



Designation: D4998 – 13 (Reapproved 2021)

Standard Test Method for Evaluating Wear Characteristics of Tractor Hydraulic Fluids¹

This standard is issued under the fixed designation D4998; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is used to screen lubricants for gear wear. It is primarily applicable to tractor hydraulic fluids but may be suitable for other applications.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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.* Specific warning information is given in Sections 7 and 9.

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:²

- D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent) (Withdrawn 2021)³
- D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)
- D329 Specification for Acetone
- D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

2.2 Deutsches Institut für Normung (DIN):⁴

- DIN 17210 Part 1: Tolerances for Spur Gears; Tolerances for the Deviation of Singly Determined Values
- DIN 3962 Casehardened Steel; Material Specifications
- DIN 50150 Testing of Steel and Cast Steel Conversion Table for Vickers Hardness, Brinell Hardness, Rockwell Hardness and Tensile Strength
- DIN 51354 Mechanical Testing of Gear Oils in the FZG Gear Test Machine

3. Terminology

3.1 Definitions:

3.1.1 *abrasive wear, n*—wear due to hard particles or hard protuberances forced against and moving along a solid surface. **D4175**

3.1.2 *scoring, n*—in tribology, a severe form of wear characterized by the formation of extensive grooves and scratches in the direction of sliding. **D4175**

3.1.3 *scratches, n*—the result of mechanical removal or displacement, or both, of material from a surface by the action of abrasive particles or protuberances sliding across the surfaces. **D4175**

3.1.4 *scuffing, n*—in lubrication, damage caused by instantaneous localized welding between surfaces in relative motion that does not result in immobilization of the parts. **D4175**

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *wear, n*—the loss of material from contacting surfaces of the gear teeth.

4. Summary of Test Method

4.1 A modified FZG gear oil test machine is operated for 20 h under controlled conditions of speed (100 r/min), torque (tenth stage), and temperature (121 °C). Test gears are lubricated with the test oil.

4.2 The test gears are weighed and visually examined before and after the test. The gear mass loss and the visually observed damage to the gear teeth are used to evaluate the wear obtained with the test fluid.

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 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.

³ The last approved version of this historical standard is referenced on www.astm.org.

⁴ DIN standards are available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

5. Significance and Use

5.1 Many modern tractor designs use the hydraulic fluid to lubricate the transmission and final drive gears. This test method is used to assess the suitability of the tractor hydraulic fluids as lubricants for transmission and final drive gears of tractors.

6. Apparatus

6.1 *FZG Gear Oil Test Machine*—The test machine is described in [Annex A1](#) and illustrated in [Fig. A2.1](#) and [A3.1](#).

6.2 *Precision Test Gears*—The test gears are standard FZG tooth profile A gears as described in [Annex A1](#) and [Table A1.1](#).

6.3 *Gear Case Heater*—A 750 W gear case heater capable of bringing the oil to test temperature in (20 to 25) min.

6.4 *Temperature Controller*—A proportional band-type 1000 W temperature controller for maintaining the oil temperature within 1 °C of the desired test temperature. The thermocouple is securely attached to the inside right wall of the gear case, 28 mm from the rear wall and 60 mm from the bottom, projecting 15 mm into the gear case.

6.5 *Analytical Balance*—An analytical balance with 2 kg capacity and accurate within 1 mg for weighing test gears.

6.6 *Magnifying Lens*, of 3 to 6 power.

6.7 *Compressed Air*—551 kPa minimum.

6.8 *Steam Hot Plate*, or bearing heater, with surface temperatures below 75 °C.

7. Reagents and Materials

7.1 *Mineral Spirits Solvent*—Commercial grade, conforming to the requirements of Specification [D235](#). (**Warning**—Flammable. Vapor harmful. Keep away from heat, sparks, and open flame. Keep container closed. Use with adequate ventilation. Avoid prolonged breathing of vapor or spray mist. Avoid prolonged or repeated skin contact.)

7.2 *Acetone*—Commercial grade, conforming to the requirements of Specification [D329](#). (**Warning**—Flammable. Vapor harmful. Keep away from heat, sparks, and open flame. Keep container closed. Use with adequate ventilation. Avoid prolonged breathing of vapor or spray mist. Avoid prolonged or repeated skin contact.)

7.3 *Pentane*—Commercial grade *n*-pentane, conforming to the requirements of [Table A5.1](#). (**Warning**—Flammable. Vapor harmful. Keep away from heat, sparks, and open flame. Keep container closed. Use with adequate ventilation. Avoid prolonged breathing of vapor or spray mist. Avoid prolonged or repeated skin contact.)

8. Preparation of Apparatus

8.1 Assemble the FZG machine according to the “Operating Instructions for the FZG Gear Oil Test Rig”⁵ except that the drive motor and gearing must be modified to provide an input

shaft speed of (100 ± 3) r/min. Use the S23 torsional shaft in assembling. Care must be taken to ensure the accuracy of shaft alignment as described in [6.3](#).⁴

9. Procedure

9.1 *FZG Test Machine Assembly*⁶—Assemble the test machine according to the instructions given in Section [3](#),⁵ except employ a modified, low speed drive motor as described in [Annex A1](#).

NOTE 1—In addition to other precautions, machinery guards are supplied with the FZG test machine to protect personnel from hazards associated with rotating machinery. These should be properly installed before operating the equipment.

NOTE 2—In addition to other precautions, the electrical connections for the drive motor and heater should be installed in accordance with the current edition of the National Electrical Code.⁷

9.2 *Machine Cleaning*—Flush the test gear case and associated parts with mineral spirits solvent (see [7.1](#)). (**Warning**—Combustible. Vapor harmful. Keep away from heat, sparks, and open flame. Keep container closed. Use with adequate ventilation. Avoid prolonged breathing of vapor or spray mist. Avoid prolonged or repeated skin contact.) Fill the gear case with mineral spirits solvent to a level that is above the shaft center line. Manually rotate the shafts so that the bearings are rinsed. Drain mineral spirits solvent from the gear case. Refill gear case with fresh mineral spirits solvent, manually rotate shafts, and drain. Dry gear case with compressed air.

9.3 *Gear Condition*—Examine the gear tooth faces with a magnifying lens of 3 to 6 power. Do not use gears with imperfections on the tooth faces.

9.4 *Gear Cleaning*—Wash the test gears in mineral spirits solvent, then acetone (see [7.2](#)), and finally in pentane (see [7.3](#)). After cleaning, handle the gears only with clean tongs or with clean gloves. Allow the gears to dry. To prevent water condensation following gear cleaning, carefully warm the gears to room temperature with a clean, steam hot plate or bearing heater with surface temperature below 75 °C.

9.5 *Gear Weighing*—Weigh the individual gears using an analytical balance. The gears shall be clean, dry, and at ambient temperature. Record the mass of each gear, rounding to the nearest milligram. Add the mass of each gear and record the sum as initial total gear mass (TM_i).

9.6 *Gear Installation*—Install the test gears.⁶

9.7 *Test Procedure*—Fill the gear case with test fluid until level with the shaft centerline. Install all machine guards in their proper operating positions. Set the temperature controller to 121 °C. With the heater on and no torque applied, start motor to run at 100 r/min test speed. When temperature stabilizes at (121 ± 3) °C for (20 to 25) min, stop the motor and apply a tenth stage load. The tenth stage load consists of applying a

⁴ The FZG testing machine gears, or suitable balance may be ordered from the following sources: Max Weiland, 8201 Sochtenau-Krottenmuhl, Germany, Strama Maschinebau GmbH, Postfach 0353, Straubing, Germany, Falex, 2055 Comprehensive Drive, Aurora, IL 60505, USA, and Petrolab, 874 Albany-Shaker Rd., Latham, NY 12110, USA.

⁷ Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

flexible coupling between the drive and the FZG test machine.
See Table A1.1.

TABLE A1.1 Design Data of the Test Gears Tooth Profile “A”

Nomenclature	Dimensional Value	Unit
Center distance	91.5	mm
Effective face width	20	mm
Diameter of pitch circle		
pinion	73.2	mm
wheel	109.8	mm
Diameter of tip circle		
pinion	88.7	mm
wheel	112.5	mm
Pitch	4.575	mm
Number of teeth		
pinion	16	...
wheel	24	...
Profile displacement		
pinion	0.8635	...
wheel	-0.5	...
Pressure angle	20	degrees
Working pressure angle	22.5	degrees
Circumferential speed at pitch circle (at 100 r/min)	0.383	m/s
Length of tip contact		
pinion	14.7	mm
wheel	3.3	mm
Maximum sliding speed		
pinion	0.257	m/s
wheel	0.061	m/s
Hertzian stress at tooth tip (under test conditions of tenth stage load and 100 r/min)		
pinion	199.9	kgf/mm ²
wheel	166.3	kgf/mm ²

A2. DIAGRAM OF FZG GEAR OIL TEST MACHINE⁵

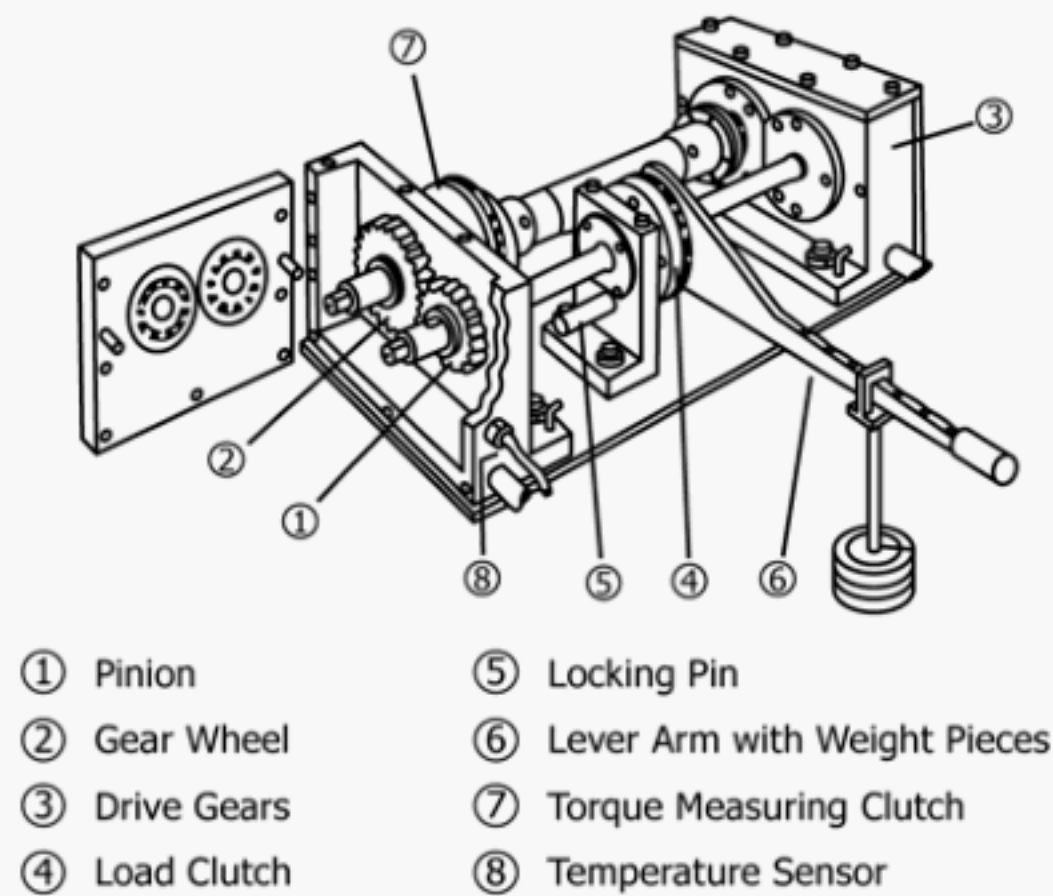


FIG. A2.1 FZG Gear Oil Test Machine

A3. DIAGRAM OF FZG GEAR OIL TEST MACHINE⁵

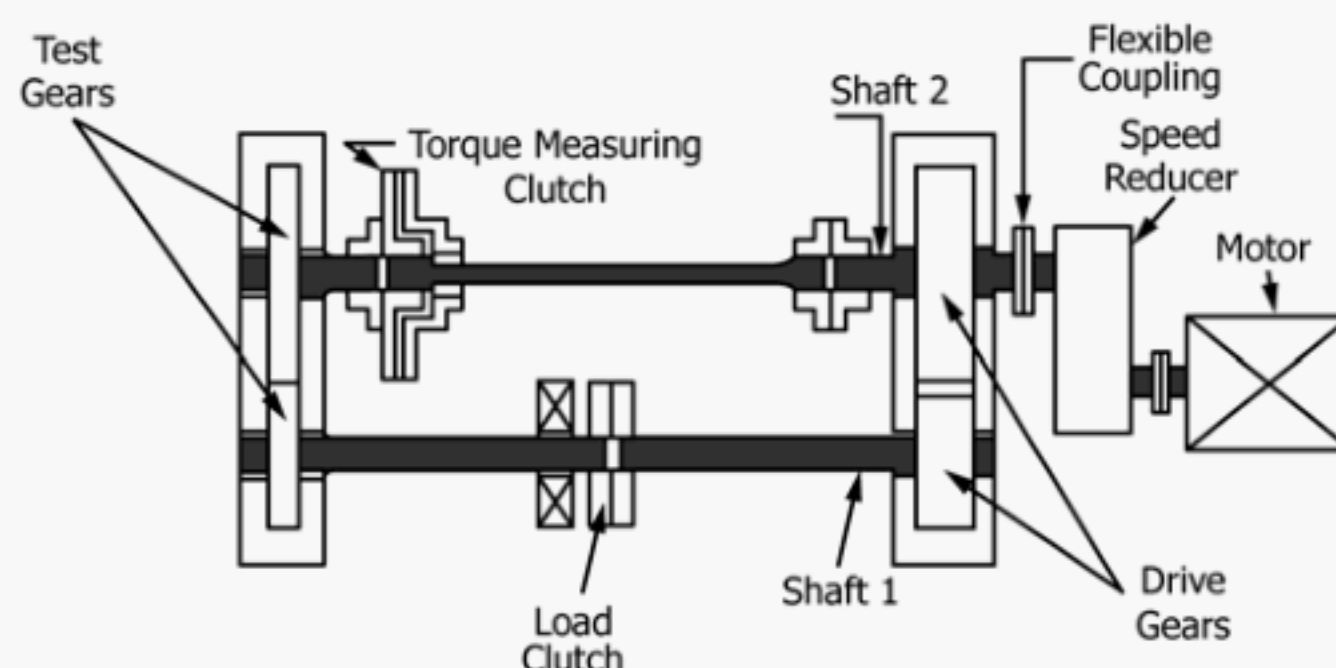


FIG. A3.1 Diagram of FZG Gear Oil Test Machine

A4. MANUFACTURING DATA FOR THE TEST GEARS, TOOTH PROFILE “A”

A4.1 Material:

A4.1.1 20 MnCr 5 according to DIN 17210, however, with a Brinell hardness HB 30 from (3.295 to 3.726) kPa after blank hardening of a 10 mm disk (that corresponds, according to DIN 50150, to a tensile strength of (1.127 to 1.274) kPa).

A4.1.2 For reasons of strength, the negatively corrected wheels ($z = 24$) are to be die-forged, whereas the pinions can be manufactured from rolled bar stock.

A4.2 Heat Treatment:

A4.2.1 The test gears are to be case-hardened to a case depth of (0.6 to 0.8) mm, the Vickers hardness HV 10 to be 4.903 kPa. Even at the tooth tips, the case shall not show any evidence of supercarbonization in form of free cementite. A boundary formation free of austenite is to be obtained by double hardening.

A4.2.2 Surface hardness after annealing is as follows: 60 to 62 HRC.

A4.2.3 Tensile strength of the core, determined from Brinell hardness according to DIN 50150 is as follows: (0.980 to 1.225) kPa.

A4.3 Gearing Quality:

A4.3.1 Grade 5 according to DIN 3962, sheet 4.

A4.3.2 Mean roughness index, R_a is as follows: (0.4 to 0.6) μm .

A4.4 Grinding—Maag cross-grinding, 154 rolling motions per minute.

A4.5 Tooth Correction—Without tip and root recess, with lateral crown.

A5. PENTANE REQUIREMENTS

A5.1 The requirements for pentane are listed in Table A5.1.

TABLE A5.1 Requirements of Pentane

Distillation	
Initial boiling point, °C, min	33.3
Dry point, °C, max	40.5
Olefins	none
Isopentane, %, max	20
n-Pentane, %, min	80
Reid Vapor Pressure, kPa, max, (Test Method D323)	17

APPENDIX

(Nonmandatory Information)

X1. SAMPLE DATA SHEET

<p>PRETEST GEAR CONDITION</p> <p>Pinion _____</p> <p>Gear _____</p> <p>PRETEST GEAR MASS, mg</p> <p>Pinion _____</p> <p>Gear _____</p> <p>Total (TM_i) _____</p> <p>POST-TEST GEAR MASS, mg</p> <p>Pinion _____</p> <p>Gear _____</p> <p>Total (TM_f) _____</p>	<p>CALCULATION OF TOTAL MASS CHANGE (TMC)</p> <p style="text-align: center;">$(TM_i) - (TM_f) = TMC$</p> <p style="text-align: center;">_____ - _____ = mg</p> <table border="0" style="width: 100%;"> <tr> <td style="width: 70%;">POST-TEST GEAR APPEARANCE</td> <td style="width: 15%; text-align: center;">Pinion</td> <td style="width: 15%; text-align: center;">Gear</td> </tr> <tr> <td>For each gear, record the number of teeth that exhibit the following:</td> <td></td> <td></td> </tr> <tr> <td>Original Grinding Marks</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> </tr> <tr> <td>Scratches</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> </tr> <tr> <td>Scoring</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> </tr> <tr> <td>Scuffing</td> <td style="text-align: center;">_____</td> <td style="text-align: center;">_____</td> </tr> <tr> <td>Total</td> <td style="text-align: center;">16</td> <td style="text-align: center;">24</td> </tr> </table> <p>Note other surface defects, if any: _____</p>	POST-TEST GEAR APPEARANCE	Pinion	Gear	For each gear, record the number of teeth that exhibit the following:			Original Grinding Marks	_____	_____	Scratches	_____	_____	Scoring	_____	_____	Scuffing	_____	_____	Total	16	24
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