



Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)¹

This standard is issued under the fixed designation D5001; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

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

1. Scope

1.1 This test method covers assessment of the wear aspects of the boundary lubrication properties of aviation turbine fuels on rubbing steel surfaces.

1.1.1 This test method incorporates two procedures, one using a semi-automated instrument and the second a fully automated instrument. Either of the two instruments may be used to carry out the test.

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

1.3 *This standard does not purport to address 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.*

2. Referenced Documents

2.1 ASTM Standards:²

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

D6708 Practice for Statistical Assessment and Improvement of Expected Agreement Between Two Test Methods that Purport to Measure the Same Property of a Material

2.2 Military Specification:³

MIL-I-25017 Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble

2.3 American Iron and Steel Institute Standard:⁴

AISI E-52100 Chromium Alloy Steel

2.4 ISO Standard:⁵

ISO 3290-1:2008 Rolling bearings -- Balls -- Part 1: Steel balls

2.5 Society of Automotive Engineers Standard:⁶

SAE 8720 Steel

3. Terminology

3.1 Definitions:

3.1.1 *lubricity*—qualitative term describing the ability of a fluid to minimize friction between, and damage to, surfaces in relative motion under load.

3.1.1.1 *Discussion*—In this test method, the lubricity of a fluid is defined in terms of a wear scar, in millimeters, produced on a loaded stationary ball from contact with a fluid-wetted rotating cylindrical test ring operating under closely defined and controlled conditions.

3.1.2 *wear scar*—*in the liquid fuels industry*, average diameter of a worn and abraded area, measured in two specified directions, produced on a test ball under defined conditions.

3.1.2.1 *Discussion*—The wear scar generated by Test Method D5001 is often referred to as the BOCLE wear scar.

3.2 Abbreviations:

3.2.1 **BOCLE**—Ball On Cylinder Lubricity Evaluator

3.2.2 **HRC**—Rockwell Hardness “C” scale.

3.2.3 **WSD**—Wear Scar Diameter

4. Summary of Test Method

4.1 The fluid under test is placed in a test reservoir in which atmospheric air is maintained at 10 % relative humidity. A non-rotating steel ball is held in a vertically mounted chuck and forced against the outside diameter of an axially mounted

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.J0.04 on Additives and Electrical Properties.

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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 Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://www.dodssp.daps.mil>.

⁴ Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, <http://www.steel.org>.

⁵ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

⁶ Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

cylindrical steel ring with an applied load. The test ring is rotated at a fixed speed while being partially immersed in the fluid reservoir. This maintains the ring in a wet condition and continuously transports the test fluid to the ball/ring interface. The wear scar generated on the test ball is a measure of the lubricating property of the fluid. For wear scar diameter (WSD) calibration and standardization, see Section 10.

5. Significance and Use

5.1 Wear due to excessive friction resulting in shortened life of engine components such as fuel pumps and fuel controls has sometimes been ascribed to lack of lubricity in an aviation fuel.

5.2 The relationship of test results to aviation fuel system component distress due to wear has been demonstrated for some fuel/hardware combinations where boundary lubrication is a factor in the operation of the component.

5.3 The wear scar generated in the ball-on-cylinder lubricity evaluator (BOCLE) 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 measurements are also sensitive to trace materials acquired during sampling and storage. Containers specified in Practice D4306 shall be used.

5.4 The BOCLE test method may not directly reflect operating conditions of engine hardware. For example, some fuels that contain a high content of certain sulfur compounds can give anomalous test results.

6. Apparatus

6.1 For details of the *Ball-On-Cylinder Lubricity Evaluator (BOCLE)*, apparatus required for each method see: Annex A1 for the semi-automatic method, Annex A2 for the fully automatic method.

6.2 *Microscope*, capable of 100x magnification and suitable of measuring the wear scar on the ball to the nearest 0.01 mm.

6.2.1 *Method of Measuring the Wear Scar*—This may be either a Glass Slide Micrometer, with a scale ruled in 0.01 mm divisions,^{7,8} or a digital micrometer and slide assembly, having a resolution of at least 0.01 mm.^{7,9}

6.3 *Cleaning Bath*—Ultrasonic seamless stainless steel tank with a capacity of 1.9 L and a cleaning power of 40W.

6.4 The test requirements are listed in Table 1.

⁷ 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.

⁸ The sole source of supply of the apparatus known to the committee at this time is Catalog No. 31-16-99 from Bausch and Lomb, Inc., Bausch & Lomb World Headquarters, One Bausch & Lomb Place, Rochester, NY 14604-2701. A certificate of traceability from the National Institute of Standards and Technology is available.

⁹ The sole source of supply of the apparatus known to the committee at this time is Microscope part number ABSMIC from PCS Instruments, 78 Stanley Gardens, London, W3 7SZ, U.K. A certificate of traceability from the National Institute of Standards and Technology is available.

TABLE 1 Standard Operating Conditions

Fluid Volume	50 ± 1.0 mL
Fluid Temperature	25 ± 1°C
Conditioned Air	10 ± 0.2 % relative humidity at 25 ± 1°C
Fluid pretreatment	0.50 L/min flowing through and 3.3 L/min over the fluid for 15 min
Fluid test conditions	3.8 L/min flowing over the fluid
Applied Load	1000 g (500 g weight) (± 1 g)
Cylinder Rotational Speed	240 ± 1 rpm
Test Duration	30 ± 0.1 min

7. Reagents and Materials

7.1 *Test Ring*, of SAE 8720 steel, having a Rockwell hardness “C” scale, (HRC) number of 58 to 62 and a surface finish of 0.56 to 0.71 µm root mean square.^{7,10} The dimensions are given in Fig. 1.

7.2 *Test Balls*, chrome alloy steel, made from AISI standard steel No. E-52100, with a diameter of 12.7 mm, Grade 5 to 10. The balls are described in ISO 3290-1:2008. The HRC shall be 64 to 66, a closer limit than is found in the ISO requirement.

7.3 *Additional Equipment*—Details of additional items of test equipment specific to each test method are given in the appropriate annex.

7.4 *Compressed Air (Warning)*—Compressed gas under high pressure. Use with extreme caution in the presence of combustible material, since the autoignition temperatures of most organic compounds in air are drastically reduced at elevated pressures. See A3.1., containing less than 0.1 ppm hydrocarbons and 50 ppm water.

¹⁰ The sole source of supply of the apparatus known to the committee at this time is (for the semi-automatic method) Test Rings Part No. F25061, Falex Corp., 2055 Comprehensive Drive, Aurora, IL 60505 and (for the fully automatic method) Test Rings, Part No. ABRING, PCS Instruments, 78 Stanley Gardens, London, W3 7SZ, U.K.

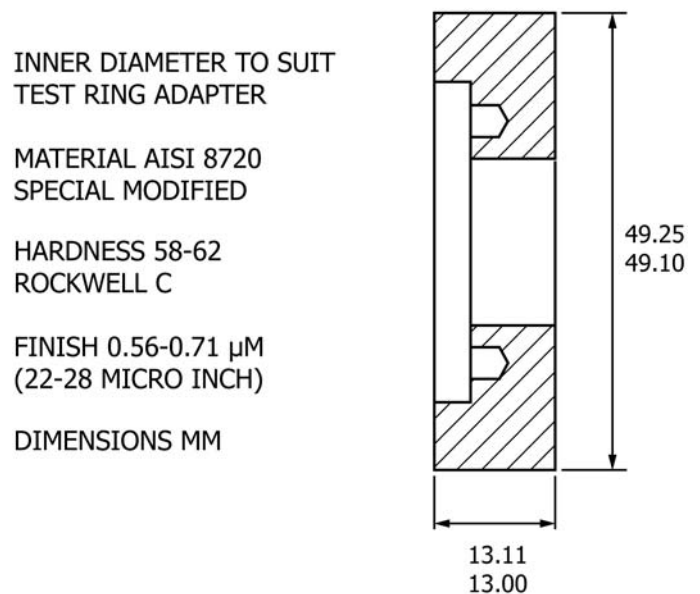


FIG. 1 Ball-on-Cylinder Test Ring

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

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

7.7 *Wiper*, wiping tissue, light duty, lint free, hydrocarbon free, disposable.

7.8 *Isooctane* (**Warning**—Extremely flammable. Harmful if inhaled. Vapors may cause flash fires. See A3.2.), conforming to American Chemical Society (ACS) Reagent/General Purpose Reagent (GPR) grade standards, 95 % purity minimum, 2,2,4-trimethylpentane.

7.9 *Isopropyl Alcohol* (**Warning**—Flammable. See A3.3.), conforming to ACS Reagent/GPR grade standards.

7.10 *Acetone* (**Warning**—Extremely flammable. Vapors may cause flash fire. See A3.4.), conforming to ACS Reagent/GPR grade standards.

7.11 *Reference Fluids*:

7.11.1 *Fluid A*—A mixture shall contain 30 mg/kg of a specific fuel soluble corrosion inhibitor/lubricity improver conforming to MIL-I-25017^{7,11} (**Warning**—Flammable. Vapor harmful. See A3.5.), in fluid B^{7,12} (**Warning**—Flammable. Vapor harmful. See A3.5.).

7.11.2 *Fluid B*—Shall be a narrow-cut isoparaffinic solvent. (**Warning**—Flammable. Vapor harmful. See A3.5.)^{7,12}

7.11.3 The reference fluids shall be stored in epoxy lined containers or borosilicate glass bottles with aluminum foil or PTFE lined insert caps. Borosilicate glass bottles shall be stored in a dark area.

8. Sampling, Test Specimens, and Test Units

8.1 *Cleaning of Apparatus and Test Components*:

8.1.1 *Test Rings, as Received*:

8.1.1.1 The test rings shall be partially stripped of any protective coatings by manually rubbing them with rags or paper towels saturated with isooctane.

8.1.1.2 Place partially cleaned rings in a clean 500 mL beaker. Transfer a sufficient volume of a 1 to 1 mixture of isooctane (2,2,4-trimethyl pentane) and isopropyl alcohol to the beaker such that the test rings are completely covered.

8.1.1.3 Place beaker in ultrasonic cleaner and turn on for 15 min.

8.1.1.4 Remove test rings and repeat ultrasonic cleaning cycle of 8.1.1.3 with a clean beaker and fresh solvents.

8.1.1.5 Handle all clean test rings with clean forceps or disposable gloves. Remove test rings from beaker and rinse with isooctane, dry, and rinse with acetone.

NOTE 1—Drying operations can be accomplished using a compressed air jet at 140 to 210 kPa pressure.

8.1.1.6 Dry and store in a desiccator.

8.1.2 *Test Balls, as Received*.

8.1.2.1 Place balls in 300 mL beaker. Transfer a sufficient volume of a 1 to 1 mixture of isooctane and isopropyl alcohol to the beaker such that the test balls are completely covered by the cleaning solvent.

NOTE 2—Approximately a five-day supply can be processed at one time.

8.1.2.2 Place beaker in ultrasonic cleaner and turn on for 15 min.

8.1.2.3 Repeat the cleaning cycle of 8.1.2.2 with a clean beaker and fresh solvent.

8.1.2.4 Remove and rinse with isooctane, dry, and rinse with acetone.

8.1.2.5 Dry and store in a desiccator.

8.1.3 *Reservoir, Reservoir Cover, Ball Chuck, Lock Ring, Mandrel Assembly (Method A, Semi Automatic Method) Test Ring Assembly (Method B, Fully Automatic Method)*, and all other parts which come into direct contact with the test fuel (refer to the appropriate annex).

8.1.3.1 Rinse with isooctane.

8.1.3.2 Clean in an ultrasonic cleaner with a 1:1 mixture of isooctane and isopropyl alcohol for 5 min.

8.1.3.3 Remove and rinse with isooctane, dry, and rinse with acetone.

8.1.3.4 Store in a desiccator until required.

8.1.4 *Hardware*:

8.1.4.1 The hardware and utensils, that is, any part that comes in contact with the test fluid shall be cleaned by washing thoroughly with isooctane and wiped with a wiper.

8.1.4.2 Store parts in desiccator when not in use.

8.1.5 *After Test*:

8.1.5.1 Remove reservoir and test ring.

8.1.5.2 Disassemble components and clean in an ultrasonic cleaner using a 1 to 1 mixture of isooctane and isopropyl alcohol for 5 min. Rinse with isooctane, dry, and rinse with acetone. Reassemble components.

8.1.5.3 Dry and store in a desiccator.

NOTE 3—When testing the same fluid, it is permissible to clean the reservoir by hand. The reservoir is rinsed with isooctane. Wipe with disposable wiper to remove residual fuel related deposits and test debris. The reservoir is rinsed again with isooctane. Dry and final rinse with acetone, dry.

8.1.5.4 Store parts in desiccator when not in use.

8.1.5.5 *Semi-Automatic (Method A) Only*—Care shall be taken to ensure that the fuel aeration tube is rinsed and dried during the cleaning procedure. Store parts in desiccator when not in use.

9. Preparation of Apparatus

9.1 Use the following procedures, where applicable:

Annex A1 for the semi-automatic method.

Annex A2 for the fully automatic method.

10. Calibration and Standardization

10.1 Visually inspect test balls before each test. Discard balls that exhibit pits, corrosion, or surface abnormalities.

10.2 *Reference Fluids*:

¹¹ The sole source of supply of the apparatus known to the committee at this time is DCI-4A Additive, Innospec Fuel Specialties, 8375 South Willow Street, Littleton, CO 80124.

¹² The sole source of supply of the apparatus known to the committee at this time is ISOPAR M Solvent, Exxon Company, USA, P.O. Box 2180, Houston, TX 77001.

10.2.1 Conduct three tests on each new batch of the reference fluids in accordance with Section 11 using a test ring previously standardized by reference fluid testing.

10.2.2 Repeat the three tests if the wear scar diameters differ by more than 0.04 mm for Reference Fluid A or by more than 0.08 mm for Reference Fluid B.

10.2.3 Reject the reference fluid concerned if the wear scar diameters for the repeat tests (10.2.2) again differ by more than the values obtained in 10.2.1.

10.2.4 Calculate the average wear scar for the three results that are within the values of 10.2.2 for the appropriate Reference Fluid.

10.2.5 Compare the average results with the following Reference Fluid values:

Reference Fluid A 0.56 mm average WSD
Reference Fluid B 0.85 mm average WSD

10.2.6 Reject the new Reference Fluid batch if the average results obtained at 10.2.4 differ by more than 0.04 mm for Reference Fluid A or by more than 0.08 mm for Reference Fluid B from the Reference Fluid values given in 10.2.5.

10.3 Test Ring Calibration:

10.3.1 Test each new ring with Reference Fluid A as per Section 11.

10.3.2 The ring is acceptable if the wear scar diameter result is within 0.04 mm WSD of the Reference Fluid A value shown in 10.2.5.

10.3.3 Repeat the test if the wear scar diameter does not agree within 0.04 mm WSD of the Reference Fluid A value shown in 10.2.5.

10.3.4 Reject the ring if the two values obtained in 10.3.1 and 10.3.3 differ by more than 0.04 mm WSD from each other or if both of the values differ by more than 0.04 mm WSD from the Reference Fluid A value shown in 10.2.5.

10.3.5 Test each new ring with Reference Fluid B as per Section 11.

10.3.6 The ring is acceptable if the wear scar diameter result is within 0.08 mm WSD of the Reference Fluid B value shown in 10.2.5.

10.3.7 Repeat the test if the wear scar diameter does not agree within 0.08 mm WSD of the Reference Fluid B value shown in 10.2.5.

10.3.8 Reject the ring if the two values obtained in 10.3.5 and 10.3.7 differ by more than 0.08 mm WSD from each other or if both of the values differ by more than 0.08 mm WSD from the Reference Fluid B value shown in 10.2.5.

NOTE 4—The BOCLE test result is very sensitive to contamination of the reference fluids, test rings, balls and hardware.

11. Procedure

11.1 The procedure for testing using the semi automatic method is described in Annex A1.

11.2 The procedure for testing using the fully automatic method is described in Annex A2.

12. Calculation and Interpretation of Results

12.1 Wear Scar Measurement:

12.1.1 Turn on the microscope light and position test ball under the microscope at 100× magnification.

12.1.2 Focus the microscope and adjust the stage such that wear scar is centered within the field of view.

12.1.3 Align the wear scar to either a divisional point of reference on the numerical scale with the mechanical stage controls, or the cross hair graticule. Measure the major axis to the nearest 0.01 mm. Ensure that the measurement is taken to include the outermost edge of the wear scar (i.e. include all the wear scar region). Repeat the procedure for the minor axis. Record the readings on the data sheet. Typical wear scars are illustrated in Fig. 2 showing the measurement points.

12.1.4 Record condition of wear area if different from the reference standard test, that is, debris color, unusual particles or wear pattern, visible galling, etc., and presence of particles in the reservoir.

12.2 Wear Scar Calculation:

12.2.1 Calculate the wear scar diameter as follows:

$$WSD = (M + N) / 2 \quad (1)$$

where:

WSD = wear scar diameter, mm,

M = major axis, mm, and

N = minor axis, mm.

13. Report

13.1 Report the following information:

13.1.1 Wear scar diameter to the nearest 0.01 mm (from 12.2),

13.1.2 Description of the wear scar area, and

13.1.3 Deviations from the standard conditions of the test load, relative humidity, and fuel temperature, etc. (Fig. 3).

14. Precision and Bias¹³

14.1 *Precision*—The precision of this test method as obtained by statistical analysis of interlaboratory test results should be used for judging the acceptability of results (95 % of confidence).^{7,13,14} The interlaboratory study was carried out on both the semi-automatic and fully automatic instruments, using 10 fuel samples and 8 participating laboratories.

14.2 *Repeatability*—The difference between successive test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, and in the normal and correct operation of the test method exceed the following values in only one case in twenty:

Semi-automatic method: $0.08311 * X^{1.5832}$ mm
Fully automatic method: $0.08580 * X^{2.5083}$ mm

Where X is the mean wear scar diameter (mm)

¹³ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1639. The following equipment, as listed in RR:D02-1639 was used to develop the precision statement and no statistically significant differences were found between these pieces of equipment (Semi-automatic method: BOCLE units, BOC 100, made by Inter Av, Inc., P.O. Box 792228, San Antonio, TX 78279. Fully automatic method: Automated BOCLE System, ABS, made by PCS Instruments, 78 Stanley Gardens, London, W3 7SZ, U.K.) This listing is not an endorsement or certification by ASTM International.

¹⁴ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1256.

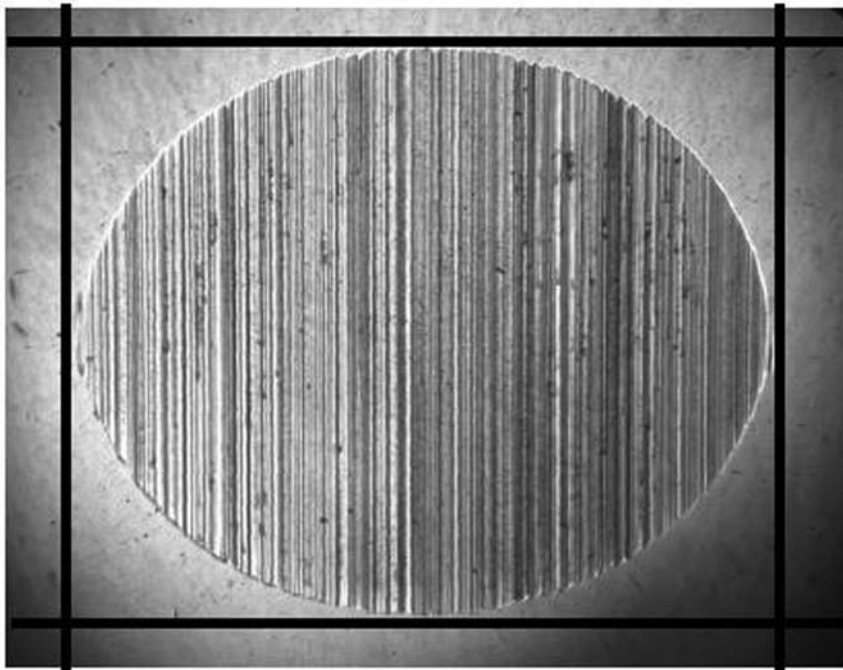
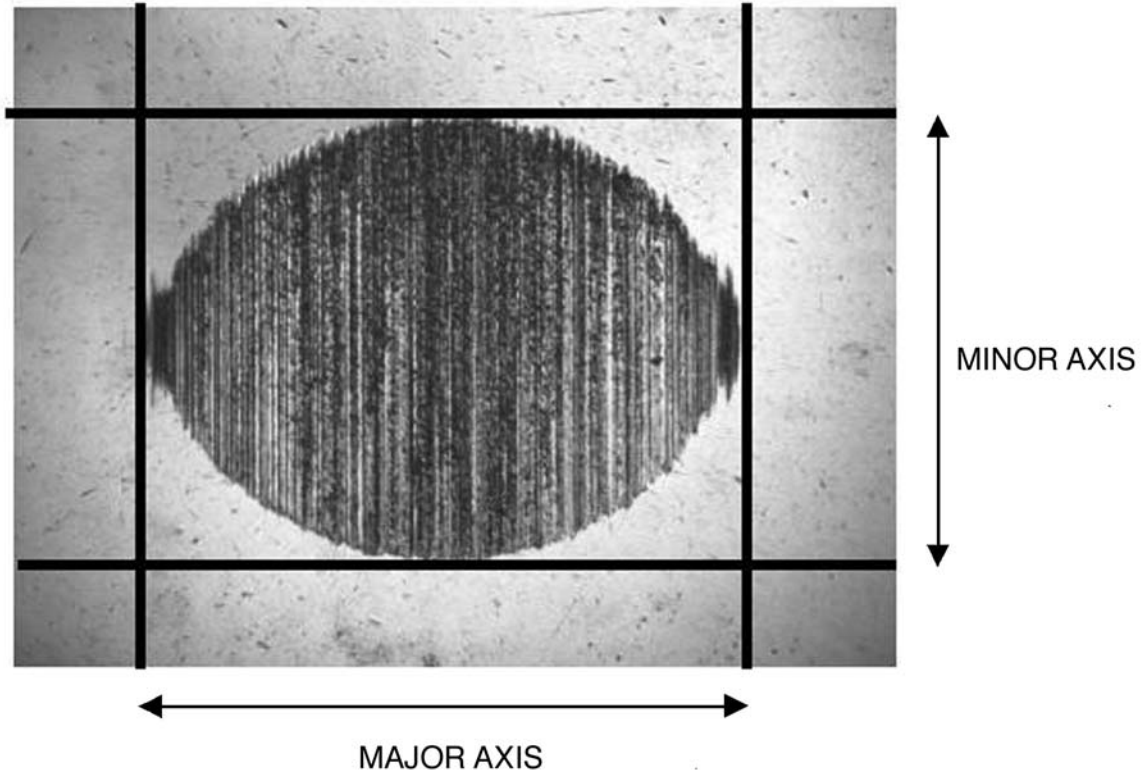


FIG. 2 Typical Wear Scars Showing Measurement Dimensions

Date	_____
ASTM DS001 test ref number	_____
Ring batch ref number	_____
Ball batch ref number	_____
Track number	_____
Operator	_____
Fuel description	_____
Fuel reference	_____
Wear scar major axis (mm)	_____
Wear scar minor axis (mm)	_____
Wear scar average (mm)	_____
Observations	_____

FIG. 3 Data Sheet

14.3 *Reproducibility*—The difference between two single and independent results, obtained by different operators work-

ing in different laboratories on identical test material would, in the long run, and in the normal and correct operation of the test method exceed the following values in only one case in twenty:

Semi-automatic method: $0.1178 * \chi^{1.5832}$ mm
 Fully automatic method: $0.09857 * \chi^{2.5083}$ mm

14.4 *Relative Bias Between the Semi-Automatic and Fully Automatic Test Methods*—There is no statistically significant relative bias between the two methods according to Practice **D6708**.

14.5 *Bias*—The procedure in this test method has no bias because lubricity is not a fundamental and measurable fluid property.

15. Keywords

15.1 aviation turbine fuel; BOCLE; boundary lubrication; jet fuel; lubricity; wear; wear scar

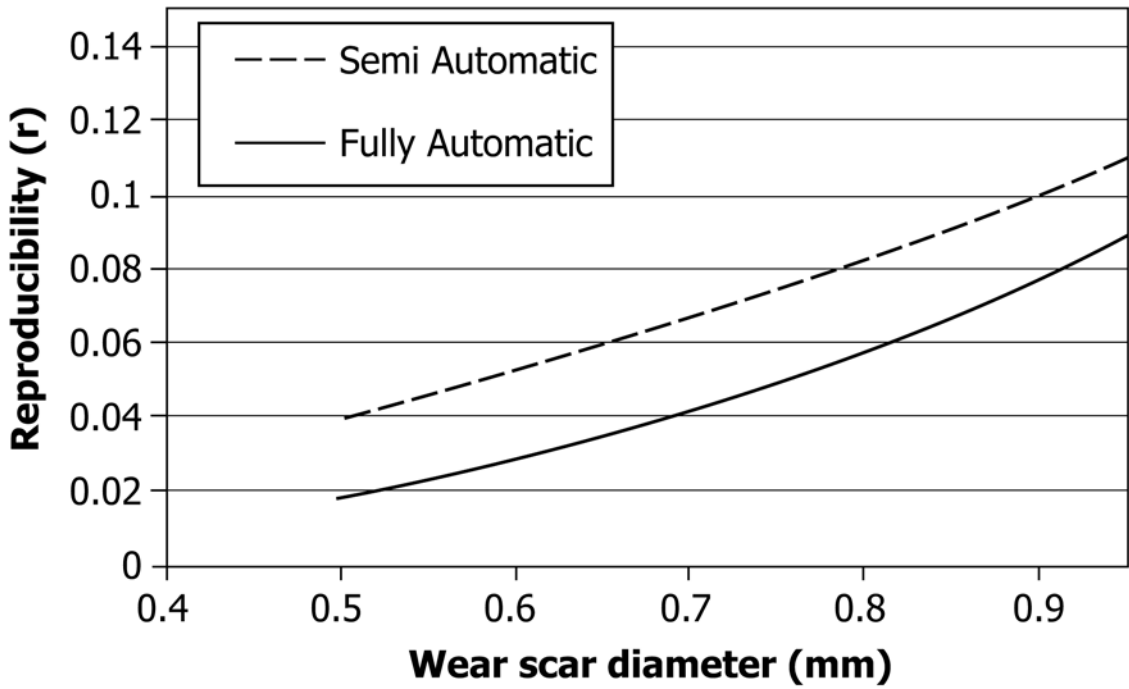
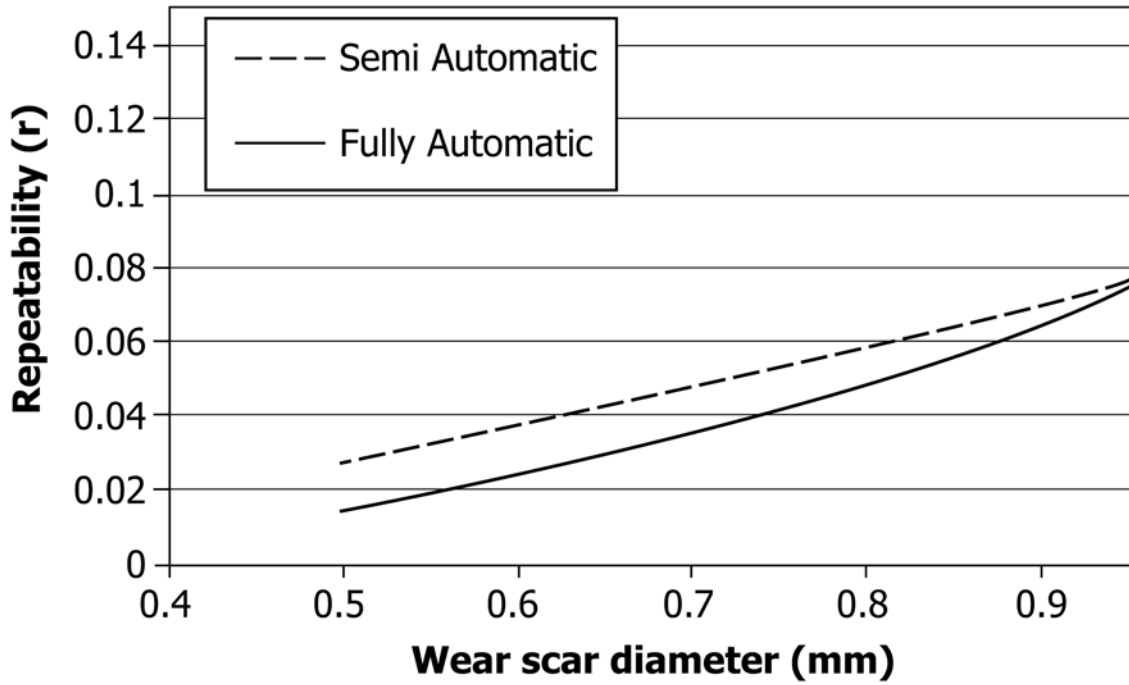


FIG. 4 Test Precision

ANNEXES
(Mandatory Information)
A1. SEMI-AUTOMATIC METHOD
A1.1 Apparatus

A1.1.1 The semi-automatic apparatus shown in **Fig. A1.1**,^{7,15}

A1.1.2 *Mandrel*, a 10° tapered short cylindrical section used for holding test ring. See **Fig. A1.2**.

A1.2 Procedure
A1.2.1 Leveling of Load Arm:

A1.2.1.1 The level of the load arm shall be inspected prior to every test. Level the motor platform by use of the circular bubble level and adjustable stainless steel legs.

A1.2.1.2 Install a test ball in the retaining nut as described in **A1.2.5**.

A1.2.1.3 Lower load arm by disengaging blue pull pin. Attach 500 g weight to end of load beam. Lower ball onto ring manually or by use of arm actuator switch.

A1.2.1.4 Check level on top of load arm. The indicator bubble shall be centered in the middle of the two lines. If required, adjust the retaining nut screw to achieve a level load arm.

A1.2.2 Assembly of Cylinder:

A1.2.2.1 Place a clean test ring on the mandrel and bolt the back plate to the mandrel as shown in **Fig. A1.2**.

A1.2.3 Installation of Cleaned Test Cylinder:

A1.2.3.1 The greatest care shall be taken to adhere strictly to cleanliness requirements and to the specified cleaning procedures. During handling and installation procedures, protect cleaned test parts (cylinder, balls, reservoir, and reservoir cover) from contamination by wearing clean cotton gloves.

A1.2.3.2 Rinse shaft with isooctane and wipe with disposable wiper.

A1.2.3.3 Push the shaft through the left hand bearing and support bracket.

A1.2.3.4 Hold the cylinder with the set screw hub facing left. Push the shaft through the cylinder bore, through the right hand bearing support bracket, and into the coupling as far as the shaft will go.

A1.2.3.5 Align the coupling set screw with the flat keyway side of the cylinder shaft. Tighten set screw.

A1.2.3.6 Set micrometer at 0.5 mm and slide cylinder to the left until it is firm against micrometer probe. Ensure that cylinder set screw is directed toward the keyway (flat surface of shaft) and tighten set screw.

A1.2.3.7 Back micrometer probe away from cylinder before drive motor is engaged.

A1.2.4 Record on the data sheet (**Fig. 3**) the ring number, if assigned, and the position of the test cylinder as indicated by the micrometer. The first and last wear tracks on a ring shall be approximately 1 mm in from either side.

A1.2.4.1 For subsequent tests, reset cylinder to a new test position with the micrometer. The new position is to be 0.75 mm from the last wear track on the ring and noted on the data sheet. After tightening the cylinder set screw to lock the cylinder in a new test position, the micrometer probe should be backed off, then advanced to the cylinder again. Check micrometer reading to ensure correct track spacing. Readjust position, if required. When the correct ring position is ensured, back the micrometer probe away from the cylinder.

A1.2.5 Install a clean test ball by first placing the ball in the retaining nut, followed by the blue retaining ring. Screw retaining nut onto the threaded chuck located on the load arm and hand tighten.

A1.2.6 Secure the load beam in the UP position by insertion of the blue pin.

A1.2.7 Install the clean reservoir. Install the blue spacing platform by raising the reservoir. Slide blue spacer platform into position under the reservoir. Place thermocouple in the hole provided at the rear left side of the reservoir.

A1.2.8 Check load beam level. Adjust, if necessary.

A1.2.9 Supply test fluid in accordance with Practice **D4306**. Transfer 50 ± 1 mL of the test fluid to the reservoir. Place cleaned reservoir cover in position and attach the ¼ and ⅛-in. air lines to reservoir cover.

A1.2.10 Move power switch to ON position.

A1.2.11 Turn on compressed air cylinder. Adjust the delivery pressure to 210 to 350 kPa and the console air pressure to approximately 100 kPa.

A1.2.12 Place arm lift actuator switch in the UP position.

A1.2.13 Lower load beam by pulling blue pull pin. Hang a 500 g weight on end of load beam to give an applied load of 1000 g.

A1.2.14 Start rotation of cylinder by switching motor drive to ON. Set rotation to 240 ± 1 r/min.

A1.2.15 Using the flow meters that control the wet and dry air flows, adjust conditioned air flow to read 3.8 L/min. Maintain 10.0 ± 0.2 % relative humidity.

A1.2.16 Adjust reservoir temperature as required until temperature stabilizes at 25 ± 1°C. Adjust thermostat of the heat exchanger circulating bath to obtain the required temperature.

A1.2.17 Set fuel aeration timer for 15 min and adjust fuel aeration flowmeter to 0.5 L/min.

¹⁵ The sole source of supply of the apparatus known to the committee at this time is BOC 100 BOCLE units, InterAv, Inc., P.O. Box 792228, San Antonio, TX 78279. Other units built to the drawings available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA, meeting the test requirements of **Table 1** in accordance with the procedure of 32 of Guidelines for Equipment Supply, Listing, and Replacement in ASTM Committee D02 methods and practices are considered acceptable. These units can have different operating procedures.

A1.2.18 At completion of aeration, the whistle will sound and aeration will cease. Continue 3.8 L/min flow through the reservoir. Move arm lift actuator switch to DOWN position. In approximately 8 s the load arm will be lowered and the ball will gently make contact with the ring. Switch timer ON for 30 min.

NOTE A1.1—The rate at which the load arm lowers is controlled by the arm lift actuator valve on the left side of the cabinet. This valve controls the bleed from the pneumatic arm lift actuator cylinder.

A1.2.19 Check all test condition readouts and adjust as necessary. Record all necessary information on data sheet.

A1.2.20 At the end of the 30 min, the whistle will sound and the test load arm will automatically spring up. Turn timer to OFF and move arm lift actuator switch to UP position.

A1.2.21 Manually remove test weight. Lift test load arm up and secure with blue pull pin.

A1.2.22 Remove reservoir cover and wipe revolving ring with a disposable wiper to remove residue from the test ring. Turn motor drive and power switch to OFF.

A1.2.23 Remove test ball from locking nut. Do not remove ball from blue retaining ring. Wipe ball clean with disposable wiper prior to microscopic examination.



FIG. A1.1 Semi-Automatic Ball-on-Cylinder Lubricity Evaluator

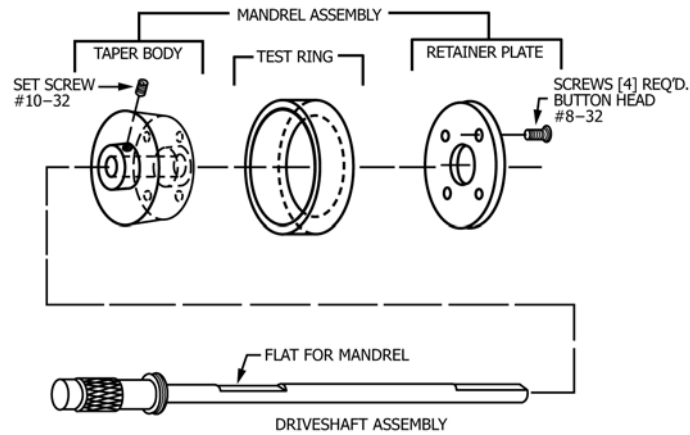


FIG. A1.2 Semi-Automatic Ring Mandrel Assembly

A2. FULLY AUTOMATIC METHOD

A2.1 Apparatus

A2.1.1 The fully automatic apparatus is shown in Fig. A2.1.^{7,16}

A2.2 Procedure

A2.2.1 Turn on instrument—wait for the self test to complete.

A2.2.2 Rinse shaft with isooctane and wipe with disposable wiper.

A2.2.3 The axial position of the test ring is set by a numbered spacer. Only one spacer should be positioned on the main shaft at any time. When starting with a new test ring this will be spacer number 1. Each subsequent test on that ring uses the next spacer in sequence until all 10 have been used or the ring is discarded for some other reason. Select the correct spacer for the test ring.

A2.2.4 The greatest care shall be taken to adhere strictly to cleanliness requirements and to the specified cleaning procedures. During handling and installation procedures, protect cleaned test parts (test ring, balls, reservoir, reservoir cover and other hardware in contact with the test fluid) from contamination by wearing clean gloves.

A2.2.5 Fit the correct axial spacer and then slide the test ring adaptor in place on the main shaft. The two pins on the adaptor face outward from the instrument.

A2.2.6 Place the test ring onto the adaptor. The recessed side of the ring with the two drive holes face towards the

instrument. Rotate the test ring until the two pins on the adaptor locate in the two holes in the test ring.

A2.2.7 Place the test ring clamp washer in place on the end of the shaft and insert the test ring retaining screw.

A2.2.8 Using the supplied tools, restrain the test ring and tighten the retaining screw. Fig. A2.2 shows a view of the items to be assembled on the shaft.

A2.2.9 Place the cleaned fuel bath in position on the fuel bath platform. Supply test fluid in accordance with Practice D4306. Transfer 50 ± 1 mL of the test fluid to the reservoir.

A2.2.10 Raise the fuel bath to the test position and fit the fuel bath cover and attach the large and small air pipes.

A2.2.11 Insert the temperature probe in the hole in the reservoir.

A2.2.12 Using forceps or gloves, place the test ball in the cup of the ball holder. Fit the securing collet and use the supplied tool to restrain the ball holder and hand tighten the collet.

A2.2.13 Locate the test ball holder in the hole in the load arm and attach the securing screw. Hand tighten the securing screw.

A2.2.14 Lower the load arm so that the ball holder enters the hole in the top of the fuel bath cover.

A2.2.15 Attach the 500 g load weight to the end of the load arm to give an applied load of 1000 g.

A2.2.16 With the D5001 option selected, press “Start” on the keypad.

A2.2.17 The instrument carries out the test sequence automatically. The test duration is between 45-50 min depending on the ambient temperature.

A2.2.18 At the end of the test, remove test weight. Lift test load arm up.

¹⁶ The sole source of supply of the apparatus known to the committee at this time is Automated BOCLE System (ABS), made by PCS Instruments, 78 Stanley Gardens, London, W3 7SZ, U.K. Other units built to the drawings available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA, meeting the test requirements of Table 1 in accordance with the procedure of 3.2 of Guidelines for Equipment Supply, Listing, and Replacement in ASTM Committee D02 methods and practices are considered acceptable. These units can have different operating procedures.



FIG. A2.1 Fully Automatic Ball-on-Cylinder Lubricity Evaluator

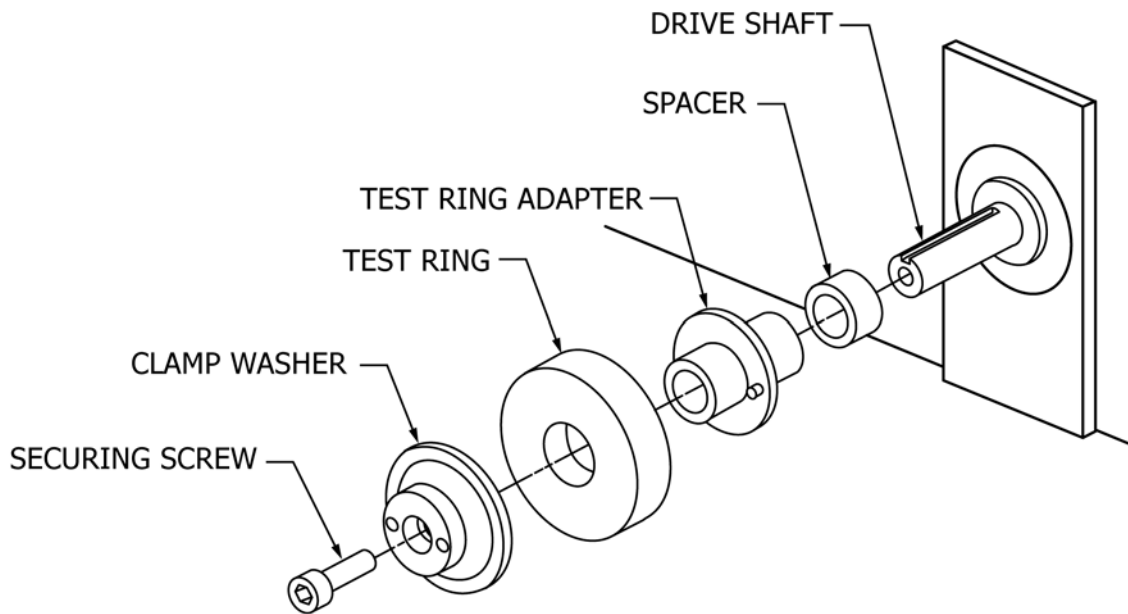


FIG. A2.2 Test Ring Assembly (Fully Automatic Method)

A2.2.19 Remove reservoir cover and wipe revolving ring with a disposable wiper to remove residue from the test ring.

A2.2.20 Remove the test ball collet assembly from the load arm. Do not remove the ball from the test ring collet. Wipe ball clean with disposable wiper prior to microscopic examination.

A3. PRECAUTIONARY STATEMENTS

A3.1 Compressed Air (Cylinder)

A3.1 Keep cylinder valve closed when not in use.

Always use a pressure regulator. Release regulator tension before opening cylinder.

Do not transfer to cylinder other than one in which air is received. Do not mix gases in cylinder.

Do not drop cylinder. Make sure cylinder is supported at all times.

Stand away from cylinder outlet when opening cylinder valve.

Keep cylinder out of sun and away from heat.

Keep cylinders from corrosive environment.

Do not use cylinder without label.

Do not use dented or damaged cylinders.

For technical use only. Do not use for inhalation purposes.

A3.2 Isooctane

A3.2 Keep away from heat, sparks, and open flames.

Keep container closed.

Use with adequate ventilation.

Avoid build-up of vapors and eliminate all sources of ignition, especially nonexplosion-proof electrical apparatus and heaters.

Avoid prolonged breathing of vapor or spray mist.

Avoid prolonged or repeated skin contact.

A3.3 Isopropyl Alcohol

A3.3 Keep away from heat, sparks, and open flame.

Keep container closed.

Use with adequate ventilation.

Avoid prolonged breathing of vapor or spray mist.

Avoid contact with eyes and skin.

Do not take internally.

A3.4 Acetone

A3.4 Keep away from heat, sparks, and open flame.

Keep container closed.

Use with adequate ventilation.

Avoid build-up of vapors, and eliminate all sources of ignition, especially nonexplosion-proof electrical apparatus and heaters.

Avoid prolonged breathing of vapor of spray mist.

Avoid contact with eyes or skin.

A3.5 Isoparaffinic Solvent and Fuel Additive

A3.5 Keep away from heat, sparks, and open flame.

Keep container closed.

Use with adequate ventilation.

Avoid breathing vapor or spray mist.

Avoid prolonged or repeated contact with skin.

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