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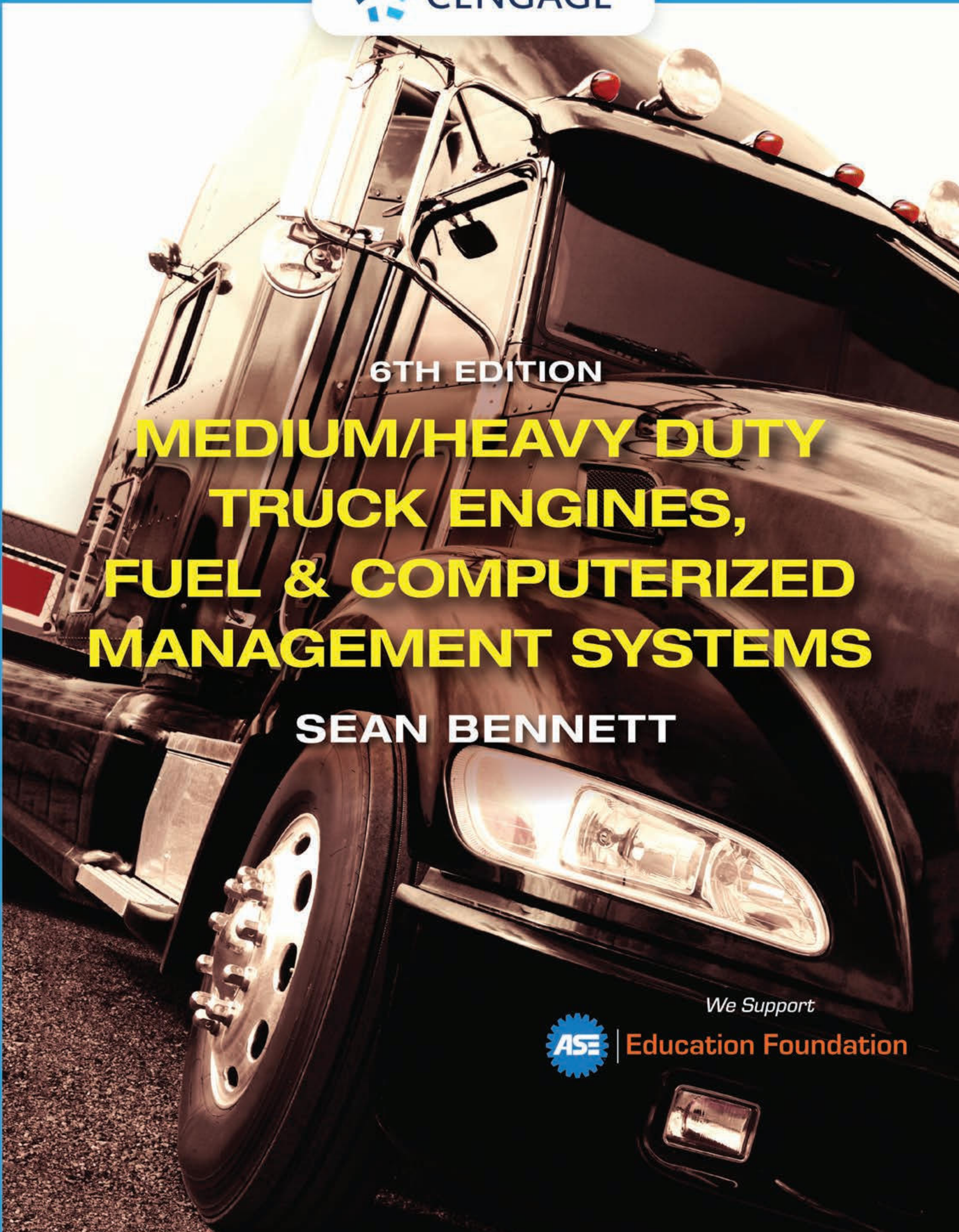

6TH EDITION

MEDIUM/HEAVY DUTY TRUCK ENGINES, FUEL & COMPUTERIZED MANAGEMENT SYSTEMS

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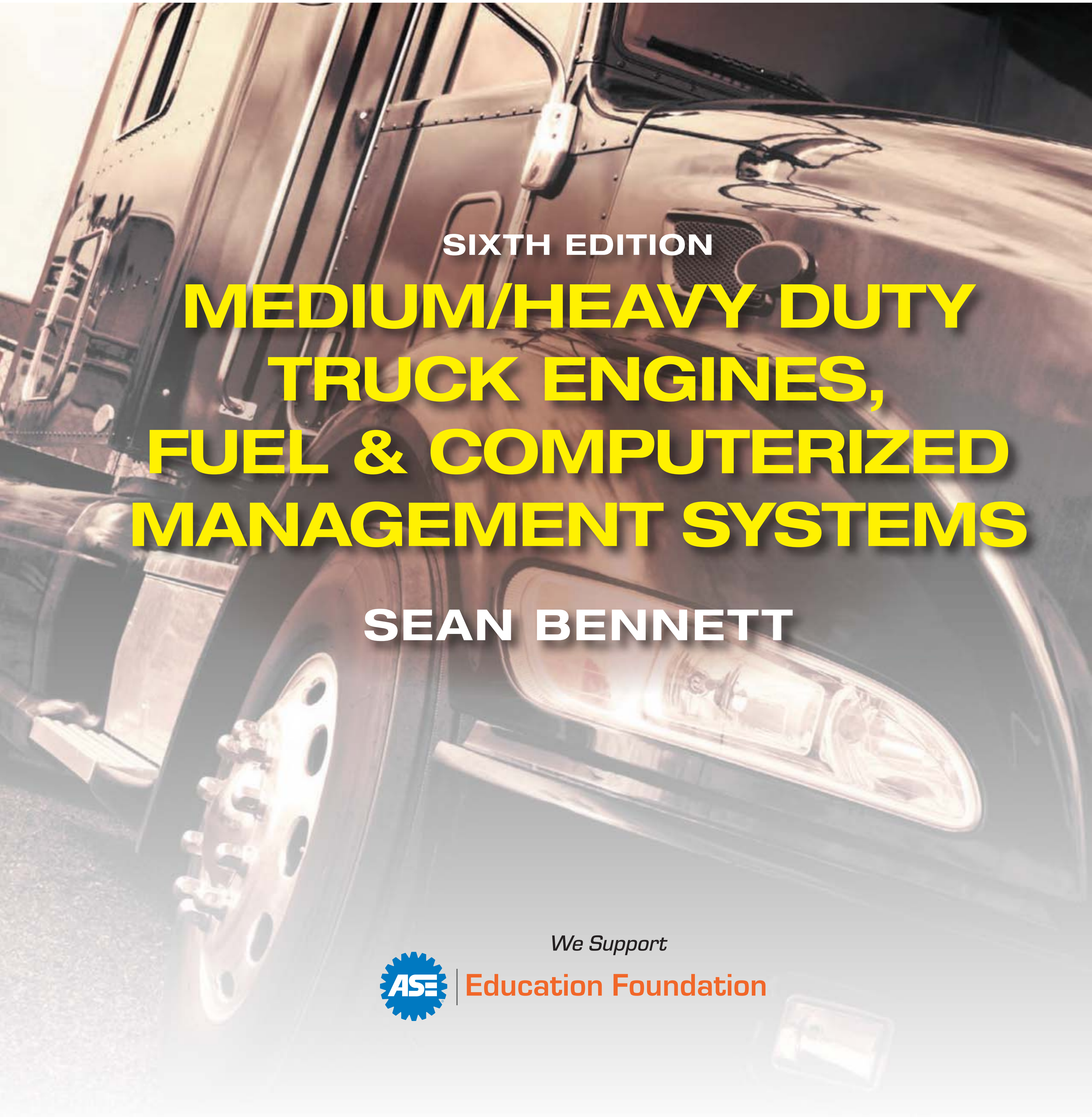

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***Medium/Heavy Duty Truck Engines, Fuel & Computerized Management Systems*, 6th Edition**
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PHOTO SEQUENCES

PREFACE

STRUCTURE OF THE 6TH EDITION

This revision required structural changes called for by the recent surge in sales of commercial vehicles with electric drivetrains. From the second edition onward, the focus of this book has been more widespread than its title suggests because it has dealt with the full spectrum of commercial vehicle drivetrain technology, extending from some of the smallest offroad commercial vehicles up to the largest land vehicles manufactured. Although ICE-hybrid electric drivetrains have been with us for a generation, fuel cell and all-electric drive is rapidly changing the urban commercial vehicle landscape—and doing it fast! This fact necessitated including new three chapters dealing exclusively with high voltage electric drivetrains.

NEW TO THIS EDITION

EPA Model Year 2010 created the ultra low emissions environment we take for granted today, and the prediction is that nothing too dramatic is likely to occur in diesel engines and emissions technology until MY2027. Diesel common rail (CR) fuel systems have now become standard with all of the major engine OEMs using it, most across all of their product lines. The changes that have occurred in the recent past and which are new to this book have to do with the way powertrains and chassis are managed. Some highlights of what is new to this edition:

- Ultrasonic sensors
- Developments in telematics
- Updates to J1939 in trucks, buses, and offroad applications
- Electronic logging device (ELD) and the technician
- Cybersecurity
- High voltage powertrain safety
- Advances in electrical energy storage systems (EESS)
- Li-ion batteries currently used in commercial vehicles
- EESS computerized management
- PEM hydrogen fuel cells in trucks and transit buses
- Battery-electric transit buses and Class 8 trucks
- Inverter operating principles
- Synchronous AC traction motors
- SCR and DPF servicing
- Single canister aftertreatment systems

SOME TRANSPORTATION HISTORY

In the early days of machine-powered transportation in the United States, mobility required roads over which wheel-driven vehicles could travel. Back in those days, this meant that “road” transportation by anything driven by wheels rather than four hooves, was limited to urban areas. Travel distances were necessarily short. Back in those days, battery-electric power competed with ICE and steam power for market dominance. In the year 1900, steam engines accounted for 40% of road vehicles, followed by 38% for battery-electric, and just 22% gasoline ICE.

The development of road networks progressed rapidly during the first years of the last century. Soon vehicles could travel beyond city limits and connect with other cities. This type of travel required the use of a gasoline ICE (diesel did not play a role until the 1920s) in which a full tank of fuel could be replenished in minutes. Electric power survived but only where it could be conducted through a rail or overhead lines. Battery-electric vehicles were dead. Battery energy density in those days was limited and recharge times were slow.

ELECTRIC DRIVETRAINS

Today’s hybrid ICE-electric, hydrogen fuel cell electric, and battery-electric vehicles all use a common powertrain. Each is equipped with an electrical energy storage system (EESS), inverters, and traction motors. ICE-hybrid electric vehicle technology has now been extensively used for two decades in urban areas, mostly using natural gas (NG) or diesel power to generate the onboard electricity and share the traction drive requirements. However, recent dramatic advances in battery energy density have opened the door for battery-electric and fuel cell electric commercial vehicles—and not limited to urban areas.

Vehicles with electric drivetrains use high potential electrical circuits. This reality requires a different skillset from service and repair technicians—and a safety-first mindset when working on, or around, high voltage circuits. Electric powertrains are here to stay. Every major city on the continent is either using or trialing fuel cell or all-electric power in transit buses. In addition, urban trucking is embracing electric drivetrain technology with vehicles that range from delivery vans to Class 8, battery-electric refuse packers.

THE FUTURE

Electric drivetrains are not a fad. The major challenge of battery energy density has now made the technology viable and it will only improve. There are just so many advantages to electric drive, not the least of which is a 90% reduction in the number of moving vehicle parts versus an equivalent ICE-powered unit. This fact alone brings with it the promise of significantly lower maintenance costs. And the commercial vehicle industry is just beginning to wake up to the potential of the hydrogen fuel cell with New Flyer and Nikola Motors leading the way. Especially notable is the recent purchase of Hydrogenics, a manufacturer of hydrogen fuel cells, by Cummins. You might conclude from this that if highway diesel engine market-leader Cummins foresees a future in hydrogen fuel cell power, it will surely come to pass!

DIESEL POWER

Diesel power will not disappear in a hurry. First, there is insufficient electricity to feed the domestic fleet even if battery technology improved sufficiently to make all-electric linehaul trucking possible. Next, the required grid and recharge infrastructure upgrades would take years to meet the needs of a nationwide electric truck fleet. Over the long term, hydrogen fuel cell electric drive is more doable, but upfront costs remain high and hydrogen is not cheap to produce or store on a vehicle. The current prediction is that battery-electric and fuel cell electric power will conquer urban areas but diesel will prevail on the highways.

HANDS-ON LEARNING

The primary objective of this textbook is to meet the ASE Education Foundation competency standards while maintaining currency with the technology that is actually running on our highways and urban streets. I have always maintained that a textbook is but one tool in a learning program that educates a competent hands-on mechanical technician. As a writer, my role is to make complex machinery and the systems that make it run, as approachable as possible to entry-level learners. This is not easy as transportation technology advances in complexity, but learning tasks can be facilitated when textbook concepts are directly correlated with hands-on learning experiences. The bottom line is that there is no substitute for learning by doing.

ACKNOWLEDGMENTS

In creating the new electrical chapters in this edition of *Medium/Heavy Duty Truck Engines, Fuel, and Computerized Management Systems*, I have to first thank the folks at the New Flyer *Vehicle Innovation Center* in Anniston, AL, and the many persons at BYD in both Shenzhen, China, and Lancaster, CA. In developing the chapter I titled *The Connected Vehicle*, I'm indebted to my many friends and associates at the ATA *Technology and Maintenance Council (TMC)*, whose conventions and meetings have hosted invaluable opportunities for lively debate and discussion over many years.

In terms of peer feedback, I would like to acknowledge the role of teaching faculty whose suggestions over two decades have significantly contributed to making this book what it is today. This critiquing and support from teaching professionals helps make me a perpetual learner.

Finally, I would like to thank the publishing team at Cengage, ever more important in this age where the printed textbook is just one component of a suite of learning tools all of which have to be created. In this respect, I'd especially like to single out my editor Sharon Chambliss whose patience and teamwork have proven to be invaluable to me over many successful years.

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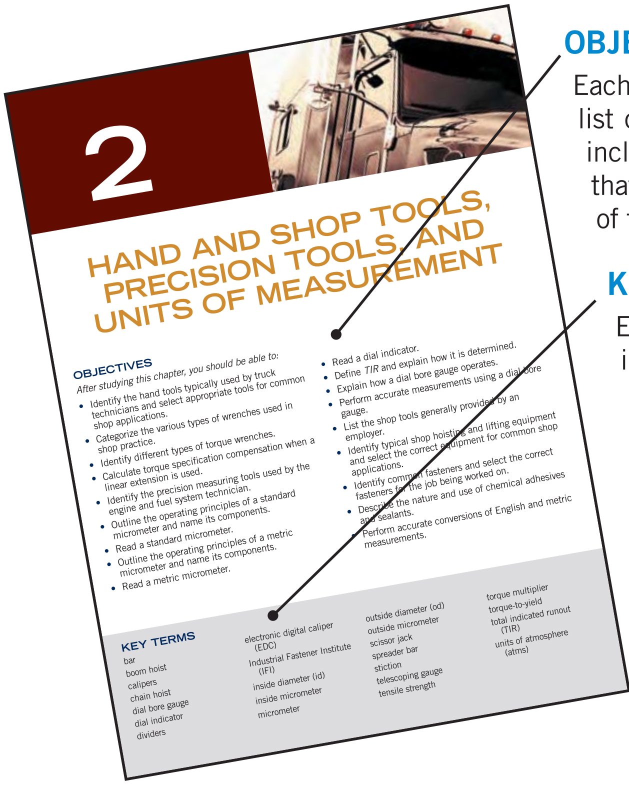
Features of the Text

Learning how to maintain and repair heavy-duty truck systems can be a daunting endeavor. To guide the readers through this complex material, we have built in a series of features that will ease the teaching and learning processes.


2

HAND AND SHOP TOOLS, PRECISION TOOLS, AND UNITS OF MEASUREMENT

OBJECTIVES

After studying this chapter, you should be able to:

- Identify the hand tools typically used by truck technicians and select appropriate tools for common shop applications.
- Categorize the various types of wrenches used in shop practice.
- Identify different types of torque wrenches.
- Calculate torque specification compensation when a linear extension is used.
- Identify the precision measuring tools used by the engine and fuel system technician.
- Outline the operating principles of a standard micrometer and name its components.
- Read a standard micrometer.
- Outline the operating principles of a metric micrometer and name its components.
- Read a metric micrometer.
- Read a dial indicator.
- Define *TIR* and explain how it is determined.
- Explain how a dial bore gauge operates.
- Perform accurate measurements using a dial bore gauge.
- List the shop tools generally provided by an employer.
- Identify typical shop hoisting and lifting equipment and select the correct equipment for common shop applications.
- Identify common fasteners and select the correct fasteners for the job being worked on.
- Describe the nature and use of chemical adhesives and sealants.
- Perform accurate conversions of English and metric measurements.

KEY TERMS

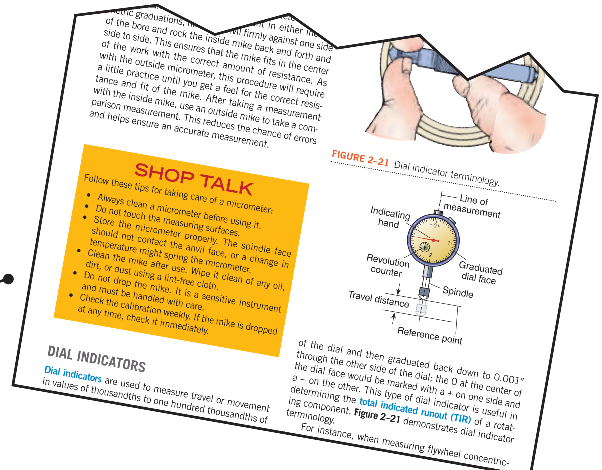
bar, boom hoist, calipers, chain hoist, dial bore gauge, dial indicator, dividers, electronic digital caliper (EDC), Industrial Fastener Institute (IFI), inside diameter (id), inside micrometer, micrometer, outside diameter (od), outside micrometer, scissor jack, spreader bar, stiction, telescoping gauge, tensile strength, torque multiplier, torque-to-yield, total indicated runout (TIR), units of atmosphere (atms)

OBJECTIVES

Each chapter begins with the purpose of the chapter, stated in a list of objectives. Both cognitive and performance objectives are included in the lists. The objectives state the expected outcome that will result from completing a thorough study of the contents of the chapters.

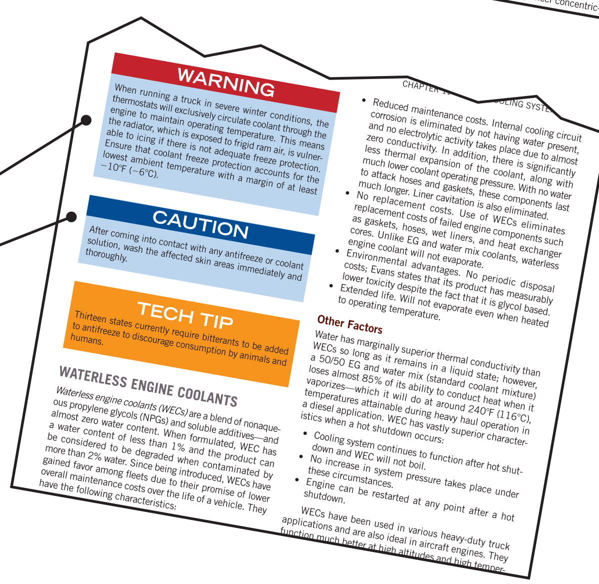
KEY TERMS

Each chapter also includes a list of the terms that are introduced in the chapter. These terms are defined in the glossary and highlighted in the text when they are first used.



SHOP TALK

These features are sprinkled throughout each chapter to give practical, common-sense advice on service and maintenance procedures.



WARNING and CAUTION

Since shop safety is the most important concern among instructors, cautions and warnings appear frequently to alert students of safety concerns.

PHOTO SEQUENCE

Step-by-step photo sequences illustrate practical shop techniques. The photo sequences focus on techniques that are common, need-to-know service and maintenance procedures. These photo sequences give students a clean, detailed image of what to look for when they perform these procedures.


358 SECTION 1 DIESEL ENGINE FUNDAMENTALS

Photo Sequence 1

CHASSIS DYNO TEST PREPARATION

PS1–1 On the control console, lock the dyno rollers. Back the truck onto the rollers. Release the roller lock and in a low gear, spin the wheels up to center the rollers.

PS1–2 Visually check the truck from the front to ensure that it is properly aligned. Check both steer tires on the dyno.

PS1–3 Install the anchor chains to the rear of the chassis, ensuring they do not interfere with any moving suspension components.

PS1–4 The hold-down chains should have the amount of slack shown in this image. When testing a truck with a steel spring suspension, the chains can be slightly more taut but not enough to exert downward force.

PS1–5 With the roller lock released, run the truck through the gears to a highway speed with no load on the rollers.


CHAPTER 2 HAND AND SHOP TOOLS, PRECISION TOOLS, AND UNITS OF MEASUREMENT 59

- When preparing to remove a truck from the shop following service work, install the exhaust extraction pipe over the stack(s) before attempting to start the engine. This way you can build the air pressure and warm the engine before moving the vehicle.

The exhaust extraction pipes are stainless steel or galvanized flex pipes designed to fit over the vertical stacks on the truck. An extraction pump helps pull the diesel exhaust out of the shop. **Figure 2–47** shows a network of exhaust extraction pipes in a truck shop.

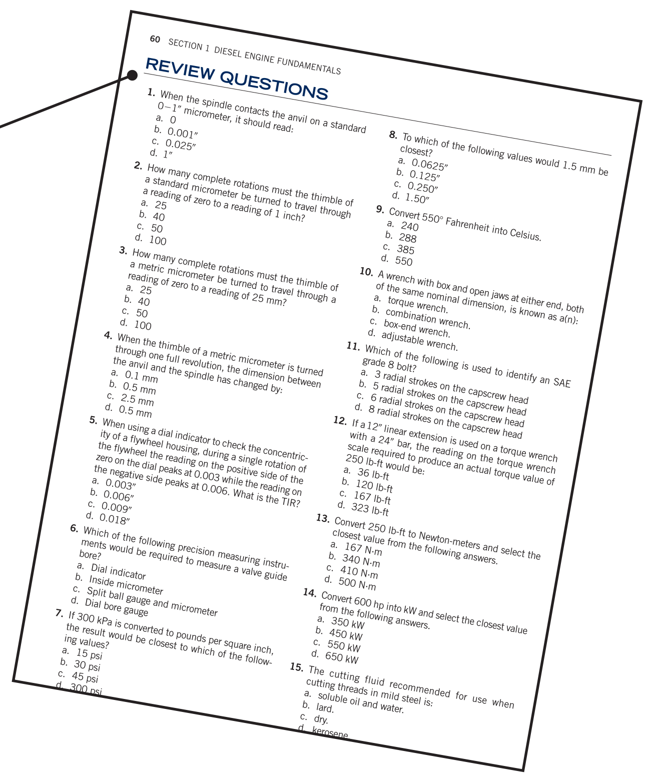
FIGURE 2–47 Exhaust extraction flex pipes in a truck shop.

SUMMARY

- The actual contents of a truck technician's toolbox will be determined by the type of work performed. However, 80% of the contents are probably common among all truck technicians.
- Cheaper tools are often bulkier and more prone to breakage.
- The personal safety of the user is always on the line when hand tools are being used, so it makes sense for the professional to invest in reliable tools.
- The apprentice technician should acquire a mastery of precision measuring tools before using them in work; this is best done by practice using the instruments to measure actual engine components.
- Reading both standard and metric micrometers becomes much easier when the technician understands exactly how they are constructed and calibrated.
- A standard micrometer must be rotated through 40 complete revolutions from the point at which the spindle contacts the anvil producing a zero reading to the point at which it reads 1″. Each complete revolution of the thimble therefore represents 0.025″.
- A metric micrometer must be rotated through 50 complete revolutions from the point at which the spindle contacts the anvil producing a zero reading to the point at which it reads 25 mm. Each complete revolution of the thimble therefore represents 0.5 mm.
- Diesel engine technicians should be familiar with setting up and using dial bore gauges.
- Shop hoisting apparatus should be routinely inspected by qualified personnel and by the technician before using it. This may be a legal requirement in some jurisdictions.
- The technician must check out shop power equipment before each use.
- The technician should know how to identify SAE, IFI, and ISO fastener grades and understand the importance of selecting the correct grade for the job being performed. The engine technician must also understand that many specialty fasteners used on engines have special metal properties and should not be replaced by generic SAE, IFI, or ISO fasteners.
- The technician should get used to both standard and metric systems and be prepared to work in both, because both are widely used in the industry. Formulae need not be remembered, but the technician should get used to rapidly converting values from each system.
- Technicians who take the trouble to organize their personal tools will benefit from the resulting minimization of tool losses.
- A key piece of shop equipment is the exhaust extraction system. To be effective at preventing harmful fumes from being discharged into a closed, indoor environment, it must be used properly.

SUMMARY

Highlights and key bits of information from the chapter are listed at the end of each chapter. This listing is designed to serve as a refresher for the reader.


60 SECTION 1 DIESEL ENGINE FUNDAMENTALS

REVIEW QUESTIONS

1. When the spindle contacts the anvil on a standard 0–1″ micrometer, it should read:
   a. 0
   b. 0.001″
   c. 0.025″
   d. 1″
2. How many complete rotations must the thimble of a standard micrometer be turned to travel through a reading of zero to a reading of 1 inch?
   a. 25
   b. 40
   c. 50
   d. 100
3. How many complete rotations must the thimble of a metric micrometer be turned to travel through a reading of zero to a reading of 25 mm?
   a. 25
   b. 40
   c. 50
   d. 100
4. When the thimble of a metric micrometer is turned through one full revolution, the dimension between the anvil and the spindle has changed by:
   a. 0.1 mm
   b. 0.5 mm
   c. 2.5 mm
   d. 0.5 mm
5. When using a dial indicator to check the concentricity of a flywheel housing, during a single rotation of the flywheel the reading on the positive side of the zero on the dial peaks at 0.003 while the reading on the negative side peaks at 0.006. What is the TIR?
   a. 0.003″
   b. 0.006″
   c. 0.009″
   d. 0.018″
6. Which of the following precision measuring instruments would be required to measure a valve guide bore?
   a. Dial indicator
   b. Inside micrometer
   c. Split ball gauge and micrometer
   d. Dial bore gauge
7. If 300 kPa is converted to pounds per square inch, the result would be closest to which of the following values?
   a. 15 psi
   b. 30 psi
   c. 45 psi
   d. 300 psi
8. To which of the following values would 1.5 mm be closest?
   a. 0.0625″
   b. 0.125″
   c. 0.250″
   d. 1.50″
9. Convert 550° Fahrenheit into Celsius.
   a. 240
   b. 288
   c. 385
   d. 550
10. A wrench with box and open jaws at either end, both of the same nominal dimension, is known as a(n):
    a. torque wrench.
    b. combination wrench.
    c. box-end wrench.
    d. adjustable wrench.
11. Which of the following is used to identify an SAE grade 8 bolt?
    a. 3 radial strokes on the capscrew head
    b. 5 radial strokes on the capscrew head
    c. 6 radial strokes on the capscrew head
    d. 8 radial strokes on the capscrew head
12. If a 12″ linear extension is used on a torque wrench with a 24″ bar, the reading on the torque wrench scale required to produce an actual torque value of 250 lb-ft would be:
    a. 36 lb-ft
    b. 120 lb-ft
    c. 167 lb-ft
    d. 323 lb-ft
13. Convert 250 lb-ft to Newton-meters and select the closest value from the following answers.
    a. 167 N-m
    b. 340 N-m
    c. 410 N-m
    d. 500 N-m
14. Convert 600 hp into kW and select the closest value from the following answers.
    a. 350 kW
    b. 450 kW
    c. 550 kW
    d. 650 kW
15. The cutting fluid recommended for use when cutting threads in mild steel is:
    a. soluble oil and water.
    b. lard.
    c. dry.
    d. kerosene.

REVIEW QUESTIONS

A combination of short-answer essay, fill-in-the-blank, multiple-choice, and ASE-style questions make up the end-of-chapter questions. Different question types are used to challenge the reader's understanding of the chapter's contents. The chapter objectives are used as the basis for the review questions.

Supplements

WORKBOOK

The Student Workbook reinforces the foundations provided by the textbook with a special emphasis on some of the hands-on competencies required of entry-level diesel technicians. Some chapters contain up to seven job sheets and these are structured to help students make the connection between the theoretical concepts introduced in the textbook and actual shop floor practice. Each job sheet is correlated with relevant ASE Education Foundation tasks. In addition, the Student Workbook contains study tips and practice questions.

INSTRUCTOR RESOURCES CD

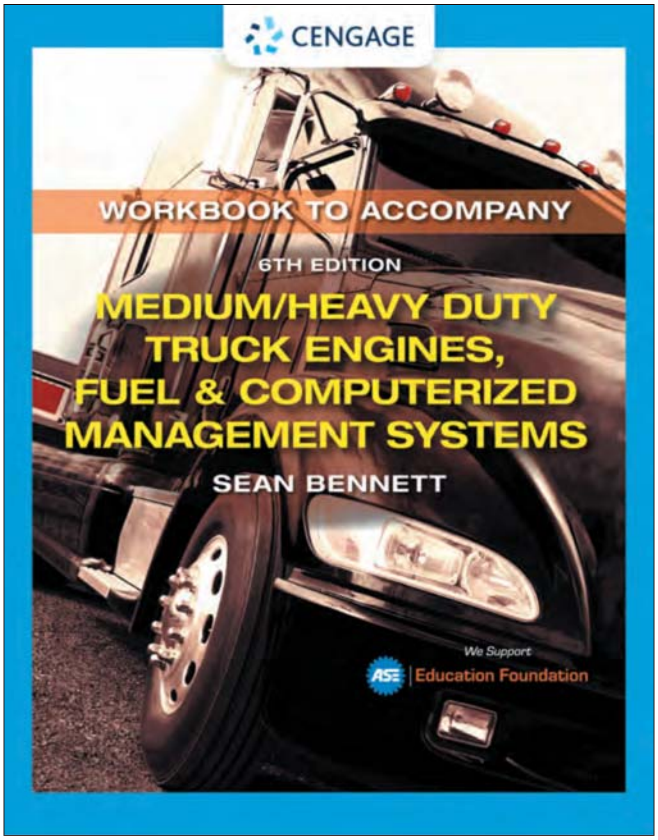
Carefully prepared, the Instructor Resources CD brings together several time-saving tools that allow for effective, efficient instruction. The Instructor Resources CD contains the following components:

- **PowerPoint®** lecture slides, which present the highlights of each chapter.
- An **Image Gallery**, which offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentations.
- **Lesson Plans** for each chapter which contain objectives, outlines, key terms, ASE Education Foundation job sheet correlations and answers to the textbook end-of-chapter review questions and workbook review questions.
- **ASE Education Foundation Correlations**, in which the current NATEF Medium/Heavy Truck Standards are correlated to the chapter of the core text and all relevant Workbook job sheets.
- **End-of-Chapter Review Questions**, which are provided in MS Word format.

INSTRUCTOR COMPANION WEBSITE

The Instructor Companion Website, found on cengagebrain.com, offers the following components to help minimize instructor preparation time and engage students:

- **PowerPoint®** lecture slides, which present the highlights of each chapter.
- An **Image Gallery** that offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentations.



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MindTap for *Medium/Heavy Duty Truck Engines* provides a customized learning solution with relevant assignments that will help students learn and apply concepts while it allows instructors to measure skills and outcomes with ease.

MindTap meets the needs of today's diesel classroom, shop, and student. Within the MindTap, faculty and students will find editable and submittable job sheets correlated to relevant ASE Education Foundation tasks. MindTap also offers students the opportunity to reinforce their understanding of theory, improve their critical thinking skills, and practice using diagnostic tools in a virtual environment with the inclusion of Cengage's unique theory simulations. A suite of S/P2® safety, pollution, and soft skills modules for diesel technicians is available in the Learning Path. Additional engaging activities include videos, animations, matching exercises, and gradable assessments.

Instructors can customize the MindTap Learning Path by adding or hiding content to match their syllabus and grading preferences. Analytics and reports provide a snapshot of class progress, time on task, engagement, and completion rates.

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Jim Wilson, Robert Bosch LLC, Chicago
Brian D . Whitmire, Lincoln Tech, Indianapolis, IN
Andrew Winslow, Navistar WG, Peterborough, ON
Gus Wright, Centennial College, Toronto
Jin Song Xiang, Guilin Junda Transport, China
Gilles Ybarro, Université Laval, Quebec
Ying Zhang, APA Group, Shenzhen, China

ORGANIZATIONS AND CORPORATIONS

Association of Diesel Specialists, Kansas City, MO
Ballard Power Systems, Burnaby, BC
BYD, Lancaster, CA
BYD, Lima, Peru
BYD, Shenzhen, China
Caterpillar Engines, Peoria, IL
Centennial College, Toronto
Cummins Eastern Canada, Toronto, Ontario
Cummins Engine Company, Columbus, IN
Cummins Northeast, Albany, NY
Daimler Trucks North America, Portland, OR
Davco Manufacturing, Saline, MI
Delphi Fuel Division, Troy, MI
Denso Corporation, Aichi, Japan
Detroit Diesel Corporation, Detroit, MI
Donaldson Corporation, Minneapolis, MN
Freightliner LLC, Portland, Oregon
Harper Detroit Diesel, Toronto
Hino Toyota, Bloomfield Hills, MI
Hutchison Center, University of Alaska, Fairbanks
Imperial Oil, Toronto, Ontario
Institution of Mechanical Engineers, London, UK
International Trucks, Chicago, IL
Isuzu America, Cerritos, CA
Jacobs Manufacturing, Bloomfield, CT Kent
Moore, Warren, MI
Kenworth of Ontario, Toronto
Kinross, Fort Knox, Fairbanks, AK
Lincoln Technical Institute, West Orange, NJ
Mack Trucks Canada, Toronto
Mack Trucks Incorporated, Greensboro, NC
Mahle Gruppe, Stuttgart, Germany
Mercedes-Benz, Montvale, NJ
Metropolitan Transit Authority, Brooklyn, NY
Mid-Ontario Freightliner, Toronto
Nashville Auto-Diesel College, Nashville, TN
Navistar International Truck, Woodbridge, IL
NC Machinery, Fairbanks, AK
New Flyer, Anniston, AL
New Flyer, Winnipeg, Manitoba
New York Networks, SUNY, Albany, NY
Nikola Motors, Phoenix, AZ
Robert Bosch America LLC, Farmington Hills, MI
Society of Automotive Engineers, Warrendale, PA
Stanadyne Corporation, Windsor, CT
State University of New York, Cobleskill, NY
Sullivan Training Systems, Raleigh, NC
Superflow Corporation, Colorado Springs, CO
Technology and Maintenance Council, ATA, Alexandria, VA
Toromont Caterpillar, Toronto
Toronto Transit Commission, Toronto
UCLA, Los Angeles, CA
Universal Technical Institute (UTI), Scottsdale, AZ
University of Northwestern Ohio, Lima, OH
Vibratech TVD, Springfield, NY
Volvo Trucks, Greensboro, NC
Wajax Power Systems, Detroit Diesel, Toronto
Westport Innovations Inc, Vancouver, BC
Williams Controls Incorporated, Portland, OR
Winslow-Gerolamy Navistar, Peterborough, ON

SECTION

1

DIESEL ENGINE FUNDAMENTALS

Section 1 begins with an introduction to the trucking industry and its technology. This chapter is followed by chapters on tools and safety; study of these is recommended before progressing to actual shop procedures. However, the section is mainly devoted to introducing the diesel engine, beginning with its operating fundamentals and historical development and then examining it on a system-by-system basis. Chapter 14 deals with engine service techniques and is important for the novice technician because it addresses some key entry-level skills. Chapter 15 provides some tips on diesel engine disassembly and reassembly procedures, and the final chapter in the section presents engine run-in and dynamometer testing.

CHAPTERS

1

INTRODUCTION

OBJECTIVES

After studying this chapter, you should be able to:

- Interpret the basic language and acronyms used by commercial vehicle industries.
- Describe some of the advances that have changed commercial vehicle technology today.
- List the major diesel engine manufacturers and correlate which engines are likely to be used by chassis OEMs.
- Identify the major engine OEMs and the market share of each.
- Categorize engines by their displacement.
- Identify some of the alternatives to ICE powertrains and the sectors of the industry in which they are embraced.
- Discuss what is meant by the "connected" vehicle and define terms such as *multiplexing* and *telematics*.
- Outline the roles and responsibilities of the contemporary commercial vehicle technician.
- Identify the five SAE categories of autonomous vehicle operation.
- Outline popular customer service trends in the truck OEM industry and explain a technician's responsibilities in keeping customers happy.
- Discuss how HD-OBD and "Right-to-Repair" legislation is impacting the service and repair industry.
- Outline the qualifications required to practice as a commercial vehicle engine technician.
- List some of the professional associations to which commercial vehicle engine specialists may belong and identify the benefits of each.
- Describe how alternate powertrain technologies are impacting traditional diesel power and discuss the impact on the future of commercial vehicles.

KEY TERMS

advanced driver-assistance systems (ADAS)
Altoona Certification
American Trucking Association (ATA)
analytics
ASE Education Foundation
Association of Diesel Specialists (ADS)
augmented reality
Automotive Service Excellence (ASE)
autonomous vehicle
broker
California Air Resources Board (CARB)
cybersecurity
electronic engine management
electronic service tool (EST)
Environmental Protection Agency (EPA)
Federal Motor Carrier Safety Administration (FMCSA)
Federal Transit Administration (FTA)
freight efficiency
heavy-duty onboard diagnostics (HD-OBD)
high-intensity kaizen event (HIKE)
information technology (IT)
internal combustion engine (ICE)
kaizen
large bore
medium bore
model year (MY)
multiplexing
new technology diesel exhaust (NTDE)
original equipment manufacturer (OEM)
oxides of nitrogen (NOx)
policy adjustment
Recommended Practices (RPs)
Right-to-Repair legislation
service information systems (SIS)
Six Sigma
small bore
SmartWay
Society of Automotive Engineers (SAE)

technical service bulletins (TSBs)
Technology and Maintenance Council (TMC)
telematics
total quality management (TQM)
triage
TRIZ
ultra-low sulfur (ULS)
vehicle identification number (VIN)
W. Edwards Deming

WHY READ THIS?

The focus of this textbook will be on the powertrains used in commercial vehicles. A generation ago, the source power in most commercial vehicles was the diesel engine, but this has changed. Although diesel power dominates in linehaul vehicles, alternates have emerged, especially in urban applications. Any book covering today's commercial vehicle technology must deal with a broad range of source power and that is reflected in the contents of this textbook.

In addition to covering the competency and certification requirements required by **Automotive Service Excellence (ASE)**, and meeting program **ASE Education Foundation** standards, this textbook has an objective of preparing technicians for the real-world workplace. The real world of the commercial vehicle service and repair industries provides employment in any of the following:

- National fleets with vehicles mostly less than five years old
- Small fleets with 100 power units or less
- OEM dealerships that perform high-level diagnostic and repairs
- Independent service shops that maintain legacy vehicles
- Transit bus service and repair garages
- Highway coach service and repair garages
- School bus service and repair garages
- Off road, heavy equipment service and repair garages

A graduate from a specialty diesel school or college program today may find employment in any of the foregoing maintenance and repair facilities. This book addresses engine, powertrain, and electronics technology from a professional technician's perspective. While the fleet technician may seldom be involved with anything more than servicing of engines, a service technician in a Cummins or Detroit Diesel would work exclusively on engine diagnostics and repairs.

COMMERCIAL VEHICLE POWERTRAINS

If you are a student of diesel, truck, transit bus, or off-road equipment technology, your first challenge will be to acquire an understanding of the terms, acronyms, and corporate players of these industries. Next, will be to understand the concepts of the many mechanical, electric, and computer systems used in the modern vehicle.

The content covered in this textbook primarily focuses on principles of operation. It is not a repair manual. The objective is to provide the technician with an understanding of engines and chassis management systems. Repair strategies are covered, and although some repair details appear in the e-resources that accompany this textbook, the emphasis is on getting students and technicians to develop the habit of using online service information systems.

SOURCE POWER

We categorize powertrains by their source-power. Source power is where the energy that provides traction to the drive wheels originates. The source power in a vast majority of commercial vehicle powertrains is an **internal combustion engine (ICE)**. Today's commercial vehicle powertrains can be categorized as follows:

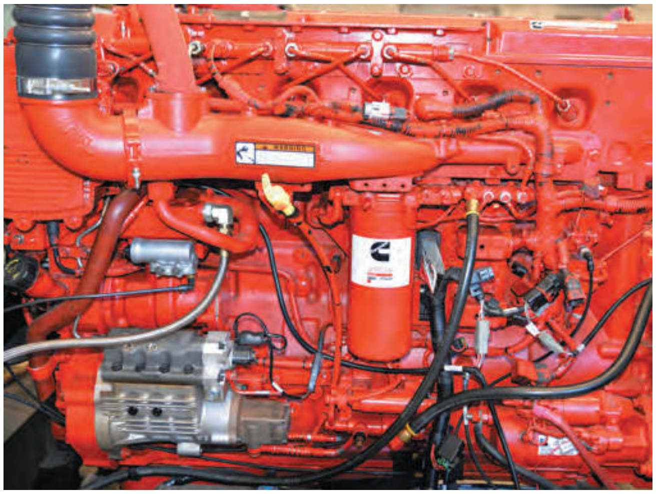
- Hydromechanical diesel fuel systems
- Electronic diesel fuel systems
- Natural gas (NG)–fueled engines
- ICE-driven hybrid electric drive
- ICE-driven hydraulic drive
- Fuel cell–powered, all-electric drive
- Battery all-electric drive

All but the final two of the foregoing categories use an ICE. This book focuses on the powertrains required to move Class 5 to Class 8 commercial vehicles. According to Diesel Technology Forum (https://www.dieselforum.org/), in the year 2018, 98% of trucks in North America in the medium and heavy duty categories were powered by diesel engines. This is predicted to drop to around 95% by the year 2025. The story is not much different on passenger buses, though you might believe otherwise if you live in a larger west coast city. In 2017, 90% of buses in North America used diesel or diesel-electric engine power. **Figure 1–1** shows the ICE of choice in a current Class 8 truck, an electronically managed diesel engine.

DIESEL POWER

Because of the increasingly restrictive statutory noxious-emissions controls required for commercial highway diesel engines and, more recently, their off-highway

FIGURE 1–1 Electronically managed diesel engine used to power a Class 8 truck.



counterparts, diesel engines have undergone some radical changes in recent years. First, industry experienced a shift away from the **hydromechanical** management systems beginning in the late 1980s. By the late 1990s, industry accepted that commercial diesel engines required management by computer, which is generally referred to as **electronic engine management**. During the period between 2004 and 2010, the changes to highway diesel engines were perhaps more dramatic, as the industry was forced to adopt a full suite of emission control devices. **Figure 1–2** shows one of two modules used to manage a DD15, an electronically managed diesel engine used to power Class 8 trucks.

FIGURE 1–2 One of two modules used to manage the Detroit Diesel DD15 engine.

Fuel and Emissions

The introduction of a previous administration's carbon dioxide and fuel efficiency standards was met and implemented by OEMs in EPA **model years (MYs)** 2017 and 2018, setting in motion the next generation of emission controls which will further reduce **oxides of nitrogen (NOx)** in exhaust gas, expected in the mid-2020s. Despite negative press and the recent cheating scandal by an automotive diesel engine manufacturer, diesel engines will prevail for the foreseeable future. The reason is that diesel has higher energy density than any other competing fuel technology (see **Chart 1–1**) along with an established coast-to-coast fueling and repair infrastructure.

ALTERNATE POWER

The term *alternate power* is used by the commercial vehicle industry to refer to any power source that does not use a diesel engine. The extent to which alternate power is used depends on:

- Geography: availability of the fuel type or electricity
- Application: linehaul trucks seldom use anything but diesel

Over the past couple of decades, ICE-powered hybrid electric and hybrid hydraulic have been commonly seen

CHART 1–1 Energy Density of Fuels (source: U.S. DOE)

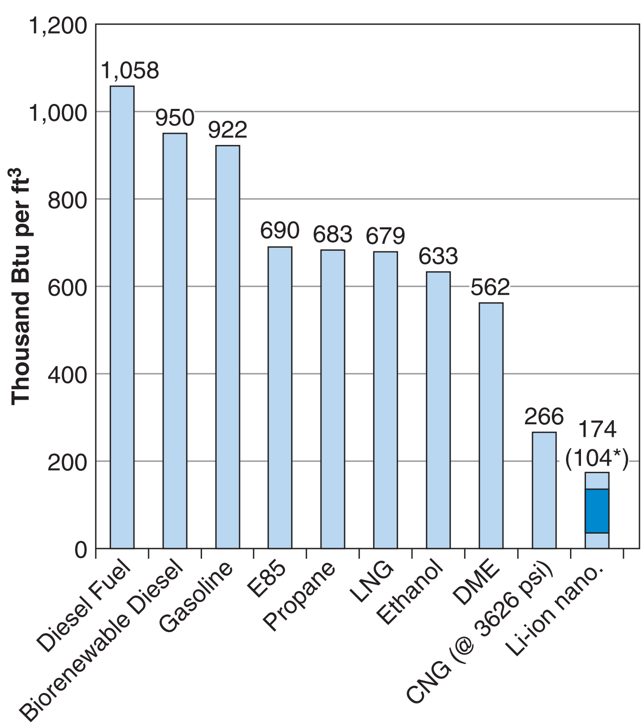


FIGURE 1–3 Diesel-electric-powered urban transit bus.

FIGURE 1–4 All-electric-powered refuse packer.

in urban applications, especially on the west coast. **Figure 1–3** shows a diesel-electric bus used on the streets of New York City and **Figure 1–4** shows an all-electric refuse packer: Note that a refuse packer has significant auxiliary electrical loads required to power an air compressor, hydraulic pump, and HVAC system.

CARB and EPA

The **California Air Resources Board (CARB)** and the federal **Environmental Protection Agency (EPA)** have driven the regulated emission control standards we live with today. As each new set of emission control standards is introduced, so also are technological advances that make the diesel engine today a work in progress.

Though the tendency may not be to embrace legislated changes, we have come to accept them. In anticipation of the introduction of **ultra-low sulfur (ULS)** fuel in 2007, engine OEMs were complaining in 2004 that fuel economy could be impacted by up to 5%, but by the time ULS legislation came into effect in October 2006, engine performance technology had advanced so that the actual hit on fuel economy turned out to be 0% to 1% negative, depending on the application. Today, every engine OEM has been able to substantially improve fuel economy.

Clean Diesel Technology

The drive toward producing cleaner diesel engines led to significant changes in the type of fuels used, more precise computerized control of combustion, and extensive exhaust gas aftertreatment devices. By MY 2010, any highway-certified diesel engine meeting the EPA standards that came into effect that year had to be equipped with a suite of external exhaust emission controls that included a diesel particulate filter (DPF) and selective catalytic reduction (SCR). California uses the term **new technology diesel exhaust (NTDE)** to describe on-highway diesels meeting the 2010 and later EPA standards. As of 2018, nearly 40% of commercial diesels in the United States were classified as NTDE and that percentage will continue to increase as pre-2010 vehicles are progressively retired.

FREIGHT EFFICIENCY

Reduction of CO_2 emission and better fuel economy are directly connected to using less hydrocarbon fossil fuel. These objectives have altered the trucking industry's definition of fuel economy and disposed of the term *miles per gallon*. This term may be appropriate for comparing the performance of one family automobile versus another but is meaningless when applied to the business of hauling freight. Today, fleets are likely to use the term **freight efficiency**, which is defined as "fuel consumed per ton hauled." It means that OEMs will look at the performance of the entire rig in terms of fuel usage, evaluating everything from tires to aerodynamics. There is a move to make low rolling resistance (LRR) tires mandatory but as yet, no date has been settled.

Aerodynamics

The aerodynamics of transport rigs have become the subject of much study in recent years for the obvious reason that along with meeting EPA standards, it saves operators money. The EPA's **SmartWay** has guided the initiative to improve vehicle aerodynamics. The average return on investment due to fuel saved is less than one year for a full rig suite of aerodynamic devices. Aerodynamic devices recognized by SmartWay include:

- Roof fairings
- Bumper aerodynamics
- Fuel tank cowling

FIGURE 1–5 A Kenworth truck designed to minimize aerodynamic resistance.

- Side extenders, panels, and skirts
- Undercarriage flow devices
- Trailer and van body boat tails

Figure 1–5 shows a Class 8 Kenworth truck designed to minimize aerodynamic drag.

COST-DRIVEN CHANGES

In recent years, some labor-intensive procedures (such as the out-of-chassis overhaul of major components) have been moved out of the service garage to remote and sometimes offshore remanufacturing centers. Remanufacturing centers are often located in a jurisdiction where labor rates are low and the remanufacturing processes can be subdivided, allowing lesser skilled but specialist workers to perform the labor. This is a result of the service and repair industry becoming highly cost conscious, something of which every technician should be aware. However, the engines used to power heavy-duty highway and off-road equipment are more likely to be repaired or reconditioned by domestic service operations because it is usually cost-effective.

Analytics

A 2005 MIT study estimated that more than 6% of the GNP of the United States (some $820 billion) was required annually to repair the damage caused by mechanical wear in general. Reducing this kind of dollar expenditure by fractions of a percent can represent massive savings. We live in a world of **analytics**, and when this is applied to commercial vehicles, the objective is to study every aspect of the repair procedure to reduce costs.

The truck engine technician of a generation ago who may have diagnosed, disassembled, reconditioned, and then tested an engine is today probably responsible only for the diagnosis. That expert is followed by someone of lesser experience who removes the engine from the chassis. After removal of the engine it is either repaired or in some cases replaced on a rebuilt/exchange basis. Larger and more costly engines are more likely to be repaired on site or by a local dealership rather than changed out with an exchange reconditioned engine.

TRUCKING AND THE ECONOMY

The trend in the trucking industry in North America is for it to grow by the year. In many ways, new truck sales provide a barometer of how the economy is doing in any given year. The saying "If you got it, a truck brought it" is true for most of the consumer items we purchase. Even if that item was transported by train, boat, or plane for a portion of its journey, trucks would have played a role in pickup and delivery at stages of the journey.

Millions of people are directly and indirectly employed by the trucking industry. Trucks have to be designed, built in factories, marketed, and then operated and maintained. The role of the technician in this industry is a small but crucial one. If all the truck technicians in the United States withheld their labor for 1 week, a large percentage of the economy would be crippled. On the other hand, Congress is in session for an average of 121 days of the 261 workdays in a year and the economy never skips a beat when they are absent from chambers.

The trucking industry, in addition to employing mechanical technicians to maintain and repair equipment, employs drivers, dispatchers, warehouse personnel, people to market services, and people to manage operations.

THE CONNECTED TRUCK

Most humans living in our society are network-connected by a variety of technologies that enable us to communicate, shop, play games, bank, learn interactively, the list goes on. Mobile vehicles are also connected. The truck chassis is a network of networks that monitor and manage every aspect of its operation. In addition, commercial vehicles communicate with infrastructure bases that include law enforcement agencies, other vehicles and fleet, and OEM data hubs.

Unfortunately, vehicle networks can be compromised in the same way your home system can be hacked, often with more serious consequences. That means every person working with the commercial vehicles today must understand the importance of **cybersecurity** and how their online behavior can create problems in vehicle and corporate network systems. We will take a detailed look at communications technology (and how it can be compromised) in Chapter 37, but any study of commercial vehicle technology requires students to have an understanding of the language of networks. Here we will briefly introduce some of that language.

MULTIPLEXING

Commercial vehicles today use engine and chassis communications networks known as **multiplexing**. Multiplexing enables the engine, transmission, brakes, and other chassis systems to talk to each other. These communications make possible high-tech chassis features such as yaw control and antirollover electronics. For example, an antirollover or collision avoidance system may require up to eight chassis controllers working together to avert a catastrophic event: these communications take place in less than a second of real time. In addition to the powertrain network, multiplexing has evolved so that most truck OEMs are using proprietary communications buses that link to the powertrain bus. In off-road applications, which can have complex powertrain configurations, multiple buses are used, including optical buses. **Figure 1–6** shows some of the multiplexed systems found on a typical truck.

FIGURE 1–6 Multiplexed chassis computer-controlled systems used on a typical Class 8 truck.