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Ninth Edition

Standards For Construction Equipment Technology

Skill standards for post-secondary schools preparing for careers as equipment technicians.

AED FOUNDATION
Constructing Paths to Opportunity

Standards for Construction Equipment Technology

The AED Foundation, through its committed industry volunteers, is improving the quality of the equipment industry's workforce by publishing and maintaining the "Standards for Construction Equipment Technology." The goal is to help post-secondary institutions prepare students with the knowledge and skills they need to embark on successful careers as equipment service technicians. The contents are regularly reviewed and updated by The AED Foundation's Technical Training Committee in response to changes in technology and learning requirements.

Now in its **ninth edition**, this document is the result of voluntary efforts by technical experts in the construction equipment industry. The project is sponsored by The AED Foundation and includes the participation of leading construction equipment distributors, equipment manufacturers and post-secondary schools. The standards cover six areas that the industry considers most important for the education of entry-level technicians:

- Safety/Administrative
- Electrical/Electronics
- Hydraulics/Hydrostatics
- Power Trains
- Diesel Engines
- Air Conditioning/Heating

Established in 1991, The AED Foundation is the workforce development and educational affiliate of Associated Equipment Distributors (AED), an international association of the construction equipment industry representing over 700 independent distributor, manufacturer and related firms. AED was established in 1919. The National Center on Education and the Economy (NCEE), Washington, DC provided guidance for the development of the original standards.

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2017 edition are in bold orange font

About the AED Foundation Technical Standards Proiect

Educational institutions and the equipment industry must work together to develop a world-class technician workforce. Significant progress is being made in developing these relationships with the goal of identifying interested students and providing them with the technical education they will need when entering the workforce. In 2001, The AED Foundation introduced the AED Foundation Accreditation Program for post-secondary schools. Accreditation requirements are based on the technical standards contained in this book; schools must meet or exceed these specifications.

The AED Foundation believes that the construction equipment industry must do all it can to help post-secondary schools recruit and educate students for careers in equipment technology. Schools must also do their part by raising the standards of learning, and seeking curriculum input from industry. Today's equipment service technicians are men and women with a high level of professional skills and knowledge. Such education is required in order to service and repair construction equipment that is increasingly complex and sophisticated. Our industry faces a shortage of these highly skilled people. Occasional industry and economic downturns cannot hide the long-term need for well-educated technicians. This document is a key step toward addressing the problem. The standards are a valuable tool to ensure that students from technical schools have the skill sets that meet the industry-expressed needs of AED members.

At the end of this book is a list of present and past standards project participants. Our thanks to all these industry experts for their time and efforts, and their commitment to industry workforce excellence. Without equipment industry participation, this book would not exist. It is our hope that industry constituents will use these standards to help them meet their workforce needs in the future. Comments and ideas are always welcome.

Sincerely,

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Purposes

1. To assist post-secondary schools, specifically colleges offering technical programs, in reviewing and updating courses in equipment technology based on what the construction equipment industry needs and expects from students entering the workforce.

2. To provide technical standards, endorsed by the construction equipment industry, that help educational institutions remove the guesswork in deciding what should be taught to students in equipment technology.

3. To create new relationships between schools and construction equipment industry businesses by developing the standards with broad industry representation, and encouraging the use of the standards by all segments of the industry. This, in turn, leads to program improvements that advance the interests of all industry stakeholders.

4. To raise educational standards so that students will be better prepared for the more demanding entry-level jobs now available to equipment technicians.

5. To address the short and long-term shortage of technicians that affects the construction equipment and related industries.

6. To help the equipment industry to develop a world-class workforce.

Background

AED technical standards answer these important questions:

1. **What knowledge and skills do student equipment technicians need when they graduate?**
2. **How do we know how well students can apply what they learn and perform well?**

Students need to have taken courses and received passing grades, but equally important is that they can demonstrate knowledge and mastery of the subjects.

The reader, whether from a school, dealer, manufacturer or a related business, should keep in mind that these standards are rigorous and set the bar high. A number of schools will meet or exceed the standards. For others, there may be difficulties as schools strive to upgrade their overall program and curriculum in accordance with the standards. However, our industry supports the standards as critical steps toward improvement; critical steps needed for the industry to move forward.

Presented here is a realistic picture painted by the equipment industry of what students need to succeed in the real world of construction equipment technology. The AED Foundation encourages educators to not only raise standards, but to work toward these standards with secondary schools as well. AED member businesses are also encouraged to use this document as a reference tool when they are discussing workforce development with local secondary and post-secondary schools.

Assistance to schools from construction equipment businesses can be offered in many ways; to name a few:

- Visit local secondary and post-secondary schools to promote career opportunities in our industry.
- Conduct local "informational events" for students, parents, school counselors, and other career influences.
- Be mentors for students in equipment technology; invite post-secondary teachers to industry companies for training.
- Provide internships, scholarships and or work/study programs for local students.
- Employ service technicians as part-time teachers of topics presented in this handbook.
- Provide part-time work or instructional programs in technology for school faculty members.
- Provide loans or donations of construction equipment, engines, parts, or testing devices to school classrooms and shops.
- Serve on school advisory committees or curriculum planning bodies.

Benefits

For Technical Schools & Colleges:

- Better understanding of the knowledge and skills students need to enter the field of equipment technology, based on high standards that are agreed upon by leading businesses in the construction equipment industry.

- Guidance for developing appropriate curriculum improvements, special programs, and teaching materials and equipment.

- Facilitation of school connections with local equipment distributor, manufacturer and related businesses familiar with the same set of published standards. This common reference point allows schools and businesses to have a good starting point from which to discuss needs and improvements.

- Detailed information for providing students with better career advice. Students can be shown: "Here is what the construction equipment industry expects you to know."

- Assistance in the marketing of school programs to students who are interested in equipment technology, and to parents who may be unaware of technical education options and this industry's attractive career opportunities.

Benefits

For Students and Parents:

- Understanding of what the construction equipment industry expects students to know and demonstrate in order to be well-qualified entry-level equipment technicians.
- Recognition of the need for high standards and high levels of knowledge and skills for a successful career in equipment technology.
- Awareness that the published AED Foundation standards are accepted by the industry as a whole, and represent a progression of knowledge that will be recognized and respected by industry businesses.
- Awareness of various career path opportunities in the construction equipment industry including not only technician positions, but various levels of management positions as well. Opportunities include: parts, service, rental, sales, product support, and senior management.
- Recognition that graduating from a school that meets AED Foundation standards leads to technical competency, a career path that enables equipment technicians to earn a good salary and benefits, and respect from employers and peers.
- Recognition of the value that dealer employers place on quality technical education and continued training, as well as the importance of hiring skilled equipment technicians and keeping them up-to-date with the latest technology innovations and techniques.

Note: Invite students and parents to visit www.aedfoundation.org/careers, a website with specific information about how to explore the dealer equipment technician career and its great opportunities.

Benefits

For Equipment Industry Businesses:

- A larger pool of skilled equipment technicians from which to draw.
- Entry-level employees who have and can demonstrate high skill levels in the disciplines required of today's equipment technicians.
- The ability of new hires who graduate from schools meeting these standards to move up the learning curve faster, learn new technology faster, and be able to handle increasingly complex technical assignments; thereby contributing to service department profitability sooner.
- Greater return on educational investment and less need for additional entry-level and/or remedial education.
- Improved customer service resulting from highly-qualified entry level people who offer a high level of performance.
- Up-front understanding of exactly what skills the new employee has, allowing easier identification of those additional or special skills needed for the particular equipment lines serviced by the company.
- Development of a more flexible workforce based on new people coming into the business who have mastered skills in safety/administrative, electronics/electrical, hydraulics/hydrostatics, power trains, diesel engines, and air conditioning/heating.

Introduction to AED Foundation Standards:

1. **Safety/Administrative**
2. **Electronics/Electrical**
3. **Hydraulics/Hydrostatics**
4. **Power Trains**
5. **Diesel Engines**
6. **Air Conditioning/Heating**

Note: AED Foundation standards are updated as necessary to reflect changes in technology and educational requirements. Content needs for this publication are determined by The AED Foundation's Technical Training Committee. Users of this publication are encouraged to submit comments and suggestions to The AED Foundation.

Post-secondary diesel/equipment technology programs that meet the standards prescribed in this publication can apply for Accreditation by The AED Foundation.

Contact The AED Foundation for more information on AED Foundation Accreditation and the application process.

AED Foundation Accreditation – Additional Requirements

1. **Accredited programs must have a minimum of two onsite full-time instructors delivering the program's technical courses.**

2. **AED Foundation Technical Assessments are required for all graduating students in AED Foundation Accredited programs, to be given during the final 8 weeks of the program, to ensure that The AED Foundation can:**
   a. Continually monitor student learning and program performance.
   b. Obtain benchmark information that better reflects the collective results of all programs.
   Exception: OEM diesel-technician programs that require usage of the OEM's test.

3. **Program faculty are required to facilitate a process for all graduating students to take a brief AED Foundation student survey that takes only minutes per student.**
   a. It is expected that the program not just provide students with the URL, but set aside a time for this to be done, and bring students to the location where they can complete the survey.
   b. Students have the right to decline to take the survey; that option is provided at the beginning of the survey.

4. **Equipment loans for teaching purposes**
   a. For teaching purposes, use of unowned equipment is allowed as long as there is a written agreement whereby the equipment provider, via loan, lease or other agreement, and the school's diesel-equipment technology department commit to ensuring that the equipment will be available at the dates/times that the course/lab instruction requires.
   b. The schools are to have owned equipment available that cover foundational subjects in diesel-equipment technology. AED Foundation Evaluation Team Leaders will advise programs on this individually due to the variety of options available that would meet this requirement.

The Standards Contain Three Key Levels of Descriptors:

Three Key Standards Description Levels

1. **Critical Functions**
2. **Key Activities**
3. **Performance Descriptions**

For each set of standards, there first are:

1 **CRITICAL FUNCTIONS -** Identify the major umbrellas of knowledge for specific bodies of skills. The critical functions are in the left columns for each set of standards.

2 **KEY ACTIVITIES -** Under each umbrella are the key activities that the learner must master to perform each of the critical functions. These are shown in the center columns of each set of standards.

3 **PERFORMANCE DESCRIPTIONS -** Knowing critical functions and learning key activities aren't enough. Educators and employers need to know when key activities are performed well by the learner. Specifically: Can the student demonstrate the activity competently? These important competencies are in the right columns of each set.

Standards details are presented in a manner that complements the post-secondary school AED Foundation Accreditation application form.

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IMPORTANT: As you review these technical standards, please note that the delivery of technical core courses must be split among two or more full-time onsite instructors.

The Standards

1a. Safety

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1a. Safety

Critical Functions	Key Activities	Performance Descriptions
1a.1 Identification and use of basic hand tools	Identification, proper and safe use, care and maintenance of basic hand tools used by a technician. Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10. • Use of and maintain/sharpen drills and punches • Use of and maintain/sharpen drills and punches • Use of taps, dies, thread chasers, thread identification and thread gauges • Use of cleaners, solvents, hot tanks, parts cleaners, glass bead machines including reading SDS sheets and understanding regulations governing solvents • Use of hydraulic and mechanical presses, pullers and pushers. • The proper use and care of all types of torque wrenches including proficiency performing the torque angle method, step method torque procedure and knowing the effects of extensions on torque wrenches.	Identify and correctly name the basic hand tools. Emphasis on safety will be demonstrated with all tool usage. Demonstrate the proper use, care and maintenance of each tool, and safe operating procedure for each. Demonstrates proper use, care and maintenance, and calibration of precision hand tools. Review assignments, evaluation of identification exercises. Written exams that will determine the competency on many items unable to check by hands-on exercises. Emphasis on safety should be demonstrated with all tool usage. Test students' use of tools/equipment to check comprehension. Demonstrate all torque and de-torque methods with hands-on exercises.

Critical Functions	Key Activities	Performance Descriptions
1a.1 (cont'd.) Identification and use of basic hand tools	• Straight edges, feeler gauges, transfer gauges. • Micrometers, dial indicators, calipers and bore gauges. • Speed/RPM indicators, magnetic/ optical tachometers and pulse generators. • Pressure/flow gauges and meters, manometers, vacuum gauges. • Temperature gauges, pyrometers, thermocouples, and infrared thermometers. • Hydrometers/refractrometers. • Special tools - diagnostic tool groups. TECHNICAL RESEARCH - proper use of Tech Service Manuals /personal computers/laptops.	The student should be able to demonstrate that they can accurately read all precision measuring tools and gauges. Convert standard to and from metric measurements, both pressure and distance. Determine engine speed and pulses per revolution. Perform tasks related to measuring, understanding and recording pressure, flows and temperature. Perform tasks related to measuring specific gravity of fuel, coolant and electrolyte.

Critical Functions	Key Activities	Performance Descriptions
1a.2 Use of electric tools	Proper and safe use of basic electric hand tools used by a technician. Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	Identify and correctly name the electrical tool. Demonstrate the proper use of the designed application and safe operating procedure for each. Demonstrate the proper inspection, care and storage for electric hand tools. Understand and exhibit the safe and proper use of ground fault circuits.
1a.3 Use of air tools	Proper and safe use of the air tools used by a technician. Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	Identify and correctly name the basic air tool. Demonstrate the proper use of the designed application and safe operating procedure for each. Demonstrate the proper inspection, care, maintenance and storage for air tools.

Critical Functions	Key Activities	Performance Descriptions
1a.4 Use of hydraulic tools	Proper and safe use of hydraulic tools used by technician, such as: a. Porta powers and pullers b. Hydraulic presses c. Hydraulic pullers **d. Hydraulic jacks** e. **Hydraulic torque wrenches** Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	Identify and correctly name the basic hydraulic tools. **Demonstrate the proper inspection, care, maintenance, and storage** as applicable. **Demonstrate the proper use of the designed application and safe operating procedure** as applicable.
1a.5 Use of lifting equipment	Proper and safe use of lifting equipment used in the shop or field location by a technician: a. Jack stands b. Hoists (overhead and floor type) c. **Hydraulic jacks** d. Blocking and cribbing e. Come-A-Long (chain and cable type) f. Lifting chains – lifting eyes, links, spreader bars, etc. g. Slings **h. Securing chains** Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	Identify and correctly name the various types of lifting equipment. Demonstrate the proper inspection, care, maintenance, and storage for each. Demonstrate the proper use of the designed application and safe operating procedure for each. Students show understanding of current regulations and standards for use, inspection and certification of lifting equipment.
1a.6 Use of various cleaning equipment	Proper and safe use of the various types of cleaning equipment used to wash parts and components of machines. Wear proper PPE when working with cleaning solvents. Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	Identify and correctly name the basic cleaning equipment used in our industry. **Demonstrates the proper use of** the designed application and safe operating procedures for each. Demonstrates the proper inspection, care, maintenance, and storage for cleaning equipment.

Critical Functions	Key Activities	Performance Descriptions
1a.6 Use of various cleaning equipment (cont.)		Identify the various solvents and solutions used in the cleaning process. **Identify the risks, hazards** and precautions **for cleaning materials,** both personal and environmental. Demonstrate an understanding of Safety Data Sheets (SDS) and requirements to meet OSHA standards.
1a.7 Use of fluid pressure testing equipment	Proper and safe use of various types of fluid pressure test equipment and accessories: Bench testers and testing equipment, such as: a. Gauges b. Transducers, wired and wireless c. Flow rating equipment d. Hydraulic cylinder tests e. Hydraulic pump and motor Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	Identify and correctly name the various types of fluid pressure test equipment and the accessories required for proper testing. Describe the proper use of the designed application and safe operation of each type of equipment. Demonstrates a proper source for calibration of precision test equipment and accessories. Identify, correctly name and demonstrate the use of the personal protective equipment required for the various types of fluid pressure testing equipment. Describe multiple dangers of working with fluids under pressure.

Critical Functions	Key Activities	Performance Descriptions
1a.8 Environment of service facility **IMPORTANT NOTE:** **It is the responsibility of the educational institution to provide a classroom and lab facility that provides an acceptable, safe learning environment for students.**	Proper and safe use of ventilation and building exhaust systems. Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10. Exhibits knowledge of a clean, contaminant free, hazard free shop as related to safety and contamination control.	Identify the various types of exhaust systems used in repair facility. **Demonstrates the proper use of** the designed application and safe operation of each type of system. Demonstrates the proper inspection, care, maintenance and storage of the systems and the equipment required for operation. Explain why carbon monoxide and diesel smoke can be hazardous to your health and the precautions required for eliminating injury or death. Recognize symptoms of exposure to carbon monoxide, diesel smoke and other hazardous materials.
1a.9 Machine identification and operation	Proper and safe operation of the machinery the technicians will be involved with. Examples: a. Excavators b. Skid steers c. Backhoes d. Compaction equipment e. Paving equipment f. Crawlers and track type loaders g. Scrapers h. Cranes i. Scissor lifts j. Fork lifts and material handlers k. Wheel loaders l. Haul trucks m. Motor graders **n. Trenchers** **o. Horizontal directional drills** *** Hybrid drives ***	Identify the various types of construction equipment and forklifts, using the standard industry names accepted by equipment manufacturers. **Demonstrates** and can explain the proper, safe and fundamental operation of the various types of machinery. Translate from a user's perspective the importance of and reasons for caution/warning lights, backup alarms, seat belts, safety instructions, decals and other customer-related safety information. Recognize hybrid systems and/or machines as they relate to safety concerns.

Critical Functions	Key Activities	Performance Descriptions
1a.9 Machine identification and operation (cont.)	Exhibits knowledge of personal protection equipment and hazardous materials – reference section 1a.10.	
1a.10 Mandated regulations	Various federal and state OSHA and MSHA regulations. a. Personal protection equipment (PPE): • Safety glasses and shoes • Fire protection • Ear protection • Respirators • Head protection • Loose clothing hazard • Proper gloves/hand protection • Protective clothing b. Hazardous material: • Right-to-know c. Proper handling of hazardous material d. Lock-out, Tag-out as it pertains to construction machinery e. Proper use of wheel chocks f. Blood-borne pathogens g. Confined space regulations h. Forklift operation and certification i. Fire protection and suppression: • Methods of fire protection • Proper handling of various types of fires; electrical grease, etc. • Use of fire extinguishers j. Safety Data Sheets (SDS) k. Machine guarding l. Proper inspection of all electrical tools. Ex. Drills and grinders	Identify and correctly name the various types of equipment required for these regulations. Demonstrate and explain the principles and procedures for each of the regulations. Demonstrates the operation, inspection, proper care and maintenance of the various equipment required for conforming with federal and state OSHA and MSHA regulations. Identify the different types of fire extinguishers and know the applications and correct use of each type. Demonstrates how to find, explain and use an SDS for a product.

Critical Functions	Key Activities	Performance Descriptions
1a.10 Mandated regulations (cont.)	m. Handling of flammable liquids and materials.	
	n. Handling of machinery with fluid leaks.	
	o. Back-up alarm requirements for construction machinery.	
	p. Rollover protective equipment for construction machinery (ROPS).	
	q. Electrical ground fault protection.	
	r. Underground utility hazard – standard markings for each type.	Recall and identify underground utility hazard marking that would commonly be encountered on a job site.
	s. Falling objects protection for construction machinery. (FOPS)	
	t. Fall protection for workers.	
	u. Sub-surface, trench, excavation safety.	
	v. Workman's compensation and accident prevention: 1. Cost of accidents 2. Lost time injury 3. Proper accident and injury reporting	Explain why working safely is important, and explain the procedures for reporting unsafe working conditions and practices.

1a. Safety

Critical Functions	Key Activities	Performance Descriptions
1a.11 Shop and in-field practices	General safe work habits in the shop; general safe work habits when doing in-field repairs or at customer's facility.	Identify safe work practices in each situation. Demonstrate safe work practices in the shop or in the field.
	Proper lifting and pulling techniques.	Identify proper lifting and pulling techniques to avoid personal injury. Demonstrate proper lifting and pulling techniques.
	Proper shop/facility cleanliness and housekeeping practices.	Demonstrate proper shop/facility cleanliness/appearance to dealer standards.
	Performing safety risk assessments.	Identify potential hazards and develop a plan to deal with them.
1a.12 Hazard identification and prevention	Proper mounting and dismounting of machinery.	Demonstrate safe mounting and dismounting practices on construction machinery.
	Load securement for transportation of components.	Explain proper types of chains and binders used in securing loads.
	General knowledge of safety practices.	Demonstrate proper lock out tag out procedures.
	Hazard Communication (HazCom) Standard	Demonstrate understanding of the HazCom standard and how to use Safety Data Sheets and Chemical Labels.
	Implement a Toolbox Talk, or Safety Share Topic in daily startup.	Write about or discuss from personal or team experience (shop, workplaces, etc.,) common safety hazards and what you would have done to eliminate them.
	Proper blocking of equipment when raised in air and working under a machine.	

1a. Safety

Critical Functions	Key Activities	Performance Descriptions
	Proper wheel assembly handling procedures. Proper tethering techniques.	Demonstrate proper work procedures in handling wheel assemblies safely. Refer to industry standard procedures. Identify when tethering is necessary and proper use of the fall protection equipment.

Note: If service vehicles are used in training, basic safety instruction should extend to include the vehicle as well as devices such as cranes, compressors, generators, pumps, winches, etc. Local equipment dealers may be helpful in providing training for field service trucks and other vehicles.

Critical Functions	Key Activities	Performance Descriptions
1b.1 Comprehend basic academic functions	Read, write and comprehend written language; and math, science, and social studies at the minimum assessment level.	Exhibit the ability to use parts and service reference/technical materials, and safety materials in print or computer format. Exhibit the ability to follow written instructions. Exhibit the ability to complete forms, time cards, work orders, accident reports, sales leads, technical bulletins, parts requisitions, and other related written forms of communication. Exhibit the ability to perform basic math functions, including measurement in both U.S. and metric, calculations, conversions, and currency.
1b.2 Utilize industry software and electronic communications systems and reference resources	Demonstrate the use of communication technology options. Adequate keyboard skills.	Develop and exhibit good listening skills. Exhibit the ability to use a computer, and related hardware, current software, Internet, and technology currently in use. Demonstrate efficient, effective, correct and timely communications to a customer and co-worker utilizing telephone, fax, computer, word processing and E-mail. Using a computer, demonstrate the ability to retrieve specifications, part numbers, bulletins, schematics, produce reports, and similar types of information using manufacturers' software and internet based resources.

Critical Functions	Key Activities	Performance Descriptions
1b.3 Awareness of dealership goals, objectives and policies *Note: Sections 1b.3 – 1b.5 have been reorganized only; previous content remains; minimal new content is in bold blue.*	Review and understand typical examples of potential dealership and college program mission statements, core values, policies/procedures manuals, hand books, and safety guidelines.	Exhibit the ability to work toward achieving established goals while in a diversified environment. Recognize organizational chart. Demonstrate understanding of how product support activities contribute to the overall profitability of the company. Identify expense control requirements. Maintain awareness of sexual harassment policy, safety rules, environmental regulations, disciplinary action policy, and equal opportunity policy. Explain the need for performance reviews and the impact of different performance levels. Maintain confidentiality as required.
1b.4 Define basic business practices	Explain the importance of quality customer service and the role it plays with company profitability, as well as the effect it has on the wage and benefit package.	Explain the need for quality performance and the impact on customer satisfaction and profitability. Demonstrate a positive attitude towards the company and other contacts. Define impact of not meeting the customers' needs in a timely manner. Recognize customer retention policies and procedures.

Critical Functions	Key Activities	Performance Descriptions
1b.4 Define basic business practices (cont.)	Demonstrate effective personal communications, organizational and learning skills	Exhibit the ability to communicate to coworkers and customers in a courteous, professional manner.
	Identify who are your customers; both internal and external customers.	Demonstrate time management and organizational skills. Develop an awareness of stressful situations, and the ability to handle and resolve problems with difficult internal and external customers. Exhibit the ability to listen and follow verbal and written instructions. Respect authority and accept the responsibilities of the position. Demonstrate proper appearance to dealer standards.
1b.5 Describe functions of the dealership service department; explain department goals and procedures	Describe how the service department fits into the corporate structure.	Identify and establish both short and long-term goals and the requirements to achieve them (business and personal).
		Describe parts inventory control, procurement and accountability.
		Demonstrate knowledge of factors that can determine shop labor rates.
		Demonstrate the ability to accurately complete work orders/repair orders and other related reports, including parts and consumables.
	Demonstrate the ability to write a service report.	Demonstrate the ability to write a thorough and comprehensive service report, including warranty repairs.
		Describe tool procurement procedures.
		Describe time tracking.
		Demonstrate the ability to use correct industry terminology.

The Standards

2. Electronics/Electrical Systems

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2. Electronics/Electrical Systems

Critical Functions	Key Activities	Performance Descriptions
2.1 Fundamental knowledge	a. Atomic structure.	Define the basic structure of conductors, insulators, and semi-conductors.
		Describe the reaction of like and unlike charges.
	b. Electron theory of electricity.	Describe the differences of conventional and electron theory current flow.
	1. Testing conductors, semi-conductors, and insulators.	Demonstrate the principles of operation and the correct usage of the various types of meters to measure volts, amps, and ohms.
		Demonstrate ability to convert between kilo, milli, and micro units.
	2. Magnetism.	Demonstrate knowledge of the laws governing permanent magnets, electromagnets, and magnetic fields.
		Demonstrate knowledge of the effects of magnetic forces on current carrying conductors.
	3. Construction and operation of storage batteries.	Describe the basic parts and operation of the basic types of storage batteries.
		Describe the knowledge and laws of electromagnetic induction as it applies to generating electrical current using a magnetic field.
	c. Telematics – remote monitoring.	Define remote monitoring systems and the ability to remotely diagnose electrical/electronic issues. Define what they are and what are their capabilities.

Critical functions	Key Activities	Performance Descriptions
2.2 Ohm's law	a. Ohm's law theory.	Demonstrate the mathematical relationship of the various terms in ohms law as they pertain to series, parallel, and series-parallel circuits.
	b. Applications to series, parallel, and series/parallel DC circuits.	Demonstrate the ability to set-up and measure voltage, amperage, and resistance values in series, parallel, and series/parallel DC circuits. Ensure these circuits are tied to specific applications on vehicles, not just as classroom bench activities.
2.3 12/24 Volt Cranking Circuits	a. Components.	Describe the basic components that make up the various types of 12/24 volt cranking systems.
	b. Operation.	Demonstrate the sequence of operation of the components contained within a cranking system. The emphasis is on how each component effects the system's overall operation.
	c. Troubleshooting.	Demonstrate the ability to isolate problems emphasizing voltage drops and other diagnostic methods.
	d. Test and Replace if Required.	**Demonstrate the ability to correctly test, evaluate and replace the following components using manufacturers' service publications and specifications.** 1. Conductors 2. Relays/ Solenoids 3. Starters

Critical Functions	Key Activities	Performance Descriptions
2.4 12/24 Volt Charging Circuits	a. Components.	Describe the basic components that make up the various types of 12/24 volt charging systems.
	b. Operation.	Demonstrate the sequence of operation of the components contained within a charging system. The emphasis is on how each component effects the system's overall operation.
	c. Troubleshooting.	Demonstrate/emphasize the ability to isolate problems using voltage drops and other diagnostic methods. Demonstrate understanding of 5V reference voltage and its effect on all sensors in the same circuit.
	d. Test and Replace if Required.	**Demonstrate the ability to properly test, evaluate and replace the following components using manufacturers' service publications and specifications.** 1. Conductors 2. Alternators 3. Regulators

Critical Functions	Key Activities	Performance Descriptions
2.5 Lighting, accessory and control systems	a. Components.	Describe the basic components that make up the various types of lighting, accessory and control systems.
	b. Operation.	Demonstrate the sequence of operation of the components contained within various lighting, accessory and control systems. The emphasis is on how each component effects the system's overall operation.
	c. Troubleshooting.	Demonstrate the ability to isolate problems within various lighting, accessory and control systems emphasizing voltage drops and other diagnostic methods.
	d. Repair.	Demonstrate the ability to correctly disassemble, test, assemble, replace, or repair lighting, accessory and control system components using manufacturers' service publications and specifications. Examples of the components are as follows: 1. Wiring harness/connectors 2. Fuses/circuit breakers 3. Lights/bulbs 4. Hall effect systems: switches, sensors, and other 5. Gauges 6. Meters 7. Horns and buzzers 8. Relays 9. Diodes 10. Resisters 11. Potentiometers

Critical Functions	Key Activities	Performance Descriptions
2.5 Lighting, accessory and control systems (cont.)		12. Solenoids 13. Rheostats 14. Switches 15. Electric motors 16. Transformers/converters 17. Pre-heat devices – i.e. Glow plugs, intake heaters 18. Sensors 19. Monitors 20. Controllers 21. HID/LED 22. Transducers 23. Transistors
2.6 Electrical schematics/diagrams	a. How to read schematics/diagrams.	Demonstrate the ability to identify basic electrical/electronic symbols. Ensure newer symbols like hall effect sensors are covered.
	b. How to use schematics/diagrams.	Demonstrate the ability to trace various circuits using wiring schematics/diagrams.
	c. Review different styles of schematics used in the industry, including system function schematic vs theory schematics vs. wiring diagrams. Know where to find connector info, splices, and source of power (controller vs batt) and ground.	Demonstrate a working knowledge of diagnosing and troubleshooting electrical systems using schematics/diagrams.
2.7 SAE computer Can-Bus standards	a. Explain communication standards.	Demonstrate a working knowledge of the different systems used on computer controlled machinery. Ex. LIN, CAN Understand the logic of wake-up and timed shut-down circuits.
	b. Explain published error codes per SAE standards.	Understand the importance of twisted and shielded wire systems. Demonstrate a working knowledge of the codes to identify errors within the different systems. Demonstrate understanding of the logic and theory of how a processor generates a code. Inputs vs. Outputs.

Critical Functions	Key Activities	Performance Descriptions
2.8 Diagnostics Systems troubleshooting Note: for "d." and "e." in key activities to the right, please cross-reference to Hydraulics/Hydrostatics Section 3.1 of this document: Theory and operation, understand hydraulic and hydrostatic theory. Reference the requirement for access to an owned or unowned hydraulic/hydrostatic trainer in Section 3.6. Also cross-reference to Power Trains Section 4.1 of this document: Theory and Operation, Theory and principles of hydrostatic transmissions.	Ask the proper questions before beginning to diagnose; capture the customer complaint. Follow technical manuals/service information to perform operational checks and troubleshooting procedures to properly diagnose an electrical malfunction in each of the following areas: a. Cranking systems b. Charging systems c. Lighting systems d. Electric and electronic controlled hydraulic systems e. Electric and electronic controlled hydrostatic systems f. Analog vs. digital sensors Given owned or unowned pieces of training equipment, exhibit the ability to solve malfunctions in each of the listed systems that have been installed or established for troubleshooting practice using proper procedures. Technical write-up competency	Describe the complaint prior to beginning diagnostic tests. Demonstrate the ability to perform a diagnostic procedure with emphasis on arriving at the root cause of failure. Demonstrate the ability to reason with regard to a specific malfunction in the system. Demonstrate the use of proper tools, including flex probes and back probing. Demonstrate mastering the use of all test equipment including digital volt ohm meter (D.V.O.M.), lap top computers, and other system specific troubleshooting devices. Demonstrate the ability to do voltage drop testing to determine available vs. potential voltage Demonstrate the ability to use schematic diagrams and follow troubleshooting flow charts in selected techncial manuals. Utilize an interactive equipment diagnostic program. Demonstrate technical write-up competency • Demonstrate logic and critical thinking in identifying, evaluating and diagnosing customer complaint. • Identify the root cause of failure • Correction procedure • Machine inspection

The Standards

3. Hydraulics/Hydrostatics

Critical Functions	Key Activities	Performance Descriptions
3.1 Theory and operation, hydraulic and hydrostatic Understand hydraulic theory See also 3.6 Troubleshooting of load-sensing hydraulics.	Learn basic hydraulic principles. Understand a basic hydraulic system. Understand and differentiate between open and closed center systems. Understand a basic hydraulic system. Applications of hydraulic systems.	Demonstrate knowledge that fluids have no shape of their own, are practically incompressible, apply equal pressure in all directions, and provide great increases in work force. Describe the function of a reservoir, pump, filters, relief valve, control valve, and cylinder in relation to each other. Describe how open and closed center systems are determined by one or all of the following: a) the type of control valve, b) the type of pump, c) use of unloading valve, d) path of oil return to reservoir from pump. Describe a basic, but complete, open center hydraulic system, explaining the operation of the system, the route of fluid during the use of a function, and the route of the fluid while the machine is running when no hydraulic function is being used. Describe a basic, but complete, closed center load sensing hydraulic system, explaining the operation of the system, the route of fluid during the use of a function, and the route of the fluid while the machine is running when no hydraulic function is being used. Identify applications, and the benefits of those applications on construction equipment.

Critical Functions	Key Activities	Performance Descriptions
3.1 Theory and operation, hydraulic and hydrostatic (cont.)	Learn the principles of hydrostatics.	Demonstrate knowledge of hydrostatic systems, including closed-loop and open-loop systems.
Understand hydrostatic theory		Understand the various types of cooling circuits.
		Understand the purpose of a charge circuit and how charge pressure relates to hydrostatic system efficiency.
Note: for this section, please cross-reference to Electronics/Electrical Systems Section 2.8, "d." and "e." of this document: Diagnostics, Systems troubleshooting (hydrostatics).		Explain the differences between hydraulic and hydrostatic systems.
	Applications of hydrostatic systems.	Demonstrate the ability to identify applications, and the benefits of those applications on construction equipment.
Also, cross-reference to Power Trains Section 4.1 of this document: Theory and Operation, Theory and principles of hydrostatic transmissions.	Understand the difference between fixed, variable, positive, and non-positive displacement pumps.	Explain the different characteristics between various types of pumps, exhibit the ability to follow the oil flow through each pump both while using a hydraulic function and with no hydraulic function being used.
Pump identification and operation	Identify a gear pump, its parts, and know its operation.	Demonstrate the ability to identify a gear pump, name all parts, follow the oil flow through a gear pump, identify inlet and outlet ports, and identify the direction of rotation of the pump.

Critical Functions	Key Activities	Performance Descriptions
3.1 Theory and operation, hydraulic and hydrostatic (cont.)	Identify a vane pump, its parts, and know its operation.	Identify a vane pump, name all parts of a vane pump, follow the oil flow through a vane pump, identify inlet and outlet ports of a vane pump, and identify the direction of rotation of the pump. Explain how a vane pump can be changed to operate in the opposite direction, when applicable.
	Identify a piston pump, its parts, and know its operation.	Identify various piston pumps, name all parts of a piston pump, follow the oil flow through a piston pump, identify inlet and outlet ports of a piston pump (both variable and fixed), and identify the direction of rotation of the pump.
	Identify types of swash plate control.	Identify types of swash plate control (manual, servo piston, electronic, etc.).
	Understand the difference between fixed or variable displacement, and 2-speed motors.	Explain the different characteristics between the various motors; exhibit the ability to follow the oil flow through each motor while using a hydraulic function.
	Identify a gear motor, its parts and know its operation.	Identify a gear motor, name all parts of a gear motor, follow the oil flow through a gear motor, identify inlet and outlet ports of a gear motor, and identify the direction of rotation of the motor.
	Identify a vane motor, its parts, and know its operation.	Identify a vane motor, name all parts of a vane motor, follow the oil flow through a vane motor, identify inlet and outlet ports of a vane motor, and identify the direction of rotation of the motor.

Critical Functions	Key Activities	Performance Descriptions
3.1 Theory and operation, hydraulic and hydrostatic; (cont.) Motor identification and operation	Identify radial and axial piston motors, their parts, and know their operation.	Identify radial and axial piston motors, name all parts of these piston motors, follow the oil flow through these piston motors, identify inlet and outlet ports of these piston motors (both variable and fixed), and identify the direction of rotation of the motors.
	Identify a gerotor motor, its parts, and know its operation.	Identify a gerotor motor, name all parts, and understand its operation.
Function and operation of hydraulic valves	Understand the three major types of hydraulic valves.	Describe the differences between these three major valve types: a.) Pressure control valves b.) Directional control valves c.) Flow control valves
	Understand the functions and uses of pressure control valves.	Exhibit knowledge of the uses and functions of the following valves: a.) Direct acting relief valves b.) Pilot operated relief valves c.) Cartridge relief valves d.) Pilot operated valves e.) Sequence valves f.) Unloading valves g.) Multi-function valves h.) Counterbalance valves i.) Pressure reducing valves j.) Pressure limiting valves k.) Pressure differential valves l.) Crossover relief valves

Critical Functions	Key Activities	Performance Descriptions
3.1 Theory and operation, hydraulic and hydrostatic; Function and operation of hydraulic valves (cont.)	Understand the functions and uses of directional control valves.	Exhibit knowledge of the uses and functions of the following valves: a.) Check valves b.) Rotary valves c.) Spool valves d.) Pilot controlled poppet valves e.) Electro-hydraulic valves f.) Electro-hydraulic control systems g.) Pulse width modulated valves
Electro-hydraulics	Electro-hydraulic valves Electro-hydraulic control systems Pulse width modulation (PWM)	
	Understand the functions and uses of volume control valves.	Exhibit knowledge of the uses and functions of the following valves: a.) Flow control valves 1. Compensated 2. Non-compensated b.) Flow divider valves 1. Priority 2. Non-priority 3. Proportional
Cylinder identification and operation	**Understand the difference between single acting and dual acting cylinders.**	Explain the uses and movements of the two types of cylinders.
	Identify a single acting cylinder, its parts and know its operation.	Identify a single acting cylinder; name all of its parts, and follow the oil flow through the cylinder.
		Demonstrate understanding of the operation of a cushioned cylinder.

Critical Functions	Key Activities	Performance Descriptions
3.1 Theory and operation, hydraulic and hydrostatic; Cylinder identification and operation (cont.)	Identify a double acting cylinder, its parts and know its operation.	Identify a double acting cylinder, name all of its parts, and follow the oil flow through the cylinder. (deleted in sentence i.e. vane type cylinder – rotary actuator)
Accumulator identification and operation	Understand the uses of accumulators.	Explain how accumulators store energy, absorb shocks, build pressure, and maintain a constant pressure within a system.
	Identify types of accumulators.	Explain where and why gas, pneumatic, spring loaded, and weighted accumulators are used.
	Understand accumulator safety.	Explain and demonstrate all accumulator safety practices.
3.2 Fluids, transfer components and filtering	Know the construction of hoses and understand the wide variety of fittings used in hydraulic systems, and the effects of these on noise and vibration.	Exhibit the ability to select the proper hose for a given function, taking into consideration the flow needed, pressures to be used, routing, clamping, fittings required and pulsating of lines. Exhibit knowledge of the understanding of hydraulic fittings, the importance of selecting the proper fitting, and their relationship to noise and vibration. Demonstrate the ability to identify various fittings and thread styles, examples: o-ring boss, NPT, NPTF, British Metric, o-ring flange, ORFS, etc. **Proper procedure to torque fittings and flanges.** **Demonstrate the ability to crimp hydraulic fittings onto hose.**

Critical Functions	Key Activities	Performance Descriptions
3.2 Fluids, transfer components and filtering (cont.) Know the construction and function of filters used in hydraulic/hydrostatic systems	Hydraulic filters: 1. Pressure, return line & suction filters 2. Filter efficiency 3. Beta ratings/ISO cleanliness codes 4. Auxiliary by-pass filtration	Describe the use of various filters in hydraulic and hydrostatic systems. Demonstrate an understanding of the concept of auxiliary by-pass filtration and its benefits to total system cleanliness.
3.3 Maintenance procedures	Know and practice safety.	Demonstrate familiarity with, and practice good hydraulic maintenance/safety practices.
Understand the importance of maintenance	Understand the importance of cleanliness.	Perform all hydraulic functions and repairs in a clean atmosphere.
	Flushing systems.	Exhibit the ability to follow the proper flushing procedure using the correct technical manual/service information.
	Preventing leaks.	Exhibit the proper maintenance techniques to prevent internal and external leaks. Demonstrate the procedure for cleaning hoses after cutting and crimping.
	Prevent overheating.	Demonstrate knowledge of overheating conditions. Prevent overheating by keeping the oil at the proper levels, cleaning dirt and mud from around lines and cylinder rods, keep relief valves adjusted properly, do not overload or overspeed systems, and do not hold control valves in a stalled position longer than necessary.
	Identify defective or worn hoses.	Identify and recognize the root causes of "blistering" or frayed hoses and procedures to avoid these problems.

Critical Functions	Key Activities	Performance Descriptions
3.3 Maintenance procedures (cont.) Know the characteristics of oils	Hydraulic oils: 1. Viscosity-effects of temperature on viscosity 2. Types: mineral, synthetic, water/oil emulsions, bio-oil, etc. 3. Characteristics of: VI improvers, anti-foaming, etc. 4. Recommended viscosity for hydraulic components 5. Explain the flash point of oil	Understand oils and show familiarity with various fluids and their effects on hydraulic systems. Understand the effects of mixing oil types.
Fluid Cleanliness	ISO cleanliness codes Interpreting fluid analysis reports	Understand ISO cleanliness code principles. Identify key elemental categories. Understand the proper way to obtain fluid samples from a system. Identify key elements found in oil analysis and the types of failures related to each. Identify key indicators on a fluid analysis report that illustrate: 1. The proper fluid type is being used. 2. Fluid types have not been mixed. 3. Indicators of fluid degradation. 4. Trend analysis.
	Demonstrate the ability to identify aeration in a hydraulic system	Demonstrate the ability to identify aeration and determine the root cause.
Understand the usage and types of seals and gasket materials	Know the variety of materials and types of seals/gaskets used in a hydraulic system	Describe how reactions of some sealant materials differ among types of hydraulic fluids. Describe the applications of various types of sealants. Demonstrate that safety practices are followed.

Critical Functions	Key Activities	Performance Descriptions
3.4 Component repair and Replacement Component repair	Understand the procedure to properly repair hydraulic components. Be sure safety practices are followed.	Following the proper technical manual/service information, exhibit the ability to remove, disassemble, diagnose failure, evaluate, repair or replace/reinstall, and test operate any given component including but not limited to: • Gear, vane, and piston pumps • Gear, vane, and piston motors • Pressure control valves • Directional control valves • Flow control valves • Single acting, double acting cylinders (If OEM recommends or allows: gas, pneumatic, spring, and weight loaded accumulators.
Component replacement	Understand the procedures to properly remove and replace hydraulic components. Ensure safety practices are followed.	Following the proper technical manual/service information, exhibit the ability to remove and replace any given component including but not limited to: • Gear, vane, and piston pumps • Gear, vane, and piston motors • Pressure control valves • Directional control valves • Flow control valves • Single acting, double acting cylinders • Gas, pneumatic, spring, and weight loaded accumulators • Hoses, steel lines, and fittings • Oil coolers • Reservoirs Describe proper system flushing/cleanup procedures to achieve ISO cleanliness code. Follow proper bleeding and priming procedures.

Critical Functions	Key Activities	Performance Descriptions
3.5 Hydraulic schematics	Identify JIC, ANSI and ISO hydraulic symbols in relation to the component they represent. Identify the position of any given component by reading a schematic. Follow flow of fluid through a hydraulic system with the use of a schematic.	Exhibit knowledge of symbol identification through demonstration. Given a selected schematic, exhibit your knowledge of schematics by using JIC, ISO and various symbols to identify locations of various components.
3.6 Diagnostics Systems and component troubleshooting Note: for this section, please cross-reference to Electronics/Electrical Systems Section 2.8, "d." and "e." of this document: Diagnostics, Systems troubleshooting (hydrostatics). Also, cross-reference to Power Trains Section 4.1 of this document: Theory and Operation, Theory and principles of hydrostatic transmissions.	Follow technical manuals/service information to perform operational checks and troubleshooting procedures to properly diagnose a **hydraulic/hydrostatic malfunction.** The school must have access to at least one engine-driven simulator or machine that meets the following requirements: a. Must be electronically controlled via EDC- Electronic Displacement Control systems. b. Must be easily accessible, both visually and mechanically. c. Must allow for faculty/students to effectively perform operational checks, test procedures and diagnostics using appropriate manuals and procedures. d. Schools must have an assortment of failed/faulty components (wiring, sensors, bugs, etc.) that can be removed or replaced for testing, diagnostics or demonstrations. Incorporate Trainer Into Curriculum Technical write-up competency	Use proper oils and fluids as per manufacturer specifications. Exhibit proficiency in the use of all test equipment including flow meters, pressure gauges, vacuum gauges, and temperature measuring devices, in both the metric and standard scales. **Demonstrate the ability to use schematic diagrams and follow a troubleshooting flow chart using a selected technical manual.** Demonstrate the ability to follow an operational check procedure using a selected technical manual. Troubleshooting of load-sensing hydraulics. Demonstrate technical write-up competency • Demonstrate logic and critical thinking in identifying, evaluating and diagnosing customer complaint. • Identify the root cause of failure • Correction procedure • Machine inspection

The Standards

4. Power Trains

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation	Learn theory of power train: 1. Clutches 2. Manual transmissions 3. Power shift transmissions 4. Hydrostatic drives 5. Hybrid and electric drive systems 6. Differential steering 7. Torque converters 8. Differentials 9. Dry brakes 10. Wet brakes 11. Final drives 12. Powertrain/hydraulic oil coolers	Demonstrate knowledge of basic power train components and how those components, as a whole, relate to one another. Demonstrate by following a power flow chart from flywheel to ground. Recognize hybrid and electric drive systems and/or machines as they relate to safety concerns.
Basic principles of power train	Learn principles of the following: Types of gears: 1. Straight cut spur 2. Helical 3. Herringbone 4. Bevel 5. Spiral bevel 6. Hypoid 7. Planetary a. Basic operation • Sun drive • Carrier drive • Compound gear b. Ratios	Demonstrate knowledge by identifying the various types of gears using a matching test. Explain the benefit of one type of gear versus other types of gears using factors such as cost, strength, quietness, bulkiness, and capability of ratios.

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation; Basic principles of power train (cont.)	8. Worm 9. Ring and pinion	
	Anti-friction bearings and plain bearings: 1. Ball 2. Roller 3. Needle	Identify types of bearings through matching tests. Demonstrate understanding of various types of bearings and proper adjustment procedures.
	Torque converter: 1. Components: a. Impeller b. Turbine c. Stator	Identify components of a torque converter and describe the relationship of those components to one another.
	2. Operation: a. Vortex flow b. Stall c. Torque multiplication d. Lock-up clutches e. Rotary flow f. Cooler flow	Describe the operation of a given torque converter and various stages of operation.
	3. Testing and troubleshooting: a. Converter in pressures b. Converter out pressures c. Lock-up clutch pressures	Use OEM manuals/service information to test a torque converter unit and determine if operation is within specifications.

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation (cont.)		
Theory and principles of manual transmissions	1. General principles: a. Sliding gear: 1. Components 2. Operation 3. Powerflow	Exhibit your understanding of "sliding gear" transmissions by identifying components, explaining operation, and demonstrating power flow through all gear sets.
	b. Collar shift: 1. Components 2. Operation 3. Powerflow	Same as above substituting "collar shift."
	c. Syncromesh: 1. Components 2. Operation 3. Powerflow	Same as above substituting "syncromesh."
	2. Manual shifting controls: a. Forks b. Rails c. Cams	Identify shifting control components and explain their operation.
	3. Adjustments: a. Endplay, preload, backlash b. Fork adjustments c. Rail adjustments d. Cam adjustments	Demonstrate ability to perform adjustments to transmissions as instructed in the OEM service manual/information.

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation (cont.)		
Theory and principles of powershift transmissions	1. General principles: a. Review multiple discs b. Review planetary gearing	Demonstrate your understanding of the operation of powershift transmissions by explaining which clutches and/or brakes are engaged, and which planetary gear sets are being used during a specific gear selection.
	c. Identify planetary and countershaft transmissions.	Explain the differences, advantages and disadvantages of planetary and countershaft transmissions.
Theory and principles of clutches	d. Multiple clutch operation: • Clutch engagement chart • Power flow through transmission • Control of clutch engagement	Use service manual/information to test and/or troubleshoot a powershift transmission (on-highway truck transmissions do not qualify), and verify if it is within OEM specifications.
The college program must have at least two school-owned static powershift transmissions (on-highway truck transmissions do not qualify) for student disassembly and assembly. Depending on the number of students in the program, more may be required.	e. Accumulator operations f. Rate of shift controls g. Clutch pressures: • On-coming clutch • Off-going clutch • Pressure gauge testing h. Hydraulic valving i. Oil flow to clutches: • Hydraulic reverses • Counter shaft (constant mesh) • Planetary transmissions • Troubleshooting methods • Preload, endplay, and backlash	Demonstrate ability to set and measure preload, endplay and backlash for a specific component using OEM manuals/service information.

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation (cont.)		
Theory and principles of clutches	Clutch identification and operation: 1. Disk and plate: a. Disc: • Solid • Button b. Pressure plate: • Springs • Plate • Release levers c. Operation 2. Multiple disc clutches: a. Components b. Relationship of number of discs to application c. Effect of pressure on torque d. Wet and dry clutches e. Clutch/plate material f. Wear patterns 3. Overrunning clutches: a. Types: • Roller • Cam • Sprag b. Operation c. Application 4. Magnetic clutches: a. Operation b. Application 5. Modulating clutch	Identify all components in a single and multiple disc and plate-type clutch, including flywheel, pilot and release bearings, disc and pressure plate parts, and power train input shaft. Also, explain differences and benefits of solid and button-type clutches. Explain operation of a selected clutch. Demonstrate knowledge and operation of single and multiple-disc clutches by explaining the relationship of the clutch components to each other and their roles in the transfer of power. Describe the relationship of the number of discs, types of discs (wet or dry), and type of clutch material to the transfer of torque and horsepower to the ground. Demonstrate understanding of overrunning clutches by identifying the different types of clutches, their operation and various applications. Explain the operation of magnetic clutches and name various applications. Explain operation and applications.

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation (cont.) Theory and principles of electronic-controlled transmissions	1. Basic principles: a. Electronically-controlled hydraulic valves: • F= P x A • Pressure drop through an orifice • Fundamentals of spring operation • Fundamentals of solenoid operation • Current vs. spring force vs. orifice relationship • Current vs. pressure relationships 2. Electronic over hydraulic systems. 3. Electronic over air systems. 4. Sensing and operational control: a. Load sensing b. Engine fuel control interface c. Speed sensing d. Torque sensing e. Manual control f. Automatic control 5. Diagnosis and Troubleshooting: a. With diagnostic unit b. Without diagnostic unit c. Component isolation procedures d. Clutch modulation pressures e. Lubrication pressure f. Pump pressure	Exhibit knowledge of electronic control systems by identifying components used on a specific unit. Demonstrate understanding of a specific unit's operation by explaining the functions of all components and their relationships to one another. Demonstrate ability to follow flow and troubleshooting charts to correctly identify the operation of a specific unit's system and troubleshooting methods used by the OEM.

Critical Functions	Key Activities	Performance Descriptions
4.1 Theory and operation (cont.) Theory and principles of hydrostatic transmissions Note: for this section, please cross-reference to Electronics/Electrical Systems Section 2.8, "d." and "e." of this document: Diagnostics, Systems troubleshooting (hydrostatics). Also, cross-reference to Hydraulics/Hydrostatics Section 3.1 of this document: Theory and operation, understand hydraulic and hydrostatic theory. Reference the requirement to have a hydraulic/hydrostatic trainer available in Section 3.6.	1. Basic principles: a. Displacement/flow relationships b. Types: • Gear • Axial piston swash plate • Cam lobe c. Open loop hydrostatics d. Closed loop hydrostatics: • Fixed-fixed combinations • Variable-fixed combinations • Fixed-variable combinations • Variable-variable combinations • Charge/cooling circuit • Lubrication circuit e. Pump f. Motor g. Forward h. Neutral i. Reverse j. Cooling circuit 2. Hydrostatic control systems: a. Manual feedback control b. Electronically controlled c. Braking system: • Fail safe • Manual systems	Demonstrate understanding of theory and principals of hydrostatic systems by explaining, in writing, how a basic hydrostatic system functions. Exhibit knowledge of hydrostatic transmission operation by explaining the flow of fluids through the charge circuit, pump, motor, control and loop circuits. Explain the differences between fixed and variable pumps and motors, and the effects of their various combinations. Explain various adjustment procedures for straight travel.

Critical Functions	Key Activities	Performance Descriptions
4.2 Driveshaft function and construction	1. Connections: **a. U Joint / Hooke joint** b. Constant velocity joint 2. Effects of angle of shaft 3. Multiple joint timing 4. Mid-ship supports 5. Repairs 6. Failure analysis	Demonstrate knowledge of driveshafts by recognizing components, realizing the effects of driveline angle and studying why driveline failures occur.
Theory and principles of differentials	1. Basic operation and components: a. Pinion gear b. Ring gear c. Bevel gear 2. Differential locking methods: a. Mechanical b. Hydraulic c. Automatic no-spin 3. Adjustments: a. Preload b. Backlash c. Gear tooth pattern	Exhibit understanding of basic differential operation by identifying the components and explaining how pinion, ring and bevel gears operate in relationship to each other. Identify each type of differential locking device and explain in detail how each one operates. Given a specific component and proper manuals/information, perform all adjustments on a differential with a new ring and pinion, and also perform all adjustments with original ring and pinion but with new bearings. Identify the most common root causes of failure with differentials.

Critical Functions	Key Activities	Performance Descriptions
4.2 Driveshaft function and construction (cont.) Theory and principles of final drives	1. Types: a. Rigid axle: • Full-floating • Semi-floating b. Flexible axle shaft c. Pinion drives: • Pinion/bull gear • Inboard planetary • Outboard planetary • Double reduction planetary 2. Front wheel drives: a. Mechanical b. Hydrostatic c. Speed lock-outs 3. Four-wheel drive: a. Front to rear ratios b. Tires and rolling radius c. Front or rear disconnects 4. Adjustments a. Rolling torque b. Bearing Preload c. Endplay	Exhibit knowledge of final drives by identifying the different types, and the components that make up final drives. Perform adjustments according to OEM standards.
4.3 Fundamental theory of hydraulic and pneumatic braking systems	1. Study the components of hydraulic and pneumatic braking systems: a. Functions b. Construction c. Operating principles d. Define and explain Pascal's law	Describe fundamental theory, adjustments and repair of hydraulic and pneumatic braking systems used primarily in mobile construction equipment. Demonstrate knowledge of basic brake components, both wet internal and dry external. Explain and sketch hydraulic and pneumatic brake systems, internal and external.

Critical Functions	Key Activities	Performance Descriptions
4.3 Fundamental theory of hydraulic and pneumatic braking systems (cont.)	2. Study hydraulic wheel cylinders: a. Functions b. Construction c. Single/double piston d. Discuss and explain the mechanical working of a hydraulic wheel cylinder 3. Study master cylinders: a. Functions b. Construction c. Operating principles 4. Air system maintenance a. Air dryers b. Alcohol injectors 5. Internal wet disc brakes a. Actuation b. Sealing c. Friction material 6. Brake retarders a. Hydraulically actuated b. Engine exhaust brake c. Dynamics	
4.4 Understanding maintenance practices in power trains	Cleanliness.	Demonstrate procedures to follow in keeping a work area, **and the parts worked with,** clean.
	Proper flushing.	Describe proper flushing procedures, including when components are replaced.
	Scheduled oil sampling.	Describe scheduled oil sampling and cite several reasons why it is necessary.

4. Power Trains

Critical Functions	Key Activities	Performance Descriptions
4.5 Power train schematics and flow diagrams	1. Identify symbols.	Be able to identify all electrical/hydraulic, pneumatic and mechanical symbols used in power train units.
	2. Technical manual/service information: a. Problem solving b. Decision making c. Problem analysis	Demonstrate ability to use schematics and flow diagrams to follow both control circuits and power flow of a given piece of equipment using the corresponding OEM manual/service information.
4.6 Troubleshooting and failure analysis	1. Steps in problem solving	Describe steps in solving a problem related to a power train system, decisions required to perform work and analysis as to why problem occurred and how it could have been prevented.
Failure analysis	2. Understanding why parts fail: a. Bending fractures b. Torsional failures c. Adhesive and abrasive wear d. Pitting and spalling failures e. Frettage, cavitation, and corrosion f. Lack of lubrication g. Contamination h. Lack of cooling/overheating	Describe common reasons for parts failure and be able to discuss symptoms of wear, corrosion, etc., of actual parts. Demonstrate ability to follow reference information, test, and determine if unit is within specifications for a hydraulic/hydrostatic trainer or equipment with a hydrostatic drive using service manuals/information/software; demonstrate ability to follow a diagnostic troubleshooting chart for a specific system.
Troubleshooting	3. Testing/ troubleshooting: a. Proper use of gauges b. Accuracy of gauges c. Oil sampling 4. Repair cautions: cleanliness, oil types, filling oil lines, bleeding pumps/motors 5. Technical write-up competency	Use proper oils and fluids as per manufacturer specifications. Demonstrate technical write-up competency • Demonstrate logic and critical thinking in identifying, evaluating and diagnosing customer complaint. • Identify the root cause of failure • Correction procedure • Machine inspection

The Standards

5. Diesel Engines

Critical Functions	Key Activities	Performance Descriptions
5.1 Safety	Instruction in proper safety practices. Emphasis on the extremely high fuel pressures we see today.	Explain safety issues specifically related to engine applications. Review assignments, evaluation of identification exercises. Successfully complete written exams that will determine the competency on many items unable to check by hands-on exercises. Emphasis on safety is to be demonstrated with all tool usage.
5.2 Theory and Operation	Understand the following engine theory, terminology and operation guidelines: • Four stroke engine cycle • Intake stroke/event • Compression stroke/event • Exhaust stroke/event • Power stroke/event • Diesel combustion • Detonation, pre-ignition • Valve overlap • Crankshaft degrees	Demonstrate competency in the application of engine theory of operation. Written tests designed for this purpose. Possible task list. Understanding and comprehension of formulas to calculate engine performance criteria. Understand the relationship between engine HP and torque. Describe the differences between spark ignited and compression ignition engines. Determine engine/component motion and speed ratios. Explain diesel 4-stroke engine cycle. Memorize the order of strokes. Identify the specific stroke of each cylinder during engine rotation. Determine the number of degrees between power strokes on various engines. Understand diesel combustion principles, and the effects of pre-ignition, detonation and misfire. Demonstrate glow plug operation & testing. Determine engine rotation by valve overlap.

5. Diesel Engines

Critical Functions	Key Activities	Performance Descriptions
5.2 Theory and operation cont'd	• Combustion chambers	Identify the various combustion chambers and know the advantages/disadvantages of each type.
	• Understand polar timing diagrams	Perform basic valve and injection timing tasks. Understand the theory of injection pump timing.
	• Cooling systems	Understand the functions of various cooling system components.
	• Lubrication systems	Understanding measurement and properties of the engine fluids. Understand cross contamination root causes and effects of each. Understand the functions and components of diesel engine lubrication systems and the effects of machine operating angle versus oil pan and pump design. Understand effects of lubrication system levels (over and under).
	• Fuel injection systems	Understand the functions and components of diesel engine fuel and governing systems, including mechanical, electronic and computer controlled systems. Understand common rail fuel systems.
	• Emission controls a. EPA regulations	Understand the functions and components of emission control systems and governmental regulations (i.e. EPA and CARB).
	b. Penalties for non-compliance	Understand penalties for non-compliance to emission regulations to the dealer, equipment owner and the technician.
	c. Emissions	Understand how emissions systems impact engine life and repairs.

Critical Functions	Key Activities	Performance Descriptions
5.3 Maintenance practices Understanding industry and OEM planned maintenance procedures	• Service literature	Locate maintenance specifications including fluid change intervals, fluid specifications (SAE/API, etc.), fuel specifications, filter replacement intervals, proper filter replacement procedures, other maintenance guidelines, etc. Understand commonly used methods for maintenance records keeping and their importance.
	• Fluid analysis • **Fuel types and grades** **Bio-fuels** **Low sulphur** **Ultra-low sulphur**	Demonstrate how to obtain proper oil, fuel and coolant samples. Demonstrate understanding in how to interpret fluid analysis results.
	• Filter dissection / inspection	Demonstrate how to inspect used filters for early warning signs of potential problems. Demonstrate preventive maintenance tasks performed to industry standards; completion of an inspection task sheet.
5.4 Component repair Understanding proper component repair procedures	Proper component repair procedures: • Parts reusability guidelines	Demonstrate, via practical exercises, parts reusability procedures and guidelines.

Critical Functions	Key Activities	Performance Descriptions
5.4 Component repair (cont.)	• Remanufactured components	Demonstrate understanding of industry remanufactured component guidelines and how to determine when to use remanufactured components. Remove and replace commonly serviced external components. Know the inspection, service, and cleaning techniques associated with replacement of these items.
5.5 Engine subsystems Engine identification of external components	Be able to identify and understand the function of the following components: • Radiator • Timing gear/front cover • Flywheel housing • Coolant manifolds • Intake manifolds • Clean air system components • Aftercooler/intercooler • Exhaust manifolds • Turbocharger: fixed & variable displacement • Water pump • Thermostat housing • Vibration damper • Oil cooler • EGR system • Exhaust after treatment systems • Heat exchanger • Valve covers • Oil pan • Crankcase ventilation filter	Locate and identify various external components. Demonstrate knowledge of vibration fundamentals. • Linear characteristics • Rotational characteristics Demonstrate understanding of the basic theory of exhaust after treatment systems like: • Diesel Particulate Filters (DPF) • Diesel Oxidation Catylist (DOC) • Selective Catalytic Reduction (SCR) • Diesel exhaust fluid (DEF) • Regeneration process

Critical Functions	Key Activities	Performance Descriptions
5.5 Engine subsystems, Engine identification of external components (cont.)	• Oil filters • Fuel filters • Coolant filters • Power take off/accessory drive • Cold start aids • Fan drives and controls	
Understanding internal engine components	Be able to identify basic internal engine components and understand the purpose of each: • Cylinder block • Cylinder head • Valvetrain • Crankshaft • Camshaft • Piston • Wrist pin • Piston rings • Cylinder liner/sleeve • Connecting rods • Bearings • Timing gear/chain/belt • Balancer shafts	Demonstrate comprehension of the removal, inspection and installation techniques associated with basic internal components. Perform identification and inspection of all internal components. Describe tasks associated with the removal, inspection and installation of internal engine components (i.e., cylinder packs). Describe bearing "roll-in" and tasks associated with in-frame overhauls. Describe valve and injector adjustments, as well as timing and idler gear installations.
Understanding basic engine subsystems	Comprehension of the key external engine driven systems: • Hydraulic systems • Accessory systems	Demonstrate knowledge of hydraulic accessories driven or operated by the engine. Demonstrate understanding of cold weather starting aids and block heaters.

Critical Functions	Key Activities	Performance Descriptions
5.6 Fuel and governing systems, mechanical and electronic systems		
Understanding basic fuel systems	Understand the basic functions of a fuel delivery system. Identify and service the different fuel systems used in various applications.	Perform basic maintenance and diagnosis of the different fuel delivery systems available today. Demonstrate a basic understanding of the adjustment and repair of various governing systems used by the major manufacturers. Understand basic hydraulic principles and fluid transfer technology.
	Comprehension of basic terms and principles used when discussing fuel systems. • Fuel delivery and performance tests • Priming/bleeding the basic system • Injector/nozzle testing • Injection pump replacement	Measure specific gravity of fuel and determine proper grade and/or contamination. Understand the use of fuel conditioners, fuel coolers and heaters. Recognize waste oil/fuel blends. Measure fuel pressure/volume with correct diagnostic tools and compare to specifications. Determine and understand the problems with the basic supply systems. Explain how contamination, such as air, water and dirt, can enter a fuel system and the effect it can have.

Critical Functions	Key Activities	Performance Descriptions
5.6 Fuel and governing systems, understanding basic fuel systems (cont.)		Proper replacement of fuel transfer pumps, filters, lines, and hoses including proper bleeding/priming procedures. Identify misfiring cylinders with appropriate tooling. Emphasis on cleanliness and safety. Replacement and timing of various injection pumps including inline, distributor and unit injector pumps.
Understanding governor fundamentals	Exercises designed to illustrate governor principles. Identification of the various fuel governing systems including mechanical, pneumatic, hydraulic and electronic controls. Comprehension of governor terminology.	Perform tasks associated with troubleshooting, adjusting and replacing governor components. Identification exercises and demonstrations of system operation.

Critical Functions	Key Activities	Performance Descriptions
5.6 Fuel and governing systems understanding governor fundamentals (cont.)	Competency demonstrated on the following fuel governing systems:	
	• Mechanical systems	Understand operation of mechanical governors and hydraulic/servo systems.
	• Hydraulic/servo systems	
	• Electronic/electric systems	Troubleshooting and programming principles of electronic governors should be emphasized. Use of scantools and PCs should be demonstrated to illustrate the self-diagnosing capabilities of this system.
	• Aneroid/smoke controls	Be able to demonstrate the ability to locate and test the following sensors: boost pressure, engine position, engine speed, throttle position, manifold pressure, fuel pressure, and high-pressure oil sensor.
5.7 Diagnostics		
Understand proper diesel engine diagnostic procedures	• Troubleshooting • Failure analysis • Tools – including PC based and onboard diagnostic systems	Tasks associated with troubleshooting emission controls and basic adjustments. Visual basic exhaust analysis; white, gray or black; as applicable.
	The ability to extract fault codes and then follow a troubleshooting procedure to a practical resolution of the problem.	Practical exercises in identification of common diesel engine problems using proper diagnostic tools and procedures.

Critical Functions	Key Activities	Performance Descriptions
5.7 Diagnostics, *Understand proper diesel engine diagnostic procedures (cont.)*		Determine root causes of failure, establish reusability, and know the recommended repair options available. Demonstrate proper use of special tools and equipment utilized in engine repair. Tasks using technical service manuals, service information, bulletins and special instructions. Proficient use of service manuals, desktop PCs, and laptops for retrieval of specifications and service procedures. Troubleshooting common problems caused by a malfunctioning engine subsystem. Testing of the engine cooling system, including overheating issues and testing procedures; especially the flow through the radiator; correct temperature drops. Use proper oils and fluids as per manufacturer specifications.
	Technical write-up competency	Demonstrate technical write-up competency • Demonstrate logic and critical thinking in identifying, evaluating and diagnosing customer complaint. • Identify the root cause of failure • Correction procedure • Machine inspection

The Standards

6. Air Conditioning/Heating

Critical Functions	Key Activities	Performance Descriptions
6.1 Fundamental knowledge	a. Heat and heat energy.	Demonstrate knowledge of heat sources, types of heat transfer, and how humidity affects heat transfer. Emphasis will be placed on factors that affect heat transfer and how to measure heat energy. Demonstrate knowledge of the following terms: 1. Sensible heat 2. Change of state 3. Saturation temperature 4. Latent heat (Hidden heat) 5. Latent heat of fusion 6. Latent heat of evaporation 7. Latent heat of condensation 8. Super heated 9. Sub-cooled 10. Vapor 11. Gas
	b. Pressure/temperature relationship of refrigerants.	Measure and calculate the effects of pressures on liquids. Emphasis will be placed on understanding and using pressure and temperature (P/T) charts.
	c. Refrigerants and refrigerant characteristics.	Describe refrigerant characteristics in relation to environmental damage. Emphasis will be placed on identification, labeling, and handling of refrigerants in accordance with EPA 609 regulations.

Critical Functions	Key Activities	Performance Descriptions
6.1 Fundamental knowledge (cont.)	d. Refrigerant oils.	Demonstrate knowledge of the types of oils used in AC systems. Demonstrate knowledge on handling and storing of refrigerant oils.
	e. Refrigerant recovery, recycle, reclaim.	Demonstrate knowledge on recovery, recycle, and reclaiming of refrigerants with respect to identifying the refrigerant currently in the system, the amounts of oil, water and particulates that are removed.
6.2 AC systems operation	a. Basic system components.	Demonstrate knowledge of the following system components: 1. Compressor 2. Condenser 3. Metering device 4. Evaporator 5. Service valves 6. Schrader valves 7. Receiver-drier 8. Accumulator 9. Lines
	b. Refrigerant cycle.	Demonstrate knowledge of refrigerant flow and states through an AC system.
	c. Refrigerant state.	Demonstrate the knowledge of the state (super heated vapor, saturated mixture, and sub-cooled liquid) of the refrigerant at various points in an AC system. Emphasis will be placed on the locations in the system that the refrigerant exists as a saturated mixture.

Critical Functions	Key Activities	Performance Descriptions
6.3 Servicing AC systems	a. System identification.	Identify various types and refrigerant capacities of AC systems. Emphasis will be placed on the ability to identify types and capacities by using manufacturers' service publications along with equipment tags, labels, and specifications. Demonstrate use of a refrigerant ID tool (gas analyzer).
	b. Connecting and disconnecting gauge manifold sets.	Demonstrate the ability to properly connect and disconnect gauge manifold sets. Emphasis will be placed on using proper procedures to purge hoses to prevent cross-contamination and introduction of non-condensables. Demonstrate the ability to connect gauge sets to systems having either Schrader or quick disconnect type service valves.
	c. System evacuation and dehydration.	Demonstrate the ability to properly evacuate and dehydrate an AC system. Demonstrate knowledge of the damage caused to AC systems by non-condensables and moisture. Emphasis will be placed on having knowledge of using micron gauges and establishing minimum evacuation pressure based on altitude as well as maximum evacuation time periods to completely dehydrate AC systems.

Critical Functions	Key Activities	Performance Descriptions
6.3 Servicing AC systems (cont.)	d. Refrigerant recovery and charging the system.	Demonstrate the ability to properly recover and charge AC systems with refrigerants. Emphasis placed on properly connecting and operating gauge manifold sets, recovery and charging equipment. Demonstrate the knowledge and ability to describe the conditions that need to exist to charge AC systems with refrigerant existing as a liquid or vapor into the high or low side.
	e. Adding oil, dye, and refrigerants to AC systems.	Demonstrate the ability to add oil, dye, and refrigerants to operating AC systems.
6.4 Testing, troubleshooting, diagnosing, and repairing AC systems	a. Ask the proper questions before beginning to diagnose; capture customer complaint.	Describe the complaint prior to beginning diagnostic tests. Describe and utilize an industry accepted diagnostic process.
	b. Visual inspection of system	Demonstrate the ability to perform a visual inspection of an AC system. a. Loose or missing service caps. b. Oily spots – connections – evaporator drain tube. c. Belt tension d. Condenser condition e. Cab filter condition f. Determine refrigerant type.
	c. Identify type of system and determine system capacity of refrigerant – weight	Demonstrate the ability to visually identify the type of AC system and determine the amount of refrigerant charge. a. TXV(H-Block) – Receiver/drier b. Metered orifice - accumulator
	d. Identify climate control systems devices and components	Demonstrate the ability to identify climate control systems and components.

Critical Functions	Key Activities	Performance Descriptions
6.4 Testing, troubleshooting, Diagnosing, and repairing AC systems (cont.)	e. Interpreting pressure and temperature readings.	Demonstrate the ability to troubleshoot and diagnose AC systems by converting system pressures to saturated mixture temperatures and comparing this to temperature readings taken at key points in the system.
	f. Metering devices and limit switches.	Demonstrate the ability to troubleshoot and diagnose metering devices and limit switch malfunctions.
	g. Leak detection.	Demonstrate the ability to detect refrigerant leaks.
	h. Contaminated system	Demonstrate to ability to determine contaminates in a system due to system component failure e.g. hoses, desiccants or compressor seal material.
	i. Component replacement/repair.	Replace or repair AC system components i.e. compressor, compressor clutch, seals, metering valves, condenser, receiver-drier, accumulator, limit switches and lines.
	j. Performance testing including control systems.	Demonstrate the ability to test the cooling capabilities of an AC system including controls. Emphasis will be placed on demonstrating the knowledge to determine the operational conditions needed to validate a performance test.
	k. Understand the relationship between AC systems and hydraulically controlled and reversing fans circuits.	
	i. Technical write-up competency	Demonstrate technical write-up competency • Demonstrate logic and critical thinking in identifying, evaluating and diagnosing customer complaint. • Identify the root cause of failure • Correction procedure • Machine inspection

Critical Functions	Key Activities	Performance Descriptions
6.5 Heating system operation	a. Basic system components.	Describe the following system components: 1. Water pump 2. Heater core 3. Coolant control valve 4. Coolant lines 5. Engine thermostat 6. Temperature control valve
	b. Water pumps.	Describe how different water pumps work.
	c. Coolant flow.	Describe coolant flow direction.
	d. Thermostats.	Demonstrate knowledge of the function of different thermostats and designs, and common troubleshooting methods.
6.6 Servicing heating systems	a. Heater core replacement.	Describe how to correctly remove and install heater core and coolant lines.
	b. Control valve.	Describe how to correctly remove and install heater system control valves.
	c. Thermostats.	Demonstrate how to correctly remove, test and install engine thermostats.
6.7 Pressurized cabs	a. Purpose and function.	State the purpose and function of pressurized cab systems.
	b. Remove, clean and install filters.	Demonstrate knowledge of how to correctly remove, inspect and replace cab air filters.

APPENDIX – TERMINOLOGY

Students are required to have a thorough understanding and comprehension of terms and abbreviations related to this Appendix. Here are some examples. The list is not exhaustive, but provides selected basic terminology; feel free to add terms as you deem appropriate.

Electrical/Electronics

A
Actuator Solenoid
Air Flow Sensor
Alternator
Alternating Current (AC)
Ambient Temperature
Ammeter
Ampere (Amp)
Ampere-Hour
Amplifier
Amplitude
Armature
Artificial Magnets
Atom
Auxiliary Speed Sensor

B
Battery
Battery Terminals
Bendix Drive

C
Calibration
Capacitor
Carbon Tracks
Charge
Charging System
Coil
Current
Current Flow
Cycle
Cycling

D
Diagnostic Code
Diode
Direct Current (DC)
Discharge
Distributor (Ignition)
Distributor Lead Connector
Dyer Drive

E
ECM
Electrical Field
Electricity
Electrochemical
Electro-Hydraulic Valve
Electrolyte
Electromagnet
Electromagnetic Clutch
Electromagnetic Field
Electromagnetic Induction
Electron
Electronic Ignition
Electronic Sensor
Electron Theory
Electronics
Electronic Control Unit (ECU)
Electronic Governor
Electronic Ignition System
Element

F
Fixed Resistor
Freouency
Fundamental Law of Magnetism
Fuse

G
Gate
Generator
Grid
Ground
Grounded Circuit
Growler

H
Hydrometer

I
Ignition Control Unit
Ignition Fire
Ignition System
Ignition Timing
Inductance
Inductor
Transistor (LGFET)
Insulator
Integrated Circuit (IC)
Integrator Circuit
Inverter
Ion
Isolation Diode

K
Knock Sensor

L
Light Emitting Diode (LED)
Lines of Force
Liquid Crystal Display (LCD)

M
Magnet
Magnetic Field
Magnetic Flux Magnetic Induction
Magnetic Lines of Force
Magnetic Material
Magnetic North
Magnetic Pickup Assembly
Magnetic South
Magnetic Switch
Magnetism
Map Sensor
Mass Airflow Sensor
Microprocessor
Milliampere
Molecule
Motor
Multimeter
Mutual Induction

N
Natural Magnet
Negative
Negative Terminal
Neutron
Non-Magnetic Material
Normally Open
Normally Closed

Ohm
Ohmmeter
Ohm'S Law
Oil Light
Open or Open Circuit
Overrunning Clutch
Oxygen Sensor

P
Parallel Circuit
Pcv Valve
Permanent Magnet
Piezo Electric Device
Plate
Polarity
Pole
Pole Shoes
Positive
Positive Terminal
Potentiometer.
Power Switch Transistor
Primary Speed Sensor
Principle Of Turning Force
Printed Circuit Board
Proton
Pulse
Pulse-Width-Modulated (PWM)

R
Rectifier
Recharge
Regulator
Relay
Reluctance
Reluctor
Resistance
Resistor
Rheostat
Right-Hand Rule
Rotor

S
Self-Induction
Semiconductor
Sending Unit
Sensor
Separator
Series Circuit
Series-Parallel Circuit
Short (Or Short Circuit)
Shunt
Slip Ring
Solenoid
Solid-State Circuits
Spark Plugs
Specific Gravity
Sprag Clutch Drive
Starter Motor
Starter Solenoid
Stator
Storage Battery
Sulfation
Switch

T
Tachometer
Temporary Magnet
Thermistor
Throttle Sensor
Transformer
Module (TVP)
Transistor

V
Vacuum Florescent Display (VDC)
Variable Resistor

Volt
Voltage
Voltage Regulator
Voltmeter

W
Watt
Watt-Hour
Wave
Waveform
Winding
Wiring Harness

Z
Zener Diode (Reverse Bias Direction Diode)

kVA - Kilo Volt Amperes
kW - Kilo Watts
kWH - Kilowatt Hour
V - Volts
I - Ampere or Current
1Ø - Single Phase (One Phase)
3Ø - Three Phase
ATS - Automatic Transfer Switch
AVR - Automatic Voltage Regulator
Hz - Hertz (Frequency)
kV - Kilovolt

Hydraulics/Hydrostatics

Accumulator
Actuator
Aeration
Air entrainment
Articulate
Attenuation
Bleed
Breakout force
Bypass
Cam
Case drain
Cavitation
Charge relief
Charge system
Closed-center system
Closed-loop system
Compensator
Controller
Cooler (oil)
Coupler
Cushion
Cycle time
Cylinder
- Double-acting cylinder
- Single acting cylinder
- Telescopic cylinder
Delta P
Detent
Displacement
Drain shuttle
Drift rate
EDC – Electronic Displacement
Efficiency
Energy
- Heat energy
- Hydraulic energy
- Kinetic energy
- Potential energy
Filter (oil)
- By-pass filter
- Full-flow filter
Filter cart
Flow meter
Flow rate
Fluid power
Force
Friction
Heat exchanger
Horsepower
Hydraulics
- Hydrodynamics
- Hydrostatics
Inert gas
Load
Load sense
Load check
Lift check
Manifold
- Distribution
- Return
- Rotary
Micron
Motor (hydraulic)
Motors
- Axial piston
- Fixed displacement
- Gear
- Gerotor
- Radial piston
- Two-speed
- Vane
- Variable displacement
Open-center system
Orbital steering valve
Orifice
Out-of-stroke
Packing
Pintle shaft
Pipe
Piston
Port
Pour point
Power beyond
Power lift
Pressure
- Back pressure
- Charge pressure
- Cracking pressure
- Differential pressure/Delta P
- Full-flow pressure
- Operating pressure
- Pilot pressure
- Pressure limiting
- Rated pressure
- Static pressure
- Surge pressure/pressure spike
- System pressure
- Working pressure
Pulsation
PSI
Pumps
- Fixed displacement
- Gear
- Piston
- Vane
- Variable displacement
Regenerative/quick drop valve
Reservoir
Restriction
Rotating groups
Sampling Ports
Seat
Servo
Servo piston
Solenoid
Sponge gun
Starvation
Strainer
Steering control unit
Stroke
Supply/feed line
Surge
Swash plate
Swivel joint/center joint
Symbols, schematic
System
Thermal expansion
Torque
Torque limiter
Tube
Valve
- Anti-cavitation valve
- Buildup valve
- Bypass regulator
- Check valve
- Closed-center
- Directional control
- Electro-hydraulic
- Flow control
- Flow divider
- Flushing valve
- Needle
- Open-center
- Pilot
- Pilot operated
- Poppet
- Pressure compensating
- Pressure control
- Pressure reducing
- Pressure sequence
- Priority valve
- Proportional flow divider
- Quick drop
- Relief
- Replenishing/relief valve
- Rotary directional
- Selector
- Sequence
- Shuttle
- Shutoff
- Spool directional
- Stroke control
- Thermal relief
- Tow valve
- Two stage relief
- Two-three-four-six-way
- Unloading
- Volume control
Valve plate
Valve stack
Velocity
Vent
Viscosity
Volume
Work port

Hydraulics/Hydrostatics Abbreviations

ANSI:	American National Standards Institute
ASAE:	American Society of Agricultural Engineers
bar:	Metric unit of measure for pressure
C:	Degrees Celsius, temperature
F:	Degrees Fahrenheit, temperature
gpm:	Gallons per minute, fluid flow
Nm:	Newton meters, metric unit of measure for torque
hp:	Horsepower
I.D.:	Inside diameter
ISO:	International Organization for Standardization
Kg/cm2:	Kilograms per square centimeter, metric unit for pressure
kPa:	Kilo Pascals, metric unit of measure for pressure
kW:	Kilowatts, metric unit of measure for power
lb-ft:	Pounds-foot, torque or turning effort
lb-in:	Pounds-inch, torque or turning effort
L/m:	Liters per minute
Mpa:	**Megapascal, ISO standard measurement for pressure**
O.D.:	Outside diameter
OEM:	Original Equipment Manufacturer
ppm:	**Parts per million**
psi:	Pounds per square inch, pressure
psia:	**Pounds per square inch absolute**
psig:	**Pounds per square inch gauge**
PWM:	**Pulse width modulation**
rpm:	Revolutions per minute
SAE:	Society of Automotive Engineers

Power Trains

Axle
Axle, hydrostatic drive
Backlash
Band-type clutches
Barrel cylinder
Bearing loads
Bearing
Bearings, ball
Bearings, roller
Belt alignment
Belt drives
Belt friction
Belt tension
Belts
Bevel gears, plain
Bevel gears, spiral
Cam drives
Carrier
Carrier Gear
Carrier bearing for midship support
Chain drives
Calipers
Clutch
Clutch pack
Collar shift transmission
Countershaft
Coolers
Coupler
CV Joints
Dampeners
Differentials
Differential pressure
Differential steering
Direct drive transmission
Disk clutch
Drop box / transfer case
Dry brakes
Electronic Control Module (ECM)
Electronic Modulation Controlled Valve (ECMV)
Electrical clutch controls
Endplay
Final drive
Fixed displacement
Fluids
Fluid coupling
Flywheel
Gear
Gear train
Gear pump /Motor-Piston type
Hybrid
Hydraulic
Hydrostatic
Hydrostatic drive
Idler gear
Impeller
Inching/modulation pedal
Infinitely variable transmission
Input shaft
Lubrication
Manual transmissions
Modulation
Modulation control valve
Output shaft
Overdrives
Pinion drives
Pinion drives
Planetary drives
Planetary gears
Pneumatic clutches
Positive traction differential
Power shift transmissions
Power take-off (PTO)
Power train
Pressure reducing valves
Proportional valve
Pump
Ratio
Reduced slip differential
Repair indicators
Reverser unit
Rim
Ring gear
Ring and pinion gears
Roller chains
Servo cylinder
Shear pins
Slip clutches
Spur
Sun gear
Swash plate
Synchromesh transmission
Tension
Torque
Torque Converter
Torque Multiplier
Universal joints / Hooke joints
V-belts
Variable Displacement Piston Pump
Variable-speed belt drives
Wear
Wear plate
Wet disc brakes
Wet disc clutch
Worm gears

Diesel Engines

Diesel Engines

Aftercooled
Back pressure
Barometric pressure
Blow-by
Bore/stroke
BTDC
Cavitation erosion
Common rail fuel systems
Compression ratio
Compression ignition
Dynamometer
ECM
Emissions
Engine displacement
Firing order
Glow plug
Heat exchanger
Horsepower
Injection system theory & timing
Mechanical efficiency
Naturally aspirated
RPM
Specific gravity
Supercharged / blower
Temperature
Thermocouple
Torque
Turbocharged
Vibration
Viscosity

Additional Acronyms/Abbreviations

AC	Volts of Alternating Current
API	American Petroleum Institute
BTU	British Thermal Unit
BTDC	Before Top Dead Center
℃	Celsius
CCA	Cold Cranking Amperes
CO	Carbon Monoxide
C.I.D.	Cubic Inch Displacement
DC	Volts of Direct Current
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EGR	Exhaust Gas Recirculation
°F	Fahrenheit
FT-LB	Foot-Pound Force
Hg	Mercury
HP	Horsepower
H_2O	Water
inHg	Inches of Mercury
In H_2O	Inches of Water
kPa	Kilopascal
N*m	Newton-meter
NOx	Mono-nitrogen oxides
O_2	Oxygen
RPM	Revolutions per minute
SCA	Supplemental Coolant Additive
SCR	Selective Catalytic Reduction
VS	Variable Speed

Emissions Terminology

ACM	After Treatment Control Module
AM	Atomization Module
APM Filter	Active Particulate Matter Filter (Not Automatic. Manually Activated)
ASU	Aftertreatment Support Module
BAT	Best Available Technology
BACT	Best Available Control Technology
BART	Best Avalable Retro fit technology
CO_X	Carbon Oxides, Mono x 1 (atom of Oxygen,) Di x 2 (atoms of Oxygen,) Tri x 3 (atoms of Oxygen.)
DEF	Diesel Exhaust Fluid
DECS	Diesel Emissions Control Strategy
DPF	Diesel Particulate Filter
EATS	Exhaust After Treatment System
ECU	Electronic Control Unit
E-ECU	Engine-Electronic Control Unit
EGR	Exhaust Gas Recirculation
E-EGR	External Exhaust Gas Recirculation
EMC	Electromagnetic Compatibility
EMS	Engine Management System
EPA	Environmental Protection Agency
HC	Hydrocarbons (Fuels)
I - EGR	Internal Exhaust Gas Recirculation
LSD	Low Sulfur Diesel 350 – 500 ppm, sulfur content
NO_X	Nitrogen Oxides, Mono x 1 (atom of Oxygen,) Di x 2 (atoms of Oxygen,) Tri x 3 (atoms of Oxygen.)
PM	Particulate Matter
PPM Filter	Passive Particulate Matter (Automatic, requires no active manual involvement)
SCR	Selective Catalytic Reduction
SOV	Shut Off Valve
SO_X	Sulfur Oxides
ULSD	Ultra Low Sulfur Diesel < 15 ppm sulfur content
VGT	Variable geometry Turbo

Air Conditioning/Heating

Air Conditioning/Heating Basic Terminology

Ambient temperature
Atmospheric pressure
Bleeding
Blower
Boiling point
BTU
Celsius
Condensation
Density
Displacement
Drier
Evaporation
Evaporator coil
Expansion valve
Fahrenheit
Gas
Heater coil
Heater evaporator blower
Heater/evaporator unit
Heater valve
Hg.
Joule
Kpa
Potentiometer
Pressure
PSI
Purging
Radiation
Receiver – Drier
Thermostat
Thermo siphon
Torque
Vacuum
Watt
Sunlight sensor
A/C controllers
Servo motors
Climate controls
Inside/outside temperature sensors

Air Conditioning Terminology

Absolute Zero
Air conditioning
Ambient temperature
Atmospheric pressure
Bleeding
Boiling point
BTU
Celsius
Compressor displacement
Condensation
Condensing temperature
Condensing pressure
Conduction of heat
Density
Desiccant
Evaporation
Fahrenheit
Head pressure
Hg.
High side
Hydrolizing action
Joule
Kpa
Latent heat
Latent heat of condensation
Latent heat of vaporization
Liquid line
Low side
Pressure drop
PSI
Purging
Radiation
Ram air
Receiver – Drier
Saturated mixture
Schrader valve
Sensible heat
Specific heat
Standard ton
Substance
Suction side
Superheat
Sweeping
Tail pipe
Total heat load
Torque
Vacuum

Standards Book, November 2017 Edition – Technical Training Committee

The following industry leaders and educators, all members of The AED Foundation Technical Training Committee (TTC), participated in the 2017 review and revision of this standards document:

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Standards Book, August 2011 Edition - Task Force Leaders

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The AED Foundation is an affiliate of Associated Equipment Distributors, the international association of distributors, suppliers, and manufacturers serving the construction equipment industry since 1919. Established in 1991, The Foundation's programs and services strengthen the equipment industry through workforce development and professional education initiatives.

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