Designation: D 5001 – 03

An American National Standard

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 D 5001; 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 assessment of the wear aspects of the boundary lubrication properties of aviation turbine fuels on rubbing steel surfaces.

1.2 The values stated in SI units are to be regarded as the 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.* Specific warning statements are given in Section 7 and Annex A1.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 329 Specification for Acetone

D 770 Specification for Isopropyl Alcohol

D 1016 Test Method for Purity of Hydrocarbons from Freezing Points

D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination

2.2 *Military Specification:*

MIL-I-25017, Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble[3]

2.3 *American Iron and Steel Institute Standard:*

AISI E-52100 Chromium Alloy Steel[4]

2.4 *American National Standards Institute Standard:*

ANSI B3.12, Metal Balls[5]

2.5 *Society of Automotive Engineers Standard:*

SAE 8720 Steel[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *cylinder*—the test ring and mandrel assembly.

3.1.2 *lubricity*—a general term used to describe the boundary lubrication properties of a fluid. In this test method, the lubricity of a fluid is defined in terms of a wear scar, in millimetres, produced on a stationary ball from contact with the fluid-wetted rotating cylinder operating under closely defined and controlled conditions.

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 an axially mounted steel ring with an applied load. The test cylinder is rotated at a fixed speed while being partially immersed in the fluid reservoir. This maintains the cylinder in a wet condition and continuously transports the test fluid to the ball/cylinder interface. The wear scar generated on the test ball is a measure of the fluid lubricating properties.

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

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J0 on Aviation Fuels.

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This test method was developed by the Coordinating Research Council and is a part of their report No. 560.

[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

[4] Available from American Iron and Steel Institute (AISI), 1101 17th St., NW, Suite 1300, Washington, DC 20036.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[6] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

FIG. 1 Ball-on-Cylinder Lubricity Evaluator

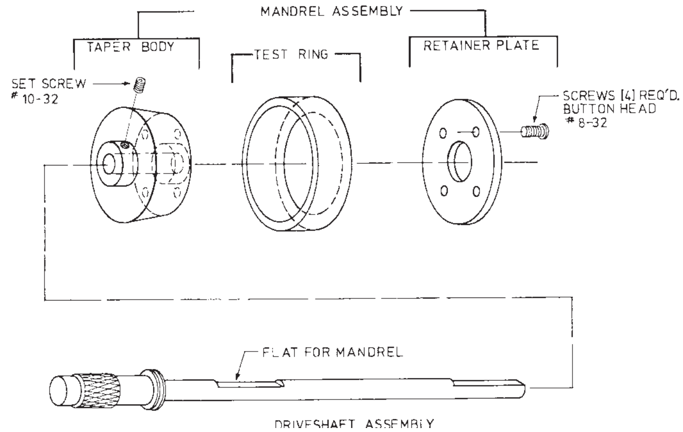

FIG. 2 Ring Mandrel Assembly

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)
Cylinder Rotational Speed	240 ± 1 r/min
Test Duration	30 ± 0.1 min

measurements are also sensitive to trace materials acquired during sampling and storage. Containers specified in Practice D 4306 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 may give anomalous test results.

6. Apparatus

6.1 *Ball-On-Cylinder Lubricity Evaluator (BOCLE)*, illustrated in Fig. 1 and Fig. 2. The test requirements are listed in Table 1.[7]

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

6.3 *Microscope*, capable of 100× magnification in graduations of 0.1 mm and incremented in divisions of 0.01 mm.

6.3.1 *Glass Slide Micrometer*, with a scale ruled in 0.01 mm divisions.[8,9]

6.4 *Cleaning Bath*—Ultrasonic seamless stainless steel tank with a capacity of 1.9 L (½ gal) and a cleaning power of 40 W.

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 (22 to 28 µin.) root mean square. The dimensions are given in Fig. 3.[9,10]

7.2 *Mandrel*, a 10° tapered short cylindrical section used for holding test ring.[9,11] See Fig. 2.

7.3 *Test Ball*, chrome alloy steel, made from AISI standard steel No. E-52100, with a diameter of 12.7 mm (0.5 in.) grade 5 to 10 EP finish. The balls are described in ANSI Specifications B 3.12. The extra-polish finish is not described in that specification. The HRC shall be 64 to 66, a closer limit than is found in the ANSI requirement.[9,12]

[7] BOCLE units, BOC 100, made by InterAv, Inc., P.O. Box 792228, San Antonio, TX 78279 have been found satisfactory. 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.

[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. A certificate of traceability from the National Institute of Standards and Technology is available.

[9] 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.

[10] The sole source of supply of the apparatus known to the committee at this time is Test Rings, Part No. F25061 from Falex Corp., 2055 Comprehensive Drive, Aurora, IL 60505.

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

[12] The sole source of supply of the apparatus known to the committee at this time is Test Balls, SKF Swedish, part No. 310995A, RB 12.7, grade 5 to 10 EP Finish, AISI 52100 Alloy from SKF Industries, Component Systems, 1690 East Race Street, Allentown, PA 90653.

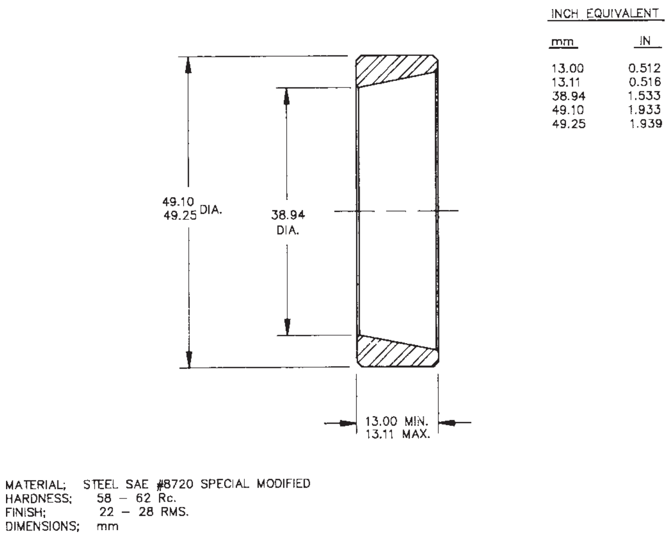

FIG. 3 BOCLE Test Ring

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 A1.1.), containing less than 0.1 ppm hydrocarbons and 50 ppm water.

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 A1.2.), conforming to Test Method D 1016, 95 % purity minimum, 2,2,4-trimethylpentane.

7.9 *Isopropyl Alcohol* (**Warning**—Flammable. See A1.3.), conforming to Specification D 770.

7.10 *Acetone* (**Warning**—Extremely flammable. Vapors may cause flash fire. See A1.4), conforming to Specification D 329.

7.11 *Reference Fluids:*[9,13]

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[9,14] (**Warning—**Flammable. Vapor harmful. See A1.5.), in fluid B[9,15] (**Warning**—Flammable. Vapor harmful. See A1.5.).

7.11.2 *Fluid B*—Shall be a narrow-cut isoparaffinic solvent (**Warning**—Flammable. Vapor harmful. See A1.5.).[9,15]

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

8. Preparation of Apparatus

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 wax-like protective coatings by manually rubbing them with rags or paper towels saturated with *iso*octane.

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 *iso*octane 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 *iso*octane, dry, and rinse with acetone.

NOTE 1—Drying operations can be accomplished using a compressed air (7.4) jet at 140 to 210 kPa (20 to 30 psi) 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 *iso*octane 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 *iso*octane, dry, and rinse with acetone.

8.1.2.5 Dry and store in a desiccator.

8.1.3 *Reservoir, Reservoir Cover, Ball Chuck, Ball Lock Ring, and Ring Mandrel Assembly Components*:

8.1.3.1 Rinse with *iso*octane.

8.1.3.2 Clean in an ultrasonic cleaner with a 1 to 1 mixture of *iso*octane and isopropyl alcohol for 5 min.

8.1.3.3 Remove and rinse with *iso*octane, dry, and rinse with acetone.

8.1.3.4 Dry and store in a desiccator.

8.1.4 *Hardware*:

8.1.4.1 The hardware and utensils, that is, shaft, wrenches, and tweezers, that come in contact with the test fluid shall be cleaned by washing thoroughly with *iso*octane 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 cylinder.

8.1.5.2 Disassemble components and clean in an ultrasonic cleaner using a 1 to 1 mixture of *iso*octane and isopropyl

[13] The sole source of supply of the apparatus known to the committee at this time is Reference Fluids A and B available in Kit form as part No. RF-930900 from InterAv Inc., P.O. Box 792228, San Antonio, TX 78279.

[14] The sole source of supply of the additive known to the committee at this time is DCI-4A, manufactured by E. I. DuPont de Nemours and Company, 1007 Market Street, Wilmington, DE 19898.

[15] The sole source of supply of the solvent known to the committee at this time is ISOPAR M, manufactured by the Exxon Company, USA, P.O. Box 2180, Houston, TX 77001.

alcohol for 5 min. Rinse with *iso*octane, 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 in-place. The reservoir is rinsed with *iso*octane. Wipe with disposable wiper to remove residual fuel related deposits and test debris. The reservoir is rinsed again with *iso*octane. Dry and final rinse with acetone, dry.

8.1.5.4 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. Calibration and Standardization

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

9.2 *Reference Fluids*:

9.2.1 Conduct three tests on each new batch of the reference fluids, in accordance with Section 10, using a cylinder previously standardized by reference fluid testing.

9.2.2 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.

9.2.3 Reject the Reference Batch concerned if the wear scar diameters for the repeat tests again differ by more than the values obtained in 9.2.1.

9.2.4 Calculate the average wear scar for the three results that are within the values of 9.2.2 for the appropriate Reference Fluid.

9.2.5 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

9.2.6 Reject the new Reference Fluid batch if the average results obtained at 9.2.4 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 9.2.5.

9.3 *Test Ring Calibration*:

9.3.1 Test each new ring with Reference Fluid A as per Section 10.

9.3.2 The ring is acceptable if the wear scar diameter result is within 0.04 mm WSD of the Reference Fluid A value shown in 9.2.5.

9.3.3 Repeat the test if the wear scar diameter does not agree within 0.04 mm WSD of the Reference Fluid A value shown in 9.2.5.

9.3.4 Reject the ring if the two values obtained in 9.3.1 and 9.3.3 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 9.2.5.

9.3.5 Test each new ring with Reference Fluid B as per Section 10.

9.3.6 The ring is acceptable if the wear scar diameter result is within 0.08 mm WSD of the Reference Fluid B value shown in 9.2.5.

9.3.7 Repeat the test if the wear scar diameter does not agree within 0.08 mm WSD of the Reference Fluid B value shown in 9.2.5.

9.3.8 Reject the ring if the two values obtained in 9.3.5 and 9.3.7 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 9.2.5.

9.4 *Leveling of Load Arm*:

9.4.1 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.

9.4.2 Install a test ball in the retaining nut as described in 10.4.

9.4.3 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.

9.4.4 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.

9.5 *Assembly of Cylinder*:

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

10. Procedure

10.1 The summary of test conditions is included in Table 1.

10.2 *Installation of Cleaned Test Cylinder*:

NOTE 4—The BOCLE is very sensitive to contamination problems.

10.2.1 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.

10.2.2 Rinse shaft with *iso*octane and wipe with disposable wiper.

10.2.3 Push the shaft through the left hand bearing and support bracket.

10.2.4 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.

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

10.2.6 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.

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

10.3 Record on the data sheet (Fig. 4) 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.

10.3.1 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.

Ball-On-Cylinder Lubricity Evaluator Date________________

Sample:

Ring No. ____________ Track No. ____________ Ball No.____________

Ambient temperature, °C	____________
Base temperature, °C start	____________
Base temperature, °C end	____________
Base temperature controlled (Y/N)	____________
Precondition Reservoir, time	____________
Start test, time	____________
Test air humidity	10
Ring speed, r/min	240
Applied load, g	1000
Volume fuel used, mL	____________

Type scar: Elliptical Circular Other

Minor axis, mm	__________
Major axis, mm	__________
WSD, mm	__________

Observations:____

FIG. 4 Data Sheet

10.4 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.

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

10.6 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.

10.7 Check load beam level. Adjust, if necessary.

10.8 Supply test fluid in accordance with Practice D 4306. 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.

10.9 Move power switch to ON position.

10.10 Turn on compressed air cylinder. Adjust the delivery pressure to 210 to 350 kPa (30 to 50 psi) and the console air pressure to approximately 100 kPa (14.5 psi).

10.11 Place arm lift actuator switch in the UP position.

10.12 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.

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

10.14 Using the flowmeters 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.

10.15 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.

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

10.17 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.

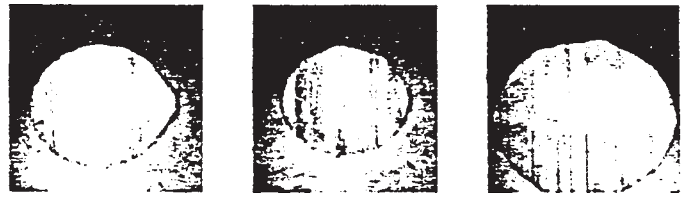

FIG. 5 Typical BOCLE Wear Scars

NOTE 5—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.

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

10.19 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.

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

10.21 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.

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

11. Measure of the Wear Scar

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

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

11.3 Align the wear scar to a divisional point of reference on the numerical scale with the mechanical stage controls. Measure the major axis to the nearest 0.01 mm. Typical wear scars are illustrated in Fig. 5. Record the readings on the data sheet.

11.4 Align the wear scar to a divisional point of reference on the numerical scale with the mechanical stage controls. Measure the minor axis to the nearest 0.01 mm. Record the readings on the data sheet.

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

12. Calculation

12.1 Calculate the wear scar diameter as follows:

$$WSD = (M + N)/2 \tag{1}$$

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, 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, and so forth.

14. Precision and Bias

14.1 *Precision*[16]—The precision was developed for fuels with a wear scar diameter between 0.45 and 0.95 mm. The precision of this test method determined by the statistical examination of interlaboratory test results[17] according to RR: D02-1007 Manual on Determining Precision Data is as follows:

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

$$\text{repeatability} = 0.109\,(WSD)^{1.80} \tag{2}$$

14.1.2 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories on identical test material would, in the long run, exceed the following values in only one case in twenty.

$$\text{reproducibility} = 0.167\,(WSD)^{1.80} \tag{3}$$

14.2 *Bias*—The procedure in this test method has no bias because the value of lubricity can be defined only in terms of a test method.

15. Keywords

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

[16] The precision statement was determined using the materials listed in Footnotes 11, 12, 13, 14, 15, and 16. Other test materials may not agree with this precision statement.

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

ANNEX

(Mandatory Information)

A1. WARNING STATEMENTS

A1.1 Compressed Air (Cylinder)

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.

A1.2 *Iso*octane

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.

A1.3 Isopropyl Alcohol

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.

A1.4 Acetone

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.

A1.5 Isoparaffinic Solvent and Fuel Additive

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.