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An American National Standard

Standard Test Method for Cummins M11 EGR Test[1]

This standard is issued under the fixed designation D 6975; 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 The test method covers a heavy-duty diesel engine test procedure conducted under high soot conditions to evaluate oil performance with regard to valve train wear, power cylinder wear, sludge deposits, and oil filter plugging[2] in an EGR environment. This test method is commonly referred to as the Cummins M11 Exhaust Gas Recirculation Test (EGR).

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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 and health 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 D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants.

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[2] The ASTM Test Monitoring Center will update changes in this test method by means of Information Letters. Information letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489, Attention: Administrator.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

D 86 Test Method for Distillation of Petroleum Products

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup

D 97 Test Method for Pour Point of Petroleum Products

D 129 Test Method for Sulfur in Petroleum Products

D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test

D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)

D 482 Test Method for Ash from Petroleum Products

D 524 Test Method for Ramsbottom Carbon Residue of Petroleum Products

D 613 Test Method for Cetane Number of Diesel Fuel Oil

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration

D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Absorption

D 2274 Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)

D 2500 Test Method for Cloud Point of Petroleum Products

D 2622 Test Method for Sulfur in Petroleum Products by X-ray Spectrometry

D 2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge

D 2896 Test Method for Base Number of Petroleum Products by Potentionmetric Perchloric Acid Titration

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter

D 4485 Specification for Performance of Engine Oils

D 4737 Test Method for Calculated Cetane Index by Four Variable Equation

D 4739 Test Method for Base Number Determination by Potentiometric Titration

D 5185 Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

D 5302 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

D 5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)

D 5967 Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine

D 6483 Test Method for Evaluation of Diesel Engine Oils in T-9 Diesel Engine

D 6557 Test Method for Evaluation of Rust Preventive Characteristics of Automotive Engine Oils

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 344 Terminology Relating to Thermometry in Hydrometry

2.2 *Coordinating Research Council (CRC):*

CRC Manual No. 20[4]

2.3 *National Archives and Records Administration:*

Code of Federal Regulations Title 40 Part 86.310-79[5]

3. Terminology

3.1 *Definitions:*

[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.

[4] Available from the Coordinating Research Council, Inc., 219 Perimeter Parkway, Atlanta, GA 30346.

[5] Available from Superintendent of Documents, Attn: New Orders, P.O. Box 371954, Pittsburgh, PA 15250-7954.

3.1.1 *blind reference oil*, *n*—a reference oil, the identity of which is unknown by the test facility. **D 5844**

3.1.2 *blowby*, *n—in internal combustion engines*, the combustion products and unburned air-and-fuel mixture that enter the crankcase. **D 5302**

3.1.3 *calibrate*, *v*—to determine the indication or output of a measuring device with respect to that of a standard. **E 344**

3.1.4 *heavy-duty*, *adj—in internal combustion engine operation*, characterized by average speeds, power output, and internal temperatures that are close to the potential maximum. **D 4485**

3.1.5 *heavy-duty engine*, *adj—in internal combustion engines*, one that is designed to allow operation continuously at or close to its peak output. **D 4485**

3.1.6 *non-reference oil*, *n*—any oil other than a reference oil, such as a research formulation, commercial oil, or candidate oil. **D 5844**

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. **D 5844**

3.1.8 *reference oil*, *n*—an oil of known performance characteristics used as a basis for comparison. **D 4485**

3.1.9 *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. **D 5302**

3.1.10 *test oil*, *n*—any oil subjected to evaluation in an established procedure. **D 6557**

3.1.11 *wear*, *n*—the loss of material from, or relocation of material on, a surface. **D 5302**

3.1.11.1 *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.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *crosshead*, *n*—an overhead component, located between the rocker arm and each intake valve and exhaust valve pair, that transfers rocker arm travel to the opening and closing of each valve pair.

3.2.1.1 *Discussion*—Each cylinder has two crossheads, one for each pair of intake valves and exhaust valves.

3.2.2 *de-rate protocols*, *n*—protocols in the engine control module that cause the engine to reduce power output when certain operating parameters are exceeded.

3.2.3 *exhaust gas recirculation (EGR)*, *n*—a method by which a portion of the engine exhaust is returned to the combustion chambers through the intake system.

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

3.2.5 *overfuel*, *v*—to cause the fuel flow to exceed the standard production setting.

3.2.6 *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 method uses a Cummins M11 400 diesel engine with a specially modified engine block. Test operation includes a 25-min warm-up, a 2-h break-in, and 300 h in six 50-h stages. During stages A, C, and E, the engine is operated with retarded fuel injection timing and is overfueled to generate excess soot. During stages B, D, and F, the engine is operated at conditions to induce valve train wear.

4.2 Prior to each test, the engine is cleaned and assembled with new cylinder liners, pistons, piston rings, and overhead valve train components. All aspects of the assembly are specified.

4.3 A forced oil drain, an oil sample, and an oil addition, equivalent to an oil consumption of 0.23 g/kW-h, is performed at the end of each 25-h period.

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

4.5 Oil performance is determined by assessing crosshead wear at 8.5 mass % soot, top ring wear, sludge deposits, and oil filter plugging.

5. Significance and Use

5.1 This test method was developed to assess the performance of an engine oil to control engine wear and deposits under heavy-duty operating conditions selected to accelerate soot generation, valve train wear, and deposit formation in a turbocharged, aftercooled four-stroke-cycle diesel engine equipped with exhaust gas recirculation hardware.

5.2 This test method may be used for engine oil specification acceptance when all details of this test method are in compliance. Applicable engine oil service categories are included in Specification D 4485.

5.3 The design of the engine used in this test method is representative of many, but not all, modern diesel engines. This factor, along with the accelerated operating conditions, needs to be considered when extrapolating test results.

6. Apparatus

6.1 *Test Engine Configuration*:

6.1.1 *Test Engine*—The Cummins M11 400 is an in-line six-cylinder heavy-duty diesel engine with 11 L of displacement and is turbocharged and aftercooled. The engine has an overhead valve configuration and EGR hardware. It features a 1994 emissions configuration with electronic control of fuel metering and fuel injection timing. Obtain the test engine, the engine build parts kit, and non-kit parts from the central parts distributor (CPD).[6] The components of the engine build parts kit are shown in Table A3.1. Non-kit parts are shown in Table A3.2.

[6] Available from Test Engineering Inc., 12758 Cimmaron Path, Suite 102, San Antonio, TX 78249-3417.

TABLE 1 Maximum Allowable System Time Responses

Measurement	Time Response (s)
Speed	2.0
Temperature	3.0
Pressure	3.0
Flow	To be determined

6.1.2 *Oil Heat Exchanger, Adapter Blocks, and Block-off Plate*—The oil heat exchanger is relocated from the stock position with the use of adapter blocks as shown in Fig. A4.1.[7] Install an oil cooler block-off plate on the back of the coolant thermostat housing (Fig. A4.1). Control the oil temperature by directing engine coolant through the oil heat exchanger (Fig. A4.2).

6.1.3 *Oil Filter Head Modification*—Modify the oil filter head by plugging the filter bypass return to sump line and the engine oil thermostat (Fig. A4.8). Block the thermostat passage to route all of the engine oil into the oil cooler.

6.1.4 *Oil Pan Modification*—Modify the oil pan as shown in Fig. A4.3.[7]

6.1.5 *Engine Control Module (ECM)*—Obtain the ECM from the CPD.[6] The ECM programming has been modified to provide overfueling and retarded injection timing to increase soot generation and overhead wear. The de-rate protocols have been disabled. However the de-rate messages will still be displayed when using Cummins electronic service tools.

6.1.6 *Engine Position Sensor*—The engine position sensor has two measurement coils. Disable the secondary coil by cutting the two outside wires colored red and black. The red and black wires are labeled A and D, respectively, on the engine position sensor plug (Fig. A4.15).

6.1.7 *Air Compressor and Fuel Pump*—The engine-mounted air compressor is not used for this test method. Remove the air compressor and install the fuel injection pump in its place (Fig. A4.4). The fuel injection pump is driven with Cummins coupling P/N 208755.[8]

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 air filter and the intake air tube, the intake air system is not specified. A typical configuration is shown in Fig. X1.1. The air filter shall have a minimum initial efficiency rating of 99.2 %. Install the intake air tube (Fig. A4.5) at the intake of the turbocharger compressor. To control intake manifold pressure, a restriction plate or valve may be used after the aftercooler and before the inlet air tubing. The system shall allow control of applicable parameters listed in Table 5.

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

[7] Available from Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX 78228.

[8] Available from a Cummins parts distributor.

TABLE 2 Warm-up Conditions

Parameter	Unit	Stage				
		A	B	C	D	E
Stage Length	min	5	5	5	5	5
Speed	r/min	700	1200	1600	1600	1600
Torque	Nom	135	270	540	1085	1470
Coolant Out Temperature[A]	°C	105	105	105	105	105
Oil Gallery Temperature[A]	°C	130	130	130	130	130
Intake Manifold Temperature[A]	°C	70	70	70	70	70

[A] Maximum.

TABLE 3 Break-in Conditions

Parameter	Unit	Specification
Stage Length	min	120
Speed	r/min	1600 ± 5 (target)
Torque[A]	Nom	1930
Fuel Flow	kg/h	64.4 ± 0.9 (target)
Coolant Out Temperature	°C	65.5
Fuel In Temperature	°C	40 ± 2
Oil Gallery Temperature	°C	115.5
Turbo Inlet Air Temperature	°C	record
Intake Manifold Temperature	°C	65.5 (target)
Oil Gallery Pressure	kPa	record
Oil Filter Delta Pressure	kPa	record
Intake Manifold Pressure	kPa abs.	≤ 320
Exhaust Pressure	kPa abs.	107 ± 1
Crankcase Pressure	kPa	record
Inlet Air Pressure	kPa abs.	record
Coolant System Pressure	kPa	103 ± 4

[A] At standard atmospheric temperature and pressure.

TABLE 4 Normal Shutdown Conditions

Parameter	Unit	Stage		
		B	A	Idle
Stage Length	min	5	5	5
Speed	r/min	1200	700	700
Torque	N·m	270	135	<40
Coolant Out Temperature	°C	105 max	105 max	105 max
Intake Manifold Temperature	°C	70 max	70 max	70 max
Oil Gallery Temperature	°C	130 max	130 max	30 max

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

6.2.4 *Exhaust System*—Install the exhaust tube (Fig. A4.6) at 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 *Exhaust Gas Recirculation System*—The set-up components for the exhaust gas recirculation system (Fig. A4.9 and Fig. A4.11) can be obtained from the CPD.[6]

6.2.6 *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.

6.2.7 *Coolant System*—The system configuration is not specified. A typical configuration consists of a non-ferrous core heat exchanger, a reservoir (expansion tank), and a temperature control valve as shown in Fig. X1.3. Pressurize the system by regulating air pressure at the top of the expansion tank. The system should have a sight glass to detect air entrapment.