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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~~

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.* ~~Specific warning statements are given in Section 7 and Annex A1.~~

2. Referenced Documents

2.1 *ASTM Standards:* [2]

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

D 6708 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:*

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

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

2.3 *American Iron and Steel Institute Standard:*

~~AISI E-52100Chromium Alloy Steel~~ [4]

AISI E-52100 Chromium Alloy Steel

2.4 *American National Standards Institute Standard:*

~~ANSI B3.12,Metal Balls~~

[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.J0.04 on Additives and Electrical Properties.

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

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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), 1101 17th St., NW, Suite 1300, Washington, DC 20036.~~

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

***A Summary of Changes section appears at the end of this standard.**

[5]

ANSI B3.12 Metal Balls

2.5 *Society of Automotive Engineers Standard:*[6]

SAE 8720 Steel

3. Terminology

~~3.1*Definitions of Terms Specific to This Standard:*~~

3.1 *Definitions:*

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.~~ —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 D 5001 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

~~4.1The~~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 cylindrical steel ring with an applied load. The test ~~cylinder~~ring is rotated at a fixed speed while being partially immersed in the fluid reservoir. This maintains the ~~cylinder~~ring in a wet condition and continuously transports the test fluid to the ~~ball/cylinder~~ball/ring interface. The wear scar generated on the test ball is a measure of the ~~fluid~~ lubricating ~~properties.~~ property of the fluid. For wear scar diameter (WSD) calibration and standardization, see Section 9~~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 D 4306shall 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~~can 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.~~

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 ~~*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.~~ capable of 100× 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

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

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

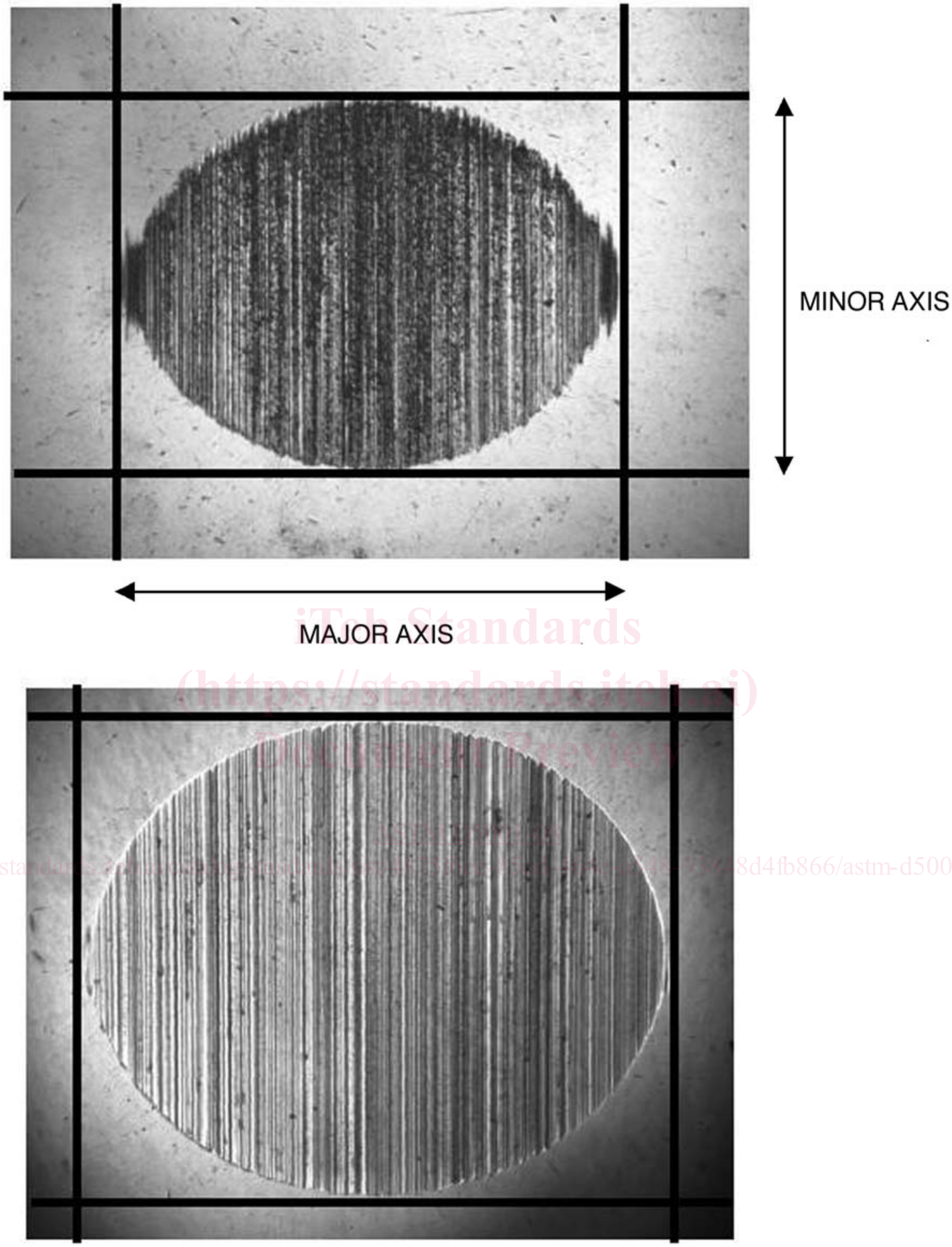


FIG. 2 Typical Wear Scars Showing Measurement Dimensions

divisions,[7,8] or a digital micrometer and slide assembly, having a resolution of at least 0.01 mm.[7,9]

~~6.4~~

6.3 *Cleaning Bath*—~~Ultrasonic seamless stainless steel tank with a capacity of 1.9 L (½ gal) and a cleaning power of 40 W.~~ —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. 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]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 ~~*Mandrel*, a 10° tapered short cylindrical section used for holding test ring.~~[9] 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.[7,11] ~~See Fig. 2.~~ The balls are described in ANSI Specifications B3.12. 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.

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 B3.12. 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].~~

~~7.4~~*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 ~~A1.1~~A3.1.), 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] 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 Table1 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.~~

[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, 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] 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 , which you may attend.~~

[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.

~~[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.~~

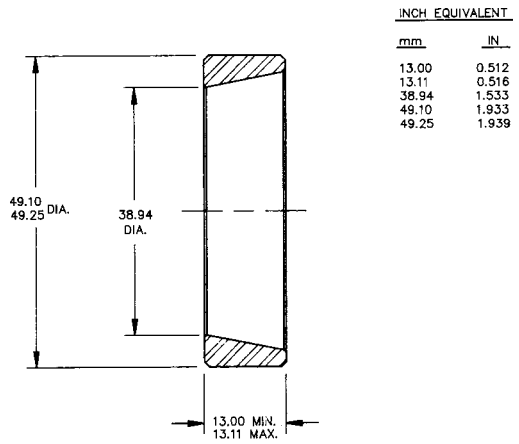
[10] The sole source of supply of the apparatus known to the committee at this time is (for the semi-automatic method) Test Rings Part No. F25061, Falex Corp., 2055 Comprehensive Drive, Aurora, IL 60505 and (for the fully automatic method) Test Rings, Part No. ABSRING, PCS Instruments, 78 Stanley Gardens,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

~~[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.~~

[11] The sole source of supply of the apparatus known to the committee at this time is (for the semi-automatic method) 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 and (for the fully automatic method) Test Balls, Part No. ABSBALL from PCS Instruments, 78 Stanley Gardens, London, W3 7SZ, U.K.

TABLE 1 Standard Operating Conditions

Fluid Volume	50 ± 1.0 mL
Fluid Temperature	25 ± 1°C
~~Conditioned Air~~	~~10 ± 0.2 % relative humidity~~
Conditioned Air	10 ± 0.2 % relative humidity at 25 ± 1°C
	~~a t 25 ± 1°C~~
Fluid pretreatment	0.50 L/min flowing through and 3.3 L/min over the fluid for 1~~°C~~
5 min	
~~Fluid pre treatment 0.50 L/min flowing through and 3.3 L/min~~	
Fluid test condition~~g through and 3.3 L/min~~	
s	~~over the fluid for 15 min.~~
~~Fluid test conditions~~3.8 L/min flowing over the fluid.	
Fluid test conditions3.8 L/min flowing over the fluid	
~~Applied Load~~	~~1000 g (500 g weight)~~
Applied Load	1000 g (500 g weight) (± l g)
~~Cylinder Rotational Speed~~	~~240 ± 1 r/min~~
Cylinder Rotational Speed	240 ± 1 rpm
Test Duration	30 ± 0.1 min



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 ~~BOCLE T~~Data Sheset ~~Ring~~

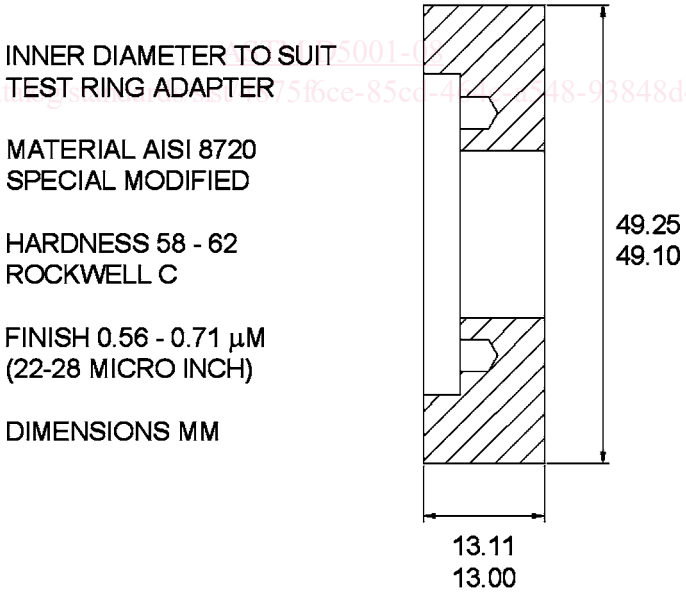


FIG. 1 Ball-on-Cylinder Test Ring

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~~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 A1.3~~ (**Warning—**Flammable. See A3.3.), conforming to ACS Reagent/GPR grade standards.

7.10 *Acetone* (**Warning—**Extremely flammable. Vapors may cause flash fire. See ~~A1.4~~A3.4.), conforming to ACS Reagent/GPR grade standards.

7.11 ~~*Reference Fluids:*~~[9] 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[7,12] (**Warning—**Flammable. Vapor harmful. See ~~A1.5~~A3.5.), in fluid B[7] ~~(**Warning**—Flammable. Vapor harmful. See A1.5~~[13] (**Warning—**Flammable. Vapor harmful. See A3.5.).

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

~~7.11.3The 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.~~ —Shall be a narrow-cut isoparaffinic solvent. (**Warning—**Flammable. Vapor harmful. See A3.5.)[7,13]

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. ~~Preparation of Apparatus~~ 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 ~~wax-like~~ protective coatings by manually rubbing them with rags or paper towels saturated with ~~isooctane.~~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~~ isooctane (2,2,4-trimethyl pentane) and isopropyl alcohol to the beaker such that the test rings are completely ~~covered.)~~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,~~isooctane, 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 ~~isooctane~~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,~~isooctane, 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*~~:

~~8.1.3.1Rinse with *iso*octane.~~

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

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

~~8.1.3.4Dry and store in a desiccator.~~ 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, ~~shaft, wrenches, and tweezers,~~ any part that comes in contact with the test fluid shall be cleaned by washing thoroughly with ~~isooctane~~isooctane and wiped with a wiper.

8.1.4.2 Store parts in desiccator when not in use.

8.1.5 *After Test*:

~~[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.~~

[12] 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.

~~[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.~~

[13] 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.