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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 Axles¹

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.

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 A6. The procedure modifications listed in Annex A6 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 A9.1, 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.

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 <https://standards.iteh.ai/astm/d6121-12>

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.

¹ This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products 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. H-2-11-3. 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.

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 Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

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

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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.

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3.1.3 *burnish, n—on ring and pinion gears*, an alteration of the original manufactured surface to a dull or brightly polished condition.

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3.1.4 *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.

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3.1.5 *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.

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3.1.6 *deposits, n—in final drive axles*, material of pasty, gummy, or brittle nature adhering to or collecting around any of the working parts.

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3.1.7 *discoloration, n—on ring and pinion gears*, any alteration in the normal color of finished steel surfaces.

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3.1.8 *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.

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3.1.9 *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.

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3.1.10 *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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3.1.11 *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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3.1.12 *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.

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3.1.13 *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.

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3.1.14 *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

3.1.15 *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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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 80 wheel r/min, 1740 lbf-ft. (2359 N-m) torque per wheel and an axle sump temperature of 275°F (135°C). (**Warning**—See 4.3.)

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

⁷ Formerly known as CRC Manual 21. Available from the ASTM website, www.astm.org, (TMCNML21).

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 A6 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 has a 3.5-in. (8.9-cm) inspection port installed, as shown in Fig. A2.1. This allows filling the axle and provides a means for inspecting the axle after the gear condition phase (see 10.1). Install a thermocouple, as described in 6.2.4.1.

6.2.3 *Test Stand Configuration*—Mount the complete assembly in a rigid fixture as shown in Fig. A3.1. 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. A4.1.

(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. A5.1. Actuate the water control valve by the temperature PID control system. See A6.3.2.1 for L-37 Canadian Version test.

(1) Spray nozzles¹¹ 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 A6.3.2.2 for L-37 Canadian Version test.

(3) Use only ¾ or ½ in. (9.5 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. A5.2. 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, which you may attend.

¹¹ This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0.03 on Automotive Gear Lubricants & Fluids.

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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 ± 0.2 -in. (10.1 ± 0.51 -cm) outside diameter with a 0.095 ± 0.005 in. (0.24 ± 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 (0-2% vol), Flash Point ($142^{\circ}\text{F}/61^{\circ}\text{C}$, 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 *Preparation of Axle:*

8.2.1 Record the “as received” drive side contact pattern length and flank values as noted on the axle housing from Dana Corp.¹⁰ Length values of L^2 and L^3 and flank values of F^{-1} , F^0 , and F^{+1} are considered acceptable. Any adjustments that are made to the axle prior to testing shall be noted in the comments section of the test report. Axle housings from prior gear batches that do not have contact pattern markings shall be patterned and reported by the test labs in the test report.

8.2.2 *Break and Turn Torque Measurements*—Determine and record the torques required to break and to turn the pinion shaft of the completely assembled test unit.

8.2.3 *Backlash Measurements*—Record the backlash on the test axle reported from the manufacturer. To be acceptable, the backlash reported by the manufacturer shall be between 0.004 to 0.012 in. (0.102 to 0.305 mm).

8.2.3.1 If the test axle does not have a reported backlash from the manufacturer, the average backlash, as measured in 8.2.3.2, shall be between 0.004 and 0.009 in. (0.102 to 0.229 mm).

8.2.3.2 Remove the cover plate. Measure and record backlash at four equally spaced locations. Report the average and the four readings.

8.2.4 *Cleaning*—Wash the test unit using a cleaning solvent (see 7.2), paying particular attention to the pinion bearings to remove all preservative oil. 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 6.0 ± 0.1 pt ($2.8 \text{ L} \pm 0.05 \text{ L}$) 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 drive shaft to the test unit.

9. Calibration and Standardization

9.1 *Reference Oils and Hardware:*

9.1.1 Reference oils for stand calibration are available from the ASTM Test Monitoring Center (TMC)² and approved hardware through ASTM Subcommittee D02.B0.03.¹²

9.1.2 Do not submit reference oils to physical or chemical analyses for identification purposes. Identifying the oils by analyses could undermine the confidentiality required to operate an effective blind reference oil system. Therefore, reference oils are supplied with the explicit understanding that they will not be subjected to analyses other than those specified within this procedure unless specifically authorized by the TMC. In such cases where analyses are authorized, supply written confirmation of the circumstances involved, the data obtained, and the name of the person authorizing the analysis to the TMC.

9.2 *Stand Calibration:*

9.2.1 Laboratories wishing to calibrate test stands using reference oils and approved hardware shall participate in the Lubricant Test Monitoring System (LTMS) calibration program administered for this test method by the TMC (see Annex A1). The TMC

¹² The responsible ASTM surveillance panel.

distributes reference oils as blind coded samples for test stand calibration. Report all test starts and test data using reference oils to the TMC. Calibration frequency is subject to change as required. Current calibration information is available from the TMC. Send all reference oil test results to the TMC within five (5) days of test completion. Extensions to this response time may be granted only with prior approval of the TMC.

9.2.2 The TMC shall inspect new test stands for compliance with this test method. A test stand is considered new when a test stand is moved. Additionally, circumstances involving significant changes to stand apparatus, instrumentation, and operation may require an existing test stand to meet new test stand calibration requirements. Consult with the TMC regarding these matters.

9.2.3 *Reference Test Frequency*—One reference test is required every four months or after 650 test hours on non-reference fluids, whichever occurs first.

9.2.3.1 Reference oil test frequency may be adjusted due to the following reasons:

(1) *Procedural Deviations*—On occasions when a laboratory becomes aware of a significant deviation from the test method, such as might arise during an in-house review or a TMC inspection, the laboratory and the TMC shall agree on an appropriate course of action to remedy the deviation. This action may include the shortening of existing reference oil calibration periods.

(2) *Parts and Fuel Shortages*—Under special circumstances, such as industry-wide parts or fuel shortages, the surveillance panel may direct the TMC to extend the time intervals between reference oil tests. These extensions shall not exceed one regular calibration period.

(3) *Reference Oil Test Data Flow*—To ensure continuous severity and precision monitoring, calibration tests are conducted periodically throughout the year. There may be occasions when laboratories conduct a large portion of calibration tests in a short period of 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.

(4) *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 is left in an excessively long pending status. 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.

9.2.4 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.

9.2.5 Report modification of test stand apparatus or completion of any nonstandard test on a calibrated test stand to the TMC immediately. The TMC will determine whether another calibration test is necessary.

9.2.6 Alternate testing of L-37 and L-42¹³ tests does not necessitate recalibration as long as the above requirements are met.

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

9.3 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.

9.4 *Instrumentation Calibration*—Using known standards traceable to the National Institute of Standards and Technology (NIST)¹⁴ (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.

9.5 *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.

10. Test Procedure

10.1 Gear Conditioning Phase:

10.1.1 Set the temperature control to maintain a lubricant temperature of $297 \pm 3^{\circ}\text{F}$ ($147.2^{\circ}\text{C} \pm 1.7^{\circ}\text{C}$). See A6.3.3.2 for L-37 Canadian Version test.

¹³ The L-42 procedure is currently being developed into a standard test method by Subcommittee D02.B0.

¹⁴ National Institute of Standards and Technology (formerly National Bureau of Standards), Gaithersburg, MD 20899.

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 load of 395 ± 15 lbf-ft ($535 \text{ N}\cdot\text{m} \pm 20 \text{ N}\cdot\text{m}$) on each wheel (see Note 1).

NOTE 1—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 load conditions, run the test for (100 ± 1) min.

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

10.1.7 At the end of the 100 min, and as the load and linear speed ramp-down is started, set the axle lubricant temperature controller to a set point of $275 \pm 3^\circ\text{F}$ ($135.0 \text{ }^\circ\text{C} \pm 1.7 \text{ }^\circ\text{C}$). Shift transmission to neutral and ensure that the axles stop turning. Record ending time and temperature of the lubricant. See A6.3.3.3 for L-37 Canadian Version test.

NOTE 2—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 $275 \pm 3^\circ\text{F}$ ($135.0 \text{ }^\circ\text{C} \pm 1.7 \text{ }^\circ\text{C}$). See A6.3.3.4 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 3—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 load to achieve a torque load of 1044 ± 35 lbf-ft ($1415 \text{ N}\cdot\text{m} \pm 47 \text{ N}\cdot\text{m}$) on each wheel. Hold at this condition until the axle lubricant temperature reaches $175 \pm 3^\circ\text{F}$ ($79.4 \text{ }^\circ\text{C} \pm 1.7 \text{ }^\circ\text{C}$).

NOTE 4—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 $175 \pm 3^\circ\text{F}$ ($79.4 \text{ }^\circ\text{C} \pm 1.7 \text{ }^\circ\text{C}$), immediately apply dynamometer load to achieve a torque load of 1740 ± 35 lbf-ft ($2359 \text{ N}\cdot\text{m} \pm 47 \text{ N}\cdot\text{m}$) on each wheel. When conducting tests with non-lubricated gear batch V1L500/P4T813, use the 13 % reduced contact stress requirements (see A6.4.1).

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, load, and temperature conditions, run the test for (24 ± 0.2) h.

10.2.6 To ensure test accuracy, record speed, load, 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 ± 35 lbf-ft ($1415 \text{ N}\cdot\text{m} \pm 47 \text{ N}\cdot\text{m}$) until the lubricant temperature reaches $175 \pm 3^\circ\text{F}$ ($79.4 \text{ }^\circ\text{C} \pm 1.7 \text{ }^\circ\text{C}$).

NOTE 5—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 $175 \pm 3^\circ\text{F}$ ($79.4 \text{ }^\circ\text{C} \pm 1.7 \text{ }^\circ\text{C}$), immediately apply dynamometer load on each

wheel to achieve the torque load 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 Results¹⁵

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 A9: 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.^{16,17}

12.2.2 Rate each distress by identifying its level of distress in accordance with Table A9.1. 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 A9.1. The pitting/spalling distress type is assigned numerical values also shown in Table A9.1.

12.2.3 When using the nonlubricated hardware, gear set C1L426/P4L415A, determine a numerical pitting/spalling value, excluding any pitting/spalling value between 9.3 and 9.9, inclusively, in the wear step area of the drive side pinion tooth, as per Annex A10.

12.2.3.1 When using the nonlubricated 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 A10.

12.2.3.2 Report this rating value on Form 1 and Form 2 (Annex A7) of the test report package.

NOTE 6—If non-reference oil test results are to be used as candidate oil test results against a specification, report the non-reference oil test results on the same standardized report form set and data dictionary as used for reference oil test results.

12.2.3.3 When using the lubricated 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 a correction factor of 0.9922 to the ring transformed ridging test result. Record these results on Form 1 of the test report (Annex A7). See A6.3.4 for L-37 Canadian Version test.

12.3 When using gear set V1L686/P4L626A, a thin polished line visible in the root heel of the pinion and on the crown of the ring gear may be evident. The polish line may 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*.

12.4 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 months¹⁸ 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 they 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 A8.

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 Consider as non-interpretable any reference or non-reference oil test that has one or more broken pinions or ring gear teeth. Note any tooth breakage 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

¹⁵ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1415.

¹⁶ Available from the ASTM website, www.astm.org.

¹⁷ 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.

¹⁸ Training for those rating gear sets for gear distress levels may be obtained from Coordinating Research Council, 219 Perimeter Ctr. Pkwy., Atlanta, GA 30346.

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.

12.9 Round test results according to Practice E29.

13. Report

13.1 For reference oil tests, the standardized report form set and data dictionary for reporting the test results and for summarizing the operational data are required. The 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.

13.2 Attach the temperature recording trace for the test as part of the report.

~~13.3 When reporting reference oil test results to the TMC, transmit by facsimile the complete report form package (see 13.3 Report reference oil test results to the TMC within five days of test completion. Use the report form package described in Annex A7) within five days of test completion. Within 30 days of test completion, mail a copy of the final test report to the ASTM Test Monitoring Center.² Electronic transfer of test results (see 13.5) is also permitted for approved laboratories.~~

13.4 *Deviations from Test Operational Limits*—Report all deviations from specified test operational limits on Form 4 (Annex A7) under Other Comments.

~~13.5 *Electronic Transmission of Test Results*—Electronic transfer of reference and non-reference oil test report data can be done utilizing the Flat File Transmission Format contained in Section 2 of the ASTM Data Communications Committee Test Report Transmission Model, available from the ASTM TMC.—For electronic transfer of test results, use the ASTM Data Communications Committee Test Report Transmission Model (see Section 2 — Flat File Transmission Format) available from the ASTM TMC.~~

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 1 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 7—“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 1 in only one case in twenty. When only a single test result is available, the Intermediate Precision Limit can be used to calculate

TABLE 1 Reference Oil Test Precision Data—Transformed Units

NOTE—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, and 1535 as of March 29, 2005¹¹. 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
Lubricated	Pinion ridging, B–ln(10.5–merit)	0.2612	0.7314	0.2719	0.7613
Lubricated	Pinion ridging, merit	1.430	4.004	1.430	4.004
	Pinion rippling, B–ln(10.5–merit)	0.2344	0.6555	0.2344	0.6555
	Pinion rippling, merit	0.476	1.333	0.479	1.341
	Pinion wear, merit	0.548	1.534	0.589	1.649
	Pinion pitting/spalling, merit	0.579	1.621	0.587	1.644
	Pinion pitting/spalling, B–ln(10.5–merit)	0.4038	1.1306	0.4095	1.1466
	Pinion wear, merit	0.519	1.453	0.563	1.576
Non-lubricated	Pinion ridging, B–ln(10.5–merit)	0.5323	1.4904	0.5323	1.4904
Non-lubricated	Pinion ridging, merit	0.666	1.865	0.691	1.935
	Pinion rippling, B–ln(10.5–merit)	0.3480	0.9744	0.3480	0.9744
	Pinion rippling, merit	0.557	1.560	0.572	1.602
	Pinion wear, merit	0.694	1.943	0.694	1.943
	Pinion pitting/spalling, merit	0.847	2.372	0.847	2.372
	Pinion pitting/spalling, B–ln(10.5–merit)	0.4603	1.2888	0.4603	1.2888
	Pinion wear, merit	0.713	1.996	0.713	1.996

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

^B This parameter is transformed using a natural log. When comparing two test results on this parameter, first apply this transformation to each test result. Compare the absolute difference between the transformed results with the appropriate (intermediate precision or reproducibility) precision limit.

a range (test result \pm 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 1 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 \pm 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. THE ROLE OF THE ASTM TEST MONITORING CENTER (TMC)

A1.1 The TMC is a nonprofit organization located at 6555 Penn Ave., Pittsburgh, PA 15206. It is staffed to administer engineering studies; conduct laboratory visits; perform statistical analysis of test; to blend, store, and ship reference oils; and to provide associated administrative functions connected with the referencing and calibration of various lubricant tests. The TMC maintains a close connection with test sponsors, test developers, the surveillance panels, and the testing laboratories. The management of these functions is vested in the Test Monitoring Board, whose members are elected by Subcommittee D02.B0. The TMC operates under the ASTM Charter and its associated bylaws and regulations, the bylaws of Committee D02 and Subcommittee D02.B0, and the Rules and Regulations of the Test Monitoring Board. The operating income of the TMC is obtained from fees levied on the reference oils supplied and on the conduct of the calibration tests. These fees are set by Subcommittee D02.B0 and are regularly reviewed.

A1.2 Information Letters

A1.2.1 It occasionally becomes necessary to change a test procedure and to notify test laboratories of the change before the change can be considered by Subcommittee D02.B0 on Automotive Lubricants or Committee D02 on Petroleum Products and Lubricants. In such a case, the TMC will issue an Information Letter. Subsequently, prior to each semiannual Committee D02 meeting, the accumulated Information Letters are balloted in Subcommittee D02.B0. This ballot is reviewed at the Subcommittee D02.B0 meeting, and the actions taken are then considered by Committee D02. In this way, the ASTM due process procedures are applied to the Information Letters.

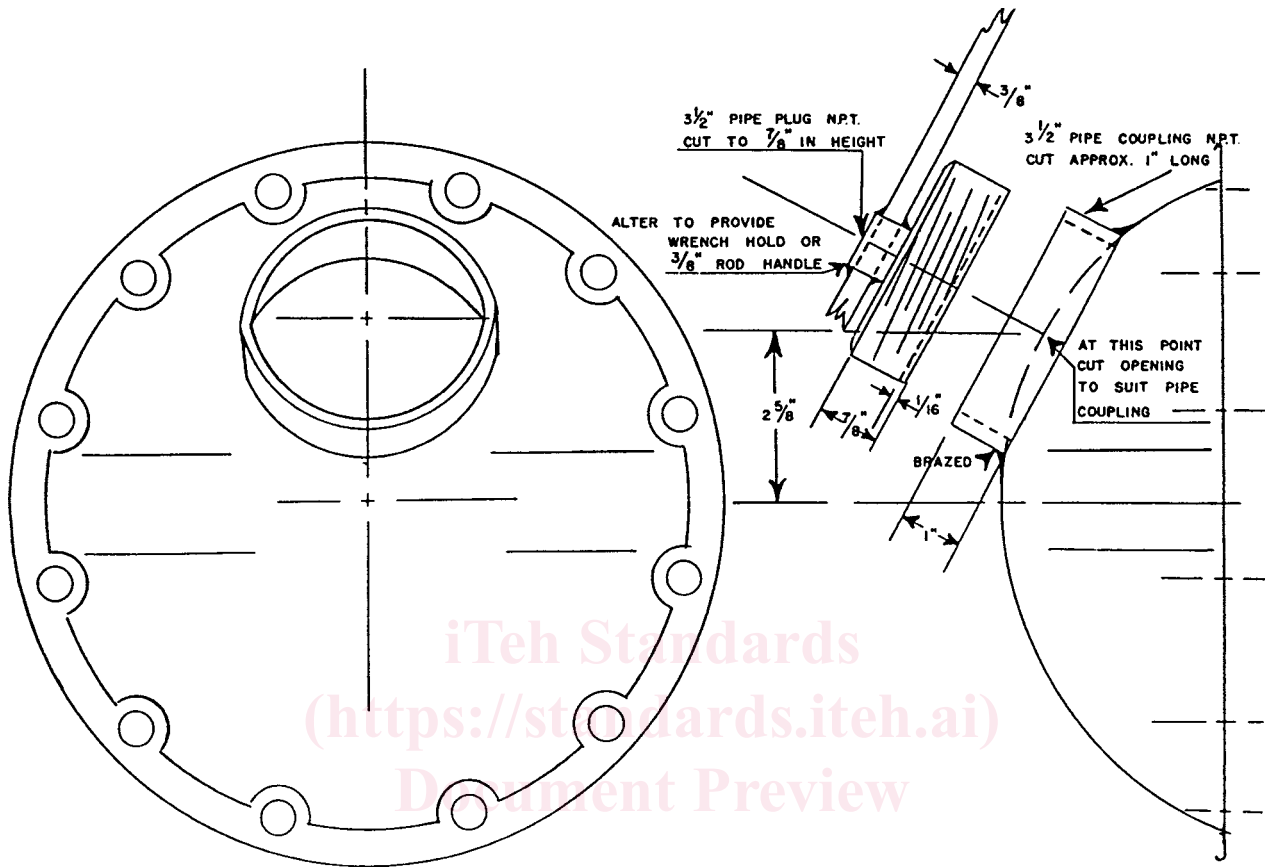
A1.2.2 The review of an Information Letter prior to its original issue will differ in accordance with its nature. In the case of an Information Letter that does not affect test results, such as notification of a part number change, the TMC is authorized to issue an Information Letter. A survey or study conducted by the Surveillance Panel resulting in a recommendation for a change in hardware or procedure may result in the issuance of an Information Letter. If an urgent change to hardware or procedure are obviously necessary, the test sponsor and the TMC may issue an Information Letter and present it for approval, with the background and data, for approval by the Surveillance Panel prior to the next semiannual Committee D02 meeting.

A1.2.3 Authority for the issue of Information Letters was given by the Committee on Technical Committee Operations (COTCO) in 1984, as follows: “COTCO recognizes that D02 has a unique and complex situation. The use of Information Letters is approved provided that each letter (at its initial issue) contains a disclaimer to the effect that it has not obtained ASTM consensus. These Information Letters should be moved to such consensus as rapidly as possible.”

A1.3 *TMC Memoranda*—In addition to the Information Letter system, the TMC will provide information to the Surveillance Panel and to participating laboratories in the form of ASTM TMC memoranda. These are used to convey such information as batch approvals for test parts or materials, to clarify misunderstandings concerning the test procedure, to provide notes and suggestions for the collection and analysis of special data that the TMC may call for, or for any other matters having no direct effect on the test performance results or precision and bias.

A1.4 *Precision Data*—One measure of test precision is established on the basis of reference oils (calibration) test results monitored by the ASTM TMC. Current data may be obtained from the TMC.

A2. AXLE COVER EXAMPLE



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Document Preview

in.	mm	ASTM D6121-12	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. A2.1 Axle Cover Example