

# AUTOMOTIVE SERVICE

• *Inspection* • *Maintenance* • *Repair*

**Fourth Edition**

**Tim Gilles**

Professor  
Santa Barbara City College  
ASE Master Automotive Technician,  
ASE Master Automotive Machinist

 **DELMAR**  
CENGAGE Learning™

Australia • Brazil • Japan • Korea • Mexico • Singapore • Spain • United Kingdom • United States

# Not For Sale

**Automotive Service: Inspection,  
Maintenance, Repair, 4th Edition**  
**Tim Gilles**

Vice President, Career and Professional  
Editorial: Dave Garza  
Director of Learning Solutions: Sandy Clark  
Executive Editor: David Boelio  
Managing Editor: Larry Main  
Senior Product Manager: Matthew Thouin  
Editorial Assistant: Jillian Borden  
Vice President, Career and Professional  
Marketing: Jennifer McAvey  
Executive Marketing Manager:  
Deborah S. Yarnell  
Marketing Manager: Kathryn Hall  
Production Director: Wendy Troeger  
Production Manager: Mark Bernard  
Content Project Manager: Cheri Plasse  
Art Director: Benj Gleeksman  
Compositor: MPS Limited,  
a Macmillan Company

© 2012 Delmar, Cengage Learning

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced, transmitted, stored, or used in any form or by any means graphic, electronic, or mechanical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the publisher.

For product information and technology assistance, contact us at  
**Professional Group Cengage Learning Customer & Sales Support,**  
**1-800-354-9706**

For permission to use material from this text or product,  
submit all requests online at [cengage.com/permissions](http://cengage.com/permissions)  
Further permissions questions can be emailed to  
[permissionrequest@cengage.com](mailto:permissionrequest@cengage.com).

Library of Congress Control Number: 2010930758

ISBN-13: 978-1-1111-2861-6

ISBN-10: 1-1111-2861-8

**Delmar**

5 Maxwell Drive  
Clifton Park, NY 12065-2919  
USA

Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil and Japan. Locate your local office at:  
**[international.cengage.com/region](http://international.cengage.com/region)**

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

For your lifelong learning solutions, visit **[delmar.cengage.com](http://delmar.cengage.com)**.

**Visit our corporate website at [cengage.com](http://cengage.com).**

**Notice to the Reader**

Publisher does not warrant or guarantee any of the products described herein or perform any independent analysis in connection with any of the product information contained herein. Publisher does not assume, and expressly disclaims, any obligation to obtain and include information other than that provided to it by the manufacturer. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities described herein and to avoid all potential hazards. By following the instructions contained herein, the reader willingly assumes all risks in connection with such instructions. The publisher makes no representations or warranties of any kind, including but not limited to, the warranties of fitness for particular purpose or merchantability, nor are any such representations implied with respect to the material set forth herein, and the publisher takes no responsibility with respect to such material. The publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or part, from the readers' use of, or reliance upon, this material.

# TABLE OF CONTENTS

**PREFACE xv**

**ACKNOWLEDGMENTS xvii**

**DEDICATION xx**

**ABOUT THE AUTHOR xx**

**FEATURES OF THE TEXT xxi**



## SECTION 1

### THE AUTOMOBILE INDUSTRY

#### CHAPTER 1

##### Introduction to the Automobile 2

Introduction 2 • Body and Chassis 2 • Engine Parts and Operation 3 • Engine Support Systems 5 • The Powertrain 9 • Accessory Systems 10 • History and Development of the Automobile 10

#### CHAPTER 2

##### Automotive Careers and Technician Certification 15

Introduction 15 • Automotive Career Opportunities 15 • Technician Certification and Licensing 17 • Technician Skill Levels and Pay 19 • Other Areas of Specialization 20 • Other Automotive Careers 21 • On the Job as an Automotive Technician 22



## SECTION 2

### SHOP PROCEDURES, SAFETY, TOOLS, AND EQUIPMENT

#### CHAPTER 3

##### Shop Safety 25

Introduction 25 • General Personal Safety 25 • Fire Safety 27 • Fire Extinguishers 27 • Flammable Materials 29 • Fuel Fires 29 • Electrical Fires 30 • Shop Habits 30 • Electrical Safety Precautions 31 • Cooling Fan Safety 32 • Coolant Burns 32 • General Hand Tool Safety 33 • Vise Safety 33 • Puller Safety 33 • Machinery Safety 33 • Electric Drill Safety 34 • Grinder Safety 34 • Wire Wheel Safety 34 • Compressed

Air Safety 34 • Impact Wrench Safety 35 • Air Chisel Safety 35 • Die Grinder/Air Drill Safety 35 • Press Safety 35 • General Lifting Safety 36 • Hydraulic Floor Jack (Service Jack) Safety 36 • Shop Crane (Engine Hoist) Safety 36 • Transmission Jack Safety 37 • Battery Safety 37 • Refrigerant Safety 39 • General Safety around Automobiles 39 • Hot Tank Safety Precautions 39 • Hazardous Materials and Environmental Safety 39 • Hazardous Communication Standards 41 • Material Safety Data Sheets 41 • Hazardous Materials Common to the Automobile Industry 42 • Cleaning Solvent Safety Precautions 43 • Skin Care Safety Precautions 43 • Breathing Safety 43

#### CHAPTER 4

##### Shop Management, Service Records, and Parts 47

Introduction 47 • Customer Relations 47 • Service Records 48 • Keep the Car Clean 49 • Linen Service 49 • Wholesale and Retail Distribution of Auto Parts 50

#### CHAPTER 5

##### Locating Service Information and Specifications 53

Introduction 53 • Service Literature 53 • Manufacturers' Service Information 55 • Generic Service Manuals 55 • Lubrication Service Manual 57 • Owner's Manual 57 • Owners' Workshop Manuals 57 • Electronic Service Information 57 • Technical Service Bulletins 59 • Hot Line Services 60 • Trade Magazines 61

#### CHAPTER 6

##### Measuring Tools and Systems 62

Introduction 62 • Metric System 62 • Measuring Tools 63 • Precision Measuring Tools 64

#### CHAPTER 7

##### Hardware, Fasteners, Drills, and Thread Repair 76

Introduction 76 • Characteristics of Fasteners 76 • Fastener Failures 79 • Drill Bits 80 • Taps and Threads 82 • Dies 84 • Repairing Broken Fasteners 84

#### CHAPTER 8

##### Shop Tools 93

Introduction 93 • Tools of the Trade 93 • Hand Tools 93 • Pullers 104 • Air Tools 106 • Special Service Tools 110

**CHAPTER 9****General Shop Equipment 112**

Shop Equipment 112 • Hydraulic Equipment 112 • Shop Electric Machinery 117 • Other Electric Equipment 120 • Other Shop Equipment 120

**CHAPTER 10****Cleaning Equipment and Methods 124**

Introduction 124 • General Shop Housekeeping Practices 124 • Cleaning Methods 125 • Cleaning the Outside of the Engine 126 • Environmental Concerns with Engine Cleaning 126 • Cleaning Internal Parts 126 • Chemical Cleaning 127 • Thermal Cleaning 134 • Vibratory Parts Cleaners 135 • Other Cleaning Methods 135 • Marking Clean Parts 135

**CHAPTER 11****Lifting Equipment and Air Compressors 137**

Introduction 137 • Lift Types 137 • Frame-Contact Lifts 138 • Wheel-Contact Lifts 139 • Wheel-Free Jacks 140 • In-Ground Lifts 140 • Surface Mount Lifts 142 • Lift Safety 143 • Air Compressors 144

**SECTION 3****VEHICLE INSPECTION (LUBRICATION/SAFETY CHECK)****CHAPTER 12****Engine Lubrication 149**

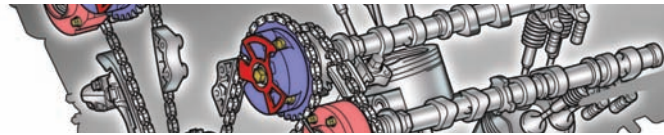
Introduction 149 • Engine Oil 150 • Engine Oil Licensing and Certification 153 • Oil Additives 154 • Changing Engine Oil 157 • Oil Filter 159 • Changing the Oil Filter 161

**CHAPTER 13****Underhood and Body Inspection (Vehicle on Ground) 165**

Introduction 165 • Brake System Inspection 165 • On-Ground Steering and Suspension Checks 167 • Fuel System Inspection 169 • Cooling System Inspection 170 • Belt Inspection 171 • Electrical System Inspection 172 • Check Operation of Lights 172 • Visibility Checks 173 • Other Safety Checks and Service 175

**CHAPTER 14****Undercar Inspection and Service 180**

Introduction 180 • Tire Visual Inspection 180 • Undercar Brake Checks 181 • Exhaust System Inspection 182 • Chassis Lubrication 182 • Suspension and Steering Checks 185 • Driveline Checks 187

**SECTION 4****ENGINE OPERATION****CHAPTER 15****Introduction to the Engine 194**

Introduction 194 • Basic Engine Operation 194 • Four-Stroke Engine Operation 195 • Engine Upper End 196 • Valve Train 196 • Cylinder Head 197 • Engine Front 199 • Cylinder Block Assembly (Lower End) 200 • Short Block and Long Block 201

**CHAPTER 16****Engine Classifications and Advanced Transportation Technologies 207**

Introduction 207 • Engine Classifications 207 • Cylinder Arrangement 208 • Firing Order 209 • Engine Cooling 209 • Valve Location 210 • Camshaft Location 211 • Other Cylinder Head Variations 211 • Combustion Chamber Designs 212 • Spark and Compression Ignition 213 • Alternate Engines 215 • New Generation Vehicles 216 • Regenerative Braking 216 • Hybrid Vehicles 216 • Types of Hybrids 218 • Hybrid Vehicle Service and Safety 221 • Hydraulic Hybrid Vehicles 222 • Fuel Cell Electric Vehicles (FCEVs) 223

**CHAPTER 17****Engine Size and Measurements 227**

Introduction 227 • Engine Size Measurements 227 • Compression Ratio 229 • Physical Principles of Work 231 • Torque 231 • Horsepower 232 • Dynamometer 233 • Dynamometer Safety Concerns 236 • Engine Efficiency 236 • Mean Effective Pressure 238

**CHAPTER 18****Engine Upper End 240**

Introduction 240 • Cylinder Head Construction 240 • Valve Guides 241 •

Valve Guide Seals 241 • Valves 243 • Retainers and Valve Locks 246 • Valve Springs 246 • Pushrods and Rocker Arms 247 • Camshaft 248 • Number of Cams and Lobes 248 • Camshaft Performance 249 • Valve Lifters and Lash Adjusters 250 • Roller Cam and Lifters 251 • Hydraulic Lifters 251 • Camshaft Drives 253 • Valve Timing 255 • Variable Valve Timing 256 • Active Fuel Management/Displacement on Demand 258

## CHAPTER 19

### Engine Lower End and Lubrication System Theory 262

Introduction 262 • Cylinder Block Construction 262 • Core Plugs 263 • Cylinder Bore 263 • Cylinder Sleeves 264 • Main Bearing Caps 264 • Lifter Bores 264 • Crankshaft Design 264 • Crankshaft End Thrust 265 • Direction of Crankshaft Rotation 266 • Vibration Damper 266 • Crankshaft Hardness 266 • Bearings 266 • Connecting Rods 269 • Pistons 270 • Piston Head 270 • Piston Ring Grooves 270 • Heat Transfer 270 • Cast and Forged Pistons 271 • Piston Skirt 271 • Piston Pin Offset 272 • Piston Pins 273 • Piston Rings 274 • Compression Rings 274 • Compression Ring Design 275 • Oil Control Rings 277 • Engine Balancing 277 • The Lubrication System 278 • Oil Pumps 278 • Pressure Relief Valve 280 • Oil Pump Screen By-Pass Valve 280 • Oil Pressure 281 • Windage Tray and Baffles 281 • Dry Sump Lubrication Systems 281



## SECTION 5

### COOLING SYSTEM, BELTS, HOSES, AND PLUMBING

## CHAPTER 20

### Cooling System Theory 285

Introduction 285 • Liquid and Air Cooling 285 • Liquid Cooling System Parts 286 • Cooling System Circulation 286 • Coolant 287 • Cooling System Pressure Cap 290 • Coolant Recovery System 291 • Radiator 292 • Thermostat 292 • Temperature Warning Light or Gauge 295 • Fans 296 • Fan Clutch 297 • Radiator Shroud 298 • Heater Core 298

## CHAPTER 21

### Cooling System Service 300

Introduction 300 • Diagnosing Cooling System Problems 300 • Radiator Cap 301 • Coolant Service 303 • Testing Coolant Condition and Strength 307 • Thermostat Service 310 • Locating Leaks 313 • External Leaks 313 • Internal Leaks 314 • Recovery Tank Service 317 • Cooling System Repairs 317 • Water Pump Service 318 • Electric Cooling Fan Service 320 • Heater Core Service 320

## CHAPTER 22

### Automotive Belts 323

Introduction 323 • Belt Material 323 • V-Belts 323 • V-Ribbed Belts 324 • Serpentine Belt Drive 325 • Stretch Belts 325 • Timing Belts 326 • Drive Belt Service 326 • Belt Inspection and Adjustment 327 • Replacing Belts 328

## CHAPTER 23

### Automotive Hoses 334

Introduction 334 • Hose Construction 334 • Hose Size 334 • Unreinforced Hose 334 • Radiator Hose 334 • Hose Types 334 • Hose Clamps 338 • Hose Inspection 339 • Replacing Hoses 340

## CHAPTER 24

### Automotive Plumbing: Tubing and Pipe 345

Introduction 345 • Tubing 345 • Flared Connections 347 • Compression Fittings 348 • Pipe Fittings 349 • Shutoff Valves 351 • Tubing Service 351 • Installing Tubing 354 • Transmission Oil Cooler Line Repairs 355 • Nylon Fuel Injection Tubing 355 • Pipe Service 356



## SECTION 6

### ELECTRICAL SYSTEM THEORY AND SERVICE

## CHAPTER 25

### Basic Electrical System Theory and Repairs 358

Introduction 358 • Electron Flow 358 • Basic Automotive Electrical System 360 • Electrical Terms 362 • Circuitry and Ohm's Law 365 • Magnetic Fields 366 • Capacitors 368 • Automotive Electronics 368 • Basic Electrical Tests 369

**CHAPTER 26****Battery Fundamentals 378**

Introduction 378 • Battery Parts and Operation 379 • Battery Recharging and Discharging 381 • Battery Capacity Ratings 382 • Battery Types 384 • Battery Plate Size 386 • Battery Selection 386 • Battery Service Life 386 • Battery Cables 387 • Battery Holddowns 388 • Reasons for Battery Failure 388 • Hybrid Electric Vehicle and Other Battery Types 388

**CHAPTER 27****Battery Service 392**

Introduction 392 • Battery Inspection 393 • Battery Service 393 • Replacing a Battery 395 • Battery Testing: Measuring a Battery's State of Charge 400 • Battery Charging 404 • Storing a Vehicle 406 • Battery Capacity Tests 406 • Battery Drain Test/Parasitic Load 408 • Battery Jump-Starting 409 • Hybrid Battery Service 410

**CHAPTER 28****Starting System Fundamentals 414**

Introduction 414 • Starter Motor 414 • Starter Motor Fundamentals 414 • Starter Drives 417 • Starter Electrical Circuit 417 • Gear Reduction Starters 420 • Brushless DC Motors 421

**CHAPTER 29****Starting System Service 423**

Introduction 423 • Starting System Service 423 • Starting System Tests 424 • Cranking Voltage and Amperage Test 425 • Circuit Resistance Test 425 • No-Crank Tests Using a Test Light 427 • Solenoid Problems 427 • Starter Repair 429 • Starter Disassembly 429 • Starter Drive Service 429 • Starter Reassembly 430 • Pinion Clearance Tests 431

**CHAPTER 30****Charging System Fundamentals 434**

Introduction 434 • Charging System 434 • Direct Current (DC) Generators 434 • AC Generator/Alternator 435 • AC Generator Bearings 439 • Voltage Regulator 440 • Charging System Indicators 442 • High-Voltage Charging Systems 443

**CHAPTER 31****Charging System Service 447**

Introduction 447 • Charging System Service 447 • Testing the Charging System 447 • Charging System Output Test 448 • Diode Tests 451 • Charging System Voltage Drops 452 • AC Generator Service and Repair 453 • AC Generator Reassembly 456

**CHAPTER 32****Lighting and Wiring Fundamentals 458**

Introduction 458 • Wire and Cable 458 • Circuit Protection Devices 459 • Lighting 461 • Headlamps 461 • Taillights 466 • Light Bulb Identification 467 • Fiber Optics 468 • Turn Signals 469 • Signal Flasher Operation 469 • Hazard Flashers 470 • Back-Up Lights 470 • Wipers and Horn 470 • Miscellaneous Gauges 475

**CHAPTER 33****Lighting and Wiring Service 480**

Analyzing Electrical Problems 480 • Wiring Service 480 • Crimp Terminals 482 • Selecting Replacement Wire 484 • Adding Electrical Accessories 484 • Soldering 486 • Broken or Damaged Ground Straps 488 • Circuit Testing and Service 489 • Finding Grounds 489 • Fuse Testing and Service 489 • Fuse Link Service 490 • Headlamp Service 490 • Headlamp Aiming 492 • Tail Lamp and Park Light Service 495 • LED Service 496 • Stoplight Switch Service 496 • Back-Up Lights 496 • Turn Signal Switch 497 • Signal Flasher/Relay 497 • Locating a Signal Flasher 498 • Instrument Panel Bulbs 498 • Windshield Washer Service 498 • Horn Service 499 • Gauge Testing 499

**CHAPTER 34****Safety, Security, Comfort Systems, and Electrical Accessories 502**

Introduction 502 • Supplemental Restraint Systems 502 • Active and Passive Restraints 503 • Restraint System Service 513 • Security, Navigation, and Electrical Accessories 515 • Security Systems 516 • Vehicle Tracking/Navigation Systems 520 • Other Comfort Systems 522 • Cruise Control 534 • Collision Avoidance Systems 536 • Lane Departure Warning System 537

**SECTION 7****HEATING AND AIR CONDITIONING****CHAPTER 35****Heating and Air-Conditioning Fundamentals 541**

Introduction 541 • Sources of Heat 541 • Ventilation 542 • Heating 542 • Air Distribution System 543 • Air Conditioning 544 • Air-Conditioning Principles 545 • Heat Transfer 545 •

Humidity 546 • States of Matter 546 • Latent Heat 546 • Air-Conditioning System Operation 547 • Absorbing Heat 548 • Reducing Humidity 548 • Compressing the Refrigerant 548 • Transferring Refrigerant Heat to Outside Air 548 • Flow Control Devices 550 • Air-Conditioning Compressors 553 • Compressor Lubrication 557 • Muffler 557 • Accumulator or Receiver/Dryer 557 • Evaporator Icing Control 559 • System Switches 560 • Heating and Air-Conditioning Controls 560 • Automatic Air-Conditioning Sensors 561 • Refrigerants and the Environment 563 • Temperature and Pressure 564

### CHAPTER 36

#### Heating and Air-Conditioning Service 567

Heater Service 567 • Air-Conditioning Service 567 • Air-Conditioning System Service and Diagnosis 568 • System Performance Test 569 • Pressure Testing 569 • Static Pressure Reading 571 • Diagnosing HVAC Electronic Problems 575 • Air Distribution System Diagnosis 576 • Leak Detection 581 • Common Air-Conditioning Component Problems 583 • Refrigerant Oil 584 • Evaporator Problems 586 • Thermal Expansion Valve or Orifice Tube Problems 586 • Compressor Service 587 • Evacuating and Recharging 591 • Vacuuming a System 591 • Evacuate the System 593 • Air-Conditioning Service Equipment 594 • Refrigerant Charging 594 • Follow-Up 596 • Refrigerant Storage 596 • Recycling and Retrofit 596



## SECTION 8

### ENGINE PERFORMANCE DIAGNOSIS: THEORY AND SERVICE

### CHAPTER 37

#### Ignition System Fundamentals 600

Introduction 600 • Basic Ignition System 600 • Primary Circuit 600 • Secondary Ignition Parts 603 • Spark Plugs 604 • Electronic Ignitions 607 • Electronic Ignition Variations 609 • Ignition Modules 613 • Ignition Timing 613 • Detonation Sensor 615 • Distributorless Ignition 615

### CHAPTER 38

#### Ignition System Service 621

Ignition System Service and Repairs 621 • Spark Plug Service 621 • Spark Plug Diagnosis 622 • Installing

Spark Plugs 624 • Repairing Damaged Spark Plug Threads 626 • Spark Plug Cable Service 626 • Distributor Ignition Service 628 • Ignition Timing 629 • Electronic Ignition Distributor Service 629 • Other Distributor Repair Service 631 • Distributor Installation 631 • Static Timing 631 • Electronic Ignition System Service 632 • Types of Scope Patterns 636 • Oscilloscope Tests 637 • Other Scope Tests 640 • Other Diagnostic Instruments 640

### CHAPTER 39

#### Petroleum Fuels and Alternative Fuel Technologies 642

Introduction 642 • Crude Oil 642 • Diesel Engines and Diesel Fuel 645 • Gasoline 647 • Air-Fuel Mixture 649 • Spark Knocks, Carbon Noise, and Abnormal Combustion 650 • Abnormal Combustion 651 • Excessive Carbon Buildup 654 • Regular versus Premium Fuels 654 • Octane Standards 655 • Gasoline Additives 655 • Reformulated Gasolines 655 • Oxygenated Fuels/Alcohols 655 • Alternative Fuels 657

### CHAPTER 40

#### Fuel System Fundamentals 663

Introduction 663 • Fuel System 663 • Fuel Tanks 663 • Fuel Lines, Hoses, and Fittings 664 • Fuel Pumps 664 • Fuel Filters 665 • Fuel Injection and Carburetion 666 • Pressure Regulator Operation 671 • Electronic Fuel System Operation 672 • Airflow Measurement 673 • Idle Speed Control 674 • Fuel Pump Control Module 675 • Computer-Controlled Fuel Systems 675 • Feedback Fuel Systems 676

### CHAPTER 41

#### Fuel System Service 683

Introduction 683 • Fuel Supply System Service 683 • Fuel Filter Service 685 • Throttle Linkage 687 • Carburetor Problems and Service 687 • Exhaust Gas Analysis 688 • Fuel Injection Diagnosis and Service 689 • EFI Computer Self-Diagnostics (OBD) 689 • Air-Fuel Mixture Problems 689 • Injector Problems 691 • Throttle Plate Service 694 • EFI Adjustments 695 • Sensor Service 695 • Throttle Position Sensor 695 • Oxygen Sensor Service 696 • Coolant Temperature Sensor 697 • Inlet Air Temperature Sensor 698 • MAP Sensor Diagnosis 698 • Mass Airflow (MAF) Sensor Diagnosis 699 • Testing Other Sensors 699 • Computer Service 700 • Mechanical Injection 700 • Carbon Deposit Service 701

**CHAPTER 42****Intake and Exhaust Systems/Turbochargers and Superchargers 703**

Introduction 703 • Intake System Fundamentals 703 • Manifolds 704 • Intake Manifolds 704 • Exhaust System Fundamentals 708 • Exhaust Manifolds 708 • Exhaust Pipes 709 • Exhaust System Service 711 • Turbochargers and Superchargers 712 • Turbochargers 713 • Belt-Driven Superchargers/Blowers 722

**CHAPTER 43****Emission Control System Fundamentals 727**

Introduction 727 • Air Pollution 727 • Automotive Emissions 727 • Pollution Control 729 • Automobile Emission Control Systems 729 • Crankcase Ventilation 730 • Air Injection System 732 • Aspirator Valve or Pulse Air System 733 • Exhaust Gas Recirculation 733 • EGR System Operation 734 • Computer-Controlled EGR Systems 735 • Catalytic Converter 736 • Types of Catalytic Converters 737 • Evaporative Controls 739 • Other Parts of the Fuel Tank System 742 • On-Board Diagnostics 743 • Engine Emission Modifications 743

**CHAPTER 44****Emission Control System Service 746**

Introduction 746 • Inspecting Emission Control Systems 746 • Computer-Controlled Emission Service 747 • Crankcase Ventilation System Service 747 • Evaporative Control System Service 748 • Evaporative System Maintenance 749 • Evaporative System Problem Diagnosis 749 • EGR System Service 751 • Air Injection System Service 753 • Catalytic Converter Service 754 • Converter Testing 754 • Catalytic Converter Replacement 754 • Analyzing Exhaust Emissions 755 • Emission Analyzers 756 • Hydrocarbons 757 • Carbon Monoxide (CO) 758 • Carbon Dioxide 758 • Oxygen (O<sub>2</sub>) 760 • Oxides of Nitrogen 760 • Catalytic Converter Tests 762

**CHAPTER 45****Electronics and Computer Systems Fundamentals 767**

Introduction 767 • Semiconductors 767 • Diodes 768 • Transistors 770 • Electronic Instrument Displays 771 • Automotive Computer Systems 771 • Parts of a Computer System 772 • On-Board Computer 772 • Information Processing 774 • Computer Memory 774 • Communication Rate 776 • Sensors and Actuators 776 • Types of Sensors 777 • Thermistors 777 • Voltage Dividers 777 •

Piezoelectric and Piezoresistive Sensors 778 • Heated Resistive Sensors 778 • Variable DC Frequency Sensors 778 • Voltage Generators 778 • Wheatstone Bridges 779 • Switches 779 • Types of Actuators 780 • Solenoid Actuators 780 • Relay Actuators 781 • Motor Actuators 781 • Actuator Switches/Modules 781 • Adaptive Strategy 781 • Ignition Advance 782 • Knock Sensor 782 • Electronic Throttle Control/Drive-by-Wire 782 • On-Board Diagnostics 783 • Diagnostic Trouble Codes 783 • Computer Self-Diagnostics 783 • Multiplexing 784 • Network Sizes and Types 785 • CAN Systems 785 • Supplemental Data Bus Networks 789 • Telematics 791 • Wireless Networks 791

**CHAPTER 46****Electronics and Computer Systems Service 794**

Introduction 794 • Inspection Sequence 794 • Perform Diagnostic Tests 796 • On-Board Diagnostics 796 • Reading Trouble Codes 797 • Scan Tools 797 • Breakout Box 799 • Retrieving Trouble Codes 799 • Working with Codes 799 • Erasing Trouble Codes 799 • Scan Tool Snapshot 800 • Closed Loop 802 • Fuel Trim Diagnosis 802 • Digital Waveforms 804 • Logic Probe/Power Probe 807 • Sensor and Actuator Testing 808 • Diagnosing Sensor Problems 808 • Sensor Tests 809 • Oxygen Sensor 809 • Load Sensors 811 • MAP Sensor 812 • BARO Sensors 812 • Vacuum Sensors 812 • Throttle Position Sensor 813 • Coolant Temperature Sensor 813 • Air Temperature Sensors 815 • Airflow Sensor Service 816 • Knock Sensor Service 816 • Actuator Service 817 • Repair the Problem 817 • Computer Wiring Service 818 • Static Electricity 821 • Electrical Damage to a Circuit 822

**CHAPTER 47****Advanced Emissions and On-Board Diagnostics (OBD) 827**

Introduction 827 • History of On-Board Diagnostics 827 • OBD II Operation 828 • Society of Automotive Engineers (SAE) Standards 829 • Trouble Codes and the Malfunction Indicator Lamp 831 • OBD II Codes 832 • OBD II Diagnostic Testing 833 • Emission Testing Programs 841

**CHAPTER 48****Diagnosing Engine Performance Problems 845**

Introduction 845 • Visual Checks 845 • Ignition System Checks 845 • Engine Performance Testing 846 • Compression Loss 846 • Vacuum Testing 847 • Other Vacuum Tests 848 • Compression

Problems 849 • Cylinder Leakage Test 851 •  
Carbon-Related Problems 852



## SECTION 9

### **AUTOMOTIVE ENGINE SERVICE AND REPAIR**

#### **CHAPTER 49**

##### **Diagnosing Engine Mechanical Problems 855**

Introduction 855 • Diagnosing Problems before a Repair 855 • Oil Consumption 855 • Causes of Oil Consumption 856 • Testing for Oil Leaks 858 • Engine Performance and Compression Loss 859 • Engine Noises 860 • Engine Knocks 860 • Oil Pressure Problems 864 • Cooling System Problems 865 • Internal Engine Leakage 865 • Seized Engine 867 • Electronic Failures/Engine Damage 867 • Engine Performance and Fuel Mixture Problems 868

#### **CHAPTER 50**

##### **Engine Removal and Disassembly 870**

Introduction 870 • Engine Removal 870 • Engine Disassembly 882 • Engines with Pushrods 885 • Overhead Cam Cylinder Head Removal 887 • Cylinder Block Disassembly 888

#### **CHAPTER 51**

##### **Engine Sealing, Gaskets, Fastener Torque 894**

Introduction 894 • Clamping Force 894 • Torque and Friction 894 • Torque Wrenches 895 • Torque-to-Yield 896 • Torque by Degrees 897 • Fastener Clamping Load 897 • Gaskets and Seals 898 • Cleaning the Head 902 • Head Gasket Installation 904 • Other Engine Gaskets 904 • Valve Cover, Timing Cover, and Oil Pan Service 904 • Gasket Sealers 909 • Silicone-RTV Sealant 910 • Rear Main Seals 913 • Transmission Front Pump Seal 914

#### **CHAPTER 52**

##### **Engine Diagnosis and Service: Cylinder Head and Valve Train 916**

Introduction 916 • Head Disassembly 916 • Carbon Removal 920 • Cylinder Head Inspection 921 • Resurfacing by Grinding, Cutting, or Sanding 922 • Straightening Cylinder Heads 922 • Crack Inspection 923 • Crack Repair 924 • Checking Valve Springs 924 • Checking Valve Stems 924 •

Valve Guide Service 925 • Guide Repair 926 • Grinding Valves 927 • Grinding Valve Seats 928 • Checking Valve Stem Installed Height 929 • Solvent Testing the Valve and Seat 929 • Reassembling the Head 930 • Valve Guide Seal Installation 931 • Install the Valve and Spring Assembly 931 • Pushrod Engine Rocker Arm Service 932 • Inspect Pushrods 932 • Inspect OHC Camshaft 932 • Reassembling OHC Heads 932 • Camshaft Service 934 • Lifter Service 934 • Cam and Lifter Break-In 935 • Timing Chain and Belt Service 935 • Timing Belt Service 935 • Timing Belt Replacement 936 • Timing Chain Service 938

#### **CHAPTER 53**

##### **Engine Diagnosis and Service: Block, Crankshaft, Bearings, and Lubrication System 943**

Introduction 943 • Cleaning the Block 943 • Oil and Water Plug Removal 943 • Oil Gallery Plug Installation 945 • Inspect and Clean Lifter Bores 945 • Checking Main Bearing Bore Alignment 945 • Check the Deck Surface for Flatness 947 • Clean All Threaded Holes 947 • Inspecting Cylinder Bores 947 • Measuring the Bore 948 • Deglazing the Cylinder Bore 949 • Clean the Block of Grit 951 • Boring for Oversized Pistons 951 • Block Distortion 952 • Honing after Boring 953 • Sleeves 954 • Cam Bearing Installation (Cam-in-Block Engines) 954 • Front Cam Bearing Installation 956 • Checking Crankshaft Condition 956 • Crankshaft and Bearing Wear 957 • Crankshaft Journal Tolerance 958 • Regrinding the Crankshaft 958 • Measuring Bearing Clearance with Plastigage 959 • Lubrication System Service 961 • Checking Oil Pumps for Wear 961 • Oil Pump Screen Service 962 • Oil Pump Failure 962 • Installing the Oil Pump 963

#### **CHAPTER 54**

##### **Engine Diagnosis and Service: Piston, Piston Rings, Connecting Rod, Engine Balancing 965**

Introduction 965 • Piston Service 965 • Piston Ring Service 968 • Installing Pins in Connecting Rods 970 • Installing Rings on Pistons 970 • Oil Ring Installation 970 • Connecting Rod Service 971 • Engine Balancing Service 973

#### **CHAPTER 55**

##### **Ordering Parts, Short and Long Blocks, Engine Assembly 978**

Introduction 978 • Ordering Parts 978 • Engine Kits 978 • Determining Part Sizes 979 • Types of Engine Rebuilds 980 • Selecting the Correct

Replacement Engine 981 • Warranty 981 • Reassembly 981 • Begin Reassembly 981 • Prepare the Crankshaft for Installation 982 • Install the Crank 983 • Install the Cylinder Heads 990 • Install OHC Heads 990 • Install the Cam Drive (Pushrod Engines) 991 • Install the Oil Pump 992 • Install the Timing Cover 992 • Install the Damper 992 • Install the Oil Pan 993 • Install the Intake Manifold 993 • Install the Thermostat and Water Outlet Housing 993 • Completing the Assembly 994 • Install Exhaust Manifold(s) 994

## CHAPTER 56

### Engine Installation, Break-In, and In-Chassis Repairs 997

Introduction 997 • Engine Installation 997 • Install Engine Mounts 997 • Install the Engine 997 • Priming the Lubrication System 999 • Pressure Priming 999 • Install Valve Covers 1000 • Ignition System Installation and Timing 1000 • Engine Starting and Initial Break-In 1001 • Valve Clearance Adjustment 1002 • Road Test and Break-In 1002 • Final Inspection 1002 • Returning the Car to the Customer 1003 • Engine Repair—Engine in the Vehicle 1003 • Valve Job or Head Gasket Repair 1003 • Valve Job or Complete Engine Overhaul 1004 • Head Gasket Problems 1004 • In-Chassis Lower End Repairs 1004 • Removing the Oil Pan 1004 • Remove the Piston and Rod Assembly 1006 • Remove the Timing Cover 1006 • Freewheeling and Interference Engines 1006 • Replace the Timing Components 1006 • Crankshaft Seal Replacement 1007 • Flywheel Ring Gear Service 1007



## SECTION 10

### BRAKES AND TIRES

## CHAPTER 57

### Brake Fundamentals 1011

Introduction 1011 • Brake Linings 1011 • Drum and Disc Brakes 1012 • Hydraulic Brake System Operation 1012 • Hydraulic Brake Fluid 1014 • Brake Hose 1015 • Brake Tubing 1015 • Hydraulic System Operation 1016 • Low Brake Pedal 1016 • Split Hydraulic System 1020 • Quick Take-Up Master Cylinder 1020 • Drum Brakes 1021 • Drum Brake Adjustment 1022 • Disc Brakes 1024 • Hydraulic

System Valves and Switches 1027 • Hydraulic Control Valves 1028 • Power Brakes 1030 • Parking Brake 1033 • Types of Parking Brakes 1034 • Stoplight Switches 1035 • Antilock Brakes 1035

## CHAPTER 58

### Brake Service 1038

Introduction 1038 • Brake Inspection 1038 • Check Brake Pedal Feel 1038 • Master Cylinder Inspection 1038 • Brake Diagnosis 1040 • Undercar Checks 1040 • Disc Brake Inspection 1040 • Inspecting Drum Brake Assemblies 1044 • Brake Fluid Service 1047 • Routine Brake Fluid Replacement 1047 • Bleeding Brakes 1048 • Brake Bleeding Methods 1049 • Adjusting Brakes 1053 • Master Cylinder Service 1054 • Master Cylinder Removal 1054 • Master Cylinder Disassembly 1054 • Bench Bleeding a Master Cylinder 1055 • Brake Job 1056 • Drum Brake Lining Removal 1056 • Rebuilding Hydraulic Cylinders 1057 • Reassembling a Wheel Cylinder 1058 • Removing Wheel Cylinders 1059 • Replacing Drum Brake Shoes 1059 • Adjusting Drum Brake Clearance 1059 • Drum and Rotor Service 1060 • Drum Service 1061 • Rotor Service 1063 • On-Vehicle Rotor Machining 1065 • Disc Brake Service 1066 • Rear Disc Pad Installation 1068 • Rebuilt Calipers 1069 • Disc Caliper Rebuilding 1069 • Selecting Brake Linings 1071 • Disc Brake Noise 1072 • Parking Brake Cable Service 1074 • Vacuum Power Brake Service 1074 • Brake Warning Lamp Diagnosis 1079 • Antilock Brake System (ABS) Service 1079

## CHAPTER 59

### Antilock Brakes, Traction, and Stability Control 1081

Introduction 1081 • Antilock Brakes 1081 • Antilock Brake System Components 1082 • Types of Antilock Brake Systems 1084 • Two-Wheel ABS 1087 • Antilock Brake System Operation 1088 • Traction Control System 1091 • Antilock Brake (ABS) Service 1092 • ABS Brake Fluid Service 1094

## CHAPTER 60

### Bearings, Seals, and Greases 1102

Introduction 1102 • Plain Bearings 1102 • Frictionless Bearings 1102 • Bearing Loads 1102 • Ball Bearings 1102 • Roller Bearings 1104 • Wheel Bearings 1106 • Greases 1107 • Wheel Bearing Seals 1110 • Seal Materials and Design 1111 • Seal Tolerance 1111 • Wheel Bearing Diagnosis and Service 1112 • Wheel Bearing Adjustment 1113 •

Disc Brake Caliper Removal 1114 • Repacking Wheel Bearings 1114 • Bearing Inspection and Diagnosis 1116 • Diagnosing Wheel Bearing Noise 1119 • Replacing Bearing Races 1120 • Servicing Front-Wheel-Drive Bearings 1120

## CHAPTER 61

### Tire and Wheel Theory 1124

Introduction 1124 • Tire Construction 1124 • Tubeless Tires 1125 • Tire Tread 1125 • Tire Tread Material 1126 • Tire Cord 1127 • Tire Ply Design 1127 • Tire Sidewall Markings 1128 • Load Rating 1133 • All-Season Tires 1134 • Snow Tires 1134 • Tire Pressure Monitoring System 1137 • Uniform Tire Quality Grading 1138 • Traction Grade 1138 • Changing Tire Size 1138 • Wheels 1140 • Custom Wheels 1141 • Lug Studs 1142 • Lug Nuts 1142 • Tire Valve Stems 1142

## CHAPTER 62

### Tire and Wheel Service 1145

Introduction 1145 • Tire Inflation 1145 • Checking Air Pressure 1145 • Adjusting Tire Pressure 1147 • Tire Wear 1148 • Sidewall Checks 1149 • Tire Rotation 1149 • Removing and Tightening Lug Nuts 1151 • Repairing Wheel Studs 1152 • Removing and Mounting Tires on Rims 1153 • Inspecting the Tire and Wheel 1156 • Valve Stem Service 1156 • Rubber Lubricant 1157 • Install the Tire 1157 • Mounting High-Performance Tires 1160 • Bead Roller Tire Changer 1161 • Tire Runout 1161 • Tire Repair 1162 • Repairing a Tire 1163 • Preparing a Tire for Repair 1164 • Patching the Tire 1165 • Tire and Wheel Balance 1166 • Types of Wheel Balance 1168 • Couple Imbalance 1169 • Dynamic Balance 1170 • Computer Balancers 1170 • Centering the Wheel on the Balancer 1170 • Match Mounting 1173 • Force Variation 1173 • Installing the Wheel 1174 • Tire Pressure Monitoring System Service 1175



## SECTION 11

### SUSPENSION, STEERING, ALIGNMENT

## CHAPTER 63

### Suspension Fundamentals 1179

Introduction 1179 • Suspension 1179 • Frame and Suspension Designs 1180 • Springs 1180 •

Suspension Construction 1182 • Suspension Types 1184 • High-Performance Suspensions 1185 • Shock Absorbers 1186 • Hydraulic Shock Absorber Operation 1187 • Compression and Rebound Resistance 1189 • Bump Stops and Limiters 1189 • Gas Shocks 1190 • Air Shocks/Leveling Devices 1191 • Other Front End Parts 1192 • Stabilizer Bar 1192 • Suspension Leveling Systems 1192

## CHAPTER 64

### Suspension System Service 1199

Introduction 1199 • Diagnosing Suspension System Problems 1199 • Shock Absorber Service 1200 • Testing a Shock 1200 • Macpherson Strut Service 1202 • Inspect the Upper Strut Bearing 1204 • Install the Coil Spring 1204 • Reinstall the Strut Assembly 1204 • Suspension Bushing Service 1204 • Strut Rod Bushing Service 1205 • Stabilizer Bar Service 1205 • Spindle Service 1206 • Ball Joint Service 1206 • Measuring Ball Joint Wear 1207 • Separating Tapered Connections 1208 • Replacing a Ball Joint 1208 • Coil Spring Service 1209 • Adjusting Spring Height 1209 • Coil Spring Replacement 1209 • SLA Coil Spring Replacement 1210 • Wheel Alignment 1212 • Electronic Suspension Service 1212 • Electronically Controlled Shock Absorbers 1213

## CHAPTER 65

### Steering Fundamentals 1216

Steering Systems 1216 • Steering Gears 1216 • Recirculating Ball and Nut Steering Gear 1217 • Rack-and-Pinion Steering 1217 • Steering Linkage 1218 • Parallelogram Steering Linkage 1219 • Ball Sockets 1219 • Tie-Rods 1219 • Steering Arm 1220 • Rack-and-Pinion Steering Linkage 1221 • Steering Column 1221 • Power Steering 1223 • Power Steering Pump 1223 • Types of Power Steering 1224 • Electronically Controlled Variable Effort Power Steering 1225 • Electronically Controlled Steering Systems 1228

## CHAPTER 66

### Steering System Service 1232

Introduction 1232 • Fluid Level Checks 1232 • Type of Fluid 1232 • Diagnosing Steering Problems 1233 • Noise Diagnosis 1233 • Hard Steering 1233 • Tire Wear 1233 • Steering Part Inspection 1233 • Steering Linkage Inspection 1233 • Steering Gear Looseness 1233 • Parallelogram Inspection 1233 • Rack-and-Pinion

Steering Linkage Inspection 1234 • Steering Linkage Repairs 1234 • Idler Arm Replacement 1234 • Pitman Arm Replacement 1235 • Tie-Rod End Replacement 1235 • Rack-and-Pinion Tie-Rods 1236 • Steering Wheel, Column, and Air Bag Service 1236 • Air Bag Service 1236 • Steering Wheel Service 1239 • Steering Column Service 1239 • Steering Gear Service 1239 • Manual Rack Service 1240 • Rack-and-Pinion Looseness 1240 • Power Steering System Service 1240 • Power Steering System Flushing 1240 • Bleeding the System of Air 1241 • Power Steering Pump Replacement 1242 • Repairing Power Steering Pump Oil Leaks 1242 • Power Steering Pressure Diagnosis 1242 • Power Steering Pump Service 1243 • Power Steering Hoses 1244 • Refilling the Power Steering System 1244 • Power Steering Gear Service 1244 • Replacing Rack-and-Pinion Units 1244 • Variable Power Steering Service 1246 • Electronically Controlled Power Steering System Service 1246

**CHAPTER 67****Wheel Alignment Fundamentals 1248**

Introduction 1248 • Wheel Alignment Angles 1248 • Toe 1248 • Camber 1249 • Caster 1250 • Steering Axis Inclination 1251 • Scrub Radius 1252 • Turning Radius 1253 • Tracking 1254 • Setback 1254 • Special Handling Characteristics 1254

**CHAPTER 68****Wheel Alignment Service 1257**

Introduction 1257 • Prealignment Inspection 1257 • Tire Wear Inspection 1257 • Ride Height Check 1259 • Toe Change 1259 • Torque Steer 1260 • Suspension Looseness 1260 • Test Drive 1261 • Tire Checks 1261 • Inspection Checklist 1262 • Wheel Alignment Procedures 1262 • Measuring Alignment 1263 • Measuring Camber 1264 • Measuring Caster 1264 • Road Crown and Pull 1264 • Measuring Steering Axis Inclination 1267 • Measuring Toe 1267 • Adjusting Toe 1268 • Centering a Steering Wheel 1271 • Checking for Toe Change 1272 • Measuring Turning Radius 1272 • General Wheel Alignment Rules 1273 • Four-Wheel Alignment 1274 • Performing a Four-Wheel Alignment 1275 • Compensating the Alignment Heads 1275 • Measuring Caster and Camber 1276 • Adjusting Rear-Wheel Alignment 1276

**SECTION 12****DRIVETRAIN****CHAPTER 69****Clutch Fundamentals 1280**

Introduction 1280 • Clutch Parts and Operation 1281 • Clutch Disc 1281 • Pressure Plate 1282 • Types of Clutch Covers 1282 • Coil Spring Clutch 1283 • Diaphragm Clutch 1283 • Pilot Bearing or Bushing 1285 • Release Bearing 1285 • Clutch Fork 1286 • Clutch Release Methods 1286 • Clutch Cable 1286 • Hydraulic Clutch Operation 1287 • Clutch Free Travel 1288 • Dual Clutch Transmissions 1288

**CHAPTER 70****Clutch Diagnosis and Service 1290**

Introduction 1290 • Diagnosis of Clutch Problem 1290 • Clutch Noises 1290 • Transmission Noise 1291 • Pedal Problems 1291 • Slipping Clutch 1291 • Dragging Clutch 1291 • Oily Clutch Facings 1292 • Damaged Friction Surfaces 1292 • Chattering or Grabbing Clutch 1293 • Clutch Service 1293 • Servicing Hydraulic Components 1294 • Clutch Replacement 1295 • Removing a Transmission or Transaxle 1295 • Clutch Removal 1295 • Flywheel Removal 1297 • Flywheel Starter Ring Gear Replacement 1297 • Flywheel Installation 1297 • Inspect New Parts 1298 • Pilot Bushing Service 1298 • Clutch Disc Service 1299 • Clutch Cover/Pressure Plate Service 1299 • Clutch Installation 1299 • Release Bearing Service 1301 • Clutch Housing Installation 1302

**CHAPTER 71****Manual Transmission Fundamentals 1305**

Introduction 1305 • Purpose of a Transmission 1305 • Using Gears to Increase Torque 1306 • Gear Ratio 1306 • Transmission Gear Ranges 1307 • Overdrive 1307 • Final Drive Ratio 1308 • Gear Types and Operation 1308 • Spur Gears 1309 • Helical Gears 1309 • Idler Gears 1309 • Transmission Parts 1309 • Transmission Lubrication 1310 • Transmission Bearings 1310 • Transmission Gears and Shafts 1310 • Synchronizer Assembly 1312 • Gear Shift Mechanisms 1314 • Shift

Patterns 1315 • Transmission Power Flow 1315 •  
 Four-Speed Transmission Power Flow 1316 •  
 Five-Speed Transmission 1318 • Speedometer  
 Drive 1318 • Switches and Sensors 1318

## CHAPTER 72

### Manual Transmission Diagnosis and Repair 1322

Introduction 1322 • Transmission Diagnosis 1322 •  
 Lubricant Checks 1323 • Transmission Removal  
 1323 • Transmission Disassembly 1324 •  
 Disassemble the Mainshaft Assembly 1326 •  
 Synchronizer Service 1326 • Synchronizer  
 Inspection 1327 • Inspect Blocker Rings 1328 •  
 Inspect Input Shaft and Mainshaft 1328 • Replace  
 Worn Bearings 1328 • Reassemble the Transmission  
 1329 • Reassemble the Synchronizers 1329 •  
 Reassemble the Mainshaft 1329 • End Play 1329 •  
 Needle Bearing Installation 1329 • Install New  
 Gaskets 1330 • Complete the Transmission  
 Reassembly 1330 • Install the Transmission 1331 •  
 Add Lubricant 1332 • Test Drive 1332

## CHAPTER 73

### Automatic Transmission Fundamentals 1334

Introduction 1334 • Automatic Transmission Parts  
 1334 • Power Transmission 1335 • Flexplate 1335 •  
 Torque Converter 1336 • Torque Multiplication  
 1336 • Torque Converter Operation 1337 • Stator  
 Clutch Operation 1339 • Stall Speed 1340 • Lock-Up  
 Torque Converters 1340 • Planetary Gears 1341 •  
 Simple Planetary Gearset 1341 • Simple Planetary  
 Operation 1342 • Compound Planetary Operation  
 (Simpson) 1343 • Driving and Holding Devices  
 1345 • Clutches 1345 • Clutch Operation 1346 •  
 One-Way Clutches 1347 • Bands 1348 •  
 Accumulator 1348 • Hydraulic System 1349 • Fluid  
 Pump 1349 • Types of Pumps 1349 • Transmission  
 Valves 1351 • Pressure Regulator 1351 • Hydraulic  
 Valve Body 1352 • Transmission Automatic Shift  
 Selection 1352 • Governor 1353 • Vacuum  
 Modulator 1354 • Kickdown Valve 1354 •  
 Automatic Transmission Fluid (ATF) 1355 • Automatic  
 Transmission Cooling 1355 • Auxiliary Cooler/Heat  
 Exchanger 1356 • Park Pawl 1356 • Electronic  
 Automatic Transmissions 1356 • Electronic Automatic  
 Transmission Operation 1359 • Electronic Torque  
 Converter Control 1359 • Electronic Pressure  
 Control 1359 • Transmission Shift Control 1360 •  
 Continuously Variable Transmission 1362 • Hybrid  
 Planetary Transmission Operation 1362

## CHAPTER 74

### Automatic Transmission Diagnosis and Service 1367

Introduction 1367 • Automatic Transmission  
 Identification 1368 • Automatic Transmission  
 Maintenance 1368 • Transmission Fluid Service  
 1368 • Fluid Level 1369 • Check Fluid Condition  
 1369 • Changing Transmission Fluid 1369 •  
 Transmission Filter Service 1370 • Remove and  
 Replace the Filter 1371 • Refill the Transmission  
 1371 • Diagnosis and Repair of Leaks 1372 • Leaks  
 from the Converter Housing 1372 • Transmission  
 Cooler Line Leak 1372 • VSS/Speedometer Drive Gear  
 Leak 1373 • Shift Lever Seal Replacement 1373 •  
 Pump Seal Replacement 1373 • Front Seal  
 Replacement 1374 • Pump Bushing Replacement  
 1374 • Reinstalling the Transmission 1375 •  
 Rear Oil Seal and Bushing Replacement 1376 •  
 Automatic Transmission Problem Diagnosis 1376 •  
 Slippage 1377 • Transmission Drainback 1377 •  
 Noises 1380 • Flexplate 1380 • Transmission Tests  
 1380 • Valve Body Removal 1382 • Transmission  
 Adjustments 1382 • Electronic Transmission Service  
 1384 • More Tests before Transmission Removal  
 1387 • Hybrid Automatic Transmission Service  
 1387 • Remanufactured Automatic Transmissions  
 and Transaxles 1387 • Transmission Rebuilding  
 1388 • Transmission Reassembly 1390

## CHAPTER 75

### Driveline Operation 1393

Introduction 1393 • Driveshaft (RWD) 1394 • Slip  
 Yoke 1394 • Universal Joints 1395 • Two-Piece  
 Driveshaft 1396 • Driveshaft Angle 1397 •  
 Constant Velocity Joints 1398 • Differential 1399 •  
 Differential Construction 1399 • Differential  
 Housing 1400 • Differential Operation 1401 •  
 Differential Gears 1402 • Gearsets 1402 • Axle  
 Ratio 1403 • Limited Slip Differential 1403 • Types  
 of Limited Slip Differentials 1403 • Drive Axles and  
 Bearings 1404 • Semi-Floating Axle Bearing Types  
 1405 • Independent Rear Suspension Axles 1406 •  
 Gear Oils 1406 • Four-Wheel Drive 1407 • Four-  
 Wheel-Drive Axle Assembly 1407 • Transfer Case  
 1408 • Locking Hubs 1409 • All-Wheel Drive 1410

## CHAPTER 76

### Driveline Diagnosis and Service 1413

Introduction 1413 • Driveshaft Diagnosis 1413 •  
 Universal Joint Diagnosis and Service 1414 •

Driveshaft Service 1414 • Universal Joint Disassembly 1415 • Universal Joint Reassembly 1416 • Driveshaft Installation 1417 • Two-Piece Driveshaft Service 1418 • Differential and Axle Diagnosis and Service 1418 • Problem Diagnosis 1418 • Axle Bearing Diagnosis 1419 • Axle Bearing Service 1420 • Removing a Bearing-Retained Axle 1420 • Axle Bearing Replacement 1421 • Axle Bearing Installation 1422 • Reinstall the Axle 1423 • Full-Floating Axle Service 1423 • Differential Pinion Seal Replacement 1424 • Differential Repair 1425 • Removing a Third Member 1425 • Disassembling a Salisbury Axle 1425 • Clean and Inspect Parts 1426 • Differential Reassembly 1427 • Adjusting a Differential 1427 • Pinion Gear Depth 1427 • Ring Gear Backlash 1428 • Side Bearing Preload 1428 • Contact Pattern 1430 • Backlash Pattern Change 1430 • Pinion Depth Pattern Change 1430 • Pinion Bearing Preload 1431 • Ring and Pinion Noise 1432 • Four-Wheel-Drive Service and Repair 1432

**CHAPTER 77****Front-Wheel-Drive (Transaxle and CV Joint) Fundamentals 1437**

Introduction 1437 • Front-Wheel Drive 1437 • Manual Transaxles 1438 • Shift Linkage 1438 • Transaxle Differential 1439 • Transaxle Power Flow 1440 • Automatic Transaxle 1442 • Front Drive Axles 1443 • Axle Shaft Parts 1443 • CV Joint Construction 1444 • Axle Shafts 1446 • CV Joint Boots 1446

**CHAPTER 78****Front-Wheel-Drive (Transaxle and CV Joint) Service 1448**

Introduction 1448 • Transaxle and Front-Wheel-Drive Service and Repair 1448 • Leaking CV Joint Boot 1448 • CV Joint Boot Service 1448 • Axle Inspection and Diagnosis 1449 • CV Joint Diagnosis 1449 • Axle Shaft Removal 1450 • CV Joint Replacement 1452 • Fixed Joint Disassembly and Inspection 1453 • CV Joint Boot Clamps 1455 • Servicing an Inner Tripod Joint 1456 • Double Offset Plunge Joints 1456 • Cross Groove Joint Service 1457 • Rebuilt Halfshafts 1457 • Installing the Axle 1457 • Transaxle Repair 1457 • Transaxle Removal 1458 • Manual Transaxle Repair 1458 • Automatic Transaxle Repair 1458 • Transaxle Differential Side Bearing Adjustment 1458 • Install the Transaxle 1458

**CHAPTER 79****Driveline Vibration and Service 1461**

Vibration Analysis 1461 • Types of Vibrations 1462 • Vibration Test Instruments 1463 • Vibration and Frequency 1463 • Driveshaft Runout 1465 • Other Causes of Vibration 1465 • Driveshaft Balance 1465 • Driveshaft Angle 1467

**APPENDIX 1470****GLOSSARY 1482****INDEX 1520**

**NOTE TO STUDENT:** *Learn to use the index. It has been constantly updated and will help you find what you need in the book.*

# PREFACE

*Automotive Service: Inspection, Maintenance, Repair, 4th edition* evolved in part from my participation in a successful articulation program between local high schools and the community college where I have been a teacher for over 37 years. The text and art manuscripts of this best-selling book have once again been updated and improved in this fourth edition revision. An array of excellent technical reviews by a dedicated group of professional teachers and technicians ensures that this is the most technically accurate and up-to-date comprehensive automotive textbook available in the marketplace. The text has been written from a carefully detailed outline to allow each chapter to follow a logical, easy-to-understand path. Many new original color photographs and sketches have been added to update and supplement earlier material.

The transportation industry in North America is vast, with one in every six people contributing to it in some way. These include people of many levels of understanding and ability. With that in mind, the introductory fundamentals chapters are written at a lower level for all the students, whereas the service chapters are for those who have mastered the introductory material.

As a teacher, my philosophy is to challenge the best students in anticipation that the rest will be brought to a higher level: “A rising tide raises all boats.”

The text can be used for a variety of educational purposes, including:

- As a basic text in any automotive repair class
- To educate entry-level or apprentice technicians
- To prepare more experienced technicians for ASE certification

*Automotive Service: Inspection, Maintenance, Repair, 4th edition* is divided into 79 chapters that cover the NATEF Auto General Service Technician Program Standards and A1–A8 (the eight ASE automotive specialty areas). Advanced engine performance and emission controls are also covered in detail. In addition to coverage of the usual repairs performed in almost any automotive repair facility, the reader is introduced to the most frequently performed inspection and service procedures—from safety inspections to tire and wheel service.

The automotive repair industry of today continues to evolve into more of a maintenance industry as vehicles last longer and require fewer repairs. Long-term customer relationships, ethics, and professionalism have become even more important to the success of a business. There are also environmental concerns today that were not a part of the industry of the past. The text includes chapters on safety, hand tools, and vehicle maintenance and lubrication that are more

comprehensive than those found in most comparable texts. An accompanying lab manual emphasizes the NATEF Auto General Service Technician Program Standards, those jobs done in service stations, fast-lube outlets, or mass merchandisers (such as Sears, Goodyear, Firestone, or Kmart). An additional lab workbook, *Automotive Service Job Sheets for NATEF Task Mastery*, covers the eight main ASE system areas.

Automobiles have become so complex in the last 30 years that to remain competent many of today’s technicians specialize in one or more systems of the car. Basic theory of all automotive and light truck systems is covered so that service personnel will understand the function of the parts being serviced. When working in the industry, there is often no time for basic theory. Therefore, automotive class work could be the one and only chance students have to learn how systems operate so they can become better diagnosticians in the future.

This book is comprehensive in that it deals with the entire car and aims to teach theory of vehicle systems at an introductory student level, followed by service, diagnosis, and light repairs at a more advanced student level.

Most of the systems used in automobiles today are strikingly similar. Repair techniques universal to all automobiles are discussed and procedures or conditions unique to only one specific automobile make are purposely avoided. The reader is encouraged to refer to the service and repair information for the specific vehicle in question.

A major challenge for me as an automotive author is to keep the scope of the book from growing out of control by expanding into areas of in-service training best covered by manufacturers and aftermarket educators. My objective is to take an abundance of sometimes complicated information and condense and simplify that information so it can be understood by a student preparing for *job-entry level*. Following the completion of this text, better students will be at a high job-entry level, at a skill level suitable for entry as an apprentice in one or more of the specialty areas of automotive repair in a new car dealership or an independent repair shop.

A primary objective of this book is to help the reader develop confidence in both thinking skills and problem-solving ability. One unique aspect of automotive education is that many automotive graduates venture into other professions and skilled trades, such as engineering or construction. They will find much of the material learned in automotive classes to be very valuable and useful in their chosen fields. This aspect of the student’s education is especially valuable when one considers how middle school and high school industrial arts programs have been scaled back in recent

years. Dealing with such things as tools, soldering, basic electrical repairs, and repairing broken fasteners helps to provide some measure of practical education.

The tremendous decline in the number of corner gasoline service stations has resulted in a loss of those jobs formerly available in abundance to students. Successful service personnel who possess necessary basic automotive skills must continually learn new things in order to progress into other (higher-paying) specialty areas. The *Lab Manual to Accompany Automotive Service* contains service jobs that students should be able to perform before enrolling in an advanced automotive specialty area class.

### ■ UPDATES AND ENHANCEMENTS TO THE FOURTH EDITION

- New and updated information on hybrid vehicles and alternative fuels.
- New coverage on the latest information on engine oils and coolants.
- Vehicle electronics coverage has been improved and increased throughout.
- New and updated engine performance and electronics coverage includes technology advances in onboard diagnostics, misfire detection, variable valve timing, displacement on demand, adaptive strategies, the latest CAN systems, drive-by-wire, and wide-band oxygen sensors.
- Chassis and powertrain coverage includes updated information on stability control and traction control systems, electronic suspension systems, electric steering, and electronic transmission and all-wheel drive.
- Updated comfort and safety topics include the newest developments in air conditioning, supplemental restraints, lighting, entertainment systems, and adaptive cruise control.
- New science, math, and history notes have been added.
- The Instructor Resources DVD and other new and greatly enhanced supplements are designed to improve the organization and quality of time spent in the classroom and shop (see the Supplements page for more detail).
- All automotive terms, abbreviations, and acronyms used in this text comply with the SAE Technical Standards Board Publication *SAE J1930*.

### ■ ACKNOWLEDGMENTS

I would like to extend special thanks to the following individuals, organizations, and companies:

- Delmar, Cengage Learning Senior Product Manager Matt Thouin for his helpful, positive attitude. Matt's dedication to excellence and his efficiency

and organizational skills were very important to the overall improvement of this fourth edition.

- Denise Denisoff and Chris Shortt, developmental editors in earlier editions of the text.
- Cheri Plasse and Joan Conlon, Content Project Managers, who managed the art, design, and production of the text. Cheri has worked on several of my projects in the past and is always a pleasure to work with.
- Bill Clark and the staff at MPS who worked tirelessly behind the scenes. Their professional talent and effort with the text and art ensure a quality final product.
- Sharon Rounds, who worked tirelessly behind the scenes securing art permissions.
- Araceli Popen, who has been copyeditor on several of my books, making certain that everything is accurate and in order.
- Cheryl Weakliem, my editorial assistant, for her excellent reviews, suggestions, and text edits in the areas of electricity, air conditioning, and science. Cheryl is a chemistry teacher with a PhD in Chemistry and an associate degree in Automotive Technology.
- Friends and colleagues Bob Stockero and Dave Brainerd of Santa Barbara City College and Chuck Rockwood of Ventura College for their continuous input and support. All three provided in-depth reviews and excellent suggestions to this edition of the text.
- Members of the North American Council of Automotive Teachers (NACAT) and California Automotive Teachers (CAT), who provided a vast amount of input.
- Students in the Automotive program at Santa Barbara City College, who provided continuous feedback and suggestions for improvement.
- Physics professor Mike Young of Santa Barbara City College for his help with the Science Notes.
- Jack Rosebro of Perfect Sky, Inc., who helped with reviews of the hybrid vehicle material.
- Bernie Carr, Senior Engineer at Bosch Diagnostics/Vetronix in Santa Barbara, who reviewed and helped with controller area networks (CAN) and other vehicle electronics material.
- Staff at all of the campuses of Universal Technical Institute, who provided helpful reviews of the manuscript.
- Tom Butera has volunteered in my class since he retired after 31 years as the owner of a NAPA store, preceded by many years as an owner of four Texaco service stations. Parts people know lots of things about the automotive industry and Tom brings many things to class to share with me and my students.

*From Tim Gilles*

# ACKNOWLEDGMENTS

The contributions of the following reviewers are gratefully acknowledged for their invaluable input during the development of this revision. In addition, the author and publisher would like to thank the reviewers who offered feedback for previous editions:

David Ames  
Evergreen Valley College  
San Jose, CA

David Brainerd  
Goleta, CA

Al Carroll  
Edgecombe Community  
College  
Tarboro, NC

Andrew Cawelti  
Oxnard College  
Oxnard, CA

Tim Dwyer  
Oklahoma State Technical  
College  
Okmulgee, OK

Julia Johnson  
Skyline College  
San Bruno, CA

Anthony Kossmann  
Hudson Valley Community  
College  
Troy, NY

Gary Neil  
Renton Technical College  
Renton, WA

James Posick  
Daytona Beach State College  
Daytona Beach, FL

Charles Rockwood  
Ventura College  
Ventura, CA

Gary Semerdjian  
Imported Automotive Service  
and Santa Barbara City College  
Santa Barbara, CA

Robert Stockero  
Santa Barbara City College  
Santa Barbara, CA

## FROM ATI SCHOOLS AND COLLEGES:

Luis Barini  
Oakland Park, FL

Arnold Burkett  
Oklahoma City, OK

Craig Couch  
Oklahoma City, OK

Andre Covas  
Oakland Park, FL

Robert Dryja  
Dallas, TX

Secundino Garza  
Corpus Christi, TX

Ryder Goin  
Dallas, TX

Jonathan Kloepfer  
Oakland Park, FL

Bruce Lazarus  
Oakland Park, FL

Herbert Leist  
San Antonio, TX

Marion McKnight  
Waco, TX

Herbey Pena  
Corpus Christi, TX

Vincent Seina  
Oakland Park, FL

John Tappan  
San Antonio, TX

Douglas Walter  
Houston, TX

## FROM UNIVERSAL TECHNICAL INSTITUTE:

Joseph Alvey  
Sacramento, CA

David Anderson  
Orlando, FL

John Archambault  
 Mooresville, NC

Leonardo Avalos  
Avondale, AZ

Jared Avent  
Sacramento, CA

Fred Bachrodt  
Avondale, AZ

Jack Batson  
Rancho Cucamonga, CA

David Beam  
Exton, PA

Oliver Beckham  
Houston, TX

Vince Blanchard  
Sacramento, CA

Terry Borkman  
Avondale, AZ

William M. Brown  
Rancho Cucamonga, CA

Benson Bunk  
 Mooresville, NC

Thomas Clark  
Rancho Cucamonga, CA

James Coll  
Exton, PA

Jon Combs  
Avondale, AZ

James Coombes  
Exton, PA

Phillip Cooper  
 Mooresville, NC

Jeffrey Covington  
 Mooresville, NC

William Crawford  
Avondale, AZ

David Cubillas  
Avondale, IL

Darren Culver  
Houston, TX

Ben Curtis  
 Mooresville, NC

Russell Curtis  
Glendale Heights, IL

Eric Davies  
Exton, PA

Steve Davies  
Exton, PA

Steve Davis  
Avondale, AZ

Ken DeLano  
Mooresville, NC

Andre Demers  
Mooresville, NC

Dennis Denz  
Glendale Heights, IL

Thomas Devitt  
Mooresville, NC

Lawrence Doran  
Sacramento, CA

Anthony Eddins  
Norwood, MA

Robert Egli  
Avondale, AZ

Steven Fair  
Exton, PA

Eric Feltman  
Orlando, FL

Martin Flannery, Jr.  
Exton, PA

James Flockhart  
Avondale, AZ

John Fournerat  
Houston, TX

Matthew Franchetti  
Norwood, MA

Scott French  
Orlando, FL

Ryan Galatti  
Exton, PA

Jessie Galey  
Mooresville, NC

Steve Garner  
Sacramento, CA

John Glusica  
Mooresville, NC

Roy Greathouse  
Sacramento, CA

Steven Greenspan  
Glendale Heights, IL

Joe Grosso  
Exton, PA

Gregory Gunter  
Exton, PA

Luciano Gurrola  
Avondale, AZ

Luis Guzman  
Orlando, FL

Mark Hall  
Sacramento, CA

Terrance Haltom  
Sacramento, CA

Richard Hamilton, Jr.  
Mooresville, NC

Ricky Harrison  
Houston, TX

Michael Hecht  
Houston, TX

William Hoffman  
Glendale Heights, IL

Jason Holdaway  
Mooresville, NC

Thomas Ingalls  
Mooresville, NC

Rodger Jerls  
Rancho Cucamonga, CA

William Jones  
Rancho Cucamonga, CA

Scott Keel  
Houston, TX

W. Scott Keene  
Glendale Heights, IL

Nathan Kulp  
Exton, PA

Dave Leja  
Glendale Heights, IL

Matthew Lokai  
Mooresville, NC

Kenneth Lowell  
Norwood, MA

Andrew Martin  
Rancho Cucamonga, CA

Bobby Masterson  
Houston, TX

Cory Mathis  
Glendale Heights, IL

Robert McCorkell  
Exton, PA

Brendan McCormick  
Exton, PA

Brian McHugh  
Orlando, FL

Danny McKay  
Sacramento, CA

David McLoud  
Norwood, MA

Donald McNabb  
Houston, TX

James Mellenthin  
Glendale Heights, IL

Steven Michelsen  
Glendale Heights, IL

Kara Moon  
Phoenix, AZ

Jason Mosler  
Avondale, AZ

Charles Nance  
Rancho Cucamonga, CA

Francis O'Connell  
Exton, PA

Michael Pair  
Glendale Heights, IL

Louis Phistry  
Avondale, AZ

Ken Nagel  
Glendale Heights, IL

Steve Nelson  
Avondale, AZ

Mark Nerad  
Glendale Heights, IL

William C. Niemeyer  
Glendale Heights, IL

Douglas Pergram  
Glendale Heights, IL

Clayton Perkins  
Avondale, AZ

Todd Peterson  
Norwood, MA

John Pflingstag  
Phoenix, AZ

Richard Ploeser  
Avondale, AZ

James Pollard  
Houston, TX

Daniel Poor  
Norwood, MA

George Potter  
Glendale Heights, IL

Juan Ramos  
Glendale Heights, IL

Carroll Randall  
 Mooresville, NC

Timothy Rayner  
Sacramento, CA

Salvatore Reina  
Avondale, AZ

Paul Rohe  
Rancho Cucamonga, CA

Dominick Saffioti  
Orlando, FL

Kurt Saverien  
Sacramento, CA

Edward Scarbrough  
Glendale Heights, IL

Donald Seene  
 Mooresville, NC

Brian Shefman  
Exton, PA

Charles Siegel  
Orlando, FL

Aaron Smith  
 Mooresville, NC

Marvin Smith  
 Mooresville, NC

Everett Jay Sinon  
 Mooresville, NC

Michael Sorensen  
Sacramento, CA

Anthony Spadafina  
Glendale Heights, IL

William Spiekerman  
Avondale, AZ

Mike Statzer  
Avondale, AZ

Chris Styffe  
Norwood, MA

John Taglini  
Norwood, MA

Adam Taylor  
Norwood, MA

Andy Taylor  
 Mooresville, NC

George Timmis  
Orlando, FL

Bob Troxler  
Chino Hills, CA

Ray Tourtelotte  
 Mooresville, NC

Robert Venditti  
Exton, PA

Steven Volkman  
Orlando, FL

Joseph Walker  
Orlando, FL

Don Walter  
Rancho Cucamonga, CA

Wayne Walters  
 Mooresville, NC

Thomas Wells  
Houston, TX

Robert Wild  
Orlando, FL

David Winfrey  
Norwood, MA

Randy Worner  
Houston, TX

Mark Yarnall  
Exton, PA

## DEDICATION

The completion of this book was made possible with help from a great many individuals. *Automotive Service: Inspection, Maintenance, Repair, 4th edition* is dedicated to them and to my wife, Joy. Her organizational skills and able assistance have been invaluable. Writing a 1,500-page comprehensive textbook with many thousands of photos and sketches is a daunting task. I would not be able to concentrate as much of my time on the important upgrading and editorial work if I did not have Joy organizing the art package and submitting final manuscript changes to the publisher. She retired from her full-time job to help with this project and has been especially helpful.

## ABOUT THE AUTHOR

Tim Gilles has authored and coauthored several textbooks. He has been an automotive teacher since 1973 and is a professor in the Automotive Technology Department at Santa Barbara City College. He earned a Bachelor of Arts degree from Long Beach State University and a Master of Arts degree in Occupational Education from Chicago State University. He holds the industry certifications of ASE Master Engine Machinist and ASE Master Automotive Technician.

Tim has been active in professional associations for many years, as president and board member of the California Automotive Teachers (CAT) and as a board member and election committee chair of the North American Council of Automotive Teachers (NACAT). He is a frequent seminar presenter at association conferences. Tim has been a longtime member of the California Community College Chancellor's Trade and Industry Advisory Committee. He is active in industry associations, including AERA, ARC, and IATN, and has served several terms as education representative on the board of the Santa Barbara Chapter of the Independent Automotive Professionals Association (IAPA).

# FEATURES

## OF THE TEXT

### OBJECTIVES

Each chapter begins with a list of the most important points discussed in the chapter. This list of objectives is intended to provide the student with a general idea of what he or she will be studying.

### KEY TERMS

Each chapter contains a list of new terms to know. These terms are **highlighted in bold** in the text. Definitions of these terms can be found in the glossary.

### CAUTIONS

Cautions are urgent warnings that personal injury or property damage could occur if careful preventive steps are not taken.

### SHOP TIPS

Appropriate shop tips are described throughout the text. These tips provide shortcuts and emphasize fine-tuning procedures to shop practices commonly performed by experienced technicians.

### NOTES

Notes are used throughout the text to highlight especially important topics.

### VINTAGE SYSTEM NOTES

Boxed information on vintage systems (and related parts) puts today's newer technologies in historical perspective and offers insights into the development of the automobile. Vintage notes are not only interesting but may even help the reader repair or restore vintage cars. This has become an important part of many automotive businesses.

**CHAPTER 12**  
**Engine Lubrication**

**OBJECTIVES**  
Upon completion of this chapter, you should be able to:  
■ Describe engine lubrication under different service conditions.  
■ Select the correct engine oil to use.  
■ Describe the operation of different types of oil filters.

**KEY TERMS**  
anti-drainback valve  
API  
boundary lubrication  
bypass oil filter  
bypass valve  
crankcase  
dry start  
full-flow oil filter  
multiple viscosity  
polymer  
viscosity  
viscosity index

**CAUTION** Do not try to substitute an un molded hose for a molded by-pass hose. It can fold when bent, restricting coolant flow.

**Power Steering Hose Service**  
When checking a power steering hose, look for signs of leakage or dampness at the connections. Also, look

**SHOP TIP** Drain the coolant into a clean drain pan. This is especially important if it is to be reused, if the customer has recently had the most likely be unhappy if he or she is billed again for new coolant.

**NOTE** Some technicians routinely replace steel core plugs in cast iron blocks with brass ones that will not corrode. If coolant is regularly maintained, this is an unnecessary practice. It is a good idea for boat engines, however.

**WATER PUMP SERVICE**  
Coolant pumps have been traditionally called water pumps. They are often replaced after many years and miles of service when they begin to leak or make noise.

**Leaking Water Pump**

**VINTAGE ENGINES**  
Almost all vintage engines suffered from taper and out-of-round cylinder wall wear. Older engines used piston rings that had higher tension than today's engines. A bigger factor in cylinder wall wear in older engines, however, was that they used a fuel delivery system that had a carburetor with a choke. The mixture that had a carburetor with a choke. The mixture for better cold driveability. A carburetor choke is nowhere near as efficient, however, in delivering fuel to a cold engine as a fuel injection system. Oil cannot be burned from the surface of a cylinder wall, but it can be washed away by fuel and then burned in the combustion chamber. When an engine was cold, the carburetor would routinely provide too much fuel. This would wash oil from the cylinder walls, leaving them susceptible to increased wear.

**CYLINDER SLEEVES**  
Aluminum blocks usually have permanently installed iron cylinder sleeves. Heavy-duty engines and some vintage automotive engines use replaceable cylinder bores, called wet or dry sleeves. When a cylinder is cracked or rusted or the block has a serious wall if the wear in all the other cylinders is acceptable the damaged cylinder can be bored oversize for installation of a pressed-fit dry sleeve (see Chapter 3). Some heavy-duty engines use removable wet sleeves that differ from conventional sleeves in that they only contact the block at the upper and lower ends of the cylinder to prevent coolant leakage.

**MAIN BEARING CAPS**

**CRANKSHAFT DESIGN**  
The crankshaft converts the reciprocating (up-and-down) motion of the pistons to rotary motion. The polished crankshaft bearing surfaces are called journals.

**Main Bearing Journals**  
The main bearing journals are the ones that support the crankshaft as it turns in the block. The journals that are in line on the same axis as the front and rear journals are all main bearing journals.

**Rod Bearing Journals**  
Journals that are offset from the main bearing journal centerline are called rod journals or conrods. Connecting rod journals transfer up-and-down motion between the crankshaft and connecting rod. Rod journals are also known as crankpins. As described in Chapter 15, for eight cylinders, 120-degree angles for even-fire six cylinders, and 180-degree angles for four cylinders.

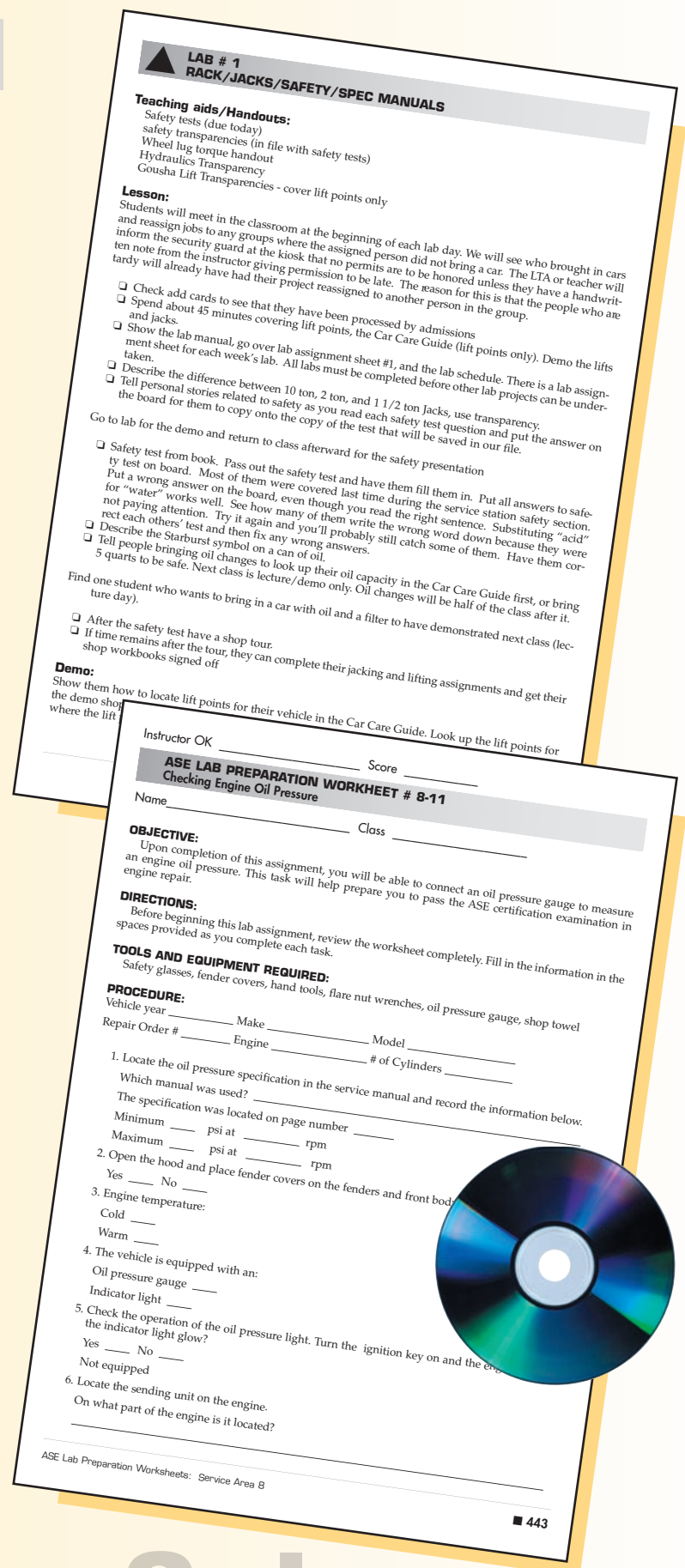
**Figure 23-15** Clean the hose fitting before installing the new hose.

**Figure 19.5** These main bearing caps have four studs and two more from the side.



## SUPPLEMENTS

- **Instructor Resources**—The fourth edition Instructor Resources DVD includes an Instructor's Guide in Microsoft Word, a Computerized Test Bank in ExamView with hundreds of modifiable questions (true/false, fill-in-the-blank, and ASE-style multiple choice), chapter presentations in PowerPoint with full-color images, video clips and animations, a searchable Image Library of hundreds of full-color photos and line art from the core text, and Correlation Grids to the NATEF Automobile Program Standards.
- **CourseMate**—The all new CourseMate for *Automotive Service, 4th edition*, offers students and instructors access to important tools and resources, all in an online environment. The CourseMate includes an Interactive eBook for Automotive Service, Fourth Edition, nearly 300 videos and animations, interactive quizzes, flashcards, an interactive glossary, and an Engagement Tracker tool for monitoring students' progress in the CourseMate product.
- **WebTutor Advantage**—Newly available for *Automotive Service* is the WebTutor Advantage for the Blackboard online course management system. The WebTutor includes chapter presentations in PowerPoint, end-of-chapter review questions, pretests and posttests, discussion springboard topics, and more, all designed to enhance the classroom and shop experience.
- **Lab Manual**—The Lab Manual includes Worksheets that define each lab procedure, presented in increasing levels of difficulty. Each project or lab assignment is built upon the next in a logical sequence in much the same manner as science instructional programs are constructed, and the reader completes one task before progressing to the next one. In addition, a variety of illustrations support the Worksheets and help visual learners better understand the jobs. The Worksheets are keyed to the NATEF Auto General Service Technician Programs Standards where applicable.
- **Automotive Service Job Sheets for NATEF Task Mastery**—The Job Sheets in this manual cover all P-1, P-2, and most P-3 procedures as identified by the most recent NATEF Automobile Program Standards. Full-color illustrations offer visual support to the Job Sheets, and the sequence of topics follows that of the core text. Each Job Sheet includes a simple and clear rating rubric for instructor evaluation of student performance on the task, and a supplemental CD-ROM includes NATEF task-tracking software for easy recording of students' mastery of the procedures.



# Not For Sale

© Cengage Learning. All rights reserved. No distribution allowed without express authorization.