ASTM Designation: DXXXX – XX

Standard Test Method for

Evaluation of Diesel Engine Oils in the Cummins M11 Engine with Exhaust Gas Recirculation [1]

This standard is issued under the fixed designation DXXXX; 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 esilion (ε) indicates an editorial change since the last reapproval.

1. Scope

1.1 This test method is commonly referred to as the Cummins M11 Exhaust Gas Recirculation Test (EGR)[2]. The test method defines a heavy-duty diesel engine test procedure to evaluate oil performance with regard to valve train wear, power cylinder wear, sludge deposits, and oil filter plugging[3] in an EGR environment.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parenthesis 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 A1 for general safety precautions*.

1.4 *Table of Contents*:

2. Referenced Documents

2.1 ASTM Standards:

D 86 Standard Test Method for Distillation of Petroleum Products[4]

D 92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup[4]

D 97 Standard Test Method for Pour Point of Petroleum Products[4]

D 129 Standard Test Method for Sulfur in Petroleum Products[4]

D 130 Standard Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[4]

D 287 Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[4]

D 445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[4]

D 482 Standard Test Method for Ash from Petroleum Products[4]

D 524 Standard Test Method for Ramsbottom Carbon Residue of Petroleum Products[4]

D 613 Standard Test Method for Cetane Number of Diesel Fuel Oil[5]

D 664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration[4]

D 1319 Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Absorption[4]

D 2500 Standard Test Method for Cloud Point of Petroleum Products[4]

D 2622 Standard Test Method for Sulfur in Petroleum Products by x-ray Spectrometry[6]

D 2709 Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge[6]

D 2896 Standard Test method for Base Number of Petroleum Products by Potentionmetric Perchloric Acid Titration[6]

D 4485 Specification for Performance of Engine Oils[6]

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

D 4737 Standard Test Method for Calculated Cetane Index by Four Variable Equation[7]

D4739 Standard Test method for Base Number Determination by Potentiometric Titration[7]

D 5185 Standard 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)[7]

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[7]

D 5844 Standard Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)[7]

D 5967 Standard Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine[7]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[8]

E178 Standard Practice for Dealing with Outlying Observations

E 344 Terminology Relating to Thermometry in Hydromometry[9]

2.2 Coordinating Research Council:

CRC Manual No. 12[10]

CRC Manual No. 18 (Revised May, 1994)[10]

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. **D 5844**

3.1.1.1 *Discussion* – This is a coded reference oil that is submitted by a source independent of 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. **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 *wear, n* — the loss of material from, or relocation of material on, a surface. **D 5302**

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.

3.2 *Descriptions 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 *exhaust gas recirculation (EGR), n* - a method by which a portion of engine's exhaust is returned to its combustion chambers via its inlet system.

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

3.2.4 *overfuel, v* – an operating condition in which the fuel flow exceeds the standard production setting.

3.2.5 *valve train, n* – in internal combustion engines, the series of components such as valves, crossheads, rocker arms, push rods and camshaft, which 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% 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 a heavy-duty engine oil to control engine wear and deposits under operating conditions selected to accelerate soot production, valve train wear, and deposit formation in a turbo-charged and intercooled four-cycle diesel engine equipped with exhaust gas recirculation hardware.

5.2 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 shall 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, aftercooled, 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 and the engine build parts kit from the supplier listed in A2.2. The components of the engine build parts kit are shown in Table A3.1.

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. Install an oil cooler block-off plate on the back of the coolant thermostat housing as shown in Fig. A4.1. The adapter blocks can be obtained from the supplier listed in X1.3. 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). The thermostat passage should blocked 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. A modified oil pan can be obtained from the supplier listed in X1.3.

6.1.5 *Engine Control Module (ECM)* — Obtain the ECM from the supplier listed in A2.2. 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. The secondary coil must be disabled by cutting the two external, outside wires colored red and black. The wires are also labeled A and D 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. The coupling can be obtained from the supplier listed in X1.1.

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 *Discussion* - The engine mounting hardware should be configured to minimize block distortion when the engine is fastened to the mounts. Excessive block distortion can 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. X2.1. 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. Construct the system to minimize airflow restriction. To control intake manifold pressure a restriction plate or valve may be used after the aftercooler and before the inlet air tubing. A method to cool the intake air is required.

6.2.2.1 *Discussion* - Difficulty in achieving or maintaining intake manifold pressure or intake manifold temperature, or both, could be indicative of insufficient or excessive restriction.

6.2.3 *Aftercooler* – A Modine aftercooler, P/N 1A012865, will be used for aftercooling. The aftercoolers can be obtained from the supplier listed in X.1.5.

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 A4.10) can be obtained from the supplier listed in X.1.2.

6.2.6 *Fuel Supply* – The fuel supply and filtration system is not specified. A typical configuration is shown in Fig. X2.2. 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. X2.3. 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.

6.2.7.1 *Discussion* - Although the system volume is not specified, an excessively large volume can increase the time required for the engine fluid temperatures to attain specification. A system volume of 45 L or less (including engine) has proven satisfactory.

6.2.8 *Pressurized Oil Fill System* – The oil fill system is not specified. A typical configuration includes an electric pump, a 50-L reservoir, and transfer hose. The location for pressurized fill is located on the filter head (Fig A4.8)

6.2.9 *External Oil System* — Configure the external oil system according to Fig. A5.1. The external reservoir shall be Moroso P/N 22660, which can be obtained from the supplier listed in X1.4.

6.2.9.1 *Oil Sample Valve Location* - The oil sample valve shall be located on the return line from the external oil system to the engine. It is recommended that the valve be located as close to the return pump as possible (Fig. A5.1).

6.2.9.1.1 *Discussion* - Brass or copper fittings can influence used oil wear metals analyses and shall not be used in the external oil system.

6.2.10 *Crankcase Aspiration* – Vent the blowby gas at the port located on the left side of the valve cover. The vent line shall proceed downward from the valve cover port to the blowby canister and be of a length between 1.2 and 1.8 meters and of a diameter of 1.588 cm.

6.2.11 *Blowby Rate* — The flowrate device is not specified. The blowby canister shall be 37.88 L in volume. The outlet of the blowby canister to the flowrate device shall be 3.18 cm in diameter. The hose connecting the blowby canister to the flowrate device shall be 3.81 cm in diameter the length of which is not specified.

6.3 *System Time Responses* – The maximum allowable system time responses are shown in Table 1. Determine system time responses in accordance with the Data Acquisition and Control Automation II (DACA II) Task Force Report[12].

6.4 *Oil Sample Containers* — High-density polyethylene containers are recommended for oil samples.

6.4.1 *Discussion* — Glass containers may break and may cause injury or exposure to hazardous materials, or both.

6.5 *Mass Balance* — A balance is required to measure the mass of the crossheads and rod bearings. An electronic or mechanical balance may be utilized. The balance shall have a minimum indication resolution of 0.1 mg.

7. Engine and Cleaning Fluids

7.1 *Test Oil* -- Approximately 115 L of test oil is required to complete the test.

7.2 *Test Fuel* -- Approximately 20,000 L of diesel fuel is required to complete the test. Purchase the fuel from the supplier listed in A2.1. The fuel shall have the properties and tolerances shown in A6.

7.3 *Engine Coolant* – Use pre-mixed Fleetguard Compleat PG. The coolant can be obtained from the supplier listed in X1.1.

7.4 *Solvent* – Aliphatic naphtha or equivalent.

7.4.1 *Discussion* – 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 Cummins M11 EGR test are indicated in this section. Use the Cummins service publications[13] listed in A7 for the preparation of other engine components. Take precautions to prevent rusting of iron components.

8.1.2 *Engine Block* – Disassemble the engine - including removal of the crankshaft, camshaft, piston cooling tubes, oil pump, oil gallery plugs – and thoroughly clean the surfaces and oil passages (galleries). It is recommended that the oil passages be cleaned with a brush. 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 *Crosshead Cleaning and Measurement*

8.1.6.1 *Handling and Orientation* - Avoid handling the crossheads with bare hands, use gloves or plastic covered tongs. Crossheads shall be oriented in the engine with the elongated slot to the exhaust valve.

8.1.6.2 Clean the crossheads with solvent. Use a non-metallic soft bristle brush if necessary.

8.1.6.3 Spray the crossheads with air until dry.

8.1.6.4 Rinse the crossheads in pentane and dry with air.

8.1.6.5 Measure crosshead mass to a tenth of a milligram (xxx.x mg).

8.1.6.6 If an electronic scale is used for mass measurement, then use the following procedure:

(a) Demagnetize (degauss) each crosshead prior to measurement

(b) Measure the crosshead twice, using two orientations 90° apart. If the difference between the two mass measurements is greater than 0.2 mg, the crosshead shall be demagnetized and the