Designation: D6078 – 04 (Reapproved 2016)

Standard Test Method for Evaluating Lubricity of Diesel Fuels by the Scuffing Load Ball-on-Cylinder Lubricity Evaluator (SLBOCLE)[1]

This standard is issued under the fixed designation D6078; 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 the evaluation of the lubricity (load carrying ability) of diesel fuels using a scuffing load ball-on-cylinder lubricity evaluator (SLBOCLE).

1.2 This test method is applicable to middle distillate fuels, such as Grades Low Sulfur No. 1 D, Low Sulfur No. 2 D, No. 1 D, and No. 2 D diesel fuels, in accordance with Specification D975; and other similar petroleum-based fuels which can be used in diesel engines.

NOTE 1—It is not known that this test method will predict the performance of all additive/fuel combinations. Additional work is underway to further establish this correlation and future revisions of the standard may be necessary once this work is complete.

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

1.4 *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 Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D975 Specification for Diesel Fuel Oils

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination

D5001 Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)

D6079 Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR)

2.2 *American Iron and Steel Institute Standard:*[3]

AISI E-52100 Chromium Alloy Steel

2.3 *American National Standards Institute Standard:*[4]

ANSI B3.12, Metal Balls

2.4 *Society of Automotive Engineers Standard:*[5]

SAE 8720 Steel

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *applied load, n*—the weight in grams added to the load arm of the SLBOCLE unit.

3.1.2 *boundary lubrication, n*—a condition in which the friction and wear between two surfaces in relative motion are determined by the properties of the surfaces and the properties of the contacting fluid, other than bulk viscosity.

3.1.2.1 *Discussion*—Metal-to-metal contact occurs and the chemistry of the system is involved. Physically adsorbed or chemically reacted soft films (usually very thin) support contact loads. As a result some wear is inevitable.

3.1.3 *contact load, n*—the force in grams with which the ball contacts the test ring.

3.1.3.1 *Discussion*—For the SLBOCLE cantilever system the contact load is two times the applied load.

3.1.4 *friction coefficient, n*— tangential friction force divided by the contact load.

3.1.5 *friction trace, n*—a recorded trace of the tangential friction force in grams.

[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.E0 on Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels.

Current edition approved April 1, 2016. Published May 2016. Originally approved in 1997. Last previous edition approved in 2010 as D6078 – 04 (2010). DOI: 10.1520/D6078-04R16.

[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] Available from American Iron and Steel Institute (AISI), 25 Massachusetts Ave., NW, Suite 800, Washington, DC 20001, http://www.steel.org.

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

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

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3.1.6 *lubricity, n*—a qualitative term describing the ability of a fluid to affect friction between, and wear to, surfaces in relative motion under load.

3.1.6.1 *Discussion*—In this test method the lubricity of a fluid is evaluated by the minimum applied load in grams that, at any time during the test, will produce a friction coefficient greater than 0.175 between a stationary ball and a fluid-wetted rotating ring operating under defined conditions.

3.1.7 *scuffing, n—in lubrication*, damage caused by instantaneous localized welding between surfaces in relative motion which does not result in immobilization of the parts.

3.1.8 *scuffing load, n*—the load required to produce scuffing of surfaces.

3.1.8.1 *Discussion*—For this test method the scuffing load is defined in terms of the applied load.

4. Summary of Test Method

4.1 A 50 mL test specimen of fuel is placed in the test reservoir of an SLBOCLE and adjusted to the test temperature of 25 °C.

4.2 When the fuel temperature has stabilized, 50 % relative humidity air is used to aerate the fuel at 0.5 L/min while 3.3 L/min flows over the fuel for 15 min. During the remainder of the test sequence, the 50 % relative humidity air flows over the fuel at a rate of 3.8 L/min.

4.3 A load arm holding a non-rotating steel ball and loaded with a 500 g mass is lowered until it contacts a partially fuel immersed polished steel test ring rotating at 525 r/min. The ball is caused to rub against the test ring for a 30 s break in period before beginning an incremental-load or a single-load test.

4.4 Wear tests are conducted by maintaining the ball in contact with the partially immersed 525 r/min test ring for 60 s. For incremental load tests, the test ring is moved at least 0.75 mm for each new load prior to bringing a new ball into contact with the test ring.

4.5 The tangential friction force is recorded while the ball is in contact with the test ring. The friction coefficient is calculated from the tangential friction force.

4.6 In the incremental-load test, the minimum applied load required to produce a friction coefficient greater than 0.175 is an evaluation of the lubricating properties of the diesel fuel.

4.7 In the single-load test, a friction coefficient less than or equal to 0.175 indicated the diesel fuel passes the lubricity evaluation, while a friction coefficient greater than 0.175 indicated the diesel fuel fails the lubricity evaluation.

5. Significance and Use

5.1 Diesel fuel injection equipment has some reliance on lubricating properties of the diesel fuel. Shortened life of engine components, such as diesel fuel injection pumps and injectors, has sometimes been ascribed to lack of lubricity in a diesel fuel.

5.2 The trend of SLBOCLE test results to diesel injection system pump component distress due to wear has been demonstrated in pump rig tests for some fuel/hardware combinations where boundary lubrication is believed to be a factor in the operation of the component.[6]

5.3 The tangential friction force, as measured in the SLBOCLE test, is sensitive to contamination of the fluids and test materials, the presence of oxygen and water in the atmosphere, and the temperature of the test. Lubricity evaluations are also sensitive to trace contaminants acquired during test fuel sampling and storage.

5.4 The SLBOCLE and High-Frequency Reciprocating Rig (HFRR, Test Method D6079) are two methods for evaluating diesel fuel lubricity. No absolute correlation has been developed between the two test methods.

5.5 The SLBOCLE may be used to evaluate the relative effectiveness of diesel fuels for preventing wear under the prescribed test conditions. If a standard SLBOCLE rating has been set, then the single-load test provides a more rapid evaluation than the incremental load test. Correlation of SLBOCLE test results with field performance of diesel fuel injection systems has not yet been determined.

5.6 This test method is designed to evaluate boundary lubrication properties. While viscosity effects on lubricity in this test method are not totally eliminated, they are minimized.

6. Apparatus

6.1 *Scuffing Load Ball-on-Cylinder Lubricity Evaluator (SLBOCLE):*

6.1.1 The SLBOCLE consists of a fluid reservoir in which a cylinder rotates, a load arm to which a ball is attached, and a hanger to hang a load on the load arm. The SLBOCLE[7,8] illustrated in Fig. 1 and Fig. 2 is identical to the ball-on-cylinder lubricity evaluator (BOCLE) specified in Test Method D5001, except for the modifications in 6.1.2 through 6.1.4. Complete operating conditions are listed in Table 1.

6.1.2 If a standard BOCLE machine is modified, a load cell is included to accurately measure tangential friction force with output to a recording device.[9,8]

6.1.3 If a standard BOCLE machine is modified, a redesigned reservoir cover or splash guards is necessary to prevent loss of fluid from the joint between the reservoir cover and reservoir.[10,8]

6.1.4 If standard BOCLE machine is modified, a heavy-duty pneumatic piston is required to facilitate the increased loads required in the SLBOCLE test.[11,8]

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[6] Nikanjam, M., Crosby, T., Henderson, P, Gray, C., Meyer, K., and Davenport, N., "ISO Diesel Fuel Lubricity Round Robin Program," SAE Paper No. 952372, SAE Fuels and Lubricants Meeting, October 16–19, 1995, Toronto, Canada.

[7] SLBOCLE units, BOC-2000, available from InterAv, P.O. Box 792228, San Antonio, TX 78279, have been found satisfactory.

[8] The sole source of supply of the apparatus known to the committee at this time is provided. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[9] Catalog No. BOC-2040-FFC, available from InterAv, Inc., P.O. Box 792228, San Antonio, TX 78279, has been found satisfactory.

[10] Catalog No. BOC-217-A, available from InterAv, Inc., P.O. Box 792228, San Antonio, TX 78279, has been found satisfactory.

[11] Catalog No. BOC-215-15, available from InterAv, Inc., P.O. Box 792228, San Antonio, TX 78279, has been found satisfactory.

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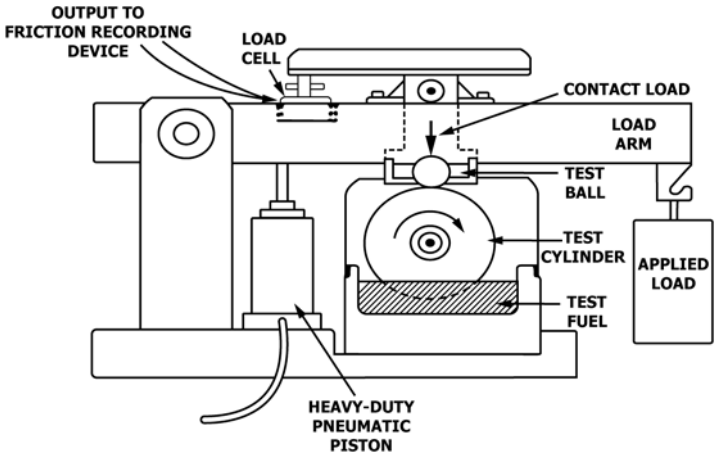

FIG. 1 Schematic Diagram of the Scuffing Load Ball-on-Cylinder Lubricity Evaluator (not including instrumentation)

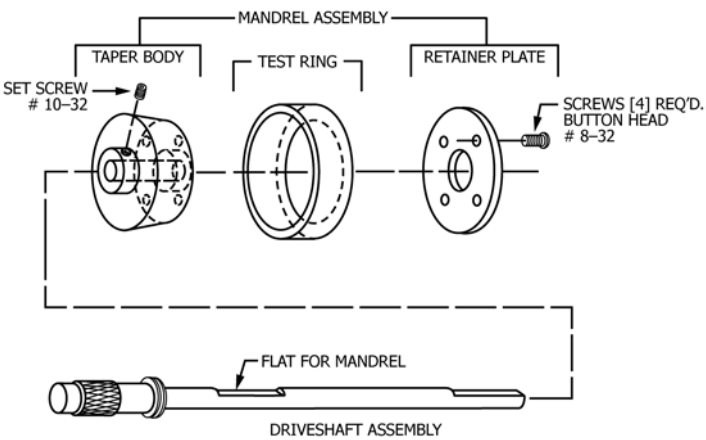

FIG. 2 Ring and Mandrel Assembly (Cylinder)

TABLE 1 Test Conditions

Parameter	Value
Fluid volume	50 mL ± 1.0 mL
Fluid temperature	25 °C ± 1 °C
Conditioned air[A]	50 % ± 1 % relative humidity at 25 °C ± 1 °C
Fluid pretreatment: 0.50 L/ min air flowing through and 3.3 L/min air flowing over the fluid for 15 min	
Fluid test conditions: 3.8 L/min air flowing over the fluid	
Cylinder rotational speed	525 r/min ± 1 r/min
Applied Load	
Break-in period	500 g
Incremental-load test	500 g to 5 000 g
Single-load test	user defined[B]
Test Duration	
Break-in period	30 s
Wear tests	60 s

[A] Fifty percent humidity should be achieved using equal volumes of dry and saturated air. The SLBOCLE has a water column through which air passes and it is assumed to be saturated when it exits this column.
[B] The applied load for the single test is set at the pass/fail requirement for the fuel being evaluated

6.1.5 *Cylinder,* the polished test ring and mandrel assembly. See Fig. 2.

6.1.6 *Mandrel,* a 10° tapered short cylindrical section used for holding test ring.[12,8] See Fig. 2.

6.2 *Constant Temperature Bath Circulator,* capable of maintaining the fluid sample at 25 °C ± 1 °C when circulating coolant through the base of the sample reservoir.

6.3 *Cleaning Bath,* ultrasonic seamless stainless steel tank with adequate capacity and a cleaning power of 40 W or greater.

6.4 One of the containers specified under Containers for Lubricity Testing in Practice D4306 shall be used to store and transport fuel samples.

6.5 *Desiccator,* containing a non-indicating drying agent, capable of storing test rings, balls, and hardware.

7. Reagents and Materials

7.1 *Acetone,* minimum reagent grade purity. (**Warning—** Extremely flammable. Vapors may cause flash fire.)

7.2 *Compressed Air,* containing less than 0.1 ppmv hydrocarbons and 50 ppmv water. (**Warning—**Compressed gas under high pressure. Use with extreme caution in the presence of combustible material.)

7.3 *Gloves,* clean, lint-free, cotton, disposable.

7.4 *Isooctane,* minimum reagent grade purity, 2,2,4-trimethylpentane. (**Warning—**Extremely flammable. Harmful if inhaled. Vapors may cause flash fires.)

7.5 *Isopropyl Alcohol,* minimum reagent grade purity. (**Warning—**Flammable.)

7.6 *Reference Fluids:*

7.6.1 *Fluid A*—High lubricity reference.[13] (**Warning—** Flammable.) Store in clean, borosilicate glass with an aluminum foil-lined insert cap. Store in a dark area.

7.6.2 *Fluid B*—Low lubricity reference.[13] (**Warning—** Flammable. Vapor harmful.)

7.7 *Test Ball,* chrome alloy steel, made from AISI standard steel No. E-52100, with a diameter of 12.7 mm, Grade 5 to 10 EP finish. The balls are described in ANSI Specification B3.12. The extra-polish finish is not described in that specification. The Rockwell hardness "C" scale (HRC) shall be 64 to 66, a closer limit than found in the ANSI requirement.[14,8]

7.8 *Test Ring,* of SAE 8720 steel, having HRC number of 58 to 62 and a surface roughness between 0.04 µm and 0.15 µm after polishing as described in A1.1.[15,8] The dimensions are given in Fig. 3.

[12] Mandrel, Part No. M-O, available from Falex Corp., or P/N BOC-2101, available from InterAv, Inc., P.O. Box 792228, San Antonio, TX 78279, have been found satisfactory.

[13] Reference fluids A and B are available from ASTM Test Monitoring Ctr., 6555 Penn Ave., Pittsburgh, PA 15026–4489.

[14] Test Balls, SKF Swedish, Part No. 310995A, RB 12.7, grade 5 to 10 EP Finish, AISI 52100 Alloy available from SKF Industries, Component Systems, 1690 East Race St., Allentown, PA 90653, when requested with extra polish finish, have been found satisfactory.

[15] Test Rings, Part No. TRXP-6 available from U.S. Army TARDEC Fuels and Lubricants Research Facility, P.O. Drawer 28510, San Antonio, TX 78228–0510 have been found satisfactory. These rings are Part No. F25061 from Falex Corp., 1020 Airpark Dr., Sugar Grove, IL 60554–9585, polished to the required surface finish by the method in Annex A3. Correct surface finish is central to test accuracy.

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