



# 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<sup>1</sup>

This standard is issued under the fixed designation D 6121; 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 ( $\epsilon$ ) 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.<sup>2</sup> 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.

1.4 *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:<sup>3</sup>

<sup>1</sup> 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 on Automotive Lubricants.

Current edition approved May 1, 2005. Published May 2005. Originally approved in 1997. Last previous edition approved in 2004 as D 6121-04.

<sup>2</sup> 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. 04-2. 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.

<sup>3</sup> 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.

**D 235** Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

2.2 *Military Specification:*<sup>4</sup>

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

2.3 *AGMA National Standard:*<sup>5</sup>

Nomenclature of Gear Tooth Failure Modes

2.4 *SAE Standard:*<sup>6</sup>

**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.

**CRC Rating Manual No. 21<sup>7</sup>**

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. **CRC Rating Manual No. 21**

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

3.1.4 *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. **CRC Rating Manual No. 21**

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg 4, Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5098.

<sup>5</sup> American Gear Manufacturers Assn. (AGMA), 1500 King St., Suite 201, Alexandria, VA 22314.

<sup>6</sup> Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

<sup>7</sup> Available from Coordinating Research Council (CRC), 219 Perimeter Ctr. Pkwy., Atlanta, GA 30346.

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

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

**CRC Rating Manual No. 21**

3.1.7 *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. **CRC Rating Manual No. 21**

3.1.8 *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.

**CRC Rating Manual No. 21**

3.1.9 *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.

**CRC Rating Manual No. 21**

3.1.10 *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.

**CRC Rating Manual No. 21**

3.1.11 *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.

**CRC Rating Manual No. 21**

3.1.12 *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.

**CRC Rating Manual No. 21**

3.1.13 *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**

3.1.14 *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).

**CRC 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 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.

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.<sup>8</sup>

5.2.2 STP-512A.<sup>9</sup>

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.<sup>10</sup> 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.

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

<sup>9</sup> "Laboratory Performance Tests for Automotive Gear Lubricants Intended for API GL-5 Service."

<sup>10</sup> 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,<sup>1</sup> which you may attend.

(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 nozzles<sup>11</sup> 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. 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. line material to the spray nozzles.

(4) Use a minimum supply water pressure of 25 psi 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.

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 be balanced up to 750 r/min.

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. (10.1-cm) outside diameter with a  $0.095 \pm 0.005$  in. ( $0.24 \pm 0.013$  cm) wall

thickness. Shaft and universal joints should be strong enough to handle the torques encountered and be balanced up to 3000 r/min.

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 *Cleaning Solvent*, A solvent meeting Specification D 235—Type II, Class C. (**Warning**—Combustible, vapor harmful.)

## 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.<sup>10</sup> Length values of L<sup>2</sup> and L<sup>3</sup> and flank values of F<sup>-1</sup>, F<sup>0</sup>, and F<sup>+1</sup> 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*—Remove the cover plate. Record backlash at four equally space locations. The average of the four readings shall be from 0.004 to 0.009 in. (0.102 to 0.229 mm).

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 Lubricate the carrier bearings, pinion bearings, differential gears, and the ring gear and pinion, using the test lubricant or a non-additized neutral base oil.

8.2.6 Lubricant added in 8.2.5 shall be drained thoroughly before installing the axle and charging the test unit with the test oil. Place the pinion in a vertical position with the yoke up and the cover off for a minimum of 5 min.

8.2.7 Install axle shafts in test unit.

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.

8.4 Bolt the axle cover with gasket (apply sealant, if needed) onto the axle housing and fill the axle assembly with  $6.0 \pm 0.1$  pt ( $2.8 \pm 0.05$  L) of test lubricant. This step may occur before or after the test unit is installed on the stand as described in 8.3.

<sup>11</sup> 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,<sup>1</sup> which you may attend.

## 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)<sup>2</sup> and approved hardware through ASTM Subcommittee D02.B0.03.<sup>12</sup>

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 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 two months or after 650 test hours on non-reference fluids, whichever occurs first.

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 lubricated and non-lubricated hardware with each reference oil calibration sequence.

9.2.7 Alternate testing of L-37 and L-42<sup>13</sup> tests does not necessitate recalibration as long as the above requirements are met.

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*—Calibrate the axle speed measuring system, temperature control system, and torque measuring system to occur at a maximum of four months or 50 tests against a known standard traceable to the National Institute of Standards and Technology (NIST)<sup>14</sup> or a physical constant.

## 10. Test Procedure

### 10.1 Gear Conditioning Phase:

10.1.1 Set the temperature control to maintain a lubricant temperature of  $297 \pm 3^\circ\text{F}$  ( $147.2 \pm 1.7^\circ\text{C}$ ). See **A6.3.3.2** 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  $440 \pm 5$  wheel r/min and apply dynamometer load to achieve a torque load of  $395 \pm 15$  lbf-ft ( $535 \pm 20$  N-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 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  $100 \pm 1$  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  $275 \pm 3^\circ\text{F}$  ( $135.0 \pm 1.7^\circ\text{C}$ ). 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  $275 \pm 3^\circ\text{F}$  ( $135.0 \pm 1.7^\circ\text{C}$ ). 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.

<sup>12</sup> The responsible ASTM surveillance panel.

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

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

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  $80 \pm 1$  wheel r/min and apply dynamometer load to achieve a torque load of  $1044 \pm 35$  lbf-ft ( $1415 \pm 47$  N-m) on each wheel. Hold at this condition until the axle lubricant temperature reaches  $175 \pm 3^\circ\text{F}$  ( $1.0 \pm 1.7^\circ\text{C}$ ).

NOTE 4—The time required to accelerate to the test conditions of 80 wheel r/min and 1044 lbf-ft is about 10 min.

10.2.3.1 Once the axle lubricant temperature reaches  $175 \pm 3^\circ\text{F}$  ( $1.0 \pm 1.7^\circ\text{C}$ ), immediately apply dynamometer load to achieve a torque load of  $1740 \pm 35$  lbf-ft ( $2359 \pm 47$  N-m) on each wheel.

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  $24 \pm 0.2$  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 Apply a dynamometer load on each wheel to achieve a torque value that is 60 % of the set point value when the shutdown occurred. Hold at this condition until the lubricant temperature reaches  $175 \pm 3^\circ\text{F}$  ( $1.0 \pm 1.7^\circ\text{C}$ ).

10.3.1.5 Once lubricant temperature reaches  $175 \pm 3^\circ\text{F}$  ( $1.0 \pm 1.7^\circ\text{C}$ ), 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 Results<sup>15</sup>

12.1 *Pinion Bearing Rating*—Examine the bearings for wear, surface fatigue corrosion, and deposits in accordance with CRC 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 CRC 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 CRC Reference Photography of Gear Distress photographs. The photographs shall have a serial number of SN001 or greater and have an issuance date of July 8, 2000 or later.

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 5—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

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

**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 127, 128, 128-1, and 129. 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.	$S_R$	R
Lubrited	Pinion ridging, <sup>A</sup> -ln(10.5-merit)	0.3836	1.0741	0.3859	1.0805
	Pinion rippling, <sup>A</sup> -ln(10.5-merit)	0.5645	1.5806	0.6412	1.7954
	Pinion wear, merit	1.0181	2.8507	1.0648	2.9814
	Pinion pitting/spalling, <sup>A</sup> -ln(10.5-merit)	0.7124	1.9947	0.7124	1.9947
Non-lubrited	Pinion ridging, <sup>A</sup> -ln(10.5-merit)	0.4847	1.3572	0.5209	1.4585
	Pinion rippling, <sup>A</sup> -ln(10.5-merit)	0.5303	1.4848	0.5993	1.6780
	Pinion wear, merit	1.0352	2.8986	1.0728	3.0038
	Pinion pitting/spalling, <sup>A</sup> -ln(10.5-merit)	0.4298	1.2034	0.4414	1.2359

<sup>A</sup> 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.

on the same standardized report form set and data dictionary as used for reference oil test results.

12.2.3.3 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 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 months<sup>16</sup> 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 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, 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 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.<sup>2</sup> 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.

### 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

<sup>16</sup> Training for those rating gear sets for gear distress levels may be obtained from Coordinating Research Council, 219 Perimeter Ctr. Pkwy., Atlanta, GA 30346.