



## Standard Specification for Performance of Engine Oils<sup>1</sup>

This standard is issued under the fixed designation D 4485; 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 approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 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 Specification), 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 Appendix of this document 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 and CA, CB, CC, CD, CD-II, CE) (see 3.1.2). SA is not included because it does not have specified engine performance requirements. SG is not included because it was a category that could not be licensed for use in the API Service Symbol after Dec. 31, 1995. 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.

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

1.4 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.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants.

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1.5 The values stated in either SI units or other units shall be regarded separately as standard. The values given in parentheses are for information only.

1.6 The test procedures referred to in this specification that are not yet standards are listed in **Table 1**.

**TABLE 1 Test Procedures**

Test Procedure	ASTM Publications <sup>A</sup>
T-6	RR: D02-1219 <sup>B</sup>
T-7	RR: D02-1220 <sup>C</sup>
T-12	under development <sup>D</sup>
ISM	under development <sup>E</sup>
ISB	under development <sup>F</sup>
C13	under development <sup>G</sup>

<sup>A</sup> Research Reports are available from ASTM International Headquarters. Request by Research Report No.

<sup>B</sup> Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Mack T-6.

<sup>C</sup> Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Mack T-7.

<sup>D</sup> Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Mack T-12.

<sup>E</sup> Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Cummins ISM.

<sup>F</sup> Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Cummins ISB.

<sup>G</sup> Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Caterpillar C13.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

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

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

**D 130** Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

**D 874** Test Method for Sulfated Ash from Lubricating Oils and Additives

**D 892** Test Method for Foaming Characteristics of Lubricating Oils

**D 2887** Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography

**D 3244** Practice for Utilization of Test Data to Determine Conformance with Specifications

**D 4683** Test Method for Measuring Viscosity at High Shear Rate and High Temperature by Tapered Bearing Simulator

**D 4684** Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature

**D 4951** Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry

**D 5119** Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine<sup>3</sup>

**D 5133** Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique

**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 5290** Test Method for Measurement of Oil Consumption, Piston Deposits, and Wear in a Heavy-Duty High-Speed Diesel Engine—NTC-400 Procedure<sup>3</sup>

**D 5293** Test Method for Apparent Viscosity of Engine Oils Between -5 and -35°C Using the Cold-Cranking Simulator

**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<sup>3</sup>

**D 5480** Test Method for Engine Oil Volatility by Gas Chromatography<sup>3</sup>

**D 5533** Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIIE, Spark-Ignition Engine<sup>3</sup>

**D 5800** Test Method for Evaporation Loss of Lubricating Oils by the Noack Method

**D 5844** Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)<sup>3</sup>

**D 5862** Test Method for Evaluation of Engine Oils in Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine

**D 5966** Test Method for Evaluation of Engine Oils for Roller Follower Wear in Light-Duty Diesel Engine

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

**D 5968** Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 121°C

**D 6082** Test Method for High Temperature Foaming Characteristics of Lubricating Oils

**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

**D 6278** Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus

**D 6335** Test Method for Determination of High Temperature Deposits by Thermo-Oxidation Engine Oil Simulation Test

**D 6417** Test Method for Estimation of Engine Oil Volatility by Capillary Gas Chromatography

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

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

**D 6593** 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

**D 6594** Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135°C

**D 6618** Test Method for Evaluation of Engine Oils in Diesel Four-Stroke Cycle Supercharged 1M-PC Single Cylinder Oil Test Engine

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Withdrawn.

- D 6681** Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure
- D 6709** Test Method for Evaluation of Automotive Engine Oils in the Sequence VIII Spark-Ignition Engine (CLR Oil Test Engine)
- D 6750** 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)
- D 6794** 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
- D 6795** 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
- D 6837** 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
- D 6838** Test Method for Cummins M11 High Soot Test
- D 6891** Test Method for Evaluation of Automotive Engine Oils in the Sequence IVA Spark-Ignition Engine
- D 6894** Test Method for Evaluation of Aeration Resistance of Engine Oils in Direct-Injected Turbocharged Automotive Diesel Engine
- D 6896** Test Method for Determination of Yield Stress and Apparent Viscosity of Used Engine Oils at Low Temperature
- D 6922** Test Method for Determination of Homogeneity and Miscibility in Automotive Engine Oils
- D 6923** Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1R Test Procedure
- D 6975** Test Method for Cummins M11 EGR Test
- D 6984** Test Method for Evaluation of Automotive Engine Oils in the Sequence III F, Spark-Ignition Engine
- D 6987/D 6987M** Test Method for Evaluation of Diesel Engine Oils in T-10 Exhaust Gas Recirculation Diesel Engine
- D 7097** Test Method for Determination of Moderately High Temperature Piston Deposits by Thermo-Oxidation Engine Oil Simulation Test—TEOST MHT
- D 7109** Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus at 30 and 90 Cycles
- D 7156** Test Method for Evaluation of Diesel Engine Oils in the T-11 Exhaust Gas Recirculation Diesel Engine
- D 7216** Test Method for Determining Automotive Engine Oil Compatibility with Typical Seal Elastomers
- D 7320** Test Method for Evaluation of Automotive Engine Oils in the Sequence III G, Spark-Ignition Engine
- E 29** Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 178** Practice for Dealing With Outlying Observations

2.2 *Society of Automotive Engineers Standards*.<sup>4</sup>

**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

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

2.3 *American Petroleum Institute Publication*.<sup>5</sup>

**API 1509** Engine Oil Licensing and Certification System (EOLCS)

2.4 *Government Standard*.<sup>6</sup>

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

2.5 *American Chemical Council Code*.<sup>7</sup>

**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 SH, SJ, SL, SM, CF-4, CF, CF-2, CG-4, CH-4, CI-4, Energy 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 *engine oil, n*—a liquid that reduces friction and wear between the moving parts within an engine, and also serves as a coolant.

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

3.1.5 *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.

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

3.1.6.1 *Discussion*—This type of engine is typically installed in large trucks and buses as well as farm, industrial, and construction equipment.

3.1.7 *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.

<sup>4</sup> Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

<sup>5</sup> Available from American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005.

<sup>6</sup> Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

<sup>7</sup> Available from American Chemical Council, 1300 Wilson Blvd., Arlington, VA 22209.

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

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

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

4.1.1.1 Test Method **D 5844**, the Sequence IID gasoline engine test, has been correlated with vehicles used in short-trip service prior to 1978,<sup>8</sup> particularly with regard to rusting. (An alternative is Test Method **D 6557**, the Ball Rust Test.)

4.1.1.2 Test Method **D 5533**, the Sequence IIIE gasoline engine test, has been correlated with vehicles used in high-temperature service prior to 1988,<sup>9</sup> particularly with regard to oil thickening and valve train wear. (Alternatives are Test Method **D 6984**, the Sequence IIIF test, or Test Method **D 7320**, the Sequence IIIG test.)

4.1.1.3 Test Method **D 5302**, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988,<sup>10</sup> particularly with regard to sludge and valve train wear. (An alternative is the combination of Test Method **D 6593**, the Sequence VG test, and Test Method **D 6891**, the Sequence IVA test.)

4.1.1.4 Test Method **D 5119**, 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 **D 6709**, the Sequence VIII test.)

(*J*) Test Method **D 5119** (or Test Method **D 6709**) is also used to determine the ability of an oil to resist permanent viscosity loss due to shearing in an engine.

4.1.1.5 In addition to passing performance in the engine tests, specific viscosity grades shall also meet bench test requirements (see **Table 2**), which are discussed in the following subsections:

(1) The volatility of engine oils relates to engine oil consumption.

(2) Test Method **D 6795**, the Engine Oil Filterability Test (EOFT) screens for the formation of precipitates that can cause oil filter plugging.

(3) Phosphorus compounds 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 can indicate if residual solvents and low-boiling fractions remain in the finished oil.

(5) 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 **D 892** and **D 6082** empirically rate the foaming tendency and stability of oils.

(6) Test Method **D 6922**, the H and M Test indicates the compatibility of an oil with standard test oils.

4.1.1.6 Licensing of the API SH category 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 *SJ*—Oil meeting the performance requirements measured in the following gasoline engine tests and bench tests:

4.1.2.1 Test Method **D 5844**, the Sequence IID, gasoline engine test has been correlated with vehicles used in short-trip service prior to 1978, particularly with regard to rusting. (An alternative is Test Method **D 6557**, the Ball Rust Test.)

4.1.2.2 Test Method **D 5533**, the Sequence IIIE gasoline engine test, has been correlated with vehicles used in high-temperature service prior to 1988, particularly with regard to oil thickening and valve train wear. (Alternatives are Test Method **D 6984**, the Sequence IIIF test, or Test Method **D 7320**, the Sequence IIIG test.)

4.1.2.3 Test Method **D 5302**, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988, particularly with regard to sludge and valve train wear. (An alternative is the combination of Test Method **D 6593**, the Sequence VG test, and Test Method **D 6891**, the Sequence IVA test.)

4.1.2.4 Test Method **D 5119**, 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 **D 6709**, the Sequence VIII test.)

(*J*) Test Method **D 5119** (or Test Method **D 6709**) is also used to determine the ability of an oil to resist permanent viscosity loss due to shearing in an engine.

4.1.2.5 In addition to passing performance in the engine tests, specific viscosity grades shall also meet bench test requirements (see **Table 2**), which are discussed in the following subsections:

<sup>8</sup> Available from ASTM International in *STP 3151 (Part 1)*. Also available from the Society of Automotive Engineers as Technical Paper No. 780931.<sup>4</sup>

<sup>9</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1225.

<sup>10</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1226.

**TABLE 2 S Engine Oil Categories**

API SH Category			
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria	
D 5844 <sup>A,B</sup> (Sequence IID) or D 6557 <sup>A</sup> (Ball Rust Test) D 5533 <sup>B,D</sup> (Sequence IIIE)	Average engine rust rating, <sup>C</sup> min	8.5	
	Number stuck lifters	none	
	Average gray value, min	100	
	Hours to 375 % kinematic viscosity increase at 40°C, min	64	
	Average engine sludge rating, <sup>E</sup> min	9.2	
	Average piston skirt varnish rating, <sup>F</sup> min	8.9	
	Average oil ring land deposit rating, <sup>F</sup> 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	
	Ring sticking (oil-related <sup>G</sup> )	none	
or D 6984 (Sequence IIIF) <sup>D</sup>	Kinematic viscosity, % increase at 40°C, max	325 <sup>H</sup>	
	Average piston skirt varnish rating, <sup>F</sup> min	8.5 <sup>I</sup>	
	Weighted piston deposit rating, <sup>J</sup> min	3.2 <sup>I</sup>	
	Screened average cam-plus-lifter wear, μm, max	20 <sup>L,K</sup>	
	Hot stuck rings	none <sup>I</sup>	
	or D 7320 (Sequence IIIG) <sup>L</sup>	Kinematic viscosity, % increase at 40°C, max	150
Weighted piston deposit rating, <sup>M</sup> min		3.5	
Cam-plus-lifter wear avg, μm, max		60	
Hot stuck rings		none	
D 5302 <sup>B,N</sup> (Sequence VE)	Average engine sludge rating, <sup>E</sup> min	9.0	
	Rocker arm cover sludge rating, <sup>E</sup> min	7.0	
	Average piston skirt varnish rating, <sup>F</sup> min	6.5	
	Average engine varnish rating, <sup>F</sup> 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	
	Average cam wear, μm <sup>O</sup>	120	
	Average engine sludge rating, <sup>E</sup> min	7.8	
	Rocker arm cover sludge rating, <sup>E</sup> min	8.0	
Average piston skirt varnish rating, <sup>F</sup> min	7.5		
Average engine varnish rating, <sup>F</sup> min	8.9		
Oil screen clogging, %, max	20		
Hot stuck compression rings		none	
	Bearing weight loss, mg, max	40 <sub>R</sub>	
D 5119 <sup>O</sup> (L-38)	Shear stability		
	Bearing weight loss, mg, max	26.4 <sub>R</sub>	
or D 6709 <sup>O</sup> (Sequence VIII)	Shear stability		
Viscosity Grade Performance Criteria <sup>S</sup>			
Bench Test and Measured Parameter (effective January 1, 1992)	SAE 5W-30	SAE 10W-30	SAE 15W-40
Test Method D 5800 volatility loss, % max <sup>T</sup>	25	20	18
Test Method D 2887 volatility loss at 371°C (700°F), % max <sup>T</sup>	20	17	15
Test Method D 6795 (EOFT), % flow reduction, max	50	50	NR <sup>U</sup>
Test Method D 4951 or D 5185, phosphorus % mass, max	0.12	0.12	NR
Test Method D 4951 or D 5185, phosphorus % mass, min	0.06	0.06	0.06
(all viscosity grades)			
(unless valid passing Test Method D 5302 results are obtained)			
Test Method D 92 flash point, °C, min <sup>V</sup>	200	205	215
Test Method D 93 flash point, °C, min <sup>V</sup>	185	190	200
Test Method D 892 foaming tendency (Option A)			
Sequence I, max, foaming/settling <sup>W</sup>	10/0	10/0	10/0
Sequence II, max, foaming/settling <sup>W</sup>	50/0	50/0	50/0
Sequence III, max, foaming/settling <sup>W</sup>	10/0	10/0	10/0
Test Method D 6082 (optional blending required)	report <sup>X</sup>	report <sup>X</sup>	report <sup>X</sup>
Test Method D 6922 homogeneity and miscibility			
API SJ Category			
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria	
D 5844 <sup>A,B</sup> (Sequence IID)	Average engine rust rating, <sup>C</sup> min	8.5	
	Number stuck lifters	none	
or D 6557 <sup>A</sup> (Ball Rust Test)	Average gray value, min	100	
D 5533 <sup>B,D</sup> (Sequence IIIE)	Hours to 375 % kinematic viscosity increase at 40°C, min	64	

**TABLE 2** *Continued*

API SJ Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
or <b>D 6984</b> (Sequence III F) <sup>P</sup>	Average engine sludge rating, <sup>E</sup> min	9.2
	Average piston skirt varnish rating, <sup>F</sup> min	8.9
	Average oil ring land deposit rating, <sup>F</sup> min	3.5
	Lifter sticking	none
	Scuffing and wear	
	Cam or lifter scuffing	none
	Cam plus lifter wear, $\mu\text{m}$	
	Average, max	30
	Maximum, max	64
	Ring sticking (oil-related) <sup>Q</sup>	none
or <b>D 7320</b> (Sequence III G) <sup>L</sup>	Kinematic viscosity, % increase at 40°C, max	325 <sup>H</sup>
	Average piston skirt varnish rating, <sup>F</sup> min	8.5 <sup>I</sup>
	Weighted piston deposit rating, <sup>J</sup> min	3.2 <sup>I</sup>
	Screened average cam-plus-lifter wear, $\mu\text{m}$ , max	20 <sup>I,K</sup>
	Hot stuck rings	none <sup>I</sup>
<b>D 5302</b> <sup>B,N</sup> (Sequence VE)	Kinematic viscosity, % increase at 40°C, max	150
	Weighted piston deposit rating, <sup>M</sup> min	3.5
	Cam-plus-lifter wear avg, $\mu\text{m}$ , max	60
	Hot stuck rings	none
	Average engine sludge rating, <sup>E</sup> min	9.0
	Rocker arm cover sludge rating, <sup>E</sup> min	7.0
	Average piston skirt varnish rating, <sup>F</sup> min	6.5
	Average engine varnish rating, <sup>F</sup> min	5.0
	Oil ring clogging, %	report
	Oil screen clogging, %, max	20.0
	Compression ring sticking (hot stuck)	none
	Cam wear, $\mu\text{m}$	
	Average, max	127
	Maximum, max	380
	Average cam wear, $\mu\text{m}$ <sup>O</sup>	120
or <b>D 6891</b> (Sequence IVA) <sup>N</sup> plus, <b>D 6593</b> <sup>N</sup> (Sequence VG)	Average engine sludge rating, <sup>E</sup> min	7.8
	Rocker arm cover sludge rating, <sup>E</sup> min	8.0
	Average piston skirt varnish rating, <sup>F</sup> min	7.5
	Average engine varnish rating, <sup>P</sup> min	8.9
	Oil screen clogging, %, max	20
	Hot stuck compression rings	none
	Bearing weight loss, mg, max	40 <sup>R</sup>
or <b>D 5119</b> <sup>Q</sup> (L-38)	Shear stability	R
	Bearing weight loss, mg, max	26.4
or <b>D 6709</b> <sup>Q</sup> (Sequence VIII)	Bearing weight loss, mg, max	26.4
	Shear stability	R

## Viscosity Grade Performance Criteria

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 <b>D 5800</b> volatility loss, % max <sup>Z</sup>	22	20 <sup>AA</sup>
Test Method <b>D 6417</b> volatility loss at 371°C (700°F), % max <sup>Z</sup>	17	15 <sup>AA</sup>
Test Method <b>D 5480</b> volatility loss at 371°C (700°F), % max <sup>Z</sup>	17	15 <sup>AA</sup>
Test Method <b>D 6795</b> (EOFT), % flow reduction, max	50	50
Test Method <b>D 6794</b> (EOWTT), % flow reduction, max		
with 0.6 % H <sub>2</sub> O	report	report
with 1.0 % H <sub>2</sub> O	report	report
with 2.0 % H <sub>2</sub> O	report	report
with 3.0 % H <sub>2</sub> O	report	report
Test Method <b>D 4951</b> or <b>D 5185</b> , phosphorus % mass, max	0.10 <sup>AB</sup>	NR <sup>U</sup>
Test Method <b>D 4951</b> or <b>D 5185</b> , phosphorus % mass, min (unless valid passing Test Method <b>D 5302</b> results are obtained)	0.06	0.06
Test Method <b>D 92</b> flash point, °C, min <sup>V</sup>	200	NR <sup>U</sup>
Test Method <b>D 93</b> flash point, °C, min <sup>V</sup>	185	NR <sup>U</sup>
Test Method <b>D 892</b> foaming tendency (Option A)		
Sequence I, max, foaming/settling <sup>AC</sup>	10/0	10/0
Sequence II, max, foaming/settling <sup>AC</sup>	50/0	50/0
Sequence III, max, foaming/settling <sup>AC</sup>	10/0	10/0
Test Method <b>D 6082</b> (optional blending required) Static foam, max, tendency/stability	200/50 <sup>AD</sup>	200/50 <sup>AD</sup>
Test Method <b>D 6922</b> homogeneity and miscibility	Y	Y

**TABLE 2** *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 <b>D 6335</b> High temperature deposits (TEOST 33), deposit wt, mg, max	60	60
Test Method <b>D 5133</b> Gelation Index, max	12	NR <sup>U</sup>

API SL Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
<b>D 6984</b> (Sequence IIIF)	Kinematic viscosity, % increase at 40°C, max	275
	Average piston skirt varnish rating, <sup>F</sup> min	9.0
	Weighted piston deposit rating, <sup>J</sup> min	4.0
	Screened average cam-plus-lifter wear, μm, max	20 <sup>K</sup>
	Hot Stuck Rings	none
	Low temperature viscosity performance <sup>AE</sup>	report
or <b>D 7320</b> (Sequence IIIG) <sup>L</sup>	Kinematic viscosity, % increase at 40°C, max	150
	Weighted piston deposit rating, <sup>M</sup> min	3.5
	Cam-plus-lifter wear avg, μm, max	60
	Hot stuck rings	none
	Low temperature viscosity performance <sup>AF</sup>	report
	<b>D 6891</b> (Sequence IVA)	Cam wear average, μm, <sup>C</sup> max
Cam wear average, μm, max		127
<b>D 5302</b> <sup>B</sup> (Sequence VE) <sup>AG</sup>	Cam wear max, μm, max	380
	<b>D 6593</b> (Sequence VG)	Average engine sludge rating, <sup>E</sup> min
Rocker arm cover sludge rating, <sup>E</sup> min		8.0
Average piston skirt varnish rating, <sup>F</sup> min		7.5
Average engine varnish rating, <sup>P</sup> 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
Bearing weight loss, mg, max		26.4
<b>D 6709</b> (Sequence VIII)	Shear stability	<sup>R</sup>

Bench Test and Measured Parameter	Performance Criteria	
Test Method <b>D 6557</b> (Ball Rust Test), average gray value, min	100	
Test Method <b>D 5800</b> volatility loss, % max	15	
Test Method <b>D 6417</b> volatility loss at 371°C (700°F), % max	10	
<b>D 6795</b> (EOFT), % flow reduction, max	50	
<b>D 6794</b> (EOWTT), % flow reduction, max	With 0.6 % H <sub>2</sub> O	50
	With 1.0 % H <sub>2</sub> O	50
	With 2.0 % H <sub>2</sub> O	50
	With 3.0 % H <sub>2</sub> O	50
	Test Method <b>D 4951</b> or <b>D 5185</b> , phosphorus % mass, max <sup>AH</sup>	0.10 <sup>AB</sup>
Test Method <b>D 4951</b> or <b>D 5185</b> , phosphorus % mass, min (unless valid passing Test Method <b>D 5302</b> results are obtained)	0.06	
Test Method <b>D 892</b> foaming tendency (Option A)	Sequence I, max, foaming/settling <sup>AC</sup>	10/0
	Sequence II, max, foaming/settling <sup>AC</sup>	50/0
	Sequence III, max, foaming/settling <sup>AC</sup>	10/0
Test Method <b>D 6082</b> (optional blending required) static foam max, tendency/stability	100/0 <sup>AD</sup>	
Test Method <b>D 6922</b> homogeneity and miscibility	Y	
Test Method <b>D 7097</b> high temperature deposits (TEOST MHT-4), deposit wt, mg, max	45	
Test Method <b>D 5133</b> (Gelation Index), max <sup>AH</sup>	12 <sup>AJ</sup>	

<sup>A</sup> Demonstrate passing performance in either Test Method **D 5844** or **D 6557**.

<sup>B</sup> 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.

<sup>C</sup> CRC Rust Rating Manual No. 7, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.

<sup>D</sup> Demonstrate passing performance in either Test Method **D 5533** or **D 6984**. However, an oil passing Test Method **D 6984** and containing less than 0.08 % mass phosphorus in the form of ZDDP shall also pass the wear limits in Test Method **D 5302** (see also footnote <sup>L</sup>).

<sup>E</sup> CRC Sludge Rating Manual No. 12, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.

<sup>F</sup> CRC Varnish Rating Manual No. 14, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.

<sup>G</sup> An oil-related stuck ring occurs on a piston with an individual oil ring land deposit rating <2.6.

<sup>H</sup> Determine at 60 h.

<sup>I</sup> Determine at 80 h.

<sup>J</sup> 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 CRC Varnish Rating Manual No. 14 for all ratings.

<sup>K</sup> Calculate by eliminating the highest and lowest cam-plus-lifter wear results and then calculating an average based on the remaining ten rating positions.

<sup>L</sup> 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 **D 5302** (Sequence VE), which was previously required for oils with less than 0.08 % mass phosphorus.

<sup>M</sup> Unlike the Sequence IIIF test, piston skirt varnish rating is not required in the Sequence IIIG test.

<sup>N</sup> Demonstrate passing performance in Test Method **D 5302**, or alternatively, in both Test Method **D 6891** and Test Method **D 6593**.

<sup>O</sup> Determine cam wear according to Test Method **D 6891**. 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.

<sup>P</sup> Determine the average engine varnish rating by averaging the piston skirt, right rocker arm cover, and left rocker arm cover varnish ratings. Use the CRC Varnish Rating Manual No. 14 for all ratings.

<sup>Q</sup> Demonstrate passing performance in either Test Method **D 5119** or **D 6709**.

<sup>R</sup> Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade).

<sup>S</sup> Passing bench test performance is only required for SAE 5W-30, SAE 10W-30, and SAE 15W-40 viscosity grades as defined in **SAE J300**.

<sup>T</sup> Meet either Test Method **D 5800** or Test Method **D 2887** volatility requirement.

<sup>U</sup> NR stands for Not Required.

<sup>V</sup> Meet either Test Method **D 92** or Test Method **D 93** flash point requirement.

<sup>W</sup> Determine settling volume at 5 min.

<sup>X</sup> Report kinetic foam volume (mL), static foam volume (mL), and collapse time, s.

<sup>Y</sup> Homogeneous with SAE reference oils.

<sup>Z</sup> Meet the volatility requirement in either Test Method **D 5800**, **D 5480**, or **D 6417**.

<sup>AA</sup> Passing volatility loss only required for SAE 15W-40 oils.

<sup>AB</sup> This is a noncritical specification as described in Practice **D 3244**.

<sup>AC</sup> Determine settling volume, in mL, at 10 min.

<sup>AD</sup> Determine settling volume, in mL, at 1 min.

<sup>AE</sup> Evaluate the 80-h test oil sample by Test Method **D 4684** at the temperature indicated by the low temperature grade of oil as determined on the 80-h sample by Test Method **D 5293**.

<sup>AF</sup> Measure the viscosity of the EOT oil sample by Test Method **D 4684**. 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.

<sup>AG</sup> Not required for oils containing a minimum of 0.08 % mass phosphorus in the form of ZDDP.

<sup>AH</sup> Requirement applies only to SAE 0W-20, 5W-20, 0W-30, 5W-30, and 10W-30 viscosity grades.

<sup>AI</sup> For gelation temperatures at or above the W grade pumpability temperature as defined in **SAE J300**.

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

(2) Test Method **D 6795**, 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 **D 892** and **D 6082** empirically rate the foaming tendency and stability of oils.

(6) Test Method **D 6922**, 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 **D 6335**, the TEOST test, may be useful in determining the deposit control of oils recommended for these engines.

(8) Test Method **D 5133**, the Gelation Index technique, might identify oils susceptible to air binding and might provide low temperature protection not adequately measured by the Test Method **D 4684**.

4.1.2.6 Licensing of the API SJ category 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.

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

4.1.3.1 Test Method **D 6984**, 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.<sup>11</sup> (An alternative is Test Method **D 7320**, the Sequence IIIG test.)

4.1.3.2 Test Method **D 6891**, 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.<sup>12</sup>

4.1.3.3 Test Method **D 5302**, 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 1—Prior to May 2004, the API SH, SJ, and SL categories required that oils with passing Test Method **D 6984** (Sequence IIIF) results, and containing less than 0.08 % mass phosphorus in the form of ZDDP, also demonstrate passing performance in Test Method **D 5302** (Sequence VE). This requirement was included to address concerns over adequate wear protection with low levels of ZDDP. However, Test Method **D 5302** has not been available to industry for some time, and an alternative method was needed. In a related activity, the next level of

<sup>11</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1391.

<sup>12</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1473.



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 **D 7320**, the Sequence IIIG, a new test, to evaluate the wear protection of oils with less than 0.08 % 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 **D 7320** (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 **D 7320** (Sequence IIIG) as an alternative to Test Method **D 6984** (Sequence IIIF) plus Test Method **D 5302** (Sequence VE) for demonstration of acceptable API SH, SJ, and SL performance on low phosphorus oils, establishing at least 0.06 % phosphorus as the minimum level. That ballot was approved by Subcommittee D02.B0 in May 2004.

4.1.3.4 Test Method **D 6593**, 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.

4.1.3.5 Test Method **D 6709**, 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.<sup>13</sup>

(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.

4.1.3.6 In addition to passing performance in the engine tests, oils shall also meet bench test requirements (see **Table 2**), which are discussed in the following subsections:

(1) Test Method **D 6557** (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 **D 5800** and **D 6417**.

(3) Test Method **D 6795**, the Engine Oil Filterability Test (EOFT) and Test Method **D 6794**, 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 **D 4951** or **D 5185**.

(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 **D 892** and **D 6082** empirically rate the foaming tendency and stability of oils.

(6) Test Method **D 6922**, 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 depos-

its caused by elevated engine operating temperatures. Test Method **D 7097**, the TEOST MHT-4 test may be useful in determining the piston deposit control capability of oils recommended for these engines.

(8) Test Method **D 5133**, the Gelation Index technique, might identify oils susceptible to air binding and might provide low-temperature protection not adequately measured by Test Method **D 4684**.

4.1.3.7 Licensing of the API SL category 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.

4.1.4 *CF-4*—Oil meeting the performance requirements in the following diesel and gasoline engine tests and bench test:

4.1.4.1 Test Method **D 6750**, the 1K diesel engine test, has been correlated with vehicles equipped with engines used in high-speed operation prior to 1989,<sup>14</sup> particularly with regard to deposits and oil consumption.

4.1.4.2 The T-6 has been correlated with vehicles equipped with engines used in high-speed operation prior to 1980,<sup>15</sup> particularly with regard to deposits, oil consumption, and ring wear. (An alternative is Test Method **D 6987/D 6987M**, the T-10 diesel engine test. See **4.1.9.2**.)

4.1.4.3 The T-7 test has been correlated with vehicles equipped with engines operated largely under lugging conditions prior to 1984,<sup>16</sup> particularly with regard to oil thickening.

4.1.4.4 Test Method **D 5968**, the bench corrosion test, has been shown to predict corrosion of engine oil-lubricated copper, lead, or tin-containing components used in diesel engines.<sup>17</sup> Test Method **D 5290**, the NTC-400 diesel engine test, has been correlated with vehicles equipped with engines in highway operation prior to 1983,<sup>18</sup> particularly with regard to oil consumption control, deposits, and wear. Test Method **D 5290** is not listed in **Table 3**, as calibrated test stands are no longer available due to unavailability of critical test parts. It has been demonstrated that the 1K test, in combination with Test Method **D 5968**, can be substituted for the NTC-400 test as an acceptable means to demonstrate performance against this category; however, data from NTC-400 tests, run in calibrated stands, can be used to support this category in accordance with the provisions of Specification D 4485–94.

4.1.4.5 Test Method **D 6709**, 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.<sup>13</sup>

<sup>14</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1273.

<sup>15</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1219.

<sup>16</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1220.

<sup>17</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1322.

<sup>18</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1194.

<sup>13</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1471.

**TABLE 3 C Engine Oil Categories**

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria				
CF-4	D 6709 (Sequence VIII) T-6 or D 6483 (T-9) <sup>B</sup>	Bearing weight loss, mg, max	33.0				
		Merit rating, <sup>A</sup> min	90				
	or, D 6987/D 6987M (T-10)	Top piston ring weight loss, <sup>C</sup> average, mg, max	150				
		Liner wear, μm, max	40				
	T-7 or D 5967 (T-8A) <sup>B</sup>	Top ring weight loss, mg, max	180				
		Liner wear, μm, max	47				
	D 5968 (CBT) <sup>D</sup>	Average rate of kinematic viscosity increase during last 50 h, mm <sup>2</sup> /s at 100°C/h, max	0.040				
		Average rate of kinematic viscosity increase from 100 to 150 h, mm <sup>2</sup> /s at 100°C/h, max	0.20				
		Copper, mg/kg (ppm) increase, max	20				
		Lead, mg/kg (ppm) increase, max	60				
		Tin, mg/kg (ppm) increase, max	report				
	D 6750 (1K)	A 1K test program <sup>F</sup> with a minimum of two tests, acceptable according to the limits shown in the columns to the right, is required to demonstrate performance for this category.	Copper strip rating, <sup>E</sup> max	3			
			Two-test <sup>F</sup>	Three-test <sup>F</sup>	Four-test <sup>F</sup>		
Weighted demerits (WDK), <sup>G,H</sup> max			332	339	342		
Top groove fill (TGF), <sup>G</sup> %, max			24	26	27		
Top land heavy carbon (TLHC), <sup>G</sup> % max			4	4	5		
Average oil consumption, g/kW-h, (0-252 h), max			0.5	0.5	0.5		
Final Oil consumption, g/kW-h, (228-252 h) max			0.27	0.27	0.27		
Piston, ring, and liner scuffing							
Number of tests allowed			none	none <sup>E</sup>	none <sup>I</sup>		
Piston ring sticking			none	none	none		
CF	D 6618 (1M-PC)	Top groove fill (TGF), <sup>G</sup> %, max	70 <sup>J</sup>	MTAC <sup>J</sup>	MTAC <sup>J</sup>		
		Weighted total demerits (WTD), <sup>G</sup> max	240 <sup>J</sup>				
D 6709 (Sequence VIII)	Bearing weight loss, mg, max	Piston ring sticking	none				
		Piston, ring and liner scuffing	none				
CF-2	D 6618 (1M-PC)		One-Test	Two-Test <sup>K</sup>	Three-Test <sup>K</sup>		
		Weighted total demerits (WTD), <sup>G</sup> max	100 <sup>J</sup>	MTAC <sup>J</sup>	MTAC <sup>J</sup>		
D 5862 (6V 92TA)	Cylinder liner scuffing area, % max Cylinder liner port plugging area, Average, % max Single cylinder, % max Piston rings face distress demerits No. 1 (fire ring), max Average of No. 2 and 3, max		One-Test	Two-Test <sup>L</sup>	Three-Test <sup>L</sup>		
			45.0	48.0	50.0		
			2	2	2		
			5	5	5		
			0.23	0.24	0.26		
			0.20	0.21	0.22		
		D 6709 (Sequence VIII)	Bearing weight loss, mg, max		One-Test	Two-Test <sup>M</sup>	Three-Test <sup>M</sup>
					29.3	31.9 <sup>K</sup>	33.0 <sup>K</sup>
		CG-4	D 6750 (1N)	Weighted demerits (WDN) <sup>G,N</sup>	286.2	311.7	323.0
				Top groove fill (TGF), <sup>G</sup> %, max	20	23	25
Top land heavy carbon (TLHC), <sup>G</sup> % max	3			4	5		
Oil consumption, g/kW-h, (0-252 h) max	0.5			0.5	0.5		
Piston, ring, and liner scuffing							
D 5967 (T-8)	Viscosity increase at 3.8 % soot, cSt, max Filter plugging, differential pressure, kPa (psi), max Oil consumption, g/kW-h (lb/bhp-h), max		Number of tests allowed	none	none	none <sup>I</sup>	
			Piston ring sticking	none	none	none	
				11.5	12.5	13.0	
				138 (20)	138 (20)	138 (20)	
				0.304 (0.0005)	0.304 (0.0005)	0.304 (0.0005)	
D 6984 (Sequence IIIF) or D 7320 (Sequence IIIG) D 6709 (Sequence VIII)	60 h viscosity (at 40°C) increase from 10 min sample, %, max Kinematic viscosity, % increase at 40°C max			325	349	360	
				150	173	184	
D 5966 (RFWT)	Bearing weight loss, mg, max Used oil viscosity, cSt greater than SAE J300 lower limit for grade, min <sup>O</sup> Wear, mils, max μm, max			29.3	31.9 <sup>K</sup>	33.0 <sup>K</sup>	
				0.5	0.5	0.5	
				0.45 (11.4)	0.49 (12.4)	0.50 (12.7)	
D 892 (Option A not allowed)	Foaming characteristics Foaming/settling, <sup>P</sup> mL, max Sequence I Sequence II Sequence III		10/0				
			20/0				
			10/0				
D 6894 (EOAT) <sup>O</sup>	Aeration, volume % max	10.0					

**TABLE 3** *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
	<b>D 5968</b>	Copper, mg/kg (ppm) increase, max	20		
		Lead, mg/kg (ppm) increase, max	60		
		Tin, mg/kg (ppm) increase, max	report		
		Copper strip rating, <sup>E</sup> max	3		
			One-test	Two-test <sup>R</sup>	Three-test <sup>R</sup>
CH-4	<b>D 6681 (1P)<sup>S</sup></b>	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 (0-360 h), max	12.4	12.4	12.4
		Final Oil Consumption, g/h (312-360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none <sup>f</sup>
	<b>D 6750 (1K)<sup>H</sup></b>	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/kW-h (0-250 h), max	0.5	0.5	0.5
		Piston, ring, and liner scuffing	none	none	none <sup>f</sup>
	<b>D 6483 (T-9)</b>	Average Liner Wear, normalized to 1.75 % soot, µm max	25.4	26.6	27.1
		Average Top Ring Weight Loss, mg max <sup>C</sup>	120	136	144
		EOT Used Oil Lead Content less New Oil Lead Content, mg/kg (ppm), max	25	32	36
	or, <b>D 6987/D 6987M (T-10)</b>	Liner wear, µm, max	32	34	35
		Ring wear, mg, max	150	159	163
		Lead content @ EOT, mg/kg (ppm), max	50	56	59
	or, T-12	Liner wear, µm, max	30.0	30.8	31.1
		Top Ring Weight Loss, mg, max	120	132	137
		Lead content @ EOT, mg/kg (ppm), max	65	75	79
	<b>D 5966 (RFWT)</b>	Average Pin Wear, mils, max	0.30	0.33	0.36
		(µm, max)	(7.6)	(8.4)	(9.1)
	<b>D 6838 (M11)<sup>T</sup></b>	Rocker Pad Average Wt. 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
	<b>D 5967 (Ext. T-8E)</b>	Relative Viscosity at 4.8 % Soot by TGA, max	2.1	2.2	2.3
		Viscosity increase at 3.8 % Soot by TGA, cSt max	11.5	12.5	13.0
	<b>D 6984 (Sequence IIIF)</b>	60 h Viscosity at 40°C, increase from 10 min sample, % max	295	295 (MTAC) <sup>U</sup>	295 (MTAC) <sup>U</sup>
	or <b>D 7320 (Sequence IIIG)</b>	Kinematic viscosity, % increase at 40°C max	150	150 (MTAC)	150 (MTAC)
	<b>D 6894 (EOAT)<sup>Q</sup></b>	Aeration, volume, % max	8.0	8.0 (MTAC) <sup>U</sup>	8.0 (MTAC) <sup>U</sup>
	<b>D 6594 (135°C, HTC BT)</b>	Used Oil Elemental Concentration			
		Copper, mg/kg (ppm) increase, max	20		
		Lead, mg/kg (ppm) increase, max	120		
		Tin, mg/kg (ppm) increase	report		
		Copper strip rating, <sup>E</sup> max	3		
	<b>D 892 (Option A not allowed)</b>	Foaming/Settling, <sup>P</sup> mL, max			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
			SAE 10W-30	SAE 15W-40	
	<b>D 5800</b> or	% volatility loss at 250°C, max	20	18	
	<b>D 6417</b>	% volatility loss at 371°C, max	17	15	
	<b>D 6278</b>	Kinematic Viscosity after shearing, cSt min	SAE XW-30	SAE XW-40	
			9.3	12.5	
			One-test	Two-test <sup>V</sup>	Three-test <sup>V</sup>
CI-4	<b>D 6923 (1R)</b>	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), (0-252 h), g/h, average	13.1	13.1	13.1
		Final oil consumption, (432-504 h), g/h, average, max	IOC + 1.8	IOC + 1.8	IOC + 1.8
		Piston, ring, and liner distress	none	none	none
		Ring sticking	none	none	none
	or, <b>D 6681 (1P)</b>	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 (0-360 h), max	12.4	12.4	12.4
		Final oil consumption, g/h (312-360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none
	<b>D 6987/D 6987M (T-10)</b>	Merit rating, <sup>V</sup> min	1000	1000	1000
	or the T-12 (T-10) test	Merit rating, <sup>V</sup> min	1000	1000	1000
	<b>D 6975 (M11 EGR)</b>	Average crosshead wt. loss, mg, max	20.0	21.8	22.6