Designation: D8165 – 19a

Standard Test Method for Evaluation of Load-Carrying Capacity of Lubricants Used in Hypoid Final-Drive Axles Operated under Low-Speed and High-Torque Conditions [1]

This standard is issued under the fixed designation D8165; 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.

INTRODUCTION

Portions of this test method are written for use by laboratories that make use of ASTM Test Monitoring Center (TMC)[2] services (see Annex A1 – Annex A4).

The TMC provides reference oils, and engineering and statistical services to laboratories that desire to produce test results that are statistically similar to those produced by laboratories previously calibrated by the TMC.

In general, the test purchaser decides if a calibrated test stand is to be used. Organizations such as the American Chemistry Council require that a laboratory utilize the TMC services as part of their test registration process. In addition, the American Petroleum Institute and the Gear Lubricant Review Committee of the Lubricant Review Institute (SAE International) require that a laboratory use the TMC services in seeking qualification of oils against their specifications.

The advantage of using the TMC services to calibrate test stands is that the test laboratory (and hence the test purchaser) has an assurance that the test stand was operating at the proper level of test severity. It should also be borne in mind that results obtained in a non-calibrated test stand may not be the same as those obtained in a test stand participating in the ASTM TMC services process.

Laboratories that choose not to use the TMC services may simply disregard these portions.

1. Scope*

1.1 This test method, commonly referred to as the L-37-1 test, describes a test procedure for evaluating the load-carrying capacity, wear performance, and extreme pressure properties of a gear lubricant in a hypoid axle under conditions of low-speed, high-torque operation.[3]

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.2.1 *Exceptions*—Where there is no direct SI equivalent such as National Pipe threads/diameters, tubing size, or where there is a sole source supply equipment specification.

1.2.1.1 The drawing in Annex A6 is in inch-pound units.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific warning statements are provided in 7.2 and 10.1.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.B0.03 on Automotive Gear Lubricants & Fluids.

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[2] ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489. www.astmtmc.cmu.edu.

[3] Until the next revision of this test method, the ASTM Test Monitoring Center (TMC) will update changes in this test method by means of Information Letters. This edition includes all Information Letters through No. 19-3. Information Letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Ave, Pittsburgh, PA 15206, Attn: Administrator. The TMC is also the source of reference oils.

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

2. Referenced Documents

2.1 *ASTM Standards:*[4]

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D6121 Test Method for Evaluation of Load-Carrying Capacity of Lubricants Under Conditions of Low Speed and High Torque Used for Final Hypoid Drive Axles

D7450 Specification for Performance of Rear Axle Gear Lubricants Intended for API Category GL-5 Service

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Other ASTM Publications:*

ASTM Distress Rating Manual 21 (Formerly CRC Manual 21)[5]

ASTM TMC L-37 Information Letter 15-1, March 17, 2015[2]

2.3 *AGMA National Standard:*[6]

AGMA 1010 Appearance of Gear Teeth—Terminology of Wear and Failure

2.4 *SAE Standards:*[7]

SAE J308 Information Report on Axle and Manual Transmission Lubricants

SAE J2360 Automotive Gear Lubricants for Commercial and Military Use

2.5 *API Standard:*[8]

API 1560 Lubricant Service Designations for Automotive Manual Transmissions, Manual Transaxles, and Axles

3. Terminology

3.1 *Definitions:*

3.1.1 *blind reference oil, n*—a reference oil, the identity of which is unknown by the test facility.

3.1.1.1 *Discussion*—This is a coded reference oil that is submitted by a source independent from the test facility. **D4175**

3.1.2 *calibrate, v*—to determine the indication or output of a device (for example, thermometer, manometer, engine) with respect to that of a standard. **D4175**

3.1.3 *candidate oil, n*—an oil that is intended to have the performance characteristics necessary to satisfy a specification and is to be tested against that specification. **D4175**

3.1.4 *cracked gear tooth, n*—a gear tooth exhibiting a linear fracture of the tooth surface. **D6121**

3.1.5 *non-reference oil, n*—any oil other than a reference oil, such as a research formulation, commercial oil or candidate oil. **D4175**

3.1.6 *reference oil, n*—an oil of known performance characteristics, used as a basis for comparison.

3.1.6.1 *Discussion*—Reference oils are used to calibrate testing facilities, to compare the performance of other oils, or to evaluate other materials (such as seals) that interact with oils. **D4175**

3.1.7 *test oil, n*—any oil subjected to evaluation in an established procedure. **D4175**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *abrasive wear, n—on ring and pinion gears*, removal of material from the operating surface of the gear caused by lapping of mating surfaces by fine particles suspended in lubricant, fuel, or air or imbedded in a surface. **ASTM Distress Rating Manual No. 21**

3.2.2 *adhesive wear, n—on ring and pinion gears*, removal of material from the operating surface of the gear caused by shearing of junctions formed between operating surfaces in direct metal-to-metal contact; sheared-off particles either remain affixed to the harder of the mating surfaces or act as wear particles between the surfaces. **ASTM Distress Rating Manual No. 21**

3.2.3 *broken gear tooth, n*—a gear tooth where a portion of the tooth face is missing and the missing material includes some part of the top land, toe, heel, or coast side of the tooth.

3.2.3.1 *Discussion*—This condition is distinct from and more extensive than "chipping," which is defined in 3.2.5.

3.2.4 *burnish, n—on ring and pinion gears*, an alteration of the original manufactured surface to a dull or brightly polished condition. **ASTM Distress Rating Manual No. 21**

3.2.5 *chipping, n—on ring and pinion gears*, a condition caused in the manufacturing process in which a small irregular cavity is present only at the face/crown edge interface. The edge-chipping phenomenon occurs when sufficient fatigue cycles accumulate after tooth surface wear relieves the compressive residual stress on the tooth profile side of the profile-to-topland interface. Chipping within 1 mm of the face/crown edge interface is to be called chipping, not pitting/spalling. **ASTM Distress Rating Manual No. 21**

3.2.6 *corrosion, n—in final drive axles*, a general alteration of the finished surfaces of bearings or gears by discoloration, accompanied by roughening not attributable to mechanical action. **ASTM Distress Rating Manual No. 21**

3.2.7 *deposits, n—in final drive axles*, material of pasty, gummy, or brittle nature adhering to or collecting around any of the working parts. **ASTM Distress Rating Manual No. 21**

3.2.8 *discoloration, n—on ring and pinion gears*, any alteration in the normal color of finished steel surfaces. **ASTM Distress Rating Manual No. 21**

3.2.9 *pitting, n—on ring and pinion gears*, small irregular cavities in the tooth surface, resulting from the breaking out of small areas of surface metal. **ASTM Distress Rating Manual No. 21**

3.2.10 *ridging, n—on ring and pinion gears*, an alteration of the tooth surface to give a series of parallel raised and polished ridges running diagonally in the direction of sliding motion,

[4] 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.

[5] Available from the ASTM website, www.astm.org (Stock #: TMCMNL21).

[6] Available from American Gear Manufacturers Association (AGMA), 1001 N. Fairfax St., Suite 500, Alexandria, VA 22314-1587, http://www.agma.org.

[7] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[8] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

either partially or completely across the tooth surfaces of gears.

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3.2.11 *rippling, n—on ring and pinion gears*, an alteration of the tooth surface to give an appearance of a more or less regular pattern resembling ripples on water or fish scales.

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3.2.12 *scoring, n—on ring and pinion gears*, the rapid removal of metal from the tooth surfaces caused by the tearing out of small contacting particles that have welded together as a result of metal-to- metal contact. The scored surface is characterized by a matte or dull finish.

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3.2.13 *scratching, n—on ring and pinion gears*, an alteration of the tooth surface in the form of irregular scratches, of random length, across the tooth surface in the direction of sliding of the surfaces.

ASTM Distress Rating Manual No. 21

3.2.14 *spalling, n—on ring and pinion gears*, the breaking out of flakes of irregular area of the tooth surface, a condition more extensive than pitting.

ASTM Distress Rating Manual No. 21

3.2.15 *surface fatigue, n—on ring and pinion gears*, the failure of the ring gear and pinion material as a result of repeated surface or subsurface stresses that are beyond the endurance limit of the material. It is characterized by the removal of metal and the formation of cavities.

AGMA National Standard

3.2.16 *wear, n—on ring and pinion gears*, the removal of metal, without evidence of surface fatigue or adhesive wear, resulting in partial or complete elimination of tool or grinding marks or development of a discernible shoulder ridge at the bottom of the contact area near the root or at the toe or heel end of pinion tooth contact area (abrasive wear).

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3.3 *Acronyms:*

3.3.1 AGMA—American Gear Manufacturers Association

3.3.2 API—American Petroleum Institute

3.3.3 ASTM—American Society for Testing Materials

3.3.4 LTMS—Lubricant Test Monitoring System

3.3.5 n/a—not available

3.3.6 NIST—National Institute of Standards and Technology

3.3.7 P/N—Part number

3.3.8 RCMS—Rater Calibration Monitoring System

3.3.9 SAE—Society of Automotive Engineers

3.3.10 TMC—Test Monitoring Center

3.4 *Quantity Symbols:*

3.4.1 D—percent deviation from test operating conditions (A9.3.2)

3.4.2 ip—intermediate precision limit (14.1.1.1)

3.4.3 M_i—the magnitude of test parameter out from specification limit at occurrence, i (A9.3.2)

3.4.4 P_R—the test parameter specification range (A9.3.2)

3.4.5 R—reproducibility limit (14.1.2.1)

3.4.6 S—estimated standard deviation (Table 2, Section 14)

3.4.7 S_{ip}—intermediate precision standard deviation (Table 2, Section 14)

3.4.8 S_R—the reproducibility standard deviation (Table 2, Section 14)

3.4.9 T_i—the length of time the test parameter is outside the specification range at occurrence, i, (A9.3.2)

3.4.10 t—test or test phase duration in the same units as T_i (A9.3.2)

4. Summary of Test Method

4.1 An axle ring and pinion gearset is mounted in an axle housing, which is installed on a test stand equipped with the appropriate controls for speed, torque, lubricant temperature, axle cooling, and various other operating parameters. The axle assembly is driven by an electric motor.

4.2 Prior to each test run, the axle assembly is built, cleaned, inspected, and build specifications are measured and recorded, and the gears conditioned under specified operating conditions.

4.3 The test method consists of running the axle unit for 24 h at 80 wheel r/min and 2359 N·m wheel torque. There are two variants of the test—the standard test, for which the lubricant temperature in the axle is 135 °C, and the Canadian test, for which the lubricant temperature is 93 °C. The Canadian test is described in a non-mandatory appendix because the gearset hardware has not yet been approved.

4.4 The ring gear and pinion gear are removed and rated for various forms of distress.

5. Significance and Use

5.1 This test method measures a lubricant's ability to protect hypoid final drive axles from abrasive wear, adhesive wear, plastic deformation, and surface fatigue when subjected to low-speed, high-torque conditions. Lack of protection can lead to premature gear or bearing failure, or both.

5.2 This test method is used, or referred to, in specifications and classifications of rear-axle gear lubricants such as:

5.2.1 Specification D7450.

5.2.2 American Petroleum Institute (API) Publication 1560.

5.2.3 SAE J308.

5.2.4 SAE J2360.

6. Apparatus

6.1 *General*—The apparatus for the standard test is described in 6.2 to 6.3 and that for the nonmandatory Canadian test in Appendix X1.

6.2 *Test Unit*—The standard test uses a Gleason Works[9,10] test axle part number (P/N) 1758276 assembled into a Dana Model 60[11,10] axle housing reused from Dana P/N 060AA100-2 or 060AA100-4.

[9] The sole source of supply of the apparatus known to the committee at this time is The Gleason Works, Gleason Sales (Americas), tel: 800-765-6525, email: service-americas@gleason.com, www.gleason.com.

[10] 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 committee1 which you may attend.

[11] The sole source of supply of the apparatus known to the committee at this time is Dana Corp., P.O. Box 2424, Fort Wayne, IN 46801.

6.3 *Test Stand and Laboratory Equipment for the Standard Test:*

6.3.1 *Axle Vent*—Vent the axle to the atmosphere throughout the entire test. Arrange the vent so that no water enters the housing.

6.3.2 *Axle Cover*—The axle cover may have a port installed to allow for ring gear inspection after the gear conditioning phase (see 10.2).

6.3.3 *Test Stand Configuration*—Mount the complete assembly in a rigid fixture as shown in Fig. A5.1. Mount the test unit in the test stand with pinion and axle shaft centerlines horizontal.

6.3.4 *Temperature Control*—Use a thermocouple, temperature recording system, and specified cooling system in conjunction with an automated control system to maintain the lubricant at the required temperature.

6.3.4.1 *Thermocouple*—Determine the thermocouple location on the rear cover using the cover plate temperature sensor locating device as shown in Fig. A6.1.

(1) Install the thermocouple such that the thermocouple tip is flush with the cover plate lip by placing the cover plate face on a flat surface and inserting the thermocouple into the cover plate until the thermocouple tip is flush with the flat surface

(2) Lock the thermocouple into place.

6.3.4.2 *Temperature Recording System*—Record the temperature of the test oil at least once every minute throughout the test using an automated control and data acquisition system.

6.3.4.3 *Axle Cooling*—Use three spray nozzles to distribute water over the cover plate and axle housing as shown in Fig. A7.1. Actuate a single water-control valve by a temperature proportional- integral-derivative (PID) control system.

(1) Spray nozzles[12,10] shall be any combination of the following part numbers depending on how the system is plumbed: straight male NPT (P/N 3/8GG-SS22), 90° male NPT (P/N 3/8GGA-SS22), straight female NPT (P/N 3/8G-SS22 and 90° female NPT (P/N 3/8GA-SS22).

(2) Use a single control valve to control the cooling water supply. The control shall be a minimum 12.7 mm (½ in.) ID.

(3) Tubing sizes of 10 mm, 12 mm, ⅜ in., or ½ in. have all been found suitable for supplying the spray nozzles used in this test.

(4) Supply water to the control valve at a pressure between 170 kPa (gauge) and 1379 kPa (gauge).

(5) Use an axle-cooling box to surround the test-axle assembly, as shown in Fig. A7.2. Its purpose is to contain water and eliminate drafts. Incorporate a drain in the cooling box to prevent water accumulation.

6.3.5 *Power Source*—For the power source, use an AC electric motor capable of driving the axle at the required test conditions. It has been found that a 150 kW motor with a base speed of 751 r/min is sufficient to power the axle.

6.3.6 *Dynamometers and Torque Control System*—Use two axle dynamometers with sufficient torque absorbing capacity to maintain axle torque and speed conditions.

6.3.7 *Dynamometer Connecting Shafts*—Fabricate shafts connecting the dynamometer to the axle shafts. Shafts shall be strong enough to handle the torques encountered. It is recommended that the shafts be dynamically (spin) balanced.

6.3.8 *Drive Shaft and Universal Joints*—Fabricate a drive shaft, with universal joints to connect the input motor and test unit. Shaft and universal joints shall be strong enough to handle the torques encountered. It is recommended that the shaft be dynamically (spin) balanced. The shaft shall not include any dampening devices.

6.3.8.1 It has been found that a driveshaft with outside diameter of 10.1 cm ± 0.51 cm (4 in. ± 0.2 in.) and a wall thickness of 0.24 cm ± 0.013 cm (0.095 in. ± 0.005 in.) is sufficient.

6.3.9 *Speed Measuring and Control System*—Use a system capable of measuring the speed of both axles and also of maintaining test conditions.

7. Reagents and Materials

7.1 *Sealing Compound*—Where necessary. Permatex[13] Form-a-Gasket No. 2 Sealant has been found satisfactory for this purpose[10].

7.2 *Solvent*—Use only mineral spirits meeting the requirements of Specification D235, Type II, Class C for volume fraction of aromatics (0 % to 2 %), flash point (61 °C, min) and color (not darker than +25 on Saybolt Scale or 25 on Pt-Co Scale). Obtain a Certificate of Analysis for each batch of solvent from the supplier. (**Warning—**Combustible. Health hazard.)

7.3 *Rust Preventative*—Use only Total Osyris 211 S[14,10,15] as a rust preventative.

8. Preparation of Apparatus

8.1 *Cleaning of Reusable Hardware*—Clean as necessary all reusable parts including axle shafts, thermocouples, axle housing, axle housing cover, carrier, and all associated drain pans and funnels used for the addition of and collection of test oil.

8.2 *Preparation of Axle:*

8.2.1 Assemble axle in accordance with the L-37-1 Axle Assembly Build Manual.[2]

8.2.1.1 Do not use Dana Model 60 Axle housings for more than 4 tests.

8.2.1.2 When rebuilding an axle assembly, use the format LAB-CXXXX-NN to create a serial number, where:

LAB designates the assembly as being lab-built;

C is the one-character TMC coded lab designation;

XXXX is a unique 4-digit identifier for the housing;

NN is a 2-digit count of the number of rebuilds on the housing.

[12] The sole source of supply of the apparatus known to the committee at this time is Spraying Systems Co., North Ave. and Schmale Road, P.O. Box 7900, Wheaton, Illinois 60187-7901 USA. www.spray.com.

[13] Permatex is a registered trademark of Permatex, 10 Columbus Blvd., Hartford, CT 06106, www.permatex.com; tel: 860-543-7500.

[14] The sole source of supply of the material known to the committee at this time is Total Specialties USA, Inc, Total Lubricants, www.totallubricantsusa.com, tel: 800-323-3198.

[15] Available from any retailer of Total products.

(1) Permanently mark the serial number into the axle tube at a location near the housing vent.

(2) Revise the 2-digit rebuild count number each time the assembly is rebuilt.

8.2.1.3 Include both drive and coast side contact pattern photos of the ring gear in the test report. Use only acceptable gear tooth contact patterns as determined in the TMC L-37-1 Axle Assembly Build Manual available from the TMC.

8.2.1.4 If a fully-assembled axle is to be stored prior to running the test, a rust preventative (see 7.3) may be used to protect the axle.

8.2.2 *Breakaway and Turning Torque Measurements*—Measure and record the torques required to break and to turn the pinion shaft of the completely assembled test unit less axle shafts. Rotate the pinion shaft a minimum of six rotations during the breakaway and turning torque measurement to ensure all ring gear teeth are contacted. Do not use any axle having breakaway or turning torque higher than 5.7 N·m.

8.2.3 *Backlash Measurements*—Measure and record the backlash on the test axle at four equally spaced locations. Report the four readings and the average. Do not use any axle having average backlash less than 0.10 mm or greater than 0.31 mm.

8.2.4 *Cleaning*—Wash the test unit using a cleaning solvent (see 7.2), paying particular attention to remove all preservative oil from the pinion bearings. Dry by blowing with clean, dry compressed air.

8.2.5 Install axle shafts in test unit.

8.2.6 Lubricate the carrier bearings, pinion bearings, differential gears, and the ring gear and pinion, using 2.8 L ± 0.05 L of test lubricant.

8.2.7 Install the axle cover plate with gasket (apply sealant, if needed). Do not drain the oil and recharge the test axle once the test oil has been charged to the axle.

8.3 Install the test unit on the stand with pinion and axle shaft centerlines horizontal. Connect dynamometers and input drive shaft to the test unit.

9. Calibration and Standardization

9.1 *General*—Annex A2 describes calibration procedures using the TMC reference oils, including their storage and conditions of use, the conducting of tests, and the reporting of results. Annex A3 describes general maintenance activities involving TMC reference oils, including special reference oil tests, special use of the reference oil calibration system, donated reference oil test programs, introducing new reference oils, and TMC information letters and memoranda. Annex A4 provides general information regarding new laboratories, the role of the TMC regarding precision data, and the calibration of test stands used for non-standard tests. Activities specific to the L-37-1 are given in 9.2 to 9.4.

9.2 *Hardware*—Only use hardware batches approved through the responsible L-37-1 Surveillance Panel.[16]

9.3 *Stand Referencing:*

9.3.1 New laboratories wishing to be calibrated shall meet the following criteria:

9.3.1.1 Obtain approval from the Surveillance Panel for build (see 8.2.1.3) capabilities by submitting relevant ring-gear, contact-pattern photographs.

9.3.1.2 Submit results to the Surveillance Panel demonstrating that the following four reference oil tests meet the criteria stated in the current LTMS requirements: two reference tests with TMC134 reference oil (or subsequently approved reblends) and two reference tests with TMC152 reference oil (or subsequently approved reblends).

9.3.2 *Reference Test Frequency*—The test stand calibration period is defined as four months or 25 tests, whichever occurs first. It begins on the completion date of an operationally and statistically acceptable reference oil test as determined by the TMC. Any test started on or before the stand calibration expiration date is defined to have been run on a calibrated stand.

9.3.3 Moving the rigid axle fixture (6.3.3) is considered a significant change to the stand and requires the test stand to meet new test stand calibration and referencing requirements as described in the LTMS document.[17]

9.3.4 Report modification of test stand apparatus on a calibrated test stand to the TMC immediately. The TMC will determine whether another calibration test is necessary.

9.3.5 When a test stand is out of reference for a period of six months or longer, renumber the stand, and recalibrate as described in A2.2 and the LTMS document.[17]

9.3.6 Within a reference period, alternate testing using different gear batches, or dynamometer torque conditions, or test temperatures does not necessitate recalibration. However, calibrate the test stand for both the standard and Canadian tests independently in order for results at either condition to be valid.

9.3.7 Every test start on any test stand shall receive a sequential test run number designated before testing begins. All tests, including aborted starts and operationally invalid tests, shall retain their test number.

9.4 *Instrumentation Calibration*—Using known standards traceable to the National Institute of Standards and Technology (NIST)[18] (or using physical constants), calibrate the axle speed measuring system, temperature control system immediately prior to every other reference test or every nine months, whichever occurs first. Calibrate load cell torque measuring systems prior to every calibration test or every four months, whichever occurs first. Calibrate torque flange measuring

[16] ASTM Subcommittee D02.B0.03.

[17] Criteria can be found in the Lubricant Test Monitoring System, available from the Test Monitoring Center, https://www.astmtmc.cmu.edu/

[18] National Institute of Standards and Technology, 100 Bureau Drive, Stop 2300, Gaithersburg, MD 20899-2300. Email: calibrations@nist.gov, tel: 301-975-2200.

TABLE 1 Test Versions

Test Version	Gear Conditioning Phase	Gear Test Phase
	Axle Temperature	Axle Temperature
Standard Test	147 °C ± 2 °C	135 °C ± 2 °C
Canadian Test	104 °C ± 2 °C	93 °C ± 2 °C

systems every twelve months. Recalibration of instrumentation in the event of failed or invalid first attempts at stand calibration are at the discretion of the test engineer.

10. Test Procedure

10.1 **Warning—**High-speed rotating equipment, electrical shock hazard, high-temperature surfaces.

10.2 *Test Versions*—There are two versions of this test which are referred to as the standard test and the Canadian test. Both versions maintain the same wheel load and wheel-speed conditions but differ in the details of the axle cooling (see X1.3) and temperature of the axle oil (see X1.4 and Table 1).

10.2.1 The test procedure for the standard test is described in 10.3 to 10.5 and that for the nonmandatory Canadian test in Appendix X1.

10.3 *Gear Conditioning Phase for Standard Test:*

10.3.1 Set the temperature control to maintain a lubricant temperature of 147 °C ± 2 °C.

10.3.2 Smoothly ramp the input motor to (440 ± 5) wheel r/min and apply dynamometer load to achieve a torque of 535 N·m ± 20 N·m on each wheel end.

10.3.2.1 The time required to accelerate to the test conditions of 440 wheel r/min and 535 N·m shall not exceed 5 min.

10.3.3 When the required speed and torque conditions are reached record the time as start of the test.

10.3.4 After reaching speed and torque conditions, run the test for 100 min ± 1 min.

10.3.5 To ensure the test conditions are accurately maintained, record speed, torque, and lubricant temperature at least once every minute.

10.3.6 After 100 min ± 1 min:

10.3.6.1 Record end time, speed, torque, and lubricant temperature.

10.3.6.2 Start the torque and linear speed ramp-down, at the same time setting the axle lubricant temperature controller to a set point of 135 °C ± 2 °C.

10.3.6.3 Ramp the input motor to 0 r/min and ensure the axles stop turning. The time required to decelerate to 0 r/min shall not exceed 5 min.

10.3.6.4 Shut off the cooling water when the axle lubricant temperature drops below the set point. Do not use cooling water after the axle is stopped.

10.3.7 If the test is stopped for any reason (for example, power outage or maintenance), restart the test as detailed in 10.5.1. Count this stoppage as one of the allowed shutdowns during the test. Do not calculate deviation percent values or report out of limit operational values until test conditions are again achieved. If the test is stopped at the start of the conditioning phase, before speed and torque conditions are reached, do not count the stoppage as one of the allowed shutdowns.

10.4 *Gear Test Phase for Standard Test:*

10.4.1 Ensure that the temperature control is still set to maintain a lubricant temperature of 135 °C ± 2 °C.

NOTE 1—The transition from the end of the conditioning phase (see 10.3.6) to the start of the gear test phase is approximately 10 min.

10.4.2 Smoothly ramp the input motor to (80 ± 2) wheel r/min and apply dynamometer torque to achieve a torque of 1415 N·m ± 47 N·m on each wheel end. Hold at this condition until the axle lubricant temperature reaches greater than or equal to 79 °C.

10.4.2.1 The time required to accelerate to the test conditions of 80 wheel r/min and 1415 N·m shall not exceed 5 min.

10.4.2.2 Once the axle lubricant temperature reaches greater than or equal to 79 °C, smoothly apply dynamometer load to achieve a torque load of 2359 N·m ± 47 N·m on each wheel end.

10.4.3 When required speed, torque, and temperature conditions are reached, record the time as start of the test phase.

10.4.4 After reaching speed, torque, and temperature conditions, run the test for 24 h ± 0.2 h.

10.4.5 To ensure the test conditions are accurately maintained, record speed, torque, and temperature at least once every minute.

10.4.6 At the end of 24 h, ramp the input motor to 0 r/min, ensure the axles stop turning and record time and lubricant temperature.

10.4.7 Disconnect the drive shaft and axle shafts from the dynamometers, and remove the test unit from the test stand.

10.4.8 If the test is stopped for any reason (for example, power outage or maintenance), restart the test as detailed in 10.5.1. Count this stoppage as one of the allowed shutdowns during the test. Do not calculate deviation percent values or report out of limit operational values until test conditions are again achieved. If the test is stopped at the start of the test phase, before test conditions are reached (speed, load, and axle temperature), do not count the stoppage as one of the allowed shutdowns.

10.5 *Unscheduled Downtime*—An unscheduled downtime event is defined as any time the gears stop turning during the steady-state gear conditioning or steady-state gear test phases after test conditions are achieved.

10.5.1 *Restart After Unscheduled Downtime*—Restart the test as outlined in 10.5.1.1 through 10.5.1.4 any time there is an unscheduled downtime event.

10.5.1.1 Set the temperature control to maintain the lubricant temperature at the set point condition when the shutdown occurred.

10.5.1.2 Smoothly ramp the input motor to the wheel r/min set point condition at the time of the shutdown. The time required to accelerate to the r/min set point shall not exceed 5 min.

10.5.1.3 If the restart occurs following a shutdown during the test phase, apply a dynamometer load on each wheel to achieve a torque value of 1415 N·m ± 47 N·m until the lubricant temperature reaches greater than or equal to 79 °C.

10.5.1.4 If the restart occurs following a shutdown during the conditioning phase, follow 10.3.1 through 10.3.3 to restart the test.

10.5.1.5 Once lubricant temperature reaches greater than or equal to 79 °C, smoothly apply dynamometer torque on each wheel to achieve the torque set point condition at the time of the shutdown.