Designation: D5704 – 17

Standard Test Method for Evaluation of the Thermal and Oxidative Stability of Lubricating Oils Used for Manual Transmissions and Final Drive Axles[1]

This standard is issued under the fixed designation D5704; 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)[2] 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 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.

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.

1. Scope*

1.1 This test method is commonly referred to as the L-60-1 test.[2] It covers the oil-thickening, insolubles-formation, and deposit-formation characteristics of automotive manual transmission and final drive axle lubricating oils when subjected to high-temperature oxidizing conditions.

1.2 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.

1.2.1 *Exceptions*—The values stated in SI units for catalyst mass loss, oil mass and volume, alternator output, and air flow are to be regarded as standard.

1.2.2 SI units are provided for all parameters except where there is no direct equivalent such as the units for screw threads, or where there is a sole source supply equipment specification.

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 and health practices and determine the applicability of regulatory limitations prior to use.* Specific warning information is given in Sections 7 and 8 and Annex A7.

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]

B224 Classification of Coppers

[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 will update changes in the test method by means of information letters. Information letters may be obtained from the ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489. Attention: Administrator. This edition incorporates revisions in all information Letters through No. 16-1.

[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.

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

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D893 Test Method for Insolubles in Used Lubricating Oils
D6984 Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIF, Spark-Ignition Engine
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standard:*[4]
ANSI/ISA-S7.3 Quality Standard for Instrument Air

2.3 *Military Specification:*[5]
MIL-L-2105D Lubricating Oil, Gear, Multipurpose

2.4 *ASTM Adjuncts:*[6]
Engineering Drawings

3. Terminology

3.1 *Definitions:*

3.1.1 *carbon, n—in manual transmissions and final drive axles*, a hard, dry, generally black or gray deposit that can be removed by solvents but not by wiping with a cloth.

3.1.2 *lubricant, n*—any material interposed between two surfaces that reduces the friction or wear, or both, between them. **D6984**

3.1.3 *sludge, n—in manual transmissions and final drive axles*, a deposit principally composed of the lubricating oil and oxidation products that do not drain from parts but can be removed by wiping with a cloth.

3.1.4 *thermal and oxidative stability, n—in lubricating oils used for manual transmissions and final drive axles*, a lack of deterioration of the lubricating oil under high-temperature conditions that is observed as viscosity increase of the lubricating oil, insolubles formation in the lubricating oil, or deposit formation on the parts, or a combination thereof.

3.1.5 *varnish, n—in manual transmissions and final drive axles*, a hard, dry, generally lustrous deposit that can be removed by solvents but not by wiping with a cloth.

4. Summary of Test Method

4.1 A sample of the lubricant to be tested is placed in a heated gear case containing two spur gears, a test bearing, and a copper catalyst. The lubricant is heated to a specified temperature and the gears are operated at predetermined power and speed conditions for 50 h. Air is bubbled through the lubricant at a specified rate and the bulk oil temperature of the lubricant is controlled throughout the test. Parameters used for evaluating oil degradation after testing are viscosity increase, insolubles in the used oil, and gear cleanliness.

5. Significance and Use

5.1 This test method measures the tendency of automotive manual transmission and final drive lubricants to deteriorate under high-temperature conditions, resulting in thick oil, sludge, carbon and varnish deposits, and the formation of corrosive products. This deterioration can lead to serious equipment performance problems, including, in particular, seal failures due to deposit formation at the shaft-seal interface. This test method is used to screen lubricants for problematic additives and base oils with regard to these tendencies.

5.2 This test method is used or referred to in the following documents:

5.2.1 American Petroleum Institute (API) Publication 1560-Lubricant Service Designations for Automotive Manual Transmissions, Manual Transaxles, and Axles,[7]

5.2.2 STP-512A–Laboratory Performance Tests for Automotive Gear Lubricants Intended for API GL-5 Service,[8]

5.2.3 SAE J308-Information Report on Axle and Manual Transmission Lubricants,[9] and

5.2.4 U.S. Military Specification MIL-L-2105D.

6. Apparatus

6.1 A description of essential apparatus features is given as follows, including mandatory equipment type and performance specification where established. See Annex A5 and Annex A6 for schematics and additional information of a general nature. Those wishing to build this test apparatus shall base construction on full engineering drawings (see 6.2). A list of suppliers is available from ASTM International Headquarters.[6]

6.1.1 *Gear Case Assembly,* used in conjunction with a new test bearing, new lip seals, new O-rings, a pair of new test gears, copper catalyst, and the lubricant to be tested. The gear case assembly has been redesigned to incorporate improvements over designs in use prior to this test method. Construct the gear case and associated parts in accordance with the engineering drawings. The gear case and associated parts shall comply in dimension, material, surface finish where prescribed, and overall design. O-rings and lip seals have been incorporated into this design and are mandatory replacements for the original cork gaskets and shaft slingers used in earlier designs.

6.1.2 *Insulated Oven,* surrounds the gear case assembly and provides insulation sufficient to allow the lubricant temperature to be elevated to and maintained at test temperature conditions. This oven also houses the heaters and heater blower. The oven dimensions, heater, blower, and oven temperature sensor locations are specified in the engineering drawings (see Annex A5 for approximate locations).

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[4] Joint standard of ANSI/ISA. Available from Instrument Society of America, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[6] Detailed drawings necessary for rig construction. Available from ASTM International Headquarters. Order Adjunct No. ADJD5704A.

[7] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1353.

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

6.1.3 *Heater Elements*—Since this test method is extremely sensitive to temperature, the following specified heater elements (two total) are mandatory:

6.1.3.1 Use one 1500W primary heater element manufactured by Chromolox, Inc. The part number may be 118-553661-505, 118-553661-514, or 118-074906-010.[10,11]

6.1.3.2 Use one 150W alternator load heater element part number FD2Z-0895 manufactured by Ogden Manufacturing.[12,11]

6.1.4 *Temperature Controller,* proportional-integral-derivative (PID) type; percent output adjustable.

6.1.5 *Thermocouples*—For determination, recording, and control of the test oil temperature, a ⅛ in. (3.2 mm) Type J open-tip thermocouple is specified. Thermocouples for other data measurements may be used as suitable to the user but in all cases shall be placed behind the baffle plate in the gear box assembly and shall not interfere with normal oil flow patterns during the test.

6.1.6 *Temperature Recorder,* any suitable recording device capable of generating a temperature record using the specified thermocouples and temperature control devices. Submit temperature traces for tests with the test report.

6.1.7 *Alternator*—Use a Remy model 10-SI Series Type 100, 63 A, 12 V negative ground alternator part number 91751 for loading the gearset.[13,11] Modify the alternator by removing the diode trio and resistor as shown in the circuit diagram in Fig. A10.1. The supplied v-belt pulley may be replaced with a multi-groove (so called micro-v) pulley provided the original metal fan and 1:1 pulley ratio are retained.

6.1.8 *Heater Blower*—The heater blower system shall supply to the insulated oven assembly 29.5 ± 5 ft^3/min (835 L/min ± 142 L/min) of air (at free flow conditions) through the 2⅛ in. (54 mm) diameter blower opening as shown in the engineering drawings. The heater blower may be a cage type blower wheel powered by an electric motor or powered by way of a toothed belt from the main drive shaft.

6.1.8.1 Confirm the heater blower system air flow at laboratory ambient conditions with a Preso Low Loss Venturi Meter[14,11] (2 in. model LPL-200NF-38) with carbon steel body, ¼-in. NPT instrument connections and 2 in. 150 lb raised-face process connections and a Dwyer digital manometer,[15,11] part number 475-00-FM. Perform the verification with the heater elements turned off.

6.1.8.2 Send the Preso Low Loss Venturi Meter together with the Dwyer digital manometer to the specified calibration laboratory[16] for cleaning and calibration at least once a year.

6.1.9 *Air Flow Controller*—The air flow controller[17,11] shall be capable of controlling the air supply at a flow rate of 22.08 mg/min ± 2.01 mg/min (see Note 1).

NOTE 1—It has been suggested that 20 to 30 ft (6 m to 9 m) of supply line between the air regulator and the mass air flow meter may help to reduce flow meter readout fluctuations.

6.1.10 *Test Gears,* one machine tool change gear (34 teeth, with a width of ⅜ in. (9.5 mm) and one machine tool change gear (50 teeth, with a width of ⅜ in. (9.5 mm)).[18,11]

6.1.11 *Test Bearing,* ball bearing.[19,11]

6.1.12 *O-ring Seals,* O-ring for the seal plate and O-ring for the cover plate.[19,11]

6.1.13 *Lip Seals,* two Chicago Rawhide or SKF shaft oil lip seals, part number 6383, are required.[19,11]

6.1.14 *Speedi-sleeve,* two Chicago Rawhide or SKF speedi-sleeves, part number 99062, are required.[19,11]

6.1.15 *Joint Radial Seal,* two Chicago Rawhide or SKF joint radial (V-ring) seals, part number 400164, are required.[19,11]

6.1.16 *Gear Holder Apparatus,* used to hold the test gears during preparation (Annex A12).

6.2 Construct all new equipment in accordance with the engineering drawings available as an adjunct from ASTM Headquarters[6] in order to meet calibration requirements. Builders unable to obtain specified parts and wishing to use substitutes shall request approval from ASTM Subcommittee D02.B0.03.

7. Reagents and Materials

7.1 *Air,* compressed, instrument quality, meeting ANSI/ISA-S7.3, that limits dew point, maximum particle size, and maximum oil content of the air at the instrument.

7.2 *Copper Catalyst,* cold-rolled, electrolytic tough pitch copper, conforming to UNS (Unified Numbering System) C11000.[12,11] Shear the two strips from stock of thickness 1⁄16 in. (1.6 mm) to approximately 9⁄16 by 1 13⁄16 in. (14 mm by 46 mm).

NOTE 2—For more information on the classification of coppers and the Unified Numbering System (UNS), consult Classification B224 and Practice E527, respectively.

7.3 *Organic Cleaning Agent.* (**Warning**—Combustible, health hazard (see Annex A7).)[20,21,11]

7.4 *Silicon Carbide Paper,* 180 grit.

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[10] The sole source of supply known to the committee at this time is Chromolox, Inc., 103 Gamma Dr., Pittsburgh, PA 15238.

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

[12] The sole source of supply known to the committee at this time is Ogden Manufacturing Co., 103 Gamma Dr., Pittsburgh, PA 15238.

[13] The sole source of supply known to the committee at this time is Remy, 600 Corporation Dr., Pendleton, IN 46064.

[14] The sole source of supply of the apparatus known to the committee at this time is SW Controls Inc., 2525 East Royalton Road, Broadview Heights, OH 44147.

[15] The sole source of supply of the apparatus known to the committee at this time is JF Good Company, 11200 Madison Ave., Cleveland, OH 44102.

[16] Bowser-Morner, 4518 Taylorsville Rd., Dayton, OH 45424.

[17] The sole source of supply of the Air Flow Controller Model 840-L-1 known to the committee at this time is Sierra Instruments, Inc., 5 Harris Court, Bldg. L, Monterey, CA 93940.

[18] The sole source of supply of the GA-34 and GA-50 gears known to the committee at this time is Boston Gear Works, 14 Hayward St., Quincy, MA 02171.

[19] The sole source of supply of the R-14 10 ball bearing, No. 2-153 (seal plate O-ring), No. 2-264 (cover plate O-ring), 6383 seals, 400164 seals, and 99062 speedi-sleeves known to the committee at this time is Motion Industries, 4620 Hinckley Parkway, Cleveland, OH 44109.

[20] The sole source of supply of the apparatus known to the committee at this time is Oakite Products, Inc., 13177 Huron River Dr., Romulus, MI 48174.

[21] The sole source of supply of the apparatus known to the committee at this time is Pentone Corp., 74 Hudson Ave., Tenafly, NJ 07670.

7.5 *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.)

7.6 *Toluene,* commercial grade. (**Warning—**Flammable. Health hazard.) An example of a satisfactory volatile hydrocarbon solvent.

7.7 *Heptane,* commercial grade. (**Warning—**Flammable. Health hazard.) An example of a satisfactory volatile hydrocarbon solvent.

8. Preparation of Apparatus

8.1 *Air Box Temperature Limiting Device*—After initial rig installation, preset the oven air temperature limit to 400 °F (204 °C). This can be achieved by placing the insulated oven cover in position on the rig and installing the air temperature sensor at a penetration depth of 3 in. (75 mm) below the top inner surface of the cover. Switch on the heaters and circulating fan. Adjust the temperature control device to deactivate the heaters when the air temperature reaches 400 °F (204 °C). This oven temperature limit may later be reduced as outlined in 10.3 to meet rig heat-up requirements.

8.2 *Temperature Recording and Controlling Instrumentation*—Since this test procedure is extremely sensitive to temperature, it is necessary to maintain a periodic check upon the accuracy of all items related to temperature measurement and control. Therefore, immediately after the installation of a new test rig, and before every set of reference tests, calibrate the instrumentation used to measure and record the air and oil temperatures against known standards traceable to NIST.[22] For instance, calibrate the oil temperature thermocouple and indicating controller. This can be accomplished by immersing the tip of the probe into an auxiliary temperature-controlled oil bath equipped with a stirrer. Accurately set the bath temperature at 325 °F (162.8 °C) and confirm the test measuring equipment to be accurate prior to testing.

8.3 *Gear Case*—Using the organic cleaning agent (see 7.3), clean the gear case, vent tube, vent tube baffle, retainer bushings, seal sleeves, case cover plate, seal plate, nuts, studs, flat washers, baffle plate, spacer bushings, bearing bushings and clamp, keys, shaft ends, shaft nuts, and catalysts. Nylon bristle brushes, steel brushes, and long pipe cleaners can be used to aid cleaning. Do not use any copper or copper-containing brushes or material as a cleaning medium. Following the cleaning procedure with an organic cleaning agent, wash parts thoroughly with cleaning solvent (see 7.5), and finally with a volatile hydrocarbon solvent (see 7.6 or 7.7), to facilitate air drying. Allow parts to air dry.

8.4 *Test Gears*—Thoroughly clean the test gears with cleaning solvent (see 7.5). Carefully examine the gear teeth for nicks and burrs. Do not use gears with major imperfections. Redress minor gear teeth imperfections with a fine stone or file. After final examination, wash gears once more with cleaning solvent and finally with a volatile hydrocarbon solvent, to facilitate air drying. Allow gears to air dry.

8.4.1 Prepare each gear with new Screen-Kut silicon carbide C-180 paper.[23,11] Place a new piece of silicon carbide paper on a solid surface that has a thickness greater than or equal to ½ in. (12.7 mm). Saturate the entire silicon carbide paper with cleaning solvent (see 7.5). Use one new piece of silicon carbide paper per gear side, using both sides of the silicon carbide paper as necessary. Sand both sides of the test gears, with the required gear holder apparatus (6.1.16) on the silicon carbide paper, using a figure eight motion. Do not apply a downward force to the gear holder while sanding. Sand the gears until the manufacturer's machining marks are removed. After final examination, wash gears once more with cleaning solvent (see 7.5) and finally with a volatile hydrocarbon solvent (see 7.6 or 7.7), to facilitate air drying. Allow gears to air dry. If the gears are not to be used immediately, wrap them in a paper towel and Nox-Rust paper.[24,11]

8.4.1.1 Discard the test gears if not used within 24 h after polishing is completed.

8.5 *Test Bearing*—Prior to installation, wash the test bearing first with cleaning solvent (see 7.5), and finally with a volatile hydrocarbon solvent, to facilitate drying. Allow the bearing to air dry.

8.6 *Copper Catalyst:*

8.6.1 Notch one strip for purpose of identification. The notch shall be triangular in shape centered on the long side of the strip. Sides of the triangular notch shall be equal and approximately 0.2 in. (approximately 5 mm) in length.

8.6.2 Polish both catalyst strips on all six sides with Screen-Kut silicon carbide C-180 paper.[23,11] Use either a new piece of Screen-Kut or one retained from the gear polishing procedure described in 8.4.1.

8.6.3 Wipe both catalyst strips with absorbent cotton pads moistened with cleaning solvent (see 7.5), and wash with a volatile hydrocarbon solvent, to facilitate drying. Allow catalyst strips to air dry.

8.6.4 Record the mass of the catalyst with the notched strip to the nearest 0.0001 g prior to installation. Handle cleaned catalyst strips with one of the following: new nitrile gloves, new latex gloves, tweezers, or ashless filter paper to avoid contamination of the catalyst surface from skin contact.

8.7 *Gear Case Assembly*—Assemble the gear case components (see Annex A6 for exploded view).

8.7.1 Inspect all parts prior to assembly of the gear case. Replace any parts that would affect proper rig operation (for example, overly worn parts). Parts replacement is left to the discretion of the rig builder. A modified seal plate, detailed on

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

[23] The sole source of supply of the apparatus (Johnson Abrasives Screen-Kut Part No. 11003) known to the committee at this time is Johnson Abrasives Co., Inc., 49 Fitzgerald Dr., Jaffrey, NH 03452, Attn: Scott Johnson (phone: 800-628-8005).

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

gear case drawing number C-3963-1277-2[6] may be used to facilitate removal of the lip seals.

8.7.2 Use new elastomer components (O-rings and lip seals) for each test.

8.7.3 Install the retainer bushings and seal sleeves. Replace the seal sleeves if they are grooved.

8.7.4 Install the lip seals and O-ring seal in the seal plate.

8.7.5 Install the seal plate in the gear case, using the flat washers to protect the seal plate surface from damage. Torque the seal plate retaining studs to approximately 25 lbf·in. (approximately 2.8 N·m).

8.7.6 Install a v-ring seal on the upper and lower shafts.

8.7.7 Install the external retaining rings on the upper and lower shafts.

8.7.8 Install the upper and lower spacer bushings on the upper and lower shafts.

8.7.9 Install the baffle plate and catalyst holder and torque to approximately 25 lbf·in. (approximately 2.8 N·m), using the flat washers to protect the baffle plate and catalyst holder surfaces.

8.7.10 Insert the bearing into the test bearing clamp with the bearing clamp shoulder on the opposite side of the bearing manufacturer's number. Use the bearing clamp cap screw to bolt the bearing clamp closed and torque to approximately 25 lbf·in. (approximately 2.8 N·m). Install the locking nut to ensure that the bolt does not move during the test.

8.7.11 Insert the test bearing bushing into the test bearing with the bearing bushing shoulder on the same side of the bearing as the manufacturer's number. Install this entire assembly on the lower shaft so that the bearing manufacturer's number faces the front of the gear case. If the bearing assembly has been assembled properly, the bearing clamp arm will be on the opposite side of the gear case as the catalyst holder.

8.7.12 Install the large gear (GA-50) on the lower shaft and the small gear (GA-34) on the upper shaft along with the shaft keys. Install the test gears so that the manufacturer's name faces the front of the case. Install the retaining nuts and torque to approximately 90 lbf·in. (approximately 10 N·m). The gear retaining nuts are different since the lower shaft is right-hand thread and the upper shaft is left-hand thread.

8.7.13 Insert the test oil thermocouple so that the tip protrudes perpendicular to the slanted lower right side of the gear case assembly and protrudes 0.50 ± 0.04 in. (13 mm ± 1 mm) into the gear case.

8.7.14 Insert catalysts in the grooves on the catalyst holder. Catalysts shall be sized for a tight fit in the catalyst holder to avoid movement of the catalysts during the test. Placement of the notched strip toward the rear of the gear case with the notch facing rearward is recommended for ease of catalyst removal after test with minimal disturbance of deposits.

8.7.15 Install the O-ring seal on the gear case cover.

8.7.16 Install the gear case cover and torque the cap screws to approximately 25 lbf·in. (approximately 2.8 N·m).

8.8 *Air Supply Line*—Ensure that the air supply line is free from obstructions and then connect the air supply line to the bottom of the gear case.

8.9 *Insulated Oven Cover*—Ensure that the oven temperature sensor is at a penetration depth of 3.0 ± 0.2 in. (76 mm ± 5 mm) below the top inner surface of the cover (see 7.5). Install the cover on the rig.

8.10 *Air Flow Controller Calibration:*

8.10.1 As a standard for all Sierra Side Trak model 840 air flow controller calibrations, use either a Sierra Top Trak model number 822S-L-2-OV1-PV1-V1-SCR2700 or 822S-L-2-OV1-PV1-V4-SCR2700 air flow meter (these model numbers supersede 822S-L-2-OV1-PV1-V1-A1 and 822S-L-2-OV1-PV1-V4-A1 which also remain acceptable for use). Calibrate the Sierra Top Trak to a traceable national standard at least once every year at a flow rate of 22.08 mg/min ± 2.01 mg/min at the outlet with 30 psig (206 kPa) inlet pressure.

8.10.2 Prior to initiating a test stand calibration run, connect the Sierra Top Trak meter to the inlet of the Sierra Side Trak controller. Connect the Side Trak outlet to the gear box. Install an air pressure measurement device to monitor and regulate air pressure to the inlet of the Top Trak to 30 psig (206 kPa). Charge the gear box with a commercial 80W-90 grade oil and bring to test conditions (325 °F ± 1 °F (162.8 °C ± 0.5 °C) at 1750 r/min ± 50 r/min). Adjust the Side Trak until its controlled flow matches that displayed by the Top Trak. Remove the Top Trak after completing the calibration.

8.10.3 Determination of the need to repeat Side Trak calibration following an unsuccessful test stand calibration run is at the discretion of the testing laboratory.

9. Calibration and Standardization

9.1 Annex A2 describes calibration procedures using the TMC reference oils, including their storage and conditions of use, the conducting of tests, and the reporting of results.

9.2 Annex A3 describes maintenance activities involving TMC reference oils, including special reference oil tests, special use of the reference oil calibration system, donated reference oil test programs, introducing new reference oils, and TMC information letters and memoranda

9.3 Annex A4 provides information regarding new laboratories, the role of the TMC regarding precision data, and the calibration of test stands used for non standard tests.‖

9.4 *Reference Test Frequency*—The test stand calibration period is defined as three months or 10 tests, whichever occurs first. It begins on the completion date of an operationally and statistically acceptable reference oil test as determined by the TMC. Any test started on or before the stand calibration expiration date is defined to have been run on a calibrated stand.

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

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

9.5 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.

9.6 *Instrumentation Calibration*—Immediately prior to commencing each reference oil test, calibrate the large gear shaft speed system, alternator output system, blower motor output system, air flow controller system, air box temperature control system, and oil temperature control system against standards traceable to NIST. Instrumentation calibrations prior to reference oil tests that follow a failed or invalid first attempt are at the discretion of the test laboratory. Retain record of these calibrations for a minimum of two years.

10. Procedure for Conducting the Test

10.1 Pour 120 mL ± 5 mL of the lubricant to be tested into a clean container. Weigh the container of oil. Charge the gear case with the test lubricant. Reweigh the container and determine the oil charged by subtraction. Record the weight of the test oil charge to the nearest 0.01 g.

10.2 Preset air flow rate to 22.08 mg/min ± 2.01 mg/min.

10.3 Record the time. Turn on the main drive motor. Heat the oil from ambient to 324 °F (162.2 °C). Any test where heat-up time is less than 45 min or greater than 60 min is operationally invalid. Record the time that the temperature reached 324 °F (162.2 °C) as the start of test time. Adjust the temperature control system to maintain the bulk test lubricant temperature at 325 °F ±1 °F (162.8 °C ± 0.6 °C).

10.3.1 Record all operational data at a minimum of once every 15 min. A reading out of specification using once-every-15 min data recording is considered to be out for the full 15 min unless otherwise documented.

10.4 If the rig heat-up time is less than 45 min, the oven temperature limit should be reduced until the heat-up time is equal to or greater than 45 min but less than 60 min. A possible cause of heat-up times greater than 60 min is improper fit between the insulated oven and insulated oven cover or other areas of excessive oven thermal leakage, or both. Under no circumstances shall the oven temperature limit be set higher than 400 °F (204 °C). The rig heat-up time should be checked prior to every set of reference tests to ensure consistent rig performance.

10.5 Adjust the field supply of the alternator for a net output of 128 W ± 5 W.

10.6 The large gear shall maintain a speed of 1750 r/min ± 50 r/min throughout the heat-up and test time.

10.7 Run the test at the conditions specified for 50.0 h ± 0.1 h. Terminate the test if more than 5 min of total downtime occurs during the test period. Record any downtime on Form 4, Annex A8.

10.7.1 A downtime occurrence is defined as the time at which the test is shut down until the time the test returns to test operating specifications.

10.7.2 Do not calculate percent deviations during downtime occurrences.

10.7.3 Record all operational data at a minimum of once every hour. A reading out of specification using once-every-hour data recording is considered to be out for the full hour unless otherwise documented.

10.8 Upon the completion of the test, immediately shut down the equipment. Remove the air line, and drain the test lubricant into a clean, weighed container. The gear case cover plate may be loosened to facilitate draining but do not remove it. Drain the test stand for 30 min ± 5 min. To determine the final oil mass measurement, weigh the container and drained oil and calculate the oil mass loss percent using the equation below:

$$\text{oil loss in mass \%} = \frac{\text{initial mass} - \text{final mass}}{\text{initial mass}} \times 100 \quad (1)$$

where:

initial mass = initial oil charge mass, and
final mass = drain oil mass.

10.8.1 Any test exceeding a mass loss of 20 % is operationally invalid.

10.9 At the completion of the oil mass loss calculation, transfer the entire oil drain, including solids, using a flat-bladed stainless steel tool from the weighed container into a single sample bottle for kinematic viscosity, pentane insolubles, tolulene insolubles, and total acid number evaluation as outlined in Section 13. The single sample bottle contents shall be homogenous prior to kinematic viscosity, pentane insolubles, toluene insolubles, and total acid number evaluation.

10.10 Remove the test gears from the gear case between 30 min and 60 min after test completion. Do not disturb any of the deposits on the gears.

11. Procedure for Determination of the Gear Cleanliness Ratings[25,11]

11.1 Evaluation of the test gears is performed after removing the catalyst strips, test gears, test bearing, and internal gear case components.

11.2 After gear case disassembly, as specified in 10.10, immediately place test parts side-by-side in a draining position (a draining position is a position within 15° of vertical.) at room temperature for a minimum of 1 h before rating. Rate the test parts within 64 h of test completion.

11.3 *Gear Sludge Rating:*

11.3.1 To fix the distance from the rating light to the gear face and to control the angle of incidence of the light on the gear, mount the gear being rated onto the L-60-1 Gear Rating Jig.[25]

11.3.2 Handle the gears at the gear teeth lands to avoid any contact with the rated area.

11.3.3 Use a cool white type fluorescent 4500 K color temperature light with a minimum illumination level of 200 fc (2150 lx).

11.3.4 Place the gear on the L-60-1 Gear Rating Jig with the keyway vertical and the front side up.

11.3.5 Using a lint-free cloth, wipe an approximately ¾ in. (20 mm) wide area across the diameter of the face of the gear along the keyway. Wipe the gear five times in the same direction.

[25] The sole source of the apparatus (L-60-1 Gear Rating Jig) known to the committee at this time is ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206.

11.3.6 Position the light on the two brackets on the top of the L-60-1 Gear Rating Jig. Verify light fixture is approximately level in all directions.

11.3.7 Rate the top half of the gear looking down on the gear.

11.3.8 Subdivide the total ratable area into percentage areas of different sludge depths and ratings using ASTM Deposit Rating Manual 20[26] (use the sludge scale and sludge gauge, included in the manual). Calculate and record the sludge volume factor for each subdivided area. The total volume factor for a gear face is determined by adding the individual area volume factors for that gear face.

11.3.9 Convert the total volume factor for each gear face to a merit rating using ASTM Deposit Rating Manual 20. Report this rating to two decimal places.

11.3.10 Do not rate the wiped area, the gear teeth, or the spacer bushing contact area for sludge.

11.3.11 Rotate the gear 180 degrees and rate the other half of the gear.

11.3.12 Repeat the same steps for the small gear.

11.3.13 The sludge rating is defined as the average of the four merit ratings of the four gear faces.

11.4 *Gear Carbon/Varnish Rating:*

11.4.1 To fix the distance from the rating light to the gear face and to control the angle of incidence of the light on the gear, mount the gear being rated onto the L-60-1 Gear Rating Jig.

11.4.2 Handle the gears at the gear teeth lands to avoid any contact with the rated area.

11.4.3 Use a cool white type fluorescent 4500 K color temperature light with a minimum illumination level of 200 fc (2150 lx).

11.4.4 Place the gear on the L-60-1 Gear Rating Jig with the keyway vertical and the front side up.

11.4.5 If not already done for previous sludge rating, use a lint-free cloth to wipe an approximately ¾ in. (20 mm) wide area across the diameter of the face of the gear along the keyway. Wipe the gear five times in the same direction.

11.4.6 Position the light on the two brackets on the top of the L-60-1 Gear Rating Jig. Verify light fixture is approximately level in all directions.

11.4.7 Rate the top half of the gear looking down on the gear.

11.4.8 The wiped area on each gear face, excluding the gear teeth and spacer bushing contact area, is the ratable area. Subdivide the total ratable area into percentage areas of different carbon depths and varnish intensities. Use any of the three Rating Scales (A, B, or C) of the ASTM Rust/Varnish/Lacquer Rating Scale for Non Rubbing Parts found in ASTM Deposit Rating Manual 20 to determine varnish rating factors for each subdivision containing varnish deposits.

11.4.9 Rate carbon from 0.00 (heavy carbon) to 0.99 (trace carbon) using an expanded rating scale. Determine carbon rating factors by referring to the ASTM L-60-1 Rating Aid in ASTM Deposit Rating Manual 20. Calculate the carbon merit rating by multiplying the rating factor by the percentage area. Report this rating to two decimal places.

11.4.10 Rotate the gear 180 degrees and rate the other half of the gear.

11.4.11 Determine the carbon/varnish merit rating for a gear face by adding the individual area merit ratings for the wiped area of that face. Determine the carbon/varnish rating using the large gear only. The small gear may be rated for additional information. Rate the front and back faces of both gears individually.

11.4.12 The carbon/varnish rating is defined as the average of the front and back face merit ratings for the large gear. The small gear should be rated similarly, but separately, for additional information.

11.5 Use Form 5, Annex A8 for calculating and reporting carbon/varnish and sludge rating measurements.

11.6 For the test rating to be valid, the gears shall be rated by an individual who has participated in a ASTM-sponsored, high-volume, gear-rater calibration workshop within the previous twelve months.

12. Procedure for Determination of Catalyst Mass Loss

12.1 *Determine the Catalyst Mass Loss:*

12.1.1 Carefully remove all the deposits from the notched copper catalyst strip by soaking for approximately 30 min in Oakite 811, Penmul L460, or equivalent.

12.1.2 Wash in cleaning solvent (see 7.5).

12.1.3 Remove deposit residue from the surface by rubbing lightly with a clean cloth.

12.1.4 Wash in cleaning solvent (see 7.5).

12.1.5 Wipe with absorbent cotton pads moistened with a volatile hydrocarbon solvent.

12.1.6 Wash in a volatile hydrocarbon solvent. Allow catalyst strip to air dry.

12.1.7 Handle the cleaned catalyst strip with tweezers or ashless filter paper in order to avoid inaccurate mass loss information. Record the mass of the cleaned catalyst with the notched strip to the nearest 0.0001 g to determine the copper activity of the test lubricant. The mass loss is reported as a percent loss based upon the original mass of the notched strip.

13. Procedure for Evaluation of Drain Oil

13.1 Determine the following test lubricant parameters (pay particular attention to the sample handling instructions in the relevant standard):

13.1.1 Kinematic viscosity of the untested oil and of the drain oil in centistokes at 212°F (100 °C) using Test Method D445. Do not filter the sample. Run the post-test viscosity determination within 48 h of the end of the test.

13.1.2 Total acid number of the drain oil using Test Method D664.

13.1.3 *n*-Pentane and toluene insolubles using Test Method D893, Procedure A without coagulant. Evaluate the pentane/toluene insolubles within 48 h of the end of the test.

[26] ASTM Deposit Rating Manual 20 available at the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org.

14. Calculation

14.1 Calculate the percent viscosity increase by Eq 2, using the initial oil kinematic viscosity and the drain oil kinematic viscosity.

$$\text{percent viscosity increase} = \frac{\text{final KV} - \text{initial KV}}{\text{initial KV}} \times 100 \quad (2)$$

where:

KV = kinematic viscosity.

14.2 Calculate the catalyst percent mass loss using Eq 3:

$$\text{percentage loss in catalyst mass} = \frac{\text{catalyst initial mass} - \text{catalyst final mass}}{\text{catalyst initial mass}} \times 100 \quad (3)$$

where:

catalyst initial mass = initial catalyst mass as determined in 8.6.4, and
catalyst final mass = final catalyst mass as determined in 12.1.7.

14.3 An industry-wide average carbon varnish severity shift began sometime in the year 2000. No cause for this shift has been determined. To compensate for this shift, correct the average carbon varnish result for all tests by adding 0.6 merits to the rated average carbon varnish. If the result is greater than 10, record 10.

14.4 Correct non-reference oil results for industry severity using the equations detailed in Annex A9. Correct non-reference oil results for stand severity using the equations detailed in Annex A11.

14.5 Calculate percent out for each parameter in Table 1 using the following equation and record results in Form 6, Annex A8.

$$\text{percent out} = \sum_{i=1}^{n} \left(\frac{Mi}{0.5R} \times \frac{Ti}{D} \right) \times 100 \quad (4)$$

where:

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

TABLE 1 Test Validity Parameters

	Parameter			
	Oil Temperature	Air Flow	Alternator Power	Large Gear Speed
Specification	325 °F (163 °C)	22.08 mg/min	128 W	1750 r/min
Range	2 °F (-17 °C)	4.02 mg/min	10 W	100 r/min
% Out of specification (warm up)	NA	10 %	10 %	5 %
% Out of specification (test)	5 %	5 %	5 %	2 %

14.5.1 Invalidate any test that exceeds the percent out limits in Table 1 for either warm up or on test conditions.

14.6 Round test results according to Practice E29.

15. Report

15.1 For reference oil results, use the standardized report form 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.

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

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

15.1.3 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.

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

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

15.4 *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.

15.5 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.

15.6 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.

15.7 Attach to the test report plots for all parameters in Table 1. Include warmup time.

15.8 For tests with viscosity results that are too viscous to measure, report a value of NA. For test results where viscosity is too viscous to measure or have a value of zero for viscosity increase, pentane insolubles, or toluene insolubles, do not apply any severity adjustment.

16. Precision and Bias

16.1 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 semi-annually by the L-60-1 Surveillance Panel. Contact the ASTM TMC for current industry data. Table 2 summarizes reference oil precision of the test as of June 30, 1997.

16.1.1 *Intermediate Precision Conditions*—Conditions where test results are obtained with the same test method using

TABLE 2 Reference Oil Test Precision Data

NOTE 1—These statistics are based on results obtained on Test Monitoring Center Reference Oils 148, 148–1, 133, 133–3, 131–4, 143, and 151–2 as of September 20, 2015.

where:

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

Variable	$S_{i.p.}$	i.p.[A]	S_R	R[A]
Average carbon varnish, (merit)	0.505	1.414	0.532	1.490
Average sludge, (merit)	0.104	0.291	0.106	0.297
Pentane insolubles, (mass fraction, %)	0.383	1.072	0.401	1.123
Toluene insolubles, (mass fraction, %)	0.295	0.826	0.312	0.874
Viscosity increase, (increase, %)	6.178	17.298	6.328	17.718

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

the same test oil, with changing conditions, such as operators, measuring equipment, test stands, test engines, and time.

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

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

16.1.2 *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.

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

16.2 Bias is determined by applying an accepted statistical technique to reference oil results, and when a significant bias is determined, a severity adjustment is permitted for non-reference oil test results (see 14.4, Annex A9, and Annex A11).

17. Keywords

17.1 carbon and varnish deposits; final drive axle; gear cleanliness; gears; insoluble; L-60; lubricants; manual transmission; oil thickening; seal failure; sludge; thermal oxidation

ANNEXES

(Mandatory Information)

A1. ASTM TEST MONITORING CENTER ORGANIZATION

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

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

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

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

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

A2. ASTM TEST MONITORING CENTER: CALIBRATION PROCEDURES

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

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

A2.2 *Calibration Testing*:

A2.2.1 Full-scale calibration testing shall be conducted at regular intervals. These full-scale tests are conducted using coded reference oils supplied by the TMC. It is a laboratory's responsibility to keep the on-site 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 TMCreference oils, either physically or chemically. Do not resell ASTM reference oils or supply them to other laboratories without the approval of the TMC. The reference oils are supplied only for the intended purpose of obtaining calibration under the ASTM Test Monitoring System. Any unauthorized use is strictly forbidden. The testing laboratory tacitly agrees to use the TMC reference oils exclusively in accordance with the TMC's published Policies for Use and Analysis of ASTM Reference Oils, and to run and report the reference oil test results according to TMC guidelines. Additional policies for the use and analysis of ASTM Reference Oils are available from the TMC.

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

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

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

A3. ASTM TEST MONITORING CENTER: MAINTENANCE ACTIVITIES

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

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

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

A3.4 *Intervals Between Reference Oil Tests*—Under special circumstances, such as extended downtime caused by industry-wide parts or fuel shortages, the TMC may extend the intervals between reference oil tests.

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

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

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

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

A4. ASTM TEST MONITORING CENTER: RELATED INFORMATION

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

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

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

A5. DIAGRAM OF TEST APPARATUS

A5.1 Fig. A5.1 presents a diagram of the test apparatus.

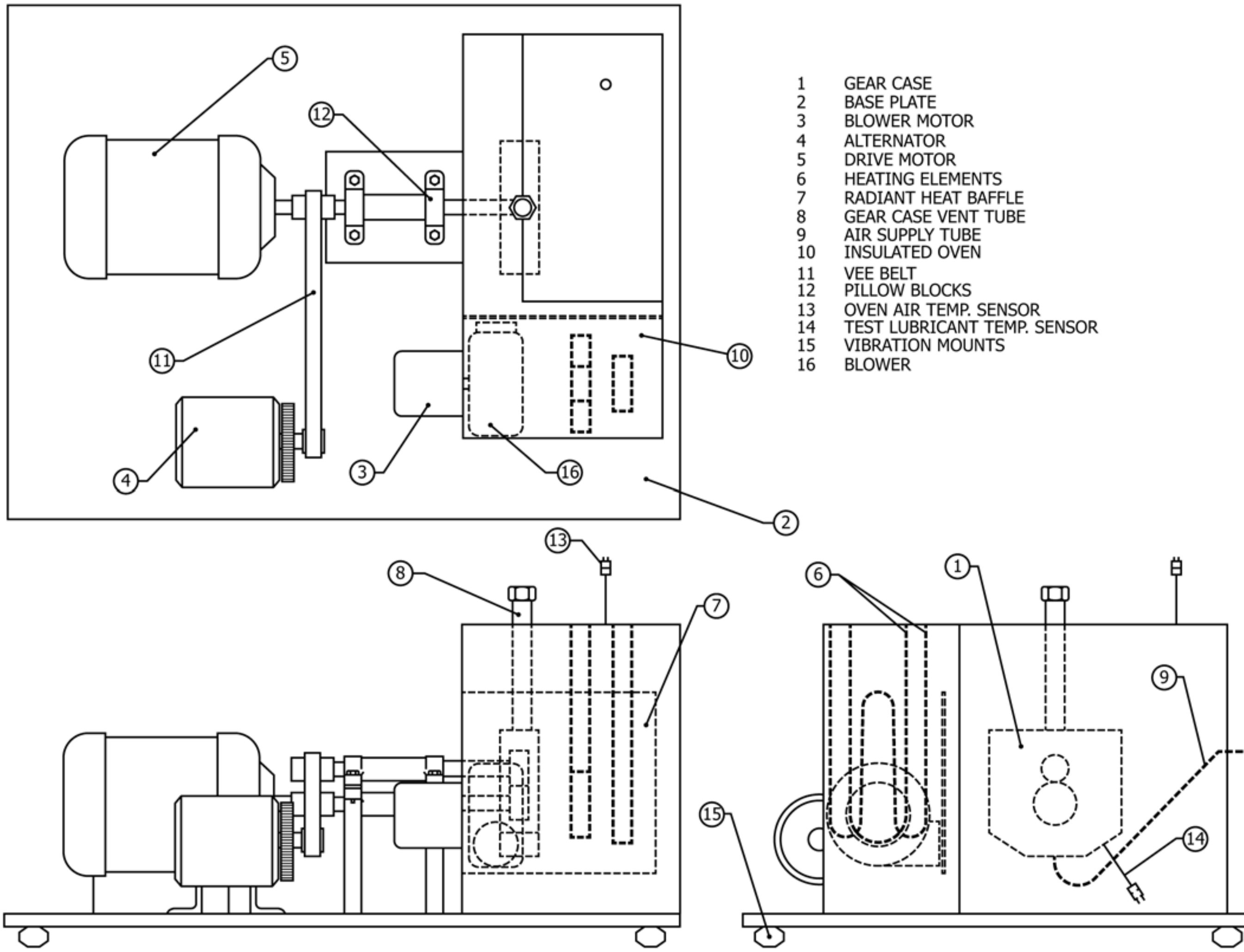

FIG. A5.1 Diagram of Test Apparatus

A6. EXPLODED VIEW OF GEAR CASE ASSEMBLY

A6.1 *Gear Case Assembly Parts List* (see Fig. A6.1):

(1) Lower Shaft (Right-Hand Thread)
(2) Upper Shaft (Left-Hand Thread)
(3) Gear Case Support
(4) Retainer Bushing
(5) Speedi-Sleeve Seal (99026)
(6) Spacer Washer
(7) Gear Case
(8) Cap Screw, 5⁄16 – 24 by 3⁄4
(9) Vent Tube
(10) O-ring (No. 2-153)
(11) Lip Seal (6383)
(12) Seal Plate
(13) V-Ring Oil Seal (400164)
(14) Stainless Steel Flat Washer, 5⁄16 in. (7.9 mm)
(15) Stainless Steel Stud
(16) Stainless Steel External Retainer
(17) Baffle Plate
(18) Catalyst Holder
(19) Stainless Steel Flat Washer, 5⁄16 in. (7.9 mm)
(20) Stainless Steel Hex Nut, 5⁄16 — 18
(21) Catalyst
(22) Upper Spacer Bushing
(23) Lower Spacer Bushing
(24) Bearing Clamp
(25) Stainless Steel Cap Screw, #10–32 by 3⁄4
(26) Stainless Steel Hex Nut, #10–32
(27) Test Bearing (R-14)
(28) Bearing Bushing
(29) Shaft Key, 1⁄8 in. by 3⁄8 in. (3.2 mm by 9.5 mm)
(30) Test Gear (GA-50)
(31) Test Gear (GA-34)
(32) Gear Retaining Nut (Right-Hand Thread)
(33) Gear Retaining Nut (Left-Hand Thread)
(34) O-ring (No. 2-264)
(35) Gear Case Cover Plate
(36) Lock Washer, #10
(37) Cap Screw, #10–32 by 3⁄4
(38) Vent Tube Baffle

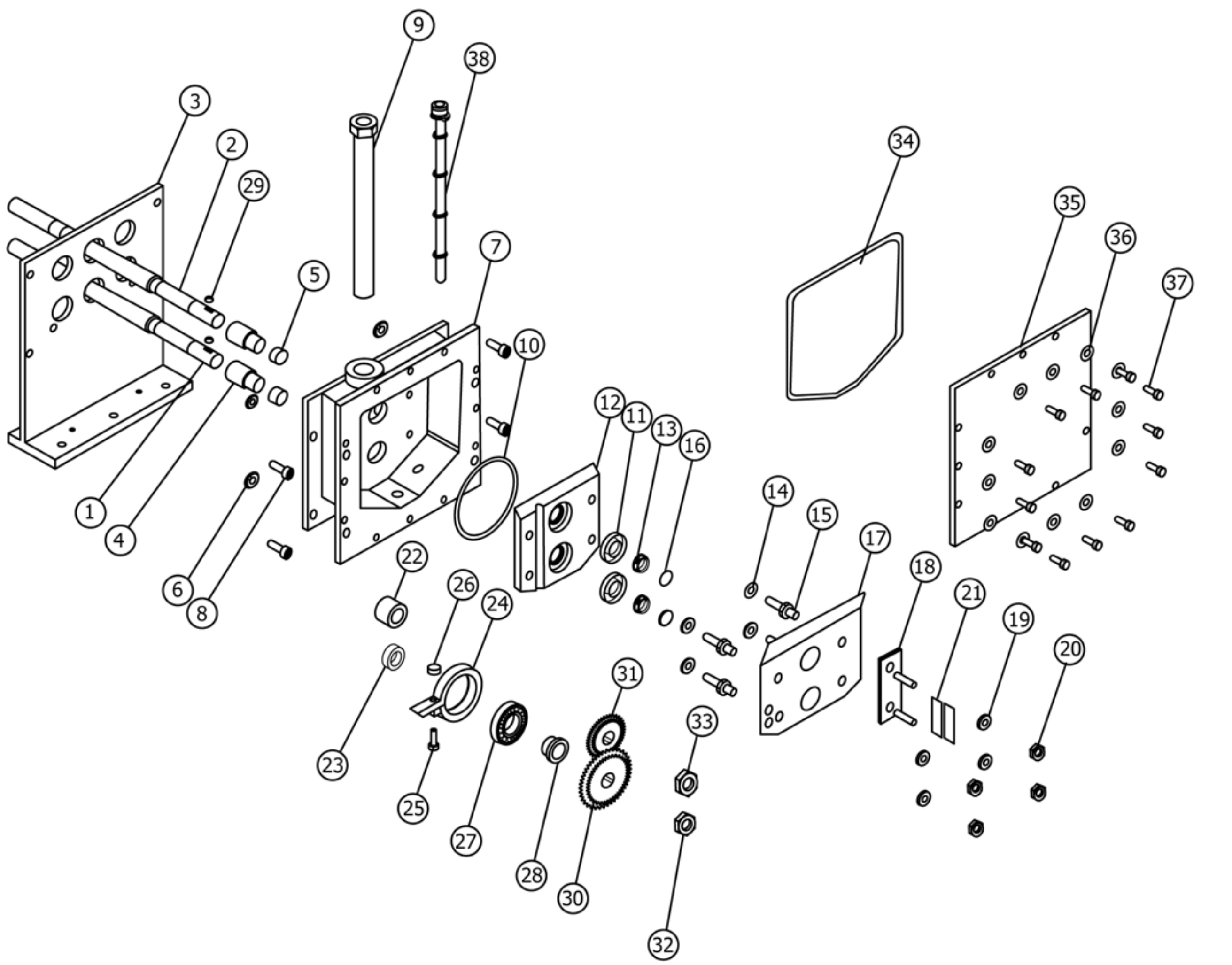

FIG. A6.1 Exploded View of Gear Case Assembly

A7. WARNING STATEMENTS

A7.1 *Oakite 811, Penmul L460* (volatile hydrocarbon solvent, examples are toluene and heptane), *Stoddard Solvent:*

A7.1.1 Vapors may cause flash fire.

A7.1.2 Keep away from heat, sparks, and open flame.

A7.1.3 Keep container closed.

A7.1.4 Use with adequate ventilation.

A7.1.5 Avoid buildup of vapors.

A7.1.6 Eliminate all sources of ignition, especially non-explosion-proof electrical devices and heaters.

A7.1.7 Avoid prolonged breathing of vapor or spray mist.

A7.2 *Physical Hazards*:

A7.2.1 High-speed rotating equipment.

A7.2.2 Electrical shock.

A7.2.3 High-temperature surfaces.

A8. L-60-1 TEST REPORT FORMS and DATA DICTIONARY

A8.1 The required report forms and data dictionary are available on the ASTM Test Monitoring Center web page at http://www.astmtmc.cmu.edu/, or they can be obtained in hard copy format from the TMC.

Form 0
Test Report Cover
Form 1
Reference Test Result Summary Page
Form 2
Non-Reference Test Result Summary Page
Form 3
Operational Summary
Form 4
Page Lost Time and Comments Sheet
Form 5
Gear Rating
Form 6
Operational Validity Summary

A9. CORRECTIONS TO NON-REFERENCE OIL TESTS FOR INDUSTRY SEVERITY

A9.1 *Viscosity Increase*Adjust end of test viscosity increase (VISINC) results for industry severity as follows.

A9.1.1 Calculate the transformed viscosity increase (TVISINC) using the equation: TVISINC = ln(VISINC).

A9.1.2 The viscosity increase correction factor (VISINCCF) is -0.1178. Calculate the corrected transformed viscosity increase (VISICCOR) using the equation: VISICCOR = TVISIC + VISINCCF.

A9.1.3 Calculate the corrected original unit viscosity increase (OVISI) using the equation: OVISI = exp(VISICCOR).

A9.2 Pentane Insolubles—Adjust end of test pentane insolubles (PEN) results for industry severity as follows.

A9.2.1 Calculate the transformed pentane insolubles (TPEN) using the equation: TPEN = ln(PEN).

A9.2.2 The pentane insolubles correction factor (PENCF) is -0.4445. Calculate the corrected transformed pentane insolubles (PENCOR) using the equation: PENCOR = TPEN + PENCF.

A9.2.3 Calculate the corrected original unit pentane insolubles (OPEN) using the equation: OPEN = exp(PENCOR).

A10. ALTERNATOR LOAD CIRCUIT

A10.1 Fig. A10.1 is a diagram of the modified 10.SI alternator load circuit.

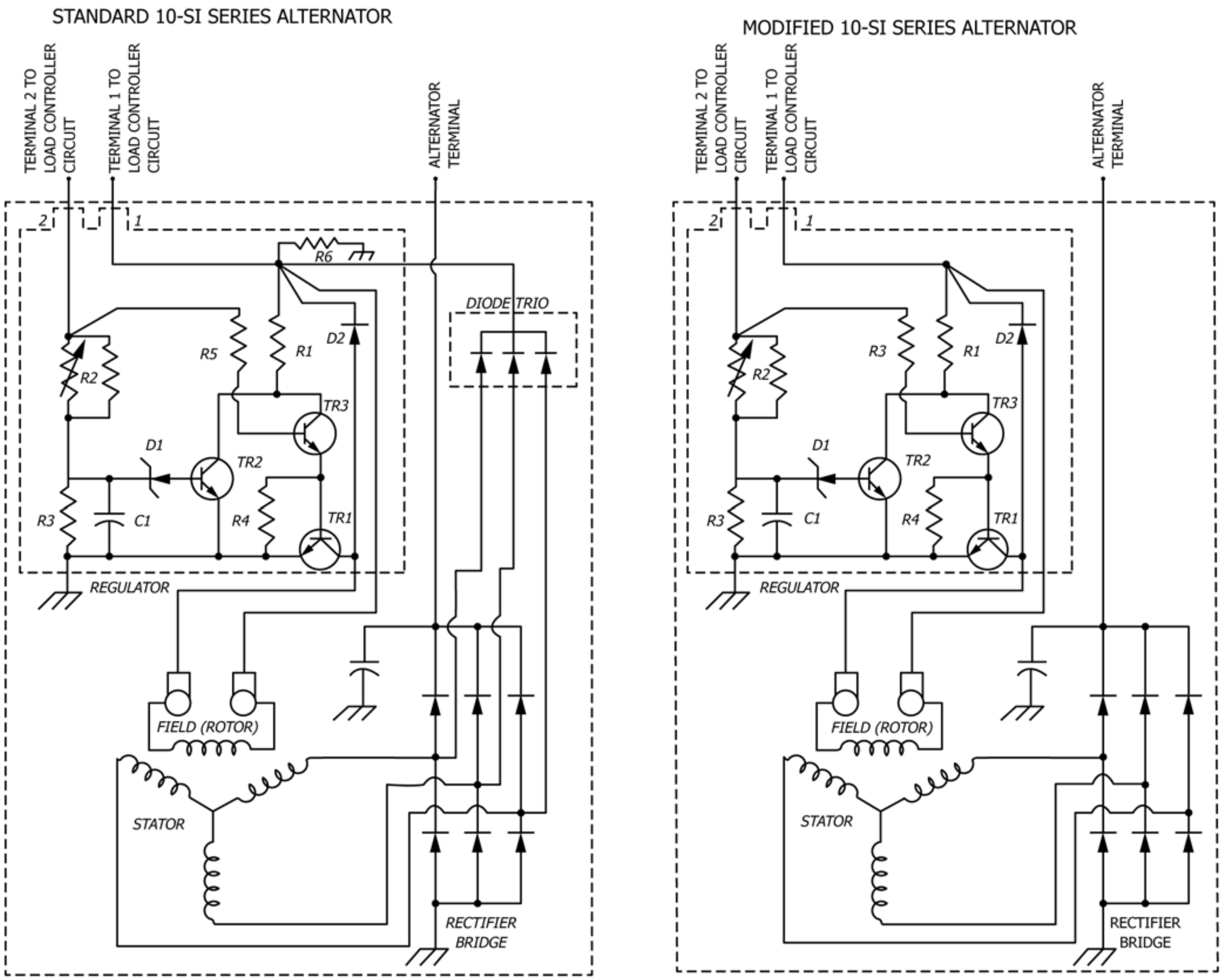

FIG. A10.1 Diagram of the Modified 10-SI Alternator Load Circuit

A11. CONTROL CHART TECHNIQUE FOR SEVERITY ADJUSTMENT (SA)

A11.1 *Viscosity Increase SA*—Apply an exponentially weighted moving average (EWMA) technique to standardized calibration test Viscosity Increase results. Standardize transformed values using delta/s ((result − target)/standard deviation). The targets and standard deviations for current reference oils are published by the ASTM TMC.

A11.1.1 Include all operationally valid reference tests in a stand control chart. Chart tests in order of completion date and time. A minimum of two tests is required to initialize a control chart. Calculate EWMA values using Eq A11.1.

$$Z_i = 0.2(Y_i)+0.8(Z_{i-1}) \quad (A11.1)$$

where:

Z_0 = 0 and Y_i = standardized test result, and
Z_i = EWMA of the standardized test result at test order i.

If the absolute value of the EWMA, rounded to three places after the decimal, exceeds 0.653, then apply an SA to subsequent non-reference oil results.

A11.1.2 The following example illustrates the application of Eq A11.1 for determining the application of Viscosity Increase SA.

$$Z_i = 0.694 \text{ and } Y_2 = 1.247 \quad (A11.2)$$

$$\text{EWMA} = 0.2(1.247)+0.8(0.694) = 0.805$$

A11.1.2.1 Since $|0.805|>0.653$, apply an SA to subsequent non-reference oil tests. Multiply 0.805 by 7.659. This value (7.659) is the viscosity increase pooled standard deviation of oils 148-1 and 151-2. Multiply this result by −1 and round a whole number. Record this value on the Test Results Summary of the test report in the space for Viscosity Increase SA.

(1) Add this value to the corrected, non-reference oil Viscosity Increase result and record this value in the Final Original Unit Viscosity Increase result space on the Test Results Summary. An SA will remain in effect until the next reference test. At that time, calculate a new EWMA.

A11.2 *Pentane Insolubles SA*—Apply an EWMA technique to standardized calibration test Pentane Insolubles results. Standardize transformed values using delta/s ((result − target)⁄standard deviation). The targets and standard deviations for current reference oils are published by the ASTM TMC.

A11.2.1 Include all operationally valid reference tests in a stand control chart. Chart tests in order of completion date and time. A minimum of two tests is required to initialize a control chart. Calculate EWMA values using Eq A11.1. If the absolute value of the EWMA (rounded to three places after the decimal) exceeds 0.653, then apply an SA to subsequent non-reference oil results.

A11.2.2 The following example illustrates the use of Eq A11.1 for determining the application of a Pentane Insolubles SA.

$$Z_1 = 0.570 \text{ and } Y_2 = 1.195 \quad (A11.3)$$

$$\text{EWMA} = 0.2(1.195)+0.8(0.570) = 0.695$$

A11.2.2.1 Since$|0.695|>0.653$, apply an SA to subsequent non-reference oil tests. Multiply 0.695 by 0.413. This value (0.413) is the pentane pooled standard deviation of oils 148-1 and 151-2. Multiply this result by −1 and round to one decimal place. Record this value on the Test Results Summary page of the test report in the space for Pentane Insolubles SA.

(1) Add this value to the corrected, non-reference oil Pentane Insolubles result and enter this value in the space for the Final Original Unit Pentane Insolubles result. If this value is less than 0, report 0. An SA will remain in effect until the next reference test. At that time, calculate a new EWMA.

A11.3 *Toluene Insolubles SA*—Apply an EWMA technique to standardized calibration test Toluene Insolubles results. Standardize transformed values using delta/s ((result − target)⁄standard deviation). The targets and standard deviations for current reference oils are published by the ASTM TMC.

A11.3.1 Include all operationally valid reference tests in a stand control chart. Chart tests in order of completion date and time. A minimum of two tests is required to initialize a control chart. Calculate EWMA values using Eq A11.1. If the absolute value of the EWMA (rounded to three places after the decimal) exceeds 0.653, then apply an SA to subsequent non-reference oil results.

A11.3.2 The following example illustrates the use of Eq A11.1 for determining the application of a Toluene Insolubles SA.

$$Z_1 = -0.572 \text{ and } Y_2 = -1.469 \quad (A11.4)$$

$$\text{EWMA} = 0.2(-1.469)+0.8(-0.572) = -0.751$$

A11.3.2.1 Since $|-0.751|>0.653$, apply an SA to subsequent non-reference oil tests. Multiply − 0.751 by 0.249. This value (0.249) is the toluene pooled standard deviation of oils 148-1 and 151-2. Multiply this result by −1 and round to one decimal place. Record this value on the Test Results Summary of the test report in the space for Toluene Insolubles SA.

(1) Add this value to the corrected, non-reference oil result and enter this value in the space for the Final Original Unit toluene result. If this value is less than 0, report 0. An SA will remain in effect until the next reference test. At that time, calculate a new EWMA.

A11.4 *Average Carbon Varnish SA*—Apply an EWMA technique to standardized calibration test Carbon/Varnish results. Standardize transformed values using delta/s ((result − target)⁄standard deviation). The targets and standard deviations for current reference oils are published by the ASTM TMC.

A11.4.1 Include all operationally valid reference tests in a stand control chart. Chart tests in order of completion date and time. A minimum of two tests is required to initialize a control chart. Calculate EWMA values using Eq A11.1. If the absolute value of the EWMA (rounded to three places after the decimal) exceeds 0.653, then apply an SA to subsequent non-reference oil results.

A11.4.2 The following example illustrates the use of Eq A11.1 for determining the application of a Carbon/Varnish SA.

$$Z_1 = 0.667 \text{ and } Y_2 = -1.062 \quad (A11.5)$$

$$\text{EWMA} = 0.2(1.062)+0.8(0.667) = 0.746$$

A11.4.2.1 Since$|0.746|>0.653$, apply an SA to subsequent non-reference oil tests. Multiply 0.746 by 0.511. This value (0.511) is the average carbon varnish pooled standard deviation of oils 148-1 and 151-2. Multiply this result by −1 and round to one decimal place. Record this value on the Test Results Summary of the test report in the space for Carbon/Varnish SA.

(1) Add this value to the corrected, non-reference oil result and record this value as the Final Original Unit average carbon varnish result. If this value is greater than 10, report 10; if it is less than 0, report 0. An SA will remain in effect until the next reference test. At that time, calculate a new EWMA.

A11.5 *Average Sludge SA*—Apply an EWMA technique to standardized calibration test Average Sludge results. Standardize transformed values using delta/s ((result − target)⁄standard deviation). The targets and standard deviations for current reference oils are published by the ASTM TMC.

A11.5.1 Include all operationally valid reference tests in a stand control chart. Chart tests in order of completion date and time. A minimum of two tests is required to initialize a control chart. Calculate EWMA values using Eq A11.1. If the absolute value of the EWMA (rounded to three places after the decimal) exceeds 0.653, then apply an SA to subsequent non-reference oil results.

A11.5.2 The following example illustrates the use of Eq A11.1 for determining the application of an Average Sludge SA.

$$Z_1 = -0.541 \text{ and } Y_2 = -1.197 \quad (A11.6)$$

$$EWMA = 0.2(-1.197)+0.8(-0.541) = -0.672$$

A11.5.2.1 Since $|0.672|>0.653$, apply an SA to subsequent non-reference oil tests. Multiply − 0.672 by 0.106. This value (0.106) is the average sludge pooled standard deviation of oils 148-1 and 151-2. Multiply this result by −1 and round to four places after the decimal. Record this value on the Test Results Summary of the test report in the space for Average Sludge SA.

(1) Add this value to the corrected, non-reference oil result and record this value in the space for the Final Original Unit result. If this value is greater than 10, report 10; if it is less than 0, report 0. An SA will remain in effect until the next reference test. At that time, calculate a new EWMA.

A12. GEAR HOLDER APPARATUS

A12.1 Fig. A12.1 and Fig. A12.2 are diagrams of the gear holders used to prepare the test gears.

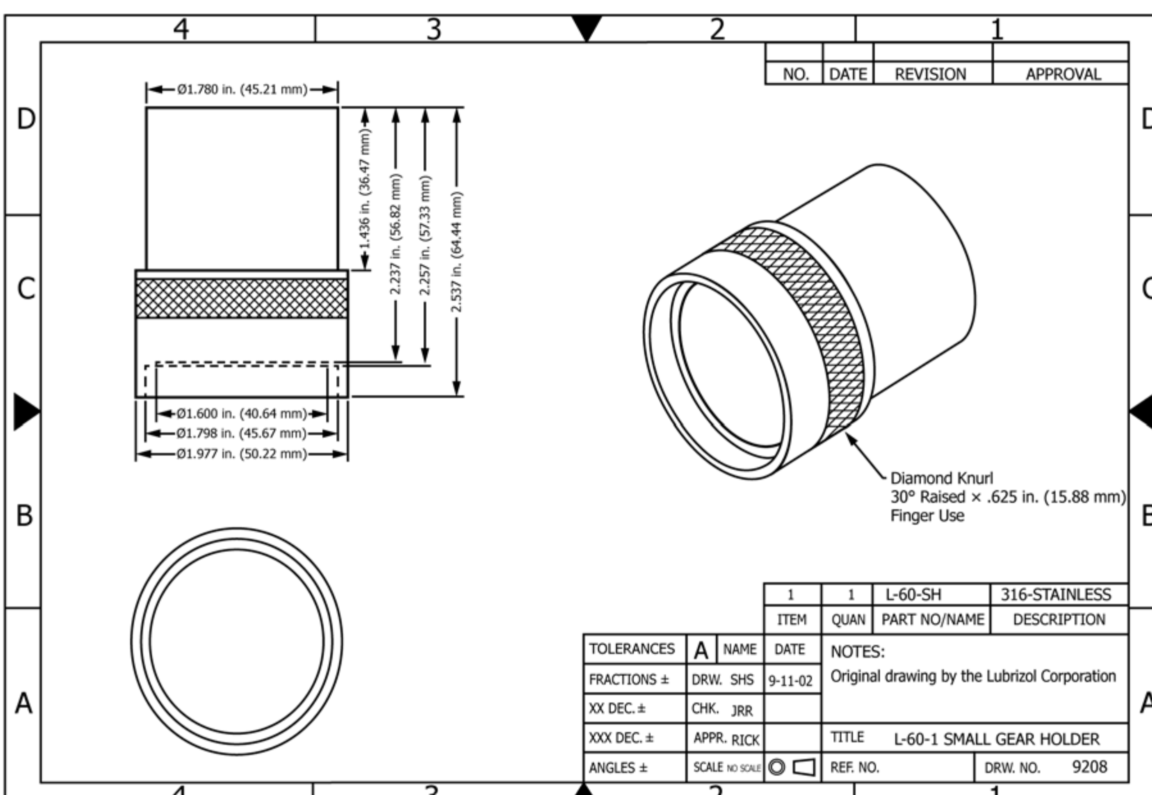

FIG. A12.1 Small Gear Holder

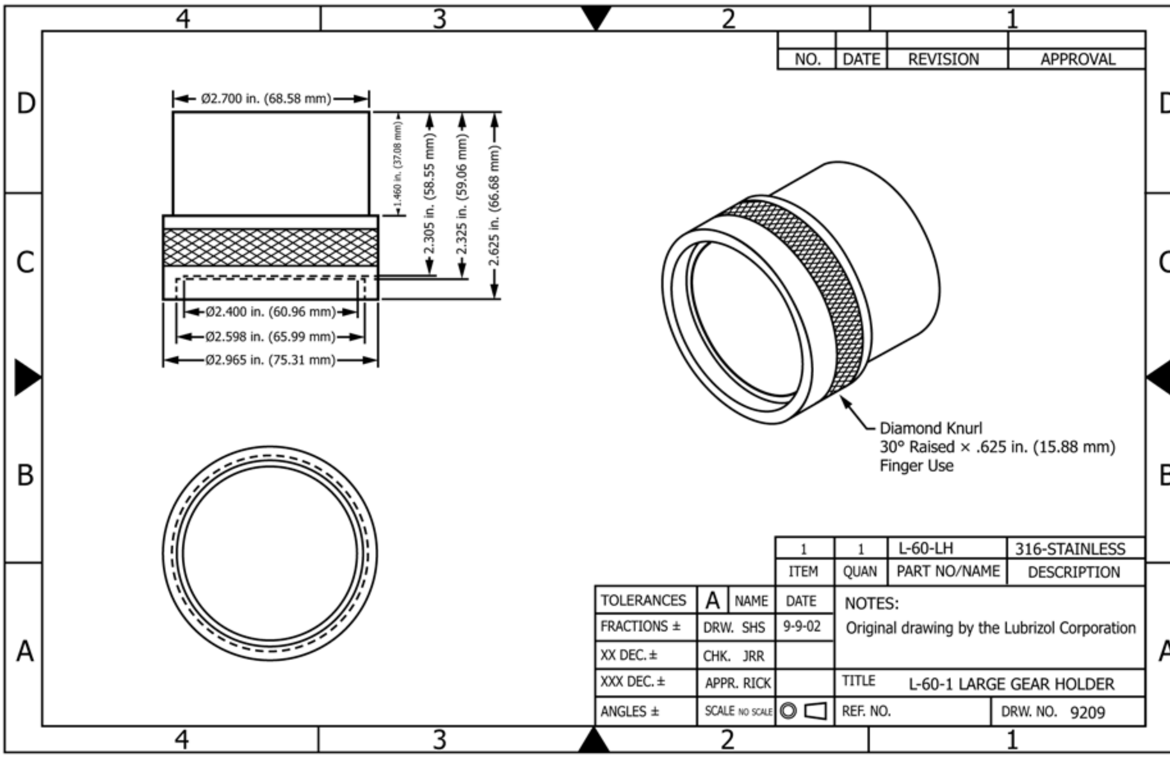

FIG. A12.2 Large Gear Holder

SUMMARY OF CHANGES

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D5704 – 16) that may impact the use of this standard. (Approved May 1, 2017.)

(1) Section Annex A11, control chart technique for severity adjustment (SA) completely revised.

(2) Subsection 14.3 revised to compensate for the severity shift in industry-wide carbon varnish ratings.

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D5704 – 15a) that may impact the use of this standard. (Approved April 1, 2016.)

(1) New Introduction section added.
(2) Section 9 rewritten.
(3) Table 2, Precision Data, updated.
(4) Subsection 14.3, replaced.
(5) Section 15, Report, rewritten.
(6) Annex A1 – Annex A4 added, and subsequent Annexes renumbered.
(7) Removed former Annex section on the TMC.
(8) Revised Annex A9.