



Designation: D4485 – 19

Standard Specification for Performance of Active API Service Category Engine Oils¹

This standard is issued under the fixed designation D4485; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

INTRODUCTION

This specification covers all the currently active American Petroleum Institute (API) engine oil performance categories that have been defined in accordance with the ASTM consensus process. There are organizations with specifications not subject to the ASTM consensus process, such as the International Lubricant Standardization and Approval Committee (ILSAC), American Petroleum Institute (API – SM, SN Specifications), and the Association des Constructeurs Européens d'Automobiles (ACEA). Certain of these specifications, which have been defined primarily by the use of current ASTM test methods, have also been included in the Appendixes for information.

In the ASTM system, a specific API designation is assigned to each category. The system is open-ended, that is, new designations are assigned for use with new categories as each new set of oil performance characteristics are defined. Oil categories may be referenced by engine builders in making lubricant recommendations, and used by lubricant suppliers and customers in identifying products for specific applications. Where applicable, candidate oil programs are conducted in accordance with the American Chemistry Council (ACC) Petroleum Additives Product Approval Code of Practice.

Other service categories not shown in this document have historically been used to describe engine oil performance (SA, SB, SC, SD, SE, SF, SG, SH and CA, CB, CC, CD, CD-II, CE, CF, CF-2, CF-4, CG-4) (see 3.1.2). SA is not included because it does not have specified engine performance requirements. SH is not included because it was a category that could not be licensed for gasoline engine oil use in the API Service Symbol after Dec. 2, 2010. (Note—The SH category has been included in Appendix X10 as relevant information in combination with “C” categories.) The others are not included because they are based on test methods for which engine parts, test fuel, or reference oils, or a combination thereof, are no longer available. Also, the ASTM 5-Car and Sequence VI Procedures are obsolete and have been deleted from the category Energy Conserving and Energy Conserving II (defined by Sequence VI). Information on excluded older categories and obsolete test requirements can be found in SAE J183.

1. Scope*

1.1 This specification covers engine oils for light-duty and heavy-duty internal combustion engines used under a variety of operating conditions in automobiles, trucks, vans, buses, and off-highway farm, industrial, and construction equipment.²

1.2 This specification is not intended to cover engine oil applications such as outboard motors, snowmobiles, lawn mowers, motorcycles, railroad locomotives, or oceangoing vessels.

1.3 This specification is based on engine test results that generally have been correlated with results obtained on reference oils in actual service engines operating with gasoline or diesel fuel. As it pertains to the API SL engine oil category, it is based on engine test results that generally have been correlated with results obtained on reference oils run in gasoline engine Sequence Tests that defined engine oil categories prior to 2000. It should be recognized that not all aspects of engine oil performance are evaluated by the engine tests in this specification. In addition, when assessing oil performance, it is desirable that the oil be evaluated under actual operating conditions.

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

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² Until the next revision of this specification, the ASTM Test Monitoring Center will update changes in specification by means of information letters. Information letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489, www.astmtmc.cmu.edu. This edition incorporates revisions in all information letters through No. 19-7.

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

1.4 This specification includes bench and chemical tests that help evaluate some aspects of engine oil performance not covered by the engine tests in this specification.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5.1 *Exceptions:*

1.5.1.1 The roller follower shaft wear in Test Method **D5966** is in mils.

1.5.1.2 The oil consumption in Test Method **D6750** is in grams per kilowatthour.

NOTE 1—The kWh unit is deprecated. The preferred SI unit is the joule (J); 1 kWh = 3.6 MJ.

1.5.1.3 The bearing wear in Test Method **D6709** is in grams and is described as weight loss, a non-SI term.

1.5.1.4 Some of the appendixes are verbatim from other sources, and non-SI units are included.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*³

- D92** Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- D93** Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
- D130** Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
- D412** Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
- D471** Test Method for Rubber Property—Effect of Liquids
- D874** Test Method for Sulfated Ash from Lubricating Oils and Additives
- D892** Test Method for Foaming Characteristics of Lubricating Oils
- D2240** Test Method for Rubber Property—Durometer Hardness
- D2622** Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
- D2887** Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
- D3244** Practice for Utilization of Test Data to Determine Conformance with Specifications
- D4171** Specification for Fuel System Icing Inhibitors
- D4683** Test Method for Measuring Viscosity of New and Used Engine Oils at High Shear Rate and High Temperature by Tapered Bearing Simulator Viscometer at 150 °C
- D4684** Test Method for Determination of Yield Stress and

- Apparent Viscosity of Engine Oils at Low Temperature
- D4741** Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer
- D4951** Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry
- D5119** Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine (Withdrawn 2003)⁴
- D5133** Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique
- D5185** Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
- D5293** Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between –10 °C and –35 °C Using Cold-Cranking Simulator
- 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
- D5480** Test Method for Engine Oil Volatility by Gas Chromatography (Withdrawn 2003)⁴
- D5481** Test Method for Measuring Apparent Viscosity at High-Temperature and High-Shear Rate by Multicell Capillary Viscometer
- D5533** Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIE, Spark-Ignition Engine (Withdrawn 2003)⁴
- D5800** Test Method for Evaporation Loss of Lubricating Oils by the Noack Method
- D5844** Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID) (Withdrawn 2003)⁴
- D5966** Test Method for Evaluation of Engine Oils for Roller Follower Wear in Light-Duty Diesel Engine
- D5967** Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine
- D6082** Test Method for High Temperature Foaming Characteristics of Lubricating Oils
- D6202** Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark Ignition Engine (Withdrawn 2009)⁴
- D6278** Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus
- D6335** Test Method for Determination of High Temperature Deposits by Thermo-Oxidation Engine Oil Simulation Test
- D6417** Test Method for Estimation of Engine Oil Volatility by Capillary Gas Chromatography
- D6483** Test Method for Evaluation of Diesel Engine Oils in T-9 Diesel Engine (Withdrawn 2009)⁴

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

- D6557** Test Method for Evaluation of Rust Preventive Characteristics of Automotive Engine Oils
- D6593** Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions
- D6594** Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135 °C
- D6681** Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure
- D6709** Test Method for Evaluation of Automotive Engine Oils in the Sequence VIII Spark-Ignition Engine (CLR Oil Test Engine)
- D6750** Test Methods for Evaluation of Engine Oils in a High-Speed, Single-Cylinder Diesel Engine—1K Procedure (0.4 % Fuel Sulfur) and 1N Procedure (0.04 % Fuel Sulfur)
- D6794** Test Method for Measuring the Effect on Filterability of Engine Oils After Treatment with Various Amounts of Water and a Long (6 h) Heating Time
- D6795** Test Method for Measuring the Effect on Filterability of Engine Oils After Treatment with Water and Dry Ice and a Short (30 min) Heating Time
- D6837** Test Method for Measurement of Effects of Automotive Engine Oils on Fuel Economy of Passenger Cars and Light-Duty Trucks in Sequence VIB Spark Ignition Engine
- D6838** Test Method for Cummins M11 High Soot Test (Withdrawn 2019)⁴
- D6891** Test Method for Evaluation of Automotive Engine Oils in the Sequence IVA Spark-Ignition Engine
- D6894** Test Method for Evaluation of Aeration Resistance of Engine Oils in Direct-Injected Turbocharged Automotive Diesel Engine
- D6896** Test Method for Determination of Yield Stress and Apparent Viscosity of Used Engine Oils at Low Temperature
- D6922** Test Method for Determination of Homogeneity and Miscibility in Automotive Engine Oils
- D6923** Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1R Test Procedure
- D6975** Test Method for Cummins M11 EGR Test (Withdrawn 2019)⁴
- D6984** Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIF, Spark-Ignition Engine
- D6987/D6987M** Test Method for Evaluation of Diesel Engine Oils in T-10 Exhaust Gas Recirculation Diesel Engine
- D7094** Test Method for Flash Point by Modified Continuously Closed Cup (MCCCFP) Tester
- D7097** Test Method for Determination of Moderately High Temperature Piston Deposits by Thermo-Oxidation Engine Oil Simulation Test—TEOST MHT
- D7109** Test Method for Shear Stability of Polymer-Containing Fluids Using a European Diesel Injector Apparatus at 30 Cycles and 90 Cycles
- D7156** Test Method for Evaluation of Diesel Engine Oils in the T-11 Exhaust Gas Recirculation Diesel Engine
- D7216** Test Method for Determining Automotive Engine Oil Compatibility with Typical Seal Elastomers
- D7320** Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIG, Spark-Ignition Engine
- D7422** Test Method for Evaluation of Diesel Engine Oils in T-12 Exhaust Gas Recirculation Diesel Engine
- D7468** Test Method for Cummins ISM Test
- D7484** Test Method for Evaluation of Automotive Engine Oils for Valve-Train Wear Performance in Cummins ISB Medium-Duty Diesel Engine
- D7528** Test Method for Bench Oxidation of Engine Oils by ROBO Apparatus
- D7549** Test Method for Evaluation of Heavy-Duty Engine Oils under High Output Conditions—Caterpillar C13 Test Procedure
- D7563** Test Method for Evaluation of the Ability of Engine Oil to Emulsify Water and Simulated Ed85 Fuel
- D7589** Test Method for Measurement of Effects of Automotive Engine Oils on Fuel Economy of Passenger Cars and Light-Duty Trucks in Sequence VID Spark Ignition Engine
- D8111** Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIG, Spark-Ignition Engine
- D8114** Test Method for Measurement of Effects of Automotive Engine Oils on Fuel Economy of Passenger Cars and Light-Duty Trucks in Sequence VIE Spark Ignition
- D8047** Test Method for Evaluation of Engine Oil Aeration Resistance in a Caterpillar C13 Direct-Injected Turbocharged Automotive Diesel Engine
- D8048** Test Method for Evaluation of Diesel Engine Oils in T-13 Diesel Engine
- D8226** Test Method for Measurement of Effects of Automotive Engine Oils on Fuel Economy of Passenger Cars and Light-Duty Trucks in Sequence VIF Spark Ignition Engine
- D8256** Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation in the Sequence VH Spark-Ignition Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions
- D8279** Test Method for Determination of Timing-Chain Wear in a Turbocharged, Direct-Injection, Spark-Ignition, Four-Cylinder Engine
- E29** Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E178** Practice for Dealing With Outlying Observations
- 2.2 *Society of Automotive Engineers Standards*:⁵
- SAE J183** Engine Oil Performance and Engine Service Classification
- SAE J300** Engine Oil Classification
- SAE J1423** Passenger Car and Light-Duty Truck Energy-Conserving Engine Oil Classification

⁵ Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

SAE J2643 Standard Reference Elastomers (SRE) for Characterizing the Effects on Vulcanized Rubber

2.3 *American Petroleum Institute Publication:*⁶

API 1509 Engine Oil Licensing and Certification System (EOLCS)

2.4 *Government Standard:*⁷

DOD CID A-A-52039A (SAE 5W-30, 10W-30, and 15W-40)

2.5 *American Chemical Council Code:*⁸

ACC Petroleum Additives Product Approval Code of Practice

3. Terminology

3.1 Definitions:

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

3.1.2 *category, n—in engine oils*, a designation such as SJ, SL, SM, SN, CH-4, CI-4, CJ-4, CK-4, FA-4, Energy Conserving, Resource Conserving, and so forth, for a given level of performance in specified engine and bench tests.

3.1.3 *classification, n—in engine oils*, the systematic arrangement into categories in accordance with different levels of performance in specified engine and bench tests.

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

3.1.5 *heavy-duty engine, n—in internal combustion engine types*, one that is designed to allow operation continuous at or close to its peak output.

3.1.6 *light-duty, adj—in internal combustion engine operation*, characterized by average speeds, power output, and internal temperatures that are generally much lower than the potential maximums.

3.1.7 *light-duty engine, n—in internal combustion engine types*, one that is designed to be normally operated at substantially less than its peak output.

3.1.7.1 *Discussion*—This type of engine is typically installed in automobiles and small trucks, vans, and buses.

3.1.8 *lugging, adj—in internal combustion engine operation*, characterized by a combined mode of relatively low-speed and high-power output.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *C category, n*—the group of engine oils that are intended primarily for use in diesel and certain gasoline-powered vehicles.

3.2.2 *Energy Conserving category, n*—the group of engine oils that have demonstrated fuel economy benefits and are

intended primarily for use in automotive gasoline engine applications, such as passenger cars, light-duty trucks, and vans.

3.2.3 *engine oil, n*—a lubricating liquid with additives that reduces friction or wear, or both, between the moving parts within an engine; removes heat, serves as a combustion-gas sealant for piston rings; and reduces potentially harmful effects such as rusting, deposit formation, oil oxidation, and foaming resulting from engine operation.

3.2.4 *F category, n*—a group of heavy duty engine oils specified to help meet greenhouse gas (GHG) emission legislation, for example, legislation first introduced on 2017 model year engines.

3.2.5 *S category, n*—the group of engine oils that are intended primarily for use in automotive gasoline engine applications, such as passenger cars, light-duty trucks, and vans.

4. Performance Classification

4.1 Automotive engine oils are classified in three general arrangements, as defined in 3.2; that is, S, C, and Energy Conserving. These arrangements are further divided into categories with performance measured as follows:

4.1.1 *SJ*—Oil meeting the performance requirements measured in the following gasoline engine tests and bench tests:

4.1.1.1 Test Method **D5844**, the Sequence IID, gasoline engine test has been correlated with vehicles used in short-trip service prior to 1978,⁹ particularly with regard to rusting. (An alternative is Test Method **D6557**, the Ball Rust Test.)

4.1.1.2 Test Method **D5533**, the Sequence IIIE gasoline engine test, has been correlated with vehicles used in high-temperature service prior to 1988,¹⁰ particularly with regard to oil thickening and valve train wear. (Alternatives are Test Method **D6984**, the Sequence IIIF test, or Test Method **D7320**, the Sequence IIIG test.)

4.1.1.3 Test Method **D5302**, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988,¹¹ particularly with regard to sludge and valve train wear. (An alternative is the combination of Test Method **D6593**, the Sequence VG test, and Test Method **D6891**, the Sequence IVA test.)

4.1.1.4 Test Method **D5119**, the L-38 gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions. (An alternative is Test Method **D6709**, the Sequence VIII test.)

(I) Test Method **D5119** (or Test Method **D6709**) is also used to determine the ability of an oil to resist permanent viscosity loss due to shearing in an engine.

⁶ Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, <http://www.api.org>.

⁷ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

⁸ Available from American Chemical Council, 1300 Wilson Blvd., Arlington, VA 22209.

⁹ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1473. Contact ASTM Customer Service at service@astm.org.

¹⁰ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1471. Contact ASTM Customer Service at service@astm.org.

¹¹ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1273. Contact ASTM Customer Service at service@astm.org.

4.1.1.5 In addition to passing performance in the engine tests, specific viscosity grades shall also meet bench test requirements (see **Table 1**), which are discussed in the following subsections:

(1) The volatility of engine oils is one of several factors that relates to engine oil consumption.

(2) Test Method **D6795**, the EOFT screens for the formation of precipitates and gels that form in the presence of water and can cause oil filter plugging.

(3) Phosphorus compounds in excessive amounts can cause glazing of automotive catalysts and exhaust gas oxygen sensors and, thereby, deactivate them. Control of the phosphorus level in the engine oil may reduce this tendency.

(4) The flash point may indicate if residual solvents and low-boiling fractions remain in the finished oil.

(5) Excessive foaming in engine oil can cause valve lifter collapse and a loss of lubrication due to the presence of air in the oil. Test Methods **D892** and **D6082** empirically rate the foaming tendency and stability of oils.

(6) Test Method **D6922**, the H and M Test indicates the compatibility of an oil with standard test oils.

(7) Newer engines designed to provide increased power and improved driveability and to meet future federal emissions and fuel economy requirements may be sensitive to internal deposits caused by elevated engine operating temperatures. Test Method **D6335**, the TEOST test, may be useful in determining the deposit control of oils recommended for these engines.

(8) Test Method **D5133**, the Gelation Index technique, might identify oils susceptible to air binding and might provide low temperature protection not adequately measured by the Test Method **D4684**.

4.1.1.6 Licensing of the API SJ category by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See **Appendix X3** for more information.)

4.1.2 *SL*—Oil meeting the performance requirements measured in the following gasoline engine tests and bench tests:

4.1.2.1 Test Method **D6984**, the Sequence IIIF gasoline engine test, is used to measure oil thickening and piston deposits under high temperature conditions and provides information about valve train wear.¹² (An alternative is Test Method **D7320**, the Sequence IIIG test.)

4.1.2.2 Test Method **D6891**, the Sequence IVA gasoline engine test, has been correlated with the Sequence VE gasoline engine test in terms of overhead cam and slider follower wear control.⁹

4.1.2.3 Test Method **D5302**, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988, with regard to valve train wear. It

is included in the *SL* performance specification to augment assessment of the wear control performance of oils containing less than 0.08 % mass of phosphorus from ZDDP additive.

NOTE 2—Prior to May 2004, the API SH, SJ, and SL categories required that oils with passing Test Method **D6984** (Sequence IIIF) results, and containing less than 0.08 % mass phosphorus in the form of ZDDP, also demonstrate passing performance in Test Method **D5302** (Sequence VE). This requirement was included to address concerns over adequate wear protection with low levels of ZDDP. However, Test Method **D5302** has not been available to industry for some time, and an alternative method was needed. In a related activity, the next level of gasoline engine oil performance, the ILSAC GF-4 standard, was developed outside the normal ASTM consensus process. Deliberations during the GF-4 development process included careful consideration of the suitability of Test Method **D7320**, the Sequence IIIG, a new test, to evaluate the wear protection of oils with less than 0.08 % mass phosphorus. Data on oils with less than 0.08 % mass phosphorus in the form of ZDDP were reviewed by members of the D02.B0 Passenger Car Engine Oil Classification Panel (PCEOCP). These data were from Test Method **D7320** (Sequence IIIG) tests and from field tests on large populations of older vehicles with different engine types. Based on these data, the PCEOCP recommended a ballot to allow the use of Test Method **D7320** (Sequence IIIG) as an alternative to Test Method **D6984** (Sequence IIIF) plus Test Method **D5302** (Sequence VE) for demonstration of acceptable API SH, SJ, and SL performance on low phosphorus oils, establishing at least the mass fraction of phosphorus is 0.06 % as the minimum level. That ballot was approved by Subcommittee D02.B0 in May 2004.

4.1.2.4 Test Method **D6593**, the Sequence VG gasoline engine test, has been correlated with the Sequence VE gasoline engine test and with vehicles used in stop-and-go service prior to 2000, with regard to sludge and varnish deposit control.

4.1.2.5 Test Method **D6709**, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.¹⁰

(1) The Sequence VIII gasoline engine test is also used to determine the ability of an oil to resist permanent viscosity loss due to shearing in an engine.

4.1.2.6 In addition to passing performance in the engine tests, oils shall also meet bench test requirements (see **Table 1**), which are discussed in the following subsections:

(1) Test Method **D6557** (Ball Rust Test), was developed to replace the Sequence IID gasoline engine test, and evaluates the ability of an oil to prevent the formation of rust under short-trip service conditions.

(2) The volatility of engine oils is one of several factors that relates to engine oil consumption. For this engine oil category, volatility is measured by Test Methods **D5800** and **D6417**.

(3) Test Method **D6795**, the Engine Oil Filterability Test (EOFT) and Test Method **D6794**, the Engine Oil Water Tolerance Test (EOWTT) screen for the formation of precipitates and gels which form in the presence of water and can cause oil filter plugging.

(4) Phosphorus compounds in excessive amounts can cause glazing of automotive catalysts and exhaust gas oxygen sensors and, thereby, deactivate them. Control of the phosphorus level in the engine oil may reduce this tendency. For this engine oil category, phosphorus content is measured by either Test Method **D4951** or **D5185**.

(5) Excessive foaming in engine oil can cause valve lifter collapse and a loss of lubrication due to the presence of air in

¹² Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1391. Contact ASTM Customer Service at service@astm.org.

TABLE 1 S Engine Oil Categories

Required Test Method	API SJ Category		
	Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
Sequence IID (D5844 ^{A,B}) or D6557 ^A (Ball Rust Test)	D5844	Average engine rust rating, ^C min Number stuck lifters	8.5 none
	D6557	Average gray value, min	100
Sequence IIIE (D5533 ^{B,D}) or Sequence IIIF (D6984 ^D) or Sequence IIIG (D7320 ^J) or Sequence IIIH (D8111 using Sequence IIIH 60/70 Hour Guideline)	D5533	Hours to 375 % kinematic viscosity increase at 40 °C, min	64
		Average engine sludge rating, ^C min	9.2
		Average piston skirt varnish rating, ^C min	8.9
		Average oil ring land deposit rating, ^C min	3.5
		Lifter sticking	none
		Scuffing and wear	
		Cam or lifter scuffing	none
	Cam plus lifter wear, μm	Average, max	30
		Maximum, max	64
	D6984	Ring sticking (oil-related) ^E	none
		Kinematic viscosity, % increase at 40 °C, max	325 ^F
		Average piston skirt varnish rating, ^C min	8.5 ^G
		Weighted piston deposit rating, ^H min	3.2 ^G
		Screened average cam-plus-lifter wear, μm, max	20 ^{G,I}
	D7320	Hot stuck rings	none ^G
		Kinematic viscosity, % increase at 40 °C, max	150
		Weighted piston deposit rating, ^K min	3.5
D8111 (60/70 Hour Guideline)	Cam-plus-lifter wear avg, μm, max	60	
	Hot stuck rings	none	
	60 h kinematic viscosity, % increase at 40 °C	307 (max)	
	70 h average weighted piston deposits, ^H merits	2.5 (min)	
Sequence VE (D5302 ^{B,L}) or Sequence IVA (D6891 ^L) plus Sequence VG (D6593 ^L)	D5302	70 h average piston skirt varnish, ^C merits	7.5 (min)
		Average engine sludge rating, ^C min	9.0
		Rocker arm cover sludge rating, ^C min	7.0
		Average piston skirt varnish rating, ^C min	6.5
		Average engine varnish rating, ^C min	5.0
		Oil ring clogging, %	report
		Oil screen clogging, %, max	20.0
	Compression ring sticking (hot stuck)	none	
	Cam wear, μm	Average, max	127
		Maximum, max	380
	D6891	Average cam wear, μm ^M	120
	D6593	Average engine sludge rating, ^C min	7.8
		Rocker arm cover sludge rating, ^C min	8.0
Average piston skirt varnish rating, ^C min		7.5	
Average engine varnish rating, ^N min		8.9	
Oil screen clogging, %, max		20	
Hot stuck compression rings		none	
L-38 (D5119 ^O) or Sequence VIII (D6709 ^O)	D5119	Bearing weight loss, mg, max	40
	D6709	Shear stability ^P	26.4 ^P

Bench Test and Measured Parameter	Viscosity Grade Performance Criteria		
	SAE 0W-20, SAE 5W-20, SAE 5W-30, SAE 10W-30	All Others	
Test Method D4683, D4741, D5481, high temperature/high shear viscosity @ 150 °C, mPa·s, min	Q	2.6	
Test Method D5800 volatility loss, % max ^R	22	20 ^S	
Test Method D6417 volatility loss at 371 °C, % max ^R	17	15 ^S	
Test Method D5480 volatility loss at 371 °C, % max ^R	17	15 ^S	
Test Method D6795 (EOFT), % flow reduction, max	50	50	
Test Method D6794 (EOWTT), % flow reduction, max	with 0.6 % H ₂ O	report	report
	with 1.0 % H ₂ O	report	report
	with 2.0 % H ₂ O	report	report
	with 3.0 % H ₂ O	report	report
Test Method D4951 or D5185, mass fraction phosphorus, %, max	0.10 ^T	NR ^U	
Test Method D4951 or D5185, mass fraction phosphorus, %, min (unless valid passing Test Method D5302 results are obtained)	0.06	0.06	
Test Method D92 flash point, °C, min ^V	200	NR ^U	
Test Methods D93 or D7094 flash point, °C, min ^V	185	NR ^U	
Test Method D892 foaming tendency (Option A)	Sequence I, max, foaming/settling ^W	10/0	10/0
	Sequence II, max, foaming/settling ^W	50/0	50/0
	Sequence III, max, foaming/settling ^W	10/0	10/0
Test Method D6082 (optional blending required) Static foam, max, tendency/stability		200/50 ^X	200/50 ^X
Test Method D6922 homogeneity and miscibility		Y	Y
Test Method D6335 High temperature deposits (TEOST 33), deposit mass, mg, max		60	60

TABLE 1 Continued

Bench Test and Measured Parameter	Viscosity Grade Performance Criteria	
	SAE 0W-20, SAE 5W-20, SAE 5W-30, SAE 10W-30	All Others
Test Method D5133 Gelation Index, max	12	NR ^U

Required Test Method	Engine Test Method	API SL Category	
		Rated or Measured Parameter	Primary Performance Criteria
Sequence IIIF (D6984) or Sequence IIIG (D7320 ^J) or Sequence IIIH (D8111 using Sequence IIIH (70 Hour Guide- line))	D6984	Kinematic viscosity, % increase at 40 °C, max	275
		Average piston skirt varnish rating, ^C min	9.0
		Weighted piston deposit rating, ^F min	4.0
		Screened average cam-plus-lifter wear, μm, max	20 ^J
		Hot Stuck Rings	none
		Low temperature viscosity performance ^Z	report
	D7320	Kinematic viscosity, % increase at 40 °C, max	150
		Weighted piston deposit rating, ^K min	3.5
		Cam-plus-lifter wear avg, μm, max	60
		Hot stuck rings	none
		Low temperature viscosity performance ^{AA}	report
		70 h kinematic viscosity, % increase at 40 °C	181 (max)
D8111 (70 Hour Guideline)	70h average weighted piston deposits, merits	3.3 (min)	
	70h average piston skirt varnish, ^C merits	7.9 (min)	
Sequence IVA (D6891)	D6891	Cam wear average, μm, ^M max	120
Sequence VE (D5302 ^{AB,J})	D5302	Cam wear average, μm, max	127
		Cam wear max, μm, max	380
Sequence VG (D6593)	D6593	Average engine sludge rating, ^C min	7.8
		Rocker arm cover sludge rating, ^C min	8.0
		Average piston skirt varnish rating, ^C min	7.5
		Average engine varnish rating, ^N min	8.9
		Oil screen clogging, %, max	20
		Hot stuck Compression rings	none
		Cold stuck rings	report
		Oil screen debris, %	report
		Oil ring clogging, %	report
Sequence VIII (D6709)	D6709	Bearing weight loss, mg, max	26.4
		Shear stability	^P

Bench Test and Measured Parameter	Viscosity Grade Performance Criteria	
	SAE 0W-20 SAE 5W-20 SAE 5W-30 SAE 10W-30	All Others
Test Method D4683 , D4741 , or D5481 , high temperature/high shear viscosity @ 150 °C, mPa·s, min	^Q	2.6
Test Method D6557 (Ball Rust Test), average gray value, min	100	100
Test Method D5800 volatility loss, % max	15	15
Test Method D6417 volatility loss at 371 °C, % max	10	10
D6795 (EOFT), % flow reduction, max	50	50
	With 0.6 % H ₂ O	50
	With 1.0 % H ₂ O	50
	With 2.0 % H ₂ O	50
	With 3.0 % H ₂ O	50
Test Method D4951 or D5185 , mass fraction phosphorus %, max	0.10 ^T	NR ^U
Test Method D4951 or D5185 , mass fraction phosphorus %, min (unless valid passing Test Method D5302 results are obtained) ^J	0.06	0.06
Test Method D892 foaming tendency (Option A)	Sequence I, max, foaming/settling ^W	10/0
	Sequence II, max, foaming/settling ^W	50/0
	Sequence III, max, foaming/settling ^W	10/0
Test Method D6082 (optional blending required) static foam max, tendency/stability	100/0 ^X	100/0 ^X
Test Method D6922 homogeneity and miscibility	Y	Y
Test Method D7097 high temperature deposits (TEOST MHT-4), deposit mass, mg, max	45	45
Test Method D5133 (Gelation Index), max ^{AC}	12 ^{AD}	12 ^{AD}

^A Demonstrate passing performance in either Test Method **D5844** or **D6557**.

^B Monitoring of this test method was discontinued in June 20, 2001. Valid test results shall predate the end of the last calibration period for the test stand in which this test method was conducted.

^C ASTM Deposit Rating Manual 20, available from ASTM Customer Relations, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

^D Demonstrate passing performance in either Test Method **D5533** or **D6984**. However, an oil passing Test Method **D6984** and containing less than 0.08 % mass phosphorus in the form of ZDDP shall also pass the wear limits in Test Method **D5302** (see also footnote ^J).

^E An oil-related stuck ring occurs on a piston with an individual oil ring land deposit rating <2.6.

^F Determine at 60 h.

^G Determine at 80 h.

^H Determine weighted piston deposits by rating the following piston areas and applying the corresponding weightings: undercrown, 10 %; second land, 15 %; third land, 30 %; piston skirt, 10 %; first groove, 5 %; second groove, 10 %; and third groove, 20 %. Use ASTM Deposit Rating Manual 20 for all ratings.

^I Calculate by eliminating the highest and lowest cam-plus-lifter wear results and then calculating an average based on the remaining ten rating positions.

- ^J For oils containing at least 0.06 % mass phosphorus in the form of ZDDP, demonstrating passing performance in the Sequence IIIG test obviates the need to also conduct Test Method **D5302** (Sequence VE), which was previously required for oils with less than 0.08 % mass phosphorus.
- ^K Unlike the Sequence IIIF test, piston skirt varnish rating is not required in the Sequence IIIG test.
- ^L Demonstrate passing performance in Test Method **D5302**, or alternatively, in both Test Method **D6891** and Test Method **D6593**.
- ^M Determine cam wear according to Test Method **D6891**. Seven wear measurements are made on each cam lobe and the seven measured values are added to obtain an individual cam lobe wear result. The overall cam wear value is the average of the twelve individual cam lobe wear results.
- ^N Determine the average engine varnish rating by averaging the piston skirt, right rocker arm cover, and left rocker arm cover varnish ratings. Use ASTM Deposit Rating Manual 20 for all ratings.
- ^O Demonstrate passing performance in either Test Method **D5119** or **D6709**.
- ^P Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade).
- ^Q Minimum high temperature/high shear viscosity @ 150 °C for these viscosity grades as defined in SAE J300.
- ^R Meet the volatility requirement in either Test Method **D5800**, **D5480**, or **D6417**.
- ^S Passing volatility loss only required for SAE 15W-40 oils.
- ^T This is a noncritical specification as described in Practice **D3244**.
- ^U NR stands for Not Required.
- ^V Meet either Test Methods **D92**, **D93**, or **D7094** flash point requirement.
- ^W Determine settling volume, in mL, at 10 min.
- ^X Determine settling volume, in mL, at 1 min.
- ^Y Homogeneous with SAE reference oils.
- ^Z Evaluate the 80 h test oil sample by Test Method **D4684** at the temperature indicated by the low temperature grade of oil as determined on the 80 h sample by Test Method **D5293**.
- ^{AA} Measure the viscosity of the EOT oil sample by Test Method **D4684**. The measured viscosity shall meet the requirements of the original grade or the next higher grade. The EOT sample can be either from a Sequence IIIG or a Sequence IIIGA test. (A Sequence IIIGA test is identical to a Sequence IIIG test, except only low temperature viscosity performance is measured.) Additional details are provided in the Sequence IIIG test method, in Section 13.6.
- ^{AB} Not required for oils containing a minimum of 0.08 % mass phosphorus in the form of ZDDP.
- ^{AC} Requirement applies only to SAE 0W-20, 5W-20, 0W-30, 5W-30, and 10W-30 viscosity grades.
- ^{AD} For gelation temperatures at or above the W grade pumpability temperature as defined in SAE J300.

the oil. Test Methods **D892** and **D6082** empirically rate the foaming tendency and stability of oils.

(6) Test Method **D6922**, the H and M Test indicates the compatibility of an oil with standard test oils.

(7) Newer engines designed to provide increased power and improved driveability and to meet future federal emissions and fuel economy requirements may be sensitive to internal deposits caused by elevated engine operating temperatures. Test Method **D7097**, the TEOST MHT-4 test may be useful in determining the piston deposit control capability of oils recommended for these engines.

(8) Test Method **D5133**, the Gelation Index technique, might identify oils susceptible to air binding and might provide low-temperature protection not adequately measured by Test Method **D4684**.

4.1.2.7 Licensing of the API SL category by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See **Appendix X3** for more information.)

4.1.3 *CH-4*—Oil meeting the performance requirements measured in the following diesel and gasoline engine tests and bench tests.

4.1.3.1 Test Method **D6750**, the 1K diesel engine test, has been correlated with vehicles equipped with engines used in high speed operation prior to 1989, particularly with respect to aluminum piston deposits and oil consumption when the mass fraction of sulfur content is nominally 0.4 %.¹¹

4.1.3.2 Test Method **D6681**, the 1P diesel engine test, has been used to predict iron piston deposit formation and oil consumption in four-stroke-cycle, direct injection, diesel engines that have been calibrated to meet 1998 U.S. federal

exhaust emissions requirements for heavy duty engines operated on fuel containing the mass fraction of sulfur less than 0.05 %.¹³

4.1.3.3 Test Method **D6483**, the T-9 diesel engine test, has been correlated with vehicles equipped with engines used in high speed operation prior to 1998, particularly in regard to ring and liner wear and used oil lead content.¹⁴ (Alternatives are Test Method **D6987/D6987M**, the T-10 diesel engine test—see 4.1.4.2, and Test Method **D7422**, the T-12 diesel engine test—see 4.1.3.2.)

4.1.3.4 Test Method **D5967** extended, the T-8E engine test, has been shown to generate soot-related oil thickening in a manner similar to 1998 emissions-controlled heavy duty diesel engines using electronic injection control systems.

4.1.3.5 Test Method **D6838**, The M11 High Soot diesel engine test has been correlated with vehicles equipped with four-stroke-cycle diesel engines used in high speed operations prior to 1998, particularly with regard to soot related valve train wear, filter plugging, and sludge control.¹⁵ (An alternative is Test Method **D7468**, the Cummins ISM diesel engine test. See 4.1.5.5.)

4.1.3.6 Test Method **D5966**, the Roller Follower Wear Test, has been correlated with hydraulic roller cam follower pin wear in medium-duty indirect injection diesel engines used in broadly based field operations.

¹³ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1441. Contact ASTM Customer Service at service@astm.org.

¹⁴ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1440. Contact ASTM Customer Service at service@astm.org.

¹⁵ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1439. Contact ASTM Customer Service at service@astm.org.

4.1.3.7 Test Method **D6984**, the Sequence IIIF test, is used to measure bulk oil viscosity increase, which indicates an oil's ability to withstand the higher temperatures found in modern diesel engines. (An alternative is Test Method **D7320**, the Sequence IIIG test.)

4.1.3.8 Test Method **D6894**, the EOAT has been correlated with oil aeration in diesel engines equipped with HEUI used in medium-duty diesel engines.¹⁶

4.1.3.9 Test Method **D892**, a foaming test, Sequences I, II and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.3.10 Test Method **D6594** operated at 135 °C, a High Temperature Corrosion Bench Test (HTCBBT), has been shown to predict the corrosion of engine oil-lubricated copper and lead containing components used in diesel engines.

4.1.3.11 Test Method **D6278**, the Diesel Injector Shear Test, has been shown to correlate with permanent shear loss of engine oils in medium-duty direct injection diesel engines used in broadly based field operations.

4.1.3.12 Test Method **D5800**, Noack Volatility or, alternatively, Test Method **D6417**, are used to measure engine oil volatility loss under high temperature operating conditions.

4.1.3.13 Licensing of the API CH-4 category by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See **Appendix X3** for more information.)

4.1.4 *CI-4*—Oil meeting the performance requirements measured in the following diesel and gasoline engine tests and bench tests.

4.1.4.1 Test Method **D6923**, the 1R single cylinder diesel engine test is used to measure engine oil performance with respect to piston deposits, oil consumption, piston and piston ring scuffing, and ring sticking using a two-piece iron/aluminum piston similar to that used in modern, production heavy-duty diesel engines. (An alternative is Test Method **D6681**, the 1P diesel engine test, see 4.1.3.2.)

4.1.4.2 Test Method **D6987/D6987M**, the T-10 diesel engine test, is used to measure engine oil performance with respect to piston ring and cylinder liner wear, bearing lead corrosion, and oil consumption in an electronically governed, open chamber, in-line six-cylinder, four-stroke cycle, turbocharged, compression-ignition engine with exhaust gas recirculation. (An alternative is Test Method **D7422**, the T-12 diesel engine test, see 4.1.5.2.)

4.1.4.3 Test Method **D6975**, the M11 EGR heavy-duty diesel engine test, is used to evaluate oil performance with respect to valve train wear, sludge deposits, and oil filter plugging in an exhaust gas recirculation environment. (An alternative is the Cummins ISM diesel engine test. See 4.1.5.5.)

4.1.4.4 Test Method **D5967** extended, the T-8E engine test, has been shown to generate soot-related oil thickening in a

manner similar to 1998 emissions-controlled heavy-duty diesel engines using electronic injection control systems.

4.1.4.5 Test Method **D6984**, the Sequence IIIF gasoline engine test, is used to measure oil thickening under high temperature conditions in spark-ignition engines. (An alternative is Test Method **D7320**, the Sequence IIIG test.)

4.1.4.6 Test Method **D6750** (1K), the 1K diesel engine test, or, alternatively, Test Method **D6750** (1N), the 1N diesel engine test, is used to evaluate performance in diesel engines equipped with aluminum pistons. The 1K test has been correlated with vehicles used in high speed operation prior to 1989, particularly with respect to aluminum piston deposits and oil consumption, when the mass fraction of fuel sulfur was nominally 0.4 %. The 1N test has been used to predict aluminum piston deposit formation in four-stroke cycle, direct-injection, diesel engines that have been calibrated to meet 1994 U.S. federal exhaust emissions requirements for heavy-duty engines operated on fuel containing the mass fraction of sulfur less than 0.05 %.

4.1.4.7 Test Method **D5966**, the Roller Follower Wear Test, has been correlated with hydraulic roller cam follower pin wear in medium-duty indirect injection diesel engines used in broadly based field operations.

4.1.4.8 Test Method **D6894**, the EOAT procedure, has been correlated with oil aeration in diesel engines equipped with HEUI used in medium-duty diesel engines.

4.1.4.9 Test Methods **D4741**, **D4683**, and **D5481** High Temperature High Shear (HTHS) tests are part of the SAE J300 Viscosity Classification System.

4.1.4.10 Test Method **D4684** (MRV TP-1) has been shown to predict field failures resulting from poor low temperature pumpability.

4.1.4.11 Test Method **D5800**, Noack Volatility, is used to measure engine oil volatility loss under high temperature operating conditions.

4.1.4.12 Test Method **D6594** operated at 135 °C, a high temperature corrosion bench test (HTCBBT), has been shown to predict corrosion of engine oil-lubricated copper and lead containing components used in diesel engines.

4.1.4.13 Test Method **D6278**, a diesel injector shear test, has been shown to correlate with permanent shear loss of engine oils in medium-duty direct injection diesel engines used in broadly based field operations.

4.1.4.14 Test Method **D892**, a foaming test, Sequences I, II, and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.4.15 Test Method **D7216**, the Elastomer Compatibility Test is used to measure the performance of four widely used elastomer compounds when exposed to diesel engine oils.

4.1.4.16 Licensing of the API CI-4 category by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See **Appendix X3** for more information.)

¹⁶ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1379. Contact ASTM Customer Service at service@astm.org.

4.1.5 *CJ-4*—Oil meeting the performance requirements measured in the following diesel and gasoline engine tests, and bench and chemical tests.

4.1.5.1 Test Method **D7156**, the Mack T-11 diesel engine test has been shown to generate soot-related oil thickening in a manner similar to 2002 EGR emission-controlled heavy-duty engines with electronic injection control. This engine test uses fuel with sulfur content of 500 mg/kg.

4.1.5.2 Test Method **D7422**, the Mack T-12 diesel engine test is used to measure engine oil performance with respect to piston ring and cylinder liner wear, bearing corrosion, and oil consumption, using an in-line six cylinder, four-stroke, direct injection, turbo-charged engine with exhaust gas recirculation at levels expected for 2007 emission control engines. This engine test uses fuel with ultra low sulfur content of 15 mg/kg.

4.1.5.3 Test Method **D7549**, the Caterpillar C13 *Advanced Combustion Emission Reduction Technology* (ACERT) is an in-line six-cylinder engine used to measure engine oil consumption and piston deposits. The engine is equipped with a single-piece forged steel piston used in emission controlled engines. This engine test uses fuel with ultra low sulfur content of 15 mg/kg.

4.1.5.4 Test Method **D7484**, the Cummins ISB diesel engine test is used to evaluate oil performance with respect to cam and tappet wear with high soot level in the engine oil. This is an in-line six cylinder turbo-charged engine with a common-rail fuel system for emission control. This engine test uses fuel with ultra low sulfur content of 15 mg/kg.

4.1.5.5 Test Method **D7468**, the Cummins ISM diesel engine test is used to evaluate oil performance with respect to valve train wear, sludge and oil filter plugging with a high soot level in the engine oil. This is an in-line six cylinder, turbo-charged engine with EGR for emission control. This engine test uses fuel with sulfur content of 500 mg/kg.

4.1.5.6 Test Method **D6750**, the 1N diesel engine test, has been used to predict piston deposit formation in four-stroke cycle, direct injection, diesel engines that have been calibrated to meet 1994 U.S. federal exhaust emissions requirements for heavy-duty engines operated on fuel containing the mass fraction of sulfur less than 0.05 %.¹⁷

4.1.5.7 Test Method **D6984**, the Sequence IIIF test, is used to measure bulk oil viscosity increase, which indicates an oil's ability to withstand the higher temperatures found in modern diesel engines. (An alternative is Test Method **D7320**, the Sequence IIIG test.)

4.1.5.8 Test Method **D5966**, the roller follower wear test (RFWT), has been correlated with hydraulic roller cam follower pin wear in medium-duty indirect injection diesel engines used in broadly based field operations.

4.1.5.9 Test Method **D4684** (MRV TP-1) has been shown to predict field failures resulting from poor low temperature pumpability.

4.1.5.10 Test Method **D7109**, a diesel injector shear test, has been shown to correlate with permanent shear loss of engine

oils in medium-duty direct injection diesel engines used in broadly based field operations.

4.1.5.11 Test Method **D6594** operated at 135 °C, a high temperature corrosion bench test (HTCBT), has been shown to predict corrosion of engine oil-lubricated copper and lead containing components used in diesel engines.

4.1.5.12 Test Methods **D4171**, **D4683**, and **D5481** High Temperature High Shear (HTHS) tests are part of the SAE J300 Viscosity Classification System.

4.1.5.13 Test Method **D892**, a foaming test, Sequences I, II, and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.5.14 Test Method **D7216**, the Elastomer Compatibility Test, is used to measure the performance of four widely used elastomer compounds when exposed to diesel engine oils.

4.1.5.15 Test Method **D6894**, the EOAT procedure, has been correlated with oil aeration in diesel engines equipped with HEUI used in medium-duty diesel engines.

4.1.5.16 Licensing of the API CJ-4 category by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See **Appendix X3** for more information.)

4.1.6 *CK-4 or FA-4*—Oil meeting the performance requirements measured in the following diesel engine tests, and bench and chemical tests.

4.1.6.1 Test Method **D8048**, the Volvo T-13 diesel engine test method, is used to evaluate the oxidation resistance performance of engine oils in turbocharged and intercooled four-cycle diesel engines equipped with EGR and running on ultra-low sulfur diesel fuel.

4.1.6.2 Test Method **D8047**, the Caterpillar-C13 Engine Oil Aeration Test (COAT) method, evaluates an engine oil's resistance to aeration under high-engine-speed, zero load conditions using a direct-injection, turbocharged, after-cooled, six-cylinder diesel engine.

4.1.6.3 Test Method **D7156**, the Mack T-11 diesel engine test, has been shown to generate soot-related oil thickening in a manner similar to 2002 EGR emission-controlled heavy-duty engines with electronic injection control. This engine test uses fuel with sulfur content of 500 mg/kg.

4.1.6.4 Test Method **D7422**, the Mack T-12 diesel engine test, is used to measure engine oil performance with respect to piston ring and cylinder liner wear, using an in-line six cylinder, four-stroke, direct injection, turbo-charged engine with exhaust gas recirculation at levels expected for 2007 emission control engines. This engine test uses fuel with ultra low sulfur content of 15 mg/kg.

4.1.6.5 Test Method **D7549**, the Caterpillar C13 *Advanced Combustion Emission Reduction Technology* (ACERT) is an in-line six-cylinder engine used to measure engine oil consumption and piston deposits. The engine is equipped with a single-piece forged steel piston used in emission controlled engines. This engine test uses fuel with ultra low sulfur content of 15 mg/kg.

¹⁷ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1321. Contact ASTM Customer Service at service@astm.org.

4.1.6.6 Test Method **D7484**, the Cummins ISB diesel engine test, is used to evaluate oil performance with respect to cam and tappet wear with high soot level in the engine oil. This is an inline six cylinder turbo-charged engine with a common-rail fuel system for emission control. This engine test uses fuel with ultra low sulfur content of 15 mg/kg.

4.1.6.7 Test Method **D7468**, the Cummins ISM diesel engine test, is used to evaluate oil performance with respect to valve train wear, sludge and oil filter plugging with a high soot level in the engine oil. This is an in-line six cylinder, turbo-charged engine with EGR for emission control. This engine test uses fuel with sulfur content of 500 mg/kg

4.1.6.8 Test Method **D6750**, the 1N diesel engine test, has been used to predict piston deposit formation in four-stroke cycle, direct injection, diesel engines that have been calibrated to meet 1994 U.S. federal exhaust emissions requirements for heavy-duty engines operated on fuel containing sulfur content of 500 mg/kg.

4.1.6.9 Test Method **D5966**, the roller follower wear test (RFWT), has been correlated with hydraulic roller cam follower pin wear in medium-duty indirect injection diesel engines used in broadly based field operations.

4.1.6.10 Test Method **D6896** (MRV TP-1) has been shown to predict field failures resulting from poor low temperature pumpability of used engine oils.

4.1.6.11 Test Method **D7109**, a diesel injector shear test, has been shown to correlate with permanent shear loss of engine oils in medium-duty direct injection diesel engines used in broadly based field operations.

4.1.6.12 Test Method **D6594** operated at 135 °C, a high temperature corrosion bench test (HTCBT), has been shown to predict corrosion of engine oil-lubricated copper and lead containing components used in diesel engines.

4.1.6.13 Test Methods **D4741**, **D4683**, and **D5481** High Temperature High Shear (HTHS) tests are part of the SAE J300 Viscosity Classification System.

4.1.6.14 Test Method **D892**, a foaming test, Sequences I, II, and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.6.15 Test Method **D7216**, the Elastomer Compatibility Test, is used to measure the performance of four widely used elastomer compounds when exposed to diesel engine oils.

4.1.6.16 Licensing of the API CK-4 or FA-4 category by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See **Appendix X3** for more information.)

5. Performance Requirements

5.1 The oils identified by the categories discussed in Section 4 shall conform to the requirements listed in **Tables 1-6**.

NOTE 3—API has developed a symbol that can be licensed for use on containers of oils that conform to the requirements of one or more categories that are currently of commercial importance. API 1509 de-

scribes the symbol and licensing procedure.

NOTE 4—In practice, engine oils are often labeled with service category designations having some combination of both S and C prefixes.

NOTE 5—Intended service applications for the various categories described in 4.1.1 – 4.1.3 can be found in API 1509. Several applicable sections of that publication have been included in **Appendix X2**.

6. Test Procedures

6.1 The requirements listed in this specification shall be determined in accordance with those standard test methods listed in Section 2.

6.2 Engine tests are run in test stands calibrated using reference oils.

6.3 For tests monitored by the TMC, results are valid only if the tests are run in currently calibrated stands/equipment.

6.4 For SJ test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods **D5119**, **D5133**, **D5480**, **D5800**, **D6082**, **D6335**, **D6417**, **D6794**, **D6795**, **D6891**, **D6984**, and **D7320**.

6.5 For SL test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods **D5133**, **D5800**, **D6082**, **D6417**, **D6557**, **D6593**, **D6709**, **D6794**, **D6795**, **D6891**, **D6984**, **D7097**, and **D7320**.¹⁸

6.6 For CH-4 test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods **D5800**, **D5966**, **D5967** (extended), **D6417**, **D6483**, **D6594**, **D6681**, **D6750**, **D6838**, **D6894**, **D6984**, **D6987/D6987M**, **D7320**, and **D7468**.

6.7 For CI-4 test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods **D5800**, **D5966**, **D5967** (extended), **D6594**, **D6750**, **D6923**, **D6894**, **D6975**, **D6984**, **D6987/D6987M**, **D7320**, and **D7468**.

6.8 For CJ-4 test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods **D874**, **D5800**, **D5966**, **D6594**, **D6750**, **D6894**, **D6984**, **D7156**, **D7216**, **D7320**, **D7422**, **D7468**, **D7484**, and **D7549**.

6.9 For CK-4 or FA-4 test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods **D874**, **D5800**, **D5966**, **D6594**, **D6750**, **D7156**, **D7216**, **D7422**, **D7468**, **D7484**, **D7549**, **D8047**, and **D8048**.

7. Keywords

7.1 automotive; engine oil; engine oil categories; engine oil test methods; heavy-duty engine; internal combustion engine; light duty engine

¹⁸ Effective October 1, 2000. If calibrated bench test equipment is unavailable, tests may be conducted in uncalibrated equipment. However, when calibrated equipment does become available, tests shall be passed in calibrated equipment within six months.

TABLE 2 Diesel Engine Oil Category CH-4

Required Test Method	Test Method	Rated or Measured Parameter	Primary Performance Criteria			
			One-test	Two-test ^A	Three-test ^A	
1P (D6681 ^B)	D6681	Weighted demerits (WDP), max	350	378	390	
		Top groove carbon (TGC), demerits, max	36	39	41	
		Top land carbon (TLC), demerits, max	40	46	49	
		Average Oil Consumption, g/h (0 h – 360 h), max	12.4	12.4	12.4	
		Final Oil Consumption, g/h (312 h – 360 h), max	14.6	14.6	14.6	
		Piston, ring, and liner scuffing	none	none	none ^C	
1K (D6750 ^D)	D6750	Weighted demerits (WDK), %, max	332	347	353	
		Top groove fill (TGF), %, max	24	27	29	
		Top land heavy carbon (TLHC), %, max	4	5	5	
		Average Oil Consumption	g/kWh (0 h – 252 h), max	0.54	0.54	0.54
			g/MJ (0 h – 252 h), max	0.15	0.15	0.15
		Piston, ring, and liner scuffing	none	none	none ^C	
T-9 (D6483) or T-10 (D6987/D6987M) or T-12 (D7422)	D6483	Average Liner Wear, normalized to 1.75 % soot, µm max	25.4	26.6	27.1	
		Average Top Ring Mass Loss, mg max ^E	120	136	144	
		EOT Used Oil Lead Content less New Oil Lead Content, mg/kg, max	25	32	36	
	D6987/D6987M	Liner wear, µm, max	32	34	35	
		Ring wear, mg, max	150	159	163	
		Lead content at EOT, mg/kg, max	50	56	59	
	D7422	Liner wear, µm, max	30.0	30.8	31.1	
		Top Ring Mass Loss, mg, max	120	132	137	
		Lead content at EOT, mg/kg, max	65	75	79	
RFWT (D5966)	D5966	Average Pin Wear	mils, max	0.30	0.33	0.36
			(µm) max	(7.6)	(8.4)	(9.1)
M11 (D6838 ^F) or ISM (D7468)	D6838	Rocker Pad Average Mass Loss, normalized to 4.5 % soot, mg max	6.5	7.5	8.0	
		Oil Filter Differential Pressure at EOT, kPa max	79	93	100	
		Average Engine Sludge, CRC Merits at EOT, min	8.7	8.6	8.5	
	D7468	Crosshead wear, mg, max	7.5	7.8	7.9	
		Oil filter delta pressure, at 150 h, kPa, max	79	95	103	
		Sludge rating, CRC merits, min	8.1	8.0	8.0	
Ext. T-8E (D5967 ^G)	D5967	Relative Viscosity at 4.8 % Soot by TGA, max	2.1	2.2	2.3	
		Viscosity increase at 3.8 % Soot by TGA, mm ² /s, max	11.5	12.5	13.0	
Sequence IIIF (D6984) or Sequence IIIG (D7320 ^I) or Sequence IIIH (D8111)	D6984	60 h Viscosity at 40 °C, increase from 10 min sample, % max	295	295 (MTAC) ^H	295 (MTAC) ^H	
		D7320	Kinematic viscosity, % increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
			D8111	60 h Kinematic viscosity, % increase at 40 °C max	110	110 (MTAC)
EOAT (D6894 ^J)	D6894	Aeration, volume, % max	8.0	8.0 (MTAC) ^H	8.0 (MTAC) ^H	
HTCBT, 135 °C (D6594)	D6594	Used Oil Elemental Concentration	N/A	N/A	N/A	
		Copper, mg/kg increase, max	20	N/A	N/A	
		Lead, mg/kg increase, max		120		
		Tin, mg/kg increase		report		
		Copper strip rating, ^K max		3		
		Foaming/Settling, ^L mL, max				
D892 (Option A not allowed)	D892 (Option A not allowed)		One-test	Two-test ^A	Three-test ^A	
		Sequence I	10/0	N/A	N/A	
		Sequence II	20/0	N/A	N/A	
		Sequence III	10/0	N/A	N/A	
Noack (D5800) or D6417	D5800		SAE 10W-30	SAE 15W-40	N/A	
		percent volatility loss at 250 °C, max	20	18	N/A	
		percent volatility loss at 371 °C, max	17	15	N/A	
D6278	D6278		SAE XW-30	SAE XW-40	N/A	
		Kinematic Viscosity after shearing, mm ² /s at 100 °C, min	9.3	12.5	N/A	

^A See Annex A2 for additional information.

^B Refer to RR:D02-1441.

^C If three or more operationally valid tests have been run, the majority of these tests shall not have scuffing. The scuffed tests are considered uninterpretable, and all data from these tests are eliminated from averaging.

^D Refer to RR:D02-1273.

^E Refer to RR:D02-1440.

^F Refer to RR:D02-1439.

^G A passing T-11 (TGA % soot at 12.0 mm²/s increase, at 100 °C, min)—6.00 (first test), 5.89 (second test), and 5.85 (third test)—can be used in place of a T-8E in the applicable categories. This is not intended to indicate equivalence.

^H See Annex A1; use method without transformations.

^I The Sequence IIIG limits shown are more restrictive than the corresponding limits in Sequence IIIF, and are not intended to indicate equivalence. Results meeting the Sequence IIIG criteria stated can be used in lieu of Sequence IIIF.

^J Refer to RR:D02-1379.

^K The rating system in Test Method D130 is used to rate the copper coupon in Test Method D6594.

^L Ten minutes for Sequence I, II, and III.

TABLE 3 Diesel Engine Oil Category CI-4

Required Test Method	Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria			
			One-test	Two-test ^A	Three-test ^A	
1R (D6923) or 1P (D6681)	D6923	Weighted demerits (WDR), max	382	396	402	
		Top groove carbon (TGC), demerits, max	52	57	59	
		Top land carbon (TLC), demerits, max	31	35	36	
		Initial oil consumption (IOC), (0 h – 252 h), g/h, average	13.1	13.1	13.1	
		Final oil consumption, (432 h – 504 h), g/h, average, max	IOC + 1.8	IOC + 1.8	IOC + 1.8	
		Piston, ring, and liner distress	none	none	none	
	D6681	Ring sticking	none	none	none	
		Weighted demerits (WDP), max	350	378	390	
		Top groove carbon (TGC), demerits, max	36	39	41	
		Top land carbon (TLC), demerits, max	40	46	49	
		Average oil consumption, g/h (0 h – 360 h), max	12.4	12.4	12.4	
		Final oil consumption, g/h (312 h – 360 h), max	14.6	14.6	14.6	
T-10 (D6987/ D6987M) or T-12 (D7422)	D6987/D6987M	Piston, ring, and liner scuffing	none	none	none	
	D7422	Merit rating, ^A min	1000	1000	1000	
M11 EGR (D6975) or ISM (D7468)	D6975	Merit rating, ^A min	1000	1000	1000	
		Average crosshead mass. loss, mg, max	20.0	21.8	22.6	
		Average top ring mass loss, mg	report	report	report	
	D7468	Oil filter differential pressure at 250 h, kPa, max	275	320	341	
		Average engine sludge, CRC merits at EOT, min	7.8	7.6	7.5	
		Crosshead wear, mg, max	7.5	7.8	7.9	
Ext. T-8E (D5967) ^B	D5967	Oil filter Δ pressure at 150 h, kPa, max	55	67	74	
		Sludge rating, CRC Merits, min	8.1	8.0	8.0	
Sequence IIIF (D6984) ^D or Sequence IIIG (D7320) ^E or Sequence IIHH (D8111)	D6984	Relative viscosity at 4.8 % soot ^C	1.8	1.9	2.0	
	D7320	Kinematic viscosity (at 40 °C), percent increase, max	275	275 (MTAC)	275 (MTAC)	
		D8111	Kinematic viscosity, percent increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
1K (D6750) ^G	D6750	70 h ^F Kinematic viscosity, % increase at 40 °C max	370	370 (MTAC)	370 (MTAC)	
		Weighted demerits (WDK), max	332	347	353	
		Top groove fill (TGF), %, max	24	27	29	
		Top land heavy carbon (TLHC), %, max	4	5	5	
		Average oil consumption	g/kWh (0 h – 252 h), max	0.54	0.54	0.54
		g/MJ (0 h – 252 h), max	0.15	0.15	0.15	
RFWT (D5966)	D5966	Piston, ring, and liner scuffing	none	none	none	
		Average pin wear	mils, max	0.30	0.33	0.36
EOAT (D6894) ^H	D6894	um, max	7.6	8.4	9.1	
		Aeration, volume percent, max	8.0	8.0 (MTAC) ^I	8.0 (MTAC) ^I	
CI-4 Bench Tests		Measured Parameter	Primary Performance Criteria			
D4683 (High temperature/High shear) or D4741 or D5481 ^J		Viscosity after shear, ^K min	3.5 mPa-s			
MRV-TP-1 (D4684)		The following limits are applied to SAE viscosity grades 0W, 5W, 10W, and 15W: Viscosity of 75 h used oil sample from T-10 test (or T-10A ^L test), or 100 h used oil sample from T-12 test (or T-12A ^M test, tested at –20 °C, mPa-s, max	25 000			
		If yield stress is detected, use modified D4684 ^N (external preheat), then mPa-s, max	25 000			
Noack (D5800)		and yield stress, Pa	<35			
135 °C HTCBT (D6594)		Evaporative loss at 250 °C, %, max	15			
		Copper, mg/kg increase, max	20			
		Lead, mg/kg increase, max	120			
		Tin, mg/kg increase	report			
D6278		Copper strip rating, ^O max	3			
		Kinematic viscosity after shearing	SAE XW-30	SAE XW-40		
		mm ² /s at 100 °C, min	9.3	12.5		
D892 (Option A not allowed)		Foaming/settling, ^P mL, max				
		Sequence I	10/0			
		Sequence II	20/0			
		Sequence III	10/0			
D7216 (Elastomer Compatibility)						

Note—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A4.

Elastomer	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation at Break Change, %
Nitrile (NBR)	(+5, -3)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)
Silicone (VMQ)	(+TMC 1006, -3)	(+5, -TMC 1006)	(+10, -45)	(+20, -30)
Polycrylate (ACM)	(+5, -3)	(+8, -5)	(+18, -15)	(+10, -35)
Fluoroelastomer (FKM)	(+5, -2)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)

TABLE 3 *Continued*
D7216 (Elastomer Compatibility)

Note—TMC 1006 is the designation for the reference oil used in this test method. This designation represents the original blend or subsequent approved re-blends of TMC 1006.

^A See **Annex A3** for additional information.

^B A passing T-11 (TGA % soot at 12.0 mm²/s increase, at 100 °C, min)—6.00 (first test), 5.89 (second test), and 5.85 (third test)—can be used in place of a T-8E in the applicable categories. This is not intended to indicate equivalence.

^C Relative Viscosity (RV) = viscosity at 4.8 % soot/viscosity of new oil sheared in Test Method **D6278**.

^D Refer to RR:D02-1391.

^E The Sequence IIIG limits shown are more restrictive than the corresponding limits in Sequence IIIF, and are not intended to indicate equivalence. Results meeting the Sequence IIIG criteria stated can be used in lieu of Sequence IIIF.

^F 70 h value is interpolated according to the equation $PVIS@70\text{ h} = \left(\frac{\sqrt{PVIS@60\text{ h}} + \sqrt{PVIS@80\text{ h}}}{2} \right)^2$, where PVIS@60 h is percent viscosity increase at 60 h and PVIS@80 h is percent viscosity increase at 80 h.

^G Refer to RR:D02-1273. Alternatively, Test Method **D6750** (1N) can be used; if this test method is used, the measured parameters and primary performance criteria are the same as those shown for Test Method **D6750** (1N) in the CJ-4 category.

^H Refer to RR:D02-1379.

^I See **Annex A1**; use method without transformations.

^J Tests as allowed in SAE J300.

^K Noncritical specification as defined by Practice **D3244**; may be superseded only by applicable higher limits set by SAE J300.

^L The T-10A test is the name given to a T-10 test run for 75 h to generate the sample for measurement by Test Method **D4684**.

^M The T-12A test is the name given to a T-12 test run for 100 h to generate the sample for measurement by Test Method **D4684**.

^N Refer to RR:D02-1517.

^O The rating system in Test Method **D130** is used to rate the copper coupon in Test Method **D6594**.

^P Ten minutes for Sequence I, II, and III.

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