



Standard Test Method for Low-Temperature Torque of Grease-Lubricated Wheel Bearings¹

This standard is issued under the fixed designation D 4693; 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.

^{ε1} NOTE — Warning information was moved editorially from notes to section text in September 2002.

1. Scope*

1.1 This test method determines the extent to which a test grease retards the rotation of a specially-manufactured, spring-loaded, automotive-type wheel bearing assembly when subjected to low temperatures. Torque values, calculated from restraining-force determinations, are a measure of the viscous resistance of the grease. This test method was developed with greases giving torques of less than 35 N·m at -40°C .

1.2 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

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.*

¹ This test method is under the jurisdiction of Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.G0 on Lubricating Grease.

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

2. Referenced Documents

2.1 ASTM Standards:²

- D 217 Test Methods for Cone Penetration of Lubricating Grease
- D 1403 Test Method for Cone Penetration of Lubricating Grease Using One-Quarter and One-Half Scale Cone Equipment
- D 3527 Test Method for Life Performance of Automotive Wheel Bearing Grease
- D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants
- E 1 Specification for ASTM Thermometers
- E 77 Test Method for Inspection and Verification of Thermometers
- E 220 Test Method for Calibration of Thermocouples by Comparison Techniques
- E 230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples
- E 563 Practice for Preparation and Use of Freezing Point Reference Baths
- E 585/E 585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base-Metal Thermocouple Cable
- E 608/E 608M Specification for Metal-Sheathed Base-Metal Thermocouples

2.2 Military Standard:³

- MIL-G-10924F Specification for Automotive and Artillery

2.3 Other Standard:

- Anti-Friction Bearing Manufacturer Assoc. (AFBMA) Standard 19, 1974 (ANSI B. 3.19-1975)

3. Terminology

3.1 Definitions:

3.1.1 *automotive wheel bearing grease, n*— a lubricating grease specifically formulated to lubricate automotive wheel bearings at relatively high grease temperatures and bearing speeds. **D 3527**

3.1.2 *lubricant, n*—any material interposed between two surfaces that reduces the friction or wear between ~~them~~ them. **D 4175**

3.1.3 *lubricating grease, n*—a semi-fluid to solid product of a dispersion of a thickener in a liquid lubricant.

3.1.3.1 *Discussion*—The dispersion of the thickener forms a two-phase system and immobilizes the liquid lubricant by surface tension and other physical forces. Other ingredients are commonly included to impart special properties. **D 217**

3.1.4 *thickener, n*—*in lubricating grease*, a substance composed of finely-divided; particles dispersed in a liquid lubricant to form the product's structure.

3.1.4.1 *Discussion*—The solid thickener can be fibers (such as various metallic soaps) or plates or spheres (such as certain non-soap thickeners) which are insoluble or, at the most, only very slightly soluble in the liquid lubricant. The general requirements are that the solid particles be extremely small, uniformly dispersed, and capable of forming a relatively stable, gel-like structure with the liquid lubricant. **D 217**

4. Summary of Test Method

4.1 A freshly stirred and worked sample of test grease is packed into the bearings of a specially-manufactured, automotive-type spindle-bearings-hub assembly. The assembly is heated and then cold soaked at -40°C , unless another test temperature is specified by the grease specification. The spindle is rotated at 1 rpm and the torque required to prevent rotation of the hub is measured at 60 s.

5. Significance and Use

5.1 This test method differentiates among greases having distinctly different low-temperature characteristics. This test is used for specification purposes and correlates with its precursor which has been used to predict the performance of greases in automotive wheel bearings in low-temperature service.⁴ It is the responsibility of the user to determine the correlation with other types of service.

6. Apparatus

6.1 *Low-Temperature Wheel Bearing Torque Apparatus*,⁵ illustrated in Fig. 1.

NOTE 1—Several apparatus configurations are available, differing mainly in the drive system. For example, with large cold chambers, a unitized apparatus (see Fig. 1) can be used totally within the cold chamber. With small cold chambers, the drive system can be mounted externally and only the

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*, Vol 05.01, volume information, refer to the standard's Document Summary page on the ASTM website.

Annual Book of ASTM Standards, Vol 05.02.

³ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

Annual Book

⁴ Verdura, T. M., "Performance of ASTM Standards, Vol 14.03: Service Station Wheel Bearing Greases in a New Low-Temperature Test," *NLGI Spokesman* 35 10-21 (1971).

⁵ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS; Koehler Instrument Co., 1595 Sycamore Avenue, Bohemia, L.I., NY 11716.

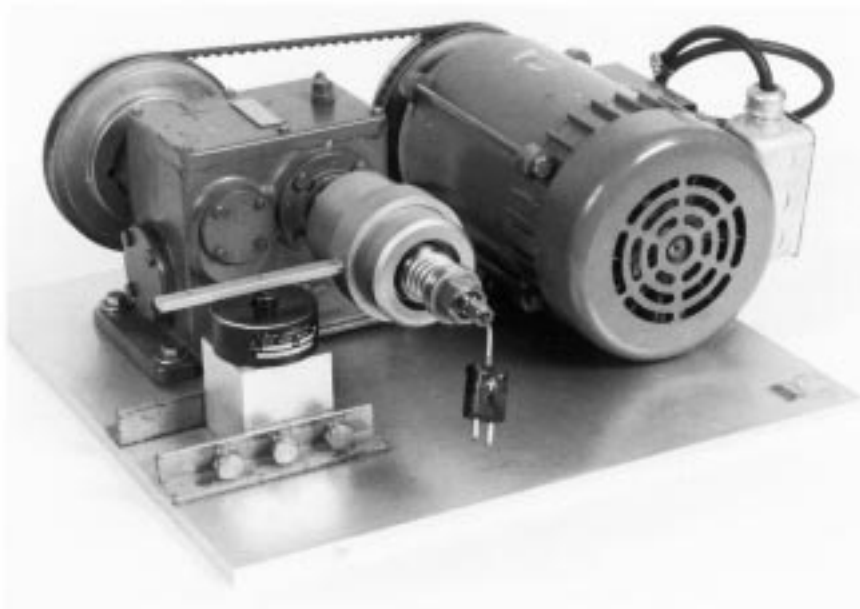


FIG. 1 Low-Temperature Torque Apparatus

test unit subjected to low temperature. Regardless of the exact configuration, the essential apparatus consists of a 1/3 hp electric motor connected to a gear reducer by means of a timing belt and pulleys, which drive a specially-manufactured spindle-bearings-hub assembly equipped with a spring-loading mechanism. For apparatus contained totally within the cold chamber, the drive system should be prepared by replacing the grease in the motor bearings with a suitable low-temperature grease (<1 N·m torque at -40°C), such as one meeting the requirements of Specification MIL-G-10924F or similar, and the lubricant in the gear reducer should be replaced with a suitable low-temperature (< -50°C pour point) worm-gear lubricant.⁶ In addition, if not already so-equipped, large-diameter (152 mm), narrow-width (13 mm) timing pulleys and a suitable timing belt should be used.

6.2 *Torque Measuring System*, consisting of a strain-gage load cell with a matching bridge-balance unit,⁷ a suitable strip-chart recorder to record the load-cell output, and a series of weights (up to 20 kg, at least) suitable for load-cell calibration.

NOTE 2—In order to calculate torque from force measurements, the load cell should be located a known distance from the test-unit centerline; 100 mm is convenient. A convenient way to do this is to centrally drill a 1.78-mm diameter hole (No. 50 drill) in the torque arm, 100 mm from the spindle centerline; temporarily replace the load cell contact with a second contact having a 1.59-mm diameter pin (soldered in place) extending about 5 mm above the contact point; position the load cell to permit insertion of the pin in the torque-arm hole; secure the position of the load cell by tightening the clamping screws; replace pin contact with original contact before running test.

6.3 *Temperature Measuring System*, consisting of Type T (preferred) or Type J (acceptable), 3.18-mm diameter metal-sheathed, grounded thermocouples meeting Specifications E 585/E 585M and E 608/E 608M and conforming to the special limits of error defined in Table 1 of Specification E 230; a suitable potentiometer, satisfying the requirements for Groups B or C as described in Test Method E 220; an ASTM 73C precision thermometer meeting Specification E 1, certified (traceable to National Institute of Standards and Technology certification) or verified and calibrated according to Test Method E 77; a suitable comparator as described in Test Method E 77; and an ice bath prepared according to Practice E 563.

NOTE 3—Other temperature-measuring instrumentation, such as a precision platinum resistance thermometer, may be used instead of thermocouples, providing the limits of error are within those defined in Specification E 230.

⁶ Verdura, T. M., "Performance of Service Station Wheel Bearing Greases in a New Low-Temperature Test," *NLGI Spokesman* 35 10-21 (1971).

⁶ Mobil SHC 624 (or similar), available from Mobil Oil Corporation, 3225 Gallows Rd., Fairfax, VA 22037.

⁷ A Model 3167-50 load cell and matching electronic circuitry are available from Koehler Instrument Co., 1595 Sycamore Avenue, Bohemia, L.I., NY 11716; Lebow Associates, Inc., 1728 Maplelawn, Troy, MI 48062.

TABLE 1 Torque Test Results at -40°C with NLGI Reference System A (Batch 3)

| | |
|--------------------------|----------|
| Mean value | 3.7 N·m |
| Standard deviation | 0.67 N·m |
| Confidence limits, 95 %: | |
| Lower | 3.2 |
| Upper | 4.1 |

6.4 *Test Bearing*—Use LM67010-LM67048 and LM11910-LM11949 (AFBMA Standard 19) inboard and outboard tapered roller bearings, respectively.⁸

6.5 *Low-Temperature Test Chamber*, equipped with internal fan, and capable of maintaining the spindle at $-40 \pm 0.5^\circ\text{C}$, and with sufficient capacity to cool the spindle at the rate shown in Fig. 2(A) and Fig. 2(B).

6.6 *Laboratory Oven*, forced air, capable of maintaining $70 \pm 3^\circ\text{C}$.

6.7 *Grease Packer*, as described in Test Method D 3527 or equivalent.

6.8 *Ultrasonic Cleaner*.⁹

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.¹⁰ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Ethylene Glycol*, commercial automotive antifreeze. (**Warning**—Moderately toxic. Can be harmful if inhaled, swallowed or absorbed through skin. Contact can irritate eyes, or mucosa.)

7.3 *Chloroform*, reagent grade. (**Warning**—Health hazard.)

7.4 *1,1,1-Trichloroethane*, reagent grade. (**Warning**—Health hazard.)

7.4.1 For routine testing, a *functionally equivalent solvent* may be substituted throughout this test method wherever 1,1,1-trichloroethane is specified. However, in referee situations, 1,1,1-trichloroethane or chloroform shall be used unless contractual parties agree on the acceptability of the functionally equivalent solvent.

7.4.1.1 To be functionally equivalent, the solvent must not affect test results, must clean as effectively as 1,1,1-trichloroethane, have similar volatility characteristics, leave no residue on evaporation, and contain no water or additives.

NOTE 4—This test method (and the precision values) was originally developed using chloroform. This was subsequently replaced by 1,1,1-trichloroethane which was declared an ozone depleting substance by the U.S. Environmental Protection Agency (EPA). Federal regulations ban the production of this material after December 31, 1995, but existing stocks may continue to be used. Currently there are no EPA restrictions on the use of chloroform, but the user should be aware of its health hazards, if it is used. No other solvent intended as a substitute for 1,1,1-trichloroethane in this test method has been cooperatively evaluated. (**Warning**—If the functionally equivalent solvent is flammable or a health hazard, proper precautions should be taken.)

⁸ Mobil SHC 624 (or similar), available from Mobil Oil Corporation, 3225 Gallows Rd., Fairfax, VA 22037.

⁸ Timken or Bower bearings are suitable.

⁹ A Model 3167-50 load cell and matching electronic circuitry are available from Lebow Associates, Inc., 1728 Maplelawn, Troy, MI 48062. Branson 220 (Branson Cleaning Equipment Co., Shelton CN 06484), having a capacity of about 4 L operating at an output frequency of about 55 kHz, with a power input of about 125 W, has been found satisfactory.

¹⁰ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

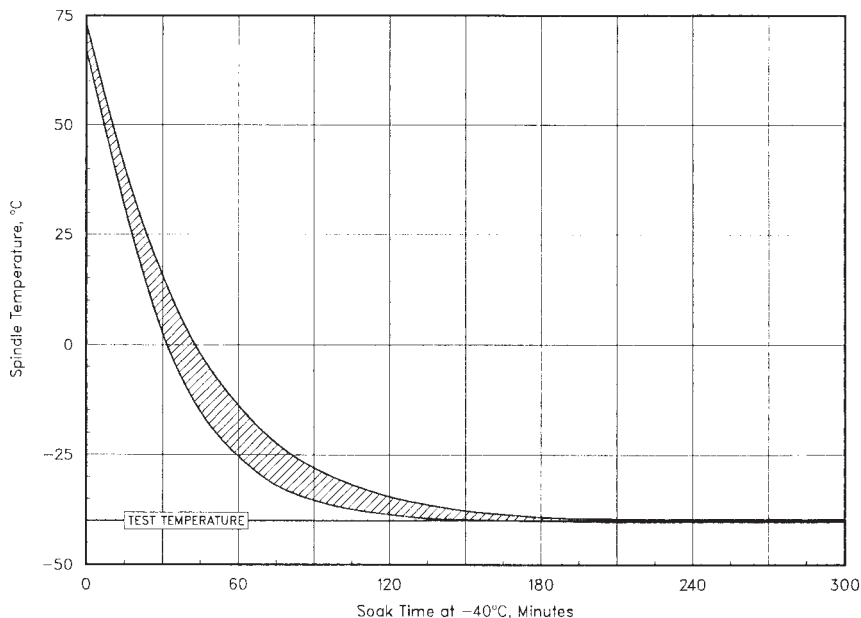


FIG. 2 (A) Upper and Lower Limits of Cooling Rate and Test Temperature

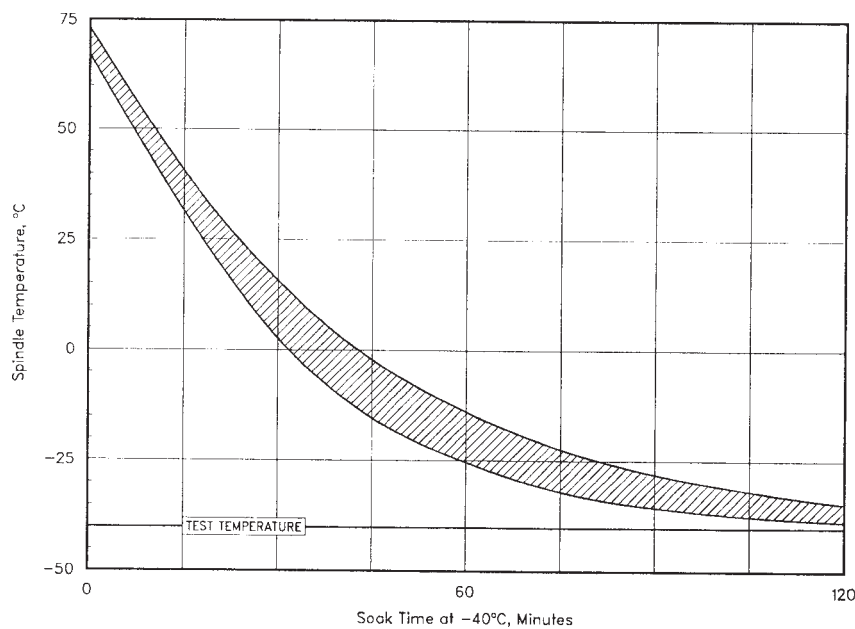


FIG. 2 (B) Detail of Critical Portion of Cooling Rate Curve (continued)

8. Calibration

8.1 Torque Calibration:

8.1.1 Place the load cell in the cold chamber at -40°C and allow it to come to temperature equilibrium. Electrically null the load cell and recording potentiometer using the adjusting potentiometer of the matching network. Adjust or standardize the range potentiometer as needed to achieve the desired zero-point and full-scale calibration. Select a millivolt range on the recording potentiometer, and record pen displacement as a known force is applied to the load cell. (It may be necessary to fabricate a platform to attach to the load cell to support the calibrating weights.) Apply several forces (up to about 200 N or more) in stepwise fashion while recording pen displacement as a function of applied force. Calibrate the other millivolt ranges in similar fashion until limited by either maximum displacement or maximum load. Remove forces stepwise to determine possible hysteresis.

8.1.2 Construct a plot of pen displacement as a function of force for each millivolt range. Use these plots for the subsequent determination of torque for the test greases. Ordinarily, the plots will be linear, and simple conversion factors can be calculated.

NOTE 5—Data logging software may be used to collect this data.

8.1.3 This calibration need be done only at the time of initial setup and when occasional checks indicate that it is required. ~~The However, the torque measuring system is to be standardized before each test, however, test.~~

8.2 Temperature Calibration:

8.2.1 In order to obtain precise torque measurements, an *accurate temperature calibration is essential*. Meticulous attention to the details described in the several ASTM methods of temperature calibration is of paramount importance.

8.2.2 Calibrate the temperature-measuring system, including both the potentiometer and the spindle thermocouple, at 0°C and -40°C by comparing the observed temperature with that of the certified thermometer as described in Test Method E 220. Alternatively, both thermometer and thermocouple can be calibrated using the freezing point of mercury as described in Test Method E 77. The reference ice bath is to be made in accordance with Practice E 563.

NOTE 56—A suitable low-temperature liquid bath can be made with a 65 volume per volume percent commercial, automotive-type, ethylene glycol antifreeze (7.2) in water.

8.2.3 The temperature correction determined by the thermocouple calibration shall be applied when measuring the temperature of the spindle.

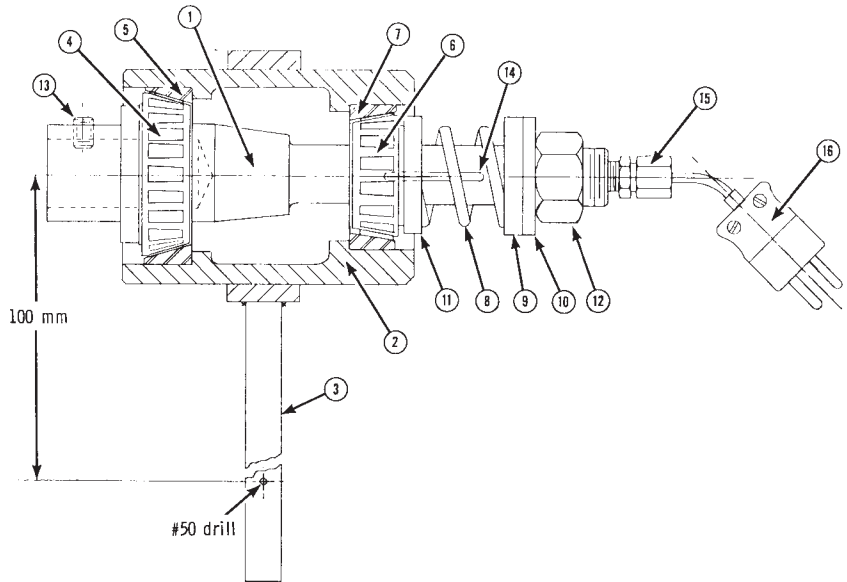
8.3 Spring Calibration:

8.3.1 Remove the spring (Part 8, Fig. 3), and outer and inner compression plates (Parts 9 and 11, Fig. 3) from the test unit.

8.3.2 Reassemble spring and compression plates in correct order. Apply a force of 400 N and measure the distance, ± 0.03 mm, between the compression plates. Since the distance between the plates varies slightly around the circumference of the plates, make the measurement at the point of shortest distance. Mark the spring and both plates to ensure repeatable alignment when assembling the test unit.

8.3.3 Using the dimension determined in 8.3.2, construct a custom spring gage of equal length. When assembling the test unit, this gage is to be used to apply a 400 N load.

NOTE 67—Some low-temperature torque-test apparatus have been supplied with a metal cylinder to be used to calibrate the spring. A small number of these have been found to be incorrect. If an apparatus includes such a cylinder, its calibration should be certified by the manufacturer or verified by



PARTS

| | |
|----|---|
| 1 | Spindle |
| 2 | Hub |
| 3 | Torque arm |
| 4 | Bearing LM-67010 |
| 5 | Bearing cup LM-67048 |
| 6 | Bearing LM-11910 |
| 7 | Bearing cup LM-11949 |
| 8 | Spring GM-13 |
| 9 | Outer compression plate |
| 10 | Compression washer |
| 11 | Inner compression plate |
| 12 | Nut |
| 13 | Set screw |
| 14 | Spindle key |
| 15 | Fitting, Conax MPG-125 w TFE-fluorocarbon ferrule |
| 16 | Thermocouple, Type T or J, sheathed, grounded |

FIG. 3 Test Unit Assembly

the test operator before use in this test. The fabrication and use of a custom spring gage is preferred.

9. Bearing Preparation

9.1 New bearings must be conditioned prior to first use in this method. Install any wheel bearing grease in the bearings and run them at room temperature for 48 h at 1000 rpm under a thrust load of 110 N·m. The apparatus used in Test Method D 3527 has been found suitable for conditioning the bearings. Alternatively, other means, such as a drill press, may be employed if the proper speed, load, and duration can be provided.

9.2 Remove excess grease from the bearings. Place the bearings in a beaker and cover with 1,1,1-trichloroethane (7.3). Place the beaker containing the bearings and solvent in the ultrasonic bath containing distilled water at a depth of about 60 mm. After cleaning for 5 to 10 min, transfer bearings to another solvent-containing beaker and repeat. Repeat as often as necessary (commonly, three times) to clean bearings; use shorter wash times with successive washes. Drain and air dry bearings.

10. Procedure

10.1 Clean races of bearing cups, previously installed in the hub, and inspect for nicks or rust spots; replace cups if damaged. Apply a thin film of the test grease to races.

10.2 Stir the test grease with a spatula. Fill a half-scale grease worker with the stirred test grease and work 60 strokes as described in Test Method D 1403.

10.3 Fill the bearings with the worked test grease using a Test Method D 3527 bearing packer, or equivalent. The bearing packer must be clean and dry prior to use. Flushing out old grease with new test grease is not acceptable.

10.4 Withdraw the bearing, and with a spatula remove excess grease from the bore and strike off grease flush with both ends of the bearing cone. Remove remaining grease from bore with a lintless cloth or tissue. Remove grease from outer surfaces of rollers and retainer. Care must be exercised to prevent relative rotation of any part of the bearing during this part of the procedure and from this point onward.

10.5 Add or remove grease so that the inner and outer bearings contain 3.0 and 2.0 ± 0.1 g, respectively.

10.6 Install the inner bearing on the spindle, without rotating the rollers and aligning bearing slot with spindle key or pin. Install hub. Install outer bearing on spindle, without rotating rollers and aligning keyway with key.

NOTE 78—Bearings are supplied with keyways or slots, and spindles with corresponding keys or pins, to prevent rotation of the inner races of the bearings during the test. Assembly of the test unit can be facilitated by securing the spindle in a vertical position in a bench vise. (**Warning**—Do not tighten vise excessively, or else spindle bore will deform and prevent installation of test unit on drive shaft.)

10.7 Complete assembly of the test unit by installing the inner compression plate (Part 11, Fig. 3), spring (Part 8, Fig. 3), outer compression plate (Part 9, Fig. 3), compression washer (Part 10, Fig. 3), and compression nut (Part 12, Fig. 3). Place the spring gage, described in 8.3.3, between the compression plates. Tighten nut until the required 400 N load is applied. Loosen the nut slightly, just enough to slip spring gage from between compression plates.

10.8 Install the thermocouple (Part 16, Fig. 3) in the spindle (Part 1, Fig. 3) such that it bottoms in the thermocouple well.

NOTE 89—The spindle is drilled to locate the thermocouple junction midway between the bearings, and the spindle end is drilled and tapped ($\frac{1}{8}$ NPT) to accept a fitting (Part 15, Fig. 3) to hold the thermocouple in place. The compression nut of the fitting should be tightened just enough to hold the thermocouple at its proper depth yet permit it to rotate during the test run. This can be accomplished when a TFE-fluorocarbon ferrule is used in the fitting. Use of the fitting is not required: (*a1*) if the cold chamber is equipped with access ports to permit installation and removal of the thermocouple without opening the cold chamber door (which would change the temperature of the test unit), and (*b2*) a means of holding the thermocouple junction in contact with the bottom of the thermocouple well is provided.

10.9 Place the assembled test unit in an oven pre-heated to $70 \pm 3^\circ\text{C}$ and heat for 60 ± 5 min. Remove test unit from oven and immediately install on drive shaft of test machine located in cold chamber pre-cooled to -40°C .

10.10 Rotate the test machine drive pulley by hand to position the torque arm slightly (not more than 3 mm) above load cell contact, but not touching. *Do not position torque arm by rotating it relative to the hub.* It is imperative that the bearings not be rotated after charging with the test grease. Consequently, it is advantageous to always orient the hub in the same position relative to the spindle during assembly. One way to do this is to align the hub torque arm in the same plane as the spindle key (Part 14, Fig. 3). In similar fashion, always preposition the keyway of the test machine drive shaft so that the test unit can be installed with the torque arm above the load cell. Rotate the pulley by hand or with short bursts of the drive motor to achieve proper position of the torque arm.

10.11 Cold soak test unit at $-40 \pm 0.5^\circ\text{C}$ for 5 ± 0.1 h at a cooling rate described in Fig. 2(A) and Fig. 2(B).

NOTE 910—Because of the wide variety of cold chambers, in order to satisfy the prescribed cooling rate, it may be necessary to insulate the test unit to slow the rate or to add a small fan or squirrel-cage blower to increase it. Once the suitable amount of insulation or wind velocity is established, the cooling rate should remain nearly constant from one test to the next and not require constant adjustment.

10.12 At the end of the cold soak period, prepare the instrumentation for the torque determination. Select the highest millivolt range on the recording potentiometer, or a lower range if foregained knowledge of the torque indicates its suitability. Standardize the potentiometer according to the manufacturer's instructions.

10.13 Measure and record the temperature of the test unit just before starting the drive motor. Start the chart drive of the recording potentiometer. Start the drive motor and run the test for a minimum of 3 min.

NOTE 11—Data logging software may be used to collect this data.

10.14 Measure the pen displacement on the potentiometer record at the equivalent of 60-s running time. Also, if maximum torque occurs after 60 s, record maximum torque and its time of occurrence, as well as the 60-s torque. Due to manufacturing tolerances, some test units may give cyclic torque records at high torques. In such cases, measure pen displacement as indicated in Fig. 4.

NOTE 12—Data logging software may be used to collect this data.

10.15 Remove test unit from apparatus and place in an oven preheated to about 70°C to preclude rusting. Do not disassemble until unit has been heated and moisture driven off. Generally, rusting can be precluded by not disassembling test unit until preparation for next test is required.

11. Calculation

11.1 Calculate torque using one of the following equations:

$$T = 0.00981 \times F \times L \quad (1)$$

(SI units)

where:

T = torque, N·m,

F = force, kgf, as determined from pen displacement and calibration determined in 7.4, and

L = distance between spindle and load-cell centerlines, mm

or

$$T = 0.113 \times F \times L \quad (2)$$

(mixed units)

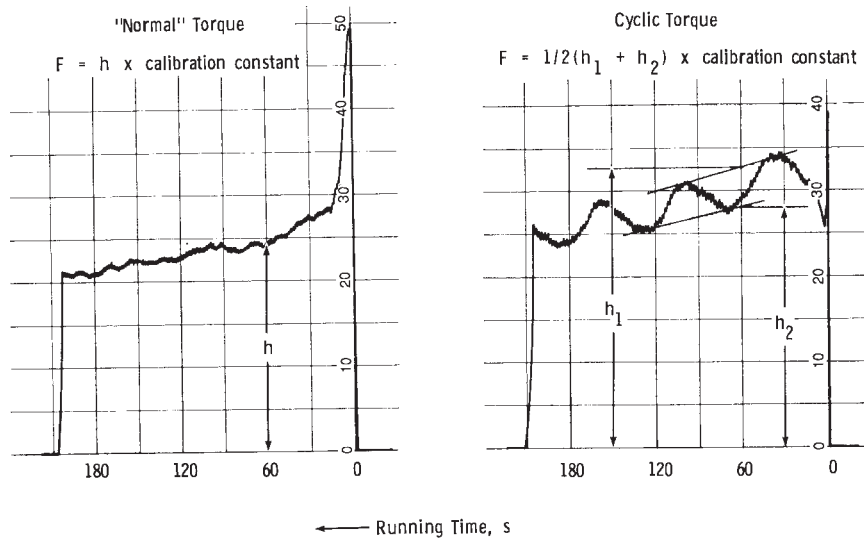


FIG. 4 Determination of Restraining Force (F) from Potentiometer Recording

where:

T = torque, N·m,

F = force, lb, as determined from pen displacement and calibration determined in 7.4, and

L = distance between spindle and load-cell centerlines, in.

12. Report

12.1 Report the following for each torque test:

12.1.1 Date of test and grease identity,

12.1.2 Corrected spindle temperature, °C, at start of run,

12.1.3 Torque, N·m, at 60 s test time, and

12.1.4 Maximum torque (see section 10.14).

NOTE 103—To provide information, Table 1 shows the torque results obtained in NLGI Reference System A (Batch 3).⁴

13. Precision and Bias ¹¹

13.1 *Precision*—The precision of the method as determined by statistical examination of interlaboratory results is as follows:

13.1.1 *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.

$$\text{Repeatability} = 0.22 M \tag{3}$$

where *M* is the average of the two results.

13.1.2 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories with 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.

$$\text{Reproducibility} = 0.55 M \tag{4}$$

where *M* is the average of the two results.

13.2 *Bias*—The procedure in this test method has no bias because the value of low temperature torque can be defined only in terms of a test method.

14. Keywords

14.1 low temperature torque; lubricating grease; wheel bearing grease

^{††} A Branson 220 (Branson Cleaning Equipment Co., Shelton CN 06484), having a capacity

¹¹ The precision of ~~about 4 L operating at an output frequency~~ this test was derived from the statistical analysis (per RR:D02-1007) of ~~about 55 kHz, the -40°C torque~~ results obtained with a power input of about 125 W, has been found satisfactory: nine greases by five cooperators in an interlaboratory test program. Supporting data are on file at ASTM Headquarters. Request RR:D02-1239.

SUMMARY OF CHANGES

Subcommittee D02.G0 has identified the location of selected changes to this standard since the last issue (D 4693-97 (2002) ^{€1}) that may impact the use of this standard.

(I) Permitted the use of instrumental software in 8.1.2, 10.13, and 10.14.

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