehicle meets
- Vacuum hose routing diagram
- Base ignition timing (if adjustable)
- Spark plug type and gap
- Valve lash
- Emission calibration code

CALIBRATION CODES **Calibration codes** are usually located on powertrain control modules (PCMs) or other controllers. Whenever diagnosing an engine operating fault, it is often necessary to use the calibration code to be sure that the vehicle is the subject of a technical service bulletin or other service procedure. ● **SEE FIGURE 1–3**.

CASTING NUMBERS When an engine part such as a block is cast, a number is put into the mold to identify the casting. ● **SEE FIGURE 1–4**. These **casting numbers** can be used to identify the part and to check dimensions, such as the cubic inch displacement, and other information, such as the year of manufacture. Sometimes changes are made to the mold, yet the casting number is not changed. Most often the casting number is the best piece of identifying information that the service technician can use for identifying an engine.

SERVICE INFORMATION

SERVICE MANUALS Service information is used by the service technician to determine specifications and service procedures, and any needed special tools.

Factory and aftermarket service manuals contain specifications and service procedures. While factory service manuals cover just one year and one or more models of the same vehicle, most aftermarket service manufacturers cover multiple years and/or models in one manual.

FIGURE 1–5 Electronic service information is available from aftermarket sources, such as All-Data and Mitchell-on-Demand, as well as on websites hosted by vehicle manufacturers.

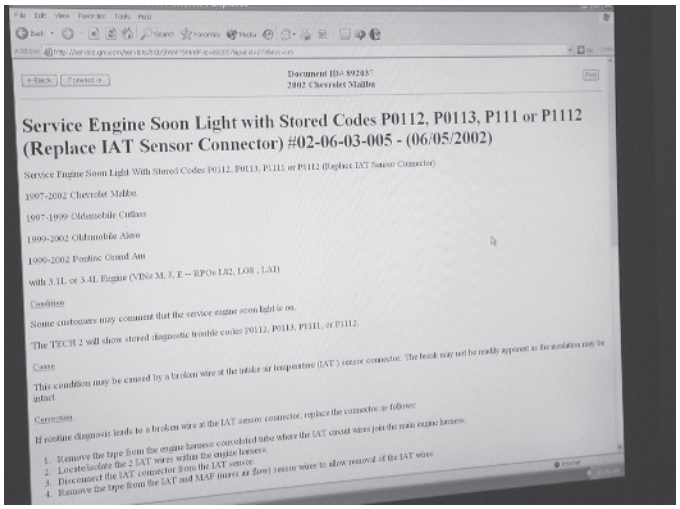


FIGURE 1–6 Technical service bulletins (TSBs) are issued by vehicle manufacturers when a fault occurs that affects many vehicles with the same problem. The TSB then provides the fix for the problem including any parts needed and detailed instructions.

Included in most service manuals are the following:

- Capacities and recommended specifications for all fluids
- Specifications including engine and routine maintenance items
- Testing procedures
- Service procedures including the use of special tools when needed

ELECTRONIC SERVICE INFORMATION Electronic service information is available mostly by subscription and provides access to an Internet site where service manual–type information is available. ● **SEE FIGURE 1–5**. Most vehicle manufacturers also offer electronic service information to their dealers and to most schools and colleges that offer corporate training programs.

TECHNICAL SERVICE BULLETINS **Technical service bulletins,** often abbreviated **TSBs,** sometimes called *technical service information bulletins (TSIBs)*, are issued by the vehicle manufacturer to notify service technicians of a problem and include the necessary corrective action. Technical service bulletins are designed for dealership technicians but are republished by aftermarket companies and made available along with other service information to shops and vehicle repair facilities. ● **SEE FIGURE 1–6**.

INTERNET The Internet has opened the field for information exchange and access to technical advice. One of the most useful websites is the International Automotive Technician's Network at **www.iatn.net**. This is a free site but service technicians must register to join. For a small monthly sponsor fee, the shop or service technician can gain access to the archives, which include thousands of successful repairs in the searchable database.

RECALLS AND CAMPAIGNS A **recall** or **campaign** is issued by a vehicle manufacturer and a notice is sent to all owners in the event of a safety-related fault or concern. Although these faults may be repaired by shops, they are generally handled by a local dealer. Items that have created recalls in the past include potential fuel system leakage problems, exhaust leakage, or electrical malfunctions that could cause a possible fire or the engine to stall. Unlike technical service bulletins whose cost is only covered when the vehicle is within the warranty period, a recall or campaign is always done at no cost to the vehicle owner.

FREQUENTLY ASKED QUESTION

What Should Be Included on a Work Order?

A work order is a legal document that should include the following information.

1. Customer information
2. Identification of the vehicle including the VIN
3. Related service history information
4. The "three Cs":
   - Customer concern (complaint)
   - Cause of the concern
   - Correction or repairs that the vehicle required to return it to proper operation

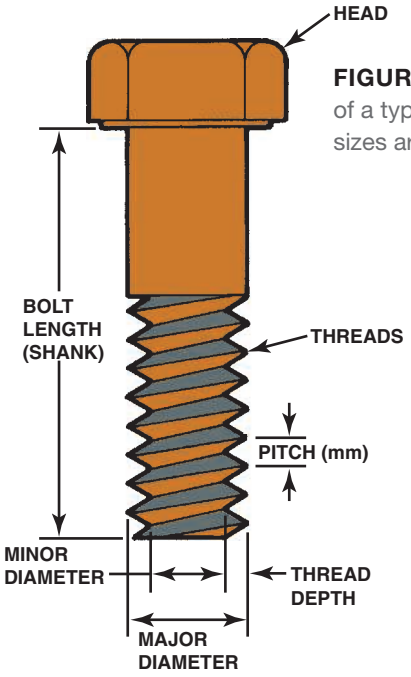


FIGURE 1–7 The dimensions of a typical bolt showing where sizes are measured.

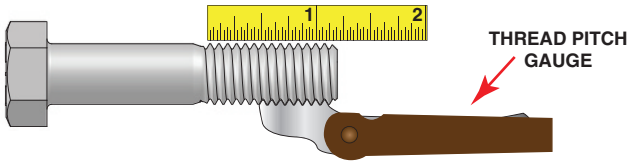


FIGURE 1–8 Thread pitch gauge used to measure the pitch of the thread. This bolt has 13 threads to the inch.

THREADED FASTENERS

BOLTS AND THREADS Most of the threaded fasteners used on vehicles are **bolts.** Bolts 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 major diameter or the *crest* of the thread. ● **SEE FIGURE 1–7.**

FRACTIONAL BOLTS 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 1–8.** Bolts are identified by their diameter and length as measured from below the head, not by the size of the head or the size of the wrench used to remove or install the bolt.

Fractional thread sizes are specified by the diameter in fractions of an inch and the number of threads per inch. Typical

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.**

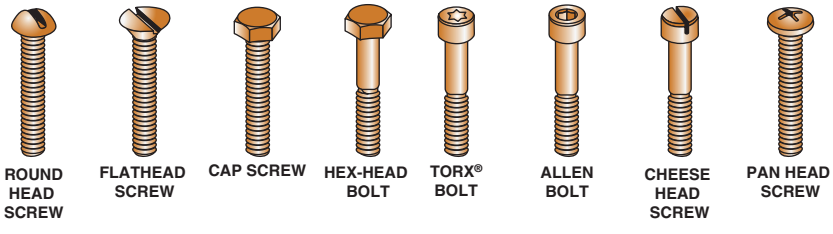


FIGURE 1–9 Bolts and screws have many different heads. The head determines what tool is needed.

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
9/16	12	. .	0.5625
9/16	. .	18	0.5625
5/8	11	. .	0.6250
5/8	. .	18	0.6250
3/4	10	. .	0.7500
3/4	. .	16	0.7500
7/8	9	. .	0.8750
7/8	. .	14	0.8750

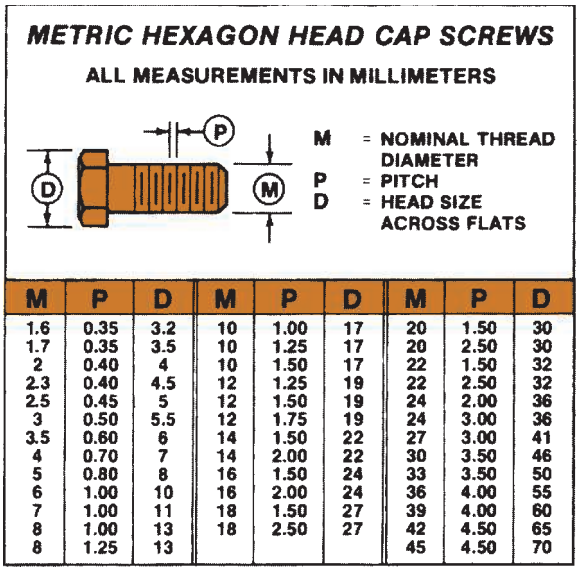
CHART 1–3

American Standard is one method of sizing fasteners.

UNC thread sizes would be 5/16–18 and 1/2–13. Similar UNF thread sizes would be 5/16–24 and 1/2–20. ● **SEE CHART 1–3**.

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 X 1.5). ● **SEE FIGURE 1–10**.



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 1–10 The metric system specifies fasteners by diameter, length, and pitch.

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.

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 1–11**. 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.**

TENSILE STRENGTH OF FASTENERS

Graded fasteners have a higher tensile strength than nongraded fasteners. **Tensile strength** is the maximum stress under tension (lengthwise force) without causing failure of the fastener. Tensile strength is specified in pounds per square inch (psi).

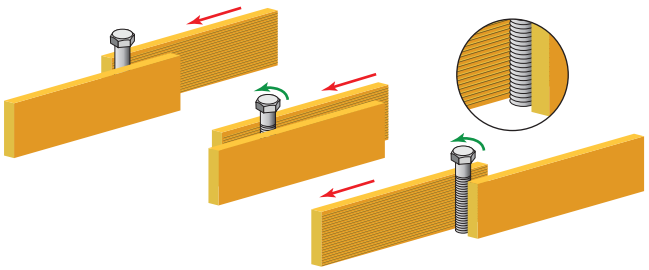


FIGURE 1–11 Stronger threads are created by cold rolling a heat-treated bolt blank instead of cutting the threads, using a die.

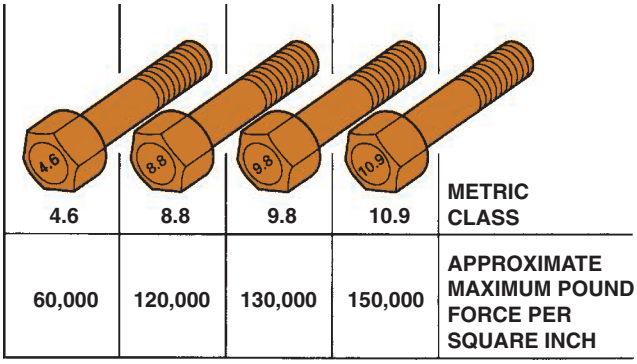


FIGURE 1–12 Metric bolt (cap screw) grade markings and approximate tensile strength.

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 and tempered	
	1-1/8 through 1 1/2	105,000		
5.2	1/4 through 1	120,000	Low carbon martensite steel,* quenched and tempered	
7	1/4 through 1 1/2	133,000	Medium carbon alloy steel, quenched and tempered	
8	1/4 through 1 1/2	150,000	Medium carbon alloy steel, quenched and tempered	
8.2	1/4 through 1	150,000	Low carbon martensite steel,* quenched and tempered	

CHART 1–4

The tensile strength rating system as specified by the Society of Automotive Engineers (SAE).
* Martensite steel is steel that has been cooled rapidly, thereby increasing its hardness. It is named after a German metallurgist, Adolf Martens.

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. ● **CHART 1–4** shows the grade and specified tensile strength.

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 1–12**.

FIGURE 1–13 Nuts come in a variety of styles, including locking (prevailing torque) types, such as the distorted thread and nylon insert type.

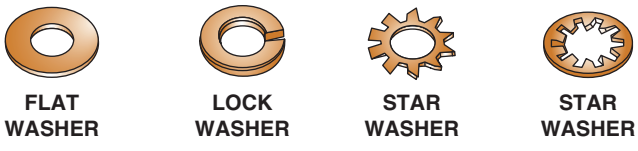


FIGURE 1–14 Washers come in a variety of styles, including flat and star (serrated), and are often used to help prevent a fastener from loosening.

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 or 13 mm*	8 mm
14 or 17 mm*	10 mm

* European (Systeme International d'Unites, or SI) metric

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. Often, the same diameter of fastener is used on a component, but the length of the bolt may vary. Spending just a couple of seconds to put the bolts and nuts back where they belong when the part is removed can save a lot of time when the part is being reinstalled. Besides making certain that the right fastener is being installed in the right place, this method helps prevent bolts and nuts from getting lost or kicked away. How much time have you wasted looking for that lost bolt or nut?

NUTS

Nuts are the female part of a threaded fastener. 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 to keep them from accidentally loosening. This means that the shape of the nut is slightly distorted or that a section of the thread 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 1–13**.

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.

WASHERS

Washers are often used under cap screw heads and under nuts. ● **SEE FIGURE 1–14**. 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.

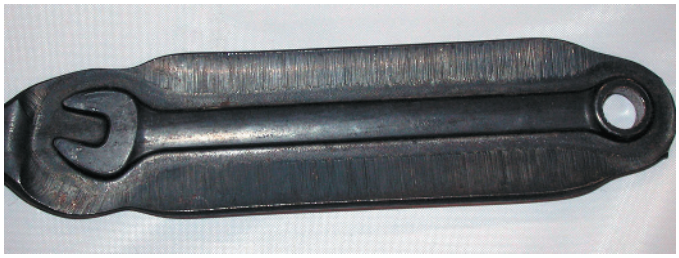


FIGURE 1–15 A wrench after it has been forged but before the flashing (extra material around the wrench) has been removed.

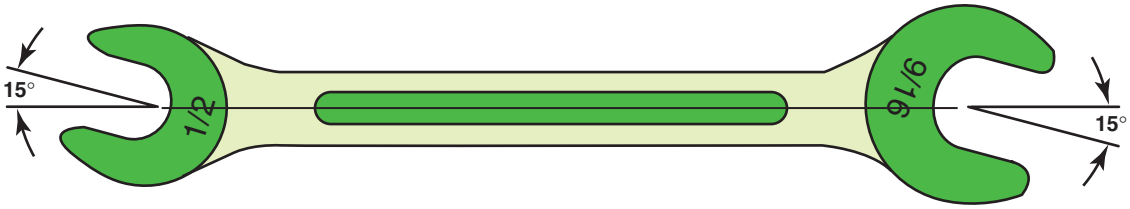


FIGURE 1–16 A typical open-end wrench. Note the size difference on each end and that the head is angled 15 degrees at the end.

HAND TOOLS

WRENCHES

Wrenches are the most used hand tool by service technicians. **Wrenches** are used to grasp and rotate threaded fasteners. Most wrenches are constructed of forged alloy steel, usually chrome-vanadium steel. ● **SEE FIGURE 1–15**.

After the wrench is formed, it is hardened, tempered to reduce brittleness, and then chrome-plated. There are several types of wrenches.

- An **open-end wrench** is often used to loosen or tighten bolts or nuts that do not require a lot of torque. Because of the *open* end, this type of 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 1–16**.
- A box-end wrench, also called a *closed-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.

  Therefore, a box-end wrench should be used to loosen or tighten fasteners because it grasps around the entire head of the fastener. A box-end wrench has two different sizes, one at each end. ● **SEE FIGURE 1–17**.

  Most service technicians purchase *combination wrenches,* which have the open end at one end and the same size box end on the other end. ● **SEE FIGURE 1–18**.

  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.
- 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 1–19**.
- Line wrenches, also called *flare-nut wrenches, fitting wrenches,* or *tube-nut wrenches,* are designed to grip almost all the way around a nut used to retain a fuel, brake, or refrigerant line, and yet be able to be installed over the line. ● **SEE FIGURE 1–20**.

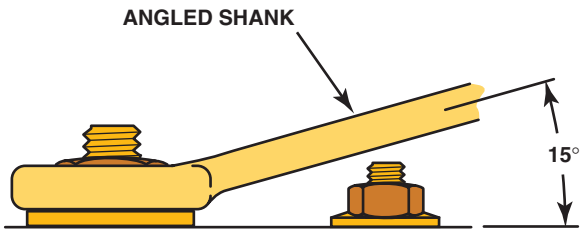


FIGURE 1–17 The end of a box-end wrench is angled 15 degrees to allow clearance for nearby objects or other fasteners.

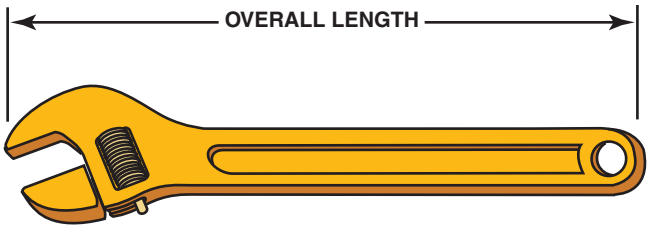


FIGURE 1–19 An adjustable wrench. Adjustable wrenches are sized by the overall length of the wrench, not by how far the jaws open. Common sizes of adjustable wrenches include 8, 10, and 12 inch.

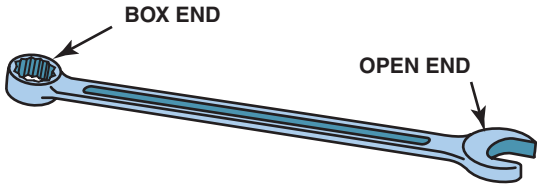


FIGURE 1–18 A combination wrench has an open end at one end and a box end at the other end.

FIGURE 1–20 The end of a typical line wrench, which shows that it is capable of grasping most of the head of the fitting.

TECH TIP

Hide Those from the Boss

An apprentice technician started working for a dealership and put his top tool box on a workbench. Another technician observed that, along with a complete set of good-quality tools, the box contained several adjustable wrenches. The more experienced technician said, "Hide those from the boss." The boss does not want any service technician to use adjustable wrenches. If any adjustable wrench is used on a bolt or nut, the movable jaw often moves or loosens and starts to round the head of the fastener. If the head of the bolt or nut becomes rounded, it then becomes much more difficult to remove.

SAFE USE OF WRENCHES

Wrenches should be inspected before use to be sure they are not crack, bent, or damaged. All wrenches should be cleaned after use before being returned to the tool box. 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 it. If you push a wrench, your knuckles may be hurt when forced into another object if the fastener breaks loose or if the wrench slips. Always keep wrenches and all hand tools clean to help prevent rust and to allow for a better, firmer grip. Never expose any tool to excessive heat. High temperatures can reduce the strength ("draw the temper") of metal tools.

Never use a hammer on any wrench unless you are using a special *staking face wrench* designed to be used with a hammer. Replace any tools that are damaged or worn.

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

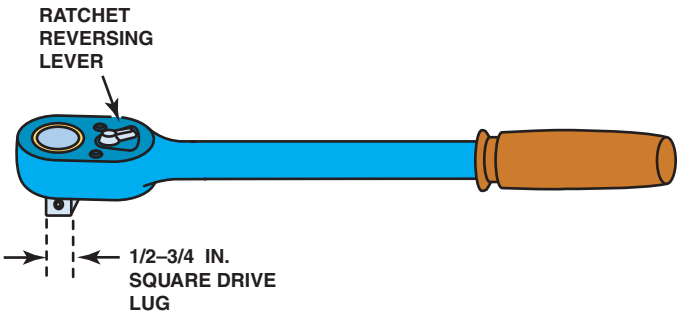


FIGURE 1–21 A typical ratchet used to rotate a socket. A ratchet makes a ratcheting noise when it is being rotated in the opposite direction from loosening or tightening. A knob or lever on the ratchet allows the technician to switch directions.

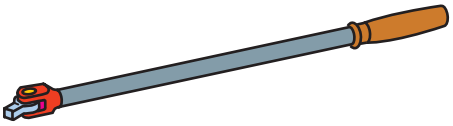


FIGURE 1–22 A typical flex handle used to rotate a socket; also called a breaker bar, because it usually has a longer handle than a ratchet and, therefore, can be used to apply more torque to a fastener than a ratchet.

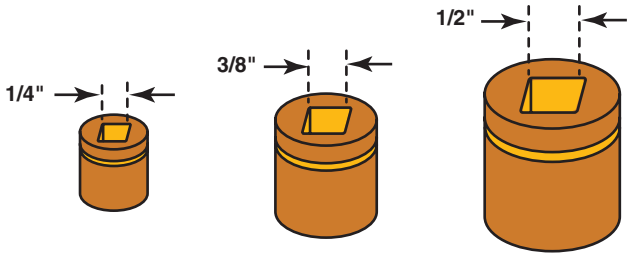


FIGURE 1–23 The most commonly used socket drive sizes include 1/4, 3/8, and 1/2 inch drives.

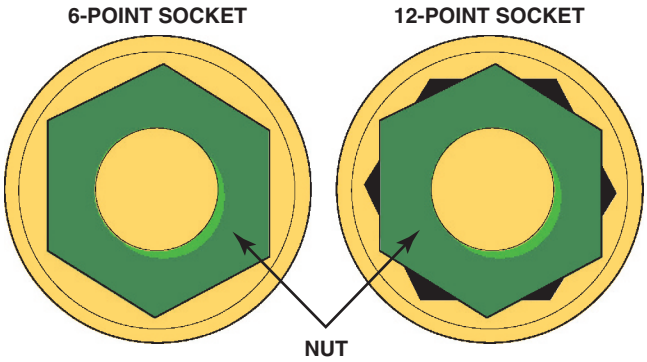


FIGURE 1–24 A 6-point socket fits the head of a bolt or nut on all sides. A 12-point socket can round off the head of a bolt or nut if great force is applied.

a **breaker bar** (flex handle) or a ratchet. ● **SEE FIGURES 1–21 AND 1–22**.

A **ratchet** is a tool that 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.

DRIVE SIZE. Sockets are available in various **drive sizes,** including 1/4, 3/8, and 1/2 inch sizes for most automotive use. ● **SEE FIGURES 1–23 AND 1–24**.

TECH TIP

Right to Tighten

It is sometimes confusing which way to rotate a wrench or screwdriver, especially when the head of the fastener is pointing away from you. To help visualize while looking at the fastener, say "righty tighty, lefty loosey."

Many heavy-duty truck and/or industrial applications use 3/4 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.

Regular and deep well sockets are available in regular lengths for use in most applications or in a deep well design that allows for access to a fastener that uses a long stud or other similar conditions. ● **SEE FIGURE 1–25**.

TORQUE WRENCHES

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

1. **Clicker type.** This type of torque wrench is first set to the specified torque and it then "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 1–26**.
2. **Beam or dial type.** This type of torque wrench is used to measure torque, but instead of presenting the value, the actual torque is displayed on the dial of the wrench as