Designation: D6121 – 19a

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, health, and environmental 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. 19-2. 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.

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

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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.

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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.

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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.

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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.

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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.

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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.

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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).

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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 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 any acceptable hardware 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 meet the LTMS acceptance criteria for approved hardware and both 134 run pinion results fail SAE J2360 acceptance criteria, the laboratory 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 laboratory 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 laboratory 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