



Designation: D 6681 – 01

An American National Standard

Standard Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure¹

This standard is issued under the fixed designation D 6681; 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.

INTRODUCTION

Any properly equipped laboratory without outside assistance can use the test method described in this standard. However, the ASTM Test Monitoring Center (TMC)² provides calibration oils and an assessment of the test results obtained on those oils by the laboratory. By this means the laboratory will know whether their use of the test method gives results statistically similar to those obtained by other laboratories. Furthermore, various agencies require that a laboratory utilize the TMC services in seeking qualification of oils against specifications. For example, the U.S. Army has such a requirement in some of its engine oil specifications. Accordingly, this test method is written for those laboratories that use the TMC services. Laboratories that choose not to use these services should ignore those portions of the test method that refer to the TMC. Information Letters issued periodically by the TMC may modify this method.³ In addition, the TMC may issue supplementary memoranda related to the test method.

1. Scope

1.1 This test method is required to evaluate the performance of engine oils intended to satisfy certain American Petroleum Institute (API) C service categories (included in Specification D 4485). It is performed in a laboratory using a standardized high-speed, single-cylinder diesel engine.⁴ Piston and ring groove deposit-forming tendency and oil consumption is measured. The piston, the rings, and the liner are also examined for distress and the rings for mobility.

1.2 The values stated in SI units are to be regarded as the standard.

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.* Being an engine test method, this standard does have definite hazards that require safe practices (see Appendix X2 on Safety).

1.4 The following is the Table of Contents:

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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.B0.02 on Heavy Duty Engine Oils.

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² ASTM Test Monitoring Ctr., 6555 Penn Ave., Pittsburgh, PA 15206-4489.

³ This edition incorporates revisions contained in all information letters through 99-1. Users of this test method shall contact the ASTM Test Monitoring Center to obtain the most recent information letters.

⁴ Available from Caterpillar Inc., Engine System Technology Development, P.O. Box 610, Mossville, IL 61552-0610.

Coolant Flow	Section 10.3	D 97 Test Method for Pour Point of Petroleum Products ⁵
Re-calibration Requirements	10.4	D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test ⁵
Fuel Injectors	10.5	D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent) ⁶
Air Flow	10.6	D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity) ⁵
Intake Air Barrel	10.7	D 482 Test Method for Ash from Petroleum Products ⁵
Fuel Filter	10.8	D 524 Test Method for Ramsbottom Carbon Residue of Petroleum Products ⁵
Oil Scale Flow Rates	10.9	D 613 Test Method for Cetane Number of Diesel Fuel Oil ⁷
Calibration of Test Stands	10.10	D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration ⁵
Extending Test Stand Calibration Period	10.11	D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption ⁵
Test Run Numbering	10.12	D 2274 Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method) ⁵
Humidity Calibration Requirements	10.13	D 2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry ⁵
Calibration of Piston Deposit Raters	10.14	D 2500 Test Method for Cloud Point of Petroleum Products ⁵
Procedure	11	D 2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry ⁵
Engine Break-in Procedure	11.1	D 2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge ⁵
Cool-down Procedure	11.2	D 3227 Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method) ⁵
Warm-up Procedure	11.3	D 3524 Test Method for Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography ⁸
Shutdowns and Lost Time	11.4	D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants ⁸
Periodic Measurements	11.5	D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter ⁸
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Engine Fuel System	11.6.2	D 4863 Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants ⁸
Engine Oil Temperature	11.6.3	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) ⁸
Exhaust Pressure	11.6.4	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 ⁸
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2. Referenced Documents

2.1 ASTM Standards:

- D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure⁵
- D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester⁵

⁶ Annual Book of ASTM Standards, Vol 06.04.

⁷ Annual Book of ASTM Standards, Vol 05.05.

⁸ Annual Book of ASTM Standards, Vol 05.02.

⁹ Annual Book of ASTM Standards, Vol 05.03.

⁵ Annual Book of ASTM Standards, Vol 05.01.

Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine⁹

D 6202 Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark-Ignition Engine⁹

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications¹⁰

E 344 Terminology Relating to Thermometry and Hydrometry¹¹

G 40 Terminology Relating to Wear and Erosion¹²

2.2 *SAE Standard:*

SAE J183 Engine Oil Performance and Engine Service Classification¹³

2.3 *API Standard:*

API 1509 Engine Service Classification and Guide to Crankcase Oil Selection¹⁴

3. Terminology

3.1 Definitions:

3.1.1 *additive, n*—a material added to another, usually in a small amount, to impart or enhance desirable properties or to suppress undesirable properties. **D 4175**

3.1.2 *automotive, adj*—descriptive of equipment associated with self-propelled machinery, usually vehicles driven by internal combustion engines. **D 4485**

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

3.1.3.1 *Discussion*—This is a coded reference oil which is submitted by a source independent from the test facility.

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

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

3.1.6 *calibrated test stand, n*—a test stand on which the testing of reference material(s), conducted as specified in the standard, provided acceptable test results. **Sub. B Glossary¹⁵**

3.1.6.1 *Discussion*—In several automotive lubricant standard test methods, the ASTM Test Monitoring Center provides testing guidance and determines acceptability.

3.1.7 *candidate oil, n*—an oil which is intended to have the performance characteristics necessary to satisfy a specification and is to be tested against that specification. **D 5844**

3.1.7.1 *Discussion*—These oils are mainly submitted for testing as *candidates* to satisfy a specified performance; hence the designation of the term.

3.1.8 *debris, n*—in internal combustion engines, solid contaminant materials unintentionally introduced into the engine or resulting from wear. **D 5862**

3.1.9 *disperant, n*—in engine oil, an additive that reduces deposits on oil-wetted surfaces primarily through suspension of particles. **D 4175**

3.1.10 *engine oil, n*—a liquid that reduces friction or wear, or both, between the moving parts within an engine; removes heat, particularly from the underside of pistons; and serves as a combustion gas sealant for the piston rings. **D 5862**

3.1.10.1 *Discussion*—It may contain additives to enhance certain properties. Inhibition of engine rusting, deposit formation, valve train wear, oil oxidation and, foaming are examples.

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

3.1.12 *lubricant, n*—any material interposed between two surfaces that reduces the friction or wear, or both, between them. **D 5862**

3.1.13 *lubricating oil, n*—a liquid lubricant, usually comprising several ingredients, including a major portion of base oil and minor portions of various additives. **Sub. B Glossary¹⁵**

3.1.14 *oxidation, n*—of engine oil, the reaction of the oil with an electron acceptor, generally oxygen, that can produce deleterious acidic or resinous materials often manifested as sludge formation, varnish formation, viscosity increase, or corrosion, or a combination thereof. **Sub. B Glossary¹⁵**

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

3.1.16 *purchaser, n*—of an ASTM test, person or organization that pays for the conduct of an ASTM test method on a specified product. **D 6202**

3.1.17 *reference oil, n*—an oil of known performance characteristics, used as a basis for comparison. **D 5844**

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

3.1.18 *scoring, n*—in tribology, a severe form of wear characterized by the formation of extensive grooves and scratches in the direction of sliding. **G 40**

3.1.19 *scuff, scuffing, n*—in lubrication, damage caused by instantaneous localized welding between surfaces in relative motion that does not result in immobilization of the parts. **D 4863**

3.1.20 *sponsor, n*—of an ASTM test method, an organization that is responsible for ensuring supply of the apparatus used in the test procedure portion of the test method. **Sub. B Glossary¹⁵**

3.1.20.1 *Discussion*—In some instances, such as a test method for chemical analysis, an ASTM working group can be the sponsor of the test method. In other instances, a company with a self-interest may or may not be the developer of the test procedure used within the method, but is the sponsor of the test method.

3.1.21 *used oil, n*—any oil that has been in a piece of equipment (for example, an engine, gearbox, transformer, or turbine), whether operated or not. **D 4175**

¹⁰ Annual Book of ASTM Standards, Vol 14.02.

¹¹ Annual Book of ASTM Standards, Vol 14.03.

¹² Annual Book of ASTM Standards, Vol 03.02.

¹³ Available from the Society of Automotive Engineers Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

¹⁴ Available from the American Petroleum Institute, 1220 L Street NW, Washington D.C., 20005.

¹⁵ Available from the Test Monitoring Center (TMC), 6555 Penn Avenue, Pittsburgh, PA 15206-4489.

3.1.22 *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. **D 5302**

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

3.1.23.1 *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.

4. Summary of Test Method

4.1 Prior to each test, the power section of the engine is disassembled, solvent-cleaned, measured, and rebuilt in strict accordance with the specifications. A new piston, ring assembly, and cylinder liner are measured and installed for each test. The engine crankcase is solvent-cleaned and worn or defective parts are replaced. The test stand is equipped with feedback control systems for fuel rate, engine speed, and other engine operating conditions. A suitable system for filtering, compressing, humidifying, and heating the inlet air shall be provided along with a system for controlling the engine exhaust pressure. Test operations involve the control of the single-cylinder diesel test engine for a total of 360 h at specified speeds and fuel rate input using the test oil as a lubricant. A defined break-in precedes each test and is also used when restarting an engine. At the end of the test, the piston deposits are rated, the piston, rings and liners are photographed, inspected and measured, oil consumption is calculated and the oil is analyzed to determine the test results. Critical engine conditions are statistically analyzed to determine if the test was precisely operated. Test acceptability parameters for each calibration test are also statistically analyzed to determine if the engine/test stand produce the specified results.

5. Significance and Use

5.1 This is an accelerated engine oil test, performed in a standardized, calibrated, stationary single-cylinder diesel engine that gives a measure of (1) piston and ring groove deposit forming tendency, (2) piston, ring and liner scuffing and (3) oil consumption. The test is used in the establishment of diesel engine oil specification requirements as cited in Specification D 4485 for appropriate API Performance Category C oils (API 1509). The test method can also be used in diesel engine oil development.

6. Apparatus and Installation

6.1 The test engine is an electronically controlled, direct injection, in-head camshaft, single-cylinder diesel engine with a four-valve arrangement. The engine has a 137.2 mm bore and a 165.1 mm stroke resulting in a displacement of 2.4 L.

6.1.1 The electronic control module (ECM) defines the desired engine fuel timing, monitors and limits maximum engine speed, maximum engine power, minimum oil pressure, and, optionally, maximum engine crankcase pressure. The ECM also controls the fuel injection duration that defines the engine fuel rate based on set conditions from the test cell feedback control systems. The oil pressure is also set by the ECM with signals to the 1Y3867 engine air pressure controller

(Mamac) to modulate the facility air supply to the 1Y3898 Johnson Controls relief valve.

6.1.2 The 1Y3700 engine arrangement also consists of inlet air piping and hoses from the cylinder head to the air barrel and exhaust piping and bellows from the cylinder head to the exhaust barrel that are specifically designed for oil testing.¹⁶

6.2 Equip the engine test stand with the following accessories or equipment:

6.2.1 *Intake Air System*—The intake air system components from the cylinder head to the air barrel are a part of the basic 1Y3700 engine arrangement. These components consisting of an adapter, elbow, hose, clamps, and flanged tube can be found in the 1Y3700 Parts Book.¹⁷

6.2.1.1 The 1Y3978 intake air barrel (which is almost identical to the exhaust barrel except for the top cover) has been specifically designed and shall be purchased from one of the three approved manufacturers.¹⁸ Install the intake air barrel at the location shown in Annex A7. Do not add insulation to the barrel.

6.2.1.2 Paint the inside of the intake air piping with Caterpillar yellow primer or red Glyptal prior to installation.¹⁹

6.2.1.3 Install the air heater elements in the intake air barrel as specified in Annex A7 (even if they will not be supplied with electricity).²⁰

6.2.1.4 Use an air filter capable of 10 μ (or smaller) filtration.

6.2.1.5 Use a Sierra Model 780 airflow meter with Feature 1 = F6, Feature 2 = CG and calibration temperature = 60°C to measure intake airflow for each calibration test.²¹ Annex A4 shows the piping requirements for the installation of the Sierra Model 780 airflow meter.

6.2.1.6 Measure the inlet air temperature at the location shown in Annex A2. Measure the inlet air pressure at the air barrel as shown in Annex A7. The location of the 1Y3977 humidity probe is shown in Annex A8. The sample line may require insulation to prevent dropping below dew point temperature and shall not be hygroscopic. Drain taps may be installed at the low points of the combustion air system.

6.2.1.7 Use feedback-equipped controls to maintain filtered, compressed, and humidified inlet air at the conditions specified in Annex A12.

6.2.2 *Exhaust System*—The exhaust system components from the cylinder head to the exhaust barrel are part of the basic 1Y3700 engine arrangement. These components consisting of an adapter, elbow, bellows, flange, and clamps can be found in the 1Y3700 Parts Book.

¹⁶ See the Caterpillar Service Manual. Available from Caterpillar Inc., Engine System Technology Development, P.O. Box 610, Mossville, IL 61552-0610.

¹⁷ Available from Caterpillar Inc., Engine System Technology Development, P.O. Box 610, Mossville, IL 61552-0610.

¹⁸ Cimino Machinery Corp., 5958 South Central Ave., Chicago, IL 60638; Gaspar Inc., 4106 Mahoning Rd. N.E., Canton, OH 44705; M.L. Wyrick Welding, 2301 Zanderson Highway 16 N, Jourdanon, TX 78026.

¹⁹ Crankcase Paint Primer: BASF Coating and Colorant Div., P.O. Box 1297, Morganton, NC 28655. (Primer No.A123590 and BASF Part No.U27YD005, Yellow CAT Primer Part No.IE2083A.)

²⁰ Watlow Air Heaters, Chicago, IL 708-490-3900.

²¹ Sierra Instruments, Inc., 5 Harris Ct., Monterey, CA 93940.