Designation: D 4485 – 07a

An American National Standard

Standard Specification for Performance of Engine Oils[1]

This standard is issued under the fixed designation D 4485; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last 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 Department of Defense.

INTRODUCTION

This specification covers all the currently active American Petroleum Institute (API) engine oil performance categories that have been defined in accordance with the ASTM consensus process. There are organizations with specifications not subject to the ASTM consensus process, such as the International Lubricant Standardization and Approval Committee (ILSAC), American Petroleum Institute (API – SM Specification), and the Association des Constructeurs 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 Appendix of this document for information.

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

Other service categories not shown in this document have historically been used to describe engine oil performance (SA, SB, SC, SD, SE, SF, SG and CA, CB, CC, CD, CD-II, CE) (see 3.1.2). SA is not included because it does not have specified engine performance requirements. SG is not included because it was a category that could not be licensed for use in the API Service Symbol after Dec. 31, 1995. The others are not included because they are based on test methods for which engine parts, test fuel, or reference oils, or a combination thereof, are no longer available. Also, the ASTM 5-Car and Sequence VI Procedures are obsolete and have been deleted from the category Energy Conserving and Energy Conserving II (defined by Sequence VI). Information on excluded older categories and obsolete test requirements can be found in SAE J183.

1. Scope

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

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

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

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

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

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

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

TABLE 1 Test Procedures

Test Procedure	ASTM Publications[A]
T-6	RR: D02–1219[B]
T-7	RR: D02–1220[C]
T-12	under development[D]
ISM	under development[E]
ISB	under development[F]
C13	under development[G]

[A] Research Reports are available from ASTM International Headquarters. Request by Research Report No.
[B] Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Mack T-6.
[C] Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Mack T-7.
[D] Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Mack T-12.
[E] Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Cummins ISM.
[F] Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Cummins ISB.
[G] Multicylinder Engine Test Procedure for the Evaluation of Lubricants-Caterpillar C13.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D 130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D 874 Test Method for Sulfated Ash from Lubricating Oils and Additives
D 892 Test Method for Foaming Characteristics of Lubricating Oils
D 2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
D 3244 Practice for Utilization of Test Data to Determine Conformance with Specifications
D 4683 Test Method for Measuring Viscosity at High Shear Rate and High Temperature by Tapered Bearing Simulator
D 4684 Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature
D 4951 Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry
D 5119 Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine[3]
D 5133 Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique
D 5185 Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D 5290 Test Method for Measurement of Oil Consumption, Piston Deposits, and Wear in a Heavy-Duty High-Speed Diesel Engine—NTC-400 Procedure[3]
D 5293 Test Method for Apparent Viscosity of Engine Oils Between -5 and -35°C Using the Cold-Cranking Simulator
D 5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions[3]
D 5480 Test Method for Engine Oil Volatility by Gas Chromatography[3]
D 5533 Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIE, Spark-Ignition Engine[3]
D 5800 Test Method for Evaporation Loss of Lubricating Oils by the Noack Method
D 5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)[3]
D 5862 Test Method for Evaluation of Engine Oils in Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine
D 5966 Test Method for Evaluation of Engine Oils for Roller Follower Wear in Light-Duty Diesel Engine
D 5967 Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine
D 5968 Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 121°C
D 6082 Test Method for High Temperature Foaming Characteristics of Lubricating Oils
D 6202 Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark Ignition Engine
D 6278 Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus
D 6335 Test Method for Determination of High Temperature Deposits by Thermo-Oxidation Engine Oil Simulation Test
D 6417 Test Method for Estimation of Engine Oil Volatility by Capillary Gas Chromatography
D 6483 Test Method for Evaluation of Diesel Engine Oils in T-9 Diesel Engine
D 6557 Test Method for Evaluation of Rust Preventive Characteristics of Automotive Engine Oils
D 6593 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions
D 6594 Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135°C
D 6618 Test Method for Evaluation of Engine Oils in Diesel Four-Stroke Cycle Supercharged 1M-PC Single Cylinder Oil Test Engine

[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] Withdrawn.

D 6681 Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure

D 6709 Test Method for Evaluation of Automotive Engine Oils in the Sequence VIII Spark-Ignition Engine (CLR Oil Test Engine)

D 6750 Test Methods for Evaluation of Engine Oils in a High-Speed, Single-Cylinder Diesel Engine—1K Procedure (0.4 % Fuel Sulfur) and 1N Procedure (0.04 % Fuel Sulfur)

D 6794 Test Method for Measuring the Effect on Filterability of Engine Oils After Treatment with Various Amounts of Water and a Long (6-h) Heating Time

D 6795 Test Method for Measuring the Effect on Filterability of Engine Oils After Treatment with Water and Dry Ice and a Short (30-min) Heating Time

D 6837 Test Method for Measurement of Effects of Automotive Engine Oils on Fuel Economy of Passenger Cars and Light-Duty Trucks in Sequence VIB Spark Ignition Engine

D 6838 Test Method for Cummins M11 High Soot Test

D 6891 Test Method for Evaluation of Automotive Engine Oils in the Sequence IVA Spark-Ignition Engine

D 6894 Test Method for Evaluation of Aeration Resistance of Engine Oils in Direct-Injected Turbocharged Automotive Diesel Engine

D 6896 Test Method for Determination of Yield Stress and Apparent Viscosity of Used Engine Oils at Low Temperature

D 6922 Test Method for Determination of Homogeneity and Miscibility in Automotive Engine Oils

D 6923 Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1R Test Procedure

D 6975 Test Method for Cummins M11 EGR Test

D 6984 Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIF, Spark-Ignition Engine

D 6987/D 6987M Test Method for Evaluation of Diesel Engine Oils in T-10 Exhaust Gas Recirculation Diesel Engine

D 7097 Test Method for Determination of Moderately High Temperature Piston Deposits by Thermo-Oxidation Engine Oil Simulation Test—TEOST MHT

D 7109 Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus at 30 and 90 Cycles

D 7156 Test Method for Evaluation of Diesel Engine Oils in the T-11 Exhaust Gas Recirculation Diesel Engine

D 7216 Test Method for Determining Automotive Engine Oil Compatibility with Typical Seal Elastomers

D 7320 Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIG, Spark-Ignition Engine

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 178 Practice for Dealing With Outlying Observations

2.2 *Society of Automotive Engineers Standards:*[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 SH, SJ, SL, SM, CF-4, CF, CF-2, CG-4, CH-4, CI-4, Energy Conserving, and so forth, for a given level of performance in specified engine and bench tests.

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

3.1.4 *engine oil, n*—a liquid that reduces friction and wear between the moving parts within an engine, and also serves as a coolant.

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

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

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

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

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

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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.

[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.

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

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

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

3.2 *Definitions of Terms Specific to This Standard:*

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

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

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

4. Performance Classification

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

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

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

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

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

4.1.1.4 Test Method D 5119, the L-38 gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions. (An alternative is Test Method D 6709, the Sequence VIII test.)

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

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

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

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

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

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

(*5*) Foaming in engine oil can cause valve lifter collapse and a loss of lubrication due to the presence of air in the oil. Test Methods D 892 and D 6082 empirically rate the foaming tendency and stability of oils.

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

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

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

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

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

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

4.1.2.4 Test Method D 5119, the L-38 gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions. (An alternative is Test Method D 6709, the Sequence VIII test.)

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

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

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

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1225.

[10] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1226.

TABLE 2 S Engine Oil Categories

API SH Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
D 5844[A,B] (Sequence IID)	Average engine rust rating,[C] min	8.5
	Number stuck lifters	none
or D 6557[A] (Ball Rust Test)	Average gray value, min	100
D 5533[B,D] (Sequence IIIE)	Hours to 375 % kinematic viscosity increase at 40°C, min	64
	Average engine sludge rating,[E] min	9.2
	Average piston skirt varnish rating,[F] min	8.9
	Average oil ring land deposit rating,[F] 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[G])	none
or D 6984 (Sequence IIIF)[D]	Kinematic viscosity, % increase at 40°C, max	325[H]
	Average piston skirt varnish rating,[F] min	8.5[I]
	Weighted piston deposit rating,[J] min	3.2[I]
	Screened average cam-plus-lifter wear, µm, max	20[I,K]
	Hot stuck rings	none[I]
or D 7320 (Sequence IIIG)[L]	Kinematic viscosity, % increase at 40°C, max	150
	Weighted piston deposit rating,[M] min	3.5
	Cam-plus-lifter wear avg, µm, max	60
	Hot stuck rings	none
D 5302[B,N] (Sequence VE)	Average engine sludge rating,[E] min	9.0
	Rocker arm cover sludge rating,[E] min	7.0
	Average piston skirt varnish rating,[F] min	6.5
	Average engine varnish rating,[F] 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 D 6891 (Sequence IVA)[N]	Average cam wear, µm[O]	120
plus, D 6593[N] (Sequence VG)	Average engine sludge rating,[E] min	7.8
	Rocker arm cover sludge rating,[E] min	8.0
	Average piston skirt varnish rating,[F] min	7.5
	Average engine varnish rating,[P] min	8.9
	Oil screen clogging, %, max	20
	Hot stuck compression rings	none
D 5119[Q] (L-38)	Bearing weight loss, mg, max	40
	Shear stability	[R]
or D 6709[Q] (Sequence VIII)	Bearing weight loss, mg, max	26.4
	Shear stability	[R]

Bench Test and Measured Parameter (effective January 1, 1992)	Viscosity Grade Performance Criteria[S]		
	SAE 5W-30	SAE 10W-30	SAE 15W-40
Test Method D 5800 volatility loss, % max[T]	25	20	18
Test Method D 2887 volatility loss at 371°C (700°F), % max[T]	20	17	15
Test Method D 6795 (EOFT), % flow reduction, max	50	50	NR[U]
Test Method D 4951 or D 5185, phosphorus % mass, max	0.12	0.12	NR
Test Method D 4951 or D 5185, phosphorus % mass, min (all viscosity grades)	0.06	0.06	0.06
(unless valid passing Test Method D 5302 results are obtained)			
Test Method D 92 flash point, °C, min[V]	200	205	215
Test Method D 93 flash point, °C, min[V]	185	190	200
Test Method D 892 foaming tendency (Option A)			
Sequence I, max, foaming/settling[W]	10/0	10/0	10/0
Sequence II, max, foaming/settling[W]	50/0	50/0	50/0
Sequence III, max, foaming/settling[W]	10/0	10/0	10/0
Test Method D 6082 (optional blending required)	report[X]	report[X]	report[X]
Test Method D 6922 homogeneity and miscibility	[Y]	[Y]	[Y]

API SJ Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
D 5844[A,B] (Sequence IID)	Average engine rust rating,[C] min	8.5
	Number stuck lifters	none
or D 6557[A] (Ball Rust Test)	Average gray value, min	100
D 5533[B,D] (Sequence IIIE)	Hours to 375 % kinematic viscosity increase at 40°C, min	64

TABLE 2 *Continued*

API SJ Category		
Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
	Average engine sludge rating,[E] min	9.2
	Average piston skirt varnish rating,[F] min	8.9
	Average oil ring land deposit rating,[F] 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)[G]	none
or D 6984 (Sequence IIIF)[D]	Kinematic viscosity, % increase at 40°C, max	325[H]
	Average piston skirt varnish rating,[F] min	8.5[I]
	Weighted piston deposit rating,[J] min	3.2[I]
	Screened average cam-plus–lifter wear, µm, max	20[I,K]
	Hot stuck rings	none[I]
or D 7320 (Sequence IIIG)[L]	Kinematic viscosity, % increase at 40°C, max	150
	Weighted piston deposit rating,[M] min	3.5
	Cam-plus-lifter wear avg, µm, max	60
	Hot stuck rings	none
D 5302[B,N] (Sequence VE)	Average engine sludge rating,[E] min	9.0
	Rocker arm cover sludge rating,[E] min	7.0
	Average piston skirt varnish rating,[F] min	6.5
	Average engine varnish rating,[F] 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 D 6891 (Sequence IVA)[N]	Average cam wear, µm[O]	120
plus, D 6593[N] (Sequence VG)	Average engine sludge rating,[E] min	7.8
	Rocker arm cover sludge rating,[E] min	8.0
	Average piston skirt varnish rating,[F] min	7.5
	Average engine varnish rating,[P] min	8.9
	Oil screen clogging, %, max	20
	Hot stuck compression rings	none
D 5119[Q] (L-38)	Bearing weight loss, mg, max	40
	Shear stability	[R]
or D 6709[Q] (Sequence VIII)	Bearing weight loss, mg, max	26.4
	Shear stability	[R]

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

TABLE 2 *Continued*

Bench Test and Measured Parameter	Viscosity Grade Performance Criteria: SAE 0W-20, SAE 5W-20, SAE 5W-30, SAE 10W-30	Viscosity Grade Performance Criteria: All Others
Test Method D 6335 High temperature deposits (TEOST 33), deposit wt, mg, max	60	60
Test Method D 5133 Gelation Index, max	12	NR[U]

API SL Category

Engine Test Method	Rated or Measured Parameter	Primary Performance Criteria
D 6984 (Sequence IIIF)	Kinematic viscosity, % increase at 40°C, max	275
	Average piston skirt varnish rating,[F] min	9.0
	Weighted piston deposit rating,[J] min	4.0
	Screened average cam-plus-lifter wear, µm, max	20[K]
	Hot Stuck Rings	none
	Low temperature viscosity performance[AE]	report
or D 7320 (Sequence IIIG)[L]	Kinematic viscosity, % increase at 40°C, max	150
	Weighted piston deposit rating,[M] min	3.5
	Cam-plus-lifter wear avg, µm, max	60
	Hot stuck rings	none
	Low temperature viscosity performance[AF]	report
D 6891 (Sequence IVA)	Cam wear average, µm,[O] max	120
D 5302[B]	Cam wear average, µm, max	127
(Sequence VE[AG])	Cam wear max, µm, max	380
D 6593		
(Sequence VG)	Average engine sludge rating,[E] min	7.8
	Rocker arm cover sludge rating,[E] min	8.0
	Average piston skirt varnish rating,[F] min	7.5
	Average engine varnish rating,[P] 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
D 6709	Bearing weight loss, mg, max	26.4
(Sequence VIII)	Shear stability	[R]

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

[A] Demonstrate passing performance in either Test Method D 5844 or D 6557.
[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] CRC Rust Rating Manual No. 7, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.
[D] Demonstrate passing performance in either Test Method D 5533 or D 6984. However, an oil passing Test Method D 6984 and containing less than 0.08 % mass phosphorus in the form of ZDDP shall also pass the wear limits in Test Method D 5302 (see also footnote [L]).
[E] CRC Sludge Rating Manual No. 12, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.
[F] CRC Varnish Rating Manual No. 14, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.
[G] An oil-related stuck ring occurs on a piston with an individual oil ring land deposit rating <2.6.
[H] Determine at 60 h.
[I] Determine at 80 h.

[J] Determine weighted piston deposits by rating the following piston areas and applying the corresponding weightings: undercrown, 10 %; second land, 15 %; third land, 30 %; piston skirt, 10 %; first groove, 5 %; second groove, 10 %; and third groove, 20 %. Use CRC Varnish Rating Manual No. 14 for all ratings.

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

[L] For oils containing at least 0.06 % mass phosphorus in the form of ZDDP, demonstrating passing performance in the Sequence IIIG test obviates the need to also conduct Test Method D 5302 (Sequence VE), which was previously required for oils with less than 0.08 % mass phosphorus.

[M] Unlike the Sequence IIIF test, piston skirt varnish rating is not required in the Sequence IIIG test.

[N] Demonstrate passing performance in Test Method D 5302, or alternatively, in both Test Method D 6891 and Test Method D 6593.

[O] Determine cam wear according to Test Method D 6891. Seven wear measurements are made on each cam lobe and the seven measured values are added to obtain an individual cam lobe wear result. The overall cam wear value is the average of the twelve individual cam lobe wear results.

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

[Q] Demonstrate passing performance in either Test Method D 5119 or D 6709.

[R] Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade).

[S] 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.

[T] Meet either Test Method D 5800 or Test Method D 2887 volatility requirement.

[U] NR stands for Not Required.

[V] Meet either Test Method D 92 or Test Method D 93 flash point requirement.

[W] Determine settling volume at 5 min.

[X] Report kinetic foam volume (mL), static foam volume (mL), and collapse time, s.

[Y] Homogeneous with SAE reference oils.

[Z] Meet the volatility requirement in either Test Method D 5800, D 5480, or D 6417.

[AA] Passing volatility loss only required for SAE 15W-40 oils.

[AB] This is a noncritical specification as described in Practice D 3244.

[AC] Determine settling volume, in mL, at 10 min.

[AD] Determine settling volume, in mL, at 1 min.

[AE] Evaluate the 80-h test oil sample by Test Method D 4684 at the temperature indicated by the low temperature grade of oil as determined on the 80-h sample by Test Method D 5293.

[AF] Measure the viscosity of the EOT oil sample by Test Method D 4684. The measured viscosity shall meet the requirements of the original grade or the next higher grade. The EOT sample can be either from a Sequence IIIG or a Sequence IIIGA test. (A Sequence IIIGA test is identical to a Sequence IIIG test, except only low temperature viscosity performance is measured.) Additional details are provided in the Sequence IIIG test method, in Section 13.6.

[AG] Not required for oils containing a minimum of 0.08 % mass phosphorus in the form of ZDDP.

[AH] Requirement applies only to SAE 0W-20, 5W-20, 0W-30, 5W-30, and 10W-30 viscosity grades.

[AI] For gelation temperatures at or above the W grade pumpability temperature as defined in SAE J300.

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

(*2*) Test Method D 6795, the EOFT screens for the formation of precipitates and gels that form in the presence of water and can cause oil filter plugging.

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

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

(*5*) Excessive foaming in engine oil can cause valve lifter collapse and a loss of lubrication due to the presence of air in the oil. Test Methods D 892 and D 6082 empirically rate the foaming tendency and stability of oils.

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

(*7*) Newer engines designed to provide increased power and improved driveability and to meet future federal emissions and fuel economy requirements may be sensitive to internal deposits caused by elevated engine operating temperatures. Test Method D 6335, the TEOST test, may be useful in determining the deposit control of oils recommended for these engines.

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

4.1.2.6 Licensing of the API SJ category requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

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

4.1.3.1 Test Method D 6984, the Sequence IIIF gasoline engine test, is used to measure oil thickening and piston deposits under high temperature conditions and provides information about valve train wear.[11] (An alternative is Test Method D 7320, the Sequence IIIG test.)

4.1.3.2 Test Method D 6891, the Sequence IVA gasoline engine test, has been correlated with the Sequence VE gasoline engine test in terms of overhead cam and slider follower wear control.[12]

4.1.3.3 Test Method D 5302, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988, with regard to valve train wear. It is included in the SL performance specification to augment assessment of the wear control performance of oils containing less than 0.08 % mass of phosphorus from ZDDP additive.

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

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

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

gasoline engine oil performance, the ILSAC GF-4 standard, was developed outside the normal ASTM consensus process. Deliberations during the GF-4 development process included careful consideration of the suitability of Test Method D 7320, the Sequence IIIG, a new test, to evaluate the wear protection of oils with less than 0.08 % phosphorus. Data on oils with less than 0.08 % mass phosphorus in the form of ZDDP were reviewed by members of the D02.B0 Passenger Car Engine Oil Classification Panel (PCEOCP). These data were from Test Method D 7320 (Sequence IIIG) tests and from field tests on large populations of older vehicles with different engine types. Based on these data, the PCEOCP recommended a ballot to allow the use of Test Method D 7320 (Sequence IIIG) as an alternative to Test Method D 6984 (Sequence IIIF) plus Test Method D 5302 (Sequence VE) for demonstration of acceptable API SH, SJ, and SL performance on low phosphorus oils, establishing at least 0.06 % phosphorus as the minimum level. That ballot was approved by Subcommittee D02.B0 in May 2004.

4.1.3.4 Test Method D 6593, the Sequence VG gasoline engine test, has been correlated with the Sequence VE gasoline engine test and with vehicles used in stop-and-go service prior to 2000, with regard to sludge and varnish deposit control.

4.1.3.5 Test Method D 6709, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.[13]

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

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

(1) Test Method D 6557 (Ball Rust Test), was developed to replace the Sequence IID gasoline engine test, and evaluates the ability of an oil to prevent the formation of rust under short-trip service conditions.

(2) The volatility of engine oils is one of several factors that relates to engine oil consumption. For this engine oil category, volatility is measured by Test Methods D 5800 and D 6417.

(3) Test Method D 6795, the Engine Oil Filterability Test (EOFT) and Test Method D 6794, the Engine Oil Water Tolerance Test (EOWTT) screen for the formation of precipitates and gels which form in the presence of water and can cause oil filter plugging.

(4) Phosphorus compounds in excessive amounts can cause glazing of automotive catalysts and exhaust gas oxygen sensors and, thereby, deactivate them. Control of the phosphorus level in the engine oil may reduce this tendency. For this engine oil category, phosphorus content is measured by either Test Method D 4951 or D 5185.

(5) Excessive foaming in engine oil can cause valve lifter collapse and a loss of lubrication due to the presence of air in the oil. Test Methods D 892 and D 6082 empirically rate the foaming tendency and stability of oils.

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

(7) Newer engines designed to provide increased power and improved driveability and to meet future federal emissions and fuel economy requirements may be sensitive to internal deposits caused by elevated engine operating temperatures. Test Method D 7097, the TEOST MHT-4 test may be useful in determining the piston deposit control capability of oils recommended for these engines.

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

4.1.3.7 Licensing of the API SL category requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

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

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

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

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

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

4.1.4.5 Test Method D 6709, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.[13]

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

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

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

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

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

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

TABLE 3 C Engine Oil Categories

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

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
	D 6894 (EOAT)[S]	Aeration, volume % max	10.0		
	D 5968	Copper, mg/kg (ppm) increase, max	20		
		Lead, mg/kg (ppm) increase, max	60		
		Tin, mg/kg (ppm) increase, max	report		
		Copper strip rating,[E] max	3		
			One-test	Two-test[T]	Three-test[T]
CH-4	D 6681 (1P)[U]	Weighted demerits (WDP), max	350	378	390
		Top groove carbon (TGC), demerits, max	36	39	41
		Top land carbon (TLC), demerits, max	40	46	49
		Average Oil Consumption, g/h (0-360 h), max	12.4	12.4	12.4
		Final Oil Consumption, g/h (312-360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none[I]
	D 6750 (1K)[H]	Weighted demerits (WDK), %, max	332	347	353
		Top groove fill (TGF), %, max	24	27	29
		Top land heavy carbon (TLHC), %, max	4	5	5
		Average Oil Consumption, g/kW-h (0-250 h), max	0.5	0.5	0.5
		Piston, ring, and liner scuffing	none	none	none[I]
	D 6483 (T-9)	Average Liner Wear, normalized to 1.75 % soot, µm max	25.4	26.6	27.1
		Average Top Ring Weight Loss, mg max[C]	120	136	144
		EOT Used Oil Lead Content less New Oil Lead Content, mg/kg (ppm), max	25	32	36
	or, D 6987/D 6987M (T-10)	Liner wear, µm, max	32	34	35
		Ring wear, mg, max	150	159	163
		Lead content @ EOT, mg/kg (ppm), max	50	56	59
	or, T-12	Liner wear, µm, max	30.0	30.8	31.1
		Top Ring Weight Loss, mg, max	120	132	137
		Lead content @ EOT, mg/kg (ppm), max	65	75	79
	D 5966 (RFWT)	Average Pin Wear, mils, max	0.30	0.33	0.36
		(µm, max)	(7.6)	(8.4)	(9.1)
	D 6838 (M11)[V]	Rocker Pad Average Wt. Loss, normalized to 4.5 % soot, mg max	6.5	7.5	8.0
		Oil Filter Differential Pressure at EOT, kPa max	79	93	100
		Average Engine Sludge, CRC Merits at EOT, min	8.7	8.6	8.5
	D 5967 (Ext. T-8E)[O]	Relative Viscosity at 4.8 % Soot by TGA, max	2.1	2.2	2.3
		Viscosity increase at 3.8 % Soot by TGA, cSt max	11.5	12.5	13.0
	D 6984 (Sequence IIIF)	60 h Viscosity at 40°C, increase from 10 min sample, % max	295	295 (MTAC)[W]	295 (MTAC)[W]
	or D 7320 (Sequence IIIG)[P]	Kinematic viscosity, % increase at 40°C max	150	150 (MTAC)	150 (MTAC)
	D 6894 (EOAT)[S]	Aeration, volume, % max	8.0	8.0 (MTAC)[W]	8.0 (MTAC)[W]
	D 6594 (135°C, HTC BT)	Used Oil Elemental Concentration			
		Copper, mg/kg (ppm) increase, max	20		
		Lead, mg/kg (ppm) increase, max	120		
		Tin, mg/kg (ppm) increase	report		
		Copper strip rating,[E] max	3		
	D 892 (Option A not allowed)	Foaming/Settling,[R] mL, max			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
			SAE 10W-30	SAE 15W-40	
	D 5800 or	% volatility loss at 250°C, max	20	18	
	D 6417	% volatility loss at 371°C, max	17	15	
	D 6278	Kinematic Viscosity after shearing,	SAE XW-30	SAE XW-40	
		cSt min	9.3	12.5	
			One-test	Two-test[X]	Three-test[X]
CI-4	D 6923 (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), (0-252 h), g/h, average	13.1	13.1	13.1
		Final oil consumption, (432-504 h), g/h, average, max	IOC + 1.8	IOC + 1.8	IOC + 1.8
		Piston, ring, and liner distress	none	none	none
		Ring sticking	none	none	none
	or, D 6681 (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 (0–360 h), max	12.4	12.4	12.4
		Final oil consumption, g/h (312–360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none
	D 6987/D 6987M (T-10)	Merit rating,[X] min	1000	1000	1000

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
	or the T-12 (T-10) test	Merit rating,[X] min	1000	1000	1000
	D 6975 (M11 EGR)	Average crosshead wt. loss, mg, max	20.0	21.8	22.6
		Average top ring weight loss, mg	report	report	report
		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, the Cummins ISM test	Crosshead wear, mg, max	7.5	7.8	7.9
		Oil filter Δ pressure @ 150 h, kPa (psig), max	55 (8)	67 (10)	74 (11)
		Sludge rating, CRC Merits, min	8.1	8.0	8.0
	D 5967 (Ext. T-8E)[O]	Relative viscosity at 4.8 % soot[Y]	1.8	1.9	2.0
	D 6984 (Sequence IIIF)[Z]	Kinematic viscosity (at 40°C), % increase, max	275	275 (MTAC)	275 (MTAC)
	or D 7320(Sequence IIIG)[P]	Kinematic viscosity, % increase at 40°C max	150	150 (MTAC)	150 (MTAC)
	D 6750[AA]	Weighted demerits (WDK), max	332	347	353
	(1K)	Top groove fill (TGF), %, max	24	27	29
		Top land heavy carbon (TLHC), %, max	4	5	5
		Average oil consumption, g/kW-h, (0-252 h), max	0.5	0.5	0.5
		Piston, ring, and liner scuffing	none	none	none
	D 5966	Average pin wear, mils, max	0.30	0.33	0.36
	(RFWT)	or (μm), max	(7.6)	(8.4)	(9.1)
	D 6894 (EOAT)[S]	Aeration, volume %, max	8.0	8.0 (MTAC)[W]	8.0 (MTAC)[W]

CI-4 Bench Tests	Measured Parameter	Primary Performance Criteria
D 4683 (High temperature/High shear)[AB]	Viscosity after shear,[AC] min	3.5 mPa-s
D 4684 (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[AD] test) tested at -20°C, mPa-s, max	25 000
	If yield stress is detected, use modified D 4684[AE] (external preheat), then mPa-s, max	25 000
	and yield stress, Pa	<35
D 5800 (Noack)	Evaporative loss at 250°C, %, max	15
D 6594 (135°C HTCBT)	Copper, mg/kg (ppm) increase, max	20
	Lead, mg/kg (ppm) increase, max	120
	Tin, mg/kg (ppm) increase	report
	Copper strip rating,[E] max	3
D 6278	Kinematic viscosity after shearing, cSt, min	SAE XW-30 / SAE XW-40 9.3 / 12.5
D 892 (Option A not allowed)	Foaming/settling,[R] mL, max	
	Sequence I	10/0
	Sequence II	20/0
	Sequence III	10/0

CI-4 Bench Tests, cont'd—D 7216 (Elastomer Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

Note—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A10.

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

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	T-12	Merit rating,[AF] min	1000	1000	1000
	ISM	Merit rating,[AF] min	1000	1000	1000
		Top ring weight loss, mg, max	100	100	100
	C13	Merit rating,[AF] min	1000	1000	1000
		Hot-stuck piston ring	none	none	none
	D 7156 (T-11)	TGA % Soot at 4.0 cSt increase, at 100°C, min	3.5	3.4	3.3
		TGA % Soot at 12.0 cSt increase, at 100°C, min	6.0	5.9	5.9
		TGA % Soot at 15.0 cSt increase, at 100°C, min	6.7	6.6	6.5
	ISB	Slider tappet weight loss, mg, average, max	100	108	112
		Cam lobe wear, μm, average, max	55	59	61

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
		Crosshead weight loss, mg, average	report	report	report
	D 6750 (1N)	Weighted demerits (WDN), max	286.2	311.7	323.0
		Top groove fill (TGF), %, max	20	23	25
		Top land heavy carbon (TLHC), %, max	3	4	5
		Oil consumption, g/kW-h, (0-252 h), max	0.5	0.5	0.5
		Piston, ring, and liner scuffing	none	none	none
		Piston ring sticking	none	none	none
	D 5966 (RFWT)	Average pin wear, mils, max	0.30	0.33	0.36
		(µm, max)	(7.6)	(8.4)	(9.1)
	D 6984 (Seq, IIIF)	Kinematic viscosity (at 40°C), % increase, max	275	275 (MTAC)	275 (MTAC)
	or, alternately, D 7320 (Sequence IIIG)[P]	Kinematic viscosity (at 40°C), % increase, max	150	150 (MTAC)	150 (MTAC)
	D 6894 (EOAT)	Aeration, volume, %, max	8.0	8.0 (MTAC)	8.0 (MTAC)

CJ-4 Bench Tests	Measured Parameter	Primary Performance Criteria
D 4683 (High temperature/High shear)	Viscosity at 150°C, mPa-s, min	3.5
D 6594 (135°C HTCBT)	Copper, mg/kg (ppm) increase, max	20
	Lead, mg/kg (ppm) increase, max	120
	Copper strip rating, max	3
D 7109	Kinematic viscosity after 90 pass shearing, cSt at 100°C, min	SAE XW-30 / SAE XW-40 9.3 / 12.5
D 5800 (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
D 892	Foaming/settling, mL, max	
	Sequence I	10/0
	Sequence II	20/0
	Sequence III	10/0
D 6896 (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)	
D 874	Sulfated ash, weight %, max	1.0
D 4951	Phosphorus, weight %, max	0.12
D 4951	Sulfur, weight %, max	0.4

CJ-4 Bench Tests, cont'd—D 7216 (Seal Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

Note—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A10.

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

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 (Seal Test)

Evaluate the Vamac G elastomer using the procedures specified in D 7216 and Annex A10.
Unadjusted specification limits for Vamac G follow:

Volume Change, %	+TMC 1006/-3
Hardness Change, Points	+5/-TMC 1006
Tensile Strength Change, %	+10/-TMC 1006
Elongation at Break Change, %	+10/-TMC 1006

[A] Requires greater than zero merits on all individual ratings. Refer to RR: D02–1219.

[B] Test Method D 6483 and its limits can be used as an alternate for the T-6 test and its limits. Test Method D 5967 (T-8A version) and its limits can be used as an alternate for the T-7 test and its limits.

[C] Refer to RR: D02–1273.

[D] Specification D 4485 – 94 Lists the NTC-400 (Test Method D 5290) as a test method required to demonstrate performance for this category. Due to lack of availability of critical test parts the NTC-400 is no longer available, as a calibrated test, and has been replaced in this category by the requirement for a second 1K test and Test Method

D 5968. Alternatively, instead of running a second 1K test and Test Method D 5968, data from NTC-400 tests, run in calibrated test stands, can be used to support this category in accordance with all of the provisions of Specification D 4485–94; see Annex A8 for detailed description.

[E] The rating system in Test Method D 130 is used to rate the copper coupon in Test Methods D 5968 and D 6594.

[F] See Annex A2 for additional information.

[G] CRC Diesel Engine Rating Manual No. 18, available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.

[H] Refer to RR: D02–1273.

[I] 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.

[J] See Annex A3 for additional information.

[K] See Annex A4 for additional information.

[L] See Annex A5 for additional information.

[M] See Annex A6 for additional information.

[N] Refer to RR: D02–1321.

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

[P] 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.

[Q] Limits do not apply to monograde oils.

[R] Ten minutes for Sequence I, II, and III.

[S] Refer to RR: D02–1379.

[T] See Annex A7 for additional information.

[U] Refer to RR: D02–1441.

[V] Refer to RR: D02–1439.

[W] See Annex A1; use method without transformations.

[X] See Annex A9 for additional information.

[Y] Relative Viscosity (RV) = viscosity at 4.8 % soot/viscosity of new oil sheared in Test Method D 6278.

[Z] Refer to RR: D02–1391.

[AA] Refer to RR: D02–1273. Alternatively, Test Method D 6750 (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 D 6750 (1N) in the CG-4 category.

[AB] Tests as allowed in SAE J300.

[AC] Noncritical specification as defined by Practice D 3244; may be superseded only by applicable higher limits set by SAE J300.

[AD] 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 D 4684.

[AE] Refer to RR: D02–1517.

[AF] See Annex A11 for additional information.

4.1.5 *CF*—Oil meeting the performance requirements in the following diesel and gasoline engine tests:

4.1.5.1 Test Method D 6618, the 1M-PC diesel engine test, has been shown to provide correlation with engine oil performance when used in naturally aspirated, turbocharged, or supercharged indirect injection engines.[19]

4.1.5.2 Test Method D 6709, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.[13]

4.1.5.3 Licensing of the API CF category requires that candidate oils meet the performance requirements of this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

4.1.6 *CF-2*—Oil meeting the performance requirements in the following diesel and gasoline engine tests:

4.1.6.1 Test Method D 6618, the 1M-PC diesel engine test, has been shown to provide correlation with engine oil performance when used in naturally aspirated, turbocharged, or supercharged indirect injection engines, *with modified piston deposit rating methodology to relate to effective piston and ring groove deposit control for two-stroke cycle diesel engines*.

4.1.6.2 Test Method D 5862, the 6V92TA diesel engine test, has been correlated with two-stroke cycle diesel engines in heavy-duty service, particularly with regard to ring face distress and liner scuffing.

4.1.6.3 Test Method D 6709, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.[13]

4.1.6.4 Licensing of the API CF-2 category requires that candidate oils meet the performance requirements of this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

4.1.7 *CG-4*—Oil meeting the performance requirements in the following diesel and gasoline engine tests and bench tests:

4.1.7.1 Test Method D 6750, 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 less than 0.05 % weight sulfur.[20]

4.1.7.2 Test Method D 5967, the T-8 diesel engine test, has been shown to generate soot-related oil thickening in a manner similar to 1992 emission-controlled heavy-duty diesel engines using mechanical injection control systems.

4.1.7.3 Test Method D 6984, 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 D 7320, the Sequence IIIG test.)

[19] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1320.

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

4.1.7.4 Test Method D 6709, the Sequence VIII gasoline engine test, is used to measure copper-lead bearing weight loss under high temperature operating conditions and has been shown to correlate with the L-38 gasoline engine test.[13]

4.1.7.5 Test Method D 5966, 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.

4.1.7.6 Test Method D 6894, the Engine Oil Aeration Test (EOAT) has been correlated with oil aeration in diesel engines equipped with hydraulically actuated electronically controlled unit injectors (HEUI) used in medium duty service.[21]

4.1.7.7 Test Method D 892, a foaming test, Sequences I, II, and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.7.8 Test Method D 5968, a bench corrosion test, has been shown to predict corrosion of engine oil-lubricated copper, lead, or tin-containing components used in diesel engines.

4.1.7.9 Licensing of the API CG-4 category requires that candidate oils meet the performance requirements of this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

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

4.1.8.1 Test Method D 6750, the 1K diesel engine test, has been correlated with vehicles equipped with engines used in high speed operation prior to 1989, particularly with respect to aluminum piston deposits and oil consumption when fuel sulfur content is nominally 0.4 % by weight.

4.1.8.2 Test Method D 6681, 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 less the 0.05 % by weight sulfur.[22]

4.1.8.3 Test Method D 6483, 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.[23] (Alternatives are Test Method D 6987/D 6987M, the T-10 diesel engine test—see 4.1.9.2, and the T-12 diesel engine test—see 4.1.8.2.)

4.1.8.4 Test Method D 5967 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.

4.1.8.5 Test Method D 6838, 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.[24]

4.1.8.6 Test Method D 5966, 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.

4.1.8.7 Test Method D 6984, 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 D 7320, the Sequence IIIG test.)

4.1.8.8 Test Method D 6894, the EOAT has been correlated with oil aeration in diesel engines equipped with HEUI used in medium-duty diesel engines.

4.1.8.9 Test Method D 892, a foaming test, Sequences I, II and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.8.10 Test Method D 6594 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.

4.1.8.11 Test Method D 6278, 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.

4.1.8.12 Test Method D 5800, Noack Volatility or, alternatively, Test Method D 6417, are used to measure engine oil volatility loss under high temperature operating conditions.

4.1.8.13 Licensing of the API CH-4 category requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

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

4.1.9.1 Test Method D 6923, 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 D 6681, the 1P diesel engine test, see 4.1.8.2.

4.1.9.2 Test Method D 6987/D 6987M, 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 the T-12 diesel engine test, see 4.1.10.2.

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

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

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

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

4.1.9.3 Test Method D 6975, the M11 EGR heavy-duty diesel engine test, is used to evaluate oil performance with respect to valve train wear, sludge deposits, and oil filter plugging in an exhaust gas recirculation environment. (An alternative is the Cummins ISM diesel engine test.)

4.1.9.4 Test Method D 5967 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.

4.1.9.5 Test Method D 6984, 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 D 7320, the Sequence IIIG test.)

4.1.9.6 Test Method D 6750 (1K), the 1K diesel engine test, or, alternatively, Test Method D 6750 (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 fuel sulfur content was nominally 0.4 % by weight. 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 less than 0.05 % weight sulfur.

4.1.9.7 Test Method D 5966, 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.

4.1.9.8 Test Method D 6894, the EOAT procedure, has been correlated with oil aeration in diesel engines equipped with HEUI used in medium-duty diesel engines.

4.1.9.9 Test Method D 4683, the High Temperature High Shear (HTHS) test is a part of the SAE J300 Viscosity Classification System.

4.1.9.10 Test Method D 4684 (MRV TP-1) has been shown to predict field failures resulting from poor low temperature pumpability.

4.1.9.11 Test Method D 5800, Noack Volatility, is used to measure engine oil volatility loss under high temperature operating conditions.

4.1.9.12 Test Method D 6594 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.

TABLE 4 Energy Conserving Categories

SJ-Related Energy Conserving Category		
Test Procedure	SAE Viscosity Grade	Primary Performance Criteria[A]
D 6202 (Sequence VIA)	0W-20 and 5W-20	FEI[B] relative to BC[C], 1.4 %, min
D 6837 (Sequence VIBSJ)	0W-20 and 5W-20	FEI[D] relative to BC[C], 1.7 %, min
D 6202 (Sequence VIA)	other 0W- and 5W-multi-grades	FEI[B] relative to BC, 1.1 %, min
D 6837 (Sequence VIBSJ)	other 0W- and 5W-multi-grades	FEI[D] relative to BC, 1.3 %, min
D 6202 (Sequence VIA)	all 10W-multi-grades	FEI[B] relative to BC, 0.5 %, min
D 6837 (Sequence VIBSJ)	all 10W-multi-grades	FEI[D] relative to BC, 0.6 %, min
D 6202 (Sequence VIA)	all others	FEI[B] relative to BC, 0.5 %, min
D 6837 (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
D 6837 (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
D 6837 (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
D 6837 (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 D 6202 (Sequence VIA) or Test Method D 6837 (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 4 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).

4.1.9.13 Test Method D 6278, 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.

4.1.9.14 Test Method D 892, a foaming test, Sequences I, II, and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.9.15 Test Method D 7216, the Elastomer Compatibility Test is used to measure the performance of four widely used elastomer compounds when exposed to diesel engine oils.

4.1.9.16 Licensing of the API CI-4 category requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

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

4.1.10.1 Test Method D 7156, 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 500 mg/kg (ppm) sulfur fuel.

4.1.10.2 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 ultra low (15 mg/kg (ppm)) sulfur fuel.

4.1.10.3 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 ultra low (15 mg/kg (ppm)) sulfur fuel.

4.1.10.4 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 ultra low (15 mg/kg (ppm)) sulfur fuel.

4.1.10.5 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 500 mg/kg (ppm) sulfur fuel.

4.1.10.6 Test Method D 6750, 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 less than 0.05 % weight sulfur.

4.1.10.7 Test Method D 6984, 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 D 7320, the Sequence IIIG test.)

4.1.10.8 Test Method D 5966, 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.

4.1.10.9 Test Method D 4684 (MRV TP-1) has been shown to predict field failures resulting from poor low temperature pumpability.

4.1.10.10 Test Method D 7109, 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.

4.1.10.11 Test Method D 6594 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.

4.1.10.12 Test Method D 4683, the High Temperature High Shear (HTHS) test, is a part of the SAE J300 Viscosity Classification System.

4.1.10.13 Test Method D 892, a foaming test, Sequences I, II, and III, has been shown to predict foaming of engine oils in diesel engines.

4.1.10.14 Test Method D 7216, the Elastomer Compatibility Test, is used to measure the performance of four widely used elastomer compounds when exposed to diesel engine oils.

4.1.10.15 Test Method D 6894, the EOAT procedure, has been correlated with oil aeration in diesel engines equipped with HEUI used in medium-duty diesel engines.

4.1.10.16 Licensing of the API CJ-4 category requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

4.1.11 *Energy Conserving Associated With SJ*—As defined by Test Method D 6202 or Test Method D 6837, oil meeting performance requirements in Table 4.

4.1.11.1 Test Method D 6202 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.

4.1.11.2 Test Method D 6837[25] 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.

4.1.12 *Energy Conserving Associated With SL*—As defined by Test Method D 6837, oil meeting performance requirements in Table 4.

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

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

4.1.13 Licensing of the Energy Conserving category as defined by Test Method D 6202 or as defined by Test Method D 6837 requires that candidate oils meet the performance requirements in this specification, and that the oils be tested in accordance with the protocols described in the ACC Petroleum Additives Product Approval Code of Practice. The methodology detailed in the ACC Code will help ensure that an engine oil meets its intended performance specification.

5. Performance Requirements

5.1 The oils identified by the categories discussed in Section 4 shall conform to the requirements listed in Tables 2-4.

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

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

NOTE 5—Intended service applications for the various categories described in 4.1.1-4.1.12 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 and the publications in Table 1.

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 D 5119, D 5133, D 5480, D 5800, D 6082, D 6202, D 6335, D 6417, D 6794, D 6795, D 6837, D 6891, D 6984, and D 7320.

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 D 5133, D 5800, D 6082, D 6417, D 6557, D 6593, D 6709, D 6794, D 6795, D 6837, D 6891, D 6984, D 7097, and D 7320.[26]

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 D 5800, D 5966, D 5967 (extended), D 6417, D 6483, D 6594, D 6681, D 6750, D 6838, D 6894, D 6984, D 6987/D 6987M, and D 7320.

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 D 5800, D 5966, D 5967 (extended), D 6594, D 6750, D 6923, D 6894, D 6975, D 6984, D 6987/D 6987M, and D 7320.

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 D 874, D 5800, D 5966, D 6594, D 6750, D 6894, D 6984, D 7156, D 7216, D 7320, T-12, ISM, ISB, and C13.

7. Keywords

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

[26] 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.

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 E 29.

A1.1.1 For light-duty categories, SH, 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, CF, CF-2, CG-4, 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.

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

Test Method	Rated Parameter	Transformation
D 5844 (Sequence IID)	Average engine rust	NA[A]
D 5533 (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
D 6984 (Sequence IIIF - as used in CH-4)	Percent viscosity increase at 60 h	LN
D 6894 (EOAT)	Aeration, volume %	NA
D 6984 (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
D 7320 (Sequence IIIG)	Viscosity, % increase	LN
D 6891 (Sequence IVA)	Cam wear	NA
D 5302 (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
D 6593 (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
D 6202 (Sequence VIA)	Fuel economy improvement	NA
D 6837 (Sequence VIB)	Fuel economy improvement	NA
D 5119 (L-38)	Total bearing weight loss	NA
D 6709 (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.

A1.2.2 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. 1K MULTIPLE-TEST PROGRAMS FOR CF-4

A2.1 The application of Test Method D 6750, 1K test, in determining the performance of an oil against the limits established for the CF-4 category allows only the running of multiple-test programs. Limits for two-test, three-test, and four-test programs are shown in Table 3.

A2.2 In applying the limits for two-test, three-test, and four-test programs, the results for the weighted demerits (WDK), top groove fill (TGF), top land heavy carbon (TLHC) and average oil consumption of the two, three, or four tests are averaged and compared to the limits shown in Table 3.

A2.3 In a three or four-test program, allowance is made for excluding one of the tests as an outlier. The basis for determining whether a test is an outlier is Practice E 178. In applying Practice E 178 to the 1K test, each parameter is considered individually. If one parameter on one of the first three or four tests is more than the limits shown on Table A2.1, then that test can be considered an outlier and another test run.

A2.4 In determining the average values of the resulting two, three, or four-test program, the results of the outlier test are not used in calculating the average values that are compared to the limits shown in Table A2.1.

TABLE A2.1 Limits for Test Method D 6750 (1K) Outlier Determinations

Parameter	Outlier Limit[A]
Weighted demerits (WDK), min	mean + 92
Top groove fill (TGF), min	mean + 22
Top land heavy carbon (TLHC), min	mean + 6

[A] The means used in these limits are the means of the individual parameters for the first three 1K tests in a program. The constants are three times the standard deviations of each parameter from the original 30 – test matrix data base on reference oil TMC 809, rounded to the nearest whole number.

A3. TEST METHOD D 6618 (1M-PC) MULTIPLE-TEST PROGRAMS

A3.1 The application of Test Method D 6618 test in determining oil performance for the CF and CF-2 categories allows the running of multiple tests, if necessary.

A3.2 The results of all operationally valid tests run are averaged to determine the final result for TGF and WTD (CF and CF-2 categories).

A3.3 When three or more tests are run, one test can be removed as an outlier result and the average calculated from the remaining test results.

A4. TEST METHOD D 6709 (Sequence VIII) MULTIPLE-TEST PROGRAMS (FOR CF AND CF-2)

A4.1 In a three-test program, allowance is made for excluding one of the tests as an outlier. The outlier criteria defined in Section 6 of Practice E 178 shall be applied at the 5 % significance level with an assumed standard deviation of 9.0 based on Reference Oil TMC 704 results.

A4.2 If a test result exceeds the outlier criterion, the remaining two tests can be used as a two-test program or a fourth test run can be made replacing the rejected result and averaged as a three-test program.

A4.3 The results of the declared outlier test are not used in calculating the average results that are compared to the published two-test or three-test limits.

A5. TEST METHOD D 5862 (6V92TA) MULTIPLE-TEST PROGRAMS

A5.1 The application of Test Method D 5862 in determining oil performance for the CF-2 category allows the running of multiple tests, if necessary.

A5.2 The results of the first 6V92TA test are compared to the one-test limit for cylinder liner scuffing, port plugging area, and piston ring face distress. In applying the limits for two-test and three-test programs, the results for cylinder liner scuffing and piston ring face distress are averaged and compared to the two-test or three-test limits, respectively. Limits for port plugging area apply to the average of the average port plugging values and the average of the maximum port plugging values for all cylinders in the retained tests.

A5.3 All tests on the same formulation, regardless of batch or blend number, are to be included in the multiple test program.

A5.4 In a three test program, allowance is made for excluding one of the tests as an outlier. The basis for determining whether the test result is an outlier is Practice E 178. In applying Practice E 178 to the 6V92TA test, each parameter is considered individually at the 95 % confidence level.

A5.5 If one parameter on one of the first three tests is more than the limits shown in Table A5.1, then the test can be considered an outlier and the remaining two tests can be used as a two-test program, or a fourth test can be made replacing the rejected result and averaged as a three-test program.

A5.6 The results of the outlier test are not used in calculating the average results which are compared to the published two-test or three-test limits.

TABLE A5.1 Limits for Test Method D 5862 Outlier Determinations

Parameter	Outlier Limit[A]
Cylinder liner scuffing area	Average + 18.1
Piston ring face distress	
No. 1 (fire ring)	Average + 0.08
Average of Nos. 2 and 3	Average + 0.06

[A] The averages used in these limits are the averages of the individual parameters for the first three 6V92TA tests in the program. The outlier limits are based on the test precision of 18 calibration oil tests.

A6. CG-4 MULTIPLE-TEST PROGRAMS

A6.1 For the CG-4 test results for which outlier criteria apply (as shown in Table A6.1), if three or more tests are run, one complete test can be discarded if the outlier criterion defined in Section 6 of Practice E 178 is met at the 5 % significance level.

A6.2 The standard deviations used in applying the outlier determination for each result are shown in Table A6.1. The standard deviations for the 1N, T-8, and RFWT tests were derived from results with Reference Oil 1004-1. In the case of the Sequence VIII test, Reference Oil TMC 704-1 was used. In the case of the Sequence IIIF test, Reference Oils TMC 433, 1006, and 1008 were used.

TABLE A6.1 Outlier Test Determination Values

Test Result	Standard Deviation
1N – WDN	27.1
1N – TGF	14.6
1N – 1n (TLHC + 1)	0.9
1N – Oil consumption	0.045
T – 8 – Viscosity increase	1.19
IIIF – ln (Viscosity increase, %)	0.1458
IIIG – ln (Viscosity increase, %)	0.2919
Sequence VIII – Bearing weight loss	9.0
RFWT – Wear (mils)	0.04

A7. CH-4 MULTIPLE-TEST PROGRAMS

A7.1 For the CH-4 test parameters on which outlier criteria apply (as shown in Table A7.1), if three or more tests are run, one complete test can be discarded if the outlier criteria defined in Practice E 178 are met at the 5 % significance level. Since the criteria are based upon the number of tests in the program, each program is unique.

A7.2 Section 6 (Recommended Criteria for Known Standard Deviations) of Practice E 178 is used to determine outliers. The standard deviation applied in the outlier determination for each parameter is shown in Table A7.1.

TABLE A7.1 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]

[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.

A8. CF-4 CATEGORY—1994 VERSION

A8.1 Test Method D 5290 (NTC-400) Oil Consumption Pass/Fail Limits

A8.1.1 The CE and CF-4 oil consumption limits for Test Method D 5290 require that the candidate oil consumption second order regression curve be compared to curves published by the ASTM TMC for the applicable reference oil (TMC 850). These published curves are derived from means and standard deviations calculated by the TMC using 20-h oil consumption data points from the last 15 valid reference oil TMC 850 runs.

A8.2 Test Method D 6750 (1K) Multiple Test Programs

A8.2.1 The application of the 1K test in determining the performance limits for the CF-4 category allow the running of multiple tests, if necessary. Limits for two-test and three-test programs are shown in Table A8.1.

A8.2.2 In applying the limits for two-test and three-test programs, the results for the weighted demerits (WDK), top groove fill (TGF), top land heavy carbon (TLHC), and average oil consumption of the two or three tests are averaged and compared to the limits shown in Table A8.1.

A8.2.3 In a three-test program, allowance is made for excluding one of the tests as an outlier. The basis for determining whether a test is an outlier is Practice E 178. In applying Practice E 178 to the 1K test, each parameter is considered individually. If one parameter on one of the first three tests is more than the limits shown on Table A8.2, then that test can be considered an outlier and a fourth test run.

A8.2.4 In determining the average values of the resulting two-test or three-test program, the results of the outlier test are not used in calculating the average values that are compared to the limits shown in Table A8.1.

TABLE A8.1 CF-4 Category Requirements

			One-test	Two-test[A]	Three-Test[A]
CF-4	Test Method D 6750 (1K)	Weighted demerits (WDK),[B,C] max	332	347	353
		Groove No. 1 (top) carbon fill (TGF),[B] % volume, max	24	27	29
		Top land heavy carbon (TLHC),[B] % max	4	5	5
		Oil consumption, average, g/kW·h, max	0.5	0.5	0.5
		Piston ring sticking	none		
	D 5119 (L-38)	Bearing weight loss, mg, max	50		
	T-6	Merit rating,[D] min	90		
	T-7	Average rate of kinematic viscosity increase during last 50 h, cSt at 100°C/h, max	0.040		
	D 5290 (NTC-400)	Oil consumption, g/s (lb/n)	Candidate oil consumption second order regression curve shall fall completely below the published mean curve for the applicable reference oil.[E]		
		Camshaft roller follower pin wear, mm (in.), average, max	0.051 (0.002)		
		Crownland (top land) deposits, area covered with heavy carbon,[B] %, average, max	15		

[A] See A8.2 for additional information.
[B] CRC Diesel Engine Rating Manual No. 18. Available from Coordinating Research Council, 219 Perimeter Center Pkwy., Atlanta, GA 30346.
[C] Refer to RR: D02–1273. Available from ASTM Headquarters.
[D] Refer to RR: D02–1219. Available from ASTM Headquarters.
[E] See A8.1 for additional information.

TABLE A8.2 Limits for Test Method D 6750 (1K) Outlier Determinations

Parameter	Outlier Limit[A]
Weighted demerits (WDK), min	mean + 92
Top groove fill (TFG), min	mean + 22
Top land heavy carbon (TLHC), min	mean + 6

[A] The means used in these limits are the means of the individual parameters for the first three 1K tests in a program. The constants are three times the standard deviations of each parameter from the original 30 – test matrix data base on reference oil TMC 809, rounded to the nearest whole number.

A9. CI-4 MULTIPLE TEST PROGRAMS AND TEST METHOD D 6987/D 6987M (T-10) MERIT RATING SYSTEM APPLICATION

A9.1 For the CI-4 test parameters on which outlier criteria apply (as shown in Table A9.1), if three or more tests are run, one complete test can be discarded if the outlier criteria defined in Practice E 178 are met at the 5 % significance level. Since the criteria are based upon the number of tests in the program, each program is unique.

A9.2 Section 6 (Recommended Criteria for Known Standard Deviations) of Practice E 178 is used to determine outliers. The standard deviation applied in the outlier determination for each parameter is shown in Table A9.1.

A9.3 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 A9.4.1-A9.4.7. The T-12(T-10) Merit Rating System is based on results obtained in 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 A9.1 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 D 6278 viscosity delta used in relative viscosity calculation.

A9.4 Tables A9.2 and A9.3 each contain *Maximum*, *Anchor*, and *Minimum* values, as well as *Weight* values, for the specified tests and the test parameters.

A9.4.1 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.

A9.4.2 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.

A9.4.3 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.

A9.4.4 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.

A9.4.5 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.

A9.4.6 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.

A9.4.7 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.

TABLE A9.2 Mack T-10 Merit System

Criterion	0-300 h Delta Lead, mg/kg (ppm)	250-300 h Delta Lead, mg/kg (ppm)	Cylinder Liner Wear, µm	Top Ring Weight 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 A9.3 Alternative Mack T-12(T-10) Merit System

Criterion	0-300 h Delta Lead, mg/kg (ppm)	250-300 h Delta Lead, mg/kg (ppm)	Cylinder Liner Wear, µm	Top Ring Weight 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

A10. PROCEDURE FOR DERIVING ADJUSTED SPECIFICATION LIMITS FOR ELASTOMER COMPATIBILITY

A10.1 Background

A10.1.1 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.

A10.1.2 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.

A10.1.3 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.

A10.2 Unadjusted Specification Limits

A10.2.1 The unadjusted specification limits are shown for the CI-4 category in Table 3. (These are reproduced in Table A10.3 at the end of this annex 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).

A10.3 Adjusted Specification Limits

A10.3.1 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.

A10.3.2 The adjusted specification limits are determined as the unadjusted specification limits plus (in absolute terms) an amount to account for test variability.

A10.4 Inherent Test Variability

A10.4.1 Table A10.1 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).

A10.5 Adjusted Specification Limits—Calculations

A10.5.1 *Calculation of Fixed Limits*:

A10.5.1.1 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.

A10.5.1.2 Multiply the standard error of the test-oil mean by 2.0.

A10.5.1.3 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).

A10.5.2 *Calculation of Variable Limits*:

A10.5.2.1 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.

A10.5.2.2 Multiply the standard error of the test-oil mean by 2.8.

A10.5.2.3 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.

A10.5.3 Table A10.2 shows an example of the calculated adjusted specification limits.

A10.6 Comparison of Unadjusted and Adjusted Specification Limits

A10.6.1 Table A10.3 reproduces the unadjusted specification limits for comparison with the above adjusted specification limits.

TABLE A10.1 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 A10.2 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 A10.1, and six observations in all cases.

TABLE A10.3 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)

A11. CJ-4 MULTIPLE TEST PROGRAMS AND T-12, C13 AND ISM MERIT RATING SYSTEM APPLICATIONS

A11.1 For the CJ-4 test parameters on which outlier criteria apply (contained in Table A11.1), if three or more tests are run, one complete test can be discarded if the outlier criteria defined in Practice E 178 are met at the 5 % significance level. Since the criteria are based upon the number of tests in the program, each program is unique.

A11.1.1 Section 6 (Recommended Criteria for Known Standard Deviations) of Practice E 178 is used to determine outliers. The standard deviation applied in the outlier determination for each parameter will be shown in Table A11.1.

A11.2 The T-12, C13 and ISM Merit Rating Systems calculation methodology is described in the corresponding test methods.

A11.3 Tables A11.2-A11.4 each contain *Maximum*, *Anchor* and *Minimum* values, as well as *Weight* values, for the specified tests and the test parameters.

A11.4 Application of the T-12, C13 and ISM Merit Rating Systems to single and multiple test results follows the guidelines provided below:

A11.4.1 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.

A11.4.2 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.

A11.4.3 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.

A11.4.4 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.

A11.4.5 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.

A11.4.6 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.

A11.4.7 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.

TABLE A11.1 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 @ 4 cSt viscosity increase	0.249
T-11 Soot @ 12 cSt viscosity increase	0.187
T-11 Soot @ 15 cSt viscosity increase	0.218
ISB camshaft wear, avg	0.3952
ISB tappet weight loss, avg	16.8574

TABLE A11.2 Mack T-12 Merit System

	Cylinder Liner Wear, µm	Top Ring Weight Loss, mg	Delta Lead, Final mg/kg (ppm)	Delta Lead, 250-300 h mg/kg (ppm)	Oil Consumption, g/h
Weight (Total = 1000)	250	200	200	200	150
Maximum	24	105	35	15	85
Anchor	20	70	25	10	65
Minimum	12	35	10	0	50

TABLE A11.3 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 A11.4 Cummins ISM Merit System

	Crosshead Weight Loss, avg mg	Delta Oil Filter Pressure, kPa	Engine Sludge, avg merits	Valve Adj. Screw Wt. 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

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 SH—1994 Gasoline Engine Warranty Maintenance Service

X2.1.1 API Service Category SH was adopted in 1992 for use in describing engine oil first mandated in 1993. This is for use in service typical of gasoline engines in current and earlier passenger-car, van, and light-truck operation under vehicle manufacturer's recommended maintenance procedures.

X2.1.2 Engine oils developed for this service category provide performance exceeding the minimum requirements for API Service Category SG, which Service Category SH is intended to replace, in the areas of deposit control, oil oxidation, wear, rust, and corrosion and must meet the engine-protection sequence test requirements of DOD CID A-A-52039A and ILSAC GF-1. In addition, all viscosity grades designated in DOD CID A-A-52039A (SAE 5W-30, 10W-30, and 15W-40) must meet the bench test requirements described in DOD CID A-A-52039A and ILSAC GF-1. (SAE 15W-40 does not have a phosphorus limitation and does not have to meet the GM filterability test.)

X2.1.3 Engine oils that meet the API Service Category SH designation have been tested in accordance with the ACC Code, may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing, and may be used where API Service Category SG and earlier S categories have been recommended.

X2.2 SJ

X2.2.1 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.

X2.2.2 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.

X2.2.3 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.

X2.3 SL—2001 Gasoline Engine Warranty Maintenance Service

X2.3.1 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.

X2.3.2 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.

X2.3.3 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).

X2.3.4 Engine oils that meet these requirements may display API Service Category SL in the upper portion of the API Service Symbol.

X2.4 SM—2005 Gasoline Engine Warranty Maintenance Service

X2.4.1 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.

X2.4.2 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.

X2.4.3 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 Appendixes E and F of API Publication 1509).

X2.4.4 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.

X2.5 CF-4—Diesel Engine Service

X2.5.1 API Service Category CF-4 describes oils for use in high-speed, four-stroke cycle diesel engines. CF-4 oils exceed the requirements of Service Category CE, are designed to replace CE oils, and provide improved control of oil consumption and piston deposits. CF-4 oils may be used in place of CC and CD oils. They are particularly suited for on-highway, heavy-duty truck applications. Oils designated for this service have been in existence since 1990.

X2.6 CF—For Off-Road Indirect Injected Diesel Engine Service

X2.6.1 API Service Category CF denotes service typical of off-road indirect injected diesel engines and other diesel engines that use a broad range of fuel types, including those using fuel with higher sulfur content, for example, over 0.5 % weight. Effective control of piston deposits, wear, and corrosion of copper-containing bearings is essential for these engines, which may be naturally-aspirated, turbocharged, or supercharged. Oils designated for this service have been in existence since 1994. Oils designated for this service may also be used when API Service Category CD is recommended. Engine oils that meet the API Service Category CF 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.

X2.7 CF-2—Two-Stroke Cycle Diesel Engine Service

X2.7.1 API Service Category CF-2 denotes service typical of two-stroke cycle engines requiring highly effective control over cylinder and ring-face scuffing and deposits. Oils designated for this service have been in existence since 1994 and may also be used when API Service Category CD-II is recommended. These oils do not necessarily meet the requirements of CF or CF-4 unless the oils have specifically met the performance requirements of these categories.

X2.7.2 Engine oils evaluated in the two-stroke cycle DD 6V92TA engine test since January 1, 1992, may be considered for this Service Category provided the tests were conducted in accordance with the test procedure as published in ASTM Research Report RR: D02–1319[27] or as revised by the ASTM TMC. All testing conducted since January 1, 1994, must be done in accordance with the most current test procedures. Engine oils that meet the API Service Category CF-2 designation have been tested in accordance with the ACC Code, may use the API Base Oil Interchangeability Guidelines and the API Guidelines for SAE Viscosity-Grade Engine Testing.

X2.8 CG-4—For Severe Duty Diesel Engine Service

X2.8.1 API Service Category CG-4 describes oils for use in high-speed, four-stroke cycle diesel engines used in highway and off-road applications where the fuel sulfur may vary from less than 0.05 % weight to less than 0.5 % weight. CG-4 oils provide effective control over high temperature piston deposits, wear, corrosion, foaming, oxidation, and soot accumulation. These oils are especially effective in engines designed to meet 1994 exhaust emission standards and may also be used in engines requiring API Service Categories CD, CE, and CF-4. Oils designated for API Service Category CG-4 have been in existence since 1995. Engine oils that meet the API Service Category CG-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.

X2.9 CH-4—1998 Diesel Engine Service

X2.9.1 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.

X2.9.2 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.

X2.9.3 CH-4 oils are superior in performance to those meeting API CG-4 and CF-4 and can effectively lubricate engines calling for those API service categories.

X2.10 CI-4—For 2004 Severe Duty Diesel Engine Service

X2.10.1 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.

X2.10.2 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.

X2.10.3 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.

X2.10.4 CI-4 oils are superior in performance to those meeting API CH-4, CG-4, and CF-4 and may be used in engines calling for those API Service Categories.

X2.10.5 The first license date for CI-4 will be September 5, 2002.

X2.10.6 Effective January 15, 2002, marketers may license products meeting API CI-4 requirements as CH-4, CG-4, and CF-4.

X2.11 CJ-4—2007 Diesel Engine Service

X2.11.1 API Service Category CJ-4 describes oils for use in high-speed four-stroke cycle diesel engines designed to meet

[27] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1319.

2007 model year on-highway exhaust emission standards as well as for previous model years.

X2.11.2 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.

X2.11.3 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.

X2.11.4 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.

X2.11.5 API CJ-4 oils exceed the performance criteria of API CI-4 with CI-4 PLUS, CI-4, CH-4, CG-4 and CF-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.

X2.11.6 The first license date for API CJ-4 will be October 15, 2006.

X2.11.7 Effective May 1, 2006, marketers may license products meeting API CJ-4 requirements as API CI-4 with CI-4 PLUS, CI-4, CH-4, CG-4, and CF-4.

X2.12 Energy Conserving—Defined by Test Method D 6202 (Sequence VIA)

X2.12.1 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.

X2.12.2 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.

X2.12.3 Oils that meet this requirement and are properly licensed may display Energy Conserving in the lower portion of the API Service Symbol.

X2.13 Energy Conserving In Conjunction with API Service Category SL

X2.13.1 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.

X2.13.2 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 D 6837 (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

X2.13.3 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.

X2.13.4 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

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
Sequence IIIG	Pass[C]	Pass
Sequence IIIGA	Pass	NR[D]
Sequence IVA (ASTM D 6891)	Pass	Pass
Sequence VG (ASTM D 6593)	Pass	Pass
Sequence VIII (ASTM D 6709)	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
ASTM D 6557 (Ball Rust Test), avg gray value, min	100	100
ASTM D 5800, evaporation loss, 1 hour at 250°C, % max[E]	15	15
ASTM D 6417, simulated distillation at 371°C, % max	10	10
ASTM D 6795, EOFT, % flow reduction, max	50	50
ASTM D 6794, EOWTT, % 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 D 4951, phosphorus % mass, max[F]	0.08[G]	NR
ASTM D 4951, phosphorus % mass, min[F]	0.06[G]	0.06[G]
ASTM D 4951 or D 2622, sulfur % mass, max[F]		
SAE 0W-20, 0W-30, 5W-20, and 5W-30	0.5[G]	NR
SAE 10W-30	0.7[G]	NR
ASTM D 892 (Option A), foaming tendency		
Sequence I, mL, max, tendency/stability[H]	10/0	10/0
Sequence II, mL, max, tendency/stability[H]	50/0	50/0
Sequence III, mL, max, tendency/stability[H]	10/0	10/0
ASTM D 6082 (Option A), high-temperature foaming mL, max, tendency/stability[I]	100/0	100/0
ASTM D 6922, homogeneity and miscibility	[J]	[J]
ASTM D 6709, (Sequence VIII) shear stability	[K]	[K]
ASTM D 7097 (TEOST MHT), high-temperature deposits, deposit wt, mg, max[F]	35	45
ASTM D 5133, gelation index, max	12[L]	NR

[A] Tests are per ASTM requirements.
[B] All oils must meet the requirements of the most recent edition of SAE J300.
[C] 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)] Note: The ILSAC GF-4 engine sequence limits are also shown in Appendix X5.
[D] NR = Not required.
[E] Calculated conversions specified in ASTM D 5800 are allowed.
[F] 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.
[G] This is a non-critical specification as described in ASTM D 3244.
[H] After 10-minute settling period.
[I] After 1-minute settling period.
[J] Shall remain homogeneous and, when mixed with ASTM reference oils, shall remain miscible.
[K] Ten-hour stripped kinematic viscosity at 100°C. Kinematic viscosity must remain in original viscosity grade.
[L] To be evaluated from –5°C to temperature at which 40 000 cP is attained, or 2 Celsius degrees below the appropriate MRV TP-1 temperature (defined by SAE J300), whichever occurs first.

X5. THE ILSAC MINIMUM PERFORMANCE STANDARD FOR PASSENGER CAR ENGINE OILS—ILSAC GF-4 (June 1, 2004)

X5.1 The Japan Automobile Manufacturers Association, Inc. and representatives from DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation, through an organization called the International Lubricants Standardization and Approval Committee (ILSAC), jointly developed and approved an ILSAC GF-4 minimum performance standard for gasoline-fueled passenger car engine oils.

X5.2 This standard specifies the minimum performance requirements (both engine sequence and bench tests) and chemical and physical properties for those engine oils that vehicle manufacturers deem necessary for satisfactory equipment performance and life.

X5.3 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 GF-4 standard. It is also the marketer's responsibility to conduct its business in a manner which represents minimum risk to consumers and the environment.

X5.4 The ultimate assessment of an engine oil's performance must include a variety of vehicle fleet tests which 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.

X5.5 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 which have proven to have satisfactory performance in service, and which are in widespread use at this time. The introduction of base oils or additive technologies which 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.

X5.6 Engine oil compatibility with sealing materials and gaskets is not controlled by performance tests in this specification. However, an SAE Committee on Automotive Rubber Specifications (CARS) has established a slate of reference elastomers (see SAE J2643), which may be used for testing of different base oils and additive technologies which constitute a significant departure from existing materials. The CARS committee has also established an ASTM reference oil (Service Oil 105) which should be considered as an aggressive oil and could also be used as a reference. ILSAC recommends that additive or base oil technologies that exceed the aggression of this reference oil be revised or adequately field tested to ensure no chance of customer seal failures when placed in commercial service.

X5.7 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 above testing of new technology was satisfactorily completed. No marketer can claim to be acting in a reasonable and prudent manner if the marketer knowingly uses a new technology based only on the results of engine sequence testing without verifying the suitability of the new technology in vehicle fleet testing which simulates the full range of customer operation.

X5.8 The ILSAC GF-4 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 which are licensed as ILSAC GF-4 with the API.

X5.9 ILSAC GF-4 Requirements

X5.9.1 *Fresh Oil Viscosity Requirements*:

X5.9.1.1 *SAE J300*—Oils shall meet all of the requirements of SAE J300. Viscosity grades are limited to SAE 0W, 5W, and 10W multigrade oils.

X5.9.1.2 *Gelation Index: ASTM D 5133*—12 maximum. To be evaluated from −5°C to the 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.

X5.9.2 *Engine Test Requirements*:

X5.9.2.1 *Wear and Oil Thickening: ASTM Sequence IIIG Test*:

Kinematic Viscosity Increase @ 40°C, %	150 max
Average Weighted Piston Deposits, merits	3.5 min
Hot Stuck Rings	None
Average Cam plus Lifter Wear, µm	60 max

X5.9.2.2 *Aged Oil Low Temperature Viscosity: ASTM Sequence IIIGA Test*—Evaluate the EOT oil from the ASTM Sequence IIIGA test with ASTM D 4684 (MRV TP-1). The D 4684 viscosity of the EOT sample must meet the requirements of the original grade or the next higher grade.

X5.9.2.3 *Wear, Sludge, and Varnish Test: Sequence VG, ASTM D 6593*:

Average Engine Sludge, merits	7.8 min
Average Rocker Cover Sludge, merits	8.0 min
Average Engine Varnish, merits	8.9 min
Average Piston Skirt Varnish, merits	7.5 min
Oil Screen Sludge, % area	20 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
Follower Pin Wear, cyl #8, avg, μm	Rate and report[A]
Ring Gap Increase, cyl #1 & #8, avg, μm	Rate and report[A]

[A] ASTM Surveillance Panel will review statistics annually.

X5.9.2.4 *Valvetrain Wear: Sequence IVA, ASTM D 6891*—Average Cam Wear (7 position average), μm, 90 max.

X5.9.2.5 *Bearing Corrosion: Sequence VIII, ASTM D 6709*—Bearing Weight Loss, mg, 26 max.

X5.9.2.6 *Fuel Efficiency: Sequence VIB, ASTM D 6837*:

SAE 0W-20 and 5W-20 viscosity grades:
- 2.3 % FEI 1 min after 16 h aging
- 2.0 % FEI 2 min after 96 h aging

SAE 0W-30 and 5W-30 viscosity grades:
- 1.8 % FEI 1 min after 16 h aging
- 1.5 % FEI 2 min after 96 h aging

SAE 10W-30 and all other viscosity grades not listed above:
- 1.1 % FEI 1 min after 16 h aging
- 0.8 % FEI 2 min after 96 h aging

NOTE X5.1—All FEI 1 and FEI 2 values determined relative to ASTM Reference Oil BC.

X5.10 Bench Test Requirements

X5.10.1 *Catalyst Compatibility*:

Phosphorus Content, ASTM D 4951	0.08 % (mass) max
Sulfur Content, ASTM D 4951 or D 2622	
SAE 0W and 5W multigrades	0.5 % (mass) max
SAE 10W multigrades	0.7 % (mass) max

X5.10.2 *Wear*—Phosphorus Content, ASTM D 4951 0.06 % (mass) min.

X5.10.3 *Volatility*:

Evaporation Loss, ASTM D 5800	15 % max, 1 h at 250°C[A]
Simulated Distillation, ASTM D 6417	10 % max at 371°C

[A] Calculated conversions specified in D 5800 are allowed.

X5.10.4 *High Temperature Deposits, ASTM D 7097*— Deposit Weight, mg, 35 max.

X5.10.5 *Filterability*:

EOWTT, ASTM D 6794	
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
Test formulation with highest additive (DI/VI) concentration. Read across results to all other base oil/viscosity grade formulations using the same or lower concentration of the identical additive (DI/VI) combination. Each different DI/VI combination must be tested.	
EOFT, ASTM D 6795	50 % max flow reduction

X5.10.6 *Foaming Characteristics, ASTM D 892 (Option A)*:

	Tendency	Stability[A]
Sequence I	10 mL max	0 mL max
Sequence II	50 mL max	0 mL max
Sequence III	10 mL max	0 mL max

[A] After 10-min settling period.

X5.10.7 *High Temperature Foaming Characteristics, ASTM D 6082 (Option A)*:

Tendency	Stability[A]
100 mL max	0 mL max

[A] After 1-min settling period.

X5.10.8 *Shear Stability, Sequence VIII, ASTM D 6709*—10-h stripped KV @ 100°C. Kinematic viscosity must remain in original SAE viscosity grade.

X5.10.9 *Homogeneity and Miscibility, ASTM D 6922*—Shall remain homogeneous and, when mixed with ASTM reference oils, shall remain miscible.

X5.10.10 *Engine Rusting, Ball Rust Test, ASTM D 6557*—Average Gray Value, 100 min.

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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.