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

Designation: D7038 – 24

Standard Test Method for Evaluation of Moisture Corrosion Resistance of Automotive Gear Lubricants[1]

This standard is issued under the fixed designation D7038; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

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

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

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

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

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

ASTM International policy is to encourage the development of test procedures based on generic equipment. It is recognized that there are occasions where critical/sole-source equipment has been approved by the technical committee (surveillance panel/task force) and is required by the test procedure. The technical committee that oversees the test procedure is encouraged to clearly identify if the part is considered critical in the test procedure. If a part is deemed to be critical, ASTM encourages alternative suppliers to be given the opportunity for consideration of supplying the critical part/component providing they meet the approval process set forth by the technical committee.

An alternative supplier can start the process by initiating contact with the technical committee (current chairs shown on ASTM TMC website). The supplier should advise on the details of the part that is intended to be supplied. The technical committee will review the request and determine feasibility of an alternative supplier for the requested replacement critical part. In the event that a replacement critical part has been identified and proven equivalent, the sole-source supplier footnote shall be removed from the test procedure.

1. Scope*

1.1 This test method covers a test procedure for evaluating the rust and corrosion inhibiting properties of a gear lubricant while subjected to water contamination and elevated temperature in a bench-mounted hypoid differential housing assembly.[2] This test method is commonly referred to as the L-33-1 test.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical

[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 on Automotive Lubricants.

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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 24-1. Information Letters may be obtained from the ASTM Test Monitoring Center, 203 Armstrong Drive, Freeport, PA 16229, Attention: Director.

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

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conversions to SI units that are provided for information only and are not considered standard.

1.2.1 *Exceptions*—(*1*) where there is no direct SI equivalent such as screw threads and national pipe threads/diameters, and (*2*) the values stated in SI units are to be regarded as standard for the definitions in 12.2, and for SI units where there are no direct inch-pounds equivalent units.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

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 *Society of Automotive Engineers Standards:*[4]

J308 Information Report on Axle and Manual Transmission Lubricants

J2360 Lubricating Oil, Gear Multipurpose (Metric) Military Use

2.3 *U.S. Military Specifications:*[5]

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

MIL-P-3420F NOX-RUST Paper

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *corrosion, n*—an alteration of a finished metal surface by discoloration, accompanied by roughening not attributable to mechanical action.

3.1.2 *downtime, n*—an interruption of power to the test unit for a period greater than ten seconds.

3.1.3 *rust, n*—a special case of corrosion, which always deteriorates or alters the original surface condition.

3.1.3.1 *Discussion*—Rust always has color (usually, but not limited to red, yellow, brown, black) and one of the following descriptive characteristics: *(1)* depth; the rusted surface is built up relative to that of adjacent areas. *(2)* texture; the surface may appear to be etched, scaly or otherwise visibly different than adjacent areas.

3.1.4 *stain, n*—a surface modification that is attributable to discoloration only.

4. Summary of Test Method

4.1 This procedure uses a new hypoid differential assembly as the primary test unit. The differential assembly is installed on a motoring rig and charged with test lubricant and a small amount of water. The test unit is then sealed and driven until the lubricant temperature has increased to 180 °F (82.2 °C). The motoring phase is continued for 4 h and the test unit is then removed from the motoring rig and placed in a storage box for 162 h with the lubricant temperature controlled at 125 °F (51.7 °C). The test is completed at that time and the differential assembly is drained, disassembled, and inspected for rust, stain, and other deposits.

5. Significance and Use

5.1 This test simulates a type of severe field service in which corrosion-promoting moisture in the form of condensed water vapor accumulates in the axle assembly. This may happen as a result of volume expansion and contraction of the axle lubricant and the accompanied breathing in of moisture-laden air through the axle vent. The test screens lubricants for their ability to prevent the expected corrosion.

5.2 The L-33-1 test procedure is used or referred to in the following documents: ASTM Publication STP-512A,[6] SAE J308, SAE J2360, and U.S. Military Specification MIL-PRF-2105E.

6. Apparatus

6.1 *Laboratory Ambient Conditions:*

6.1.1 *Test Operating Area*—The ambient laboratory atmosphere shall be free of dirt, dust, and other contaminants as required by good laboratory standards.

6.1.2 *Parts Cleaning and Abrasive Blasting (6.2.8) Areas*—Provide adequate ventilation in areas where solvents (7.2) are used. (**Warning—**Combustible, vapor harmful.)

6.1.3 *Build-up Area*—It is recommended that the atmosphere in the test unit build-up area be filtered and maintained at uniform temperature and low humidity to prevent accumulation of dirt or rust on test parts. Otherwise it shall conform to requirements of 6.1.1.

6.1.4 *Parts Rating Area*—Conduct the rating of all test parts under conditions as defined in ASTM Distress Rating Manual 21.[7]

6.2 *Test Unit*—This procedure uses a hypoid differential assembly (without axle tubes). See the critical parts list under the L-33-1 Information Letter section of the Test Monitoring Center website, www.astmtmc.org, for hardware approved for test use.

6.2.1 Mount the differential housing assembly on the motoring rig so that the housing cover attaching face is in the

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

[5] Available from the Defense Printing Service Office, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094.

[6] ASTM Publication STP-512A, Laboratory Performance Tests for Automotive Gear Lubricants Intended for API GL-5 Service, ASTM International, West Conshohocken, PA.

[7] For stock #TMCMNL21, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org.

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vertical plane and at a height that allows the temperature sensing probe to be located in the bottom of the housing. Elements of the motoring rig design are shown in Figs. A5.1-A5.4.

6.2.2 *Drive System*—The drive system design is not precisely specified; however, the following equipment or its equivalent have been found to be suitable to turn the drive pinion at the specified 2500 r/min ± 25 r/min. (**Warning—** Rotating test stand equipment presents a physical hazard, use safety guards.)

6.2.2.1 *Electric Motor,* approximately 2.0 hp (1.5 kW), enclosed, 3600 r/min, 0.87 in. (22.2 mm) diameter shaft.

6.2.2.2 *Slide Motor Base,* Dyn-Adjust No. 20-C.

6.2.2.3 *Dodge Taper Lock Pulleys,* No. 40L100 (Driven) and No. 28L100 (Drive).

6.2.2.4 *Dodge Timing Belt,* No. 480L100.

6.2.2.5 Additional components such as shafts, couplings, and bearing blocks are also necessary to connect the above components to drive the carrier pinion, but are left to the option of the testing laboratory.

6.2.3 *Vapor Pressure Control System*—Control the internal vapor pressure of the unit during the warm-up portion of the motoring phase with a specified water column pressure relief system set for 1.0 psi ± 0.1 psi (7 kPa ± 0.7 kPa) connected to the housing cover with an appropriately sized National Pipe Threads (NPT) stainless steel 90° street ell and a stainless steel full port valve. The system shall contain an oil trap and return vessel to return test oil to the unit in case of foaming, and a water trap and return vessel to prevent column water from moving back to test unit. The example set up in Fig. A5.1 has been shown to be acceptable.

6.2.4 *Housing Cover Gasket*—Replace the factory-supplied gasket with a single TFE fluorocarbon gasket for every test.[8,9]

6.2.5 *Housing Axle Tube Opening Seals*—Since the differential is tested without axle shafts or axle tubes, use a stainless steel plumbing test plug for a 2.9 in. to 3.1 in. (74 mm to 79 mm) pipe diameter to seal the housing openings. McMasterCarr p/n 2908K28 or 2908K29[11,9] with the outer washer and seal ring cut to 2.9 in. to 3.1 in. (74 mm to 79 mm) has been found acceptable for this purpose. Install a pair of seals in the axle housing openings before installing carrier/case into the axle housing.

6.2.6 *Temperature Control System, Motoring Phase*—During the motoring phase, the bulk oil temperature is sensed by a resistance temperature device (RTD) or thermocouple (E, J, or K type). The controller switches on a pair of 250 W lamps or cooling fan, or both, that are directed toward the differential as needed to control bulk oil temperature at 180 °F ± 1 °F (82 °C ± 0.6 °C). A household-type electric fan having 12.0 in. (310 mm) diameter blades has been shown to provide acceptable cooling capability. Fig. A5.3 shows an example of the location of the heat lamp pair and the cooling fan. Fig. A5.4 shows the location of the temperature sensor in the differential housing.

6.2.7 *Storage Box and Temperature Control System, Storage Phase*—During the storage phase of the test, a double-walled aluminum or stainless steel box covers the differential housing assembly. An RTD or thermocouple (E, J, or K type) in conjunction with the controller regulates heat input from four strip heaters giving a total output of 1700 Btu/h (500 W). A small electric motor turns a fabricated impeller at 1700 r/min ± 100 r/min to provide air circulation within the box. Dayton part number 3M562 available from Grainger has been found suitable for this purpose.[10,9] Control the bulk oil temperature at 125 °F ± 1 °F (52 °C ± 0.6 °C). Fig. A5.5 shows details of the impeller. Fig. A5.6 shows construction and electrical details of this box.

NOTE 1—Insulation on the outside surface of the box only may be necessary to maintain test temperature specifications.

6.2.8 *Abrasive Blasting*—Blast the entire differential case, ring, pinion, side gears, differential pinion gears (spider gears), all four thrust washers and the inside surface of the differential housing cover plate with 80 grit aluminum oxide so as to remove pre-existing corrosion and produce a uniform surface. Do not abrasive blast the bearings, bearing cups and differential shaft (cross shaft pin). (**Warning—**Provide adequate safety equipment for abrasive blasting operations.)

6.2.9 The following specifies the abrasive blasting equipment and material:

6.2.9.1 *Abrasive Blasting Cabinet*—Grainger Econo-Line 36 in. by 24 in., Grainger Item No. 3Z850.[10,9]

(1) Use solely for cleaning L-33-1 test units.

(2) Measure air pressure for the blasting gun at the regulator just prior to entering the cabinet enclosure. Set the regulator to maintain 80 psig ± 2 psig (552 kPa ± 14 kPa) while flowing abrasive material.

6.2.9.2 *Dust Collector*—Grainger Econo-Line 1000 ft^3/min, Grainger Item No. 3JR93.[10,9]

6.2.9.3 *Blasting Gun Setup:*

(1) Grainger Econo-Line 12 ft^3/min Gun Assembly, Grainger Item No. 3JT01.[10,9]

(2) Grainger Econo-Line tungsten carbide Nozzle Tip ¼ in. I.D. Grainger Item No. 3JT08.[10,9] Take care to install this nozzle with the *smaller opening facing out*. The nozzle's shape makes it possible for it to be installed incorrectly. Change the nozzle after fifteen L-33-1 units are blasted.

(3) Grainger Econo-Line Air Jet 12 ft^3/min, Grainger Item No. 3JT04.[10,9]

6.2.9.4 *Abrasive Blasting Material*—Alodur Fused Brown Aluminum Oxide,[11,9] 80 grit—ANSI Table 3 Grade.[12,9] Change the entire cabinet supply of abrasive blasting material

[8] The sole source of supply of the apparatus known to the committee at this time is AP Services Inc., 18001 Sheldon Road, Middleburg Heights, OH 44130. Request ASTM L-33-1 Die.

[9] 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.

[10] The sole source of supply of the apparatus known to the committee at this time is Grainger Inc., 120 Beta Drive, Pittsburgh PA 15238.

[11] The sole source of supply for this material known to the committee at this time is Imerys Fused Materials Niagara Falls, Inc., 2000 College Avenue, M.P.O. Box 1438, Niagara Falls, NY 14302, USA.

[12] The sole source of supply of the apparatus known to the committee at this time is the American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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after 15 L-33-1 units are blasted. (**Warning—**Abrasive blasting presents a physical hazard; consult and follow equipment manufacturer's precautions.)

7. Reagents and Materials

7.1 *Specified Test Water*—Fisher Scientific deionized ultra filtered water, Part No. W2-4 or W2-20.[13,9]

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.

7.3 *Rust Prevention Oil*—Mobil Arma 245.[14,9] (**Warning—**Combustible mixture. Harmful or fatal if swallowed.)

7.4 *Build-up Lubricant*—Use test oil for test unit build-up.

8. Test Oil

8.1 Use 1.0 gal (3.7 L) of fluid for each test. The housing capacity is 91 oz (2.7 L); the remaining oil is used for coating the test parts during assembly.

9. Preparation of American Axle & Manufacturing Hardware

9.1 *Cleaning of Reused Fittings, Seals, and so forth*—Clean, as necessary, all reusable parts including axle tube opening seals, pressure relief system and elbow, and the temperature sensor and its fittings.

9.2 *Differential Assembly Build-Up:*

9.2.1 *Cleaning and Preparation of Parts:*

9.2.1.1 *Disassembly*—Disassemble the differential housing assembly, leaving the pinion inner and outer races in place. Remove and discard the oil drain plug magnet (if present). Remove all parts from the differential case. Disassemble all bearings from their mating parts. Maintain right differential case shim for axle assembly.

(1) Be aware that the bolts attaching the ring gear to the carrier are left-hand thread.

9.2.1.2 *Differential Housing Modification*—Drill and tap the housing to accept the temperature sensor using the template shown in Figs. A5.12 and A5.13. Install the temperature sensor so that the tip of the sensor is 1 in. ± 0.25 in. (25.4 mm ± 6.4 mm) from the floor of the differential housing as shown in Fig. A5.4. Tap the housing vent tube opening to ¼ in. NPT to install the pressure control device.

9.2.1.3 *Cleaning*—Pressure wash the differential housing and each individual component with solvent (see 7.2) using a round plastic bristle brush. Rinse the differential housing and each individual component with solvent, and dry them with compressed air or nitrogen. *Do not* use wire brushes or abrasive cleaning pads to clean the differential housing and individual components. Remove all grease and oil used during manufacturer's assembly from bearings and wipe clean lip seals with a dry cloth.

9.2.1.4 *Functional Surface and Cover Plate Preparation*—Abrasive blast the entire differential case, ring, pinion, side gears, differential pinion gears (spider gears), all four thrust washers and the inside surface of the housing cover plate by uniformly abrasive blasting with 80 grit aluminum oxide. *Do not* abrasive blast the bearings, bearing cups and differential shaft (cross shaft pin). *Do not touch any cleaned surface with bare hands as moisture can cause rusting.*

(1) After abrasive blasting and pre-test inspection (see 9.2.1.5), pressure wash abrasive blasted parts, all four bearings, and bearing cups with solvent and a round plastic bristle brush (pressure not to exceed 30 psi (207 kPa) (see 6.1.2). After pressure washing, rinse with solvent and dry with filtered compressed air or nitrogen (pressure not to exceed 30 psi (207 kPa) (see 7.2). A Wilkerson filter, model M18-02-CH00[15,9] is required to filter the compressed air or nitrogen. A Wilkerson model MTP-96-64617[15,9] is the required replacement element for the filter assembly. *Do not* use wire brushes or abrasive-cleaning pads to clean the abrasive blasted parts. *Do not* spin dry the bearings with the compressed air or nitrogen. Only use blowguns without a safety bypass to air-dry the parts. A Milton model S15[16,9] has been found to be acceptable.

9.2.1.5 *Pre-Test Inspection*—After the parts have been abrasive blasted, and before cleaning and rinsing, carefully inspect the abrasive blasted parts, bearings, and bearing cups for rust or corrosion and damage. If any rated area is found to have rust, re-prepare as described in 9.2.1.4. If defects are found, such as casting flaws and so forth, that might be mistaken for rust at the end of test inspection, add a notation of their pre-test existence to the test report. If any bearing is found to have rust or damage, replace it with a new one that is rust-free. The replaced bearing shall be from the same manufacturer and have the same bearing part number. At the end of test inspection and rating make no allowances for parts rusted before start of test.

9.2.1.6 *Test Oil Coating*—Immediately coat all abrasive blasted parts evenly with test oil after they have been cleaned, rinsed, and dried. Immediately coat all four bearings, bearing cups, and differential shaft (cross shaft pin) evenly with test oil after they have been cleaned and rinsed. (Bearings, bearing cups, and differential shaft (cross shaft pin) are not abrasive blasted). Dipping the parts in test oil or pouring the test oil over the parts are acceptable methods. Do not use brushes to coat the parts with test oil. Do not touch any test parts with bare hands; fingerprints can cause rusting.

9.2.1.7 Lightly coat all bolts with test oil prior to assembly of test axle.

9.2.1.8 Clean, rinse, dry, and coat all parts with test oil within 2 h after abrasive blasting.

9.2.2 *Assembly of Test Unit:*

[13] The sole source of supply of the apparatus known to the committee at this time is Fisher Scientific, 2000 Park Lane Drive, Pittsburgh, PA 15275.

[14] The sole source of supply of the apparatus known to the committee at this time is Exxon\Mobil Oil Company, Fairfax, VA.

[15] The sole source of supply of the apparatus known to the committee at this time is Wilkerson Instrument Company, Inc., 2915 Parkway Street, Lakeland, FL 33811.

[16] The sole source of supply of the apparatus known to the committee at this time is McMaster Carr Supply Company, 200 Aurora Industrial Pkwy, Cleveland, OH 44202.

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9.2.2.1 *Drive Pinion Shaft Installation*—Assemble the drive pinion shaft with its bearings and install it in the housing following the guidelines in 9.2.2. A late model GM, GMC, or Chevrolet service manual may be used for assembly details not included here.

(1) Install the rear pinion bearing onto the pinion shaft with the original shim.

(2) Place the front pinion bearing into the housing and then install the pinion front seal into the housing. Note that the front seal might be damaged during disassembly and may need to be replaced.

(3) Install the pinion shaft into the differential housing. The front bearing may need to be tapped into place using a small punch. Install the pinion yoke washer and nut. Torque pinion-nut until a turning torque of 3 lbf-in. to 10 lbf-in. (0.3 N·m to 1.1 N·m) is achieved.

(4) If necessary, replace the pinion crush collar and repeat pinion assembly process.

(5) Record the final pinion break and turning torque on the appropriate test report form.

9.2.2.2 *Differential Case Installation*—Assemble the differential pinion, side gears, shafts and thrust washers, shims, bearings, and ring gears. Be aware that the bolts attaching the ring gear to the carrier are left-hand thread. Install the differential case assembly and bearing caps in the differential housing. Torque the differential housing bearing caps to 35 lbf-ft to 50 lbf-ft (48 N·m to 68 N·m). Measure break and turning torque; turn torque shall be 7 lbf-in. to 13 lbf-in. (0.8 N·m to 1.5 N·m) and break torque shall be 8 lbf-in. to 18 lbf-in. (0.9 N·m to 2.0 N·m).

(1) Adjust the final turning torque by removing the differential case, adding or removing shims on the left ring gear side only, and then reassemble to obtain final preload.

(2) Repeat Item 1 of 9.2.2.2 until the appropriate final turning torque is reached.

(3) Record final break and turning torque in the space provided in the test report.

(4) After completion of the test axle build and before the cover plate installation, place the test axle in a vertical position with the yoke oriented upward. Place the cover in a vertical position. Allow the assembled test axle and cover plate to drain for a minimum of 10 min.

9.2.2.3 *Test Oil Addition*—Charge 91 oz ± 2.3 oz (2.7 L ± 0.07 L) of test oil to the test unit.

9.2.2.4 *Cover Plate, Seals, Temperature Probe, and Pressure Control Valve Installation*—Install the cover plate with a new TFE fluorocarbon gasket, pre-wetted with the test oil on both sides (see 6.2.4). Use a new TFE fluorocarbon cover plate gasket for every test. Orient the gasket such that the hook on the gasket is nearest the tapped vent hole in the axle housing.

(1) Torque the cover plate bolts to 20 lbf-ft to 25 lbf-ft (27 N·m to 34 N·m).

(2) Install the temperature probe using TFE fluorocarbon tape as shown in Fig. A5.4, Fig. A5.11, and Fig. A5.12.

(3) Install the NPT stainless steel fittings and stainless steel full port valve into the pre-tapped axle housing vent tube opening. Some of the cover plate bolts may be replaced with longer bolts or studs which are then used to attach a bracket used to mount the axle housing in the motoring stand. Ensure that all fasteners used to attach the cover plate are evenly torqued to the given specification.

10. Calibration

10.1 *Reference Test Frequency*—Conduct one reference test every ten test starts or every five months, whichever comes first. This calibration frequency is subject to change as required. Current calibration information is available from the TMC.

10.2 All tests are consecutively numbered on a storage box basis. Each storage box has its own unique, permanent identifier. Every test start shall receive a sequential test run number designated before testing begins. All test starts, including aborted starts and operationally invalid tests, shall retain their test run number.

10.3 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 this test method.

10.4 *Instrumentation Calibration:*

10.4.1 Prior to every stand calibration attempt, calibrate the drive speed measuring system and the temperature control systems (storage box and motoring stand) against a known standard, traceable to NIST.[17]

10.4.2 Prior to every stand calibration attempt, calibrate the pressure relief system, using the following process:

10.4.2.1 From the bottom of the dip tube, measure 27.75 in. ± 0.125 in. (704.9 mm ± 3.18 mm) and mark this distance on the dip tube.

10.4.2.2 Apply 1 psi (6.9 kPa) to the dip tube.

10.4.2.3 Fill the water column reservoir with specified test water, (see 7.1), until 1 psi (6.9 kPa) is displaced.

10.4.2.4 Release the pressure in the dip tube, and mark the static water level on the dip tube.

10.4.2.5 Apply air pressure to the dip tube until air begins to bubble from the tube to verify calibration. Air pressure shall be 1 psi ± 0.1 psi (6.9 kPa ± 0.7 kPa).

11. Test Procedure

11.1 *Pre-Test, Start, and Motoring Phase:*

11.1.1 *Installation of Test Unit*—Install the assembled test unit on the motoring rig. Connect the driveshaft and temperature probe. Install the cooling fan and heat lamp pair as shown in Fig. A5.3.

11.1.2 Adjust the temperature controller to maintain 180 °F ± 1 °F (83 °C ± 0.6 °C).

11.1.3 Start the driving motor and immediately accelerate the motor to 2500 r/min ± 25 r/min. Record the time and the initial oil temperature at the time of the driving motor start up.

11.1.4 Do not exceed 8 h between the beginnings of the abrasive blasting of axle parts to the start of the motoring phase of the test.

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

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11.1.5 Using a syringe, add 2.3 oz ± 0.02 oz (67.5 mL ± 0.6 mL) of specified test water to the test unit through the full port valve within 5 min after starting the drive motor. Connect the pressure relief system.

11.1.6 Monitor oil temperature and when the oil temperature reaches 180 °F ± 1 °F (83 °C ± 0.6 °C), close full port ball valve, disconnect the pressure relief system, and plug the downstream side of valve. This prevents escape of any additional water vapor. Measure and record drive pinion r/min and oil temperature, and report the time at the beginning of motoring phase. Allow a 1 h maximum warm up time for the oil to reach operating temperature of 180 °F ± 1 °F (83 °C ± 0.6 °C).

11.1.6.1 Occasionally, a small amount of the test oil and water emulsion will foam up from the axle housing into the accumulator during warm-up. Make every effort to allow the test oil and water emulsion to return to the test axle. Stop the motoring and heating of the test unit in an attempt to return the test oil and emulsion to the test axle. There may be occasions when the test oil and water emulsion will not completely drain back into the carrier as the unit reaches operating temperature. Use caution not to exceed the 1 h maximum warm-up time. Report the number of shutdowns and the estimated amount of test oil and water emulsion that did not return to the carrier in the comment section of the test report.

11.1.7 Motor the test unit for 4.0 h ± 0.1 h at 180 °F ± 1 °F (83 °C ± 0.6 °C) and 2500 r/min ± 25 r/min.

11.1.8 At the end of the motoring phase, measure, and record drive pinion r/min and report the time. Stop the driving motor, turn off the heat lamps and cooling fan.

11.2 *Transition Phase:*

11.2.1 Move the test unit to the storage box within 30 min of the end of the motoring phase. See Fig. A5.6 for physical position. Set the controller at 125 °F ± 1 °F (52 °C ± 0.6 °C). Position the axle such that the axle tube openings and the pinion shaft are on a horizontal plane.

11.2.2 Switch on the internal fan. Activate the control system to maintain a test oil temperature of 125 °F ± 1 °F (52 °C ± 0.6 °C). The maximum allowable time for the test oil to reach operating temperature of 125 °F ± 1 °F (52 °C ± 0.6 °C) from the end of the motoring phase of the test as stated in 11.1.8 is 90 min.

11.3 *Storage Phase:*

11.3.1 Record the time of the first occurrence of the test oil temperature reaching 125 °F ± 1 °F (52 °C ± 0.6 °C). This is the start of the storage phase.

11.3.2 Continue the storage phase for a total of 162 h ± 0.2 h.

11.3.3 At the end of the storage phase, record the time, then switch off the storage box-heating unit and circulating fan. The end of the storage phase is the end of the test.

11.4 *Post Test Procedure:*

11.4.1 Immediately remove the test unit from the storage box. Disconnect the temperature sensor. Drain and discard the used test oil. Completely disassemble the test axle within 1 h after the test complete as stated in 11.3.3.

11.4.2 Lightly pressure wash all parts with a solvent (see 7.2) to remove used test oil being careful not to remove any small rust spots (pressure not to exceed 30 psi (207 kPa) and without mechanical means such as a brush).

11.4.3 Coat test parts in Mobil Arma 245[14,9] prior to final rating.

11.4.4 Clean and coat all parts in Mobil Arma 245[14,9] within 1 h after disassembling the test axle.

11.4.5 If the rating is not to be conducted within 24 h of the end of the test, the coated test parts shall either be stored submerged in the preservative oil, or stored as is in airtight, closed containers. Wrapping the test parts in NOX-RUST paper[18,9] for long-term storage has also been found to be acceptable.

NOTE 2—To preserve test parts in storage or for shipment after completion of all rating and optional documentation photographs, the rust preventative Mobil Arma 245 has been found to be effective in preventing new rust buildup in post-test ambient storage conditions.

12. Determination of Test Results

12.1 Conduct parts rating within 14 days from the end of test, under lighting conditions described in ASTM Distress Rating Manual 21.[7] Rate parts in accordance to ASTM Distress Rating Manual 21 and Annex A7. The rating procedure described in Annex A7 supersedes that found in ASTM Distress Rating Manual 21 where applicable. Deposits on rated items will fall under one of two categories: *(1)* Rust or corrosion; *(2)* Stain and sludge or other.

12.2 Rust or corrosion deposits will be assigned one of the following integer values: 10, 9, 8, 5, or 0, using these definitions:

None	– 10
Trace	– 9 – not more than six spots, each less than 1 mm in diameter
Light	– 8 – 7 or more spots, each less than 1 mm in diameter or, one or more spots greater or equal to 1 mm in diameter with a combined area of all the spots no greater than 1 % of the total rated component surface
Moderate	– 5 – in excess of above and up to 5 % of considered surface
Severe	– 0 – covering more than 5 % of considered surface

12.3 The areas in Table 1 will be rated as described above.

TABLE 1 Area Number and Rated Surfaces

Area Number	Description
1	differential case pinion spherical machined thrust surfaces
2	differential case side gear thrust surface and hub I.D.
3	differential gears (side gears) thrust surface and hub O.D.
4	axle housing cover plate excluding the plug[A]
5	ring gear (Drive gear) tooth surfaces
6	drive pinion tooth surfaces
7	drive pinion roller surfaces
8	drive pinion cup (total raceway length)
9	differential case roller surfaces
10	differential case cup (total raceway length)

[A] Axle cover plate plug is not to be removed for rating.

[18] The sole source of supply of the apparatus known to the committee at this time is Dauber VCI, Inc., 1333 Burr Ridge Parkway, Suite 200, Burr Ridge, IL 60527.

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TABLE 2 Test Precision

	Intermediate Precision		Reproducibility	
Variable, merits	$S_{I.P.}$[A]	*i.p.*[B]	S_R[A]	R[B]
Rust (AAM)[C]	0.19	0.52	0.19	0.52

[A] S = standard deviations.
[B] This value is obtained by multiplying the standard deviation by 2.8.
[C] These statistics are based on results obtained on TMC Reference Oil 155-1 from June 15, 2015 to May 2, 2017 using AAM hardware.

12.4 By filling in values on the rating sheet and then applying the appropriate weighting values shown in Annex A9, a final deposit merit value is obtained. To maintain comparable test severity to the Dana Model 30 hardware, add 0.6 merits to the final deposit merit value when using AAM K2XX hardware for non-reference oil testing. In instances where this results in a merit value greater than 10, report the result as 10 merits. Note the presence, location, and amount of additional deposits, such as stain and sludge, or other, in the Remarks section on the rating sheet. Also note rust in non-rated areas in the Remarks section.

12.4.1 Prior to January 2, 2020: to maintain comparable test severity to the Dana Model 30 hardware add 0.6 merits to the final deposit merit value when using AAM K2XX hardware for non-reference oil testing. In instances where this results in a merit value greater than 10, report the result as 10 merits.

12.4.2 On and after January 2, 2020: to maintain comparable test severity to the Dana Model 30 hardware, add a +1 correction to the rated values for areas #2 and #3 when using AAM hardware. The application of these +1 values does not permit a rated value to exceed a value of 10.

12.5 For a valid rating, rate the test by an individual who has met the requirements for rater calibration stated in the Rater Calibration Monitoring System (RCMS) document. The document can be found on the TMC website (astmtmc.org).

12.6 *Test Validity*—The test is determined to be operationally valid if the percent deviation of the critical operating parameters and number of downtimes are within the limits specified and defined in Annex A6.

12.7 *Severity Adjustment*—Calculate severity adjustments (SA) for results of non-reference gear oil tests. Use the control chart technique, referenced in Annex A8, for determining the laboratory bias for rust or corrosion deposits. Enter the adjustments on the appropriate test form.

13. Final Test Report

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

NOTE 3—Report the non-reference oil test results on these same forms if the results are intended to be submitted as candidate oil results against a specification.

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

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

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

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

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

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

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

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

14. Precision and Bias

14.1 *Precision:*

14.1.1 Test precision is established on the basis of operationally valid reference oil test results monitored by the TMC. Test precision shown in Table 2 is considered current as of Feb. 16, 2005. Research Report RR:D02-1554[19] contains industry data developed prior to establishment of this test method.

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

NOTE 4—Intermediate precision is the appropriate term for this method rather than repeatability, which defines more rigorous within-laboratory conditions.

14.1.3 *Intermediate Precision Limit* (*i.p.*)—The difference between two results obtained under intermediate precision conditions that would in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 2 in one case in twenty.

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

14.1.5 *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 in Table 2 only in one case in twenty.

[19] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1554. Contact ASTM Customer Service at service@astm.org.

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14.2 *Bias*—Bias will be determined by applying an accepted statistical technique to reference oil test results, and when a significant bias is determined, a severity adjustment will be permitted for non-reference oil test results.

15. Keywords

15.1 corrosion; final drive axle; gear failure; gears; lubricants; L-33-1; moisture; rust

ANNEXES

(Mandatory Information)

A1. ASTM TEST MONITORING CENTER ORGANIZATION

A1.1 The Test Monitoring Center (TMC), an affiliate of ASTM International, is a nonprofit organization located at 203 Armstrong Drive, Freeport, PA 16229. It is staffed to administer engineering studies; conduct laboratory visits; perform statistical analyses of test data; 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 ASTM Test Monitoring System Executive Committee, whose members are elected by Subcommittee D02.B0. The TMC operates under its associated bylaws and regulations, the bylaws of Committee D02 and of Subcommittee D02.B0, and the Rules and Regulations of the ASTM Test Monitoring System. The operating income of the TMC is obtained from fees levied on the reference oils supplied and on test reviews. These fees are set by the Test Monitoring Center Board of Directors.

A2. ASTM TEST MONITORING CENTER: CALIBRATION PROCEDURES

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

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

A2.2 *Calibration Testing*:

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

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

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

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

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

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

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

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