Two-Stroke Tests

Test Description	Typical Cost (U.S. $)	Duration (Hours)	Oil Required (Liters)
Suzuki SX 800 Blocking	3600	Variable	20
Suzuki SX 800 Smoke	2000	2	1
Honda DIO Lubricity	2100	3	1
Honda DIO Detergency	2500	1	1
Honda DIO Severe Detergency	2500	3	1
Piaggio Detergency	5500	20	2
Yamaha Y350M	6600	20	4
Yamaha Y350M2	6600	20	4
Yamaha 50CC Tightening (Lubricity)	3800	12	0.5
Yamaha 50CC—50-Hr Preignition	8000	50	8
Yamaha 50CC Tightening (Lubricity)	3100	20	4
Yamaha CE50S Pre-Ignition (TCW3)	10,000	100	11
OMC 70-HP Detergency (TCW3)	30,000	98	60
Mercury 15-HP (TCW3)	13,400	100	12

APPENDIX 9

Engine Oil Viscosity Classification (SAE J300)

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

SAE J300 REV. DEC1999

Issued 1911-06
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Superseding J300 APR1997

Submitted for recognition as an American National Standard

Engine Oil Viscosity Classification

1. ***Scope***—This SAE Standard defines the limits for a classification of engine lubricating oils in rheological terms only. Other oil characteristics are not considered or included.

2. ***References***

2.1 **Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J510—Lubricants for Two-Stroke-Cycle Engines
SAE J1536—Two-Stroke-Cycle Engine Oil Miscibility/Fluidity Classification

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 97—Standard Test Method for Pour Point of Petroleum Oils
ASTM D 445—Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D 2500—Standard Test Method for Cloud Point of Petroleum Oils
ASTM D 3244—Standard Practice for Utilization of Test Data to Determine Conformance with Specifications
ASTM D 3829—Standard Test Method for Predicting the Borderline Pumping Temperature of Engine Oil
ASTM D 4683—Standard Test Method for Measuring Viscosity at High Temperature and High-Shear Rate by Tapered Bearing Simulator
ASTM D 4684—Standard Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature
ASTM D 4741—Standard Test Method for Measuring Viscosity at High Temperature and High-Shear Rate by Tapered-Plug Viscometer
ASTM D 5133—Standard Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique
ASTM D 5293—Standard Test Method for Apparent Viscosity of Engine Oils Between –30 and –5 °C Using the Cold-Cranking Simulator
ASTM D 5481—Standard Test Method for Measuring Apparent Viscosity at High-Temperature and High-Shear Rate by Multicell Capillary Viscometer

SAE J300 Revised DEC1999

2.1.3 OTHER PUBLICATIONS

CEC L-36-A-90—The Measurement of Lubricant Dynamic Viscosity Under Conditions of High Shear Using the Ravenfield Viscometer
CRC Report No. 409—Evaluation of Laboratory Viscometers for Predicting Cranking Characteristics of Engine Oils at 0 °F and –20 °F, April 1968
Hodges and Rodgers, "Some New Aspects of Pour Depressant Treated Oils," Oil and Gas Journal, p. 89, October 4, 1947
McNab, Rodgers, Michaels, and Hodges, "The Pour Stability Characteristics of Winter Grade Motor Oils," Quarterly Transactions, Society of Automotive Engineers, Inc. Vol. 2, No. 1, p. 34, January 1948

2.2 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

ASTM Data Series DS 62—The Relationship Between High-Temperature Oil Rheology and Engine Operation—A Status Report
ASTM STP 1068—High-Temperature, High-Shear Oil Viscosity—Measurement and Relationship to Engine Operation
ASTM STP 1143—Low-Temperature Lubricant Rheology: Measurement and Relevance to Engine Operation
ASTM Research Report RR-D02-1442—Cold Starting and Pumpability Studies in Modern Engines

3. ***Significance and Use***—The limits specified in Table 1 are intended for use by engine manufacturers in determining the engine oil viscosity grades to be used in their engines, and by oil marketers in formulating, manufacturing, and labeling their products. Oil marketers are expected to distribute only products which are within the relevant specifications in Table 1.

Disputes between laboratories as to whether a product conforms with any specification in Table 1 shall be resolved by application of the procedures described in ASTM D 3244. For this purpose, all specifications in Table 1 are critical specifications to which conformance based on reproducibility of the prescribed test method is required. The product shall be considered to be in conformance if the Assigned Test Value (ATV) is within the specification.

Two series of viscosity grades are defined in Table 1: (a) those containing the letter W and (b) those without the letter W. Single viscosity-grade oils ("single-grades") with the letter W are defined by maximum low-temperature cranking and pumping viscosities, and a minimum kinematic viscosity at 100 °C. Single-grade oils without the letter W are based on a set of minimum and maximum kinematic viscosities at 100 °C, and a minimum high-shear-rate viscosity at 150 °C. The shear rate will depend on the test method used. Multiviscosity-grade oils ("multigrades") are defined by both of the following criteria:

a. Maximum low-temperature cranking and pumping viscosities corresponding to one of the W grades, and
b. Maximum and minimum kinematic viscosities at 100 °C and a minimum high-shear-rate viscosity at 150 °C corresponding to one of the non-W grades.

SAE J300 Revised DEC1999

TABLE 1—SAE VISCOSITY GRADES FOR ENGINE OILS(1)(2)

SAE Viscosity Grade	Low-Temperature (°C) Cranking Viscosity(3), cP Max	Low-Temperature (°C) Pumping Viscosity(4) cP Max with No Yield Stress(4)	Low-Shear-Rate Kinematic Viscosity(5) (cSt) at 100 °C Min	Low-Shear-Rate Kinematic Viscosity(5) (cSt) at 100 °C Max	High-Shear-Rate Viscosity(6) (cP) at 150 °C Min
0W	6200 at –35	60 000 at –40	3.8	—	—
5W	6600 at –30	60 000 at –35	3.8	—	—
10W	7000 at –25	60 000 at –30	4.1	—	—
15W	7000 at –20	60 000 at –25	5.6	—	—
20W	9500 at –15	60 000 at –20	5.6	—	—
25W	13 000 at –10	60 000 at –15	9.3	—	—
20	—	—	5.6	<9.3	2.6
30	—	—	9.3	<12.5	2.9
40	—	—	12.5	<16.3	2.9 (0W-40, 5W-40, and 10W-40 grades)
40	—	—	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	—	—	16.3	<21.9	3.7
60	—	—	21.9	<26.1	3.7

1. Notes—1 cP = 1 mPa•s; 1 cSt = 1 mm^2/s
2. All values are critical specifications as defined by ASTM D 3244 (see text, Section 3.)
3. ASTM D 5293
4. ASTM D 4684: Note that the presence of any yield stress detectable by this method constitutes a failure regardless of viscosity.
5. ASTM D 445
6. ASTM D 4683, CEC L-36-A-90 (ASTM D 4741), or ASTM D 5481.

SAE J300 Revised DEC1999

4. ***Low-Temperature Test Methods***—The low-temperature cranking viscosity is measured according to the procedure described in ASTM D 5293 and is reported in centipoise (mPa·s). Viscosities measured by this method have been found to correlate with the ability of engines to start at low temperature.

The pumping viscosity is a measure of an oil's ability to flow to the engine oil pump and provide adequate oil pressure during the initial stages of operation. The pumping viscosity is measured in centipoise (mPa.s) according to the procedure in ASTM D 4684. This procedure uses the Mini-Rotary Viscometer to measure either the existence of yield stress or the viscosity in the absence of measured yield stress after the sample has been cooled through a prescribed slow cool (so-called TP1) cycle. This cooling cycle has predicted as failures several SAE 10W-30 and SAE 10W-40 engine oils which are known to have suffered pumping failures in the field after short-term (two days or less) cooling. These field failures are believed to be the result of the oil forming a gel structure that results in excessive yield stress and/or viscosity of the engine oil. The significance of the ASTM D 4684 method is projected from the preceding SAE 10W-30 and SAE 10W-40 data.

Limited test work has shown that in a few specific instances, stable pour point (Appendix A, Test Method for Stable Pour Point of Engine Oils), borderline pumping temperature (ASTM D 3829), and/or Scanning Brookfield method (ASTM D 5133) can provide additional information regarding low-temperature performance. It is suggested that these tests be conducted when formulating new engine oils, or when there are significant changes in base oil or additive components of existing products.

Because engine pumping, cranking, and starting are all important at low temperatures, the selection of an oil for winter operation should consider both the viscosity required for successful oil flow, as well as that for cranking and starting, at the lowest ambient temperature expected.

5. ***High-Temperature Test Methods***—Kinematic viscosity at 100 °C is measured according to ASTM D 445, and the results are reported in centistokes (mm^2/s). Kinematic viscosities have been related to certain forms of oil consumption and have been traditionally used as a guide in selecting oil viscosity for use under normal engine operating temperatures. Also, kinematic viscosities are widely used in specifying oils for applications other than in automotive engines.

High-shear-rate viscosity measured at 150 °C and reported in centipoise (mPa·s) is widely accepted as a rheological parameter which is relevant to high-temperature engine performance. In particular, it is generally believed to be indicative of the effective oil viscosity in high-shear components of an internal combustion engine (for example, within the journal bearings and between the rings and cylinder walls) under severe operating conditions. While the specific temperature and shear rate conditions experienced by an oil in a particular application depend on mechanical design and operating parameters, the measurement conditions specified in Table 1 are representative of a wide range of engine operating conditions.

Many commercial engine oils contain polymeric additives for a variety of purposes, one of the most important of which is viscosity modification. Specifically, the use of such additives in creating multigrade oils is commonplace. However, oils containing a significant polymeric additive concentration, whether for viscosity modification or another lubricant function, are generally characterized by having a non-Newtonian, "shear thinning" viscosity (i.e., a viscosity which decreases with increasing shear rate).

To insure that polymer-containing oils do not create a situation in which the viscosity of the oil decreases to less than a specified limit, minimum values of high-shear-rate viscosity are assigned to each of the non-W viscosity grades in Table 1. A special situation exists regarding the SAE 40 grade. Historically, SAE 0W-40, 5W-40, and 10W-40 oils have been used primarily in light-duty engines. These multigrade SAE 40 oils must meet a minimum high-temperature, high-shear-rate viscosity limit of 2.9 cP.

In contrast, SAE 15W-40, 20W-40, 25W-40, and 40 oils have typically been used in heavy-duty engines. The manufacturers of such engines have required high-shear-rate viscosity limits consistent with good engine durability in high-load, severe service applications. Thus, SAE 15W-40, 20W-40, 25W-40, and single-grade 40 oils must meet a minimum high-temperature, high-shear-rate viscosity limit of 3.7 cP.

SAE J300 Revised DEC1999

There are three acceptable methods for the measurement of high-shear-rate viscosity. For rotation viscometer methods ASTM D 4683 and CEC L-36-A-90 (ASTM D 4741), the shear rate is $1.0 \times 10^6\ s^{-1}$. For the capillary viscometer method, ASTM D 5481, the shear rate is $1.4 \times 10^6\ s^{-1}$ at the wall. The latter shear rate has been found to provide high-shear-rate viscosities in the capillary viscometer that are equivalent to those obtained by the rotational viscometer methods.

6. ***Labeling***—In properly describing the viscosity grade of an engine oil according to this document, the letters "SAE" must precede the grade number designation. In addition, for multigrade oil formulations this document requires that the W grade precede the non-W grade, and that the two grades be separated by a hyphen (i.e., SAE 10W-30). Other forms of punctuation or separation are not acceptable.

Most oils will meet the viscosity requirements of at least one of the W grades. Nevertheless, consistent with historic practice, any Newtonian oil may be labeled as a single-grade oil (either with or without a W). Oils which are formulated with polymeric viscosity index improvers for the purpose of making them multiviscosity-grade products are non-Newtonian and must be labeled with the appropriate multiviscosity grade (both W and high-temperature grade). Since each W grade is defined on the basis of maximum cranking and pumping viscosities as well as minimum kinematic viscosities at 100 °C, it is possible for an oil to satisfy the requirements of more than one W grade. In labeling either a W grade or a multiviscosity grade oil, only the lowest W grade satisfied may be referred to on the label. Thus, an oil meeting the requirements for SAE grades 10W, 15W, 20W, 25W, and 30 must be referred to as an SAE 10W-30 grade only.

The intent of the low-temperature portion of SAE J300 is to insure that if oil viscosity is sufficiently low for an engine to crank, the viscosity must also be low enough that the oil will flow after the engine starts. Accordingly, the cranking viscosity is the primary criterion for establishing the W grade. Specifically, an oil must meet the pumping viscosity requirement of the lowest W grade satisfied by the cranking viscosity. If the W grade defined by the pumping viscosity is higher than the lowest grade satisfied by the cranking viscosity, the oil does not meet the requirements of this document and is, therefore, inappropriate for use.

Similarly, the intent of the kinematic viscosity limits for each W grade is to insure that the viscosities of these oils are high enough at engine operating temperatures to provide adequate protection. Thus, if the kinematic viscosity at 100 °C does not meet the requirements of the lowest W grade satisfied by the cranking viscosity, then the oil does not meet the requirements of this document and is, therefore, inappropriate for use.

Some engine oils are prediluted, usually to assist in mixing with fuel when used in certain two-stroke-cycle engines. If any viscosity grade in SAE J300 is used to describe a prediluted engine oil, the grade indicated should relate to the viscosity of the oil in its undiluted state. In displaying SAE J300 viscosity grades of prediluted oils, containers should indicate that the SAE grade applies to the oil in its undiluted state.

More accurately, the rheological properties of two-stroke-cycle engine oils should be identified using the terminology and grades described in SAE J1536. Further information on prediluted oils is also provided in SAE J1510.

7. ***Notes***

7.1 **Marginal Indicia**—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE FUELS AND LUBRICANTS TECHNICAL COMMITTEE 1—
ENGINE LUBRICATION

APPENDIX A

TEST METHOD FOR STABLE POUR POINT OF ENGINE OILS

Preface—Use ASTM D 4684 for the Determination of the Pumpability Viscosity Requirements in Table 1.

When formulating new engine oils or when there are significant changes in base oils or additives, the following stable pour point test method is suggested to check the characteristics of formulated engine oils using as formulation guidelines the previously established limits of –35 °C, max, for SAE 5W oils and –30 °C, max, for SAE 10W oils.

A.1 Scope

A.1.1 The test for stable pour point is primarily intended for use with engine lubricating oils. The potential for applicability to other lubricants is unknown.

A.2 Summary of Method

A.2.1 After preliminary warming, the sample is subjected to a controlled temperature/time cycle over five and one-half to seven days. The cycle was originally established to reproduce pour instability or reversion which has occurred during storage of oils in moderately cold cyclic ambient conditions. More recent work has shown relevance to engine oil pumpability failure. Oils exhibiting pour reversion are essentially "solid" resulting from wax gel formation, at temperatures significantly above their ASTM D 97 pour points.

NOTE— Refer to: McNab, Rodgers, Michaels, and Hodges, "The Pour Stability Characteristics of Winter Grade Motor Oils," Quarterly Transaction, Society of Automotive Engineers, Inc., Vol. 2, No. 1, p. 34, January 1948; Hodges and Rodgers, "Some New Aspects of Pour Depressant Treated Oils," Oil and Gas Journal, October 4, 1947, p. 89.

A.3 Definitions

A.3.1 Pour Stability Temperature—That specified temperature at which oil remains fluid on completion of an established temperature/time cycle.

A.3.2 Stable Pour Point—The lowest temperature at which oil remains fluid when subjected to the specified temperature/time cycle.

A.4 Apparatus

A.4.1 Test Jar—Identical to ASTM D 97 and D 2500 pour point/cloud point test jar.

A.4.2 Thermometer—ASTM E 1 6C with temperature range of +20 to –80 °C.

A.4.3 Cork or Rubber Stoppers—To fit test jar.

A.4.4 Any equipment suitable to heat sample uniformly to precondition test samples.

A.4.5 Cooling Bath—Low temperature with controller to follow temperature/time cycles from +15 to –45 °C. Spacing between test jars is to be about 15 mm with jars suspended so that cooling medium circulates around bottom and sides of jar.

A.4.6 Temperature Recorder—Two channels to record temperatures of bath and sample.

A.5 Procedure

A.5.1 Adjust cooling bath temperature to 15 °C with one temperature sensing bulb in the cooling bath medium.

A.5.2 Prepare two temperature measurement samples as follows:

A.5.2.1 Select a sample oil which is known to be fluid to at least –45 °C.

A.5.2.2 Fill each of two test jars with approximately 60 mL of selected oil sample. Identify these bottles as "Temperature Measurement Sample."

A.5.2.3 Prepare cork stopper to accommodate the standardized calibrated ASTM thermometer.

A.5.2.4 Insert stopper and thermometer into one jar so that thermometer immersion line is visible but not more than 3 mm above top of stopper. Place jar in center of cooling bath.

A.5.2.5 Prepare cork stopper to accommodate recorded temperature sensing bulb.

A.5.2.6 Insert stopper and one temperature sensing bulb in the second jar and position the bulb approximately 7 mm into the control oil sample. Place jar in center of cooling bath next to jar with thermometer.

A.5.2.7 Place the other temperature sensing bulb in cooling bath medium adjacent to the two control sample bottles.

A.5.3 Prepare samples of test oils using clean, dust-free test jars. Fill jar with about 60 mL of test oil.

A.5.4 Pretreat the test oil samples.

A.5.4.1 Heat sample in such a way as to maintain oil temperature at 80 °C for 2 h.

A.5.4.2 After allowing sample to cool to room temperature, stopper the jar with a clean, solid cork or rubber stopper.

A.5.4.3 Place test sample jars in cooling bath adjacent to control sample jars. All samples must be at same level if liquid bath is used.

A.5.5 Prepare bath for cyclic temperature test.

A.5.5.1 Temperature of bath should be 15 °C. Check thermometer and recorded temperature of temperature measurement sample.

A.5.5.2 If liquid bath is used, adjust level in bath to slightly above sample level in test jars.

A.5.5.3 Initiate the temperature cycle as indicated in Tables A1 and A2.

A.5.6 During the final cool down, check proper temperature control each day as follows:

A.5.6.1 Read the "Temperature Measurement Sample" thermometer. Return this sample to the center of the bath.

A.5.6.2 Compare this temperature with the recorded temperature.

A.5.6.3 Determine whether a correction is required in the reading of recorded temperature. Estimate the correct time to make the first pour stability determination at the correct thermometer temperature (±1 °C).

TABLE A1—CYCLE C, SOFT METRICATION

Total Time, h	Time, h	Direction and Temp., °C
0	0	Set at 15 °C
15	15	Down to –22 °C
17	2	Down to –23 °C
19	2	Up to –21 °C
21	2	Up to –18 °C
26	5	Up to –14 °C
31	5	Up to –12 °C
34	3	Up to –11 °C
50	16	at –11 °C
60	10	Up to 0 °C
62	2	At 0 °C
63	1	Down to –1 °C
66	3	Down to –3 °C
69	3	Down to –4 °C
73	4	Down to –5 °C
91	18	At –5 °C
94	3	Down to –6 °C
96	2	Down to –7 °C
168	72	Down to –41 °C

TABLE A2—CYCLE C, READING TIMES ON FINAL DROP

Approx. h to Test	Temperature, °C
91	–5
98	–8
106	–12
113	–15
119	–18
126	–21
132	–24
138	–27
145	–30
152	–33
158	–36
164	–39
168	–41

A.5.7 The stable pour point is determined during the final cool down in the temperature/time cycle as follows:

A.5.7.1 At the sample temperature of –12 °C, carefully remove the test jar vertically from the bath and carefully tilt only enough to ascertain whether the oil surface moves and is "fluid." If movement is detected while tilting, return the bottle to a vertical position and carefully replace in bath. Total time for this operation shall be less than 3 s. Use care in handling jars in and out of bath. Shaking can cause a change in the onset or rate of gelation. Handle jars by cork end only. If frosting occurs, wipe with a rag to prevent heating of sample.

A.5.7.2 If no movement of the oil is detected when the jar is tilted at 90 degrees (horizontal) for 5 s, the sample is "solid." Record the reading of the temperature measurement sample thermometer.

A.5.7.3 For oils which remain fluid, repeat step A.5.7.1 at successively lower temperatures, in 3 °C increments, until no movement of the oil is detected and the oil is "solid" by A.5.7.2, or until temperature cycle is complete.

A.6 Report

A.6.1 Report stable pour point as 3 °C higher than the temperature recorded in A.5.7.2. If the sample is still fluid at –41 °C, report stable pour point as less than or equal to –41 °C.