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Standard Method for

# MEASURING FRICTIONAL PROPERTIES OF SLIDEWAY LUBRICANTS[1]

This Standard is issued under the fixed designation D 2877; 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.

## 1. Scope

1.1 This method[2] describes a procedure for making an evaluation of the antifriction characteristics of lubricating oils used on machine tool slideway bearings by means of a stick-slip apparatus.

NOTE 1—The values stated in U.S. customary units are to be regarded as standard.

## 2. Summary of Method

2.1 The test consists of slowly traversing a base block beneath a top block under a 49.5-lb (22.45-kg) total load with the oil sample between the blocks. Deflection resulting from kinetic thrust force is observed while the block is moving from right to left and from left to right. Deflection resulting from static thrust force is observed after this movement is terminated. The magnitude of deflection is determined by dial indicators mounted on the apparatus. From the deflection readings, the static coefficient of friction ($U_s$), kinetic coefficient of friction ($U_k$) and stick-slip number ($U_s/U_k$) are calculated.

NOTE 2—The static friction measured is not the usual breakaway force, but is the motion-resisting force 1 min after the motor is turned off.

## 3. Significance

3.1 The stick-slip test is used to determine the frictional characteristics of slideway oils. Results obtained by the test method described have been found to correlate closely with the performance of lubricants on slides operating at speeds of less than 6 in. (152.4 mm)/min. In this test, a high stick-slip number, or sliding with stick-slip action, implies poor performance in slideways.

## 4. Apparatus

4.1 *Stick-Slip Machine*,[3] as shown in Fig. 1 or 2.

## 5. Materials

5.1 *Set of Test Blocks*, schematically shown in Fig. 3. Materials, manufacturing procedure, and break-in procedure are covered in Appendix A1.

5.2 *Oil*, with known stick-slip number.

NOTE 3—Fluid TDL-XI-5-1 or TDL-XI-5-2, used in cooperative testing covered in Table A1, is suitable.

5.3 *Alcohol*, denatured, conforming to Formula 30 or 3A of the U.S. Bureau of Internal Revenue.

5.4 *Chlorothene (1,1,1-Trichloroethane)*, industrial grade.

5.5 *Lintless Tissue* or absorbent cotton.

5.6 *Medicine Dropper*.

5.7 *Timer*, graduated in seconds.

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[1] This method is under the jurisdiction of ASTM Committee D-2 Petroleum Products and Lubricants.
Effective Sept. 11, 1970.

[2] Merchant, M. E., "Characteristics of Typical Polar and Non-Polar Lubricant Additives Under Stick-Slip Conditions," *Lubrication Engineering*, LUENA, Vol 2, No. 2, June, 1946, pp. 56–61.

[3] Test machines manufactured by Cincinnati Milling Machine Co., Cincinnati, Ohio (Method A), and by Laboratory Equipment Corp., Mooresville, Ind. (Method B), have been found satisfactory for this purpose.

## Method A

### 6. Preparation of Apparatus

6.1 *Cleaning Test Blocks:*

6.1.1 Apply alcohol. Dry with lintless tissue or absorbent cotton. Repeat.

6.1.2 Apply chlorothene. Dry with lintless tissue or absorbent cotton (Note 4). Repeat until all traces of dirt and oil are removed. Remove any traces of lint with dry compressed air.

Note 4—Do not allow the chorothene to evaporate from the blocks. It should be absorbed by the tissue or cotton.

6.2 *Assembly of Apparatus:*

6.2.1 Place base block (Fig. 1, Item 1) in base block holder (Fig. 1, Item 2) so that it is centered and the stamped arrow is to the front and pointing upward.

6.2.2 Insert the right and left actuating rods (Fig. 1, Items 3 and 4) in their respective housings.

6.2.3 Place the top block (Fig. 1, Item 5) on the base block so that the stamped arrow is to the front and pointing downward. Place the top block holder (Fig. 1, Item 6) on the top block and make sure it is centered.

6.2.4 Check the clearance between the ends of the actuating rods and the top block. Clearance should be within 0.002 to 0.005 in. (0.051 to 0.127 mm). If not satisfactory, adjust the lengths of the rods accordingly.

6.2.5 Place the encased spring assembly (Fig. 1, Item 7) in position and apply approximately 15-lb (approx 6.8-kg) load (Note 5).

6.2.6 Adjust the position of the top block holder on the top block so that the spring assembly is perpendicular to the surface of the base block.

6.2.7 Tighten the three set screws in the base block holder and the two set screws in the top block holder very lightly.

6.2.8 Increase the load to approximately 75 lb (approx 34.0 kg) and tighten all the set screws snugly. Check the alignment of the test blocks. The front edge of the top block should be flush with the front edge of the base block.

Note 5—In all cases where load is specified, either spring loading or dead weights may be employed.

6.3 *Test for Cleanliness of Test Blocks:*

6.3.1 Adjust the top block spring load to 30 lb (13.6 kg). Total load = 30 lb + 4.5 lb tare (13.6 + 2.0 kg).

6.3.2 Clamp the base block holder to the table by tightening the base block holder clamping bolts (Fig. 1, Items 8 and 9).

6.3.3 Run the table to the right by pushing the "Run Right" button on the control panel. Watch closely the deflection indicator (Fig. 1, Item 10) on the right side. When a deflection reading corresponding to a kinetic coefficient of friction within the range 0.30 to 0.50 is reached, stop the table (Note 6). If a coefficient of friction within this range is not reached, clean the blocks and retest, with the table running in the opposite direction and observing the deflection indicator on the left side. Repeat until the above range of coefficient of friction is obtained, indicating satisfactorily clean test blocks.

Note 6—Kinetic coefficient of friction, $U_k$ =

$$\frac{\text{spring deflection} \times \text{spring rate}}{\text{total load}}$$

Using Method A, $U_k$ =

$$\frac{\text{spring deflection, in.,} \times \text{spring rate, lb/in.}}{34.5}$$

6.4 *Preliminary Run-In Procedure:*

6.4.1 Separate the test blocks and apply approximately 5 ml of the test oil to the base block, using a medicine dropper; then reassemble the test blocks.

6.4.2 Adjust the applied load to 15 lb (6.8 kg). Total load = 15 lb plus 4.5 lb tare (6.8 + 2.0 kg). Adjust the blocks so that the top block is properly aligned with the base block.

6.4.3 Tighten the knurled locknuts (Fig. 1, Items 12 and 13) on the actuating rods so that the top block is restricted from moving to the right or left.

6.4.4 Loosen the base block holder clamping bolts so that the base block holder is free to slide on the table.

6.4.5 Turn the handle (Fig. 1, Item 14) to the horizontal (lap) position and set the rate valve (Fig. 1, Item 15) approximately one-quarter turn out to obtain a lapping rate of approximately 80 cpm. Air lap not less than 6 in. (152.4 mm) of the base block for 2 min (Note 7). At the end of the first minute apply, with a medicine dropper, approximately 2 ml of the test oil to the exposed surface of the base block.

Stop the airlapping operation and turn the handle to the test position.

Note 7—Lapping is necessary to establish uniform contact of the mating surfaces of the test blocks. With apparatus that has a motor drive instead of an air drive for lapping, set the motor drive at "Rapid Traverse" and operate for 160 cycles.

## 7. Procedure

7.1 Recenter the base block holder on the table and reclamp the base block holder clamping bolts (two marks are scribed in the table to assist in centering the holder).

7.2 Loosen the knurled locknuts on the actuating rods and add about 2 ml of the oil being tested to each end of the base block.

7.3 Adjust the applied load to 45 lb (20.4 kg). Total load = 45 lb plus 4.5 lb tare (20.4 + 2.0 kg).

7.4 Check both deflection indicators to be sure they are properly "zeroed." This is done by positioning the top block so that it is not in contact with the actuating rods and then manually applying a small force to each rod. As the load is removed from the rod the deflection indicators should return to zero. If the deflection indicators do not return to zero and there is clearance between the end of the actuating rod and the test block, rezero the indicator dials.

7.5 Set the limit switch trip dogs (Fig. 1, Items 16 and 17) to the "R" position to obtain a total table travel of about 1 in. (25.4 mm) in the center of the base block.

7.6 Start the machine by pushing either the "Run Right" or "Run Left" button on the control panel (Note 8) and allow the blocks to cycle three or four times until the deflection indicator readings have become consistent.

Note 8—The machine in operation gives a rubbing velocity of 0.50 in./min (12.7 mm/min) between the test blocks.

7.7 While the table is traveling to the left, observe the left hand deflection indicator when the base block is at the mid-point of its travel, that is, the center set screw in the base block holder is in line with the notch in the top block holder. Record this value as "Spring Deflection, Kinetic, Run Left."

Note 9—A suitable reporting form and typical data on TDL-XI-5-1 are shown in Table A2.

Note 10—If deflection readings are not steady, stick-slip sliding is occurring. Terminate the test and report the results as "Stick-Slip."

7.8 Push the "Table Stop" button on the control panel. After 1 min observe the spring deflection. Continue to make spring-deflection observations at 1-min intervals until successive readings are in agreement within 0.0005 in. Record this value as "Spring Deflection, Static, Run Left."

7.9 Push the "Run Left" button on the control panel and allow the table to run on out to the left and reverse. When the table is traveling to the right and the base block is at the mid-point of its travel, observe the right-hand deflection indicator. Record this value as "Spring Deflection, Kinetic, Run Right."

7.10 Push the "Table Stop" button on the control panel. After 1 min observe the spring deflection. Continue to make spring-deflection observations at 1-min intervals until successive readings are in agreement within 0.0005 in. Record this value as "Spring Deflection, Static, Run Right."

7.11 Repeat 7.6 through 7.10 to obtain five sets of consistent results.

### Method B

## 8. Preparation of Apparatus

8.1 *Cleaning Test Blocks*—Use same procedure as prescribed in 6.1.

8.2 *Assembly of Apparatus:*

8.2.1 Place the base block (Fig. 2, Item 1) in the base block holder so that it is centered and the stamped arrow is to the front and pointing upward.

8.2.2 Place the top block (Fig. 2, Item 2) on the base block so that the stamped arrow is to the front and pointing downward. Place the top block holder on the top block and make sure it is centered.

8.2.3 Place the spring assembly in position and apply approximately 15-lb (6.8-kg) load (Note 5, 6.2).

8.2.4 Adjust the position of the top block holder on the top block so that the spring assembly is perpendicular to the surface of the base block.

8.2.5 Adjust the applied load to 30 lb (13.6 kg) by means of the hand wheel (Fig. 2, Item 3). Check the alignment of the test blocks. The front edge of the top block should be flush with the front edge of the base block.

8.3 *Test for Cleanliness of Test Blocks:*

8.3.1 Adjust the top block spring load to 15 lb (6.8 kg). Total load = 15 lb + 3.5 lb tare (6.8 + 1.6 kg).

8.3.2 Place the dial indicator (Fig. 2, Item 5) in position. Make sure the top block is in neutral position (centered directly below the load spring) and set the dial indicator at zero.

8.3.3 Set the transmission selector (Fig. 2, Item 4) at "Low Speed" setting (Note 11).

8.3.4 Push the "Start" button and observe the maximum deflection of the dial indicator. When a deflection corresponding to a kinetic coefficient of friction within the range 0.30 to 0.50 is reached, stop the table (Note 12). If a coefficient of friction within this range is not reached, clean blocks and retest, with the table running in the opposite direction. Repeat until the above range of coefficient of friction is obtained, indicating satisfactorily clean test blocks.

NOTE 11—The electric motor-transmission systems of the LABECO machines used in the test work reported in Table A1 gave different rubbing velocities at the "Low Speed" settings, ranging from 0.50 in./min to 0.75 in./min (12.7 to 19.0 mm/min). The differences in rubbing velocities did not affect test results.

NOTE 12—Kinetic coefficient of friction, $U_k$ =

$$\frac{\text{spring deflection} \times \text{spring rate}}{\text{total load}}$$

Using Method B, $U_k$ =

$$\frac{\text{spring deflection, in.,} \times \text{spring rate, lb/in.}}{18.5}$$

8.4 *Preliminary Run-In Procedure:*

8.4.1 Separate the test blocks and apply approximately 5 ml of the test oil to the base block, using a medicine dropper; then reassemble the test blocks.

8.4.2 Adjust the applied load to 46 lb (20.9 kg). Total load = 46 lb plus 3.5 lb tare (20.9 + 1.6 kg). Adjust the blocks so that the top block is properly aligned with the base block.

8.4.3 Set the transmission selector at "High Speed" (Note 13).

8.4.4 Start the motor and lap for 3 min, lapping not less than 6 in. (152.4 mm) of the base block (Note 14). At the end of the first and second minute apply, with a medicine dropper, approximately 2 ml of the test oil to the exposed surface of the base block. After lapping for 3 minutes, stop the motor.

NOTE 13—The electric motor-transmission system of the LABECO machines used in the test work reported in Table A1 gave different rubbing velocities at the "High Speed" settings, ranging from 54 in./min to 103 in./min (1371 to 2816 mm/min). The differences in rubbing velocities did not affect test results.

NOTE 14—Lapping is necessary to establish uniform contact of the mating surfaces of the test blocks.

## 9. Procedure

9.1 Set the transmission selector at "Low Speed" (0.50 to 0.75 in./min) (12.7 to 19.0 mm/min).

9.2 Push the "Start" button and allow the blocks to cycle three or four times until the deflection indicator readings become consistent.

9.3 While the table is traveling to the left, observe the deflection indicator when the base block is at the mid-point of its travel, that is, the center set screw in the base block holder is in line with the notch in the top block holder. Record this value as "Spring Deflection, Kinetic, Run Left."

NOTE 15—A suitable reporting form and typical data on TDL-XI-5-1 are shown in Table A2.

NOTE 16—If deflection readings are not steady, stick-slip sliding is occurring. Terminate the test and report the results as "Stick-Slip."

9.4 Push the "Stop" button. After 1 min observe the spring deflection. Continue to make spring-deflection observations at 1-min intervals until successive readings are in agreement within 0.0005 in. Record this value as "Spring Deflection, Static, Run Left."

9.5 Push the "Start" button.

9.6 While the table is traveling to the right, observe the deflection indicator when the base block is at the mid-point of its travel. Record this value as "Spring Deflection, Kinetic, Run Right."

9.7 Push the "Stop" button. After 1 min observe the spring deflection. Continue to make spring-deflection observations at 1-min intervals until successive readings are in agreement within 0.0005 in. Record this value as "Spring Deflection, Static, Run Right."

9.8 Repeat 9.2 through 9.7 to obtain five sets of consistent results.

METHODS A AND B

## 10. Calculations

10.1 Calculate for each set of values, the coefficient of friction under kinetic conditions ($U_k$) and under static conditions ($U_s$), as follows:

$$U_k = \frac{F_k}{L}$$

$$= \frac{\text{spring deflection under kinetic conditions, in.,} \times \text{spring rate, lb/in.}}{L}$$

$$U_s = \frac{F_s}{L}$$

$$= \frac{\text{spring deflection under static conditions, in.,} \times \text{spring rate, lb/in.}}{L}$$

where:

$F_k$ = horizontal force, lb, under kinetic conditions,

$F_s$ = horizontal force, lb, under static conditions, and

$L$ = total applied load, lb, typical 49.5 (that is 45 + 4.5 in Method A or 46 + 3.5 in Method B).

Spring rate—The machines used in the test work covered in Table A1 had spring rates ranging from 160 lb/in. to 445 lb/in.

10.2 Obtain the average $U_k$ and $U_s$ values, using the five individual values in best agreement.

10.3 Calculate the Stick-Slip Number (Notes 17, 18) as follows:

$$\text{Stick-slip number} = \frac{\text{average } U_s}{\text{average } U_k}$$

Note 17—A suggested report form with typical data and calculations from a test on TDL-XI-5-1 is shown in Table A2.

Note 18—If coefficient of friction values are not desired, the stick-slip number calculation may be simplified:

Stick-slip number

$$= \frac{\text{spring deflection under static conditions, in.}}{\text{spring deflection under kinetic conditions, in.}}$$

## 11. Report

11.1 Report "stick-slip" if deflection readings are not steady.

11.2 Report stick-slip number, that is the value of average $U_s$/average $U_k$.

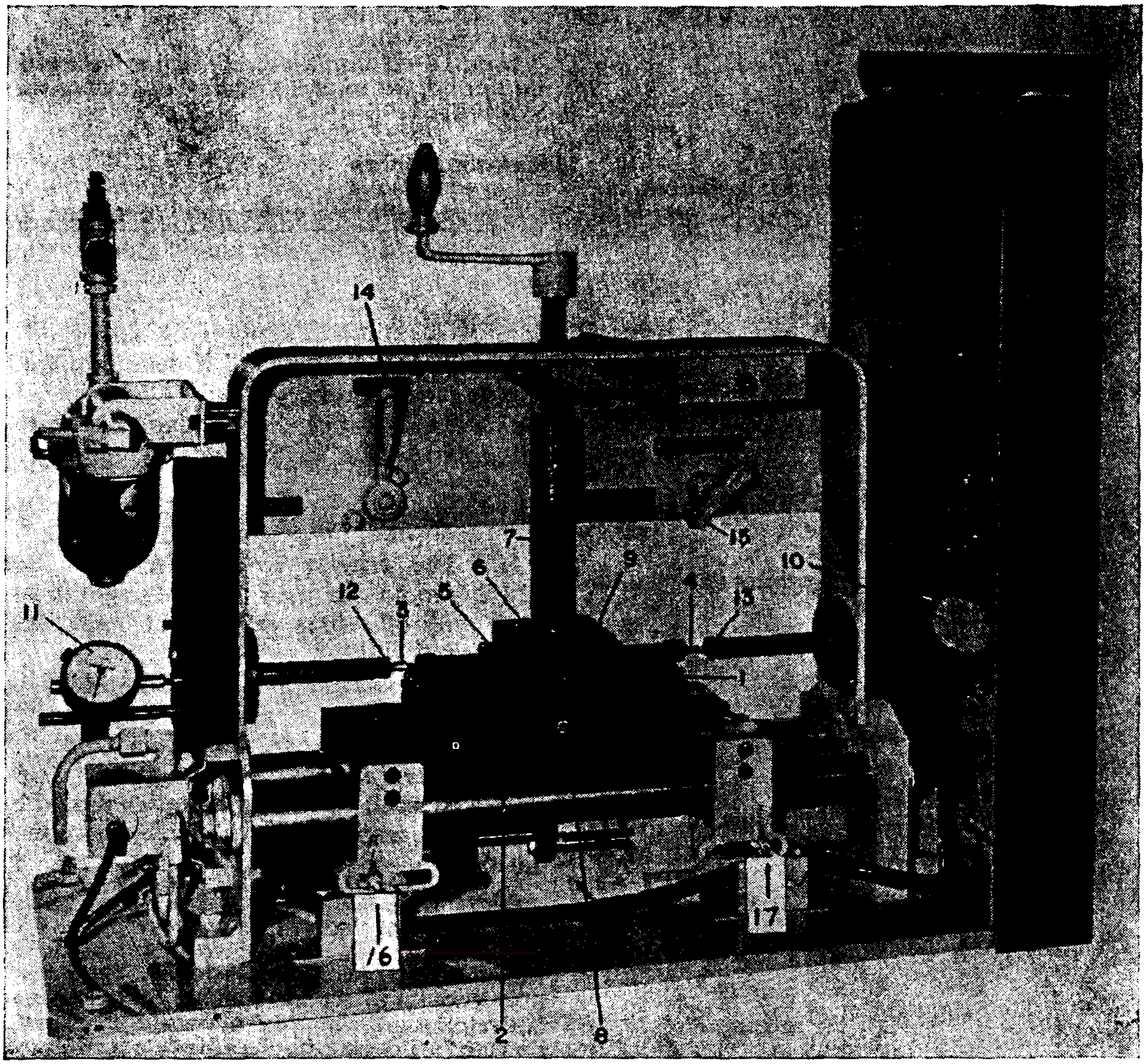
## 12. Precision

12.1 The criteria covered in 12.1.1 and 12.1.2 should be used for judging the acceptability of results (95 percent confidence) (Note 19).

12.1.1 *Repeatability*—Duplicate results by the same operator should be considered suspect if they differ by more than 0.021.

12.1.2 *Reproducibility*—The results submitted by each of two laboratories should be considered suspect if they differ by more than 0.070.

Note 19—The precision data were derived from results of cooperative tests on TDL-XI-5-1 and TDL-XI-5-2, covered in Table A1. The reproducibility value is considered only approximate because of the low number of participating laboratories. A summary of statistical information used in deriving the precision data is presented, for information, in Table A3.

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|---|---|
| 1—Base block | 8, 9—Base block holder clamping bolts |
| 2—Base block holder | 10, 11—Deflection indicators |
| 3, 4—Actuating rods | 12, 13—Actuating rod locknuts |
| 5—Top block | 14—Handle |
| 6—Top block holder | 15—Air rate valve |
| 7—Spring assembly | 16, 17—Limit switch trip dogs |

**FIG. 1 Stick-Slip Apparatus (Method A).**