Designation: D2625 – 94 (Reapproved 2010)

Standard Test Method for Endurance (Wear) Life and Load-Carrying Capacity of Solid Film Lubricants (Falex Pin and Vee Method)[1]

This standard is issued under the fixed designation D2625; 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 Department of Defense.

1. Scope

1.1 This test method (see Note 1) covers the determination of the endurance (wear) life and load-carrying capacity of dry solid film lubricants in sliding steel-on-steel applications.

NOTE 1—Reference may be made to Coordinating Research Council, Inc. (CRC) Report No. 419, "Development of Research Technique for Measuring Wear Life of Bonded Solid Lubricant Coatings for Airframes, Using the Falex Tester." See also Military Specification MIL-L-8937 (ASG), Jan. 22, 1963, and Methods 3807 and 3812 of Federal Test Method 791a.

1.2 The values stated in SI units are to be regarded as the standard except where equipment is supplied using inch-pound units and would then be regarded as standard. The metric equivalents of inch-pound units given in such cases in the body of the standard may be approximate.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B16/B16M Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines

F22 Test Method for Hydrophobic Surface Films by the Water-Break Test

2.2 *U.S. Military Specifications:*[3]

MIL-L-8937

MIL-P-16232F Phosphate Coatings, Heavy, Manganese or Zinc Base (for Ferrous Metals)

2.3 *Other Standards:*[4]

42USC7671a Clean Air Act Amendments of 1990

Federal Test Method 791a Methods 3807 and 3812

3. Terminology

3.1 *Definitions:*

3.1.1 *dry solid film lubricants*—dry coatings consisting of lubricating powders in a solid matrix bonded to one or both surfaces to be lubricated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *direct load, n*—the load that is applied linearly, bisecting the angle of the vee block corrected to either the 800-lbf (3550-N) gauge reference or the 3000-lbf (13 300-N) gauge reference.

3.2.1.1 *Discussion*—This load is equivalent to the true load times the cos 42°.

3.2.2 *endurance (wear) life*—the length of test time before failure under a constant loaded condition, in minutes, in which the applied test lubricant performs its function.

3.2.3 *gauge load, n*—the value obtained from the gauge while running the test after being corrected to the standard curve using the calibration procedure for the 4500-lbf (20 000-N) reference gauge.

3.2.3.1 *Discussion*—The gauge reading is irrespective of the particular gauge used, and corrections are made by comparison to the Brinell ball impression diameters on a standard reference copper test coupon with a Rockwell hardness range of HB 37 to HB 39. An electronic calibration instrument[5] is available which can be used in place of the copper coupon.

3.2.4 *load carrying capacity*—the highest indicated load sustained for a minimum of 1 min.

[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.L0.05 on Solid Lubricants.

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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://dodssp.daps.dla.mil.

[4] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[5] Trademark of and available from Falex Corp., 1020 Airpark Dr., Sugar Grove, IL 60554. A new model of the Falex Pin and Vee Block Test Machine has been available since 1983. Certain operating procedures are different for this new model. Consult instruction manual of machine for this information. 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.

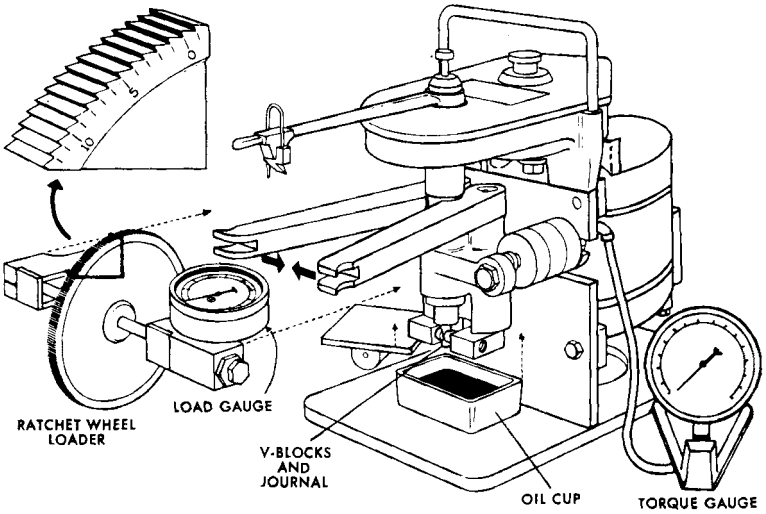

FIG. 1 Schematic Diagram of Falex Pin and Vee Block Test Machine

4. Summary of Test Method

4.1 The endurance test (Procedure A) consists of running two stationary steel vee block specimens loaded to a predetermined value against a rotating steel pin specimen. The endurance (wear) life is determined when the torque increases by 10 in·lbf (1.13 N·m).

4.2 The load-carrying capacity test (Procedure B) consists of running two stationary steel vee block specimens against a rotating steel pin, increasing the load on the pin until a sharp increase (10 in·lbf (1.13 N·m)) in steady-state torque or pin breakage is experienced. Prior to both tests, the solid film lubricant is deposited on the surfaces of the test specimens.

5. Significance and Use

5.1 This test method differentiates between bonded solid lubricants with respect to their wear life and load-carrying capacity. If the test conditions are changed, wear life may change and relative ratings of the bonded solid film lubricants may be different.

6. Apparatus

6.1 *Falex Pin and Vee Block Test Machine,*[5] illustrated in Fig. 1 and Fig. 2.

6.1.1 *Load Gauge,*[5] 4500-lbf (20 000-N) range, or 3000-lbf (13 300-N) direct-reading gauge. An 800-lbf (3550-N) direct-reading load gauge may be used for Procedure A, but does not have a high enough load range for Procedure B.

NOTE 2—Primary figures for loads are shown for the 4500-lbf (20 000-N) gauge. Equivalent readings on either 800 or 3000-lbf (3550 or 13 300-N) direct-reading gauges are shown in parentheses and can be obtained from the curve in Fig. 3.

6.1.2 *Optional*—An automatic cutoff, torque recorder, and timer may be used in place of the standard indicating torque gauge.

6.2 *Required for Calibration of Load Gauge*:

6.2.1 *Standardized Test Coupon,*[5] soft, annealed copper HB 37/39.

6.2.2 *Allen Screw,*[5] with attached 10-mm Brinell ball.

6.2.3 *Back-up Plug.*[5]

6.2.4 *Brinell Microscope*, or equivalent.

6.2.5 *Rule*, steel, 150 mm (6 in.) long.

6.2.6 *Timer*, graduated in minutes and seconds.

6.3 *Required for Application of Dry Solid Film Lubricants-* (see Annex A1):

6.3.1 *Desiccator*, for storing test parts. The bottom of the desiccator shall be filled with desiccant to maintain approximately 50 % relative humidity. (Not required if parts can be stored in a fume-free room at 50 ± 5 % relative humidity.)

6.3.2 *Forced-Circulation Oven*, capable of maintaining a temperature of 149 ± 5°C (300 ± 10°F).

6.3.3 *Micrometer*, reading 0 to 25 ± 0.0025 mm (0 to 1 ± 0.0001 in.), with a one-ball anvil.

6.3.4 *Vapor Degreasing Bath.*

7. Reagents and Materials

7.1 *Required for Procedures A and B*:

7.1.1 *Eight Standard Vee Blocks,*[5] 96 ± 1° angle, heat treated to 1.24×10^9 to 1.38×10^9 Pa (180 000 to 200 000 psi) tensile strength; or standard coined vee blocks, 96 ± 1° angle, of AISI C-1137 steel as an alternative, with a Rockwell hardness of HRC 20 to 24 and surface finish of 1.3×10^{-7} to 2.5×10^{-7} m (5 to 10 µin.), rms.

7.1.2 *Four Standard Test Pins,*[5] 6.35-mm (¼-in.) outside diameter by 31.75 mm (1¼ in.) long, heat treated to 1.24×10^9 to 1.38×10^9 Pa (180 000 to 200 000 psi) ultimate hardness; or Standard No. 8 Pins of AISI 3135 steel as an alternative, with a hardness of HRB 87 to 91, on a ground, flat surface (or approximately HRB 80 to 83 on the round), and a surface finish of 1.3×10^{-7} to 2.5×10^{-7} m (5 to 10 µin.) rms.

7.1.3 *Locking (Shear) Pin,*[5] ½ H Brass, conforming to Specification B16/B16M.

7.2 *Required for Application of Dry Solid Film Lubricant-* (see Annex A1):

7.2.1 *Phosphate Coating*, manganese, conforming to Military Specification MIL-P-16232F, Type M, Class 3 controlled to a coating weight of 16 to 22 g/m^2.

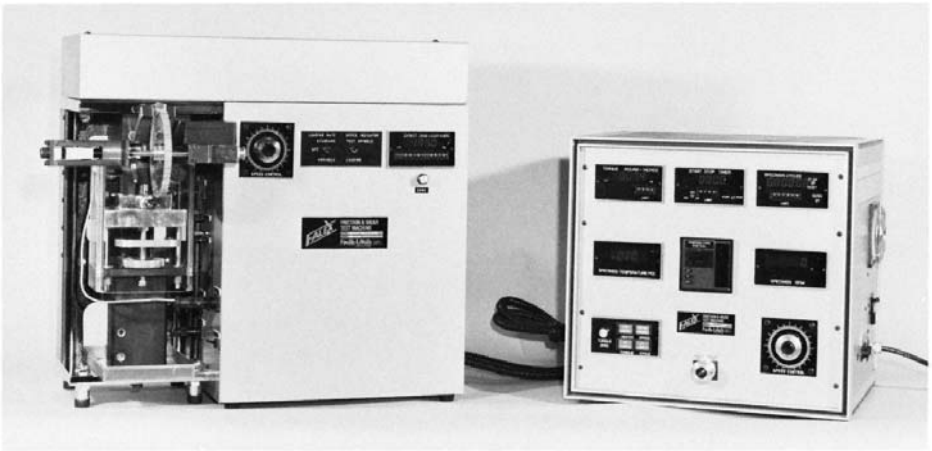

FIG. 1 Digital Pin and Vee Block Test Machine *(continued)*

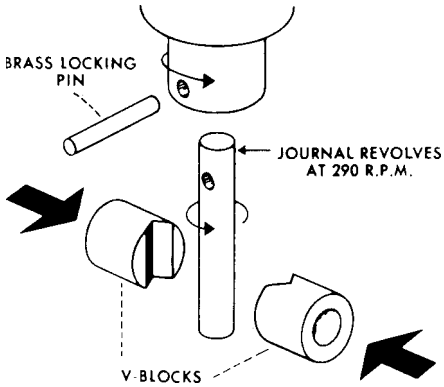

FIG. 2 Exploded View of Vee Blocks and Journal Arrangement, Falex Pin and Vee Block Test Machine

NOTE 3—Lack of rigid control of the phosphate coating weight can significantly impact the data scatter. A film controlled to the minimum range is preferred over the uncontrolled standard heavy phosphate originally called out.

7.2.2 *Cleaners*—Select a cleaning media and method which is safe, non-film forming and which does not in any way attack or etch the surface chemically. In addition, no Class 1 ozone depleting substances conforming to Section 602(a) of the Clean Air Act Amendments of 1990 (42USC7671a) as identified in Section 326 of PL 102-484 should be used. Use a procedure as outlined in Test Method F22 to judge the merit of the selected cleaning technique.

NOTE 4—A typical solvent found acceptable for this purpose is Stoddard solvent.

7.2.2.1 No method of cleaning can be judged as acceptable unless there is a valid method of judging the success or failure of the cleaning method. Test Method F22 is a simple procedure that can be used on the actual test apparatus or on test coupons to judge each cleaning method's viability.

7.2.3 *Aluminum Oxide*, white angular abrasive, 180 grit to 220 grit.

8. Preparation of Apparatus

8.1 Thoroughly clean the jaw supports for the vee blocks and test journals, by washing with the solvent selected from 7.2.2, of all debris or oil from previous test runs. See Note 4.

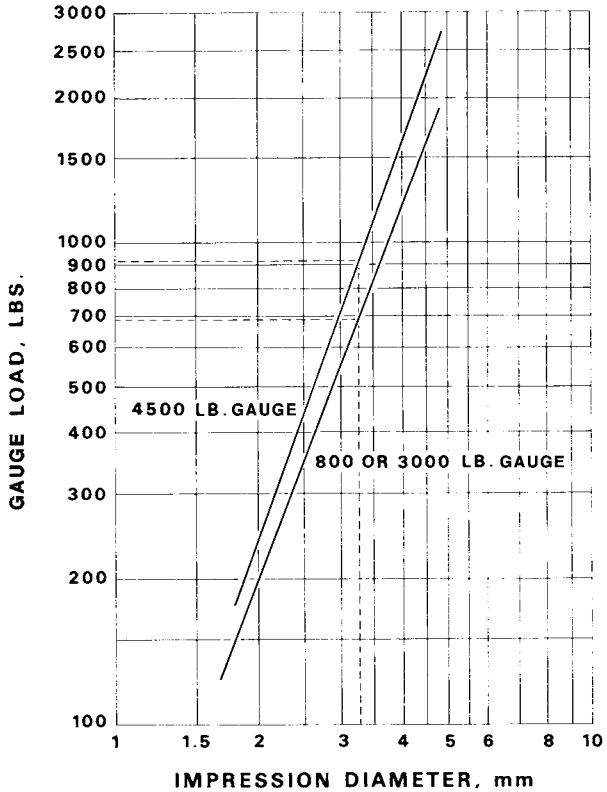

FIG. 3 Standard Curves for Load Gauge Calibration or Conversion, Brinell Impression Diameter versus Gauge Load Reading, Using Standard Copper Test Coupon of HB 37/39

8.2 Avoid contact with the fingers of the mating surfaces of the vee blocks and test pins.

8.3 Avoid atmospheric contamination such as cigarette smoke, as this can adversely affect the test results.

9. Calibration of Load Gauge

9.1 *Calibration Procedure with 4500-lbf (20 000-N) Load Gauge*:

9.1.1 Remove the Allen set screw and 12.70-mm (½-in.) ball from the left jaw socket (Fig. 4).

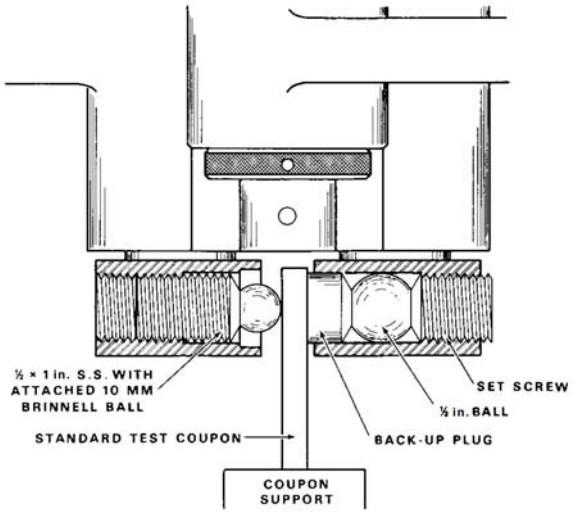

FIG. 4 Schematic Drawing of Calibration Accessories for Falex Pin and Vee Block Test Machine

9.1.2 Insert the special Allen screw with the attached 10-mm Brinell ball into the working face of the left jaw. Adjust so that the ball projects about 4 mm (5⁄32 in.) from face of the jaw.

9.1.3 Insert the back-up plug in the counterbore of the right-hand jaw. Adjust so that the plug projects about 0.8 mm (1⁄32 in.) from the face.

9.1.4 Support the standard test coupon so that the upper edge of the coupon is about 2.5 mm (3⁄32 in.) below the upper surface of the jaws. Place a steel rule across the face of the jaws. Adjust the Allen screw with the attached 10-mm ball until the face of the jaws are parallel to the steel rule with the test coupon in position for indentation.

9.1.5 With the test coupon in position for the first impression, place the load gauge assembly on the lever arms.

9.1.6 Place the loading arm on the ratchet wheel and actuate the motor. Allow the motor to run until the load gauge indicates a load of 300 lbf (1330 N). A slight takeup on the ratchet wheel is required to hold the load due to the ball sinking into the test coupon. After the 300-lbf (1330-N) load is obtained, hold for 1 min for the indentation to form.

9.1.7 Turn off the machine and back off the load until the test coupon is free of the jaws. Advance the test coupon approximately 9.5 mm (3⁄8 in.) (additional indentations should be separated by a minimum distance of 2.5 × the diameter of the initial indentation). Check the alignment of the jaws, and repeat the procedure described in 9.1.6 at gauge loads of 750, 1000, and 1500 lbf (3300, 4450, and 6650 N).

9.1.8 Remove the load gauge assembly and test coupon and measure the diameter of each indentation to 0.01 mm with the Brinell microscope. Make three measurements of the indentation diameter, rotating the test coupon to ensure that no two measurements represent the same points. Average the three measurements of each impression and record.

9.1.9 Plot the four impression readings versus gauge load readings on log-log paper (K&E 467080 or equivalent). If they do not plot as an approximately straight line, repeat steps 9.1.4-9.1.8. A standard curve of impression diameter versus gauge reading is shown in Fig. 3. If the indentation diameter, plotted as above, is lower or higher than that shown on the standard curve, determine the actual load necessary to produce the indentation diameter that will correspond to that shown on the standard curve.

NOTE 5—A full-size standard calibration curve, plotted on log-log paper and similar to Fig. 3 but with finer subdivision lines included, should be used for accurate calibration.

9.2 *Calibration Procedure with 800 or 3000-lbf (3550 or 13 300-N) Direct-Reading Load Gauge*:

9.2.1 Use the same procedure as with the 4500-lbf (20 000-N) gauge above, except obtain impressions at gauge readings of 300, 500, 700, and 800 lbf (1330, 2220, 3100, and 3550 N) on the 800-lbf (3550-N) gauge; or at 300, 700, 1100, and 1700 lbf (1330, 3100, 4880, and 7550 N) on the 3000-lbf (13 300-N) gauge. Plot the impression readings versus gauge load readings, as in 9.1.9, with similar adjustments to the load in order to produce indentation diameter that corresponds to the indentation diameter on the standard curve.

10. Procedure A

10.1 Insert the solid film coated vee blocks in the recesses of the load jaws.

10.2 Mount the solid film coated pin in the test shaft and insert a new brass shear pin as shown in Fig. 1 and Fig. 2.

10.3 Swing the arms inward so that the vee blocks contact the test pin in such a way that the vee grooves are aligned with the pin's major axis as shown in Fig. 2. Check this alignment visually. Place the automatic loading mechanism with attached load gauge on the load arms and turn the ratched wheel by hand until the test parts are securely seated, indicated by a slight upward movement of the load gauge needle. At this point the torque gauge should read zero or be adjusted to read zero.

10.4 Start the motor and engage the automatic loading ratchet until a gauge load of 300 lbf (1330 N) is reached (approximately 265 lbf (1170 N) on the direct-reading gauge). Remove the load applying arm and continue running (at 290 ± 10 r/min) for 3 min, then increase the load to 500 lbf (2220 N) (approximately 410 lbf (1820 N) on the direct-reading gauge) using the load applying arm, and run for 1 min.

10.5 Increase load to 750 lbf (3330 N) (590 lbf (2620 N) on the direct-reading gauge) and run for 1 min. Then increase the load to 1000 lbf (4450 N) (765 lbf (3400 N) on the direct-reading gauge). Maintain this load and measure the time until failure. Load should be maintained by taking up on the rachet wheel as necessary. The total time until failure shall not include the 3-min run-in.

10.6 Failure is indicated by a torque rise of 10 in.·lbf (1.13 N·m) above the steady-state value, or breakage of the shear pin. The test shall be continued until one of the above failure criteria is attained. If the optional automatic cutoff, torque recorder, and timer (6.1.2) is used, set the cutoff point to 10 in.·lbf (1.13 N·m) above the initial steady state torque. When this preset torque is reached, the machine will shut off and the time of test may be read from the torque recorder tracer[5] (Fig. 5).

10.7 Four runs shall constitute a test.

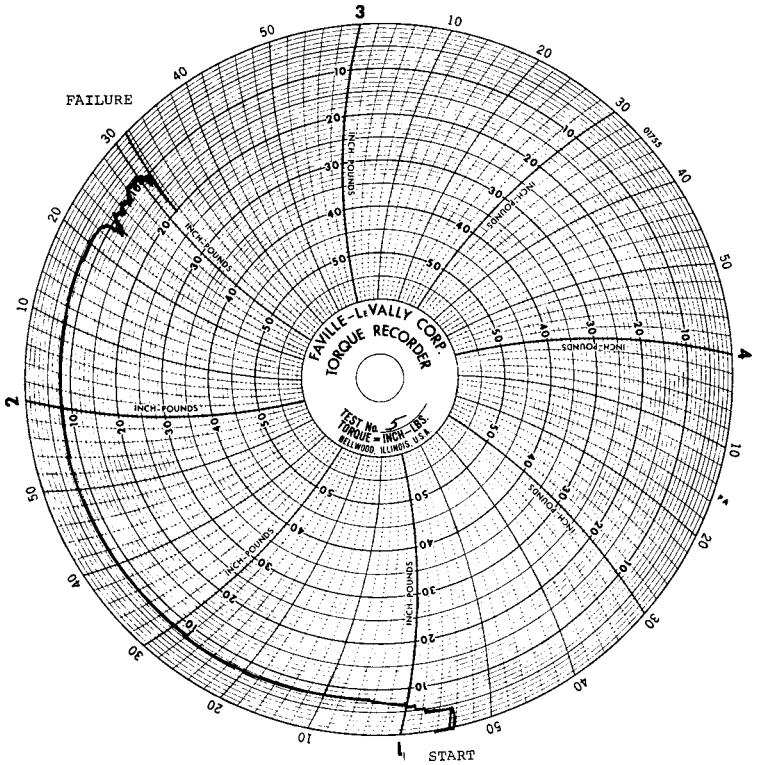

FIG. 5 Trace of Typical Torque Pattern for Procedure A, Using Falex Torque Recorder and Automatic Cutoff

11. Procedure B

11.1 Repeat the cleaning and set-up procedures outlined in Section 8 and 10.1-10.3.

11.2 Start the motor and engage the automatic loading ratchet until a gauge load of 300 lbf (1330 N) (approximately 265 lbf (1170 N) on the direct-reading gauge) is reached. Remove the load applying arm and continue running (at 290 ± 10 r/min) for 3 min. Then increase the load to 500 lbf (2220 N) (approximately 410 lbf (1820 N) on the direct-reading gauge) using the load applying arm and run for 1 min.

11.3 Continue to apply load in increments of 250 lbf (1110 N) (corresponding loads on the direct-reading gages may be taken from the curve in Fig. 3) using 1-min runs at each load until the maximum range of the load gauge is reached, or until failure occurs.

11.4 Failure is indicated by the inability of the lubricating film to maintain the load for 1 min, breakage of the shear pin, breakage of the test pin, or a sharp increase in torque (10 in.·lbf (1.13 N·m) or more) over the gradual increase accompanying the increase in load.

11.5 Conduct four tests. Report load-carrying capacity as the last gauge load that sustained a 1-min load before failure.

12. Report

12.1 *Procedure A*—Report the average of four tests on the endurance (wear) life procedure as the number in minutes.

12.2 *Procedure B*—Report the load carrying capacity as the last gauge load that sustained a 1-min load before failure.

12.3 Report the conditions of application and curing of the coatings.

13. Precision and Bias

13.1 *Precision*—Test data were obtained by Coordinating Research Council, Inc. (CRC), using the AISI 4130 steel vee blocks, and pins with Procedure A. Repeatability and reproducibility calculations are based on results from a total of 63 individual tests on one test sample, in which 11 laboratories operated a total of 14 machines. The average of all 63 test results was 73 min. These data show that the following criteria should be used for judging acceptability of results:

13.1.1 *Repeatability*—Duplicate results by the same operator should be considered suspect if they differ by more than 34 min.

13.1.2 *Reproducibility*—The results submitted by each of two laboratories should be considered suspect if the two results differ by more than 48 min.

NOTE 6—The above precision statement is based on the Fourth CRC Cooperative Test, for which all the data are shown in Annex A1, Table A1.1. In addition, the data from the Second CRC Cooperative Test are shown in Table A1.2. This program was run on a different lubricant, under comparable conditions, and therefore was not put in the precision statement. A total of 108 tests was run on this sample, at a total of 14 laboratories. The average of all 108 tests was 77 min, with a repeatability of 39 min and a reproducibility of 43 min. The close agreement of these two programs lends considerable weight to the statements in 13.1.1 and 13.1.2.

13.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedures in Test Method D2625, no statement on bias is being made.

14. Keywords

14.1 endurance; load; load gauge; pin and vee; water-break; wear

ANNEX

(Mandatory Information)

A1. SPECIMEN PREPARATION

A1.1 This test method may be used to determine the endurance (wear) life and load-carrying capacity of any dry solid film lubricant. One method of specimen preparation is as follows:

A1.1.1 Degrease the vee blocks and journal (pin) (small ultrasonic bath preferred) using a cleaning media and method which is safe, non-film forming and which does not in any way attack or etch the surface chemically. In addition, no chlorinated or other Class I ozone depleting substances conforming to Section 602(a) of the Clean Air Act Amendments of 1990 (42USC7671a) as identified in Section 326 of PL 102-484 should be used. Use a procedure, as outlined in Test Method F22, to judge the merit of the selected cleaning technique. See Note A1.1.

A1.1.1.1 No method of cleaning can be considered acceptable unless there is a valid method of judging the success or failure of the cleaning method. Procedures such as Test Method F22 can be used on the actual test apparatus or on test coupons to judge each cleaning method's viability.

A1.1.2 *Surface Preparation*:

A1.1.2.1 After degreasing, pressure blast both the vee blocks and the test pins using clean (preferably new) aluminum oxide white angular abrasive. The preferred grit size is 180 to 240 and the surface finish after blasting must be between 20 µin. (5.0×10^{-7} m) and 40 µin. (10.0×10^{-7} m) rms. Remove all traces of abrasive; use the ultrasonic bath again as needed.

A1.1.2.2 Store the cleaned vee blocks and journals (pins) in a desiccator to await use.

A1.1.2.3 *Optional Secondary Preparation*—After pressure blasting, A1.1.2, coat the test specimens with a thin phosphate film conforming to Mil-P-16232F, Type M, Class 3, with a controlled coating weight of 16 g, minimum, to 22 g, maximum, per square metre (g/m^2). Deviation from this controlled amount can significantly affect data scatter.

NOTE A1.1—The use of this optional secondary preparation, A1.1.2.3, was part of the basic preparation used to develop the original precision statement. It should also be noted, that for the round robin, trichloroethylene in a vapor degreasing bath was used to degrease the specimens before they were phosphated. See Table A1.1 and Table A1.2.

TABLE A1.1 Results of Fourth Round-Robin Cooperative Tests by Coordinating Research Council, Inc. (CRC)

Laboratory	Machine No.	Wear Life, min				
		Results (In Order Run)				Average
W	...	100	83	68	...	83.67
Q	539	54	40	71	80	61.25
M	72[A]	45	66	51	58	55
C	535	56	54	62	50	55.50
A	...	100	94	69	60	80.75
K	293[B]	47	44	73	74	59.50
	530	60	55	55	75	61.25
	542[B]	71	73	72	55	67.75
I	432	105	96	81	88	...
		72	79	86	82	86
N	435[B]	75	88	76	84	80.75
	445[B]	102	76	61	87	81.50
G	[C]	74	80	67	46	67
F	...	80	76	88	82	...
		62	74	76	70	76
J	411[B]	85	112	86	93	94

[A] Run at 3.5-mm indent and 800-lbf (3550-N) load.
[B] 4500-lbf (20 000–N) gauge used.
[C] 3000-lbf (13 300–N) gauge used.

A1.1.3 Coat the test specimens with solid film lubricant by spraying or an equivalent method to produce a dry film thickness between 0.005 to 0.0125 mm (0.0002 to 0.0005 in.) and cure the film.

A1.1.4 In most cases, curing will be according to the particular manufacturer's specifications. If such instructions are not provided, cure the film by air drying for 6 h at 27 ± 3°C (80 ± 5°F) or by air drying for 30 min at 27°C (80°F) followed by 1 h in an air-circulating oven at 149°C (300°F).

A1.1.5 Measure the dry film thickness on the pin using a micrometer and record as one half the increase in diameter from A1.1.2.

A1.1.6 Store test parts in a desiccator or controlled humidity room for at least 24 h prior to running the test. Handle parts with lint-free cotton gloves.

TABLE A1.2 Results of Second Round-Robin Cooperative Tests by Coordinating Research Council, Inc. (CRC)

Laboratory	Wear Life, min		Laboratory	Wear Life, min	
	First Set	Second Set		First Set	Second Set
G	97	76	J	69	63
	89	88		75	71
	65	62		74	69
	48	72		80	69
A	97	96	K	82	95
	90	42		95	72
	81	68		89	97
	73	101		87	94
C	63	82	L	89	80
	75	80		81	75
	21	79		87	103
	41	79		84	77
E	71	47	M	66	70
	82	78		78	85
	92	81		87	75
	89	80		75	88
H	56	62	N	106	95
	72	71		67	74
	79	59		92	96
	53	68		75	74
F	76		O	107	58
	45			58	99
	66			87	79
	80			75	63
I	106	80	P	79	105
	77	77		84	76
	48	79		89	64
	62	76		97	80