HEAVY EQUIPMENT POWER TRAINS AND SYSTEMS

Second Edition

Timothy W. Dell, Ph.D.

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Preface

Heavy Equipment Power Trains and Systems was developed to educate students who are planning a career in the off-highway industry, especially construction and agricultural equipment. However, this text will empower students working in other heavy equipment power train fields, like forestry or mining, and is appropriate for students who are pursuing a certificate, associate's degree, bachelor's degree, or master's degree.

The author and publisher proudly support the mission of the AED Foundation, which encourages continuous learning, provides educational opportunities for today's employees, and improves the availability and quality of tomorrow's equipment industry technicians. The contents of this text have been carefully correlated to the Power Trains section and key areas of the Safety and Hydraulics/Hydrostatics sections of AED's "Standards for Construction Equipment Technology."

This textbook includes traditional power train content such as safety, overhead lifting, belts, chains, gearing, manual transmissions, planetary transmissions, countershaft transmissions, powershift and automatic transmissions, torque converters, hydrostatic drives, brake systems, axles, differentials, final drives, suspensions, tires, undercarriages, track steering, wheeled steering systems, and electric drives. In addition, the book is especially unique in providing an in-depth explanation of late-model continuously variable transmissions.

The text provides fundamental instruction on hydrostatic transmissions with the goal of having students fully comprehend the systems rather than needing to rely on discrete (or limited) troubleshooting charts. Students will also gain instruction in hydraulic diagnostic principles such as how to tap into the system, what tools are available, how to properly use those tools, and how to perform the tests safely.

Heavy Equipment Power Trains and Systems provides students the necessary foundational building blocks, equipping them for a bright future in off-highway power train technology. The book includes over 1000 images comprised of multicolor line art, cross-sectional drawings, photographs, and 3-D images. The book includes review questions, case studies, and helpful techniques for diagnosing power trains.

About the Author

Timothy W. Dell, Ph.D. is a Professor of Automotive Technology at Pittsburg State University and serves as the department's Diesel and Heavy Equipment Coordinator. Dr. Dell received his doctoral degree in curriculum and instruction from Kansas State University, a master of science degree in technology education from Pittsburg State University, and a bachelor of science degree in automotive technology with an emphasis in diesel and heavy equipment from Pittsburg State University.

He began his career working for Case IH in their Technical Service Group specializing in combine diagnostics. He has served on John Deere's Agricultural National Service Training Advisory Board and has been the adviser of Pittsburg State University's Caterpillar ThinkBIGGER four-year degree since its inception. He currently teaches Automotive Electricity and Electronic Systems, Fluid Power, Automotive Automatic Transmissions, Advanced Hydraulic Systems, and Construction Equipment Systems. He has also taught Off-Highway Systems. In addition, he teaches three- and four-day workshops to industry representatives and educators on the topics of hydraulic systems and heavy equipment power train systems for the Kansas Center for Career and Technical Education. Dr. Dell has served as the automotive department chair for four years but returned to the classroom full-time to pursue his passion for curriculum development and teaching. He is also the author of *Hydraulic Systems for Mobile Equipment*.

Reviewers

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New to This Edition

Some notable updates in this edition of ***Heavy Equipment Power Trains and Systems*** include additional information about torque multipliers and pressure taps in Chapter 2, drills in Chapter 3, and centrifugal clutches in Chapter 8. Chapter 9 has updates on Caterpillar planetary transmissions including the new elevated dozer four-speed transmission, and an introduction to fracking transmissions. The Allison TC10 transmission was relocated to Chapter 10 due to its countershaft design. Chapter 10 also includes the description and clutch apply chart for the John Deere e23 transmission. Chapter 11 includes a case study for diagnosing warped clutches in non-electronic transmissions. Chapter 12 contains updates to three-stage torque converters and torque dividers, and new content on a multiple-disc stator clutch and dozers with lockup clutches. Chapter 18 has a new vibration analysis case study. Chapter 19 includes a New Holland telehandler parking brake case study. Chapter 23 lists several styles of Caterpillar track chains. Chapter 24 has new content on agricultural tractors with four rubber tracks. Chapter 25 includes new content on equipment with multi-steer axles, steering amplifiers, and Danfoss MultiAxis steering.

The chapters with significant updates include:

- Chapter 13: new content on Danfoss single-servo pumps, Rexroth DA speed-sensing-pumps, Danfoss pressure-limiting controls, John Deere X9 overspeed limit control, and improvements to Eaton IPOR controls.
- Chapter 14: new content on how to adjust Bosch Rexroth DA pumps, shaft runout, a combine case study, and a dual-path skid steer.
- Chapter 15: new content on mechanical variators, John Deere X9 pro-drive twin HST motor transmission, and Caterpillar wheel loaders with twin HST transmissions.
- Chapter 26: includes some of the most extensive enhancements. It has been reorganized around the main topics of alternators, six types of electric-drive motors (including synchronous switched reluctance motors), electric-drive mining trucks, electric-drive wheel loaders (including extensive new material), electric-drive dozers, electric and hybrid electric excavators, and electric/hybrid safety and service.

Credentialing Partners and Support

Goodheart-Willcox appreciates the value of industry credentials, certifications, and accreditation. We are pleased to partner with leading organizations to support students and programs in achieving credentials. Integrating industry-recognized credentialing into a career and technical education (CTE) program provides many benefits for the student and for the institution. By achieving third-party certificates, students gain confidence, have proof of a measurable level of knowledge and skills, and earn a valuable achievement to include in their résumés. For educators and administrators, industry-recognized credentials and accreditation validate learning, enhance the credibility of programs, and provide valuable data to measure student performance and help guide continuous program improvement.

The AED and ASE Education Foundation Connections

Goodheart-Willcox is pleased to partner with the *Associated Equipment Distributors (AED)* and *ASE Education Foundation* by correlating ***Heavy Equipment Power Trains and Systems*** to both the *AED Standards for Construction Equipment* and the *ASE Education Foundation Medium/Heavy Duty Truck* task list. These standards were created in concert with industry and subject matter experts to match real-world job skills and marketplace demands.

To see how ***Heavy Equipment Power Trains and Systems*** correlates to credentialing and certification standards, visit the Correlations tab at www.g-w.com/heavy-equipment-power-trains-systems-2024

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Features of the Textbook

The instructional design of this textbook includes student-focused learning tools to help you succeed. This visual guide highlights these features.

Chapter Opening Materials

Each chapter opener contains a list of learning objectives. **Objectives** clearly identify the knowledge and skills to be gained when the chapter is completed.

Additional Features

Additional features are used throughout the body of each chapter to further learning and knowledge. **Warnings** alert you to potentially dangerous materials and practices. **Cautions** alert you to practices that could potentially damage equipment or instruments. **Notes** are tips that help you develop critical thinking, diagnostic and troubleshooting skills needed in the workplace today. **Step-by-Step Procedures** are presented throughout the textbook to provide clear instructions for hands-on service activities. **Pro Tips** provide advice and guidance that is especially applicable for on-the-job situations. **Case Studies** describe real-life situations encountered by technicians in the field to help you understand what you can anticipate and expect in the workplace.

Illustrations

Illustrations have been designed to clearly and simply communicate the specific topic. Numerous illustrations have been replaced or updated for this edition. Photographic images have been updated to show the latest equipment.

End-of-Chapter Content

End-of-chapter material provides an opportunity for review and application of concepts. A concise **Summary** provides an additional review tool and reinforces key learning objectives. This helps you focus on important concepts presented in the text. **Know and Understand** questions enable you to demonstrate knowledge, identification, and comprehension of chapter material. **Apply and Analyze** questions extend learning and develop your abilities to use learned material in new situations and to break down material into its component parts. **Critical Thinking** questions develop higher-order thinking and problem-solving, personal, and workplace skills.


Chapter 11
Powershift and Automatic Transmission Controls, Service, and Repair
Objectives
After studying this chapter, you will be able to:
✓ Explain hydraulic flow through a powershift transmission.
✓ List the different methods for controlling powershift transmissions.
✓ List tools used for diagnosing powershift transmissions.
Transmission Fluids, Pumps, Reservoirs, and Circuitry
Transmissions require fluid for engaging clutches, maintaining lubrication, operating the torque converter, and cooling. Without the proper fluid, the transmission will not operate. Using the appropriate fluid for the application is critical. Tractors can have sudden transmission failures if equipped with the wrong fluid. Manufacturers will specify the type of transmission fluid for the transmission.
Some transmissions have their own oil reservoir; other transmissions share the reservoir used for the machine's hydraulic system.
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Warning
If a lock screw is backed out too far, the eccentric rod can shoot out of the housing. If this happens, oil will spew out of the housing and the machine will default to maximum forward or reverse propulsion. It will also require finding all of the parts and reassembling them. The eccentric shaft, spool valve, a washer, the feedback link, two lever arms, and the spring must be assembled inside of the housing. *Always* follow the manufacturer's service and safety specifications.
Note
When making the null adjustment, if the servo pressures are unbalanced but the tires or tracks are stationary, the servo piston is not centered and the control valve has been adjusted to hold the HST in a neutral position. The servo piston will need to be centered first. The null adjustment will need to be adjusted last. It is likely that the servo piston was slightly adjusted out of neutral when the jam nut was tightened. After centering the servo piston, always be sure that the closed loop leg pressures are equal, and the tires or tracks are truly stationary at high engine speeds. Then proceed to adjust the null adjustment.
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Case Study
Uncommanded Actuation of a Hydraulic Pump
An MT 845 Challenger uses a hydraulic steering pump and motor (essentially a hydrostatic transmission) as the hydraulic steering input for the differential steering system (covered in *Chapter 24, Track Steering Systems*). The machine uses a permanent-magnet speed sensor to detect rotation in the hydraulic steering motor. A customer complained that her MT 845 Challenger would steer without command during engine startup. After the fault code was cleared and the machine was restarted, the machine performed as follows:
- Steered in one direction for a brief moment.
- The ECM de-energized the steering pump solenoids.
Summary
- The Allison TC10 is an automatic countershaft transmission that uses a torque converter and contains a planetary gear set at the back of the transmission.
- Automatic transmissions automatically upshift or downshift based on the travel speed and load.
- Operators must command powershift transmissions to upshift and downshift.
- Automatic and powershift transmissions have fixed gear ratios for a given transmission gear selection.
- Automatic and powershift transmissions can use planetary gear sets, countershafts, or both.
- Countershaft transmissions are less compact than planetary transmissions.
- The Case IH Magnum tractors use a countershaft powershift transmission. It can be equipped with an optional creeper transmission or an optional 19th speed.
- Case IH Magnum tractors require three clutches and the master clutch to be applied to achieve power flow.
- MFWD agricultural tractors have a spring-applied clutch in the transmission for engaging the tractor's four-wheel drive.
- Caterpillar H, M, and non-suffix series motor graders use a countershaft powershift transmission. It produces eight forward and six reverse speeds and requires three clutches to be applied to propel the machine.
- John Deere 8R series tractors and many Challenger MT700, MT800, and MT900 tractors have powershift transmissions that use both countershafts and planetary gear sets.
- The John Deere 8000 series 16-speed powershift transmission requires that either one input clutch and one output clutch or one input clutch and brake A be applied to move forward or reverse.
Technical Terms
auto field operation
automatic transmission
auto road operation
auto shift control
clutch pedal
countershaft powershift transmission
creeper transmission
cycling transmission
directional clutch
drop box
ground-drive pump (GDP)
hauling transmission
inching pedal
master clutch
MFWD clutch
output clutch
powershift transmission
preselect gear
pulser lever
skip shifting
speed matching
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TOOLS FOR STUDENT AND INSTRUCTOR SUCCESS

Student Tools

Student Text

Heavy Equipment Power Trains and Systems is a comprehensive text that focuses on the theory, diagnosis, and service of power train and related systems in heavy equipment used in construction, mining, forestry, and agriculture.

Lab Workbook

- Hands-on practice includes questions and activities.
- Jobs offer students opportunities to perform various hands-on tasks like those they will be required to perform in the industry.

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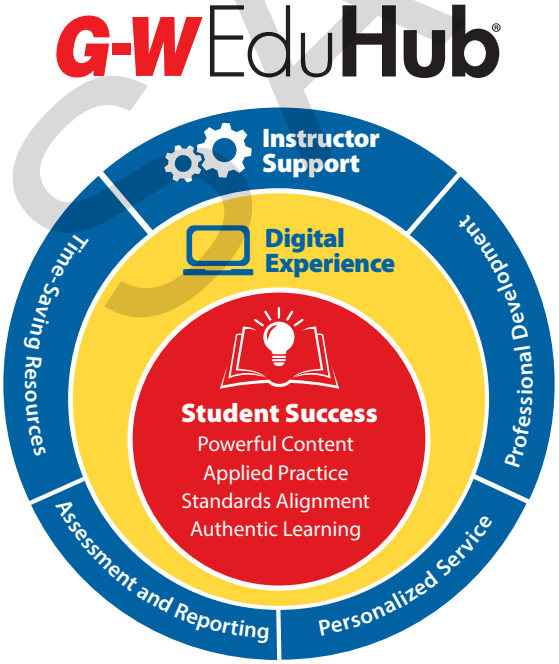
- **Instructor's Presentations for PowerPoint®** are fully customizable, richly illustrated slides that help you teach and visually reinforce the key concepts from each chapter.
- Administer and manage assessments to meet your classroom needs using **Assessment Software with Question Banks**, which include hundreds of matching, completion, multiple choice, and short answer questions to assess student knowledge of the content in each chapter.

See www.g-w.com/heavy-equipment-power-trains-systems-2024 for a list of all available resources.

Professional Development

- Expert content specialists
- Research-based pedagogy and instructional practices
- Options for virtual and in-person Professional Development



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