# Standard Test Method for Evaluating Thin Film Fluid Lubricants in a Drain and Dry Mode Using a Pin and Vee Block Test Machine[1]

This standard is issued under the fixed designation D 5620; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the endurance (wear) life and load carrying capacity of thin film fluid lubricants that are intended to operate after a single application and after excess material has drained from the contact area of sliding metal to metal surfaces, and which operates in what functionally is a drain and dry mode with no additional lubricant being applied.

1.2 The values stated in SI units are to be regarded as the standard except where equipment is supplied using inch-pound units which would then be regarded as the standard. The metric equivalents of the inch-pound units given 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:*

B 16 Specification for Free-Cutting Brass Rod, Bar, and Shapes used in Screw Machines[2]

D 2625 Test Method for Endurance (Wear) Life and Load-Carrying Capacity of Solid Film Lubricants (Falex Pin and Vee Method)[3]

F 22 Test Method for Hydrophobic Surface Films by the Water Break Test[4]

2.2 *U.S. Military Specifications:*[5]

Mil-P-16232 Phosphate Coatings, Heavy, Manganese or Zinc Base (for ferrous metals)

TT-C-490 Cleaning Methods for Ferrous Surfaces and Pretreatment for Organic Coatings

## 3. Terminology

3.1 *Definitions:*

3.1.1 *drain and dry mode*, *n*—the effect from being sprayed, dipped, or brushed with a fluid lubricant and the excess material draining from the surface leaving behind a thin film that remains wet and must act as a lubricant on its own, without benefit of recirculation or continuous supply.

3.1.2 *Newtonian flow*, *n*—a Newtonian liquid is one that flows immediately on application of even the smallest force, and for which the rate of flow is directly proportional to the force applied.

3.1.3 *non-Newtonian flow*, *n*—a non-Newtonian liquid is one whose viscosity depends on the rate of shear. Some will not flow until the force applied is greater than a definite value called the yield point.

3.1.4 *thin film fluid lubricant*, *n*—fluid lubricants consisting of a primary liquid with or without additives of lubricating powders and without binders or adhesives, which form a film on one or both surfaces to be lubricated and perform their function after application and after excess material has drained from the application area, and without additional material being supplied by either a continuous or intermittent method.

3.1.5 *wear*, *n*—damage to a solid surface, generally involving progressive loss of material, due to the relative motion between that surface and a contacting substance or substances.

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) gage reference or the 3000-lbf (13 300-N) gage 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 the test time before failure under a constant loaded condition, in minutes, in which the applied test lubricant performs its function.

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

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

## 4. Summary of Test Method

4.1 Prior to both tests, the thin film lubricant test fluid is deposited on the pin and vee blocks and allowed to drain for a minimum of 1 min and not to exceed 4 min unless deemed

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[2] *Annual Book of ASTM Standards*, Vol 02.01.

[3] *Annual Book of ASTM Standards*, Vol 05.02.

[4] *Annual Book of ASTM Standards*, Vol 10.05.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

necessary by the user, such as under conditions where component evaporation is a consideration for the final data base desired.

4.2 The endurance (wear) life test (Procedure A) consists of running two stationary steel vee blocks loaded to a predetermined value against a steel pin rotating at 290 rev/min ± 10 rev/min. The endurance (wear) life is determined from the test duration in minutes until the steady state torque is interrupted by a sharp increase in torque of an additional 10 in-lbf (1.13 N.m), breakage of the shear pin is experienced, or failure to maintain the load. Typically during the test, a rise in temperature of the test apparatus from friction occurs which may generate a gradual increase in the steady state torque which is not to be considered a failure.

4.3 The load carrying capacity test (Procedure B) consists of running two stationary steel vee block specimens against a steel pin rotating at 290 rev/min ± 10 rev/min, and increasing the load on the pin after a 3 min break-in period with 1 min intervals at each individual load above the break-in load, until a sharp increase in torque of an additional 10 in-lbf (1.13 N-m) over the operating torque, breakage of the shear pin is experienced, or failure to maintain the load.

4.4 All tests should be conducted under conditions where a starting temperature of 20°C ± 2° exists for the test apparatus, test specimens, and atmosphere. Any deviation from this can severely affect the data.

4.5 Analysis of the condition of the test specimens can provide valuable data. Color, condition of the test pin, and the condition and size of the wear scar on the vee block are all part of the performance values.

## 5. Significance and Use

5.1 This test method is intended primarily to differentiate between liquid thin film lubricants which exhibit the properties of Newtonian flow with respect to their endurance (wear) life and load carrying capacity when they are used in a manner similar to the bonded dry solid film lubricants. (See Test Method D 2625 for definition of dry solid film lubricants.) The test conditions for thin film lubricants are very critical and must be maintained to ensure reliability of the data when used to compare different lubricants.

5.2 Liquid thin film lubricants which exhibit the properties of non-Newtonian flow can also be tested if the procedure for preparing the pin and vee blocks is modified to account for their different behavior.

## 6. Apparatus

6.1 *Pin and Vee Block Test Machine*, [6] illustrated in Figs. 1, Figs. 1A, Figs. 2, and Figs. 4 of Test Method D 2625.

6.1.1 *Load Gage*, [6] 4500-lbf (20 000-N) range, or 3000-lbf (13 300-N) direct-reading gage. An 800-lbf (3550-N) direct reading load gage may be used for Procedure A, but does not have a high enough load range for Procedure B.

6.1.2 *Indicating Torque Meter*, [6] (with load cell) which provides a digital reading of the resistant torque of the moving test pieces. A torque recorder with optional automatic cutoff and timer may also be used. A data acquisition system for recording the torque is highly recommended for accurate data analysis.

6.2 *Required for Calibration of Load Gage*:

6.2.1 *Standardized Test Coupon*, soft, annealed copper HB 37/39.[7]

6.2.2 *Allen Screw*, with attached 10-mm Brinell Ball.[6]

6.2.3 *Back-up Plug.*[6]

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.

6.2.7 *2 cc micro pipette*, any pipette capable of delivering 2 cc of the test fluid.

## 7. Reagents and Materials

7.1 *Required for Procedures A and B*:

7.1.1 *Standard Coined Vee Blocks* [6] of AISI 1137 Steel, 96° angle, Rockwell hardness of Rc 20–24 and surface finish of $1.3 \times 10^{-7}$ to $2.5 \times 10^{-7}$ m (5 to 10 µin.) rms. Eight are required.

7.1.2 *Standard No. 8 Test Pins*, [6] 6.35-mm (¼-in.) outside diameter by 31.75-mm (1¼-in.) long of AISI 3135 steel, with a Rockwell hardness of Rb 80-N83 on the round and a surface finish of $1.3 \times 10^{-7}$ to $2.5 \times 10^{-7}$ m (5 to 10 µin.) rms.

7.1.3 *Locking Shear Pin*, [6] ½ hard brass conforming to Specification B 16.

7.2 *Required Before Application of the Thin Film Fluid Lubricant (see* Annex A1*)*:

7.2.1 *Aluminum Oxide White Angular Abrasive*, 180 grit to 220 grit.

7.2.2 *Optional Surface Preparations*:

7.2.2.1 *Phosphate Coating, Manganese*, conforming to Mil-P-16232, Type M, Class 3, with the coating weight controlled from 16 minimum to 22 maximum g/m $^2$.

7.2.2.2 *Phosphate Coating, Zinc*, conforming to Specification TT-C-490 with the coating weight controlled to 300 mg ± 50 mg.

7.3 *Cloth, Oil and Lint Free*, a cloth capable of being used to wipe parts without depositing a contaminant on the surface being wiped or handled. Procedures such as Test Method F 22 can be used to determine if the selected cloth will deposit a hydrophobic film on the surface of a metal coupon.

## 8. Preparation of Apparatus

8.1 *Preparation of the Pin and Vee Block Test Machine*:

8.1.1 Thoroughly clean the jaw supports for the vee blocks and test journal (pin). Refer to A1.2.1 for information on selecting the correct cleaning media.

8.1.2 Avoid atmospheric contamination such as cigarette smoke or oil fumes, as this can adversely affect the test results.

8.2 *Vee Block Preparation*:

8.2.1 Place vee blocks, prepared by the procedures in Annex A1, on a flat surface with the vee groove facing up.

[6] The Falex pin and vee block test machine and support equipment, available from Falex Corp., 1020 Airpark Dr., Sugar Grove, IL 60554, has been found satisfactory for this method. A new model of this machine has been available since 1983. Certain operating procedures are different for this new model. Consult instruction manual of machine for this information.

[7] The Condensed Chemical Dictionary, Eighth Edition, published by Van Nostrand Reinhold Company, New York, NY.

8.2.2 Fill the vee groove with the test fluid and allow 1 min to pass for the liquid to react with the surface.

8.2.3 Lay the vee block on the side with the vee groove vertical and place on an absorbent towel selected from 7.3 to remove excess lubricant draining to the bottom of the groove.

8.2.4 Place the drained vee blocks into the test jaws. Avoid contact with the mating surfaces of the vee blocks and test pins when installing them in the test machine.

8.3 *Pin Preparation*:

8.3.1 Place a pin, prepared by the procedures in Annex A1, into the test shaft and secure with a brass shear pin.

8.3.2 Fill a pipette with 2 cc of the test fluid.

8.3.3 Coat the test pin with the entire 2 cc of the fluid, from the pipette, while manually rotating the test shaft.

8.3.4 Allow 1 min (maximum 4 min) for the test fluid to drain and remove all excess fluid from the bottom of the test pin by dapping with a cloth selected from 7.3.

8.3.4.1 Be very careful to not disturb the coated test surfaces of either the vee blocks or the test pin while removing the excess fluid from the bottom of the test pin, then follow Procedure A or B as necessary.

## 9. Calibration and Load Gage

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

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

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 (5⁄32in.) from the face of the jaw.

9.1.3 Insert the backup 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 of the jaw.

9.1.4 Support the standard test coupon so that the upper edge of the coupon is about 2.5 mm (3⁄32in.) 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 gage 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 gage indicates a load of 300-lbf (1330-N). A slight take-up 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 the load 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 times the diameter of the initial indentation). Check the alignment of the jaws and repeat the procedure described in 9.1.6 at gage loads of 750, 1000, and 1500-lbf (3300, 4450, and 6550-N).

9.1.8 Remove the load gage 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 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 gage load readings on the log-log paper. If they do not plot as an approximately straight line, repeat steps 9.1.4-9.1.8. A standard curve of the impression diameter versus gage reading can be found in Fig. 3 of Test Method D 2625. 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. For those machines with electronic load gages that can calibrate the load gage before use, correction to the standard curve is not necessary.

NOTE 1—A full size standard calibration curve plotted on log-log paper can be obtained from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111, Attn: NPODS.

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

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

## 10. Procedure A

10.1 Complete the procedures outlined in Section 8.

10.2 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 pins major axis. Check this alignment visually. Place the automatic loading mechanism with the attached load gage (or load cell) on the load arms and turn the ratchet wheel by hand until the test parts are securely seated, indicated by a slight upward movement of the load gage needle (increased reading when using an electronic load cell and meter). At this point the torque gage should read zero or be adjusted to read zero.

10.3 Start the motor and engage the automatic loading ratchet until a gage load of 300-lbf (1330-N) is reached (approximately 265-lbf (1170-N) on the direct reading gage). Remove the load applying arm and continue running (at 290 rev/min) until failure occurs. Adjust the load as necessary to maintain the 300-lbf (1330-N) value.

10.3.1 When the endurance (wear) life exceeds 60 min, then increase the load after 3 min from the starting load of 300-lbf (1330-N) to 500-lbf (2220-N) (approximately 410-lbf (1820-N) on the direct reading gage) and continue running (at 290 rev/min) until failure occurs.

10.4 Failure is indicated when the steady state torque is interrupted by a sharp increase in torque of an additional 10 in.-lbf (1.13 N.m), breakage of the shear pin is experienced, or failure to maintain the load. Typically during the test, a rise in temperature of the test apparatus from friction occurs which may generate a gradual increase in the operating torque which is not to be considered a failure.

10.5 Four runs constitute a test.

## 11. Procedure B

11.1 Complete the procedures outlined in Section 8.

11.2 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. Check this alignment visually. Place the automatic loading mechanism with the attached load gage (or load cell) on the load arms and turn the ratchet wheel by hand until the test parts are securely seated, indicated by a slight upward movement of the load gage needle (increased reading when using an electronic load cell and meter). At this point the torque gage should read zero or be adjusted to read zero.

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

11.4 Continue to apply the load in increments of 250-lbf (1110-N) (corresponding loads for the direct gage may be taken from the curve in Fig. 3 of Test Method D 2625) using 1 min runs at each load until the maximum range of the load gage is reached or failure occurs.

11.5 Failure is indicated when the steady state torque is interrupted by a sharp increase in torque of an additional 10 in.-lbf (1.13 N.m), breakage of the shear pin is experienced, or failure to maintain the load. Typically, during the test, a rise in temperature of the test apparatus from friction occurs which may generate a gradual increase in the operating torque which is not to be considered a failure.

11.6 Four runs constitute a test.

## 12. Report

12.1 Report the following information:

12.1.1 Report, in minutes, the average time of the four runs till failure generated in Procedure A, including the original 3-min run-in period if the load is raised to 500-lbf (2220-N), as the endurance (wear) life.

12.1.2 Report the average of the last gage load that sustained the load for 1 min from four tests generated in Procedure B as the load carrying capacity.

12.1.3 Report, for informational purposes, the test conditions, actual drain time, and the ambient conditions that existed at the time of the test, as well as the condition and color of the test pin, and the wear scar on the vee blocks after the test is completed. Where possible, record the apparatus temperature both at the start of the test and the completion.

## 13. Precision and Bias

13.1 The precision and bias is being developed.

## 14. Keywords

14.1 drain and dry; endurance; pin and vee block; load wear; thin film; water-break

# 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 thin film fluid lubricant, with or without lubricating solids, which does not have the capacity to cure into a solid film like the bonded dry solid film lubricants, yet must function as a drained and dry lubricant after being sprayed, dipped, or brushed on the surface to be lubricated. One method to prepare the test specimens for test is described in A1.1.1-A1.1.5.

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 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 Test Method F 22, to judge the merit of the selected cleaning technique.

NOTE A1.1—A typical solvent found acceptable for this purpose is Stoddard Solvent.

NOTE A1.2—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 F 22 can be used on the actual test apparatus or on test coupons to judge each cleaning methods viability.

A1.1.2 Avoid contact with the fingers of the mating surfaces of the vee blocks and test pins. When it is necessary to handle the test vee blocks or journals (pins), use a cloth which conforms to 7.3, cloth, oil, and lint free.

A1.1.3 Avoid atmospheric contamination, such as cigarette smoke or other oil containing fumes, as this can adversely affect the test results.

A1.1.4 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. ($5.0 \times 10^{-7}$ m) and 40 µin. ($10.0 \times 10^{-7}$ m) rms. Remove all traces of abrasive, use the ultrasonic bath again, as needed.

A1.1.5 Store the cleaned vee blocks and journals (pins) in a desiccator to await use.

A1.2 *Optional Secondary Film Evaluation:*

A1.2.1 *Phosphating Options*

After the pressure blasting in A1.2.4 , secondary films can be applied to evaluate possible compatibility concerns. However, when using the traditional phosphate films, controlling the coating weight is extremely critical and even then data scatter is still potentially high.

A1.2.1.1 *Phosphate Coating, Manganese*, conforming to Mil-P-16232, Type M, Class 3, with the coating weight controlled from 16 minimum to 22 maximum $g/m^2$.

A1.2.1.2 All cleaning methods described in Mil-P-16232 will be replaced with those described in this Annex, including the aluminum oxide pressure blasting.

A1.2.1.3 *Phosphate Coating, Zinc*, conforming to Specification TT-C-490 with the coating weight controlled to 300 mg ± 50 mg.

A1.2.1.4 Zinc phosphate can be substituted, when desired, using Specification TT-C-490 where the use of a thin phosphate is anticipated. All cleaning methods described in TT-C-490 will be replaced with those described in this Annex, including the aluminum oxide pressure blasting.

A1.2.1.5 After coating with the phosphate of choice, proceed with Procedure A or B, as necessary, applying the fluid test lubricant as described in Section 8.

A1.3 *Bonded Dry Solid Film Options*—Compatibility with bonded dry solid film lubricants can be evaluated using the techniques used for the phosphating by simply substituting the selected bonded dry solid film lubricant or applying the dry solid film lubricant over the phosphate.