Designation: ~~D5183 – 05 (Reapproved 2011)~~ D5183 – 05 (Reapproved 2016)

Standard Test Method for Determination of the Coefficient of Friction of Lubricants Using the Four-Ball Wear Test Machine[1]

This standard is issued under the fixed designation D5183; 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.

1. Scope

1.1 This test method covers a procedure for determining the coefficient of friction by means of the Four-Ball Wear Test Machine.[2]

1.2 The values stated in either SI units or in the former cm-kgf metric units are to be regarded separately as the standard. Within the text the cm-kgf units are shown in parentheses. The values stated in each system are not exact equivalents, therefore each system must be used independently of the other. Combining values from the two systems can result in nonconformance to specification.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific warning statements are given in 7.3 – 7.6.

2. Referenced Documents

2.1 *ASTM Standards:*[3]
D4172 Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method)
2.2 *ANSI Standard:*[4]
B3.12 Specification for Metal Balls

3. Terminology

3.1 *Definitions:*
3.1.1 *coefficient of friction, (μ)*—the ratio of the tangential force that is needed to start or to maintain uniform relative motion between two contacting surfaces to the perpendicular force holding them in contact.

4. Summary of Test Method

4.1 Three ~~12.7 mm (0.5 in.)~~ 12.7 mm (0.5 in.) diameter steel balls are clamped together and covered with ~~10 mL~~ 10 mL of the wear-in lubricant. A fourth ~~12.7 mm~~ 12.7 mm diameter ball, referred to as the "top ball" is pressed with a force of ~~392 N (40 kgf)~~ 392 N (40 kgf) into the cavity formed by the three clamped balls for three-point contact. The temperature of the wear-in lubricant is regulated at ~~75°C (167°F),~~75 °C (167 °F), and then, the top ball is rotated at ~~600~~600 r ~~rpm for 60 min.~~/min for 60 min.

4.2 Fluid is discarded and balls cleaned. The wear scar diameter on each of the lower three balls is examined. If the wear scars average ~~0.67 ± 0.03 mm, (0.026 ± 0.001 in.) then the 10 mL~~ 0.67 mm ± 0.03 mm, (0.026 in. ± 0.001 in.) then the 10 mL of test fluid is added to the ball cup with the worn-in test balls in place. The temperature of the test lubricant is regulated at ~~75°C (167°F)~~75 °C (167 °F) and the top ball is rotated at ~~600~~600 r ~~rpm at 98.1 N (10 kgf) for 10 min.~~/min at 98.1 N (10 kgf) for 10 min.

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[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.L0.11 on ~~Tribological~~Tribological Properties of Industrial Fluids and Lubricates.
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[2] The sole source of supply of the Four-Ball Wear Test Machine known to the committee at this time is Falex Corp., 1020 Airpark Dr., Sugar Grove, IL 60554. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[3] 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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

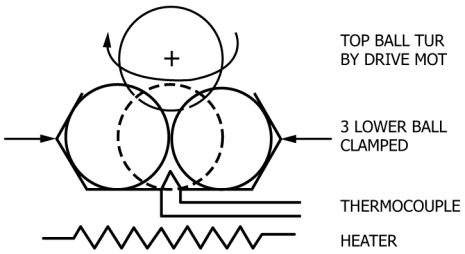

FIG. 1 Schematic of a Four-Ball Wear Test Machine

4.3 The load is then increased by ~~98.1 N (10 kgf)~~ 98.1 N (10 kgf) at the end of each successive ~~10 min~~ 10 min interval up to the point where the frictional trace indicates incipient seizure. The coefficient of friction is measured at the end of each ~~10 min~~ 10 min interval.

5. Significance and Use

5.1 This test method can be used to determine the coefficient of friction of lubricating fluids under the prescribed test conditions. The user of this test method should determine to his own satisfaction whether results of this test method correlate with field performance or other bench test machines.

6. Apparatus

6.1 *Four-Ball Test Machine*[5]—See Figs. 1-3.

NOTE 1—It is important to distinguish between the Four-Ball E.P. and the Four-Ball Wear Test Machine (see Test Method D4172). The Four-Ball E.P. Test Machine is designed for testing under heavier loads and lacks the sensitivity necessary for wear tests.

6.2 *Microscope,*[5]capable of measuring the diameters of the scars produced on the three balls to an accuracy of ~~0.01 mm~~ 0.01 mm without removal from the ball test cup.

6.3 *Test Balls,* chrome alloy steel, made from AISI Standard Steel No. E-52100, with diameter of ~~12.7 mm (0.5 in.)~~ 12.7 mm (0.5 in.) Grade 25 EP (extra polish). Such balls are described in ANSI Specifications B3.12. The extra-polish finish is not described in that specification. The Rockwell C hardness shall be 64 to 66, a closer limit than is found in the ANSI requirement.

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.[6] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Wear-In Lubricant,* white oil having a viscosity at ~~40°C~~40 °C of ~~24.3 to 26.1 cSt (100°F~~ 24.3 cSt to 26.1 cSt (100 °F of 125/135 SUS). It should be percolated through activated alumina to remove any residual impurities.

7.3 *Acetone*—(**Warning—**Flammable. Health hazard.)

7.4 *n-Heptane*—(**Warning—**Flammable. Health hazard.)

7.5 *Methyl ethyl ketone*—(**Warning—**Flammable. Health hazard.)—

7.6 *Pyridine*—(**Warning—**Flammable. Health hazard.)—

8. Preparation of Apparatus

8.1 Set up the drive of the machine to obtain a spindle speed of ~~600~~600 r/min ± ~~30~~ 30 r ~~rpm./~~min.

8.2 Set temperature regulator to produce a test-oil temperature of ~~75~~75 °C ± ~~2°C (167~~2 °C (167 °F ± ~~4°F).~~4 °F).

8.3 If an automatic timer is used to terminate a test, it should be checked for the required ~~±1 min~~ ±1 min accuracy at ~~60 min~~ 60 min elapsed time, and ~~±10 s at 10 min~~ ±10 s at 10 min elapsed time.

[5] The Four-Ball Wear Test Machine and the Falex Multi-Specimen Friction and Wear Test Machine, both made by Falex Corp., 1020 Airpark Dr., Sugar Grove, IL 60554 have been found satisfactory for this purpose. This company can also furnish a microscope with a special base to measure the wear scars without removing the balls from the test-oil cup. Discontinued models of the Four-Ball Wear Test Machine made by Precision Scientific Co. and Roxana Machine Works are also satisfactory.

[6] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For Suggestions on the testing of reagents not listed by the American Chemical Society, see *Annual Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

FIG. 2 Falex Variable—Speed Four-Ball Wear Test Machine

8.4 The loading mechanism should be balanced to a zero reading with all parts and test oil in place. To demonstrate proper precision an addition or subtraction of ~~2.0 N (0.2 kgf)~~ 2.0 N (0.2 kgf) should be detectable in imbalance. Determination of accuracy of loading at ~~147 and 392 N (15 and 40 kgf)~~ 147 N and 392 N (1 kgf5 and 40 kgf) is difficult and generally limited to careful measurement of lever-arm ratios and weights or piston diameter and pressure ~~gage~~gauge calibration.

NOTE 2—Because of differences in the construction of the various machines on which the four-ball can be made, the manufacturer's instructions should be consulted for proper machine set up and operation.

9. Conditioning

9.1 *Test Conditions*—See Table 1.

10. Procedure

10.1 Thoroughly clean four test balls, clamping parts for upper and lower balls and the ball cup by first soaking in heptane for ~~1 min~~ 1 min and then with sonic agitation for ~~10 s.~~ 10 s. Drain and rinse with fresh heptane.

10.1.1 Repeat 10.1 using acetone. Blow dry under a stream of nitrogen gas. After cleaning, handle all parts using only a fresh wipe. No trace of solvent should remain when wear-in lubricant is introduced and the machine assembled.

10.2 Tighten one of the clean balls into the spindle of the test machine.

10.3 Assemble three of the clean balls in the test-oil cup.

10.4 Pour the wear-in lubricant indicated in ~~7.2~~7.2 into the test-oil cup to a level at least ~~3 mm~~ 3 mm (~~⅛ in.~~ in.) above the top of the balls. Observe that this oil level still exists after the lubricant fills all of the voids in the test oil cup assembly.

10.5 Install the test-oil cup/three balls in the machine and avoid shock loading by slowly applying the test load ~~392 N (40 kgf).~~392 N (40 kgf).

10.6 Turn on the heaters and set controls to obtain ~~75~~75 °C ± ~~2°C (167~~2 °C (167 °F ± ~~4°F).~~4 °F). Heater voltage or offset on proportional controllers should be capable of bringing stabilized temperature within the prescribed limits.

10.7 When the test temperature is reached, start the drive motor that was previously set to drive the top ball at ~~600~~600 r/min ± ~~30~~30 r ~~rpm./~~min. Machines with automatic start using a proportional controller will start below the set temperature. Set the proportional band so that test machines start at temperatures ~~2°C (4°F)~~2 °C (4 °F) below the set point temperature.