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

This standard is issued under the fixed designation D6121; 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

This test method is written for use by laboratories that use the portions of the test method that refer to ASTM Test Monitoring Center (TMC) services (see Annex A1 – Annex A4). Laboratories that choose not to use the TMC services may simply disregard these portions.

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.

NOTE 1—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.

## 1. Scope*

1.1 This test method is commonly referred to as the L-37 test.[2] This test method covers a test procedure for evaluating the load-carrying, wear, and extreme pressure properties of a gear lubricant in a hypoid axle under conditions of low-speed, high-torque operation.

1.2 This test method also provides for the running of the low axle temperature (Canadian) L-37 test. The procedure for the low axle temperature (Canadian) L-37 test is identical to the standard L-37 test with the exceptions of the items specifically listed in Annex A9. The procedure modifications listed in Annex A9 refer to the corresponding section of the standard L-37 test method.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3.1 *Exceptions*—In Table A12.1, the values stated in SI units are to be regarded as standard. Also, no SI unit is provided where there is not a direct SI equivalent.

1.4 *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.* Specific warning information is given in Sections 4 and 7.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[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] 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. 16-2. 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

*Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

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

2.2 *Military Specification:*[4]

MIL-PRF-2105E Lubricating Oil, Gear, Multipurpose

2.3 *AGMA National Standard:*[5]

Nomenclature of Gear Tooth Failure Modes

2.4 *SAE Standard:*[6]

SAE J308 Information Report on Axle and Manual Transmission Lubricants

SAE J2360 Lubricating Oil, Gear Multipurpose (Metric) Military Use

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *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**[7]

3.1.2 *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**

3.1.3 *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.

3.1.3.1 *Discussion*—This condition is distinct from and more extensive than "chipping," which is defined in 3.1.5.

3.1.4 *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**

3.1.5 *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**

3.1.6 *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**

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

3.1.8 *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**

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

3.1.10 *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**

3.1.11 *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, either partially or completely across the tooth surfaces of gears.
**ASTM Distress Rating Manual No. 21**

3.1.12 *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.
**ASTM Distress Rating Manual No. 21**

3.1.13 *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.
**ASTM Distress Rating Manual No. 21**

3.1.14 *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**

3.1.15 *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**

3.1.16 *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**

3.1.17 *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

[3] 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.

[4] Available from Standardization Documents Order Desk, Bldg 4, Section D, 700 Robbins Avenue, Philadelphia, PA 19111–5098.

[5] American Gear Manufacturers Assn. (AGMA), 1500 King St., Suite 201, Alexandria, VA 22314.

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

[7] Formerly known as CRC Manual 21. Available from the ASTM website, www.astm.org, (TMCMNL21).

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).

**ASTM Distress Rating Manual No. 21**

## 4. Summary of Test Method

4.1 Prior to each test run, inspect the test unit (final axle assembly) and measure and record confirming manufacturing specifications.

4.2 Begin the test when the axle assembly is installed on the test stand and charged with test lubricant.

4.3 *Gear Conditioning Phase*—Run the charged test unit for 100 min at 440 wheel r/min and 395 lbf-ft (535 N·m) torque per wheel, maintaining an axle sump temperature of 297°F (147 °C). (**Warning**—High-speed rotating equipment, electrical shock, high-temperature surfaces.)

4.4 *Gear Test Phase*—Next, run the test unit for 24 h at the operating conditions dictated by the hardware batch and type combination (see 10.2.3.1).

4.5 The test is completed at the end of the gear test phase. Visually inspect the test parts.

4.5.1 Remove the ring gear, pinion, and pinion bearing, and rate for various forms of distress. Use the condition of the ring gear and pinion to evaluate the performance of the test oil.

## 5. Significance and Use

5.1 This test method measures a lubricant's ability to protect 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 the following documents:

5.2.1 American Petroleum Institute (API) Publication 1560.[8]

5.2.2 STP-512A.[9]

5.2.3 SAE J308.

5.2.4 Military Specification MIL-PRF-2105E.

5.2.5 SAE J2360.

## 6. Apparatus

6.1 *Test Unit*—The test unit is a new complete hypoid truck axle assembly less axle shafts, Dana Model 60, 5.86 to 1 ratio.[10] See Annex A9 for part numbers.

6.2 *Test Stand and Laboratory Equipment:*

6.2.1 *Axle Vent*—Vent the axle to the atmosphere throughout the entire test and arrange the vent so that no water enters the housing.

6.2.2 *Axle Cover*—The axle cover may have a port installed to allow for ring gear inspection after the gear condition phase (see 10.1). See Fig. A5.1 for an example.

6.2.3 *Test Stand Configuration*—Mount the complete assembly in a rigid fixture as shown in Fig. A6.1. Mount the test unit in the test stand with pinion and axle shaft centerlines horizontal.

6.2.4 *Temperature Control*—The test axle housing shall include a means of maintaining the lubricant at a specified temperature. This shall include a thermocouple, a temperature recording system, and a cooling method.

6.2.4.1 *Thermocouple*—Determine the thermocouple location on the rear cover using the cover plate temperature sensor locating device as shown in Fig. A7.1.

*(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.

6.2.4.2 *Temperature Recording System*—The temperature recording system shall record the temperature of the test oil throughout the test.

6.2.4.3 *Axle Cooling*—Use three spray nozzles to distribute water over the cover plate and axle housing as shown in Fig. A8.1. Actuate the water control valve by the temperature PID control system. See A9.3.2.1 for L-37 Canadian Version test.

*(1)* Spray nozzles[11] shall be any combination of the following part numbers depending on how the system is plumbed: Straight Male NPT (Part No. 3/8GG-SS22), 90° Male NPT (Part No. 3/8GGA-SS22), Straight Female NPT (Part No. 3/8G-SS22), and 90° Female NPT (Part No. 3/8GA-SS22).

*(2)* Use a single control valve to control the cooling water supply. The control shall be a ½ in. (12.7 mm) two-way, C linear trim, air to close, Research Control valve. Use a single PID loop to maintain the axle lubricant temperature control for both the Standard and Canadian version test. A separate PID loop control for each version is not permitted. See A9.3.2.2 for L-37 Canadian Version test.

*(3)* Use only ⅜ or ½ in. (9.5 mm or 12.7 mm) line material to the spray nozzles.

*(4)* Use a minimum supply water pressure of 25 psi (172 kPa) to the control valve.

*(5)* Use an axle box cover as shown in Fig. A8.2. The purpose is to contain water and eliminate drafts.

*(6)* Use a locating pin or stop block as an indexing device to ensure that all subsequent axle installations are consistently installed perpendicular with the axle housing cover to engine and transmission driveshaft centerline.

6.2.5 *Power Source*—The power source consists of a gasoline-powered V-8 engine capable of maintaining test conditions.

[8] "Lubricant Service Designations for Automotive Manual Transmissions, Manual Transaxles, and Axles," available from American Petroleum Institute, 1220 L St. NW, Washington, DC 20005.

[9] "Laboratory Performance Tests for Automotive Gear Lubricants Intended for API GL-5 Service."

[10] 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. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[11] The sole source of supply of the apparatus known to the committee at this time is Spray Systems Company, and the spray nozzles can be purchased through E.I. Pfaff Company, 3443 Edwards Road, Suite D, Cincinnati, OH 45208. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

6.2.6 *Dynamometers and Torque Control System*—Use two axle dynamometers with sufficient torque absorbing capacity to maintain axle torque and speed conditions. Suitable control equipment with sensitivity of adjustment to permit maintenance of test conditions is required.

6.2.7 *Dynamometer Connecting Shafts*—Fabricate shafts connecting the dynamometer to the axle shafts. Shafts shall be strong enough to handle the torques encountered and shall be dynamically (spin) balanced.

6.2.8 *Drive Shaft and Universal Joints*—Fabricate a shaft with universal joints connecting the manual transmission and test axle. The shaft shall have a 4 in. ± 0.2 in. (10.1 cm ± 0.51 cm) outside diameter with a 0.095 in. ± 0.005 in. (0.24 cm ± 0.013 cm) wall thickness. Shaft and universal joints should be strong enough to handle the torques encountered and shall be dynamically (spin) balanced.

6.2.9 *Transmission and Coupling*—Couple the engine to the test unit through a clutch and manual transmission of sufficient torque carrying capacity to operate normally under test conditions.

6.3 *Speed Measuring and Control System,* capable of measuring speed of both axles and also of maintaining test conditions.

## 7. Reagents and Materials

7.1 *Sealing Compound,* where necessary, Permatex No. 2, or equivalent.

7.2 *Solvent*—Use only mineral spirits meeting the requirements of Specification D235, Type II, Class C for Aromatic Content (0 % to 2 % vol), Flash Point (142 °F/61 °C, min) and Color (not darker than +25 on Saybolt Scale or 25 on Pt-Co Scale). (**Warning—**Combustible. Health hazard.) Obtain a Certificate of Analysis for each batch of solvent from the supplier.

## 8. Preparation of Apparatus

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

8.2 *Lab-built Axles:*

8.2.1 To be approved to build axles acceptable for testing, obtain a separate approval for each of the two hardware types (lubrited and non-lubrited). Approval may be obtained for both hardware types by conducting three tests on each hardware type, or approval can be obtained with either hardware type independently by conducting just three tests on that type. To be approved to build axles acceptable for testing, assemble three axles in accordance with subsection 8.4 using a new V1L528/P4T883A pinion and ring set. Run these axles in tests using a blind mix of the following TMC-assigned oils: one TMC 152-2 and two TMC 134's (or approved re-blends of 134).

8.2.1.1 If all three of these tests are operationally valid and the 152-2 run meets the LTMS acceptance criteria for V1L528 hardware and both 134 run pinion results fail SAE J2360 acceptance criteria, the builder is approved to build axles for testing and the test stand is calibrated for the period described in 9.1.

8.2.1.2 If only the TMC 152-2 does not meet the LTMS acceptance criteria, rerun one TMC 152-2 fluid. If the repeat run meets LTMS acceptance criteria, the builder is approved to build axles for testing and the test stand is calibrated for the period described in 9.1.

8.2.1.3 If only one of the two TMC 134 pinion results does not fail SAE J2360 acceptance criteria, rerun two consecutive TMC 134's. If the pinion results for both repeats fail SAE J2360 acceptance criteria, the builder is approved to build axles for testing and the test stand is calibrated for the period described in 9.1.

8.2.1.4 If two of the three tests do not meet their designated acceptance criteria, or the required repeats described in 8.2.1.2 or 8.2.1.3 do not meet the designated acceptance criteria, repeat 8.2.1.

8.3 *Serial Number Reporting*—When rebuilding an axle assembly, follow this template for creating a serial number: LAB-CXXXX-NN

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

8.3.1 Permanently mark the serial number into the axle tube at a location near the housing vent. Revise the 2-digit rebuild count number each time the assembly is rebuilt.

8.4 *Preparation of Axle:*

8.4.1 Use either a newly manufactured axle assembly or, if the lab-built provisions of 8.2 have been met, a new V1L528/P4T883A gear set assembled into a reused axle housing according to the Dana Model 60 Maintenance Manual and using components from the Dana rebuild parts list given in Annex A9, Table A9.2.

8.4.2 When using an axle assembly rebuilt per 8.4.1 or an assembly from an older approved hardware batch that was not marked with contact pattern information by the manufacturer, apply gear contact pattern grease on the drive and coast side of the ring gear. Turn the input of the axle assembly while applying a resisting force to the ring sufficient to require an axle input torque of approximately 30 lbf·ft (40.7 N·m). Rotate ring and pinion through the gear contact pattern grease on the drive and coast side and verify that the patterns for both sides are acceptable. Record the drive side contact pattern length and flank values in the test report. Include drive side pattern photos of the ring gear in the test report.

8.4.3 If the axle assembly is a newly manufactured assembly received from Dana Corporation,[10] the drive side contact pattern length and flank values will be marked on the axle housing. Record these drive side contact pattern values in the test report.

8.4.4 Use only axle assemblies having a length value of $L^2$ or $L^3$ and a flank value of $F^{-1}$, $F^0$, or $F^{+1}$.

8.4.5 *Breakaway and Turning Torque Measurements*—Measure and record the breakaway and turning torques of the completely assembled test unit. Do not use any axle assembly where the breakaway or turning torque exceeds 55 lbf·in. (6.2 N·m).

8.4.6 *Backlash Measurements*—Record the backlash marked on the axle by the manufacturer. Use only axle assemblies having a manufacturer-reported backlash measurement from 0.004 in. to 0.012 in. (0.102 mm to 0.305 mm).

8.4.6.1 If the test axle is lab-built or is not marked with a manufacturer-reported backlash measurement, remove the cover plate and measure the backlash at four equally spaced locations. Record these four measurements and their average in the test report. Use only axle assemblies with an average backlash from 0.004 in. and 0.009 in. (0.102 mm to 0.229 mm).

8.4.7 *Cleaning*—Wash the test unit using a cleaning solvent (see 7.2). Pay particular attention to remove all preservative oil from the pinion bearings and any contact pattern grease that may be present. Dry by blowing with clean, dry compressed air.

8.4.8 Install axle shafts in test unit.

8.4.9 Lubricate the carrier bearings, pinion bearings, differential gears, and the ring gear and pinion, using 6.0 pt ± 0.1 pt (2.8 L ± 0.05 L) of test lubricant.

8.4.10 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.

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

## 9. L-37-specific Calibration and Standardization Items (See Annex A2 for General Calibration and Standardization Information)

9.1 *Reference Test Frequency*—The test stand calibration period is defined as four months or 650 test hours, 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.

9.1.1 When a test stand is out of calibration for a period of six months or longer, renumber the stand, and follow LTMS guidelines for new stand introduction.

9.1.2 Report modification of test stand apparatus or completion of any nonstandard test on a calibrated test stand to the TMC immediately.

9.1.3 Alternate testing of L-37 and L-42[12] tests does not necessitate recalibration as long as the above requirements are met.

9.1.4 Within a calibration period, alternate testing using different gear batches and dynamometer torque conditions does not necessitate recalibration.

9.2 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, must retain their test number.

9.3 *Instrumentation Calibration*—Using known standards traceable to the National Institute of Standards and Technology (NIST)[13] (or using physical constants), calibrate the axle speed measuring system, temperature control system, and torque measuring system immediately prior to every other calibration test or every nine months, whichever occurs first. 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 *Gear Conditioning Phase:*

10.1.1 Set the temperature control to maintain a lubricant temperature of 297 °F ± 3 °F (147.2 °C ± 1.7 °C). See A9.3.3.2 for L-37 Canadian Version test.

10.1.2 With the engine warmed up and with no load on the dynamometers, shift smoothly to a gear appropriate for the test conditions.

10.1.3 After reaching the appropriate gear, accelerate smoothly to 440 ± 5 wheel r/min and apply dynamometer load to achieve a torque of 395 lbf-ft ± 15 lbf-ft (535 N·m ± 20 N·m) on each wheel (see Note 2).

NOTE 2—The time required to accelerate to the test conditions of 440 wheel r/min and 395 lbf-ft (535 N·m) is about 5 min.

10.1.4 The test starts when required speed and torque conditions are reached. Record the time as start of the test.

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

10.1.6 To ensure accuracy of the test, record speed, torque, and temperature at a minimum of once every minute.

10.1.7 At the end of the 100 min, and as the torque and linear speed ramp-down is started, set the axle lubricant temperature controller to a set point of 275 °F ± 3 °F (135.0 °C ± 1.7 °C). Shift transmission to neutral and ensure that the axles stop turning. Record ending time and temperature of the lubricant. See A9.3.3.3 for L-37 Canadian Version test.

NOTE 3—The intent is to allow water to be added to the axle unit while it is still turning to cool the axle lubricant temperature and ensure that the water is shut off when the axle lubricant temperature drops below the set point.

10.1.8 Restart the test, as detailed in 10.3.1, if the test is stopped for any reason (power outage, maintenance, and so forth). This stoppage shall count 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, the stoppage will not count as one of the allowed shutdowns.

10.2 *Gear Test Phase:*

10.2.1 Ensure that the temperature control is still set to maintain a lubricant temperature of 275 °F ± 3 °F (135.0 °C ± 1.7 °C). See A9.3.3.4 for L-37 Canadian Version test.

10.2.2 With the engine warmed up and with no load on the dynamometers, shift smoothly to a gear appropriate for the test conditions.

NOTE 4—The transition from the end of the conditioning phase (see 10.1.7) to the appropriate test gear of the gear test phase is approximately 5 min.

10.2.3 After reaching the appropriate gear, accelerate smoothly to 80 ± 1 wheel r/min and apply dynamometer

[12] The L-42 procedure is currently being developed into a standard test method by Subcommittee D02.B0.

[13] National Institute of Standards and Technology (formerly National Bureau of Standards), Gaithersburg, MD 20899.

torque to achieve a torque of 1044 lbf-ft ± 35 lbf-ft (1415 N·m ± 47 N·m) on each wheel. Hold at this condition until the axle lubricant temperature reaches 175 °F ± 3 °F (79.4 °C ± 1.7 °C).

NOTE 5—The time required to accelerate to the test conditions of 80 wheel r/min and 1044 lbf-ft (1415 N·m) is about 10 min.

10.2.3.1 Once the axle lubricant temperature reaches 175 °F ± 3 °F (79.4 °C ± 1.7 °C), immediately apply dynamometer load to achieve a torque of 1740 lbf-ft ± 35 lbf-ft (2359 N-m ± 47 N-m) on each wheel. When conducting tests with non-lubrited gear batch V1L500/P4T813 or lubrited gear batch V1L528/P4T883A, use the 13 % reduced contact stress requirements (see A9.4.1).

10.2.4 The test phase starts when required speed, torque, and temperature conditions are reached. Record the time as start of the test phase.

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

10.2.6 To ensure test accuracy, record speed, torque, and temperature at a minimum of once every minute.

10.2.7 At the end of 24 h, close the throttle smoothly, shift the transmission to neutral, and record time and temperature of the lubricant.

10.2.8 Disconnect the drive shaft and axle shafts from the dynamometers, and remove the test unit from the test stand while the test unit is hot.

10.2.9 Restart the test, as detailed in 10.3.1, if the test is stopped for any reason (power outage, maintenance, and so forth). This stoppage shall count 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), the stoppage will not count as one of the allowed shutdowns.

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

10.3.1 *Restart After Unscheduled Downtime*—Restart the test as outlined in 10.3.1.1 through 10.3.1.5 any time there is an unscheduled downtime event.

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

10.3.1.2 With the engine warmed up and with no load on the dynamometers, shift smoothly to a gear appropriate for the test condition.

10.3.1.3 After reaching the appropriate gear, accelerate smoothly to the wheel r/min set point condition at the time of the shutdown.

10.3.1.4 If the restart occurs following a shutdown during the test phase, apply a dynamometer load on each wheel to achieve a torque value of 1044 lbf·ft ± 35 lbf·ft (1415 N·m ± 47 N·m) until the lubricant temperature reaches 175 °F ± 3 °F (79.4 °C ± 1.7 °C).

NOTE 6—If the restart occurs following a shutdown during the conditioning phase, follow 10.1.1 through 10.1.4 to restart the test.

10.3.1.5 Once lubricant temperature reaches 175 °F ± 3 °F (79.4 °C ± 1.7 °C), immediately apply dynamometer torque on each wheel to achieve the torque set point condition at the time of the shutdown.

## 11. Axle Post Test Measurements

11.1 *Break and Turn Torques:*

11.1.1 While the unit is hot, determine and record the torque required to break and to turn the pinion shaft of the completely assembled test unit.

11.1.2 Allow the unit to cool, and record the torques required to break and to turn the pinion shaft of the completely assembled test unit.

11.2 Drain the axle of test lubricant. This may occur anytime after 10.2.7 has been completed.

11.3 *Backlash Measurements*—Remove the cover plate. Record backlash at four equally spaced locations on the ring gear and calculate the average of the four readings.

11.4 Completely disassemble the differential and the pinion shaft assemblies for inspection.

## 12. Determination of Test Results[14]

12.1 *Pinion Bearing Rating*—Examine the bearings for wear, surface fatigue corrosion, and deposits in accordance with ASTM Distress Rating Manual 21.

12.2 *Gear Rating:*

12.2.1 Examine the tooth surfaces on the drive side of the pinion and ring gear for the following distresses in accordance with ASTM Distress Rating Manual 21 and Annex A12: burnishing, wear, pitting/spalling, ridging, rippling, scoring, discoloration, corrosion, and deposits. Rate the distress types of wear, rippling, and ridging using the ASTM Photographs for Gear Distress. The photographs shall be an ASTM item TMCGEARDISTRESS2010PR and shall have been issued on or after November 9, 2010.[15,16]

12.2.2 Rate each distress by identifying its level of distress in accordance with Table A12.1. Four distress types (ridging, rippling, scoring, and wear) are assigned a numerical value between 0 and 10 corresponding to the rated level of distress, as shown in Table A12.1.

12.2.2.1 The pitting/spalling distress type is assigned a numerical value shown separately in Table A12.1.

12.2.3 Transform the rated test results according to Table 1. Add any applicable corrections outlined in 12.3 and then un-transform the value for final result reporting.

12.3 *Correction Factors and Exclusions:*

12.3.1 *C1L426/P4L415A Nonlubrited Gear Set*—When using the nonlubrited hardware, gear set C1L426/P4L415A, determine a numerical pitting/spalling value, excluding any

[14] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1415.

[15] Available from the ASTM website, www.astm.org.

[16] Training for individuals rating gear sets for gear distress level may be coordinated through the ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA, 15206.

**TABLE 1 Transformations**

| Parameter | Transformation |
|---|---|
| Ridging | –ln (10.5 – merit) |
| Rippling | –ln (10.5 – merit) |
| Pitting/Spalling | –ln (10.5 – merit) |
| Wear | none |

pitting/spalling value between 9.3 and 9.9, inclusively, in the wear step area of the drive side pinion tooth, as per Annex A13.

12.3.2 *V1L303/P4L514A Nonlubrited Gear Set*—When using the nonlubrited hardware, gear set V1L303/P4L514A, determine a numerical pitting/spalling value, excluding any pitting/spalling value between 3.0 and 9.9, inclusive, in the wear step area of the drive side pinion tooth, as per Annex A13.

12.3.3 *V1L686/P4L626A Lubrited Gear Set*—When using the lubrited hardware, gear set V1L686/P4L626A, for non-reference oil tests, add a correction factor of 0.5186 to the pinion transformed ridging test result, and add 0.9922 to the ring transformed ridging test result.

12.3.3.1 On the V1L686/P4L626A gear set, a thin polished line visible in the root heel of the pinion and on the crown of the ring gear might be evident. The polish line might vary in length and prominence due to the build position of the ring and pinion gears and manufacturing accuracy of the carrier. This condition is normal and not oil-related. Note this condition in the final test report comment section as *Root and Tip line polishing and a function of the gear set manufacturing process — V1L686/P4L626A*.

12.3.4 *V1L528/P4T883A Nonlubrited Gear Set*—When using the nonlubrited hardware gear set V1L528/P4T883A for non-reference oil tests, add 0.3365 to the transformed test result of both pinion ridging and pinion rippling. Rate each pinion tooth for pitting/spalling and report the fourth lowest tooth rating for the final pinion pitting/spalling test result.

12.3.4.1 See A9.3.4 for L-37 Canadian Version test.

12.3.5 *V1L528/P4T883A Lubrited Gear Set*—When using the lubrited hardware gear set V1L528/P4T883A for non-reference oil tests, add 0.3365 to the transformed pinion ridging test result. Rate each pinion tooth for pitting/spalling and report the second lowest tooth rating for the final pinion pitting/spalling test result.

12.3.5.1 See A9.3.4 for L-37 Canadian Version test.

12.4 For a test rating to be valid, the gears shall be rated by an individual who has participated in an ASTM gear-rater calibration workshop within the previous twelve months[16] and has been calibrated as outlined in the L-37 Rater Calibration Monitoring System (RCMS). The RCMS calibration period is every six months or as otherwise required by the RCMS. A copy of the RCMS document is available on the ASTM Test Monitoring Center web page at http://www.astmtmc.cmu.edu/, or it can be obtained in hardcopy format from the TMC.

12.5 *Test Validity*—The test is determined to be operationally valid if the percent deviation of the critical operating parameters and number of shutdowns are within the limits specified and defined in Annex A11.

12.6 Consider as non-interpretable any non-reference oil test that has not been run in a calibrated test stand or not conducted on approved hardware, or both. Indicate on the cover page of the test report that the test is non-interpretable and that it has not been conducted in a valid manner in accordance with the test method.

12.7 Any reference or non-reference oil test exhibiting a broken or cracked pinion or ring gear tooth is non-interpretable. Note any broken teeth in the comment section of the test report.

12.8 Rate only the corrosion on the contact surface of the drive side of any pinion or ring gear tooth. Enter the corrosion rating in the rating section of the rating form. Note any corrosion on the pinion and ring in a non-contact surface area in the comment section of the rating form.

## 13. Report

13.1 For reference oil tests, use the standardized report form set available from the TMC.

NOTE 7—Report the non-reference oil test results on these same forms if the results are intended to be submitted as candidate oil results against a specification.

13.1.1 Fill out the report forms according to the formats shown in the data dictionary.

13.1.2 Transmit results to the TMC within 5 working days of test completion.

13.1.3 Transmit the results electronically as described in the ASTM Data Communications Committee Test Report Transmission Model (Section 2 — Flat File Transmission Format) available from the ASTM TMC. Upload files via the TMC's website

13.2 Report all reference oil test results, whether aborted, invalidated, or successfully completed, to the TMC.

13.3 *Deviations from Test Operational Limits*—Report all deviations from specified test operational limits.

13.4 *Precision of Reported Units*—Use the Practice E29 rounding off method for critical pass/fail test result data. Report the data to the same precision as indicated in data dictionary.

13.5 In the space provided, note the time, date, test hour, and duration of any shutdown or offtest condition. Document the outcome of all prior reference oil tests from the current calibration sequence that were operationally or statistically invalid.

13.6 If a calibration period is extended beyond the normal calibration period length, make a note in the comment section and attach a written confirmation of the granted extension from the TMC to the test report. List the outcomes of previous runs that may need to be considered as part of the extension in the comment section.

13.7 Attach to the test report a plot of the temperature data recorded.

## 14. Precision and Bias

14.1 *Precision*—Test precision is established on the basis of reference oil test results (for operationally valid tests) monitored by the ASTM TMC. The data are reviewed semiannually by the L-37 Surveillance Panel. Contact the ASTM TMC for current industry data. Table 2 summarizes reference oil precision of the test as of March 29, 2005.

14.1.1 *Intermediate Precision Conditions*—Conditions where test results are obtained with the same test method by the same laboratory, with the same gear batch using the same test oil, with changing conditions such as operators, measuring equipment, test stands, test engines, and time.

NOTE 8—"Intermediate precision" is the appropriate term for this test method, instead of "repeatability," which defines more rigorous within-laboratory conditions.

14.1.1.1 *Intermediate Precision Limit (i.p.)*—The difference between two results obtained under intermediate precision conditions that would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 2 in only one case in twenty. When only a single test result is available, the Intermediate Precision Limit can be used to calculate a range (test result ± Intermediate Precision Limit) outside of which a second test result would be expected to fall about one time in twenty.

14.1.2 *Reproducibility Conditions*—Conditions where test results are obtained with the same test method using the same gear batch on the same test oil in different laboratories with different operators using different equipment.

14.1.2.1 *Reproducibility Limit (R)*—The difference between two results obtained under reproducibility conditions that would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 2 in only one case in twenty. When only a single test result is available, the Reproducibility Limit can be used to calculate a range (test result ± Reproducibility Limit) outside of which a second test result would be expected to fall about one time in twenty.

14.2 *Bias*—No estimate of bias for this test method is possible because the performance results for an oil are determined only under specific conditions of the test and no absolute standards exist.

## 15. Keywords

15.1 abrasive wear; adhesive wear; bearing failure; final drive axle; gear; gear failure; hypoid axle; L-37; lubricants; surface fatigue

# ANNEXES

**(Mandatory Information)**

## A1. ASTM TEST MONITORING CENTER ORGANIZATION

A1.1 *Nature and Functions of the ASTM Test Monitoring Center (TMC)*—The TMC is a non profit organization located in Pittsburgh, Pennsylvania and is staffed to: administer engineering studies; conduct laboratory inspections; perform statistical analyses of reference oil test data; blend, store, and ship reference oils; and provide the associated administrative functions to maintain the referencing calibration program for various lubricant tests as directed by ASTM Subcommittee D02.B0 and the ASTM Executive Committee. The TMC coordinates its activities with the test sponsors, the test developers, the surveillance panels, and the testing laboratories. Contact TMC through the TMC Director at:

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

**TABLE 2 Reference Oil Test Precision Data**

NOTE 1—These statistics are based on the L-37 Standard version test results obtained on Test Monitoring Center Reference Oils 151-2, 151-3, 152, 152-1, 153, 153-1, 155, and 155-1 as of June 2015. There are no statistics for the Canadian version test at this time.

Legend:
$S_{i.p.}$ = intermediate precision standard deviation,
*i.p.* = intermediate precision,
$S_R$ = reproducibility standard deviation, and
*R* = reproducibility.

| Hardware Type | Variable | $S_{i.p.}$ | i.p.[A] | $S_R$ | R[A] |
|---|---|---|---|---|---|
| Lubrited | Pinion ridging, merit | 1.482 | 4.150 | 1.482 | 4.150 |
| | Pinion rippling, merit | 0.580 | 1.624 | 0.594 | 1.663 |
| | Pinion pitting/spalling, merit | 0.728 | 2.038 | 0.753 | 2.108 |
| | Pinion wear, merit | 0.571 | 1.599 | 0.589 | 1.649 |
| Non-lubrited | Pinion ridging, merit | 0.649 | 1.817 | 0.676 | 1.893 |
| | Pinion rippling, merit | 0.551 | 1.543 | 0.577 | 1.616 |
| | Pinion pitting/spalling, merit | 0.818 | 2.290 | 0.818 | 2.290 |
| | Pinion wear, merit | 0.683 | 1.912 | 0.683 | 1.912 |

[A] This value is obtained by multiplying the standard deviation by 2.8.

A1.2 *Rules of Operation of the ASTM TMC*—The TMC operates in accordance with the ASTM Charter, the ASTM Bylaws, the Regulations Governing ASTM Technical Committees, the Bylaws Governing ASTM Committee D02, and the Rules and Regulations Governing the ASTM Test Monitoring System.

A1.3 *Management of the ASTM TMC*—The management of the Test Monitoring System is vested in the Executive Committee elected by Subcommittee D02.B0. The Executive Committee selects the TMC Director who is responsible for directing the activities of the TMC.

A1.4 *Operating Income of the ASTM TMC*—The TMC operating income is obtained from fees levied on the reference oils supplied and on the calibration tests conducted. Fee schedules are established by the Executive Committee and reviewed by Subcommittee D02.B0.

## A2. ASTM TEST MONITORING CENTER: CALIBRATION PROCEDURES

A2.1 *Reference Oils*—These oils are formulated or selected to represent specific chemical, or performance levels, or both. They are usually supplied directly to a testing laboratory under code numbers to ensure that the laboratory is not influenced by prior knowledge of acceptable results in assessing test results. The TMC determines the specific reference oil the laboratory shall test.

A2.1.1 *Reference Oil Data Reporting*—Test laboratories that receive reference oils for stand calibration shall submit data to the TMC on every sample of reference oil they receive. If a shipment contains any missing or damaged samples, the laboratory shall notify the TMC immediately.

A2.2 *Calibration Testing*:

A2.2.1 Full scale calibration testing shall be conducted at regular intervals. These full scale tests are conducted using coded reference oils supplied by the TMC. It is a laboratory's responsibility to keep the onsite reference oil inventory at or above the minimum level specified by the TMC test engineers.

A2.2.2 *Test Stands Used for Non Standard Tests*—If a non standard test is conducted on a previously calibrated test stand, the laboratory shall conduct a reference oil test on that stand to demonstrate that it continues to be calibrated, prior to running standard tests.

A2.3 *Reference Oil Storage*—Store reference oils under cover in locations where the ambient temperature is between –10 °C and +50 °C.

A2.4 *Analysis of Reference Oil*—Unless specifically authorized by the TMC, do not analyze TMC reference oils, either physically or chemically. Do not resell ASTM reference oils or supply them to other laboratories without the approval of the TMC. The reference oils are supplied only for the intended purpose of obtaining calibration under the ASTM Test Monitoring System. Any unauthorized use is strictly forbidden. The testing laboratory tacitly agrees to use the TMC reference oils exclusively in accordance with the TMC's published Policies for Use and Analysis of ASTM Reference Oils, and to run and report the reference oil test results according to TMC guidelines. Additional policies for the use and analysis of ASTM Reference Oils are available from the TMC.

A2.5 *Conducting a Reference Oil Test*—When laboratory personnel are ready to run a reference calibration test, they shall request an oil code via the TMC website.

A2.6 *Reporting Reference Oil Test Results*—Upon completion of the reference oil test, the test laboratory transmits the data electronically to the TMC, as described in Section 13. The TMC reviews the data and contacts the laboratory engineer to report the laboratory's calibration status. All reference oil test results, whether aborted, invalidated, or successfully completed, shall be reported to the TMC.

A2.6.1 All deviations from the specified test method shall be reported.

## A3. ASTM TEST MONITORING CENTER: MAINTENANCE ACTIVITIES

A3.1 *Special Reference Oil Tests*—To ensure continuous severity and precision monitoring, calibration tests are conducted periodically throughout the year. Occasionally, the majority or even all of the industry's test stands will conduct calibration tests at roughly the same time. This could result in an unacceptably large time frame when very few calibration tests are conducted. The TMC can shorten or extend calibration periods as needed to provide a consistent flow of reference oil test data. Adjustments to calibration periods are made such that laboratories incur no net loss or gain in calibration status.

A3.2 *Special Use of the Reference Oil Calibration System*—The surveillance panel has the option to use the reference oil system to evaluate changes that have potential impact on test severity and precision. This option is only taken when a program of donated tests is not feasible. The surveillance panel and the TMC shall develop a detailed plan for the test program. This plan requires all reference oil tests in the program to be completed as close to the same time as possible, so that no laboratory/stand calibration status is left pending for an excessive length of time. In order to maintain the integrity of the reference oil monitoring system, each reference oil test is conducted so as to be interpretable for stand calibration. To facilitate the required test scheduling, the surveillance panel may direct the TMC to lengthen and shorten reference oil calibration periods within laboratories such that the laboratories incur no net loss or gain in calibration status. To ensure accurate stand, or laboratory, or both severity assessments, conduct non reference oil tests the same as reference oil tests.

A3.3 *Donated Reference Oil Test Programs*—The surveillance panel is charged with maintaining effective reference oil test severity and precision monitoring. During times of new parts introductions, new or re blended reference oil additions, and procedural revisions, it may be necessary to evaluate the possible effects on severity and precision levels. The surveillance panel may choose to conduct a program of donated reference oil tests in those laboratories participating in the monitoring system, in order to quantify the effect of a particular change on severity and precision. Typically, the surveillance panel requests its panel members to volunteer enough reference oil test results to create a robust data set. Broad laboratory participation is needed to provide a representative sampling of the industry. To ensure the quality of the data obtained, donated tests are conducted on calibrated test stands. The surveillance panel shall arrange an appropriate number of donated tests and ensure completion of the test program in a timely manner.

A3.4 *Intervals Between Reference Oil Tests*—Under special circumstances, such as extended downtime caused by industry wide parts or fuel shortages, the TMC may extend the intervals between reference oil tests. Such extensions shall not exceed one regular calibration period.

A3.5 *Introducing New Reference Oils*—Reference oils produce various results. When new reference oils are selected, participating laboratories will be requested to conduct their share of tests to enable the TMC to recommend industry test targets. ASTM surveillance panels require a minimum number of tests to establish the industry test targets for new reference oils.

A3.6 *TMC Information Letters*—Occasionally it is necessary to revise the test method, and notify the test laboratories of the change, prior to consideration of the revision by Subcommittee D02.B0. In such a case, the TMC issues an Information Letter. Information Letters are balloted semi annually by Subcommittee D02.B0, and subsequently by D02. By this means, the Society due process procedures are applied to these Information Letters.

A3.6.1 *Issuing Authority*—The authority to issue an Information Letter differs according to its nature. In the case of an Information Letter concerning a part number change which does not affect test results, the TMC is authorized to issue such a letter. Long term studies by the surveillance panel to improve the test procedure through improved operation and hardware control may result in the issuance of an Information Letter. If obvious procedural items affecting test results need immediate attention, the test sponsor and the TMC issue an Information Letter and present the background and data supporting that action to the surveillance panel for approval prior to the semiannual Subcommittee D02.B0 meeting.

A3.7 *TMC Memoranda*—In addition to the Information Letters, supplementary memoranda are issued. These are developed by the TMC and distributed to the appropriate surveillance panel and participating laboratories. They convey such information as batch approvals for test parts or materials, clarification of the test procedure, notes and suggestions of the collection and analysis of special data that the TMC may request, or for any other pertinent matters having no direct effect on the test performance, results, or precision and bias.

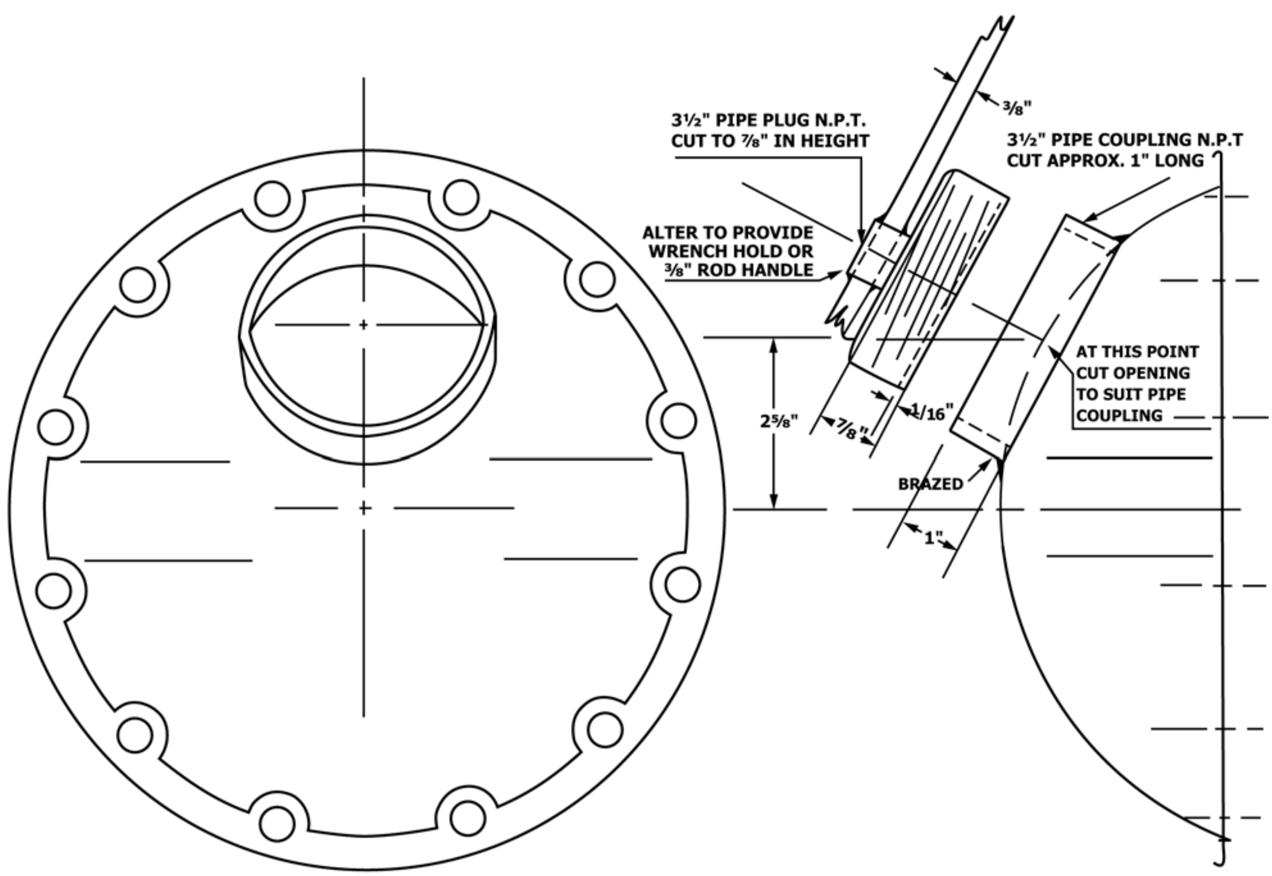
## A4. ASTM TEST MONITORING CENTER: RELATED INFORMATION

A4.1 *New Laboratories*—Laboratories wishing to become part of the ASTM Test Monitoring System will be requested to conduct reference oil tests to ensure that the laboratory is using the proper testing techniques. Information concerning fees, laboratory inspection, reagents, testing practices, appropriate committee membership, and rater training can be obtained by contacting the TMC Director.

A4.2 *Information Letters: COTCO Approval*—Authority for the issuance of Information Letters was given by the committee on Technical Committee Operations in 1984, as follows: "COTCO recognizes that D02 has a unique and complex situation. The use of Information Letters is approved providing each letter contains a disclaimer to the affect that such has not obtained ASTM consensus. These Information Letters should be moved to such consensus as rapidly as possible."

A4.3 *Precision Data*—The TMC determines the precision of test methods by analyzing results of calibration tests conducted on reference oils. Precision data are updated regularly. Current precision data can be obtained from the TMC.

## A5. AXLE COVER EXAMPLE




| in. | mm | in. | mm |
|---|---|---|---|
| 1⁄16 | (1.6) | 1 | (25.4) |
| 3⁄8 | (9.5) | 2 5⁄8 | (66.7) |
| 7⁄8 | (22.2) | 3 1⁄2 | (88.9) |

**FIG. A5.1 Axle Cover Example**

## A6. RIGID AXLE MOUNT EXAMPLE

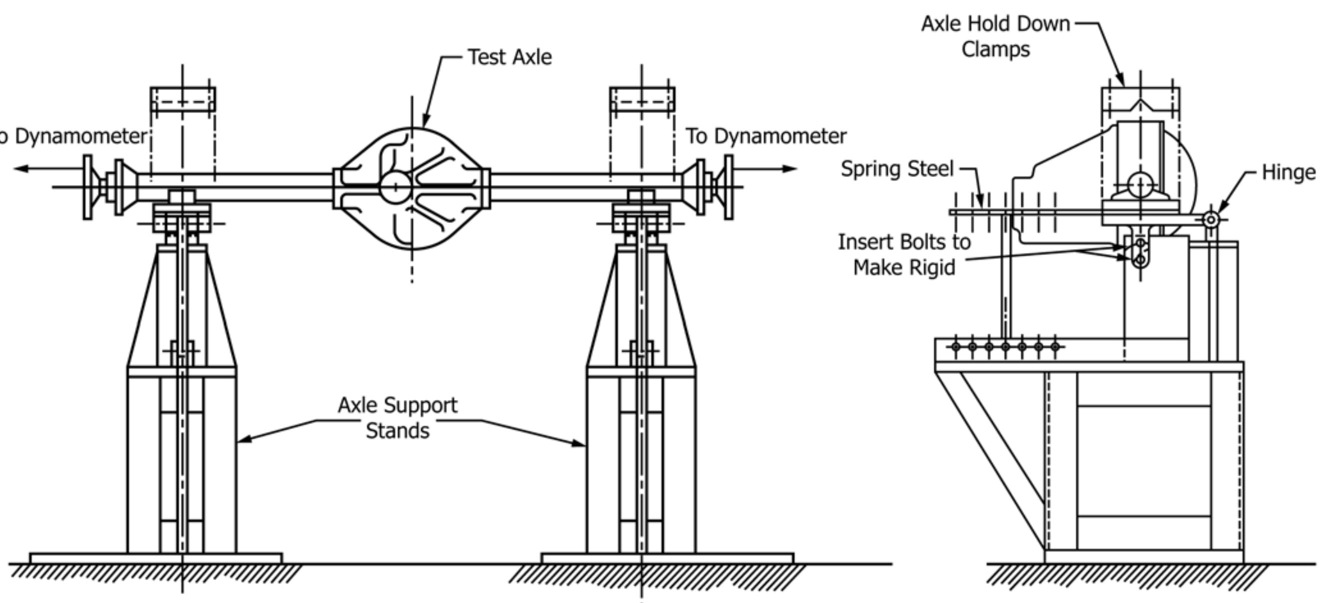
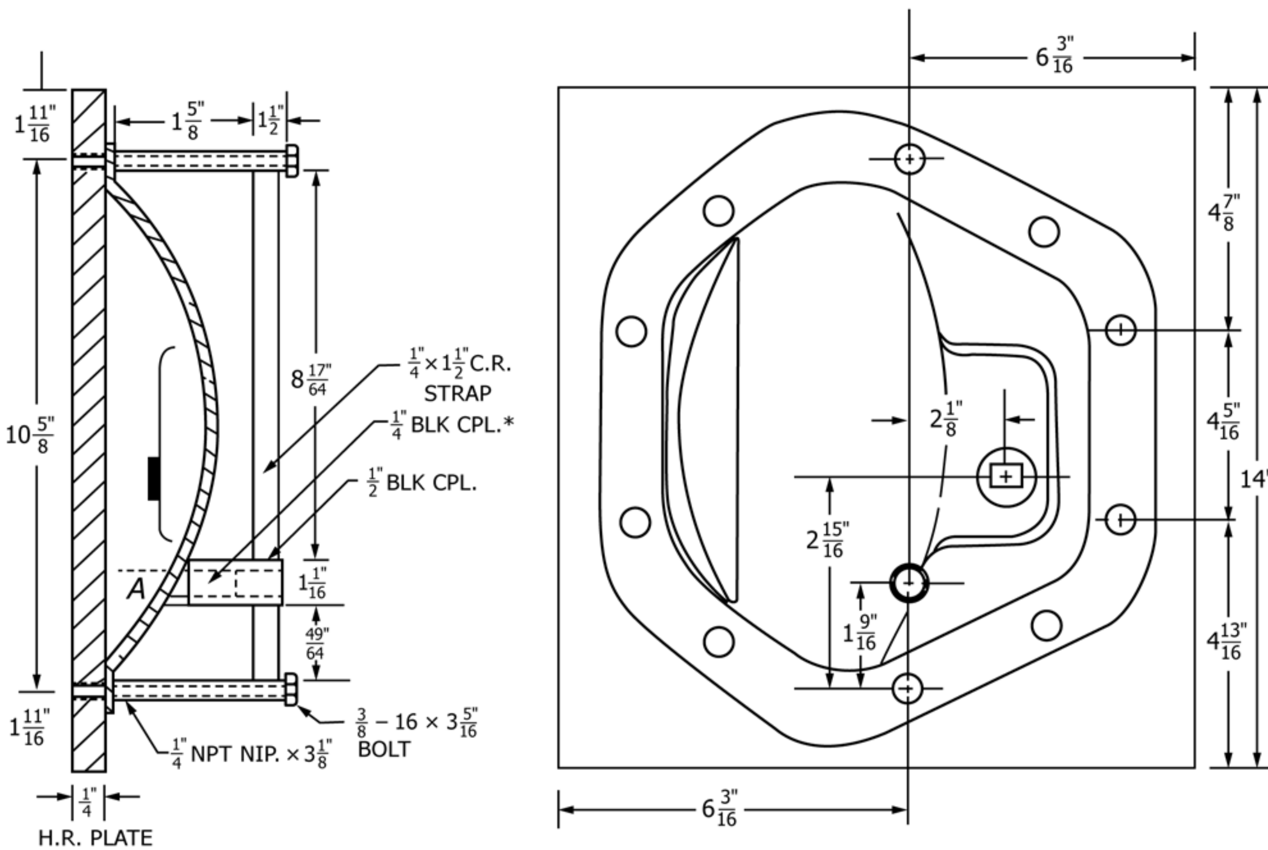



**FIG. A6.1 Example of Rigid Axle Mount on Test Stand**

## A7. COVER PLATE TEMPERATURE SENSOR LOCATING DEVICE

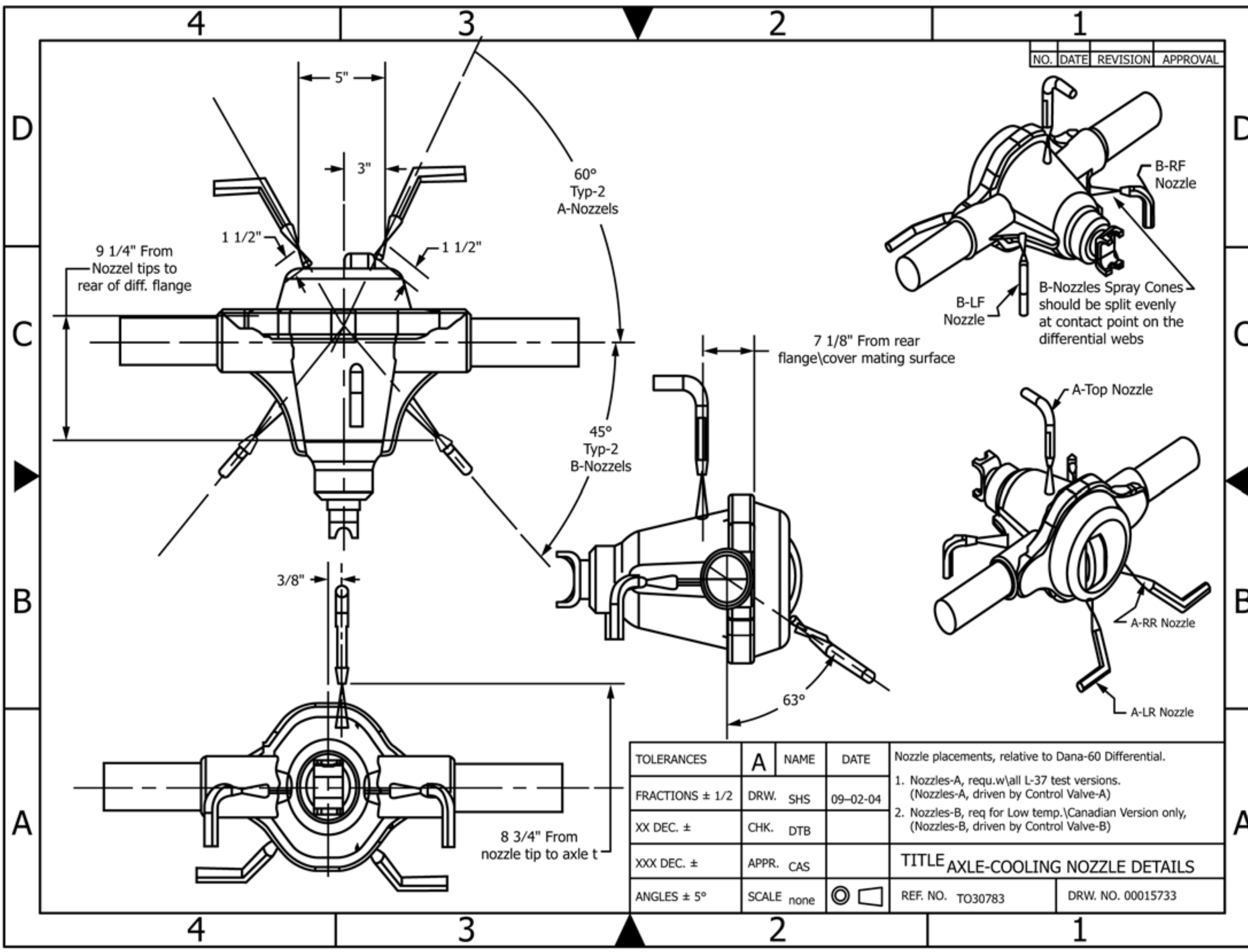



*A* CPL cut a approximately 50° angle (sand cpl to match contour of cover)

| in. | mm | in. | mm |
|---|---|---|---|
| ¼ | (6.4) | 3⅛ | (79.4) |
| ⅜ | (9.5) | 3⁵⁄₁₆ | (84.1) |
| ½ | (12.7) | 4⁵⁄₁₆ | (109.5) |
| 1¹⁄₁₆ | (27.0) | 4¹³⁄₁₆ | (122.2) |
| 1½ | (38.1) | 4⅞ | (123.8) |
| 1⁹⁄₁₆ | (39.7) | 6³⁄₁₆ | (157.2) |
| 1⅝ | (41.3) | 8¹⁷⁄₆₄ | (209.9) |
| 1¹¹⁄₁₆ | (42.9) | 10⅝ | (269.9) |
| 2⅛ | (54.0) | 13 | (330.2) |
| 2¹⁵⁄₁₆ | (76.6) | | |

**FIG. A7.1 Cover Plate Temperature Sensor Locating Device**

## A8. AXLE COOLING SYSTEM




| in. | mm |
|---|---|
| ⅜ | (10) |
| 1½ | (42) |
| 3 | (76) |
| 5 | (127) |
| 7⅛ | (181) |
| 8¾ | (222) |
| 9¼ | (235) |

**FIG. A8.1 Location of Spray Nozzles on Axle**

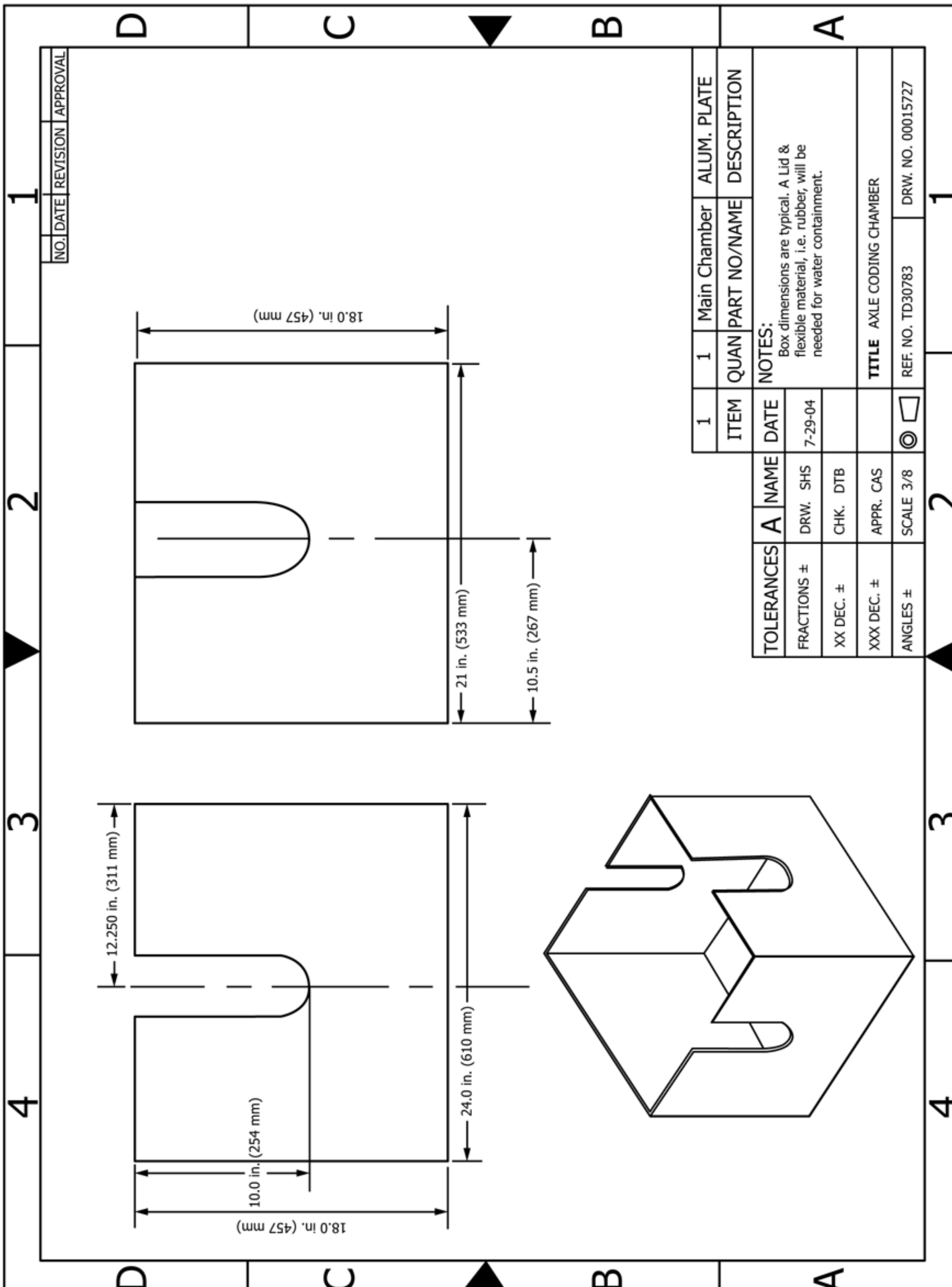



FIG. A8.2 Axle Box Cover

## A9. TEST VERSIONS AND AXLE PART NUMBERS

A9.1 *Axle Used in Test*—Two types of test axle are run in this test.

A9.1.1 *Uncoated Axle*—Dana Model 60, 5.86 ratio, standard differential with uncoated ring gear and uncoated pinion, Part No. 060AA100-2.[10] Also referred to as plain or green axles.

A9.1.2 *Coated Axle (manganese phosphate coating)*—Dana Model 60, 5.86 ratio, standard differential with coated ring gear and coated pinion, Part No. 060AA100-4.[10] Also referred to as lubrited or lubrized axles.

A9.2 *Test Versions*—This test has four commonly used versions. The test procedures and conditions described previously in this test method will be referred to as the standard version. All versions maintain the same test procedures, wheel load, and wheel speed conditions. The differences occur in the axle oil temperature and axle type used. Table A9.1 describes each version.

A9.3 *L-37 Canadian Version Test Requirements*:

A9.3.1 *Calibration Test Acceptance* (see Section 9):

A9.3.1.1 Calibration status of the L-37 Canadian Version test is determined by successfully calibrating a test stand according to the L-37 Standard Version test requirements detailed in Section 9. In other words, a stand that is calibrated for the L-37 Standard Version test is automatically calibrated for the L-37 Canadian Version test.

A9.3.2 *Apparatus:*

A9.3.2.1 Use five spray nozzles to distribute water over the cover late and axle housing as shown in Fig. A8.1. Actuate the water control valves by the temperature PID control system (see 6.2.4.3).

A9.3.2.2 Use two control valves to control the cooling water supply. The control valves shall be a ½ in. two-way, C linear trim, air to close, Research Control valve. Use only one PID loop to maintain axle lubricant temperature control (see 6.2.4.3*(2)*).

A9.3.3 *Test Procedure:*

A9.3.3.1 Operate the test as outlined in 10.1 through 10.3 of the L-37 Standard Version test with the exceptions of the following sections. The procedure modifications listed in this annex refer to the corresponding section of the L-37 Standard Version test.

**TABLE A9.2 Rebuild Parts List for Lab Built Axles using V1L528/P4T883A**

| Dana Part Number | Timken Part Number | Part |
|---|---|---|
| 30271 | | Pinion Nut[A] |
| 42449 | | Pinion Seal[A] |
| 550358 | HM88542 | Outer Pinion Cone |
| 550359 | HM88510 | Outer Pinion Cup |
| 34801 | | Pre-load Shim[A] |
| 550360 | HM803146 | Inner Pinion Cone |
| 550361 | HM803110 | Inner Pinion Cup |
| 30291–1 | | Pinion Position Shim[A] |
| 30291–2 | | Pinion Position Shim[A] |
| 30291–3 | | Pinion Position Shim[A] |
| 550363 | 382S | Diff. Bearing Cup |
| 550362 | 387A | Diff. Bearing Cone |
| 30276–1 | | Diff. Shims[A] |
| 30276–2 | | Diff. Shims[A] |
| 30276–3 | | Diff. Shims[A] |
| 30276–4 | | Diff. Shims[A] |
| 40638 | | Ring Gear Screws (120–140 lb/ft)[A] |
| 34686 | | Cover Gasket (replaced by 34687)[A] |

[A] Or equivalent part from another manufacturer.

A9.3.3.2 Set the temperature control to maintain a lubricant temperature of 220 °F ± 3 °F (104.4 °C ± 1.7 °C) (see 10.1.1).

A9.3.3.3 At the end of the 100 min, set the temperature control to maintain a lubricant temperature of 200 °F ± 3 °F (93.3 °C ± 1.7 °C), close the throttle smoothly, shift transmission to neutral, and record ending time and temperature of the lubricant (see 10.1.7).

A9.3.3.4 Ensure that the axle temperature control is still set to maintain a lubricant temperature of 200 °F ± 3 °F (93.3 °C ± 1.7 °C) (see 10.2.1).

A9.3.4 *Correction Factors and Exclusions:*

A9.3.4.1 *V1L686/P4L626A Lubrited Gear Set*—When using the lubrited hardware, gear set V1L686/P4L626A, for non-reference oil tests, add 0.6065 to the pinion and ring transformed ridging test result.

A9.3.4.2 *L247/T758A Lubrited Gear Set*—When using the lubrited hardware gear set L247/T758A, for non-reference oil tests, add 0.5878 to the transformed pinion ridging test result and add 0.7340 to the transformed pinion pitting/spalling test result.

A9.3.4.3 *V1L528/P4T883A Nonlubrited Gear Set*—When using the nonlubrited hardware gear set V1L528/P4T883A for non-reference oil tests, add 0.7566 to the transformed pinion

**TABLE A9.1 Test Versions[A,B]**

| Test Version | Axle Type | Gear Conditioning | Gear Test Phase |
|---|---|---|---|
| | | Axle Temperature | Axle Temperature |
| Standard | uncoated | 297 °F ± 3 °F (147.2 °C ± 1.7 °C) | 275 °F ± 3 °F (135.0 °C ± 1.7 °C) |
| Standard | coated | 297 °F ± 3 °F (147.2 °C ± 1.7 °C) | 275 °F ± 3 °F (135.0 °C ± 1.7 °C) |
| Canadian | uncoated | 220 °F ± 3 °F (104.4 °C ± 1.7 °C) | 200 °F ± 3 °F (93.3 °C ± 1.7 °C) |
| Canadian | coated | 220 °F ± 3 °F (104.4 °C ± 1.7 °C) | 200 °F ± 3 °F (93.3 °C ± 1.7 °C) |

[A] All versions use the same wheel speed, load conditions, and test procedures, which are described in Section 10.
[B] Both Canadian test versions typically used for evaluation of 75W lubricants.

rippling test result. Rate each pinion tooth for pitting/spalling and report the fourth lowest tooth rating for the final pinion pitting/spalling test result.

A9.3.4.4 *V1L528/P4T883A Lubrited Gear Set*—When using the lubrited hardware gear set V1L528/P4T883A for non-reference oil tests, add 0.5878 to the transformed test result of both pinion ridging and pinion rippling. Rate each pinion tooth for pitting/spalling and report the second lowest tooth rating for the final pinion pitting/spalling test result. Add 0.3365 to the transformed ring ridging test result.

A9.4 *L-37 13 % Reduced Contact Stress Test Requirements*:

A9.4.1 Once the axle lubricant temperature reaches 175 °F ± 3 °F (79.4 °C ± 1.7 °C), immediately apply dynamometer torque to achieve a torque of 1213 lbf-ft ± 25 lbf-ft (1645 N·m ± 34 N·m) on each wheel.

## A10. L-37 TEST REPORT FORMS and DATA DICTIONARY

A10.1 The required report forms and data dictionary are available on the ASTM Test Monitoring Center web page at http://www.astmtmc.cmu.edu/, or they can be obtained in hardcopy format from the TMC.

| | |
|---|---|
| Form 0 | Test Report Cover |
| Form 1 | Test Result Summary Page |
| Form 2 | Gear Tooth Surface Condition |
| Form 3 | Operational Summary Sheet |
| Form 4 | Operational Summary Sheet |
| Form 5 | Operational Validity Summary |

## A11. TEST VALIDITY CALCULATION AND LIMITS

A11.1 For a test to be operationally valid it shall not exceed the limits on unscheduled downtime and deviation from critical operating parameters.

A11.2 *Downtime Limits*:

A11.2.1 During the warm-ups of the gear conditioning and test phases of the test, there is no limit on number of occurrences.

A11.2.2 During the test, a maximum number of two downtime occurrences are permitted in addition to the shutdown between the gear conditioning and gear test phases.

A11.3 *Deviation from Test Operating Parameters*:

A11.3.1 Axle sump temperature, wheel speed, and wheel torque are considered critical operating parameters for this test method.

A11.3.2 Calculate the percent deviation as follows:

$$percent\ out = \sum_{i=1}^{n} \left( \frac{Mi}{0.5R} \times \frac{Ti}{D} \right) \times 100 \quad (A11.1)$$

where:

$Mi$ = magnitude of test parameter out from specification limit at occurrence, $i$,
$R$ = test parameter specification range,
$Ti$ = length of time the test parameter was outside of specification range at occurrence, $i$, ($Ti$ is assumed to be no less than the recorded dtas-acquisition frequency unless supplemental readings are documented), and
$D$ = test or test phase duration in same units as $Ti$.

A11.3.3 A reading out of specification using once-every-hour data recording is considered to be out for the full hour unless otherwise documented.

A11.3.4 The deviation percentages for the critical operating parameters are shown in Table A11.1.

A11.3.5 The test is considered invalid if the axle oil temperature reaches 325 °F (162.7 °C) any time during the test.

A11.3.6 Calculate axle oil temperature percent deviation after 294 °F (145.6 °C) is reached for the gear conditioning phase.

**TABLE A11.1 Critical Operating Parameter Limits**

| Parameter | Gear Conditioning Limits | Gear Testing Limits |
|---|---|---|
| Axle oil temperature | 5 % | 5 % |
| Wheel speed | 5 % | 5 % |
| Wheel load | 5 % | 5 % |

## A12. GEAR RATING RULES

A12.1 Additional descriptions have been developed to aid the rater in accurately assessing the distress on the ring gear and pinion following the completion of the test. The definitions described in this annex supersede those found in ASTM Distress Rating Manual 21 where applicable.

A12.2 *Severity Levels*:

A12.2.1 Document the most severe level for each individual distress. Use the photographs in ASTM Distress Manual 21 as examples.

A12.2.2 *None*—Absence of distress.

A12.2.3 *Trace*—Barely discernible, may need magnification (4× maximum).

A12.2.4 *Light*—Discernible without magnification.

A12.2.5 *Medium*—Easily discernible, midway between light and heavy.

A12.2.6 *Heavy*—Intense or severe (the severity level is such that the distress is instantaneously recognizable).

A12.3 *Distress Types*—Severity levels applied to distress types. When rating the following distress types, the definitions described supersede those found in ASTM Distress Rating Manual 21.

A12.3.1 *Discoloration*—Severity level definitions described in A12.2.

A12.3.2 *Pitting/Spalling*—Use the numerical values provided in Table A12.1 in accordance with the level of distress.

A12.3.2.1 Spalling severity levels definitions described in A12.2.

A12.3.3 *Ridging*—Severity level definitions described in A12.2.

A12.3.4 *Rippling*—Severity level definitions described in A12.2.

A12.3.5 *Scoring*—Severity level definitions described in A12.2. Also note the estimated percent of contact area that is scored.

A12.3.6 *Wear*—Confirm the presence of a wear step both visually and tactilely.

A12.3.6.1 *Trace*—Tool marks are easily discernible at heel and toe area without a wear step.

A12.3.6.2 *Trace/Light*—Tool marks are barely discernible at heel and toe area without a wear step.

A12.3.6.3 *Light*—Absence of tool marks at the heel or the toe without a wear step.

A12.3.6.4 *Light/Medium*—The presence of a wear step.

A12.3.6.5 *Medium*—Shall have an easily discernible wear step, midway between Light and Heavy.

A12.3.6.6 *Heavy*—The severity level is so intense/severe that the distress is instantaneously recognizable.

A12.3.7 *Chipping*—Note chipping observations in the comment section of the test report.

A12.3.8 *Broken or Cracked Tooth*—Note any broken or cracked teeth in the comment section of the test report.

A12.4 *Rating with Magnification*:

A12.4.1 Do not use magnification for any level of severity for the wear distress. Magnification (4 power) may be used to verify trace levels of severity for the ridging, rippling, and scoring distresses. Do not use magnification for any other level of severity for the ridging, rippling, and scoring distresses.

A12.4.2 Magnification (4 power) may be used to verify all levels of severity for pitting/spalling distress.

A12.4.3 Do not use any other power of magnification to verify severity levels of distress.

**TABLE A12.1 Gear Rating Guidelines**

| Use for All Distress Except Pitting/Spalling | |
|---|---|
| Numerical Value | Level of Distress |
| 10.0 | None |
| 9.0 | Trace |
| 8.0 | Trace-Light |
| 7.0 | Light |
| 6.0 | Light-Medium |
| 5.0 | Medium |
| 4.0 | Medium-Heavy |
| 3.0 | Heavy |
| 2.0 | Heavy to Catastrophic (up to 50 % of gear tooth contact area) |
| 1.0 | Heavy to Catastrophic (greater than 50 % and less than 100 % of the gear tooth contact area) |
| 0.0 | Catastrophic (100 % of the gear tooth contact area) |

| Use for Pitting/Spalling Distress Only | | |
|---|---|---|
| Numerical Value | Level of Distress | Corresponding ASTM Distress Rating Manual 21 Spalling Scale |
| 10.0 | None | |
| 9.9 | Trace Pitting—Pit size up to 0.24 mm diameter | |
| 9.8 | Trace-Light Pitting | |
| 9.7 | Light Pitting—Pit size 0.50 mm diameter | |
| 9.6 | Light-Medium Pitting | |
| 9.5 | Medium Pitting—Pit size 0.74 mm diameter | |
| 9.4 | Medium-Heavy Pitting | |
| 9.3 | Heavy Pitting—Pit size 0.98 mm diameter | |
| 9.0 | Trace Spalling | 1 $mm^2$ |
| 8.0 | Trace-Light Spalling | 4 $mm^2$ |
| 7.0 | Light Spalling | 9 $mm^2$ |
| 6.0 | Light-Medium Spalling | 16 $mm^2$ |
| 5.0 | Medium Spalling | 25 $mm^2$ |
| 4.0 | Medium-Heavy Spalling | 36 $mm^2$ |
| 3.0 | Heavy Spalling | 49 $mm^2$ |
| 2.0 | Heavy to Catastrophic (up to 50 % of gear tooth contact area and for pitting/spalling, greater than a 3.0 on the spalling template) | |
| 1.0 | Heavy to Catastrophic (greater than 50 % and less than 100 % of the gear tooth contact area not ratable) | |
| 0.0 | Catastrophic (100 % of the gear tooth contact area not ratable) | |

Spalling in the range from 9.0 to 3.0 references ASTM Distress Rating Manual 21 Spalling Template. Any tooth breakage will be noted in the comment section of the final test report.

## A13. C1L425/P4L415A AND V1L303/P4L514A (NONLUBRITED HARDWARE) PITTING/SPALLING EXCLUSION AREA

A13.1 The side of the pinion tooth that curves inward, or is concave, is referred to as the *drive* side. The convex side is the coast side. The end farthest away for the pinion shaft is referred to as the *toe* end. The end of the tooth nearest the pinion shaft is the *heel* end. The toe end of the tooth is smaller than the heel.

A13.2 The exclusion area is defined as a $\frac{1}{16}$-in. wide area from the bottom to the top of the drive side of pinion, running parallel with the wear step on the toe side of the wear step. This is shown in Fig. A13.1.

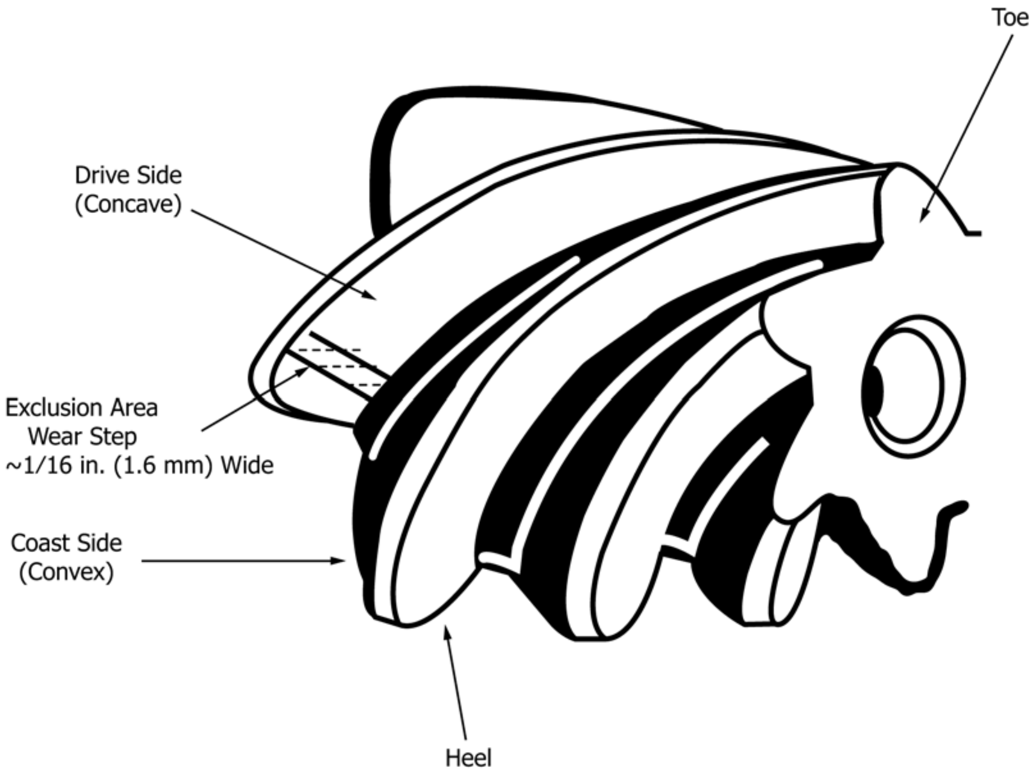



**FIG. A13.1 Exclusion Area on Pinion**

## A14. GEAR BATCH EXCLUSIONS

A14.1 Comments have been developed to accurately describe approved gear batch exclusions. When reporting test results, place one of the comments from Table A14.1 on Form 2 (Annex A10) in the area of Exclusion Comments.

**TABLE A14.1 Gear Batch Exclusion Comments**

| Gear Batch | Comment |
|---|---|
| CIL426/P4L415A Non-lubrited hardware | Excludes any pitting/spalling values between 9.3 and 9.9, inclusively, in the wear step area 1⁄16 in. (1.6 mm) of the drive side pinion tooth. |
| VIL303/P4L514A Non-lubrited hardware | Excludes any pitting/spalling values between 3.0 and 9.9, inclusively, in the wear step area 1⁄16 in. (1.6 mm) of the drive side pinion tooth. |
| VIL686/P4L626A Non-lubrited hardware | References how to report the observations of a thin polished line that is sometimes visible in the root heel of the pinion and on the crown of the ring gear. This condition is normal and not oil-related and is to be noted as "Root and tip line polishing and a function of the gear set manufacturing process." |
| V1L528/ P4T883A Lubrited hardware, nonreference oil test | Reported pitting/spalling value excludes distress from the worst pinion tooth. |
| V1L528/ P4T883A Non-lubrited hardware, non-reference oil test | Reported pitting/spalling value excludes distress from the 3 worst pinion teeth. |
| All other gear batches | No exclusion applied. |

## SUMMARY OF CHANGES

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D6121 – 16a) that may impact the use of this standard. (Approved May 1, 2017.)

*(1)* Subsection 8.2.1 revised to clarify approval steps necessary for building axles.

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D6121 – 16) that may impact the use of this standard. (Approved Oct. 1, 2016.)

*(1)* Subsections 8.2.1 through 8.2.1.4 revised to clarify the approval procedure for lab-built axles.

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D6121 – 15a) that may impact the use of this standard. (Approved April 1, 2016.)

*(1)* Subsection 9.1, revised to clarify frequency of reference oil testing.

*(2)* Table 2, Reference Oil Test Precision updated as of June 2015.