Standard Specification for Performance of Active API Service Category Engine Oils[1]

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 (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. 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 Europeans 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

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

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

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

1.5.1 *Exceptions:*

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

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

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

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
D471 Test Method for Rubber Property—Effect of Liquids
D874 Test Method for Sulfated Ash from Lubricating Oils and Additives
D892 Test Method for Foaming Characteristics of Lubricating Oils
D2240 Test Method for Rubber Property—Durometer Hardness
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
D3244 Practice for Utilization of Test Data to Determine Conformance with Specifications
D4171 Specification for Fuel System Icing Inhibitors
D4683 Test Method for Measuring Viscosity of New and Used Engine Oils at High Shear Rate and High Temperature by Tapered Bearing Simulator Viscometer at 150 °C
D4684 Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature
D4741 Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer
D4951 Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry
D5119 Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine (Withdrawn 2003)[3]
D5133 Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5293 Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between –5 °C and –35 °C Using Cold-Cranking Simulator
D5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions (Withdrawn 2003)[3]
D5480 Test Method for Engine Oil Volatility by Gas Chromatography (Withdrawn 2003)[3]
D5481 Test Method for Measuring Apparent Viscosity at High-Temperature and High-Shear Rate by Multicell Capillary Viscometer
D5533 Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIE, Spark-Ignition Engine (Withdrawn 2003)[3]
D5800 Test Method for Evaporation Loss of Lubricating Oils by the Noack Method
D5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID) (Withdrawn 2003)[3]
D5966 Test Method for Evaluation of Engine Oils for Roller Follower Wear in Light-Duty Diesel Engine
D5967 Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine
D6082 Test Method for High Temperature Foaming Characteristics of Lubricating Oils
D6202 Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark Ignition Engine (Withdrawn 2009)[3]
D6278 Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus
D6335 Test Method for Determination of High Temperature Deposits by Thermo-Oxidation Engine Oil Simulation Test
D6417 Test Method for Estimation of Engine Oil Volatility by Capillary Gas Chromatography
D6483 Test Method for Evaluation of Diesel Engine Oils in T-9 Diesel Engine (Withdrawn 2009)[3]
D6557 Test Method for Evaluation of Rust Preventive Characteristics of Automotive Engine Oils

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

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

D6593 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions
D6594 Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135 °C
D6681 Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure
D6709 Test Method for Evaluation of Automotive Engine Oils in the Sequence VIII Spark-Ignition Engine (CLR Oil Test Engine)
D6750 Test Methods for Evaluation of Engine Oils in a High-Speed, Single-Cylinder Diesel Engine—1K Procedure (0.4 % Fuel Sulfur) and 1N Procedure (0.04 % Fuel Sulfur)
D6794 Test Method for Measuring the Effect on Filterability of Engine Oils After Treatment with Various Amounts of Water and a Long (6 h) Heating Time
D6795 Test Method for Measuring the Effect on Filterability of Engine Oils After Treatment with Water and Dry Ice and a Short (30 min) Heating Time
D6837 Test Method for Measurement of Effects of Automotive Engine Oils on Fuel Economy of Passenger Cars and Light-Duty Trucks in Sequence VIB Spark Ignition Engine
D6838 Test Method for Cummins M11 High Soot Test
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:*[4]
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:*[5]
API 1509 Engine Oil Licensing and Certification System (EOLCS)

2.4 *Government Standard:*[6]
DOD CID A-A-52039A (SAE 5W-30, 10W-30, and 15W-40)

2.5 *American Chemical Council Code:*[7]
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.

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[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096–0001.

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

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

[7] Available from American Chemical Council, 1300 Wilson Blvd., Arlington, VA 22209.

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

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

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

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

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

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

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

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *Energy Conserving category, n*—the group of engine oils that have demonstrated fuel economy benefits and are intended primarily for use in automotive gasoline engine applications, such as passenger cars, light-duty trucks, and vans.

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

3.2.4 *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,[5,8] 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,[9] 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,[10] 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.)

(*1*) 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 by the American Petroleum Institute (API) requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the

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

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

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

TABLE 1 S Engine Oil Categories

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

Bench Test and Measured Parameter	Viscosity Grade Performance Criteria	
	SAE 0W-20, SAE 5W-20, SAE 5W-30, SAE 10W-30	All Others
Test Method D5800 volatility loss, % max[Q]	22	20[R]
Test Method D6417 volatility loss at 371 °C, % max[Q]	17	15[R]
Test Method D5480 volatility loss at 371 °C, % max[Q]	17	15[R]
Test Method D6795 (EOFT), % flow reduction, max	50	50
Test Method D6794 (EOWTT), % flow reduction, max		
with 0.6 % H_20	report	report
with 1.0 % H_20	report	report
with 2.0 % H_20	report	report
with 3.0 % H_20	report	report
Test Method D4951 or D5185, mass fraction phosphorus, %, max	0.10[S]	NR[T]
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[U]	200	NR[T]
Test Method D93 flash point, °C, min[U]	185	NR[T]
Test Method D892 foaming tendency (Option A)		
Sequence I, max, foaming/settling[V]	10/0	10/0
Sequence II, max, foaming/settling[V]	50/0	50/0
Sequence III, max, foaming/settling[V]	10/0	10/0
Test Method D6082 (optional blending required) Static foam, max, tendency/stability	200/50[W]	200/50[W]
Test Method D6922 homogeneity and miscibility	[X]	[X]
Test Method D6335 High temperature deposits (TEOST 33), deposit mass, mg, max	60	60

TABLE 1 *Continued*

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

API SL Category

Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
D6984 (Sequence IIIF)	Kinematic viscosity, % increase at 40 °C, max	275
	Average piston skirt varnish rating,[C] min	9.0
	Weighted piston deposit rating,[H] min	4.0
	Screened average cam-plus-lifter wear, μm, max	20[I]
	Hot Stuck Rings	none
	Low temperature viscosity performance[Y]	report
or D7320 (Sequence IIIG)[J]	Kinematic viscosity, % increase at 40 °C, max	150
	Weighted piston deposit rating,[K] min	3.5
	Cam-plus-lifter wear avg, μm, max	60
	Hot stuck rings	none
	Low temperature viscosity performance[Z]	report
D6891 (Sequence IVA)	Cam wear average, μm,[M] max	120
D5302[B] (Sequence VE[AA])	Cam wear average, μm, max	127
	Cam wear max, μm, max	380
D6593 (Sequence VG)	Average engine sludge rating,[C] min	7.8
	Rocker arm cover sludge rating,[C] min	8.0
	Average piston skirt varnish rating,[C] min	7.5
	Average engine varnish rating,[N] min	8.9
	Oil screen clogging, %, max	20
	Hot stuck Compression rings	none
	Cold stuck rings	report
	Oil screen debris, %	report
	Oil ring clogging, %	report
D6709 (Sequence VIII)	Bearing weight loss, mg, max	26.4
	Shear stability	[P]

Bench Test and Measured Parameter	Performance Criteria
Test Method D6557 (Ball Rust Test), average gray value, min	100
Test Method D5800 volatility loss, % max	15
Test Method D6417 volatility loss at 371 °C, % max	10
D6795 (EOFT), % flow reduction, max	50
D6794 (EOWTT), % flow reduction, max	
With 0.6 % H_2O	50
With 1.0 % H_2O	50
With 2.0 % H_2O	50
With 3.0 % H_2O	50
Test Method D4951 or D5185, mass fraction phosphorus %, max[AB]	0.10[S]
Test Method D4951 or D5185, mass fraction phosphorus %, min (unless valid passing Test Method D5302 results are obtained)	0.06
Test Method D892 foaming tendency (Option A)	
Sequence I, max, foaming/settling[V]	10/0
Sequence II, max, foaming/settling[V]	50/0
Sequence III, max, foaming/settling[V]	10/0
Test Method D6082 (optional blending required) static foam max, tendency/stability	100/0[W]
Test Method D6922 homogeneity and miscibility	[X]
Test Method D7097 high temperature deposits (TEOST MHT-4), deposit mass, mg, max	45
Test Method D5133 (Gelation Index), max[AB]	12[AC]

[A] Demonstrate passing performance in either Test Method D5844 or D6557.
[B] Monitoring of this test method was discontinued in June 20, 2001. Valid test results shall predate the end of the last calibration period for the test stand in which this test method was conducted.
[C] ASTM Deposit Rating Manual 20, available from ASTM Customer Relations, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.
[D] Demonstrate passing performance in either Test Method D5533 or D6984. However, an oil passing Test Method D6984 and containing less than 0.08 % mass phosphorus in the form of ZDDP shall also pass the wear limits in Test Method D5302 (see also footnote [J]).
[E] An oil-related stuck ring occurs on a piston with an individual oil ring land deposit rating <2.6.
[F] Determine at 60 h.
[G] Determine at 80 h.
[H] Determine weighted piston deposits by rating the following piston areas and applying the corresponding weightings: undercrown, 10 %; second land, 15 %; third land, 30 %; piston skirt, 10 %; first groove, 5 %; second groove, 10 %; and third groove, 20 %. Use ASTM Deposit Rating Manual 20 for all ratings.
[I] Calculate by eliminating the highest and lowest cam-plus-lifter wear results and then calculating an average based on the remaining ten rating positions.
[J] For oils containing at least 0.06 % mass phosphorus in the form of ZDDP, demonstrating passing performance in the Sequence IIIG test obviates the need to also conduct Test Method D5302 (Sequence VE), which was previously required for oils with less than 0.08 % mass phosphorus.
[K] Unlike the Sequence IIIF test, piston skirt varnish rating is not required in the Sequence IIIG test.
[L] Demonstrate passing performance in Test Method D5302, or alternatively, in both Test Method D6891 and Test Method D6593.
[M] Determine cam wear according to Test Method D6891. Seven wear measurements are made on each cam lobe and the seven measured values are added to obtain an individual cam lobe wear result. The overall cam wear value is the average of the twelve individual cam lobe wear results.

[N] Determine the average engine varnish rating by averaging the piston skirt, right rocker arm cover, and left rocker arm cover varnish ratings. Use ASTM Deposit Rating Manual 20 for all ratings.
[O] Demonstrate passing performance in either Test Method D5119 or D6709.
[P] Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade).
[Q] Meet the volatility requirement in either Test Method D5800, D5480, or D6417.
[R] Passing volatility loss only required for SAE 15W-40 oils.
[S] This is a noncritical specification as described in Practice D3244.
[T] NR stands for Not Required.
[U] Meet either Test Method D92 or Test Method D93 flash point requirement.
[V] Determine settling volume, in mL, at 10 min.
[W] Determine settling volume, in mL, at 1 min.
[X] Homogeneous with SAE reference oils.
[Y] 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.
[Z] 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.
[AA] Not required for oils containing a minimum of 0.08 % mass phosphorus in the form of ZDDP.
[AB] Requirement applies only to SAE 0W-20, 5W-20, 0W-30, 5W-30, and 10W-30 viscosity grades.
[AC] For gelation temperatures at or above the W grade pumpability temperature as defined in SAE J300.

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.[11] (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.[8]

4.1.2.3 Test Method D5302, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988, with regard to valve train wear. It is included in the SL performance specification to augment assessment of the wear control performance of oils containing less than 0.08 % mass of phosphorus from ZDDP additive.

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

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

4.1.2.5 Test Method D6709, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.[9]

(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.

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

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

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

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

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

4.1.3.1 Test Method D6750, the 1K diesel engine test, has been correlated with vehicles equipped with engines used in high speed operation prior to 1989, particularly with respect to aluminum piston deposits and oil consumption when the mass fraction of sulfur content is nominally 0.4 %.[10]

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 %.[12]

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.[13] (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.[14] (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.[15]

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

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

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

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

4.1.4.3 Test Method D6975, the M11 EGR heavy-duty diesel engine test, is used to evaluate oil performance with respect to valve train wear, sludge deposits, and oil filter

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

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

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

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

plugging in an exhaust gas recirculation environment. (An alternative is the Cummins ISM diesel engine test. See 4.1.5.5.)

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

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

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

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

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

4.1.4.9 Test Methods 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.

TABLE 2 Energy Conserving Categories

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

[A] 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.
[B] 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.
[C] 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.
[D] 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.
[E] 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.
[F] 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).

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

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

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

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

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

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

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

4.1.5.6 Test Method D6750, the 1N diesel engine test, has been used to predict piston deposit formation in four-stroke cycle, direct injection, diesel engines that have been calibrated to meet 1994 U.S. federal exhaust emissions requirements for heavy-duty engines operated on fuel containing the mass fraction of sulfur less than 0.05 %.[16]

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

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

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

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

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

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

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

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

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

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

4.1.6 *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[17] 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 3—Energy-conserving oils are also described in SAE J1423.

4.1.8 Licensing of the Energy Conserving category by the American Petroleum Institute (API) 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

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

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

protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification. (See Appendix X3 for more information.)

5. Performance Requirements

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

NOTE 4—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 5—In practice, engine oils are often labeled with service category designations having some combination of both S and C prefixes.

NOTE 6—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.

6. Test Procedures

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

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

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

6.4 For SJ and SJ-related Energy Conserving test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods D5119, D5133, D5480, D5800, D6082, D6202, D6335, D6417, D6794, D6795, D6837, D6891, D6984, and D7320.

6.5 For SL and SL-related Energy Conserving test results to be valid from the following test types, they shall have been conducted in stands/equipment in current calibration by the TMC: Test Methods D5133, D5800, D6082, D6417, D6557, D6593, D6709, D6794, D6795, D6837, D6891, D6984, D7097, and D7320.[18]

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

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

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

7. Keywords

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

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

TABLE 3 C Engine Oil Categories

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
			One-test	Two-test[A]	Three-test[A]
CH-4	D6681 (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 h – 360 h), max	12.4	12.4	12.4
		Final Oil Consumption, g/h (312 h – 360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none[C]
	D6750 (1K)[D]	Weighted demerits (WDK), %, max	332	347	353
		Top groove fill (TGF), %, max	24	27	29
		Top land heavy carbon (TLHC), %, max	4	5	5
		Average Oil Consumption, g/kWh (0 h – 252 h), max	0.54	0.54	0.54
		(g/MJ) (0 h – 252 h), max	(0.15)	(0.15)	(0.15)
		Piston, ring, and liner scuffing	none	none	none[C]
	D6483 (T-9)	Average Liner Wear, normalized to 1.75 % soot, µm max	25.4	26.6	27.1
		Average Top Ring Mass Loss, mg max[E]	120	136	144
		EOT Used Oil Lead Content less New Oil Lead Content, mg/kg, max	25	32	36
	or, D6987/D6987M (T-10)	Liner wear, µm, max	32	34	35
		Ring wear, mg, max	150	159	163
		Lead content at EOT, mg/kg, max	50	56	59
	or, D7422 (T-12)	Liner wear, µm, max	30.0	30.8	31.1
		Top Ring Mass Loss, mg, max	120	132	137
		Lead content at EOT, mg/kg, max	65	75	79
	D5966 (RFWT)	Average Pin Wear, mils, max	0.30	0.33	0.36
		(µm) max	(7.6)	(8.4)	(9.1)
	D6838 (M11)[F]	Rocker Pad Average Mass Loss, normalized to 4.5 % soot, mg max	6.5	7.5	8.0
		Oil Filter Differential Pressure at EOT, kPa max	79	93	100
		Average Engine Sludge, CRC Merits at EOT, min	8.7	8.6	8.5
	or, D7468 (ISM)	Crosshead wear, mg, max	7.5	7.8	7.9
		Oil filter delta pressure, at 150 h, kPa, max	79	95	103
		Sludge rating, CRC merits, min	8.1	8.0	8.0
	D5967 (Ext. T-8E)[G]	Relative Viscosity at 4.8 % Soot by TGA, max	2.1	2.2	2.3
		Viscosity increase at 3.8 % Soot by TGA, mm^2/s, max	11.5	12.5	13.0
	D6984 (Sequence IIIF)	60 h Viscosity at 40 °C, increase from 10 min sample, % max	295	295 (MTAC)[H]	295 (MTAC)[H]
	or D7320 (Sequence IIIG)[I]	Kinematic viscosity, % increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
	D6894 (EOAT)[J]	Aeration, volume, % max	8.0	8.0 (MTAC)[H]	8.0 (MTAC)[H]
	D6594 (135 °C, HTC BT)	Used Oil Elemental Concentration			
		Copper, mg/kg increase, max	20		
		Lead, mg/kg increase, max	120		
		Tin, mg/kg increase	report		
		Copper strip rating,[K] max	3		
	D892 (Option A not allowed)	Foaming/Settling,[L] mL, max			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
			SAE 10W-30	SAE 15W-40	
	D5800 or	percent volatility loss at 250 °C, max	20	18	
	D6417	percent volatility loss at 371 °C, max	17	15	
	D6278	Kinematic Viscosity after shearing, mm^2/s, min	SAE XW-30 9.3	SAE XW-40 12.5	
			One-test	Two-test[M]	Three-test[M]
CI-4	D6923 (1R)	Weighted demerits (WDR), max	382	396	402
		Top groove carbon (TGC), demerits, max	52	57	59
		Top land carbon (TLC), demerits, max	31	35	36
		Initial oil consumption (IOC), (0 h – 252 h), g/h, average	13.1	13.1	13.1
		Final oil consumption, (432 h – 504 h), g/h, average, max	IOC + 1.8	IOC + 1.8	IOC + 1.8
		Piston, ring, and liner distress	none	none	none
		Ring sticking	none	none	none
	or, D6681 (1P)	Weighted demerits (WDP), max	350	378	390
		Top groove carbon (TGC), demerits, max	36	39	41
		Top land carbon (TLC), demerits, max	40	46	49
		Average oil consumption, g/h (0 h – 360 h), max	12.4	12.4	12.4
		Final oil consumption, g/h (312 h – 360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none
	D6987/D6987M (T-10)	Merit rating,[M] min	1000	1000	1000
	or the T-12 (T-10) test	Merit rating,[M] min	1000	1000	1000
	D6975 (M11 EGR)	Average crosshead mass. loss, mg, max	20.0	21.8	22.6
		Average top ring mass loss, mg	report	report	report

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
		Oil filter differential pressure at 250 h, kPa, max	275	320	341
		Average engine sludge, CRC merits at EOT, min	7.8	7.6	7.5
	or, D7468 (ISM)	Crosshead wear, mg, max	7.5	7.8	7.9
		Oil filter Δ pressure at 150 h, kPa, max	55	67	74
		Sludge rating, CRC Merits, min	8.1	8.0	8.0
	D5967 (Ext. T-8E)[G]	Relative viscosity at 4.8 % soot[N]	1.8	1.9	2.0
	D6984 (Sequence IIIF)[O]	Kinematic viscosity (at 40 °C), percent increase, max	275	275 (MTAC)	275 (MTAC)
	or D7320(Sequence IIIG)[I]	Kinematic viscosity, percent increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
	D6750[P] (1K)	Weighted demerits (WDK), max	332	347	353
		Top groove fill (TGF), %, max	24	27	29
		Top land heavy carbon (TLHC), %, max	4	5	5
		Average oil consumption, g/kWh (0 h – 252 h), max	0.54	0.54	0.54
		(g/MJ) (0 h – 252 h), max	(0.15)	(0.15)	(0.15)
		Piston, ring, and liner scuffing	none	none	none
	D5966 (RFWT)	Average pin wear, mils, max or (µm), max	0.30 (7.6)	0.33 (8.4)	0.36 (9.1)
	D6894 (EOAT)[J]	Aeration, volume percent, max	8.0	8.0 (MTAC)[H]	8.0 (MTAC)[H]

CI-4 Bench Tests	Measured Parameter	Primary Performance Criteria
D4683 (High temperature/High shear) or D4171 or D5481[Q]	Viscosity after shear,[R] min	3.5 mPa-s
D4684 (MRV-TP-1)	The following limits are applied to SAE viscosity grades 0W, 5W, 10W and 15W:	
	Viscosity of 75 h used oil sample from T-10 test (or T-10A[S] test), or 100 h used oil sample from T-12 test (or T-12A[T] test, tested at –20 °C, mPa-s, max	25 000
	If yield stress is detected, use modified D4684[U] (external preheat), then mPa-s, max	25 000
	and yield stress, Pa	<35
D5800 (Noack)	Evaporative loss at 250 °C, %, max	15
D6594 (135 °C HTCBT)	Copper, mg/kg increase, max	20
	Lead, mg/kg increase, max	120
	Tin, mg/kg increase	report
	Copper strip rating,[K] max	3
D6278	Kinematic viscosity after shearing, mm^2/s, min	SAE XW-30 / SAE XW-40 9.3/12.5
D892 (Option A not allowed)	Foaming/settling,[L] mL, max	
	Sequence I	10/0
	Sequence II	20/0
	Sequence III	10/0

CI-4 Bench Tests, cont'd—D7216 (Elastomer Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

NOTE 1—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A4.

NOTE 1—TMC 1006 is the designation for the reference oil used in this test method. This designation represents the original blend or subsequent approved re-blends of TMC 1006.

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

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
			One-test	Two-test	Three-test
CJ-4	D7422 (T-12)	Merit rating,[V] min	1000	1000	1000
	D7468 (ISM)	Merit rating,[V] min	1000	1000	1000
		Top ring mass loss, mg, max	100	100	100
	D7549 (C13)	Merit rating,[V] min	1000	1000	1000
		Hot-stuck piston ring	none	none	none
	D7156 (T-11)	TGA % Soot at 4.0 mm^2/s increase, at 100 °C, min	3.5	3.4	3.3
		TGA % Soot at 12.0 mm^2/s increase, at 100 °C, min	6.0	5.9	5.9
		TGA % Soot at 15.0 mm^2/s increase, at 100 °C, min	6.7	6.6	6.5
	D7484 (ISB)	Slider tappet mass loss, mg, average, max	100	108	112
		Cam lobe wear, µm, average, max	55	59	61
		Crosshead mass loss, mg, average	report	report	report
	D6750 (1N)	Weighted demerits (WDN), max	286.2	311.7	323.0

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
		Top groove fill (TGF), %, max	20	23	25
		Top land heavy carbon (TLHC), %, max	3	4	5
		Oil consumption, g/kWh, (0 h – 252 h), max	0.54	0.54	0.54
		(g/MJ) (0 h – 252 h), max	(0.15)	(0.15)	(0.15)
		Piston, ring, and liner scuffing	none	none	none
		Piston ring sticking	none	none	none
	D5966 (RFWT)	Average pin wear, mils, max	0.30	0.33	0.36
		(µm) max	(7.6)	(8.4)	(9.1)
	D6984 (Sequence IIIF)	Kinematic viscosity (at 40 °C), % increase, max	275	275 (MTAC)	275 (MTAC)
	or, alternately, D7320 (Sequence IIIG)[I]	Kinematic viscosity (at 40 °C), % increase, max	150	150 (MTAC)	150 (MTAC)
	D6894 (EOAT)	Aeration, volume, %, max	8.0	8.0 (MTAC)	8.0 (MTAC)

CJ-4 Bench Tests	Measured Parameter	Primary Performance Criteria
D4683 (High temperature/High shear) or D4171 or D5481	Viscosity at 150 °C, mPa-s, min	3.5
D6594 (135 °C HTCBT)	Copper, mg/kg increase, max	20
	Lead, mg/kg increase, max	120
	Copper strip rating, max	3
D7109	Kinematic viscosity after 90 pass shearing, mm^2/s at 100 °C, min	SAE XW-30 / SAE XW-40 9.3 / 12.5
D5800 (Noack)	Evaporative loss at 250 °C, %, max (Viscosities other than SAE 10W-30)	13
	Evaporative loss at 250 °C, %, max (SAE 10W-30 viscosity)	15
D892	Foaming/settling, mL, max	
	Sequence I	10/0
	Sequence II	20/0
	Sequence III	10/0
D6896 (MRV TP-1)	Viscosity of the 180 h used oil drain sample from a T-11 test, tested at –20 °C, mPa-s, max	25 000
	If yield stress is detected, use the modified test method (external preheat), then measure the viscosity, mPa-s, max	25 000
	Measure the yield stress, Pa	<35
	Chemical Limits (non-critical)	
D874	Mass fraction sulfated ash, %, max	1.0
D4951	Mass fraction phosphorus, %, max	0.12
D4951	Mass fraction sulfur, %, max	0.4

CJ-4 Bench Tests, cont'd—D7216 (Seal Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

NOTE 1—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A4.

NOTE 1—TMC 1006 is the designation for the reference oil used in this test method. This designation represents the original blend or subsequent approved re-blends
of TMC 1006.

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

[A] See Annex A2 for additional information.
[B] Refer to RR:D02-1441.
[C] If three or more operationally valid tests have been run, the majority of these tests shall not have scuffing. The scuffed tests are considered uninterpretable, and all data from these tests are eliminated from averaging.
[D] Refer to RR:D02-1273.
[E] Refer to RR:D02-1440.
[F] Refer to RR:D02-1439.
[G] A passing T-11 (TGA % soot at 12.0 mm^2/s increase, at 100 °C, min)—6.00 (first test), 5.89 (second test), and 5.85 (third test)—can be used in place of a T-8E in the applicable categories. This is not intended to indicate equivalence.
[H] See Annex A1; use method without transformations.
[I] The Sequence IIIG limits shown are more restrictive than the corresponding limits in Sequence IIIF, and are not intended to indicate equivalence. Results meeting the Sequence IIIG criteria stated can be used in lieu of Sequence IIIF.
[J] Refer to RR:D02-1379.
[K] The rating system in Test Method D130 is used to rate the copper coupon in Test Method D6594.
[L] Ten minutes for Sequence I, II, and III.
[M] See Annex A3 for additional information.
[N] Relative Viscosity (RV) = viscosity at 4.8 % soot/viscosity of new oil sheared in Test Method D6278.
[O] Refer to RR:D02-1391.

[P] Refer to RR:D02-1273. Alternatively, Test Method D6750 (1N) can be used; if this test method is used, the measured parameters and primary performance criteria are the same as those shown for Test Method D6750 (1N) in the CJ-4 category.
[Q] Tests as allowed in SAE J300.
[R] Noncritical specification as defined by Practice D3244; may be superseded only by applicable higher limits set by SAE J300.
[S] The T-10A test is the name given to a T-10 test run for 75 h to generate the sample for measurement by Test Method D4684.
[T] The T-12A test is the name given to a T-12 test run for 100 h to generate the sample for measurement by Test Method D4684.
[U] Refer to RR:D02-1517.
[V] See Annex A5 for additional information.

ANNEXES

(Mandatory Information)

A1. MULTIPLE TEST ACCEPTANCE CRITERIA

A1.1 Multiple Test Acceptance Criteria (MTAC) is any data-based approach for evaluation of the quality and performance of a formulation where more than one test may be run. Generally for a candidate tested once, test data for each criterion shall be a pass. For a candidate tested twice, the mean (average) value of each result shall be a pass. For a candidate tested three or more times, one test might be declared an outlier and thus discarded and the mean (average) value of retained test data for each result shall be a pass. Data are rounded in accordance with the procedures specified in Practice E29.

TABLE A1.1 Parameters to Be Transformed and Averaged in Determination of MTAC

Test Method	Rated Parameter	Transformation
D5844 (Sequence IID)	Average engine rust	NA[A]
D5533 (Sequence IIIE)	Viscosity increase[B] (h to 375 %)	NA
	Average engine sludge	–LN (10-AES)
	Average piston varnish	NA
	Oil ring land deposits	NA
	Average camshaft plus lifter wear[C]	LN (ACLW)
	Maximum camshaft plus lifter wear[C]	LN (MCLW)
	Oil-related ring sticking	NA
D6984 (Sequence IIIF - as used in CH-4)	Percent viscosity increase at 60 h	LN
D6894 (EOAT)	Aeration, volume %	NA
D6984 (Sequence IIIF)	Viscosity, % increase	1/square root of the % viscosity increase at 80 h
	Average piston varnish	NA
	Weighed piston deposits	NA
	Screened average camshaft plus lifter wear	NA
	Hot stuck rings	NA
	Oil Consumption	NA
D7320 (Sequence IIIG)	Viscosity, % increase	LN
D6891 (Sequence IVA)	Cam wear	NA
D5302 (Sequence VE)	Average engine sludge	–LN (9.65 – AES)
	Rocker cover sludge	–LN (9.65 – RCS)
	Average piston varnish	NA
	Average engine varnish	NA
	Average camshaft wear	Square root of ACW
	Maximum camshaft wear	NA
	Oil screen clogging	NA
	Ring sticking	NA
D6593 (Sequence VG)	Average engine sludge	NA
	Rocker arm cover sludge	NA
	Average piston skirt varnish	NA
	Average engine varnish	NA
	Oil screen clogging	LN (Oil screen clogging + 1)
	Hot stuck compression rings	NA
D6202 (Sequence VIA)	Fuel economy improvement	NA
D6837 (Sequence VIB)	Fuel economy improvement	NA
D5119 (L-38)	Total bearing weight loss	NA
D6709 (Sequence VIII)	Total bearing weight loss	NA

[A] NA stands for Not Applicable.
[B] For tests reaching 375 % viscosity increase after 64 h, estimated hours = 64 + (6.163-LN (viscosity increase at 64 h + 100)/0.072). For tests reaching 375 % viscosity increase before 64 h, estimated hours are determined by a straight line interpolation between the two nearest 8 h points.
[C] When more than one test is run and if maximum wear is more than six times the average wear on any one test, the highest mating cam lobe/lifter result can be discarded and the remaining eleven combinations used to calculate a new maximum and average wear. This can only be done for one retained test.

A1.1.1 For light-duty categories, SJ, SL, and the Energy Conserving categories, and the Sequence IIIF, Sequence IIIG, and EOAT tests as used in CH-4, CI-4 and CJ-4, the only requirement for declaring an outlier is that three or more tests have been run. Generally, light-duty pass criteria are constant regardless of the number of tests run. The results for which MTAC apply and appropriate transformations are shown in Table A1.1.

A1.1.2 For heavy-duty categories and most CH-4, CI-4 and CJ-4 parameters, outlier criteria are specified in the following annexes, and tiered, constant, or other pass criteria are shown in Table 3.

A1.2 The following process shall be used to calculate the MTAC mean of test results for a formulation with two or more operationally valid test results (unless otherwise specified).

A1.2.1 Obtain severity adjusted (if applicable) test results for engine test of interest.

A1.2.2 Transform each test result for each criterion in accordance with the transformed unit of measure in Table A1.1. Round each transformed test result to seven decimal places.

A1.2.3 Calculate the mean (arithmetic average) of the test results or transformed test results for each test criterion.

A1.2.4 Transform back, if applicable, each calculated criterion mean to its original units.

A1.2.5 Round each criterion mean, now in original units, to the same number of decimal places as in the applicable criterion pass limit.

A1.2.6 Compare each round criterion mean to its applicable pass limit to determine if performance criteria have been met.

A2. CH-4 MULTIPLE-TEST PROGRAMS

A2.1 For the CH-4 test parameters on which outlier criteria apply (as shown in Table A2.1), if three or more tests are run, one complete test can be discarded if the outlier criteria defined in Practice E178 are met at a significance level of 5 %. Since the criteria are based upon the number of tests in the program, each program is unique.

A2.2 Section 6 (Recommended Criteria for Known Standard Deviations) of Practice E178 is used to determine outliers. The standard deviation applied in the outlier determination for each parameter is shown in Table A2.1.

TABLE A2.1 Outlier Test Determination Values

Test Parameter	Estimate of Standard Deviation
1P-WDP	57.6^{A}
1P-TGC	7.74^{A}
1P-TLC	13.15^{A}
1P-AOC	0.3238^{A} Natural log transform
1P-FOC	0.5177^{A} Natural log transform
1K-WDK	35.6^{B}
1K-TGF	15.7^{B}
1K-TLHC	1.1^{B} (Ln TLHC + 1)
1K - AOC	0.145^{C}
T-9 - ALW	2.35^{A}
T-9 - TRWL	29.29^{A}
T-9 - EOT ΔPb	1.203^{A} Square root transform
T-10 – CLW	4.2^{D}
T-10 – TRWL	18^{D}
T-10 – EOT ΔPb	0.2339^{D} Natural log transform
RFWT - APW	0.04^{B}
M11 - XHEAD WEAR	2.2^{A}
M11 - OFDP	0.3270^{A} Natural log transform
M11 - SLUDGE	0.27^{A}
T-8E - VISCOSITY$_{REL}$ at 4.8 % SOOT	0.15^{E}
T-8E - VISCOSITY INCREASE at 3.8 % SOOT	0.93^{B}
ISM—Crosshead wear	0.6
ISM—OFDP	0.4227 Ln transform
ISM—Sludge	0.2

^{A} Value obtained from the PC-7 Precision/BOI Matrix conducted in 1997, and reported upon in the ASTM Research Report associated with this test D02-1441.
^{B} LTMS document as of February 1998. Available from the ASTM Test Monitoring Center.
^{C} Standard Deviation for Reference Oil 809 as of January 1998.
^{D} From LTMS document 9-05 standard deviations for Oil 830–2.
^{E} Standard Deviation for Reference Oil 1005 as of 24 October 1997.

A3. CI-4 MULTIPLE TEST PROGRAMS AND TEST METHOD D6987/D6987M (T-10) MERIT RATING SYSTEM APPLICATION

A3.1 For the CI-4 test parameters on which outlier criteria apply (as shown in Table A3.1), if three or more tests are run, one complete test can be discarded if the outlier criteria defined in Practice E178 are met at a significance level of 5 %. Since the criteria are based upon the number of tests in the program, each program is unique.

A3.2 Section 6 (Recommended Criteria for Known Standard Deviations) of Practice E178 is used to determine outliers. The standard deviation applied in the outlier determination for each parameter is shown in Table A3.1.

A3.3 Application of the Mack T-10 or, alternatively, the T-12 (T-10) Merit Rating Systems to single and multiple test results follows the guidelines shown in A3.4.1 – A3.4.7. The T-12(T-10) Merit Rating System is based on results obtained in Test Method D7422, the T-12 test method, but with rating values specified that approximate those established for the T-10 test method. The Mack T-10 and T-12 Rating System calculation methodology is described in the respective test methods.

TABLE A3.1 Outlier Test Determination Values

Test Parameter	Estimate of Standard Deviation
1K – WDK	35.6
1K – TGF	15.7
1K – TLHC	1.1 Ln(TLHC + 1) transform
1K – AOC	0.145
1N – WDN	27.1
1N – TGF	14.6
1N – TLHC	0.9 Ln(TLHC + 1) transform
1N – AOC	0.045
1R – WDR	29
1R – TGC	9.7
1R – TLC	7.84
1R – IOC	1.32
1R – (FOC – IOC)	1.38
M11 EGR – CWL (corrected to 4,6 % average soot)	3.7 (after transform)
M11 EGR – OFDP	2.7000 square root transform
M11 EGR – Sludge	0.38
ISM – Crosshead wear	0.6
ISM – OFDP	0.4227 Ln transform
ISM – Sludge	0.2
RFWT – APW	0.04
T-8E – Viscosity$_{rel}$ at 4.8 % soot[A]	0.27
T-10 – Liner Wear	3.4
T-10 – TRWL	26
T-10 – EOT Lead	7.1
T-10 – 250-300 Lead	5.2
T-10 – AOC	10.9

[A] 100 % of Test Method D6278 viscosity delta used in relative viscosity calculation.

A3.4 Tables A3.2 and A3.3 each contain *Maximum*, *Anchor*, and *Minimum* values, as well as *Weight* values, for the specified tests and the test parameters.

A3.4.1 If all of the test parameter results from a given test method are equal to or better than the *Anchor* values shown in the corresponding table, this is a passing merits result.

A3.4.2 If all of the test parameter results from a given test method exactly meet the *Anchor* values in the corresponding table, each test result receives merits equal to the *Weight* values and the total merit rating of 1000 is a passing merits result.

A3.4.3 If any of the test parameter results from a given test method are at the *Maximum* values shown in the corresponding table, zero merit points are earned for that parameter.

A3.4.4 If any of the test parameter results from a given test method are worse than the *Maximum* values shown in the corresponding table, this is a failing result.

A3.4.5 If results for all of the test parameters from a given test method are better than the corresponding *Maximum* values, but one or more results is worse than the corresponding *Anchor* values, the appropriate Merit Rating System applies a mathematical calculation methodology to determine whether marginal results worse than the *Anchor* values are compensated by better than *Anchor* values on other test parameters.

A3.4.6 If any of the test parameters from a given test method are at or better than the *Minimum* values shown in the corresponding table, merit points are received equal to twice the *Weight* values in the corresponding table for that parameter.

A3.4.7 Multiple test evaluation for a given test method consists of averaging the individual test parameter results across multiple tests. The T-10 or, alternatively, T-12(T-10) Merit Rating Systems are then applied to the averages of the test parameter results. (See Appendix X7 for the detailed T-12/T-10 calculation methodology.)

TABLE A3.2 Mack T-10 Merit System

Criterion	(0 h – 300 h) Delta Lead, mg/kg	(250 h – 300) h) Delta Lead, mg/kg	Cylinder Liner Wear, µm	Top Ring Mass Loss, mg	Oil Consumption, g/h
Weight (Total = 1000)	225	225	250	150	150
Maximum	35	14	32.0	158	65.0
Anchor	30	10	30	140	57
Minimum	5	0	12	50	25

TABLE A3.3 Alternative Mack T-12(T-10) Merit System

Criterion	(0 h –300) h) Delta Lead, mg/kg	(250 h –300) h) Delta Lead, mg/kg	Cylinder Liner Wear, µm	Top Ring Mass Loss, mg	Oil Consumption, g/h
Weight (Total = 1000)	200	200	250	200	150
Maximum	42	18	26	117	95
Anchor	35	13	23	82	82
Minimum	10	0	12	47	50

A4. PROCEDURE FOR DERIVING ADJUSTED SPECIFICATION LIMITS FOR ELASTOMER COMPATIBILITY

A4.1 Background

A4.1.1 This annex describes a statistical method to account for the inherent test variability in the elastomer compatibility test method. The need to take account of the inherent test variability arises in part because batch-to-batch, sheet-to-sheet and within-sheet variations in the properties of the reference elastomers (the four elastomers listed for the CI-4 category in Table 3) can be sufficiently large that they complicate making a decision as to whether or not a candidate oil has passed the elastomer compatibility requirements.

A4.1.2 Applying this statistical method to the unadjusted specification limits noted in Table 3 produces the adjusted specification limits. *Passing* candidate-oil results shall lie within the range defined by the adjusted specification limits.

A4.1.3 The statistical method for determining the adjusted specification limits uses updated information about the industry test variability relevant to the time frame in which the candidate oil is tested. The TMC provides the updated information based on test results obtained by different test laboratories with different batches of reference elastomers on the same TMC 1006 reference oil.

A4.2 Unadjusted Specification Limits

A4.2.1 The unadjusted specification limits are shown for the CI-4 category in Table 3. (These are reproduced in Table A4.1 for comparison purposes.) The test method involves sixteen criteria. These criteria are the unadjusted specified limits for the four elastomer types (nitrile, silicone, polyacrylate and fluoroelastomer), with changes in four properties (volume, hardness, tensile strength and elongation at break).

A4.3 Adjusted Specification Limits

A4.3.1 The adjusted specification limits are calculated by adjusting the numerical limits in Table 3 (referred to as *fixed limits*), and the TMC 1006 limit in Table 3 (referred to as a *variable limit*). The reference oil TMC 1006 is run in parallel with the candidate oil as a control for each experiment.

A4.3.2 The adjusted specification limits are determined as the unadjusted specification limits plus (in absolute terms) an amount to account for test variability.

A4.4 Inherent Test Variability

A4.4.1 Table A4.2 shows examples of the standard deviation estimates of the four reference elastomers and the four performance parameters, as reported by the TMC. The standard deviation estimates, applicable at the time a test oil is evaluated, are obtained from the TMC website (ftp://ftp.astmtmc.cmu.edu/refdata/bench/elastomer_pc9/PC-9_Elastomer_1006.xls).

A4.5 Adjusted Specification Limits—Calculations

A4.5.1 *Calculation of Fixed Limits:*

A4.5.1.1 Calculate the standard error of the test-oil mean by dividing the appropriate *total standard deviation* estimate by the square root of the number of observations in the sample. The number of observations in the sample, in the absence of outliers, is six.

A4.5.1.2 Multiply the standard error of the test-oil mean by 2.0.

A4.5.1.3 Add or subtract the resulting number to or from the respective upper or lower unadjusted specification limits to obtain the *fixed* adjusted specification limit(s).

A4.5.2 *Calculation of Variable Limits:*

A4.5.2.1 Calculate the standard error of the test-oil mean by dividing the appropriate *within-lab standard deviation* estimate by the square root of the number of observations in the sample. The number of observations in the sample, in the absence of outliers, is six.

A4.5.2.2 Multiply the standard error of the test-oil mean by 2.8.

A4.5.2.3 Add or subtract the resulting number to or from the mean result obtained with TMC 1006 (run in parallel with the test oil) to obtain either the upper or lower *variable* adjusted specification limit.

A4.5.3 Table A4.3 shows an example of the calculated adjusted specification limits.

A4.6 Comparison of Unadjusted and Adjusted Specification Limits

A4.6.1 Table A4.1 reproduces the unadjusted specification limits for comparison with the above adjusted specification limits.

TABLE A4.1 Unadjusted Specification Limits for the Elastomer Test Method as Part of the CI-4 Engine Oil Category

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

TABLE A4.2 Example of Total and Within-Laboratory Standard Deviation Estimates for the Four Reference Elastomers[A]

Elastomer		Volume Change	Hardness Change	Tensile Strength Change	Elongation at Break Change
Nitrile (NBR)	Total	0.91	1.84	7.67	7.66
Nitrile (NBR)	Within-Lab	0.91	1.51	7.44	7.66
Silicone (VMQ)	Total	2.33	2.59	5.40	9.98
Silicone (VMQ)	Within-Lab	2.30	1.57	5.37	9.97
Polyacrylate (ACM)	Total	0.83	1.92	10.19	11.20
Polyacrylate (ACM))	Within-Lab	0.81	1.90	10.17	11.11
Fluoroelastomer (FKM)	Total	0.16	2.40	5.59	10.48
Fluoroelastomer (FKM)	Within-Lab	0.13	1.82	5.27	8.44

[A] Applicable for the period March 1, 2004 to March 15, 2004, as reported on the TMC website.

TABLE A4.3 An Example of Adjusted Specification Limits for the Four Reference Elastomers—Applicable for the Period March 1, 2004 to March 5, 2004[A]

Elastomer	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation at Break Change, %
Nitrile (NBR)	(+5.7, -3.7)	(+8.5, -6.5)	(+16.3, -TMC 1006 - 8.5)	(+16.3, -TMC 1006 – 8.8)
Silicone (VMQ)	(+TMC 1006 + 2.6, -4.9)	(+7.1, -TMC 1006 -1.8)	(+14.4, -49.4)	(-28.1, -38.1)
Polyacrylate (ACM)	(+5.7, -3.7)	(+9.6, -6.6)	(+26.3, -23.3)	(+19.1, -44.1)
Fluoroelastomer (FKM)	(+5.1, -2.1)	(+9.0, -7.0)	(+14.6, -TMC 1006 - 6.0)	(+18.6, -TMC 1006 – 9.6)

[A] Based on unadjusted specification limits, standard deviation estimates shown in Table A4.2, and six observations in all cases.

A5. CJ-4 MULTIPLE TEST PROGRAMS AND TEST METHOD D7422 (T-12), D7549 (C13), AND D7468 (ISM) MERIT RATING SYSTEM APPLICATIONS

A5.1 For the CJ-4 test parameters on which outlier criteria apply (contained in Table A5.1), if three or more tests are run, one complete test can be discarded if the outlier criteria defined in Practice E178 are met at a significance level of 5 %. Since the criteria are based upon the number of tests in the program, each program is unique.

A5.1.1 Section 6 (Recommended Criteria for Known Standard Deviations) of Practice E178 is used to determine outliers. The standard deviation applied in the outlier determination for each parameter will be shown in Table A5.1.

TABLE A5.1 Outlier Test Determination Values

Test Parameter	Estimate of Standard Deviation
1N – WDN	27.1
1N – TGF	14.6
1N – TLHC	0.9 Ln(TLHC + 1) transform
1N – AOC	0.045
RFWT – APW	0.04
T-11 Soot at 4 mm^2/s viscosity increase	0.249
T-11 Soot at 12 mm^2/s viscosity increase	0.187
T-11 Soot at 15 mm^2/s viscosity increase	0.218
ISB camshaft wear, µm, avg	8.3952
ISB tappet weight loss, mg, avg	16.8574

A5.2 The T-12, C13 and ISM Merit Rating Systems calculation methodology is described in the corresponding test methods.

A5.3 Tables A5.2-A5.4 each contain *Maximum*, *Anchor* and *Minimum* values, as well as *Weight* values, for the specified tests and the test parameters.

A5.4 Application of the T-12, C13, and ISM Merit Rating Systems to single and multiple test results follows the guidelines provided below:

TABLE A5.2 Mack T-12 Merit System

	Cylinder Liner Wear, µm	Top Ring Mass Loss, mg	Delta Lead, Final mg/kg	Delta Lead, (250 – 300) h mg/kg	Oil Consumption, g/h
Weight (Total = 1000)	250	200	200	200	150
Maximum	24.0	105	35	15	85.0
Anchor	20.0	70	25	10	65.0
Minimum	12.0	35	10	0	50.0

TABLE A5.3 Caterpillar C13 Merit System

	Delta Oil Consumption, g/h	Top Land Carbon, avg %	Top Groove Carbon, avg %	Second Ring Top Carbon, %
Weight (Total = 1000)	300	300	300	100
Maximum	31	35	53	33
Anchor	25	30	46	22
Minimum	10	15	30	5

TABLE A5.4 Cummins ISM Merit System

	Crosshead Mass Loss, avg mg	Delta Oil Filter Pressure, kPa	Engine Sludge, avg merits	Valve Adj. Screw Mass Loss, mg
Weight (Total = 1000)	350	150	150	350
Maximum	7.1	19	8.7	49
Anchor	5.7	13	9.0	27
Minimum	4.3	7	9.3	16

A5.4.1 If all of the test parameter results from a given test method are equal to or better than the *Anchor* values shown in the corresponding table, this is a passing merits result.

A5.4.2 If all of the test parameter results from a given test method exactly meet the *Anchor* values in the corresponding table, each test result receives merits equal to the *Weight* values and the total merit rating of 1000 is a passing merits result.

A5.4.3 If any of the test parameter results from a given test method are at the *Maximum* values shown in the corresponding table, zero merit points are earned for that parameter.

A5.4.4 If any of the test parameter results from a given test method are worse than the *Maximum* values shown in the corresponding table, this is a failing result.

A5.4.5 If results for all of the test parameters from a given test method are better than the corresponding *Maximum* values, but one or more results is worse than the corresponding *Anchor* values, the appropriate Merit Rating System applies a mathematical calculation methodology to determine whether marginal results worse than the *Anchor* values are compensated by better than *Anchor* values on other test parameters.

A5.4.6 If any of the test parameters from a given test method are at or better than the *Minimum* values shown in the corresponding table, merit points are received equal to twice the *Weight* values in the corresponding table for that parameter.

A5.4.7 Multiple test evaluation for a given test method consists of averaging the individual test parameter results across multiple tests. The T-12, C13, and ISM Merit Rating Systems are then applied to the averages of the test parameter results.

APPENDIXES

(Nonmandatory Information)

X1. CLASSIFICATION MAINTENANCE

X1.1 Successful changes in minimum performance standards rely on close coordination among all affected parties. Technical societies, trade associations, original equipment manufacturers, oil and additive marketers, and consumers may perform different roles to define the need, develop the test methods, and establish oil performance limits.

X1.2 A new definition of oil performance can be requested by any individual, company, or association, including ILSAC, API, EMA, ILMA, ACC, any individual marketer, additive supplier, or original equipment manufacturer (OEM), the U. S. Army, or consumer.

X1.3 Appropriate organizations (detailed in API 1509, Appendix C) consider the request for a new definition of oil performance, and if a need is deemed to exist, test methods are chosen, or developed if none are available or suitable.

X1.4 Oil performance pass/fail criteria are generally selected through technical society consensus procedures, and after appropriate balloting, a new minimum oil performance standard is established.

X1.5 Typically, API then ballots the new standard for inclusion in API 1509, and develops consumer language, the designation, and licensing requirements for the new engine oil category.

X1.6 For a comprehensive description of how new oil performance standards are developed, refer to API 1509, Appendix C.

X2. API DESCRIPTIONS

X2.1 SJ

X2.1.1 API Service Category SJ is to be adopted in 1996 for use in describing engine oil first mandated in 1997. This oil is for use in service typical of gasoline engines in current and earlier passenger car, van, and light truck operation under vehicle manufacturers' recommended maintenance procedures.

X2.1.2 Engine oils developed for this category provide performance exceeding the minimum requirements for API Service Category SH, which Service Category SJ is intended to replace. SJ has new requirements in the areas of volatility, water compatibility, foam inhibition, low temperature properties, high temperature deposit control, and phosphorus limits. All SJ oils must meet specified bench and engine tests.

X2.1.3 Engine oils that meet the API SJ designation have been tested in accordance with ACC Product Approval Code of Practice. These oils may use the API Base Oil Interchange Guidelines and the API Viscosity-Grade Read Across Guidelines, and may be used where API Service Category SH and earlier categories have been recommended.

X2.2 SL—2001 Gasoline Engine Warranty Maintenance Service

X2.2.1 API Service Category SL is for use in describing engine oils available in 2001. These oils are for use in service typical of gasoline engines in current and earlier passenger car, sport utility vehicle, van, and light truck operations under vehicle manufacturers' recommended maintenance procedures.

X2.2.2 Engine oils that meet the API Service Category SL designation (see Appendix G of API Publication 1509) may be used where API Service Category SJ and earlier Categories have been recommended.

X2.2.3 Engine oils that meet the API Service Category SL designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing (see Appendixes E and F of API Publication 1509).

X2.2.4 Engine oils that meet these requirements may display API Service Category SL in the upper portion of the API Service Symbol.

X2.3 SM—2005 Gasoline Engine Warranty Maintenance Service

X2.3.1 API Service Category SM was adopted for use in describing engine oils available in 2004. These oils are for use in service typical of gasoline engines in current and earlier passenger cars, sport utility vehicles, vans, and light-duty trucks operating under vehicle manufacturers' recommended maintenance procedures.

X2.3.2 Engine oils that meet the API Service Category SM designation (see Appendix G of API Publication 1509) may be used where API Service Category SL and earlier S Categories have been recommended.

X2.3.3 Engine oils that meet the API Service Category SM designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing (see Appendices E and F of API Publication 1509).

X2.3.4 Starting November 30, 2004, oils that meet these requirements may display API Service Category SM in the upper portion of the API Service Symbol. Before the November 30, 2004, introduction date, oil marketers may license API SM oils as API SL.

X2.4 CH-4—1998 Diesel Engine Service

X2.4.1 API Service Category CH-4 describes oils for use in those high-speed, four stroke-cycle diesel engines designed to meet 1998 exhaust emission standards as well as for previous model years. API CH-4 oils are specifically compounded for use with diesel fuels ranging in sulfur content up to 0.5 % by weight.

X2.4.2 These oils are especially effective to sustain engine durability even under adverse applications that may stress wear control, high-temperature stability, and soot handling properties. In addition, optimum protection is provided against nonferrous corrosion, oxidative and insolubles thickening, foaming, and viscosity loss due to shear. These oils also have the performance capability to afford a more flexible approach to oil drain intervals in accordance with the recommendations of the individual engine builders for their specific engines.

X2.5 CI-4—For 2004 Severe Duty Diesel Engine Service

X2.5.1 API Service Category CI-4 describes oils for use in high-speed, four-stroke cycle diesel engines designed to meet 2004 exhaust emission standards implemented in 2002. These oils are intended for use in all applications with diesel fuels ranging in sulfur content up to 0.5 % weight.

X2.5.2 These oils are specifically formulated to sustain engine durability where Exhaust Gas Recirculation (EGR) is used and the impact of these oils on other supplemental exhaust emission devices has not been determined. Optimum protection is provided against corrosive and soot-related wear tendencies, piston deposits, degradation of low- and high-temperature viscometric properties due to soot accumulation, oxidative thickening, loss of oil consumption control, foaming, degradation of seal materials, and viscosity loss due to shear.

X2.5.3 Engine oils that meet the API Service Category CI-4 designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing.

X2.5.4 CI-4 oils are superior in performance to those meeting API CH-4, and may be used in engines calling for that API Service Category.

X2.5.5 The first license date for CI-4 will be September 5, 2002.

X2.5.6 Effective January 15, 2002, marketers may license products meeting API CI-4 requirements as CH-4.

X2.6 CJ-4—2007 Diesel Engine Service

X2.6.1 API Service Category CJ-4 describes oils for use in high-speed four-stroke cycle diesel engines designed to meet 2007 model year on-highway exhaust emission standards as well as for previous model years.

X2.6.2 These oils are compounded for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm (0.05 % by weight). However, the use of these oils with greater than 15 ppm (0.0015 % by weight) sulfur fuel may impact aftertreatment system durability and/or oil drain interval.

X2.6.3 These oils are especially effective at sustaining emission control system durability where particulate filters and other advanced aftertreatment systems are used. Optimum protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposits, low- and high-temperature stability, soot handling properties, oxidative thickening, foaming, and viscosity loss due to shear.

X2.6.4 Engine oils that meet the API Service Category CJ-4 designation have been tested in accordance with the ACC Code and may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing.

X2.6.5 API CJ-4 oils exceed the performance criteria of API CI-4 with CI-4 PLUS, CI-4 and CH-4, and can effectively lubricate engines calling for those API Service Categories. When using CJ-4 oil with higher than 15 ppm sulfur fuel, consult the engine manufacturer for service interval.

X2.6.6 The first license date for API CJ-4 will be October 15, 2006.

X2.6.7 Effective May 1, 2006, marketers may license products meeting API CJ-4 requirements as API CI-4 with CI-4 PLUS, CI-4, and CH-4.

X2.7 Energy Conserving—Defined by Test Method D6202 (Sequence VIA)

X2.7.1 Engine oils categorized as Energy Conserving are formulated to improve the fuel economy of passenger cars, vans, and light-duty trucks powered by modern low friction gasoline engines.

X2.7.2 These oils have produced a fuel economy improvement over a standard high performance reference oil in a standard test procedure. For 0W-20 and 5W-20 oils, this improvement is 1.4 % or more. For other 0W- and 5W-oils, this improvement is 1.1 % or more. For all 10W-30 multi-grades and for all other oils, this improvement is 0.5 % or more.

X2.7.3 Oils that meet this requirement and are properly licensed may display Energy Conserving in the lower portion of the API Service Symbol.

X2.8 Energy Conserving In Conjunction with API Service Category SL

X2.8.1 API Service Category SL engine oils categorized as Energy Conserving are formulated to improve the fuel economy of passenger cars, sports utility vehicles, vans, and light-duty trucks powered by gasoline engines.

X2.8.2 These oils have produced a fuel economy improvement, when compared with the standard reference oil, at both 16 h and 96 h in Test Method D6837 (Sequence VIB test).

Viscosity Grade	FEI after 16 h, %	FEI after 96 h, %	Sum of FEI after 16 h and FEI after 96 h
0W-20 and 5W-20 viscosity grades	2.0	1.7	not applicable
0W-30 and 5W-30 viscosity grades	1.6	1.3	3.0
All other viscosity grades	0.9	0.6	1.6

X2.8.3 Oils that meet this requirement and are properly licensed may display *Energy Conserving* in the lower portion of the API Service Symbol in conjunction with API Service Category SL in the upper portion.

X2.8.4 The fuel economy obtained by individual vehicle operators using engine oils labeled Energy Conserving may differ because of many factors, including the type of vehicle and engine, engine manufacturing variables, the mechanical condition and maintenance of the engine, oil that has been previously used, operating conditions, and driving habits.

X3. AMERICAN CHEMISTRY COUNCIL PETROLEUM ADDITIVES PANEL PRODUCT APPROVAL CODE OF PRACTICE

X3.1 Through the American Chemistry Council (ACC) Petroleum Additives Panel, the Product Approval Protocol Task Group developed the Product Approval Code of Practice for engine oil testing that was implemented in March 1992. Compliance with the Code of Practice is voluntary. The American Petroleum Institute (API) requires that all engine tests conducted in support of API certification and licensing be conducted under the ACC Product Approval Code of Practice. More information is available from the ACC website:

http://www.americanchemistry.com/paptg

X4. THE API SERVICE CATEGORY SM

X4.1 See Table X4.1.

TABLE X4.1 Requirements for API Service Category SM

Engine Test Requirements[A]	Viscosity Grade Performance Requirements[B]	
	SAE 0W-20, SAE 5W-20, SAE 0W-30, SAE 5W-30, SAE 10W-30	All Others[C]
Sequence IIIG (ASTM D7320)	Pass[D]	Pass
Sequence IIIGA	Pass	NR[E]
Sequence IVA (ASTM D6891)	Pass	Pass
Sequence VG (ASTM D6593)	Pass	Pass
Sequence VIII (ASTM D6709)	Pass	Pass
Bench Test and Measured Parameter[A]	**Viscosity Grade Performance Requirements[B]**	
	SAE 0W-20, SAE 5W-20, SAE 0W-30, SAE 5W-30, SAE 10W-30	All Others[C]
ASTM D6557 (Ball Rust Test), avg gray value, min	100	100
ASTM D5800, evaporation loss, 1 h at 250 °C, % max[F]	15	15
ASTM D6417, simulated distillation at 371 °C, % max	10	10
ASTM D6795, EOFT, percent flow reduction, max	50	50
ASTM D6794, EOWTT, percent flow reduction, max		
with 0.6 % H_20	50	50
with 1.0 % H_20	50	50
with 2.0 % H_20	50	50
with 3.0 % H_20	50	50
ASTM D4951, phosphorus percent mass, max[G]	0.08[H]	NR
ASTM D4951, phosphorus percent mass, min[G]	0.06[H]	0.06[H]
ASTM D4951 or D2622, sulfur percent mass, max[G]		
SAE 0W-20, 0W-30, 5W-20, and 5W-30	0.5[H]	NR
SAE 10W-30	0.7[H]	NR
ASTM D892 (Option A), foaming tendency		
Sequence I, mL, max, tendency/stability[I]	10/0	10/0
Sequence II, mL, max, tendency/stability[I]	50/0	50/0
Sequence III, mL, max, tendency/stability[I]	10/0	10/0
ASTM D6082 (Option A), high-temperature foaming mL, max, tendency/stability[J]	100/0	100/0
ASTM D6922, homogeneity and miscibility	[K]	[K]
ASTM D6709, (Sequence VIII) shear stability	[L]	[L]
ASTM D7097 (TEOST MHT), high-temperature deposits, deposit mass, mg, max[G]	35	45
ASTM D5133, gelation index, max	12[M]	NR

[A] Tests are per ASTM requirements.
[B] All oils must meet the requirements of the most recent edition of SAE J300.
[C] Does not include SAE 0W-16 and SAE 5W-16.
[D] The "Pass" limits for the Sequence IIIG, IIIGA, IVA, VG and VIII are the engine sequence test limits published in the ILSAC GF-4 Passenger Car Engine Oil Minimum Performance Standard [Table Q-4 in Technical Bulletin 2 to the 15th edition of API 1509 (issued May 2, 2004)].
[E] NR = Not required.
[F] Calculated conversions specified in ASTM D5800 are allowed.
[G] For all viscosity grades: If CF-4, CG-4, and/or CI-4 categories precede the "S" category and there is no API Certification Mark, the limits for phosphorus, sulfur, and the TEOST MHT do not apply. Note that these oils have been formulated primarily for diesel engines and may not provide all of the performance requirements consistent with vehicle manufacturers' recommendations for gasoline-fueled engines.
[H] This is a non-critical specification as described in ASTM D3244.
[I] After 10 min settling period.
[J] After 1 min settling period.
[K] Shall remain homogeneous and, when mixed with ASTM reference oils, shall remain miscible.
[L] Ten-hour stripped kinematic viscosity at 100 °C. Kinematic viscosity must remain in original viscosity grade.
[M] To be evaluated from –5 °C to temperature at which 40 000 cP is attained, or 2 °C below the appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first.

X5. REQUIREMENTS FOR API SERVICE CATEGORY SN AND API SN WITH RESOURCE CONSERVING

X5.1 See Table X5.1.

TABLE X5.1 Requirements for API Service Category SN and API SN with Resource Conserving

NOTE 1—All oils must meet the requirements of the most recent edition of SAE J300.

NOTE 2—NR = Not required.

	API SN	API SN	API SN with Resource Conserving
	SAE 0W-16, SAE 5W-16, SAE 0W-20, SAE 5W-20, SAE 0W-30, SAE 5W-30, SAE 10W-30	Other Viscosity Grades	All Viscosity Grades[A]
Engine Test Requirements[B] (see Table X6.1)			
ASTM D7320, (Sequence IIIG)	Pass	Pass	Pass
ASTM D6891, (Sequence IVA)	Pass	Pass	Pass
ASTM D6593, (Sequence VG)[C]	Pass	Pass	Pass
ASTM D7589, (Sequence VID)[D]	NR	NR	Pass
ASTM D6709, (Sequence VIII)	Pass	Pass	Pass
Bench Test and Measured Parameter[B]			
Aged oil low-temperature viscosity			
ASTM D4684, (Sequence IIIGA),	Pass	Pass[E]	Pass
aged oil low-temperature viscosity or			
ASTM D7528, (ROBO Test),	Pass	Pass[E]	Pass
aged oil low temperature viscosity			
ASTM D7320, (Sequence IIIGB) phosphorus retention, percent min	NR	NR	79
ASTM D6557 (Ball Rust Test), avg. gray value, min[C]	100	100	100
ASTM D5800, evaporation loss, 1 h at 250 °C, percent max[F]	15	15	15
ASTM D6417, simulated distillation at 371 °C, percent max	10	10	10
ASTM D6795, EOFT, percent flow reduction, max	50	50	50
ASTM D6794, EOWTT, percent flow reduction, max			
with 0.6% H_2O	50	50	50
with 1.0% H_2O	50	50	50
with 2.0% H_2O	50	50	50
with 3.0% H_2O	50	50	50
ASTM D4951, phosphorus percent mass, max[G]	0.08[H]	NR	0.08[H]
ASTM D4951, phosphorus percent mass, min[G]	0.06[H]	0.06[H]	0.06[H]
ASTM D4951 or D2622, sulfur percent mass, max[G]			
SAE 0W–16, 0W-20, 0W-30, 5W–16, 5W-20, and 5W-30	0.5[H]	NR	0.5[H]
SAE 10W-30	0.6[H]	NR	0.6[H]
All other viscosity grades	NR	NR	0.6[H]
ASTM D892 (Option A), foaming tendency			
Sequence I, mL, max, tendency/stability	10/0[I]	10/0[J]	10/0[I]
Sequence II, mL, max, tendency/stability	50/0[I]	50/0[J]	50/0[I]
Sequence III, mL, max, tendency/stability	10/0[I]	10/0[J]	10/0[I]
ASTM D6082 (Option A), high-temperature foaming mL, max, tendency/stability[I]	100/0	100/0	100/0
ASTM D6922, homogeneity and miscibility	[K]	[K]	[K]
ASTM D6709, (Sequence VIII) shear stability	[L]	[L]	[L]
ASTM D7097, TEOST MHT, high-temperature deposits, deposit mass, mg, max[F]	35	45	35
ASTM D5133, gelation index, max[C]	12[M]	NR	12[M]
ASTM D6335, TEOST 33C, high-temperature deposits, total deposit weight, mg, max			
SAE 0W-20	NR	NR	NR
All other viscosity grades	NR	NR	30
ASTM D7563, emulsion retention	NR	NR	no water separation
ASTM D7216, Annex A2, elastomer compatibility	Table G-6	Table G-6	Table G-6

[A] Resource Conserving does not apply to SAE 0W-16 and SAE 5W-16.
[B] Tests are per ASTM requirements.
[C] If CI-4 and/or CJ-4 categories precede the "S" category and there is no API Certification Mark, the Sequence VG (ASTM D6593), Ball Rust (ASTM D6557), and Gelation Index (ASTM D5133) tests are not required.
[D] Viscosity grades are limited to 0W, 5W and 10W multigrade oils.
[E] Not required for monograde and 15W, 20W, and 25W multigrade oils.
[F] Calculated conversions specified in ASTM D5800 are allowed.
[G] For all viscosity grades: If CH-4, CI-4 and/or CJ-4 categories precede the "S" category and there is no API Certification Mark, the "S" category limits for phosphorus, sulfur, and the TEOST MHT do not apply. However, the CJ-4 limits for phosphorus and sulfur do apply for CJ-4 oils. Note that these "C" category oils have been formulated primarily for diesel engines and may not provide all of the performance requirements consistent with vehicle manufacturers' recommendations for gasoline-fueled engines.
[H] This is a non-critical specification as described in ASTM D3244.
[I] After 1 min settling period.
[J] After 10 min settling period.
[K] Shall remain homogenous and, when mixed with ASTM reference oils, shall remain miscible.
[L] Ten hour stripped kinematic viscosity at 100 °C. Kinematic viscosity must remain in original viscosity grade except XW-20, which must remain ≥5.6 mm^2/s.
[M] To be evaluated from –5 °C to temperature at which 40 000 cP is attained or –40 °C, or 2 °C below the appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first.

X6. ILSAC GF-5 STANDARD FOR PASSENGER CAR ENGINE OILS (EFFECTIVE OCTOBER 1, 2010)

X6.1 The Japan Automobile Manufacturers Association, Inc. and representatives from Chrysler Group LLC, Ford Motor Company and General Motors LLC, through an organization called the International Lubricants Standardization and Approval Committee (ILSAC), jointly developed and approved an ILSAC GF-5 minimum performance standard for engine oils for spark-ignited internal combustion engines.

X6.2 This standard specifies the minimum performance requirements (both engine sequence and bench tests) and chemical and physical properties for engine oils for spark-ignited internal combustion engines. It is expected that many engine manufacturers will recommend ILSAC GF-5 oil. However, performance parameters other than those covered by the tests included or more stringent limits on those tests included in this standard may be required by individual OEMs.

X6.3 In addition to meeting the requirements of the standard, it is the oil marketer's responsibility to be aware of and comply with all applicable legal and regulatory requirements on substance use restrictions, labeling, and health and safety information when marketing products meeting the ILSAC GF-5 standard. It is also the marketer's responsibility to conduct its business in a manner that represents minimum risk to consumers and the environment.

X6.4 The ultimate assessment of an engine oil's performance must include a variety of vehicle fleet tests that simulate the full range of customer driving conditions. The engine sequence tests listed in this document have been specified instead of fleet testing to minimize testing time and costs. This simplification of test requirements is only possible because the specified engine sequence tests have been judged to be predictive of a variety of vehicle tests.

X6.5 The relationships between engine sequence tests and vehicle fleet tests are judged valid based only on the range of base oils and additive technologies investigated—generally those that have proven to have satisfactory performance in service and that are in widespread use at this time. The introduction of base oils or additive technologies that constitute a significant departure from existing practice requires sufficient supporting vehicle fleet testing data to ensure there is no adverse effect to vehicle components or to emission control systems. This vehicle fleet testing should be conducted in addition to the other performance requirements listed in this specification.

X6.6 It is the responsibility of any individual or organization introducing a new technology to perform this vehicle fleet testing, and the responsibility of the oil marketer to ensure the testing of new technology was satisfactorily completed. No marketer can claim to be acting in a reasonable and prudent manner if they knowingly use a new technology based only on the results of engine sequence testing without verifying the suitability of the new technology in vehicle fleet testing that simulates the full range of customer operation.

X6.7 The ILSAC GF-5 Minimum Performance Standard includes tests for which Viscosity Grade Read Across and Base Oil Interchange Guidelines have been developed by the appropriate groups. It should be pointed out, however, that when oil marketers use the guidelines, they do so based on their own judgment and at their own risk. The use of any guidelines does not absolve the marketer of the responsibility for meeting all specified requirements for any products the marketer sells in the marketplace that are licensed as ILSAC GF-5 with API. (See Table X6.1.)

TABLE X6.1 ILSAC GF-5 Passenger Car Engine Oil Standard[A]

Requirement	Criterion
Fresh Oil Viscosity Requirements	
High temperature/high shear viscosity @ 150 °C, mPa-s	ASTM D4683, D4741, D5481 2.6 (min)
SAE J300	Oils shall meet all requirements of SAE J300. Viscosity grades are limited to SAE 0W, 5W, and 10W multigrade oils
Gelation index	ASTM D5133 12 (max) To be evaluated from –5 °C to temperature at which 40 000 cP is attained or –40 °C, or 2 °C below appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first
Engine Test Requirements	
Wear and oil thickening	ASTM Sequence IIIG (ASTM D7320)
Kinematic viscosity increase @ 40 °C, %	150 (max)
Average weighted piston deposits, merits	4.0 (min)
Hot stuck rings	None
Average cam plus lifter wear, µm	60 (max)
Wear, sludge, and varnish	ASTM Sequence VG (ASTM D6593)
Average engine sludge, merits	8.0 (min)
Average rocker cover sludge, merits	8.3 (min)
Average engine varnish, merits	8.9 (min)
Average piston skirt varnish, merits	7.5 (min)
Oil screen sludge, % area	15 (max)
Oil screen debris, % area	Rate and report
Hot-stuck compression rings	None
Cold stuck rings	Rate and report
Oil ring clogging, % area	Rate and report
Valvetrain wear	ASTM Sequence IVA (ASTM D6891)
Average cam wear (7 position avg), µm	90 (max)
Bearing corrosion	ASTM Sequence VIII (ASTM D6709)
Bearing weight loss, mg	26 (max)
Fuel efficiency	ASTM Sequence VID (ASTM D7589)
SAE XW-20 viscosity grade	
FEI SUM	2.6% min
FEI 2	1.2% min after 100 h aging
SAE XW-30 viscosity grade	
FEI SUM	1.9% min
FEI 2	0.9% min after 100 h aging
SAE 10W-30 and all other viscosity grades not listed above	
FEI SUM	1.5% min
FEI 2	0.6% min after 100 h aging
Bench Test Requirements	
Catalyst compatibility	
Phosphorus content, % (mass)	ASTM D4951 0.08 (max)
Phosphorus volatility (Sequence IIIGB, phosphorus retention)	ASTM D7320 79% (min)
Sulfur content	ASTM D4951 or D2622
SAE 0W and 5W multigrades, % (mass)	0.5 (max)
SAE 10W-30, % (mass)	0.6 (max)
Wear	ASTM D4951
Phosphorus content, % (mass)	0.06 (min)
Volatility	ASTM D5800
Evaporation loss, %	15 (max), 1 h at 250 °C (Note: Calculated conversions specified in D5800 are allowed.)
Simulated distillation, %	ASTM D6417 10 (max) at 371 °C
High temperature deposits	TEOST MHT (ASTM D7097)
Deposit weight, mg	35 (max)
High temperature deposits	TEOST 33C (ASTM D6335)
Total deposit weight, mg	30 (max) Note: No TEOST 33C limit for SAE 0W-20.
Filterability	ASTM D6794
EOWTT, %	
with 0.6% H_2O	50 (max) flow reduction
with 1.0% H_2O	50 (max) flow reduction
with 2.0% H_2O	50 (max) flow reduction
with 3.0% H_2O	50 (max) flow reduction Note: Test formulation with highest additive (DI/VI) concentration. Read across results to all other base oil/viscosity grade formulations using same or lower concentration of identical additive (DI/VI) combination. Each different DI/VI combination must be tested.
EOFT, %	ASTM D6795 50 (max) flow reduction
Fresh oil foaming characteristics	ASTM D892 (Option A and excluding paragraph 11)
Tendency, mL	
Sequence I	10 (max)
Sequence II	50 (max)

TABLE X6.1 *Continued*

Requirement	Criterion
Sequence III	10 (max)
Stability, mL, after 1 min settling	
Sequence I	0 (max)
Sequence II	0 (max)
Sequence III	0 (max)
Fresh oil high temperature foaming characteristics	ASTM D6082 (Option A)
Tendency, mL	100 (max)
Stability, mL, after 1 min settling	0 (max)
Aged oil low temperature viscosity	ROBO (ASTM D7528)
Measure CCS viscosity of EOT ROBO sample at CCS temperature corresponding to original viscosity grade	a) If CCS viscosity measured is less than or equal to the maximum CCS viscosity specified for the original viscosity grade, run ASTM D4684 (MRV TP-1) at the MRV temperature specified in SAE J300 for the original viscosity grade. b) If CCS viscosity measured is higher than the maximum viscosity specified for the original viscosity grade in J300, run ASTM D4684 (MRV TP-1) at 5 °C higher temperature (i.e., at MRV temperature specified in SAE J300 for the next higher viscosity grade). EOT ROBO sample must show no yield stress in the D4684 test and its D4684 viscosity must be below the maximum specified in SAE J300 for the original viscosity grade or the next higher viscosity grade, depending on the CCS viscosity grade, as outlined in a) or b) above. or
Aged oil low temperature viscosity	ASTM Sequence IIIGA (ASTM D7320) a) If CCS viscosity measured is less than or equal to the maximum CCS viscosity specified for the original viscosity grade, run ASTM D4684 (MRV TP-1) at the MRV temperature specified in SAE J300 for the original viscosity grade. b) If CCS viscosity measured is higher than the maximum viscosity specified for the original viscosity grade in J300, run ASTM D4684 (MRV TP-1) at 5 °C higher temperature (i.e., at MRV temperature specified in SAE J300 for the next higher viscosity grade). c) EOT IIIGA sample must show no yield stress in the D4684 test and its D4684 viscosity must be below the maximum specified in SAE J300 for the original viscosity grade or the next higher viscosity grade, depending on the CCS viscosity grade, as outlined in a) or b) above.
Shear stability	
10 h stripped KV @ 100 °C	ASTM Sequence VIII (ASTM D6709) Kinematic viscosity must remain in original SAE viscosity grade, except XW-20, which must remain $\geq$5.6 mm^2/s.
Homogeneity and miscibility	ASTM D6922 Shall remain homogeneous and, when mixed with ASTM Test Monitoring Center (TMC) reference oils, shall remain miscible.
Engine rusting	
Average gray value	Ball Rust Test (ASTM D6557) 100 (min)
Emulsion retention	ASTM D7563
0 °C, 24 h	No water separation
25 °C, 24 h	No water separation
Elastomer compatibility	ASTM D7216, Annex A2 Candidate oil testing for elastomer compatibility shall be performed using the five Standard Reference Elastomers (SREs) referenced herein and defined in SAE J2643. Candidate oil testing shall be performed according to ASTM D7216, Annex A2. The post-candidate-oil-immersion elastomers shall conform to the specification limits detailed below:

Elastomer Material (SAE J2643)	Test Procedure	Material Property	Units	Limits
Polyacrylate Rubber (ACM-1)	ASTM D471	Volume	% Δ	-5, 9
	ASTM D2240	Hardness	pts.	-10, 10
	ASTM D412	Tensile Strength	% Δ	-40, 40
Hydrogenated Nitrile Rubber (HNBR-1)	ASTM D471	Volume	% Δ	-5, 10
	ASTM D2240	Hardness	pts.	-10, 5
	ASTM D412	Tensile Strength	% Δ	-20, 15
Silicone Rubber (VMQ-1)	ASTM D471	Volume	% Δ	-5, 40
	ASTM D2240	Hardness	pts.	-30, 10
	ASTM D412	Tensile Strength	% Δ	-50, 5
Fluorocarbon Rubber (FKM-1)	ASTM D471	Volume	% Δ	-2, 3
	ASTM D2240	Hardness	pts.	-6, 6
	ASTM D412	Tensile Strength	% Δ	-65, 10
Ethylene Acrylic Rubber (AEM-1)	ASTM D471	Volume	% Δ	-5, 30
	ASTM D2240	Hardness	pts.	-20, 10
	ASTM D412	Tensile Strength	% Δ	-30, 30

[A] See Bibliography, items 1–3, 5, and 6.

X7. MACK T-10 MERIT CALCULATIONS USING MACK T-12 RESULTS

X7.1 Various oil specifications may use T-12 test results to obtain T-10 Mack Merits, using the calculation methodology shown in X7.2 – X7.3.

X7.2 Merit System Components

X7.2.1 *Anchors*—Anchor performance level based on one test.

X7.2.2 *Maximums*—Limit of acceptable performance.

X7.2.3 *Minimums*—Limit of best performance.

X7.2.4 *Weights*—Relative contribution to total merit.

X7.2.5 *Multipliers*—Using Table X7.1, determine the multiplier for each parameter as follows:

X7.2.5.1 If a result is at the anchor, multiplier is one (for example, Liner Wear = 23 yields multiplier = 1).

X7.2.5.2 If a result is at or below the minimum, multiplier is two (for example, Liner Wear = 10 yields multiplier = 2).

X7.2.5.3 If a result is at the maximum, multiplier is zero (for example, Liner Wear = 26.0 yields multiplier = 0).

X7.2.5.4 If a result is between minimum and anchor, linearly interpolate multiplier between 2 and 1 (for example, Liner Wear = 14 yields multiplier = 1.82).

X7.2.5.5 If a result is between anchor and maximum, linearly interpolate multiplier between 1 and 0 (for example, Liner Wear = 25 yields multiplier = 0.33).

X7.2.5.6 If a result is above the maximum, linearly extrapolate multiplier on the same line as between 1 and 0 (for example, Liner Wear = 28.0 yields multiplier = -0.67).

X7.3 *Calculated Merit Result*—Sum the products of weights and multipliers across the five results. This is the calculated merit result. In equation form:

$$Calculated\ Merit = \sum_{i=1}^{5} Weight_i$$

$$x \left\{ \begin{array}{c} \delta(result_i > anchor_i) \times (max_i - result_i)/(max_i - anchor_i) \\ + \delta(min_i < result_i \leq anchor_i) \times [1 + (anchor_i - result_i) / (anchor_i - min_i) \\ + \delta(result_i \leq min_i) \times 2 \end{array} \right\}$$

where:

$\delta(x)$ = 1 if x is true; 0 if x is false.

TABLE X7.1 Multipliers

Criterion	0 h – 300 h Delta Pb	250 h – 300 h Delta Pb	Cylinder Liner Wear	Top Ring Weight Loss	Oil Consumption
Weight	200	200	250	200	150
Maximum	42	18	26.0	117	95.0
Anchor	35	13	23.0	82	82.0
Minimum	10	0	12.0	47	50.0

X8. SH ENGINE OIL CATEGORY (RELEVANT INFORMATION IN COMBINATION WITH A "C" CATEGORY)

X8.1 Report the results of the merit calculations on the appropriate form. (See Table X8.1.)

TABLE X8.1 SH Engine Oil Category

NOTE 1—(Relevant information in combination with a “C” category).

Engine Test Method	API SH Category Rated or Measured Parameter	Primary Performance Criteria
D5844[A,B] (Sequence IID)	Average engine rust rating,[C] min	8.5
	Number stuck lifters	none
or D6557[A]	(Ball Rust Test) Average gray value, min	100
D5533[B,D] (Sequence IIIE)	Hours to 375 % kinematic viscosity increase at 40 °C, min	64
	Average engine sludge rating,[C] min	9.2
	Average piston skirt varnish rating, min	8.9
	Average oil ring land deposit rating,[C]	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[C])	none
or D6894 (Sequence IIIF)[D]	Ring sticking (oil-related[C]) none	
	Kinematic viscosity, % increase at 40 °C, max	325[E]
	Average piston skirt varnish rating,[C] min	8.5[F]
	Weighted piston deposit rating,[G] min	3.2[F]
	Screened average cam-plus-lifter wear, µm, max	20[F,H]
	Hot stuck rings	none[F]
or D7320 (Sequence IIIG)[I]	Kinematic viscosity, % increase at 40 °C, max	150
	Weighted piston deposit rating,[J] min	3.5
	Cam-plus-lifter wear avg, µm, max	60
	Hot stuck rings	none
D5302[B,K] (Sequence VE)	Average engine sludge rating,[C] min	9.0
	Rocker arm cover sludge rating,[C] min	7.0
	Average piston skirt varnish rating,[C] min	6.5
	Average engine varnish rating,[C] min	5.0
	Oil ring clogging, %	report
	Oil screen clogging, %, max	20.0
	Compression ring sticking (hot stuck)	none
	Cam wear, µm	
	Average, max	127
	Maximum, max	380
or D6891 (Sequence IVA)[K]	Average cam wear, µm[L]	120
plus, D6593[K] (Sequence VG)	Average engine sludge rating,[C] min	7.8
	Rocker arm cover sludge rating,[C] min	8.0
	Average piston skirt varnish rating,[C] min	7.5
	Average engine varnish rating,[M] min	8.9
	Oil screen clogging, %, max	20
	Hot stuck compression rings	none
D5119[N] (L-38)	Bearing weight loss, mg, max	40
	Shear stability	[O]
or D6709[N] (Sequence VIII)	Bearing weight loss, mg, max	26.4
	Shear stability	[O]

Bench Test and Measured Parameter (effective January 1, 1992)	Viscosity Grade Performance Criteria[P]		
	SAE 5W-30	SAE 10W-30	SAE 15W-40
Test Method D5800 volatility loss, % max[Q]	25	20	18
Test Method D2887 volatility loss at 371 °C, % max[Q]	20	17	15
Test Method D6795 (EOFT), % flow reduction, max	50	50	NR[R]
Test Method D4951 or D5185, mass fraction phosphorus %, max	0.12	0.12	NR
Test Method D4951 or D5185, mass fraction phosphorus %, min (all viscosity grades) (unless valid passing Test Method D5302 results are obtained)	0.06	0.06	0.06
Test Method D92 flash point, °C, min[S]	200	205	215
Test Method D93 flash point, °C, min[S]	185	190	200
Test Method D892 foaming tendency (Option A)			
Sequence I, max, foaming/settling[T]	10/0	10/0	10/0
Sequence II, max, foaming/settling[T]	50/0	50/0	50/0
Sequence III, max, foaming/settling[T]	10/0	10/0	10/0
Test Method D6082 (optional blending required)	report[U]	report[U]	report[U]
Test Method D6922 homogeneity and miscibility	[V]	[V]	[V]

[A] Demonstrate passing performance in either Test Method D5844 or D6557.
[B] Monitoring of this test method was discontinued in June 20, 2001. Valid test results shall predate the end of the last calibration period for the test stand in which this test method was conducted.
[C] ASTM Deposit Rating Manual 20, available from ASTM Customer Relations, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.
[D] Demonstrate passing performance in either Test Method D5533 or D6984. However, an oil passing Test Method D6984 and containing less than 0.08 % mass phosphorus in the form of ZDDP shall also pass the wear limits in Test Method D5302 (see also footnote L).
[E] Determine at 60 h.
[F] Determine at 80 h.
[G] 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.

[H] Calculate by eliminating the highest and lowest cam-plus-lifter wear results and then calculating an average based on the remaining ten rating positions.
[I] 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.
[J] Unlike the Sequence IIIF test, piston skirt varnish rating is not required in the Sequence IIIG test.
[K] Demonstrate passing performance in Test Method D5302, or alternatively, in both Test Method D6891 and Test Method D6593.
[L] 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.
[M] 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.
[N] Demonstrate passing performance in either Test Method D5119 or D6709.
[O] Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade).
[P] 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.
[Q] Meet either Test Method D5800 or Test Method D2887 volatility requirement.
[R] NR stands for Not Required.
[S] Meet either Test Method D92 or Test Method D93 flash point requirement.
[T] Determine settling volume at 5 min.
[U] Report kinetic foam volume (mL), static foam volume (mL), and collapse time, s.
[V] Homogeneous with SAE reference oils.

BIBLIOGRAPHY

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(2) SAE Standard, Standard Reference Elastomers (SRE) for Characterizing the Effects on Vulcanized Rubbers, Proposed Draft 2003-5—SAE J2643, *SAE Handbook*.
(3) ASTM Annual Book of Standards, Volume 5, Petroleum Products and Lubricants, current edition.
(4) ASTM Sequence IIIG Test Research Report.
(5) Batko, M., and Florkowski, D. W., "Low Temperature Rheological Properties of Aged Crankcase Oils," SAE Paper 2000-01-2943.
(6) Batko, M., and Florkowski, D. W., "Lubricant Requirements of an Advanced Designed High Performance, Fuel Efficient Low Emissions V-6 Engine," SAE Paper 01FL-265.

SUMMARY OF CHANGES

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D4485 – 15) that may impact the use of this standard. (Approved April 15, 2015.)

(1) Revised units statements in Scope subsection 1.5.1.
(2) Revised units for Test Method D6750 in Table 3, including a revision to Footnote P.

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D4485 – 14) that may impact the use of this standard. (Approved April 1, 2015.)

(1) 4.1.1.6, 4.1.2.7, 4.1.3.13, 4.1.4.16, 4.1.5.16, and 4.1.8 were revised to include the American Petroleum Institute's role in licensing the API categories of engine oil.
(2) Table X4.1 and Table X5.1 updated to include new SAE viscosities 0W-16 and 5W-16.
(3) Table X6.1, viscosity shear stability requirements updated.

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D4485 – 11c) that may impact the use of this standard. (Approved Dec. 1, 2014.)

(1) Exception language was added to the Scope units statement.
(2) "Weight" replaced with "mass" throughout except when referring to bearing wear.