Designation: D7583 – 16 (Reapproved 2023)

Standard Test Method for John Deere Coolant Cavitation Test[1]

This standard is issued under the fixed designation D7583; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is commonly referred to as the John Deere Cavitation Test.[2] The test method defines a heavy-duty diesel engine to evaluate coolant protection as related to cylinder liner pitting caused by cavitation.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only. The only exception is where there is no direct SI equivalent such as screw threads, national pipe threads/diameters, and tubing sizes.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* See Annex A1 for general safety precautions.

1.4 *Table of Contents:*

[1] This test method is under the jurisdiction of ASTM Committee D15 on Engine Coolants and Related Fluids and is the direct responsibility of Subcommittee D15.11 on Heavy Duty Coolants.

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[2] American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D97 Test Method for Pour Point of Petroleum Products
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)
D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer/Method)
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D482 Test Method for Ash from Petroleum Products
D524 Test Method for Ramsbottom Carbon Residue of Petroleum Products
D613 Test Method for Cetane Number of Diesel Fuel Oil
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D976 Test Method for Calculated Cetane Index of Distillate Fuels
D1121 Test Method for Reserve Alkalinity of Engine Coolants and Antirusts
D1177 Test Method for Freezing Point of Aqueous Engine Coolants
D1287 Test Method for pH of Engine Coolants and Antirusts
D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D2274 Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)
D2500 Test Method for Cloud Point of Petroleum Products and Liquid Fuels
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4485 Specification for Performance of Active API Service Category Engine Oils
D4737 Test Method for Calculated Cetane Index by Four Variable Equation
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions (Withdrawn 2003)[4]
D5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID) (Withdrawn 2003)[4]
D5967 Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E202 Test Methods for Analysis of Ethylene Glycols and Propylene Glycols
E344 Terminology Relating to Thermometry and Hydrometry

3. Terminology

3.1 *Definitions:*

3.1.1 *blind reference coolant, n*—a reference coolant, the identity of which is unknown by the test facility.

3.1.2 *blowby, n—in internal combustion engines*, the combustion products and unburned air-and-fuel mixture that enter the crankcase. **D5302**

3.1.3 *calibrate, v*—to determine the indication or output of a measuring device with respect to that of a standard. **E344**

3.1.4 *heavy-duty, adj—in internal combustion engine operation*, characterized by average speed, power output, and internal temperatures that are close to the potential maximum. **D4485**

3.1.5 *heavy-duty engine, n—in internal combustion engines*, one that is designed to allow operation continuously at or close to its peak output. **D4485**

3.1.6 *non-reference coolant, n*—any coolant other than a reference coolant, such as a research formulation, commercial coolant or candidate coolant. **D5844**

3.1.7 *non-standard test, n*—a test that is not conducted in conformance with the requirements in the standard test method; such as running in an non-calibrated test stand or using different test equipment, applying different equipment assembly procedures, or using modified operating conditions. **D5844**

3.1.8 *reference coolant, n*—a coolant of known performance characteristics, used as a basis for comparison.

3.1.9 *test coolant, n*—any coolant subjected to evaluation in an established procedure.

3.1.10 *wear, n*—the loss of material from, or relocation of material on, a surface.

3.1.10.1 *Discussion*—Wear generally occurs between two surfaces moving relative to each other, and is the result of mechanical or chemical action or by a combination of mechanical and chemical actions. **D5302**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cylinder liner, n—in internal combustion engines*, the replaceable cylinders in which the pistons move up and down and combustion takes place.

3.2.2 *overhead, n—in internal combustion engines*, the components of the valve train located in or above the cylinder head.

3.2.3 *valve train, n—in internal combustion engines*, the series of components, such as valves, crossheads, rocker arms, push rods and camshaft, that open and close the intake and exhaust valves.

4. Summary of Test Method

4.1 This test engine is a John Deere six-cylinder 10.1 L (6101H). Test operation includes a 19 min engine break-in, a 20 h coolant break-in, and 230 h in five cyclic steps.

4.2 Prior to each test, the engine is cleaned and assembled with new cylinder liners and gaskets.

4.3 The test stand is equipped with the appropriate instrumentation to control engine speed, fuel flow, and other operating parameters.

4.4 Coolant performance is characterized by determining the total liner pit count area.

5. Significance and Use

5.1 This test method was developed to evaluate the ability of a heavy-duty diesel engine coolant to provide protection against damage resulting from a phenomenon known as cylinder liner cavitation corrosion.

5.2 This test method may be used for engine coolant specification acceptance when all details of this test method are in compliance.

5.3 The design of the engine used in this test method is a production OEM diesel engine modified to consistently produce the operating conditions that accelerate damage from cylinder liner cavitation. This factor, along with the accelerated operating conditions needs to be considered when extrapolating test results.

[4] The last approved version of this historical standard is referenced on www.astm.org.

6. Apparatus

6.1 *Test Engine Configuration:*

6.1.1 *Test Engine*—The John Deere 6101H is an inline six-cylinder heavy duty diesel engine with 10.1 L of displacement and is turbocharged and aftercooled. The engine has an overhead valve configuration. It features mechanical control of fuel metering and fuel injection timing.

6.1.2 *Oil Pan Modification*—Modify the oil pan as shown in Fig. A4.9.

6.2 *Test Stand Configuration:*

6.2.1 *Engine Mounting*—Install the engine so that it is upright and the crankshaft is horizontal.

6.2.1.1 The engine mounting hardware should be configured to minimize block distortion when the engine is fastened to the mounts. Excessive block distortion may influence test results.

6.2.2 *Intake Air System*—With the exception of the intake air tube, the intake air system is not specified. A typical configuration is shown in Fig. X1.1. The air filter should be typical of air filters used for engines in heavy-duty applications. Install the intake air tube (Fig. A4.2) near the intake of the turbocharger compressor. The system shall allow control of applicable parameters listed in Table 1 and Table 2.

6.2.3 *Aftercooler*—Use a Modine aftercooler. Instructions for obtaining the correct aftercooler are listed in A2.1.

NOTE 1—Difficulty in achieving or maintaining intake manifold pressure or intake manifold temperature, or both, may be indicative of insufficient or excessive restriction.

6.2.4 *Exhaust System*—Install the exhaust tube (Fig. A4.7) near the discharge flange of the turbocharger turbine housing. The piping downstream of the exhaust tube is not specified. A method to control exhaust pressure is required.

6.2.5 *Fuel System*—The fuel supply and filtration system is not specified. A typical configuration is shown in Fig. X1.2. The fuel consumption rate is determined by measuring the rate of fuel flowing into the day tank. A method to control the fuel temperature is required.

6.2.6 *Coolant System*—The system configuration is not specified. A typical configuration consists of a non-ferrous core heat exchanger, a reservoir (expansion tank), a temperature control valve, and a vent line from the coolant vent block on the engine to the bottom of the expansion tank as shown in Fig. X1.3. This is a non-pressurized system. The system should have a sight glass to detect air entrapment.

6.2.7 *Oil System:*

6.2.7.1 *Oil Volume*—Although the system volume is not specified, an excessively large volume may increase the time required for the engine fluid temperatures to attain specification. A system volume of 50.5 L or less, including the volume contained in the engine, has proven satisfactory.

6.2.7.2 *Pressurized Oil Fill System*—The oil fill system is not specified. A typical configuration includes an electric pump, a 50 L reservoir, and a transfer hose. The location for the pressurized fill is located on the filter head (Fig. A4.12).

6.2.7.3 *External Oil System*—Configure the external oil system according to Fig. A4.12. Use a 10 L to 13 L container for the external oil reservoir. Use Viking Pump model number SG053514. Nominal pump motor speed is 1725 r/min.

6.2.7.4 *Oil Sample Valve Location*—Locate the oil sample valve on the return line from the external oil system to the engine. Locate the valve as close to the return pump as possible (Fig. A4.11).

6.2.7.5 *Unacceptable Oil System Materials*—Brass or copper fittings can influence used oil wear metals analyses and shall not be used in the external oil system.

6.3 *Crankcase Aspiration*—Vent the blowby gas at the port located on the left side of the valve cover (Fig. A4.10). Route the vent line downward from the valve cover port to the blowby canister. The line shall be between 1.2 m and 1.8 m in length and minimum 15.9 mm inside diameter.

6.4 *Blowby Rate*—The flow rate measurement device is not specified. The blowby canister shall be a minimum of 35 L in volume. The outlet of the blowby canister to the flow rate device shall be a minimum of 31.8 mm inside diameter. The hose connecting the blowby canister to the flowrate device shall be a minimum of 38.1 mm inside diameter. The length of this hose is not specified.

6.5 *System Time Responses*—The maximum allowable system time responses are shown in Table 3.

6.6 *Clearance Measurements*—Piston skirt outside diameter and liner inside diameter, piston pin, rod and main bearings.

6.6.1 *Piston Skirt*—Measure and record the piston skirt outside diameter.

Spec = 130.04–130.05 mm, max

6.6.2 *Main Bearings*—Inspect the crankshaft main bearings for condition and clearance. The crankshaft will have to be supported to perform the plastigage clearance check.

TABLE 1 230-Hour Test Sequence Controlled Conditions[A]

Parameter	Unit	Stage				
		Low Idle	Peak Torque	Full Load	Over Speed	Fast Idle
Stage Length	min	1.5	1	4	1	0.5
Speed	r/min	900 ± 5	1500 ± 5	2100 ± 5	2300 ± 5	2500 ± 5
Power	kW	record	record	record	record	record
Torque (typical)[A]	N·m	0 ± 5	1680 ± 10	1220 ± 10	1080 ± 10	0 ± 5
Intake Manifold Temperature[A]	°C	93 ± 5	100 ± 5	100 ± 5	100 ± 5	100 ± 5
Coolant Out Temperature[A]	°C	70 ± 2	70 ± 2	70 ± 2	70 ± 2	70 ± 2
Fuel In Temperature	°C	40 ± 2	40 ± 2	40 ± 2	40 ± 2	40 ± 2
Turbo Compressor Inlet Temperature[A]	°C	30 ± 2	30 ± 2	30 ± 2	30 ± 2	30 ± 2
Exhaust Pressure	kPa	record	record	5 ± 1	record	record

[A] Intended set point, but may vary due to cyclic conditions.

TABLE 2 230-Hour Test Sequence Typical Conditions

Parameter	Unit	Stage				
		Low Idle	Peak Torque	Full Load	Over Speed	Fast Idle
Fuel Flow	Kg/h	0 ± 1	40 ± 1	68 ± 1	68 ± 1	45 ± 1
Blowby Flow	l/min	85 ± 2	311 ± 2	311 ± 2	283 ± 2	141 ± 2
Coolant In Temperature	°C	56 ± 2	66 ± 2	63 ± 2	61 ± 2	61 ± 2
Oil Gallery Temperature	°C	82 ± 2	83 ± 2	89 ± 2	91 ± 2	90 ± 2
Intake Manifold Pressure	kPa	≥1	≥70	≥70	≥70	≥55
Exhaust Temperature	°C	260 ± 100	705 ± 100	760 ± 100	760 ± 100	427 ± 100
Fuel Pressure	kPa	record	record	record	record	record
Oil Gallery Pressure	kPa	record	record	record	record	record
Coolant Inlet Pressure	kPa	record	record	record	record	record
Coolant Outlet Pressure	kPa	record	record	record	record	record
Coolant System Pressure	kPa	open	open	open	open	open
Crankcase Pressure	kPa	record	record	record	record	record
Inlet Air Pressure	kPa	record	record	record	record	record

TABLE 3 Maximum Allowable System Time Responses

Measurement	Time Response (s)
Speed	2.0
Temperature	3.0
Pressure	3.0
Flow	15.0

Spec = 0.046–0.152 mm, max

6.6.3 *Rod Bearings*—Inspect the crankshaft main bearings for condition and clearance. The crankshaft will have to be supported to perform the plastigage clearance check.

Spec = 0.046–0.152 mm, max

6.6.4 *Cylinder Liners*—Measure and record the cylinder liners inside diameter.

OEM liner ID spec = 130.165–130.175 mm
Test liner ID spec = Piston Skirt OD + 0.254 mm
Test liner OD spec = Block ID – 0.1016 mm

6.6.5 *Piston Ring End Gap*—Measure and record the piston ring end gap and the oil control ring side clearance.

Spec Top = 0.432–0.686 mm
2nd = 1.016–1.27 mm
Oil = 0.330–0.635 mm
OCSC = 0.061–0.102 mm
New Max Used = 0.165 cm

6.6.6 *Piston Pin to Connecting Rod Bushing*—Measure and record the piston pin to connecting rod bushing clearance.

Spec = 0.018–0.762 mm

6.6.7 *Connecting Rod Bearing Clearance*—Install the pistons and connecting rods. Use plastigage to measure the connecting rod bearing clearance.

Spec = 0.051–0.127 mm

6.6.8 *Cylinder Head*—Measure and record the cylinder head specifications in accordance with Table 4.

7. Engine and Cleaning Fluids

7.1 *Engine Oil*—Approximately 70 L of John Deere Plus 50 TY6391 is required to complete the test.

7.2 *Test Fuel*—Approximately 4500 gal of Off-Highway diesel fuel is required to complete the test. Fuel property tolerances are shown in Annex A5.

TABLE 4 Cylinder Head Rebuild Specifications

Head Flatness	0.1016 mm entire length or width
Head Thickness	166.294 mm to 166.802 mm
Intake Valve Stem OD	9.462 mm to 9.487 mm
Exhaust Valve Stem OD	9.436 mm to 9.462 mm
Valve Guide ID	9.512 mm to 9.538 mm
Valve Guide Installed Height	36.170 mm to 39.167 mm
Intake Valve to Guide Clear	0.025 mm to 0.127 mm
Exhaust Valve to Guide Clear	0.051 mm to 0.152 mm
Valve Seat Run Out	0.051 mm max
Intake Spring Tension Closed	35.3802 kg to 40.82331 kg at 52.578 mm
Intake Spring Tension Open	82.55381 kg to 89.81129 kg at 38.1 mm
Exhaust Spring Tension Closed	29.02991 kg to 34.47302 kg at 54.61 mm
Exhaust Spring Tension Open	81.19303 kg to 88.45051 kg at 38.608 mm
Intake Valve Seat Angle	29.5 degrees to 30.5 degrees
Exhaust Valve Seat Angle	37 degrees to 38 degrees
Intake Valve Recession	2.692 mm to 3.327 mm
Exhaust Valve Recession	1.626 mm to 2.286 mm
Intake Valve Lash	0.330 mm to 0.432 mm
Exhaust Valve Lash	0.584 mm to 0.686 mm
Intake Seat Width	1.600 mm to 2.997 mm
Exhaust Seat Width	1.194 mm to 2.997 mm

7.3 *Engine Coolant*—Use specified test coolant mixed with deionized water.

7.4 *Solvent*—Use a solvent which meets Specification D235 for mineral spirits, Type II, Class C for Aromatic Content (0–2 % vol), Flash Point (142 °F / 61 °C, min), and Color (not darker than +25 on Saybolt Scale or 25 on Pt-Co Scale).[5] Obtain a Certificate of Analysis for each batch of solvent from the supplier. (**Warning—**Combustible. Health Hazard. Use adequate safety precautions with all solvents and cleaners.)

8. Preparation of Apparatus

8.1 *Cleaning of Parts:*

8.1.1 *General*—The preparation of test engine components specific to the John Deere Coolant Cavitation Test are indicated in this section. Use the John Deere publication CTM61 (13MAY93) 6101 Component Technical Manual[6] for preparation of other engine parts. Take precautions to prevent rusting of iron components.

[5] Cleaning solvent that meets the requirements of 7.4 is available from local petroleum products suppliers.
[6] Available from http://www.deere.com.

8.1.2 *Engine Block*—Disassemble the engine, including removal of the pistons and cylinder liners. Thoroughly clean the surfaces and oil passages (galleries). Removal of camshaft bearings is at the discretion of the laboratory.

8.1.3 *Cylinder Head*—Disassemble and clean the cylinder head. Use a brush as necessary to remove deposits.

8.1.4 *Rocker Cover and Oil Pan*—Clean the rocker cover and oil pan. Use a brush as necessary to remove deposits.

8.1.5 *External Oil System*—Flush the internal surfaces of the oil lines and the external reservoir with solvent. Repeat until the solvent drains clean. Flush solvent through the oil pumps until the solvent drains clean.

8.1.6 *Rod Bearing Cleaning and Measurement:*

8.1.6.1 Clean the rod bearings with Stoddard solvent. Use a non-metallic soft bristle brush if necessary. Avoid handling the rod bearings with bare hands. Use gloves or plastic covered tongs.

8.1.6.2 Spray the rod bearings with air until dry.

8.1.6.3 Rinse the rod bearings in pentane and dry with air.

8.1.6.4 Perform the plastigage clearance check (0.051 cm to 0.127 cm max).

8.1.7 *Ring Cleaning and Measurement:*

8.1.7.1 After the piston rings have been removed from the piston use carburetor cleaner or Stoddard solvent to soften the carbon deposits. Once the deposits have softened use a hand held brass wire brush or a brass pick to remove the carbon deposits. Scotch-Brite (3M part number 7440) may also be used to help remove carbon deposits. Once the piston rings have had all of the carbon removed spray them down with Stoddard solvent and dry them with compressed air. Place the piston rings in clean numbered bags for later measurement and installation on the pistons. Avoid handling the rings with bare hands. Use gloves or plastic covered tongs.

8.1.8 *Injector Nozzle:*

8.1.8.1 Verify nozzle retaining nut torque is tightened to 88 N·m.

8.1.8.2 Test nozzle for opening pressure, leakage, chatter, and spray pattern per the CTM61 component technical manual.

8.1.9 *Pistons*—Care must be taken in cleaning the pistons in order to prolong life.

8.1.9.1 After the pistons have been removed from the connecting rods remove loose carbon and oil by washing the pistons in hot soapy water or Stoddard solvent.

8.1.9.2 Carefully remove the piston rings with ring pliers and place them in numbered plastic bags.

8.1.9.3 Soak the pistons in carburetor cleaner until the carbon deposits are softened, then wash the pistons in hot soapy water to neutralize the carburetor cleaner.

8.1.9.4 Remove any remaining carbon deposits with a hand held brass wire brush or a brass pick.

8.1.9.5 When all of the carbon deposits have been removed from the pistons spray them down with solvent and dry them with compressed air.

8.1.9.6 Place the pistons in clean numbered bags for later measurement and installation.

8.2 *Engine Assembly:*

8.2.1 *General*—Except as noted in this section, use the procedures indicated in the John Deere CTM61 (13MAY93) Component Technical Manual. Assemble the engine with new liners and gaskets.

8.2.2 *Parts Reuse and Replacement*—Engine components may be reused or replaced at the discretion of the laboratory, except as noted in 8.2.6.

8.2.3 *Build-Up Oil*—Use John Deere Plus 50 SAE 15w-40.

8.2.4 *Coolant Thermostat*—Lock the engine coolant thermostat open.

8.2.5 *Fuel Injectors*—The fuel injectors may be reused. Dedicate the injectors to a particular cylinder.

8.2.6 *New Parts*—The only standard new parts are liners and gaskets.

8.3 *Operational Measurements:*

8.3.1 *Units and Formats*—See Annex A7.

8.3.2 *Instrumentation Calibration:*

8.3.2.1 *Fuel Consumption Rate Measurement Calibration*—Calibrate the fuel consumption rate measurement system before every reference test sequence and at least once every twelve months. Temperature-compensate volumetric systems, and calibrate them against a mass flow device. The flow meter located on the test stand shall indicate within 0.2 % of the calibration standard. Trace the calibration standard to national standards.

8.3.2.2 *Temperature Measurement Calibration*—Calibrate the temperature measurement systems before every reference test sequence and at least once every twelve months. Each temperature measurement system shall indicate within ±0.5° C of the laboratory calibration standard. Trace the calibration standard to national standards.

8.3.2.3 *Pressure Measurement Calibration*—Calibrate the pressure measurement systems before every reference test sequence and at least once every 12 months. Trace the calibration standard to national standards.

8.3.3 *Temperatures:*

8.3.3.1 *Measurement Location*—The temperature measurement locations are specified in this section. The measurement equipment is not specified. Install the sensors such that the tip is located midstream of the flow unless otherwise indicated. The accuracy and resolution of the temperature measurement sensors and the complete measurement system shall follow the guidelines detailed in ASTM Research Report RR:D02-1218.[7]

8.3.3.2 *Coolant Out Temperature*—Install the sensor in a ¼ in. NPT hole at the top of the coolant out tube (Fig. A4.4).

8.3.3.3 *Coolant In Temperature*—Install the sensor located on the right side of the coolant pump intake housing in a ¼ in. NPT hole (Fig. A4.3).

8.3.3.4 *Fuel In Temperature*—Install the sensor in a ¼ in. NPT hole located on the side of the injector pump (Fig. A4.5).

8.3.3.5 *Oil Gallery Temperature*—Install the sensor in a ¼ in. NPT hole located at the right rear of the engine (Fig. A4.8).

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1218. Contact ASTM Customer Service at service@astm.org.

8.3.3.6 *Intake Air Temperature*—Install the sensor in a ¼ in. NPT hole located approximately 26 in. from the compressor inlet (Fig. A4.2).

8.3.3.7 *Intake Air after Compressor Temperature*—Install the sensor in a ¼ in. NPT hole located approximately 24 in. from the compressor outlet (Fig. A4.1).

8.3.3.8 *Intake Manifold Temperature*—Install the sensor in a ¼ in. NPT hole located approximately 24 in. from the modine outlet (Fig. A4.1).

8.3.3.9 *Exhaust Temperature*—Install the sensors on the center flange of the exhaust manifold as per Fig. A4.6.

8.3.3.10 *Exhaust after Turbo Temperature*—Install the sensor in a ¼ in. NPT hole located approximately 48 in. from the turbo outlet (Fig. A4.7).

8.3.3.11 *Additional Temperatures*—Monitor any additional temperatures considered to be beneficial.

8.3.4 *Pressures:*

8.3.4.1 *Measurement Location and Equipment*—The pressure measurement locations are specified in this section. The measurement equipment is not specified. The accuracy and resolution of the pressure measurement sensors and the complete measurement system shall follow the guidelines detailed in ASTM Research Report RR:D02-1218.[7]

8.3.4.2 *Condensation Trap*—A condensation trap should be installed at the lowest elevation of the tubing between the pressure measurement location and the final pressure sensor for Crankcase Pressure, Intake Air Pressure, and Exhaust Pressure. Route the tubing to avoid intermediate loops or low spots before and after the condensation trap.

8.3.4.3 *Coolant Pressure*—Tank is open to atmosphere.

8.3.4.4 *Fuel Pressure*—Measure the pressure at the ¼ in. NPT hole located on the side of the injector pump (Fig. A4.5).

8.3.4.5 *Oil Gallery Pressure*—Measure the pressure at the ¼ in. NPT hole located at the right rear of the engine (Fig. A4.8).

8.3.4.6 *Intake Air Pressure*—Measure the pressure at the ¼ in. NPT hole located approximately 26 in. from the compressor inlet (Fig. A4.2).

8.3.4.7 *Intake Air Pressure after Compressor*—Measure the pressure at the ¼ in. NPT hole located approximately 24 in. from the compressor outlet (Fig. A4.1).

8.3.4.8 *Intake Manifold Pressure*—Measure the pressure at the ¼ in. NPT hole located approximately 24 in. from the modine outlet (Fig. A4.1).

8.3.4.9 *Exhaust after Turbo Pressure*—Measure the pressure at the ¼ in. NPT hole located approximately 48 in. from the turbo outlet (Fig. A4.7).

8.3.4.10 *Crankcase Pressure*—Measure the pressure at the boss on the top-front, left-hand side of the rocker cover (Fig. A4.10).

8.3.4.11 *Additional Pressures*—Monitor any additional pressures considered to be beneficial.

8.3.5 *Flow Rates:*

8.3.5.1 *Flow Rate Location and Measurement Equipment*—The flow rate measurement locations are specified in this section. The equipment for the blowby rate and the fuel rate are not specified. The accuracy and resolution of the flow rate measurement system shall follow the guidelines detailed in ASTM Research Report RR:D02-1218.[7]

8.3.5.2 *Blowby*—The device used to measure the blowby flow rate is not specified. See 6.4 for blowby measurement system configuration details.

8.3.5.3 *Fuel Flow*—The fuel consumption rate is determined by measuring the fuel flowing to the day tank (Fig. X1.2).

9. Engine/Stand Calibration and Non-Reference Oil Tests

9.1 *General*—Calibrate the test stand by conducting a test with the designated reference coolant. Submit the results to the ASTM Test Monitoring Center (TMC) for determination of acceptance according to the Lubricant Test Monitoring System (LTMS).[8]

9.2 *New Test Stand*—A new test stand is defined as a test stand that has never been calibrated.

9.2.1 *New Test Stand Calibration*—New stand calibration is determined according to the LTMS.[8]

9.3 *Stand Calibration Period*—The calibration period is 12 months for all calibration periods. Up to 12 operationally valid, non-reference coolant tests may be completed during each calibration period.

9.3.1 The TMC may schedule more frequent reference coolant tests or extend the calibration period.

9.4 *Stand Modification and Calibration Status*—Stand calibration status may be invalidated by conducting any non-standard test or modification of the test and control systems or both. A non-standard test includes any test conducted under a modified procedure, non-procedural hardware, controller set-point modifications, or any combination thereof. The TMC should be contacted prior to any changes to determine the effect on the calibration status.

9.5 *Test Numbering System:*

9.5.1 *General*—The test number has three parts, W-X-Y-Z. W represents the test stand number, X represents the stand run number, Y represents the engine serial number, and Z represents the block run number. For example, test number 27-10-4B4607-2 indicates stand number 27, stand test number 10, engine serial number 4B4607, and the second test on engine number 4B4607.

9.5.2 *Reference Coolant Tests*—The block run number shall be 1 for the first reference attempt. If a second attempt must be made the block run number shall be 2, etc. For example, if two consecutive reference coolant tests were conducted and the first test number was 27-10-4B4607-1, the second test number would be 27-11-4B4607-2 etc.

9.5.3 *Non-Reference Coolant Tests*—Increment X and Z by one for each non-reference test start.

9.6 *Reference Coolant Test Acceptance:*

9.6.1 Reference coolant test acceptance is determined in accordance with the LTMS.[8]

9.7 *Reference Coolant Accountability:*

[8] Available from the ASTM Test Monitoring Center at Carneige Mellon University, 6555 Penn Avenue, Pittsburgh, PA 15206, http://www.astmtmc.cmu.edu.

9.7.1 Laboratories shall provide a full accounting of the identification and quantities of all reference coolant used. No physical or chemical analyses of reference coolant shall be performed without written permission from the TMC. In such an event, include the written confirmation and the data generated in the reference coolant test report.

9.7.2 Retain used reference coolant samples for 90 days from the EOT date.

9.8 *Last Start Date*—In order for a non-reference coolant test to be within a calibration period, the assembled engine shall be cranked (10.3.3) prior to the expiration of the calibration period (9.3).

9.9 *Donated Reference Coolant Test Programs*—The surveillance panel is charged with maintaining effective reference coolant test severity and precision monitoring. During times of new parts introductions and procedural revisions, it may be necessary to evaluate the possible effects on severity and precision levels. The surveillance panel may choose to conduct a program of donated reference coolant tests in those laboratories participating in the monitoring system, in order to quantify the effect of a particular change on severity and precision. Typically, the surveillance panel requests its panel members to volunteer enough reference coolant test results to create a robust data set. Broad laboratory participation is needed to provide a representative sampling of the industry. To ensure the quality of the data obtained, donated tests are conducted on calibrated test stands. The surveillance panel shall arrange an appropriate number of donated tests and ensure completion of the test program in a timely manner.

9.10 *Adjustments to Reference Coolant Calibration Periods:*

9.10.1 *Procedural Deviations*—On occasions when a laboratory becomes aware of a significant deviation from the test method, such as might arise during an in-house review or a TMC inspection, the laboratory and the TMC shall agree on an appropriate course of action to remedy the deviation. This action may include the shortening of existing reference coolant calibration periods.

9.10.2 *Parts and Fuel Shortages*—Under special circumstances, such as industry-wide parts or fuel shortages, the surveillance panel may direct the TMC to extend the time intervals between reference coolant tests. These extensions shall not exceed one regular calibration period.

9.10.3 *Reference Coolant Test Data Flow*—To ensure continuous severity and precision monitoring, calibration tests are conducted periodically throughout the year. There may be occasions when laboratories conduct a large portion of calibration tests in a short period of time. This could result in an unacceptably large time frame when very few calibration tests are conducted. The TMC can shorten or extend calibration periods as needed to provide a consistent flow of reference coolant test data. Adjustments to calibration periods are made such that laboratories incurred no net loss (or gain) in calibration status.

9.10.4 *Special Use of the Reference Coolant Calibration System*—The surveillance panel has the option to use the reference coolant system to evaluate changes that have potential impact on test severity and precision. This option is only taken when a program of donated tests is not feasible. The surveillance panel and the TMC shall develop a detailed plan for the test program. This plan requires all reference coolant tests in the program to be completed as close to the same time as possible, so that no laboratory/stand calibration is left in an excessively long pending status. In order to maintain the integrity of the reference coolant monitoring system, each reference coolant test is conducted so as to be interpretable for stand calibration. To facilitate the required tests and scheduling, the surveillance panel may direct the TMC to lengthen and shorten reference coolant calibration periods within laboratories such that the laboratories incur no net loss (or gain) in calibration status.

10. Procedure

10.1 *Engine Installation and Stand Connections*—Install the test engine on the stand and connect the engine to the stand support equipment.

NOTE 2—A final check of valve and injector settings is recommended at this time.

10.2 *Break-in*—Perform a break-in on each new engine build prior to the start of the 250 h test procedure.

10.2.1 *Coolant System Fill for Break-in:*

10.2.1.1 Install a new Deere RE1192 coolant filter.

10.2.1.2 Charge the cooling system with 52 L of the specified concentration of new coolant and record the weight.

10.2.1.3 *Coolant Sample*—Take a 0.5 L coolant sample at the start of the break-in.

NOTE 3—The coolant system should be pressurized to specification and checked for leaks prior to adding the engine oil.

10.2.2 *Oil Fill for Break-in:*

10.2.2.1 Install a new Deere RE44647 oil filter.[9]

10.2.2.2 Use the pressurized oil fill system (6.2.7.2) to charge the engine with 33.7 L of John Deere Torque Guard Plus 50 oil at the location shown in Fig. A4.12.

10.2.2.3 *Oil Sample*—Take a 0.25 L oil sample at the start of the break-in.

10.2.3 *Engine Build Committed*—After the test coolant has been introduced into the engine, the engine build and the test number are valid only for the respective test. However, if the engine has not been started (whereby the test parts have not been subjected to heated coolant), then the new build may be used again.

10.2.4 *Break-in Conditions*—Start the engine and proceed directly to the break-in (Table 5 and Table 6).

10.2.5 *Shutdown during Break-in*—If a shutdown occurs during the break-in, rerun the entire break-in.

10.2.6 At the completion of the break-in, perform a normal shutdown (Table 7) and shut off the engine.

10.2.7 Drain the oil from the engine and the external oil system.

10.2.8 Remove the RE44647 oil filter.

10.2.9 Properly dispose of the drain oil and oil filter.

10.2.10 Once completed, the break-in is not repeated for the respective test.

[9] Available from a Cummins parts distributor.

TABLE 5 Break-in Conditions

Parameter	Unit	Stage				
Stage Length	min	5	2	10	5	1
Speed	r/min	700	1150	2100	2100	2500
Torque	N·m	13.5	40	760	1186	13.5
Coolant Out Temperature	°C			70 ± 2		
Fuel In Temperature	°C			40 ± 2		
Turbo Compressor Inlet Air Temperature	°C			30 ± 2		
Intake Manifold Temperature	°C			100 ± 2		
Exhaust Pressure	kPa			3.5 ± 2		

TABLE 6 Break-in Typical Conditions

Parameter	Unit	Stage				
Fuel Flow	Kg/h	4.5	20	41	68	27
Oil Gallery Temperature	°C			85 ± 2		
Oil Gallery Pressure	kPa			380 ± 4.5		
Intake Manifold Pressure	kPa			155 ± 7		
Crankcase Pressure	kPa			71 ± 7		
Inlet Air Pressure	kPa			record		
Coolant System Pressure	kPa			open		

TABLE 7 Shutdown Conditions

Parameter	Unit	Stage	
		A	B
Stage Length	min	2	5
Speed	r/min	Ramp down to 1200	900
Torque	N·m	Ramp down to low load (~20 Nm)	No load
Coolant Out Temperature	°C	70 max	70 max
Intake Manifold Temperature	°C	100 max	100 max

NOTE 4—Use the break-in as an opportunity to confirm engine performance and to make repairs prior to the start of the 250 h test procedure.

10.3 *250-Hour Test Procedure:*

10.3.1 *Coolant Fill for Test*—Charge the system with approximately 52 L of the specified concentration of new coolant and record the weight.

10.3.1.1 *Zero-hour Coolant Sample*—Take a 0.7 L coolant sample of the fresh coolant from the original container.

10.3.2 *Oil Fill for Test*—Use the pressurized oil fill system (6.2.7.2) to charge the engine with 33.7 kg of John Deere Plus 50 oil at the location shown in Fig. A4.12.

10.3.2.1 *Zero-hour Oil Sample*—Take a 0.4 L oil sample of the fresh oil from the original oil container.

10.3.3 *Warm Up*—This warm-up procedure is used after the break-in and every time the engine is brought up.

10.3.3.1 Start the engine and perform the warm-up (Table 8 and Table 9).

10.3.3.2 *Shutdown During Warm-up*—If a shutdown occurs during the warm-up restart the warm-up procedure.

TABLE 8 Warm-up Conditions

Parameter	Unit	Stage		
		A	B	C
Stage Length	min	5	5	5
Speed	r/min	900	1200	2100
Torque	N·m	0	520	766
Coolant Out Temperature	°C	70 max	70 max	70 max
Intake Manifold Temperature	°C	100 max	100 max	100 max

TABLE 9 Warm-up Typical Conditions

Parameter	Unit	Stage		
		A	B	C
Oil Gallery Temperature	°C	50	62	78

10.3.4 *20-Hour Steady State Extended Break-in*—After the warm-up, proceed directly to the 20-Hour Steady State Extended Break-in (Table 10 and Table 11).

10.3.4.1 Run the engine at the conditions stated in the 20-Hour Steady State Extended Break-in Conditions (Table 10).

10.3.4.2 *Shutdown During Extended Break-in*—If a shutdown occurs during the 20-Hour Extended Break-in, Stop the Test Timer and proceed to the Normal Shutdown (Table 7).

10.4 *230-Hour Cyclic*—No intervention is necessary between the 20-Hour Steady State and the 230-Hour Cyclic portions of the test.

10.4.1 Run the engine at the conditions stated in the 230-Hour Test Sequence (Table 1).

10.4.2 *Shutdown During 230-Hour Cyclic*—If a shutdown occurs during the 230-Hour Cyclic, Stop the Test Timer and proceed to the Normal Shutdown (Table 7).

10.5 *Shutdown and Maintenance*—The test may be shut down at the discretion of the laboratory to perform repairs. However, the intent of this test method is to conduct the 250 h test procedure without shutdowns.

10.5.1 *Normal Shutdown*—Proceed directly from the operating conditions to the shutdown schedule (Table 7).

10.5.2 *Emergency Shutdown*—An emergency shutdown occurs when the normal shutdown cannot be performed, such as an alarm condition.

10.5.3 *Maintenance*—Engine components or stand support equipment, or both, may be repaired or replaced at the discretion of the laboratory and in accordance with this test method.

10.5.4 *Downtime*—The limit for total downtime and number of shutdowns is not specified. Record all shutdowns, pertinent actions, and total downtime during the 250 h test procedure.

TABLE 10 20-Hour Steady State Extended Break-in Conditions

Parameter	Unit	Stage
Stage Length	h	20
Speed	r/min	2100 ± 10
Torque	N·m	766 ± 5
Coolant Out Temperature	°C	70 ± 2
Fuel In Temperature	°C	40 ± 2
Turbo Inlet Air Temperature	°C	30 ± 2
Intake Manifold Temperature	°C	100 ± 2
Exhaust Pressure	kPa	3.5 ± 2

TABLE 11 20-Hour Steady State Extended Break-in Typical Conditions

Parameter	Unit	Stage
Fuel Flow	kg/h	42 ± 2
Oil Gallery Temperature	°C	85 ± 2
Intake Manifold Pressure	kPa	155 ± 7
Oil Gallery Pressure	kPa	380 ± 4.5
Crankcase Pressure	kPa	71 ± 7
Inlet Air Pressure	kPa	record
Coolant System Pressure	kPa	open
Coolant Inlet Pressure	kPa	record
Coolant Outlet Pressure	kPa	record

10.6 *Operating Conditions:*

10.6.1 *Stage Transition Times*—Less than 10 s with the exception of Intake Manifold Temperature.

10.6.2 *Test Timer*—The 250 h test timer starts when all controlled parameters in the Steady State Extended Break-in are within specification. If a shutdown occurs, stop the test timer immediately at the initiation of the shutdown. The test timer shall resume when the test has been returned to the appropriate stage and all controlled parameters are within specification.

10.6.3 *Operational Data Acquisition*—Record all operational parameters shown in Tables 1 and 10, with automated data acquisition 15 s before the end of each step.

10.6.4 *Operational Data Reporting*—The operational data is reported on Form 5 listed in Annex A8, Table A8.1.

10.6.5 *Coolant Sampling*—Take a coolant sample at the end of each 125 h period. Do not shut down the engine for coolant sampling.

10.6.5.1 *Coolant Sample*—Remove a nominal 500 mL coolant sample and retain at the stand. Identify the coolant sample container with the test number, coolant code, date, and test hour.

10.6.6 *Oil Sampling*—Take an oil sample at the end of each 50 h period before any new oil is added during the oil addition procedure. Do not shut down the engine for oil sampling and oil addition.

10.6.6.1 *Oil Sample*—Remove a nominal 250 mL purge. Remove a nominal 250 mL oil sample and retain at the stand. Return the purge to the engine oil system. Identify the oil sample container with the test number, date, and test hour.

10.6.6.2 *Oil Addition*—Verify oil adder tank is approximately 50 % full after 1 h. After the oil sampling has been completed at the end of each 50 h period, add John Deere Plus 50 as needed to return to the full mark.

10.7 *End of Test (EOT):*

10.7.1 *Shutdown*—After completing the test procedure, perform a normal shutdown (Table 7), and shut down the engine. Disconnect the test stand support equipment. (**Warning—**The coolant and oil may be hot. The installation of a valve to safely vent the coolant system pressure is recommended.)

10.7.2 *Oil Drain*—Drain the oil from the engine and the external oil system and retain at stand.

10.7.3 *Coolant Drain*—Drain the coolant from the engine and external cooling system and retain at stand.

10.7.4 *Engine Disassembly*—Disassemble the engine and remove the liners for ratings.

11. Calculations, Ratings and Test Validity

11.1 *Liner Pit Count*—Using a microscope, place the transparent grid (squares are 2.14 mm) on the liner surface over the pitted area(s) of the liner. Assign a count of one pit area to each grid square containing a pit or pits. The pit (or pits) does not have to cover the entire square. If any portion of a pit or group of pits is contained in a square, it receives a count of one. Total all the pit areas on a given liner. Total the pit areas on all six liners, and this is the total pit count for the coolant being tested.

11.2 *Coolant Analysis*—Typical coolant analysis results are itemized in Annex A9.

11.3 *Oil Analysis*—Typical oil analysis results are listed in Annex A10.

11.4 *Assessment of Operational Validity*—Determine operational validity according to Annex A11.

12. Report

12.1 *Report Forms*—For reference coolant tests the standardized report form set and data dictionary for reporting test results and for summarizing the operational data are required. The report forms and data dictionary are available from the TMC. Instructions for obtaining the report forms and data dictionary and a list of report forms are shown in Annex A8.

12.1.1 Report latest stand Reference Data, Pit Counts, Operational Summary, Coolant and Oil Analysis, Downtime, and Photographs on the appropriate form in the test report.

12.2 *Reference Coolant Test*—Send the test report forms and any other supporting information, to the TMC[8] by facsimile or electronic transmission within five days of the EOT date for test acceptance determination. Reference oil test reports should be mailed or electronically transmitted to the TMC within 30 days of the EOT date.

12.3 *Electronic Transmission of Test Results*—Use ASTM Data Communications Committee Test Report Transmission Model (Section 2–Flat File Transmission Format).

13. Precision and Bias

13.1 *Precision*—Precision is based on operationally valid calibration test results monitored by the TMC. The research report contains industry data developed prior to the establishment of this test method.

13.1.1 *Intermediate Precision (formerly called repeatability) Conditions*—Conditions where test results are obtained with the same test method using the same test coolant, with changing conditions such as operators, measuring equipment, test stands, test engines, and time.

13.1.2 *Intermediate Precision Limit (i.p.)*—The difference between two results obtained under intermediate precision conditions that would in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 1 in only one case in twenty.

13.2 *Reproducibility Conditions*—Conditions where test results are obtained with the same test method using the same test coolant in different laboratories with different operators using different equipment.

13.2.1 *Reproducibility Limit (R)*—The difference between two results obtained under reproducibility conditions that would, in the long run, in the normal and correct conduct of the test method, exceed the values in Table 7 in only one case in twenty.

13.3 *Bias*—Bias is determined by applying a defined statistical technique to calibration test results. When a significant bias is determined, a severity adjustment is applied to the non-reference coolant test result.

14. Keywords

14.1 cavitation; engine coolant; heavy duty; liner pitting; piston liners

ANNEXES

(Mandatory Information)

A1. SAFETY PRECAUTIONS

A1.1 The operation of engine tests may expose personnel and facilities to safety hazards. Personnel trained and experienced with engine testing should perform the design, installation, and operation of test stands.

A1.2 Guards (shields) should be installed around all external moving, hot, or cold components. Design the guard to contain the energy level of a rotating component should the component break free. Fuel, oil, coolant and electrical wiring should be properly routed, guarded, grounded and kept in good order.

A1.3 The test stand should be kept free of oil and fuel spills and tripping hazards. Containers of oil or fuel, or both, should not be permitted to accumulate in the testing area. Fire fighting equipment should be immediately accessible. Normal precautions should be observed whenever using flammable solvents for cleaning purposes.

A1.4 Safety masks, glasses, or hearing protection, or a combination thereof, should be worn by personnel working on the test stand. No loose or flowing clothing, including long hair or other accessory to dress, should be worn near rotating equipment. Personnel should be cautioned against working alongside the engine and driveline while the engine is running.

A1.5 Interlocks should automatically shut down the engine when an anomaly of any of the following occur: engine or dynamometer coolant temperature, engine oil pressure, dynamometer field current, engine speed, exhaust temperature, excessive vibration or when the fire protection system is activated. The interlock should include a method to cut off the fuel supply to the engine at the injector pump (including the return line). A remote fuel cut off station (external to the test stand) is recommended.

A1.6 Employ other safety precautions as required by regulations.

A2. INTAKE AIR AFTERCOOLER

A2.1 Obtain the Modine aftercooler from a Mack Truck dealer. Order the aftercooler using part number 5424 03 928 031. This is a non-stocked part in the Mack Parts Distribution System and will appear as an invalid part number. Instruct the dealer to expedite the aftercooler on a Ship Direct purchase order. The aftercooler will be shipped directly from Modine, bypassing the normal Mack Parts Distribution System.