Designation: D 6681 – 04

An American National Standard

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

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 All measurements made in accordance with this standard shall use the SI system of units.

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:



[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.

Current edition approved Nov. 1, 2004. Published November 2004. Originally approved in 2001. Last previous edition approved in 2001 as D 6681–01.

[2] ASTM Test Monitoring Center (TMC), 6555 Penn Ave., Pittsburgh, PA 15206–4489.

[3] This edition incorporates revisions contained in all information letters through 03-1. 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.

## 2. Referenced Documents

2.1 *ASTM Standards:* [5]

D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure

D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D 97 Test Method for Pour Point of Petroleum Products

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

D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (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 Adsorption

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

D 2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry

D 2500 Test Method for Cloud Point of Petroleum Products

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

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

D 3227 Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)

D 3524 Test Method for Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography

D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants

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

D 4485 Specification for Performance of Engine Oils

D 4739 Test Method for Base Number Determination by Potentiometric Titration

D 4863 Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants

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

[5] 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.

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 5862 Test Method for Evaluation of Engine Oils in the Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine
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 Engine
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 344 Terminology Relating to Thermometry and Hydrometry
G 40 Terminology Relating to Wear and Erosion

2.2 *SAE Standard:*

SAE J183 Engine Oil Performance and Engine Service Classification[6]

2.3 *API Standard:*

API 1509 Engine Service Classification and Guide to Crankcase Oil Selection[7]

## 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 Glossary**[2]

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 *dispersant*, *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 Glossary**[2]

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 Glossary**[2]

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 Glossary**[2]

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**

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

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

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. See the Caterpillar Service Manual.[4]

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.[4]

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.[8,9] 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.[9,10]

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).[9,11]

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.[9,12] 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

[8] The sole sources of supply of the intake air barrel known to the committee at this time are Cimino Machinery Corp., 5958 South Central Ave., Chicago, IL 60638; Gaspar Inc., 4106 Mahoning Rd. N.E., Canton, OH 44705; and M.L. Wyrick Welding, 2301 Zanderson Highway 16 N, Jourdanton, TX 78026.

[9] 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.

[10] The sole source of supply of the crankcase paint primer known to the committee at this time is 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.)

[11] The sole source of supply of the air heater elements known to the committee at this time is Watlow Air Heaters, Chicago, IL 708-490-3900.

[12] The sole source of supply of the airflow meter known to the committee at this time is Sierra Instruments, Inc., 5 Harris Ct., Monterey, CA 93940.