



Designation: D4485 – 11b

## Standard Specification for Performance of Active API Service Category Engine Oils<sup>1</sup>

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 reapproval. 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, 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 X8 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.

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.

1.4 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.

Current edition approved Oct. 1, 2011. Published November 2011. Originally approved in 1985. Last previous edition approved in 2011 as D4485–11a. DOI: 10.1520/D4485-11B.

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*—The roller follower shaft wear in Test Method **D5966** is in mils. Some of the appendixes are verbatim from other sources, and non-SI units are included.

## 2. Referenced Documents

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

**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

**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<sup>3</sup>

**D5133** Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique

**D5185** 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)

**D5293** Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between –5 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<sup>3</sup>

**D5480** Test Method for Engine Oil Volatility by Gas Chromatography<sup>3</sup>

**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<sup>3</sup>

**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)<sup>3</sup>

**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<sup>3</sup>

**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<sup>3</sup>

**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

<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. The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

**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

**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

**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

**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 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

**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*:<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 SJ, SL, SM, SN, CH-4, CI-4, CJ-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:

<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 20005-4070, <http://www.api.org>.

<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.

3.2.1 *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 *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,<sup>5,8</sup> 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,<sup>9</sup> 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,<sup>10</sup> 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.

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 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.<sup>11</sup> (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.<sup>8</sup>

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 1—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,

<sup>8</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1473.

<sup>9</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1471.

<sup>10</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1273.

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

**TABLE 1 S Engine Oil Categories**

API SJ Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
D5844 <sup>A,B</sup> (Sequence IID) or D6557 <sup>A</sup> (Ball Rust Test) D5533 <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>C</sup> min	9.2
	Average piston skirt varnish rating, <sup>C</sup> min	8.9
	Average oil ring land deposit rating, <sup>C</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>E</sup>	none
or D6984 (Sequence IIIF) <sup>D</sup>	Kinematic viscosity, % increase at 40 °C, max	325 <sup>F</sup>
	Average piston skirt varnish rating, <sup>C</sup> min	8.5 <sup>G</sup>
	Weighted piston deposit rating, <sup>H</sup> min	3.2 <sup>G</sup>
	Screened average cam-plus-lifter wear, μm, max	20 <sup>G,I</sup>
	Hot stuck rings	none <sup>G</sup>
or D7320 (Sequence IIIG) <sup>J</sup>	Kinematic viscosity, % increase at 40 °C, max	150
	Weighted piston deposit rating, <sup>K</sup> min	3.5
	Cam-plus-lifter wear avg, μm, max	60
	Hot stuck rings	none
D5302 <sup>B,L</sup> (Sequence VE)	Average engine sludge rating, <sup>C</sup> min	9.0
	Rocker arm cover sludge rating, <sup>C</sup> min	7.0
	Average piston skirt varnish rating, <sup>C</sup> min	6.5
	Average engine varnish rating, <sup>C</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
or D6891 (Sequence IVA) <sup>L</sup> plus, D6593 <sup>L</sup> (Sequence VG)	Average cam wear, μm <sup>M</sup>	120
	Average engine sludge rating, <sup>C</sup> min	7.8
	Rocker arm cover sludge rating, <sup>C</sup> min	8.0
	Average piston skirt varnish rating, <sup>C</sup> min	7.5
	Average engine varnish rating, <sup>N</sup> min	8.9
	Oil screen clogging, %, max	20
	Hot stuck compression rings	none
D5119 <sup>O</sup> (L-38) or D6709 <sup>O</sup> (Sequence VIII)	Bearing weight loss, mg, max	40 <sup>P</sup>
	Shear stability	26.4 <sup>P</sup>
	Bearing weight loss, mg, max	26.4 <sup>P</sup>

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 D5800 volatility loss, % max <sup>Q</sup>	22	20 <sup>R</sup>
Test Method D6417 volatility loss at 371 °C, % max <sup>Q</sup>	17	15 <sup>R</sup>
Test Method D5480 volatility loss at 371 °C, % max <sup>Q</sup>	17	15 <sup>R</sup>
Test Method D6795 (EOFT), % flow reduction, max	50	50
Test Method D6794 (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 D4951 or D5185, mass fraction phosphorus, %, max	0.10 <sup>S</sup>	NR <sup>T</sup>
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 <sup>U</sup>	200	NR <sup>T</sup>
Test Method D93 flash point, °C, min <sup>U</sup>	185	NR <sup>T</sup>
Test Method D892 foaming tendency (Option A)		
Sequence I, max, foaming/settling <sup>V</sup>	10/0	10/0
Sequence II, max, foaming/settling <sup>V</sup>	50/0	50/0
Sequence III, max, foaming/settling <sup>V</sup>	10/0	10/0
Test Method D6082 (optional blending required) Static foam, max, tendency/stability	200/50 <sup>W</sup>	200/50 <sup>W</sup>
Test Method D6922 homogeneity and miscibility	x	x

**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 <b>D6335</b> High temperature deposits (TEOST 33), deposit wt, mg, max	60	60
Test Method <b>D5133</b> Gelation Index, max	12	NR <sup>T</sup>
API SL Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
<b>D6984</b> (Sequence IIIF)  or <b>D7320</b> (Sequence IIIG) <sup>J</sup>	Kinematic viscosity, % increase at 40 °C, max	275
	Average piston skirt varnish rating, <sup>C</sup> min	9.0
	Weighted piston deposit rating, <sup>H</sup> min	4.0
	Screened average cam-plus-lifter wear, μm, max	20 <sup>I</sup>
	Hot Stuck Rings	none
	Low temperature viscosity performance <sup>Y</sup>	report
	Kinematic viscosity, % increase at 40 °C, max	150
	Weighted piston deposit rating, <sup>K</sup> min	3.5
	Cam-plus-lifter wear avg, μm, max	60
	Hot stuck rings	none
<b>D6891</b> (Sequence IVA) <b>D5302</b> <sup>B</sup> (Sequence VE <sup>AA</sup> ) <b>D6593</b> (Sequence VG)	Low temperature viscosity performance <sup>Z</sup>	report
	Cam wear average, μm, <sup>M</sup> max	120
	Cam wear average, μm, max	127
	Cam wear max, μm, max	380
<b>D6709</b> (Sequence VIII)	Average engine sludge rating, <sup>C</sup> min	7.8
	Rocker arm cover sludge rating, <sup>C</sup> min	8.0
	Average piston skirt varnish rating, <sup>C</sup> min	7.5
	Average engine varnish rating, <sup>N</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 <sup>P</sup>
Shear stability		
Bench Test and Measured Parameter		Performance Criteria
Test Method <b>D6557</b> (Ball Rust Test), average gray value, min		100
Test Method <b>D5800</b> volatility loss, % max		15
Test Method <b>D6417</b> volatility loss at 371 °C, % max		10
<b>D6795</b> (EOFT), % flow reduction, max		50
<b>D6794</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>D4951</b> or <b>D5185</b> , mass fraction phosphorus %, max <sup>AB</sup>		0.10 <sup>S</sup>
Test Method <b>D4951</b> or <b>D5185</b> , mass fraction phosphorus %, min (unless valid passing Test Method <b>D5302</b> results are obtained)		0.06
Test Method <b>D892</b> foaming tendency (Option A)		
Sequence I, max, foaming/settling <sup>V</sup>		10/0
Sequence II, max, foaming/settling <sup>V</sup>		50/0
Sequence III, max, foaming/settling <sup>V</sup>		10/0
Test Method <b>D6082</b> (optional blending required) static foam max, tendency/stability		100/0 <sup>W</sup>
Test Method <b>D6922</b> homogeneity and miscibility		x
Test Method <b>D7097</b> high temperature deposits (TEOST MHT-4), deposit wt, mg, max		45
Test Method <b>D5133</b> (Gelation Index), max <sup>AB</sup>		12 <sup>AC</sup>

<sup>A</sup> Demonstrate passing performance in either Test Method **D5844** or **D6557**.

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

<sup>D</sup> 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 <sup>J</sup>).

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

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

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

<sup>H</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 ASTM Deposit Rating Manual 20 for all ratings.

<sup>I</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>J</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 **D5302** (Sequence VE), which was previously required for oils with less than 0.08 % mass phosphorus.

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

<sup>L</sup> Demonstrate passing performance in Test Method **D5302**, or alternatively, in both Test Method **D6891** and Test Method **D6593**.

<sup>M</sup> 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.

<sup>N</sup> 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.

<sup>O</sup> Demonstrate passing performance in either Test Method **D5119** or **D6709**.

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

<sup>Q</sup> Meet the volatility requirement in either Test Method **D5800**, **D5480**, or **D6417**.

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

<sup>S</sup> This is a noncritical specification as described in Practice **D3244**.

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

<sup>U</sup> Meet either Test Method **D92** or Test Method **D93** flash point requirement.

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

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

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

<sup>Y</sup> 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**.

<sup>Z</sup> 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.

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

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

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

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.<sup>9</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.

4.1.2.6 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 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 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 **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 %.<sup>10</sup>

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 %.<sup>12</sup>

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.<sup>13</sup> (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.<sup>14</sup> (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.

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.<sup>15</sup>

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 (HTCBT), 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 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 **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

<sup>12</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1441.

<sup>13</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1440.

<sup>14</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1439.

<sup>15</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1379.



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 **D4171**, **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 (HTCBT), 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 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.

4.1.5 **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.

**TABLE 2 Energy Conserving Categories**

SJ-Related Energy Conserving Category		
Test Procedure	SAE Viscosity Grade	Primary Performance Criteria <sup>A</sup>
<b>D6202</b> (Sequence VIA) <b>D6837</b> (Sequence VIBSJ)	0W-20 and 5W-20	FEI <sup>B</sup> relative to BC <sup>C</sup> , 1.4 %, min FEI <sup>D</sup> relative to BC <sup>C</sup> , 1.7 %, min
<b>D6202</b> (Sequence VIA) <b>D6837</b> (Sequence VIBSJ)	other 0W- and 5W-multi-grades other 0W- and 5W-multi-grades	FEI <sup>B</sup> relative to BC, 1.1 %, min FEI <sup>D</sup> relative to BC, 1.3 %, min
<b>D6202</b> (Sequence VIA) <b>D6837</b> (Sequence VIBSJ)	all 10W-multi-grades all 10W-multi-grades	FEI <sup>B</sup> relative to BC, 0.5 %, min FEI <sup>D</sup> relative to BC, 0.6 %, min
<b>D6202</b> (Sequence VIA) <b>D6837</b> (Sequence VIBSJ)	all others all others	FEI <sup>B</sup> relative to BC, 0.5 %, min FEI <sup>D</sup> relative to BC, 0.6 %, min
SL-Related Energy Conserving Category		
Test Procedure	SAE Viscosity Grade	Primary Performance Criteria
<b>D6837</b> (Sequence VIB)	0W-20 and 5W-20	FEI 1 <sup>E</sup> relative to BC, 2.0 %, min, <i>and</i> FEI 2 <sup>F</sup> relative to BC, 1.7 % min
<b>D6837</b> (Sequence VIB)	0W-30 and 5W-30	FEI 1 <sup>E</sup> relative to BC, 1.6 %, min, <i>and</i> FEI 2 <sup>F</sup> relative to BC, 1.3 % min, <i>and</i> sum of FEI 1 and FEI 2 relative to BC, 3.0 % min
<b>D6837</b> (Sequence VIB)	all others	FEI 1 <sup>E</sup> relative to BC, 0.9 %, min, <i>and</i> FEI 2 <sup>F</sup> relative to BC, 0.6 % min, <i>and</i> sum of FEI 1 and FEI 2 relative to BC, 1.6 %, min

<sup>A</sup> Passing performance shall be demonstrated in either Test Method **D6202** (Sequence VIA) or Test Method **D6837** (Sequence VIB). A passing result in only one of these procedures is required.

<sup>B</sup> Fuel Economy Improvement (FEI) measured against the performance of BC run before and after the candidate oil, according to the requirements of the Sequence VIA procedure.

<sup>C</sup> BC is the designation for the reference oil. In practice, dashed suffixes are used to indicate sequential batches of the reference oil. The minimum FEI values shown in **Table 2** for the Sequence VIA were established for performance against Batch 2, and for the Sequence VIB against Batch 3. Performance requirements against currently approved batches of the reference oil can be provided by the ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489.

<sup>D</sup> If the Sequence VIB is used to determine SJ-related Energy Conserving performance, calculate FEI at 16 h and base the comparison only to the BC run before the candidate. No BC stage after the candidate is required.

<sup>E</sup> FEI 1 is fuel economy improvement measured after 16 h of candidate oil aging and compared to a ratio of results obtained with BC run before and after the candidate oil, according to the requirements of the VIB procedure.

<sup>F</sup> FEI 2 is fuel economy improvement measured after 80 h of additional candidate oil aging beyond the 16 h aging used to establish FEI 1 (see Footnote E).

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 %.<sup>16</sup>

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 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.

4.1.6 *Energy Conserving Associated With SJ*—As defined by Test Method **D6202** or Test Method **D6837**, oil meeting performance requirements in **Table 2**.

4.1.6.1 Test Method **D6202** has been correlated with the EPA FTP 75 vehicle test cycle using vehicles with engine types that represent a cross-section of engine technology circa 1996 in order that passing oils will demonstrate fuel economy benefits in consumer vehicle service.

4.1.6.2 Test Method **D6837**<sup>17</sup> test has been correlated with the EPA FTP 75 vehicle test cycle using vehicles with engine types that represent a cross-section of current engine technology in order that passing oils will demonstrate fuel economy benefits in consumer vehicle service.

4.1.7 *Energy Conserving Associated With SL*—As defined by Test Method **D6837**, oil meeting performance requirements in **Table 2**.

NOTE 2—Energy-conserving oils are also described in **SAE J1423**.

4.1.8 Licensing of the Energy Conserving category as defined by Test Method **D6202** or as defined by Test Method **D6837** 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.

## 5. Performance Requirements

5.1 The oils identified by the categories discussed in Section 4 shall conform to the requirements listed in **Tables 1-3**.

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** describes 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 4.1.1-4.1.7 can be found in **API 1509**. Applicable sections of that publication have been included in **Appendix X2**.

<sup>16</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1321.

<sup>17</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1469.

**TABLE 3 C Engine Oil Categories**

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
			One-test	Two-test <sup>A</sup>	Three-test <sup>A</sup>
CH-4	<b>D6681</b> (1P) <sup>B</sup>	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
	<b>D6750</b> (1K) <sup>D</sup>	Piston, ring, and liner scuffing	none	none	none <sup>C</sup>
		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/MJ (0-252) h, max	0.139	0.139	0.139
	<b>D6483</b> (T-9)	Piston, ring, and liner scuffing	none	none	none <sup>C</sup>
		Average Liner Wear, normalized to 1.75 % soot, $\mu\text{m}$ max	25.4	26.6	27.1
	or, <b>D6987/D6987M</b> (T-10)	Average Top Ring Weight Loss, mg max <sup>E</sup>	120	136	144
		EOT Used Oil Lead Content less New Oil Lead Content, mg/kg, max	25	32	36
		Liner wear, $\mu\text{m}$ , max	32	34	35
	or, <b>D7422</b> (T-12)	Ring wear, mg, max	150	159	163
		Lead content at EOT, mg/kg, max	50	56	59
		Liner wear, $\mu\text{m}$ , max	30.0	30.8	31.1
	<b>D5966</b> (RFWT)	Top Ring Weight Loss, mg, max	120	132	137
		Lead content at EOT, mg/kg, max	65	75	79
	<b>D5966</b> (RFWT)	Average Pin Wear, mils, max	0.30	0.33	0.36
		( $\mu\text{m}$ ) max	(7.6)	(8.4)	(9.1)
	<b>D6838</b> (M11) <sup>F</sup>	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
		Crosshead wear, mg, max	7.5	7.8	7.9
		Oil filter delta pressure, at 150 h, kPa, max	79	95	103
	or, <b>D7468</b> (ISM)	Sludge rating, CRC merits, min	8.1	8.0	8.0
		Relative Viscosity at 4.8 % Soot by TGA, max	2.1	2.2	2.3
	<b>D5967</b> (Ext. T-8E) <sup>G</sup>	Viscosity increase at 3.8 % Soot by TGA, $\text{mm}^2/\text{s}$ , max	11.5	12.5	13.0
		60 h Viscosity at 40 °C, increase from 10 min sample, % max	295	295 (MTAC) <sup>H</sup>	295 (MTAC) <sup>H</sup>
	<b>D6984</b> (Sequence IIIF)	Kinematic viscosity, % increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
		Aeration, volume, % max	8.0	8.0 (MTAC) <sup>H</sup>	8.0 (MTAC) <sup>H</sup>
or <b>D7320</b> (Sequence IIIG) <sup>I</sup>	Used Oil Elemental Concentration				
	Copper, mg/kg increase, max	20			
<b>D6894</b> (EOAT) <sup>J</sup>	Lead, mg/kg increase, max	120			
	Tin, mg/kg increase	report			
<b>D6594</b> (135 °C, HTC BT)	Copper strip rating, <sup>K</sup> max	3			
	Foaming/Settling, <sup>L</sup> mL, max				
<b>D892</b> (Option A not allowed)	Sequence I	10/0			
	Sequence II	20/0			
	Sequence III	10/0			
	SAE 10W-30		SAE 15W-40		
	% volatility loss at 250°C, max	20	18		
<b>D5800</b> or <b>D6417</b>	% volatility loss at 371°C, max	17	15		
	Kinematic Viscosity after shearing, $\text{mm}^2/\text{s}$ , min	SAE XW-30 9.3	SAE XW-40 12.5		
<b>D6278</b>		One-test	Two-test <sup>M</sup>	Three-test <sup>M</sup>	
		382	396	402	
CI-4	<b>D6923</b> (1R)	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
	or, <b>D6681</b> (1P)	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 (0-360 h), max	12.4	12.4	12.4
<b>D6987/D6987M</b> (T-10) or the T-12 (T-10) test	Final oil consumption, g/h (312-360 h), max	14.6	14.6	14.6	
	Piston, ring, and liner scuffing	none	none	none	
	Merit rating, <sup>M</sup> min	1000	1000	1000	
	Merit rating, <sup>M</sup> min	1000	1000	1000	
	Average crosshead wt. loss, mg, max	20.0	21.8	22.6	
<b>D6975</b> (M11 EGR)	Average top ring weight loss, mg	report	report	report	