Designation: D6987/D6987M – 13a

Standard Test Method for Evaluation of Diesel Engine Oils in T-10 Exhaust Gas Recirculation Diesel Engine[1]

This standard is issued under the fixed designation D6987/D6987M; 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 Mack T-10.[2] This test method covers an engine test procedure for evaluating diesel engine oils for performance characteristics, including lead corrosion and wear of piston rings and cylinder liners.

1.2 This test method also provides the procedure for running an abbreviated length test, which is commonly referred to as the T-10A. The procedures for the T-10 and T-10A are identical with the exception of the items specifically listed in Annex A8. Additionally, the procedure modifications listed in Annex A8 refer to the corresponding section of the T-10 procedure.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *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 and health practices and determine the applicability of regulatory limitations prior to use.* See Annex A7 for specific Safety Hazards.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D97 Test Method for Pour Point of Petroleum Products
D129 Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
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
D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
D2274 Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)
D2500 Test Method for Cloud Point of Petroleum Products
D2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D3338 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
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
D4739 Test Method for Base Number Determination by Potentiometric Hydrochloric Acid Titration

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricantsand is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants.

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[2] The ASTM Test Monitoring Center (TMC) will update changes in this test method by means of Information Letters. This edition includes all Information Letters through 13–1. Information Letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489, Attention: Administrator. www.astmtmc.cmu.edu

[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.

***A Summary of Changes section appears at the end of this standard**

D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5186 Test Method for Determination of the Aromatic Content and Polynuclear Aromatic Content of Diesel Fuels and Aviation Turbine Fuels By Supercritical Fluid Chromatography
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
D6078 Test Method for Evaluating Lubricity of Diesel Fuels by the Scuffing Load Ball-on-Cylinder Lubricity Evaluator (SLBOCLE)
D6483 Test Method for Evaluation of Diesel Engine Oils in T-9 Diesel Engine (Withdrawn 2009)[4]
D6681 Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E178 Practice for Dealing With Outlying Observations
E344 Terminology Relating to Thermometry and Hydrometry

3. Terminology

3.1 *Definitions:*

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

3.1.1.1 *Discussion*—This is a coded reference oil that is submitted by a source independent from the test facility. **D5844**

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 *candidate oil, n*—an oil that is intended to have the performance characteristics necessary to satisfy a specification and is intended to be tested against that specification. **D5844**

3.1.5 *exhaust gas recirculation (EGR), n*—the mixing of exhaust gas with intake air to reduce the formation of nitrogen oxides (NO_x). **Automotive Handbook**[5]

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

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

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

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

3.1.10 *oxidation, n*—of engine oil, the reaction of the oil with an electron acceptor, generally oxygen, which can produce deleterious acidic or resinous materials often manifested as sludge formation, varnish formation, viscosity increase, or corrosion, or a combination thereof. **Sub. B Glossary**[6]

3.1.11 *reference oil, n*—an oil of known performance characteristics and used as a basis for comparison.

3.1.11.1 *Discussion*—Reference oils are used to calibrate testing facilities, to compare the performance of other oils, or to evaluate other materials (such as seals) that interact with oils. **D5844**

3.1.12 *sludge, n—in internal combustion engines*, a deposit, principally composed of insoluble resins and oxidation products from fuel combustion and the lubricant, that does not drain from engine parts but can be removed by wiping with a cloth. **D5302**

3.1.13 *standard test, n*—a test on a calibrated test stand using the prescribed equipment according to the requirements in the test method, and conducted according to the specified operating conditions.

3.1.13.1 *Discussion*—The specified operating conditions in some test methods include requirements for determining a test's operational validity. These requirements are applied after a test is completed and can include (*1*) mid-limit ranges for the average values of primary and secondary parameters that are narrower than the specified control ranges for the individual values, (*2*) allowable deviations for individual primary and secondary parameters for the specified control ranges, (*3*) downtime limitations, and (*4*) special parameter limitations. **D5844**

3.1.14 *varnish, n—in internal combustion engines*, a hard, dry, generally lustrous deposit that can be removed by solvents but not by wiping with a cloth. **D5302**

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

3.1.15.1 *Discussion*—Wear generally occurs between two surfaces moving relative to each other, and is the result of

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

[5] Available from Robert Bosch GmbH, Postfach 50, D-7000 Stuttgart 1., Germany.

[6] Available from the ASTM Test Monitoring Center (TMC), 6555 Penn Avenue, Pittsburgh, PA 15206-4489, Attention: Administrator.

mechanical or chemical action or by a combination of mechanical and chemical action. D5302

4. Summary of Test Method

4.1 The test operation involves use of a Mack E-TECH V-MAC III diesel engine with exhaust gas recirculation (EGR). A warm-up and a 1 h break-in are followed by a two-phase test consisting of 75 h at 1800 r/min and 225 h at 1200 r/min, both at constant speed and torque.

4.2 Take oil samples periodically and analyze for viscosity increase and wear metals content.

4.3 Rebuild the engine prior to each test. Disassemble, solvent-clean (see 7.4), measure, and rebuild the engine power section using all new pistons, rings, cylinder liners, and connecting rod bearings in strict accordance with furnished specifications.

4.4 Solvent-clean (see 7.4) the engine crankcase and replace worn or defective parts.

4.5 Equip the test stand with appropriate accessories for controlling speed, torque, and various engine operating conditions.

5. Significance and Use

5.1 This test method was developed to evaluate the wear performance of engine oils in turbocharged and intercooled four-cycle diesel engines equipped with EGR. Obtain results from used oil analysis and component measurements before and after the test.

5.2 The test method may be used for engine oil specification acceptance when all details of the procedure are followed.

6. Apparatus

6.1 *General Description:*

6.1.1 The test engine is a Mack E-TECH V-MAC III, electronically controlled fuel injection with six electronic unit pumps, P/N 11GBA81025 (Annex A2). It is an open-chamber, in-line, six-cylinder, four-stroke, turbocharged, charge air-cooled, and compression ignition engine. The bore and stroke are 124 mm by 165 mm [4⅞ by 6½ in.], and the displacement is 12 L [728 in.^{3}].

6.1.2 The ambient laboratory atmosphere shall be relatively free of dirt and other contaminants as required by good laboratory standards. Filtering air, controlling temperature, and controlling humidity in the engine buildup area helps prevent accumulation of dirt and other contaminants on engine parts and aids in measuring and selecting parts for assembly.

6.2 *The Test Engine:*

6.2.1 *Mack T-10 Test Engine*—The engine is available from Mack Trucks, Inc. A complete parts list is shown in Table A2.1. Use test parts on a first-in/first-out basis.

6.2.2 *Engine Cooling System:*

6.2.2.1 Use a new Mack coolant conditioner shown in Table A2.1, for every test to limit scaling in the cooling system. Pressurize the system to 103 kPa [15 psi] at the expansion tank. Use the coolant shown in 7.3.1.

6.2.2.2 Use a closed-loop, pressurized external engine cooling system composed of a nonferrous core heat exchanger, reservoir, and water-out temperature control valve. The system shall prevent air entrainment and control jacket temperatures within the specified limit. Install a sight glass between the engine and the cooling tower to check for air entrainment and uniform flow in an effort to prevent localized boiling. Block the thermostat wide open.

6.2.2.3 Flow the coolant from the engine block fitting to the EGR coolers (see Fig. A1.3). Return the EGR coolant flow to the engine coolant-in line near the coolant pump inlet (see Fig. A1.7).

6.2.3 *Auxiliary Oil System*—To maintain a constant oil level in the pan, provide an additional 9.5 L [10 qt] sump by using a separate closed tank connected to the sump. Circulate oil through the tank at a rate of 5.7 L/min ± 1.9 L/min [1.5 ± 0.5 gal/min] with an auxiliary pump. The system schematic is shown in Fig. A1.1. The No. 6 and No. 8 lines are to have inside diameters of 10 mm [⅜ in.] and 13 mm [½ in.], respectively. Use a minimum No. 8 size vent line. Equivalent lines may be substituted for Aeroquip[7] lines provided they have the proper inside diameters.

6.2.3.1 Locate the auxiliary oil system suction line on the exhaust side of the oil pan, 127 mm [5.00 in.] down from the oil pan rail and 178 mm [7.00 in.] back from the front of the pan. This location is directly above the oil sump temperature thermocouple. Refer to Fig. A1.4. Connect the auxiliary oil system return line to the power steering pump cover on the front timing gear cover. Refer to Fig. A1.5. Connect the auxiliary oil scale vent line to the top of the auxiliary oil sump bucket and the dipstick tube opening.

6.2.3.2 Use a Viking pump Model No. SG053514 as the auxiliary oil pumps. Pump speed is specified as 1725 r/min.[8]

6.2.4 *Oil Cooling System:*

6.2.4.1 Use the oil cooler adapter blocks to mount the oil cooler to the engine. The adapter blocks are available from the supplier list in A2.7, Annex A2.

6.2.4.2 Use the oil filter housing (part no. 27GB525M) shown in Fig. A1.8.

6.2.5 *Blowby Meter*—Use a meter capable of providing data at a minimum frequency of 6 min. To prevent blowby condensate from draining back into the engine, the blowby line shall have a downward slope to a collection bucket. The collection bucket shall have a minimum volume of 18.9 L [5 gal]. Locate the blowby meter downstream of the collection bucket. The slope of the blowby line downstream of the collection bucket is unspecified.

6.2.6 *Air Supply and Filtration*—Use the Mack air filter element and the Mack filter housing shown in A2.3, Annex A2. Replace filter cartridge when 2.5 kPa [10 in. H_2O] ΔP is reached. Install an adjustable valve (flapper) in the inlet air system at least two pipe diameters before any temperature, pressure, and humidity measurement devices. Use the valve to maintain inlet air restriction within required specifications.

[7] Aeroquip lines are available at local industrial hose suppliers.

[8] The sole source of supply of the apparatus known to the committee at this time is Viking Pump, Inc., A Unit of IDEX Corp., 406 State St., P.O. Box 8, Cedar Falls, IA 50613-0008. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.