



## **DEXRON® High Performance Automatic Transmission Fluid (DEXRON® HP-ATF)**

### **1 Scope**

**1.1 Material Description.** This mineral based group III plus (+) oil specification covers DEXRON® Automatic Transmission Fluid (ATF) primarily for use in General Motors automatic transmissions. This specification describes, in terms of laboratory and simulated service test results, the requirements for a minimum-performance fluid. The primary requirement is satisfactory performance in normally functioning transmissions under normal and severe conditions.

**1.2 Symbols.** Not applicable.

**1.3 Applicability.** This lubricant is to be used in GM automatic transmissions and other specified applications.

**1.4 Remarks.**

**1.4.1** This specification may involve hazardous materials, operations, and equipment. This specification does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this specification to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

**1.4.2** This specification uses the International System of Units (SI) as standard per IEEE/ASTM SI 10, except where, certain components which are commercially available only in American conventional units.

**1.4.3** This specification uses the Rounding-Off Method per ASTM E29 for significant figures to determine conformance to specification requirements.

**1.4.4** Unless otherwise noted, part numbers of this specification refer to those of the General Motors Global Propulsion System.

### **2 References**

**Note:** Only the latest approved standards are applicable unless otherwise specified.

**2.1 External Standards/Specifications.**

|            |            |            |                 |
|------------|------------|------------|-----------------|
| ASTM D92   | ASTM D1748 | ASTM D5185 | CEC L-45-99     |
| ASTM D130  | ASTM D2240 | ASTM D5293 | CEC L-48-A-00   |
| ASTM D412  | ASTM D2270 | ASTM D5800 | DIN 51819       |
| ASTM D445  | ASTM D2624 | ASTM D5949 | FE-STD-791      |
| ASTM D471  | ASTM D2983 | ASTM D6082 | FVA NO. 2/IV    |
| ASTM D664  | ASTM D3182 | ASTM D6304 | IEEE/ASTM SI 10 |
| ASTM D665  | ASTM D3183 | ASTM D6443 | JASO M-349      |
| ASTM D892  | ASTM D4052 | ASTM D6922 | PV1454          |
| ASTM D893  | ASTM D4629 | ASTM D7043 | SAE J2643       |
| ASTM D1169 | ASTM D4683 | ASTM D7896 |                 |
| ASTM D1418 | ASTM D4927 | ASTM E29   |                 |
| ASTM D1500 | ASTM D4951 | ASTM E168  |                 |

**2.2 GM Standards/Specifications.**

|         |          |
|---------|----------|
| GMW3059 | GMW14270 |
|---------|----------|

### 2.3 Additional References.

- Complete Part Drawings Including Material Specifications, are available from Southwest Research Institute (San Antonio, Texas).
- Installation Information, contact Southwest Research Institute or PerkinElmer Automotive Research.
- SAE International (SAE) Paper 2004-01-2914. Morgan, C., Cummings, J.M., Fewkes, R. Jackson, J.M., A New Method of Measuring Aeration and Deaeration of Fluids.
- SAE Paper 2004-01-3026, Morgan, C., Fewkes, R., McCombs, T., Tersigni, S.H., Jackson, J.M., Low-Speed Carbon Fiber Torque Capacity and Frictional Properties Test for ATFs.

#### 2.3.1 Test Method Sources.

- American Society for Testing Material (ASTM) International. 100 Barr Harbor Drive, Post Office Box C700, West Conshohocken, Pennsylvania, 19428-2959, USA (available at: [www.enterprise.astm.org](http://www.enterprise.astm.org)).
- EHDPROC\_11 is available from Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas, USA.
- MERCON SP Procedure 3.14 Modified. Ford Motor Company, ATF Committee, 36200 Plymouth Road, Livonia, Michigan, 48150, USA.
- Test Methods CEC L-45-99 Coordinated European Council (CEC), Madou Plaza, 25th Floor, Place Madou 1, B-1030 Brussels, Belgium. (Available at: [www.cectests.org](http://www.cectests.org)).

#### 2.3.2 Forms.

- A spreadsheet is available from the GM ATF Committee that contains all Testing Report/Form formats (see Appendix K, Table K1).
- All GM DEXRON® Testing Report/Form including Form A are available from the; Team Leader for Service Parts Engineering and DEXRON® Licensing or the GM ATF and Gear Oil Committee Chairman via; GM Supply Power. See Folders/ENGINEERING/Powertrain Product Engineering/Transmission. ([gmsupplypower.covisint.com/c/document\\_library/get\\_file?p\\_l\\_id=4211828&folderId=4501165&name=DLFE-188908.docx](http://gmsupplypower.covisint.com/c/document_library/get_file?p_l_id=4211828&folderId=4501165&name=DLFE-188908.docx)).

#### 2.3.3 Other.

- 3D Instruments, Model Number 25502-29B55 Pressure Gage.
- Aalborg Instrument Company, Model Number FM032-15 calibrated rotameter.
- Allen-Bradley, Model Number 712 DAB 26-43, K-Series controller.
- Automatic Switch Company, Number 83441, 115 V, 60 Hz, 10.5 W four-way solenoid valve.
- Bendix-Westinghouse, Number 224417 quick release valve.
- BorgWarner Automotive (Frankfort, Illinois), 4L60-E modified band.
- C. A. Norgren Company, Model Number 11-042-003 regulator controls.
- Chevrolet Service Manual ST368-92.
- Coors Ceramics United States of America (USA), Model Number 60248, 253 mm diameter Buchner Funnel.
- Delta Power Hydraulic Company, Model Number A1+A354 density circuit pump.
- Donaldson Duramax high pressure spin-on filter, Part Number P165354, 2 µm filter element, and Part Number P169310, filter head.
- Eaton, Model Number RV-1-10-S-0-3 pressure relief valve.
- Electro Corporation, Model Number 3010AN speed transducer.
- Fluid Profile Proprietary GM Test.
- General Controls, Model Number CE600 BS 602 cycle counter.
- GM Customer Care and Aftersales (CCA) Part Number 24214202, VTi; the GM version of an electronically controlled Continuously Variable Transmission (CVT), pump drive sprockets.
- GM CCA Part Number 1050026.
- GM CCA Part Number 8654654, (Available thru Southwest Research Institute, San Antonio, Texas.)
- GM CCA Part Number 24218069.

- GM CCA Part Number 24219551, pump drive chain.
- GM CCA Part Number 24221347.
- GM CCA Part Number 24223118, Variable Valve Lift and Timing Injection (VTi) pump.
- GM Cycling Test
- GM Part Number GMPT-0506.
- GM Part Number CAH0404, GM Racing (Flint, Michigan).
- Himmelstein and Company MCRT Non-Contact Driveline Torquemeter Model MRCT 6-02T (15-3), Daytronic Model 3178.
- Iron-Constantan Thermocouple, Type 22J34-E-4-TGFS36 thermosensor.
- ITT Standard Company, Part Number 5-160-02-008-002 Water-Cooled Heat Exchanger.
- ITT Standard Company, Part Number 5-160-03-014-002, Water-Cooled Heat Exchanger.
- Lebow Load Cell, Model Number 3397 torque transducer.
- Leeds and Northrup Speedmax 165, Model Number 168-10-001-0010-6-C0000-000, chart J68-F.
- MicroMotion, Model Number CMF010M323NU Mass Flow Meter.
- Nupro Company Micrometering Valve.
- Omega, Model Number DP81T temperature measurement and thermosensor iron-constantan thermocouple, type 2J34-E-6-TP6.
- Part Drawings, including material specifications, are available from Southwest Research Institute (San Antonio, Texas) (see Appendix K).
- Precision Products and Control Research Control Valve (pneumatic-activated water-temperature control), Type 755, Diaphragm 3-15, Trim J, Action Air-To-Close (ATC), Model Number 1001GCN36SVCSFLN36.
- Safety and Industrial Hygiene (S&IH) Technical Standard (TS), S&IH TS 3.4-160-02 (available at [www.gmsupplypower.covisint.com](http://www.gmsupplypower.covisint.com)).
- Sensotech, Model Number TJU708-12 pressure transducer.
- Sensotech, Model Number TJE/0761-29TJG pressure transducer.
- Texas Instruments, Model Number 510 timer.
- Thomas Industries, Model Number 130, Pressure/Vacuum Pump.
- Toshiba main drive motor, Model Number B0102FLF2UMH04.
- Toshiba, variable frequency control, Model Number VFS9-2075PL-WN.
- VWR is the name of a laboratory supply company: VWR International, Grade 417, 25.0 cm diameter, Part Number 28313 160 Filter Paper.
- Watlow FireRod Cartridge Heaters, Model Number J7A57-6258.

### 3 Requirements

**3.1 Test Requirements.** Form A (refer to 2.3.3.2) is required for testing to be started on ATF pursuing DEXRON® High Performance ATF approval.

**3.2 Mechanical Requirements.** Conduct test procedures as specified, with no deviation, unless the General Motors ATF and Gear Oil Committee provides an expressly written authorization. Use the test transmissions and parts as received. Only replace or modify any part, if directed per this specification to replace damaged parts. The laboratory must target to the mean of the specified test conditions.

**3.3 Physical Requirements.** Fluids qualified under this specification shall conform to the test methods and requirements as listed in Table 1.

**3.4 Approved Additive Chemistries.**

**3.4.1** Fluids meeting this specification shall be manufactured using additive chemistries listed in Table 2, Approved DEXRON® High Performance ATF Additive Chemistry Combinations.

**3.5 Requirements for New DEXRON® High Performance ATF Additive Chemistry Combinations.**

**3.5.1** Successful completion of a complete DEXRON® High Performance ATF qualification program (see Table 1).

**3.5.2** Successful completion of a complete DEXRON® High Performance ATF qualification program (see Table 1) using the fluid blends in 3.5.2.1 thru 3.5.2.4.

**3.5.2.1** Fluid Blend: 75% Candidate, 25% Reference Fluid.

**3.5.2.2** Fluid Blend: 50% Candidate, 50% Reference Fluid.

**3.5.2.3** Fluid Blend: 25% Candidate, 75% Reference Fluid.

**3.5.2.4** Fluid Blend: if applicable, 50% Candidate, 50% any previously approved chemistry other than the Reference Fluid.

**3.5.3** Successful completion of tests listed in Table 3.

**3.5.4** Successful completion of a 241 400 km (150 000 mi) fleet test using the new candidate chemistry and blends of fluids from 3.5.2. Before commencing the fleet test, submit the fleet test proposal to the GM ATF and Gear Oil Committee for approval.

**3.5.5** Any additional testing as directed by the GM ATF and Gear Oil Committee.

### 3.6 Additional Requirements.

**3.6.1** The test requirements given in this specification are minimum or maximum acceptance limits for valid tests. No adjustments for test precision are necessary as test variability was, taken into account in the determination of the requirements.

**3.6.2** The General Motors ATF and Gear Oil Committee reserves the right to require additional tests necessary to ensure satisfactory performance of fluids submitted for qualification as DEXRON® High Performance Automatic Transmission Fluids.

**3.6.3 HiTEC 3491 Modification.** HiTEC 3491 "B" will replace the current approved factory and service fill additive package HiTEC 3491 "A".

**3.6.3.1** The blend is HiTEC 3491 "B" additive package with Polyalphaolefin (PAO) base stocks.

**3.6.4** Additive supplier shall deliver HiTEC 3491 package targeting a limit of 100% to 103% treat level of friction modifiers.

**Table 1: DEXRON® High Performance ATF Test Methods and Requirements**

| Test                        | Method                                        | Requirement                                                                                                        |
|-----------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| Color                       | ASTM D1500                                    | 6.0 to 8.0                                                                                                         |
| Elemental Analysis          | ASTM D5185                                    | Report, parts per million (ppm): Al, Ba, B, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Si, Ag, Na, S, Sn, Ti, V, Zn |
|                             | ASTM D6443                                    | Report, ppm: Cl                                                                                                    |
|                             | ASTM D4629                                    | Report, ppm: N                                                                                                     |
|                             | ASTM D4927                                    | Report, ppm: S                                                                                                     |
| Fluid Profile               | Fluid Profile Proprietary GM Test             | Report                                                                                                             |
| Miscibility and Homogeneity | ASTM D6922                                    | No separation or color change at end of test using reference fluid                                                 |
| FE-STD-791                  | 3430-Compatibility<br>3440-Storage Solubility | Pass<br>Pass                                                                                                       |
| Water Content               | ASTM D6304                                    | 0.10% weight maximum                                                                                               |
| Density                     | ASTM D4052: 15 °C                             | Report                                                                                                             |
| Kinematic Viscosity         | ASTM D445                                     | 32 cSt at 40 °C (maximum)                                                                                          |
|                             |                                               | 6.4 cSt at 100 °C (maximum)                                                                                        |
|                             |                                               | 150 °C (Report)                                                                                                    |
| Viscosity Index             | ASTM D2270                                    | 145 (minimum)                                                                                                      |
| Flash Point                 | ASTM D92                                      | 180 °C (minimum)                                                                                                   |
| Fire Point                  | ASTM D92                                      | 195 °C (minimum)                                                                                                   |
| Pour Point                  | ASTM D5949                                    | -50 °C                                                                                                             |
| Brookfield Viscosity        | ASTM D2983                                    | 8000 cP (maximum) at -40 °C                                                                                        |

| Test                                                                                                              | Method                                                                                                                                              | Requirement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cold Crank Simulation                                                                                             | ASTM D5293                                                                                                                                          | Report at -30 °C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Copper Strip Corrosion Test                                                                                       | ASTM D130 Modified: 3 h at 150 °C                                                                                                                   | 1B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Corrosion Test                                                                                                    | ASTM D665: Procedure A; 4 h                                                                                                                         | Pass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Rust Protection Test                                                                                              | ASTM D1748 <ul style="list-style-type: none"> <li>Sandblasted surface</li> <li>40 °C</li> <li>50 h</li> <li>New coupon for each test</li> </ul>     | No rust or corrosion on any test surface                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Wear Test                                                                                                         | ASTM D7043 Modified: <ul style="list-style-type: none"> <li>80 °C ± 3 °C</li> <li>6.9 MPa</li> <li>11.356 L (3 gal) Conestoga Pump Parts</li> </ul> | 5 mg weight loss (maximum)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Bearing Test                                                                                                      | DIN 51819 T3<br>Bearing: Aßmann TBA/TBB<br>Wear:<br>100 kN/7.5 rpm/80 °C/80 h<br>Pitting:<br>60 kN/500 rpm/100 °C/200 h                             | Report in milligrams (mg) wear<br>Report in hours (h) pitting                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Thermal Conductivity<br>Run with fresh and used fluid after DeutscherKoordinierungsauss huss (DKA) oxidation test | ASTM D7896<br>100 °C, 130 °C, 170 °C                                                                                                                | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| High Temperature, High Shear                                                                                      | ASTM D4683: 150 °C                                                                                                                                  | 2.00 cP (minimum)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Noack Evaporation                                                                                                 | ASTM D5800                                                                                                                                          | 10% evaporation (maximum) 1 h at 200 °C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Elastohydrodynamic (EHD) Film Thickness                                                                           | EHDPROC_11 at Imperial College<br>60 °C, 80 °C, 100 °C, 120 °C                                                                                      | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Tapered Roller Bearing Shear;<br>Kugel Rollen Lager (KRL)                                                         | CEC L-45-99 <ul style="list-style-type: none"> <li>3 480 000 revolutions (~40 h) at 100 °C</li> <li>100 h at 100 °C</li> </ul>                      | KV100, 5.5 cSt (minimum) at End of Test (EOT), 10% Decrease (maximum) at EOT (Base Oil Viscosity (BOV) plus (+) End of Test Viscosity (EOTV))/2 > 5.0 cSt at 100 °C<br><br>Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Foam Test                                                                                                         | Appendix A, Table A1 and Table A2.<br>ASTM D892 Modified                                                                                            | <b>New Fluid:</b> <ol style="list-style-type: none"> <li>Sequence I, ASTM D892; 50/0 (maximum)</li> <li>Sequence II, ASTM D892; 50/0 (maximum)</li> <li>Sequence III, ASTM D892; 50/0 (maximum)</li> <li>Sequence IV, ASTM D6082; 50/0 (maximum)</li> </ol> <b>After Cycling Test Filtered Fluid:</b> <ol style="list-style-type: none"> <li>Sequence I, ASTM D892; Report</li> <li>Sequence II, ASTM D892; Report</li> <li>Sequence III, ASTM D892; Report</li> <li>Sequence IV, ASTM D6082; Report</li> </ol> <b>After Thermal Aging at 130 °C for 100 h</b> <ol style="list-style-type: none"> <li>Sequence I, ASTM D892; 50/0 (maximum)</li> <li>Sequence II, ASTM D892; 50/0 (maximum)</li> <li>Sequence III, ASTM D892; 50/0 (maximum)</li> <li>Sequence IV, ASTM D6082; 150/0 (maximum)</li> </ol> |
| Seal Test<br>Original and New Chemistry Only                                                                      | <b>Elastomer:</b> Fluid Interaction Phase I Validation (Appendix B, Table B2, Schedule 1 and Schedule 2)                                            | Report and Pass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

| Test                                                                                                                                                                                                                                               | Method                                                                                               | Requirement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Seal Test</b><br>Reblend Program                                                                                                                                                                                                                | <b>Elastomer:</b> Fluid Interaction<br>Phase I Validation (Appendix B,<br>Table B2, Schedule 1 only) | Report and Pass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Low-Speed Carbon Fiber Friction Test</b><br>Use Production Intent Friction Material                                                                                                                                                             | Appendix J, Table J1 and<br>Figure J1                                                                | New fluid must be equal to or better than the<br>reference fluid.<br>Report result from used (cycling test) fluid                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>GM Three (3) Day Wear Test</b><br>Use Production Intent Friction Material                                                                                                                                                                       | GM Test Procedure<br>Appendix G                                                                      | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Low Velocity Friction Apparatus (LVFA)</b><br><ul style="list-style-type: none"> <li>Run with fresh and used fluids after Aluminum Beaker Oxidation Test (ABOT)</li> <li>Run at the Additive Supplier</li> <li>Run for New Chemistry</li> </ul> | JASO M-349<br><br>Appendix H, Table H1.                                                              | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Aluminum Beaker Oxidation Test</b>                                                                                                                                                                                                              | Appendix D                                                                                           | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>DKA Oxidation Stability Test</b>                                                                                                                                                                                                                | CEC L-48-A-00<br>175 °C for 192 h<br>Method B<br><br>Appendix E                                      | <ul style="list-style-type: none"> <li>Delta KV 40%, 13 maximum.</li> <li>Delta KV 100%, 12 maximum.</li> <li>Peak Area Interval (PAI) (units), Report.</li> <li>Delta Total Acid Number (TAN) (mg KOH/g fluid), Report (typical one (1) to typical three (3)).</li> <li>Sludge rating of flask, maximum 1.0.</li> <li>Blotter, report with photo.</li> </ul>                                                                                                                                                                                                                                                                                                        |
| <b>Cycling Test</b>                                                                                                                                                                                                                                | Appendix F (see Table F1 thru<br>Table F3, Data Sheet F1, and<br>Figure F1 thru Figure F9)           | <ul style="list-style-type: none"> <li>Satisfactory operation for 42 000 cycles.</li> <li>Condition of transmission parts must be equal to or better than that obtained with the reference fluid.</li> <li>TAN Increase &lt; 2.0.</li> <li>Carbonyl absorbance increase &lt; 0.30.</li> <li>Used fluid viscosity at 100 °C &gt; 5.0 cSt.</li> <li>Used fluid viscosity at -20 °C &lt; 2 000 cP.</li> <li>Used fluid viscosity at -40 °C &lt; 12 000 cP.</li> <li>1 to 2 shift time between 0.30 s and 0.75 s.</li> <li>2 to 3 shift time between 0.30 s and 0.75 s.</li> <li>3 to 4 shift time, seconds (Report).</li> <li>No expulsion of ATF from vent.</li> </ul> |
| <b>Achsil-Rillen-Kugal-Lager (ARKL)</b>                                                                                                                                                                                                            | PV1454                                                                                               | Report in Degrees Celsius ( °C)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Aeration Test</b><br><br>Factory fill DEXRON VI fluid reference shall be run before every candidate fluid                                                                                                                                       | Appendix K                                                                                           | New fluid must have the following limits: <ul style="list-style-type: none"> <li>&lt; 3% above reference;</li> <li>Aeration percent 60 °C</li> <li>&lt; 3% above reference;</li> <li>Aeration percent 90 °C</li> <li>&lt; 3% above reference;</li> <li>Aeration percent 120 °C</li> <li>&lt; 5 s above reference;</li> <li>Deaeration 60 °C</li> <li>&lt; 5 s above reference;</li> <li>Deaeration 90 °C</li> <li>&lt; 5 s above reference;</li> <li>Deaeration 120 °C</li> </ul> Report result for used fluid after cycling test.                                                                                                                                   |
| <b>Electrical Conductivity</b><br>Candidate plus reference<br><br>Run upon request from GM ATF Committee                                                                                                                                           | ASTM D1169<br><br>22 °C, 30 °C, 40 °C, 50 °C,<br>60 °C, 70 °C, 100 °C, 120 °C,<br>150 °C             | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Electrical Conductivity After ABOT Test</b><br>Run upon request from GM ATF Committee                                                                                                                                                           | ASTM D2624-06 Modified                                                                               | Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

Table 2: DEXRON® High Performance ATF Approved Chemistry Combinations <sup>Note 1</sup>

| Company                    | Chemistry Name             | Treat Rate (wt%) |
|----------------------------|----------------------------|------------------|
| Afton Chemical Corporation | HiTEC 3491 A<br>HiTEC 5738 | 22.6<br>1 to 5   |
| Afton Chemical Corporation | HiTEC 3491 B               | 23.57            |

**Note 1:** For the most up to date list of approved chemistries, contact the GM ATF Committee Chairman.

Table 3: DEXRON® VI Additional Test Methods and Requirements for New Chemistries

| Test                                                                                                                                                                                | Method                                                                | Requirement                                               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------|
| Forschungstelle Fur Zahnrad und Getriebebau (FZG) Pitting                                                                                                                           | FVA NO. 2/IV: PT-C/9/90                                               | Report, Committee Decision                                |
| Low Velocity Friction Apparatus (LVFA)<br>• Run with fresh and used fluids after Aluminum Beaker Oxidation Test (ABOT)<br>• Run at the Additive Supplier<br>• Run for New Chemistry | JASO M-349<br><br>Appendix H, Table H1                                | Report                                                    |
| Elastomer-Fluid Interaction Phase I Validation                                                                                                                                      | Appendix B                                                            | Report and Pass                                           |
| Carbon Fiber Durability                                                                                                                                                             | MERCON SP Procedure 3.14 Modified:<br>• Low Speed Carbon Fiber Plates | Equal to or Better than Reference <sup>Note 1</sup> Fluid |
| Fleet Test                                                                                                                                                                          | See 3.5.4                                                             | See 3.5.4                                                 |

**Note1:** Reference Fluid: The fluid with known performance characteristics, designated by the GM ATF and Gear Oil Committee.

**3.7** All materials supplied to this standard must comply with GMW3059, **Restricted and Reportable Substances**, including the requirement to submit a full material composition disclosure to GM via the International Material Data System (IMDS) or via a completed GMW3059 report form.

## 4 Manufacturing Process

Not applicable.

## 5 Rules and Regulations

**5.1 Legal Regulations.** All materials must satisfy applicable laws, rules, regulations and recommendations valid in the country of usage.

**5.2 Language.** In the event of conflict between the English and domestic language, the English language shall take precedence.

**5.3 Inspection and Rejection.** All shipments of material or parts under contract or purchase order manufactured to this specification shall be equivalent in every respect to the initial samples approved by Engineering. There shall be no changes in either formulation or manufacturing processes permitted without prior notification and approval by Engineering. Lack of notification by the supplier constitutes grounds for rejection of any shipment. While samples may be taken from incoming shipments and checked for conformance to this specification, the supplier shall accept the responsibility for incoming shipments meeting this specification without dependence upon purchaser's inspection.

The series of tests used to approve each batch of product along with acceptance limits will be agreed upon by the purchaser and seller. The laboratory providing the certificate of analysis must also participate in a proficiency testing program (round robin) that is approved by the Fuels, Fluids, and Lubricants Global Subsystem Leadership Team (GSSLT) or designate. The Fuels, Fluids, and Lubricants GSSLT or designate must receive copies of the proficiency testing reports directly from the test program administrator.

**5.4 Initial Source Approval.** No shipment shall be made by any supplier until representative initial production samples have been approved by the Fuels, Fluids, and Lubricants Global Subsystem Leadership Team or designees meeting the requirements of this specification.

**5.5 Material Safety Data Sheets/Safety Data Sheets (MSDS/SDS).** For new product submissions, or when a change in chemical composition of an existing product has occurred, a complete copy of the Material Safety Data Sheet/Safety Data Sheet must be submitted in compliance with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) requirements or other country-specific MSDS/SDS requirements. In addition, product MSDS/SDS submissions must be in compliance with specific country General Motors S&IH TS 3.4-160-02 where available.

## 6 Approved Sources

Materials supplied to this specification must be approved by General Motors.

The appropriate GM Materials Engineering department(s) must confirm material as meeting the requirements of this specification. Any test data sheets of material submitted to General Motors for such confirmation (e.g., during Production Part Approval Process (PPAP)) under this material specification must list all properties and must apply corresponding test methods of this material specification.

Engineering qualifications of an approved source are required for this standard. Only sources listed in the GM Materials File (i.e., GM SupplyPower) under this standard number have been qualified by engineering as meeting the requirements of this standard. To access this list, reference GMW14270 for latest location.

For other GM locations, the responsible engineering group should be contacted to obtain the approved source in that individual country.

## 7 Notes

### 7.1 Glossary.

**Φ:** Is the pressure angle of cam profile.

**Plate Max<sub>Avg</sub>:** Average Maximum Plate Temperature

**R<sub>e</sub>:** The effective radius of the friction surface.

**Reference Fluid:** The fluid with known performance characteristics, designated by the GM ATF and Gear Oil Committee.

**VTi:** The GM version of an electronically controlled Continuously Variable Transmission (CVT).

**VWR:** VWR is the name of a laboratory supply company.

### 7.2 Acronyms, Abbreviations, and Symbols.

|                        |                                       |
|------------------------|---------------------------------------|
| <b>μ<sub>Avg</sub></b> | Average Coefficient of Friction       |
| <b>μ</b>               | Coefficient of Friction               |
| <b>μV</b>              | Microvolts                            |
| <b>%</b>               | Percent                               |
| <b>+</b>               | Plus                                  |
| <b>ABOT</b>            | Aluminum Beaker Oxidation Test        |
| <b>ACM</b>             | Alkyl Acrylate Copolymer              |
| <b>AEM</b>             | Ethylene Acrylic Elastomers           |
| <b>Ag</b>              | Silver                                |
| <b>Al</b>              | Aluminum                              |
| <b>ARDL</b>            | Akron Rubber Development Laboratory   |
| <b>ARKL</b>            | Achsial-Rillen-Kugal-Lager            |
| <b>ASTM</b>            | American Society for Testing Material |
| <b>ATC</b>             | Air-To-Close                          |
| <b>ATF</b>             | Automatic Transmission Fluid          |
| <b>B</b>               | Boron                                 |
| <b>Ba</b>              | Barium                                |
| <b>BOV</b>             | Base Oil Viscosity                    |

|                      |                                                                        |
|----------------------|------------------------------------------------------------------------|
| <b>Ca</b>            | Calcium                                                                |
| <b>CCA</b>           | Customer Care and Aftersales                                           |
| <b>CEC</b>           | Coordinated European Council                                           |
| <b>Cl</b>            | Chlorine                                                               |
| <b>cP</b>            | Centipoise                                                             |
| <b>Cr</b>            | Chromium                                                               |
| <b>cSt</b>           | CentiStoke                                                             |
| <b>Cu</b>            | Copper                                                                 |
| <b>CVT</b>           | Continuously Variable Transmission                                     |
| <b>DC</b>            | Direct Current                                                         |
| <b>DIA</b>           | Diameter                                                               |
| <b>DIN</b>           | Deutsches Institute fur Normung (German Institute for Standardization) |
| <b>DKA</b>           | Deutscher Koordinierungsausschuss                                      |
| <b>ECCC</b>          | Electronically Controlled Capacity Clutch                              |
| <b>ECM</b>           | Electronic Control Module                                              |
| <b>EHD</b>           | Elastohydrodynamic                                                     |
| <b>EOT</b>           | End of Test                                                            |
| <b>EOTV</b>          | End of Test Viscosity                                                  |
| <b>ES</b>            | Elastomer Standard                                                     |
| <b>Fe</b>            | Iron                                                                   |
| <b>FKM</b>           | Fluoroelastomer                                                        |
| <b>FTP</b>           | Federal Test Procedure                                                 |
| <b>FVC</b>           | Frequency to Voltage Converter                                         |
| <b>FZG</b>           | Forschungstelle Fur Zahnrad und Getriebebau                            |
| <b>GHS</b>           | Globally Harmonized System of Classification and Labeling of Chemicals |
| <b>GMPT</b>          | General Motors Propulsion Team                                         |
| <b>GSSLT</b>         | Global Subsystem Leadership Team                                       |
| <b>HNBR</b>          | Hydrogenated Nitrile Butadiene Rubber                                  |
| <b>HP ATF</b>        | High Performance Automatic Transmission Fluid                          |
| <b>ID</b>            | Inside Diameter                                                        |
| <b>IMDS</b>          | International Material Data System                                     |
| <b>J</b>             | Joules                                                                 |
| <b>JASO</b>          | Japanese Automotive Society Organization                               |
| <b>K</b>             | Potassium                                                              |
| <b>KRL</b>           | Kugel Rollen Lager                                                     |
| <b>LBS</b>           | Pounds                                                                 |
| <b>LVFA</b>          | Low Velocity Friction Apparatus                                        |
| <b>m/s</b>           | meters per second                                                      |
| <b>m<sup>2</sup></b> | meters squared                                                         |
| <b>Mg</b>            | Magnesium                                                              |
| <b>min-1</b>         | rotations per minute (rpm)                                             |
| <b>MJ</b>            | Megajoule                                                              |
| <b>Mn</b>            | Manganese                                                              |
| <b>Mo</b>            | Molybdenum                                                             |

|                  |                                  |
|------------------|----------------------------------|
| <b>MPa</b>       | Megapascals                      |
| <b>ms</b>        | milliseconds                     |
| <b>MSDS</b>      | Material Safety Data Sheet       |
| <b>MY</b>        | Model Year                       |
| <b>N</b>         | Nitrogen                         |
| <b>NA</b>        | Not applicable                   |
| <b>Na</b>        | Sodium                           |
| <b>NBR</b>       | Nitrile Butadiene Rubber         |
| <b>NEC</b>       | North-East Corner                |
| <b>Ni</b>        | Nickle                           |
| <b>Nm</b>        | Newton meters                    |
| <b>No</b>        | Number                           |
| <b>NPT</b>       | Needle Pipe Tee                  |
| <b>OD</b>        | Outside Diameter                 |
| <b>P</b>         | Phosphorus                       |
| <b>Pa</b>        | Pascals                          |
| <b>PAI</b>       | Peak Area Interval               |
| <b>PAO</b>       | PolyAlphaOlefin                  |
| <b>Pavg</b>      | Average Apply Pressure           |
| <b>Pb</b>        | Lead                             |
| <b>PPAP</b>      | Production Part Approval Process |
| <b>ppm</b>       | parts per million                |
| <b>PTFE</b>      | Polytetrafluoroethylene          |
| <b>Req'd</b>     | Required                         |
| <b>S</b>         | Sulfur                           |
| <b>S&amp;IH</b>  | Safety and Industrial Hygiene    |
| <b>SAE</b>       | SAE International                |
| <b>SDS</b>       | Safety Data Sheet                |
| <b>SI</b>        | International System of Units    |
| <b>Si</b>        | Silicone                         |
| <b>Sn</b>        | Tin                              |
| <b>SOT</b>       | Start of Test                    |
| <b>SRE</b>       | Standard Reference Elastomer     |
| <b>SS</b>        | Stainless Steel                  |
| <b>Std. Dev.</b> | Standard Deviation               |
| <b>TAN</b>       | Total Acid Number                |
| <b>Tavg</b>      | Average Torque                   |
| <b>TBA</b>       | Test Bearing A                   |
| <b>TBB</b>       | Test Bearing B                   |
| <b>TCM</b>       | Transmission Control Module      |
| <b>Ti</b>        | Titanium                         |
| <b>Tp</b>        | Plate Temperature                |
| <b>Trans</b>     | Transmission                     |
| <b>TS</b>        | Technical Standard               |

|            |                                          |
|------------|------------------------------------------|
| <b>TV</b>  | Transmission Via                         |
| <b>UHP</b> | Ultra High Purity                        |
| <b>UNF</b> | Unified National Fine                    |
| <b>USA</b> | United States of America                 |
| <b>V</b>   | Vanadium                                 |
| <b>VTi</b> | Variable Valve Lift and Timing Injection |
| <b>W/s</b> | Watts per Second                         |
| <b>Z</b>   | Zinc                                     |

## 8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Material per GMW16974

## 9 Release and Revisions

This standard was originated in May 2013. It was first approved by the Fuels, Fluids & Lubricants Global Subsystem Leadership Team in July 2013. It was first published in July 2013.

| Issue | Publication Date | Description (Organization)                                              |
|-------|------------------|-------------------------------------------------------------------------|
| 1     | JUL 2013         | Initial publication.                                                    |
| 2     | MAY 2017         | Revised Specification. (Materials - Fuels, Fluids and Lubricants GSSLT) |

## Appendix A

### A1 Foam Test Objective

**A1.1** Determine the foaming characteristics of new and used automatic transmission fluid.

### A2 Test Equipment

**A2.1 Standardized Foam Test Equipment.**

**A2.1.1 ASTM D892 Equipment.**

**A2.1.2 Automated Oven.** Lawler, Model Number 323-4.

**A2.1.3 Mott Diffuser.**

**A2.2 Used Cycling Test Fluid Filtration.**

**A2.2.1 Filtering Flask.** Erlenmeyer style, Borosilicate glass, 4 L capacity.

**A2.2.2 Buchner Funnel.** Coors Ceramics United States of America (USA). Model Number 60248, 253 mm diameter or equivalent.

**A2.2.3 Filter Paper.** VWR (VWR is the name of a laboratory supply Company) VWR Grade 417, 25.0 cm diameter, Part Number 28313 160.

**A2.2.4 Rubber Stopper Adaptor.** Rubber stopper, with hole to adapt, Buchner funnel to filter flask.

### A3 Procedure

**A3.1** Follow the ASTM D892 exactly as written with the following points included.

**A3.1.1** As indicated in Note 4 of ASTM D892, use only liquid baths (i.e., silicone oil) for Sequence I, Sequence II, and Sequence III.

**A3.2** Run ASTM D6082.

**A3.3** Repeat A3.1 thru A3.2 for ATF taken from the end of the cycling test. Perform this step within 24 h of completion of the GM aeration test. Filter the fluid through the filtration system described in A2.2 before testing commences.

### A4 Test Results

**A4.1** Report the foaming tendency in milliliters (mL) at the end of the 5 minute blowing period.

**A4.2** Report the foam stability in milliliters (mL) at the end of the 10 minute settling period.

### A5 Test Criteria

**A5.1 New Fluid.**

**A5.1.1** Candidate fluid results for new fluid shall meet the test limits in Appendix A, Table A1.

**A5.2 Used Fluid.**

**A5.2.1** Candidate fluid results for the fluid after the GM Cycling Test and filtration shall meet the limits in Appendix A, Table A2.

**Table A1: New Fluid Limits**

| Test                    | Tendency (mL) | Stability (mL) |
|-------------------------|---------------|----------------|
| ASTM D892, Sequence I   | 50            | 0              |
| ASTM D892, Sequence II  | 50            | 0              |
| ASTM D892, Sequence III | 50            | 0              |
| ASTM D6082, Sequence IV | 50            | 0              |

Table A2: Used Fluid Limits

| Test                    | Tendency (mL) | Stability (mL) |
|-------------------------|---------------|----------------|
| ASTM D892, Sequence I   | Report Result | Report Result  |
| ASTM D892, Sequence II  | Report Result | Report Result  |
| ASTM D892, Sequence III | Report Result | Report Result  |
| ASTM D6082, Sequence IV | Report Result | Report Result  |

## Appendix B

### B1 Elastomer; Fluid Interaction, Phase I Validation Objective

**B1.1** Determine the effects of ATF on elastomeric seal materials.

**B1.2** The fluid defined under this standard shall demonstrate limited effects on the standard reference elastomers under definite conditions of temperature and time when tested in accordance to ASTM D471.

### B2 Test Equipment

**B2.1** Refer to ASTM D471.

**B2.2** Reference Fluids. As defined under the current reference fluids standard.

#### B2.3 Elastomeric Compounds and Specimens.

**B2.3.1** Use SAE J2643 defined Standard Reference Elastomers (SRE) listed in Table B1.

**B2.3.2** Except as otherwise specified in the applicable specifications, specimens shall be prepared in accordance with the requirements of ASTM Practices ASTM D3182 and ASTM D3183. Order ASTM standard testing slabs from Akron Rubber Development Laboratory (ARDL) Incorporated, the only SAE International (SAE) approved organization for SAE J2643 SRE.

**Table B1: Standard Reference Elastomers (SRE)**

| SAE J2643 SRE <sup>Note 1</sup> | GM Reference | ASTM D1418 | Base Polymer                |
|---------------------------------|--------------|------------|-----------------------------|
| FKM-2                           | ES-1         | FKM Type 1 | DuPont A401C, Tg, -16 °C    |
| FKM-3                           | ES-2         | FKM Type 2 | DuPont GBL 600S, Tg, -17 °C |
| AEM-2                           | ES-7         | AEM        | DuPont VAMAC G              |
| ACM-1                           | ES-10        | ACM        | ZEON HYTEMP 4052            |
| ACM-2                           | ES-11        | ACM        | ZEON HYTEMP AR12            |
| NBR-1                           | ES-12        | NBR        | ZEON NIPOL DN2850, 28% ACN  |
| HNBR-1                          | ES-14        | HNBR       | ZEON ZEPTOL 2010, 36% ACN   |

**Note 1:** SAE J2643-2013. Approved facility; Akron Rubber Development Laboratory, 2887 Gilchrist Road, Akron, Ohio 44305.

**Note:** Alkyl Acrylate Copolymer (ACM), Ethylene Acrylic Elastomers (AEM), Elastomer Standard (ES), Fluoroelastomer (FKM), Hydrogenated Nitrile Butadiene Rubber (HNBR), Nitrile Butadiene Rubber (NBR).

### B3 Tests Procedure

**B3.1** Refer to ASTM D471 and references therein for test details.

#### B3.2 Requirements.

**B3.2.1** When tested with the designated standard reference elastomers, the effects of the fluid to the elastomers shall meet the requirements specified in Appendix B, Table B2 after the exposure defined therein.

Table B2: Elastomer Impact Tests

| Materials/Parameters                   | Test Method       | Unit           | Limits     |
|----------------------------------------|-------------------|----------------|------------|
| <b>SRE SAE J2643 ACM-1</b>             | ASTM D471         |                |            |
| <b>Schedule 1</b>                      | 150 °C, 168 h     |                |            |
| Change in Durometer Hardness           | ASTM D2240        | Points         | ± 5        |
| Change in Tensile Strength             | ASTM D412         | %              | ± 30       |
| Change in Ultimate Elongation          | ASTM D412         | %              | ± 30       |
| Change in Stress at 50% Elongation     | ASTM D412         | %              | Report     |
| Volume Swell                           | ASTM D471         | %              | ± 5        |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1            | Not applicable | Pass       |
| <b>SRE SAE J2643 ACM-2</b>             | ASTM D471         |                |            |
| <b>Schedule 1</b>                      | 150 °C, 168 h     |                |            |
| Change in Durometer Hardness           | ASTM D2240        | Points         | ± 10       |
| Change in Tensile Strength             | ASTM D412         | %              | ± 30       |
| Change in Ultimate Elongation          | ASTM D412         | %              | -35 to 10  |
| Change in Stress at 50% Elongation     | ASTM D412         | %              | Report     |
| Volume Swell                           | ASTM D471         | %              | 0 to 15    |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1            | Not applicable | Pass       |
| <b>Schedule 2</b>                      | 150 °C, 1008 h    |                |            |
| Change in Durometer Hardness           | ASTM D2240        | Points         | -10 to +15 |
| Change in Tensile Strength             | ASTM D412         | %              | ± 50       |
| Change in Ultimate Elongation          | ASTM D412         | %              | ± 50       |
| Change in Stress at 50% Elongation     | ASTM D412         | %              | Report     |
| Volume Swell                           | ASTM D471         | %              | 0 to 15    |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1            | Not applicable | Pass       |
| <b>SRE SAE J2643 AEM-2</b>             | ASTM D471         |                |            |
| <b>Schedule 1</b>                      | 150 °C, 168 hours |                |            |
| Change in Durometer Hardness           | ASTM D2240        | Points         | -15 to +5  |
| Change in Tensile Strength             | ASTM D412         | %              | ≥ -30      |
| Change in Ultimate Elongation          | ASTM D412         | %              | ≥ -35      |
| Change in Stress at 50% Elongation     | ASTM D412         | %              | Report     |
| Volume Swell                           | ASTM D471         | %              | 0 to 20    |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1            | Not applicable | Pass       |
| <b>Schedule 2</b>                      | 150 °C, 1008 h    |                |            |
| Change in Durometer Hardness           | ASTM D2240        | Points         | -15 to +5  |
| Change in Tensile Strength             | ASTM D412         | %              | ≥ -45      |
| Change in Ultimate Elongation          | ASTM D412         | %              | ≥ -45      |
| Change in Stress at 50% Elongation     | ASTM D412         | %              | Report     |
| Volume Swell                           | ASTM D471         | %              | 0 to 20    |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1            | Not applicable | Pass       |
|                                        |                   |                |            |

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 15 of 63



Documents

Document Sharing Hub

| Materials/Parameters                   | Test Method    | Unit           | Limits    |
|----------------------------------------|----------------|----------------|-----------|
| <b>SRE SAE J2643 FKM-2</b>             | ASTM D471      |                |           |
| <b>Schedule 1</b>                      | 150 °C, 168 h  |                |           |
| Change in Durometer Hardness           | ASTM D2240     | Points         | ± 5       |
| Change in Tensile Strength             | ASTM D412      | %              | ≥ -55     |
| Change in Ultimate Elongation          | ASTM D412      | %              | ≥ -60     |
| Change in Stress at 50% Elongation     | ASTM D412      | %              | Report    |
| Volume Swell                           | ASTM D471      | %              | ± 5       |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1         | Not applicable | Pass      |
| <b>Schedule 2</b>                      | 150 °C, 1008 h |                |           |
| Change in Durometer Hardness           | ASTM D2240     | Points         | -5 to +10 |
| Change in Tensile Strength             | ASTM D412      | %              | ≥ -65     |
| Change in Ultimate Elongation          | ASTM D412      | %              | ≥ -70     |
| Change in Stress at 50% Elongation     | ASTM D412      | %              | Report    |
| Volume Swell                           | ASTM D471      | %              | -5 to 10  |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1         | Not applicable | Report    |
| <b>SRE SAE J2643 FKM-3</b>             | ASTM D471      |                |           |
| <b>Schedule 1</b>                      | 150 °C, 168 h  |                |           |
| Change in Durometer Hardness           | ASTM D2240     | Points         | ± 5       |
| Change in Tensile Strength             | ASTM D412      | %              | ≥ -50     |
| Change in Ultimate Elongation          | ASTM D412      | %              | ≥ -50     |
| Change in Stress at 50% Elongation     | ASTM D412      | %              | Report    |
| Volume Swell                           | ASTM D471      | %              | ± 5       |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1         | Not applicable | Pass      |
| <b>SRE SAE J2643 NBR-1</b>             | ASTM D471      |                |           |
| <b>Schedule 1</b>                      | 125 °C, 168 h  |                |           |
| Change in Durometer Hardness           | ASTM D2240     | Points         | ± 5       |
| Change in Tensile Strength             | ASTM D412      | %              | ≥ -60     |
| Change in Ultimate Elongation          | ASTM D412      | %              | ≥ -70     |
| Change in Stress at 50% Elongation     | ASTM D412      | %              | Report    |
| Volume Swell                           | ASTM D471      | %              | 0 to 10   |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1         | Not applicable | Pass      |
| <b>SRE SAE J2643 HNBR-1</b>            | ASTM D471      |                |           |
| <b>Schedule 1</b>                      | 150 °C, 168 h  |                |           |
| Change in Durometer Hardness           | ASTM D2240     | Points         | ± 5       |
| Change in Tensile Strength             | ASTM D412      | %              | ≥ -25     |
| Change in Ultimate Elongation          | ASTM D412      | %              | ≥ -25     |
| Change in Stress at 50% Elongation     | ASTM D412      | %              | Report    |
| Volume Swell                           | ASTM D471      | %              | 0 to 10   |
| 180 degree Bend Test <sup>Note 1</sup> | Note 1         | Not applicable | Pass      |

**Note1:** Bending Test of 180 degrees prior to and after ATF age by looping specimens the size of 25 mm x 50 mm x 2 mm until the two (2) ends meet, no surface cracks should be, observed.

## Appendix C

### C1 Plate Friction Test Objective

**C1.1** To determine the friction characteristics and durability of an automatic transmission fluid in a plate friction test.

### C2 Test Equipment

#### C2.1 Motor.

##### C2.1.1 SAE Number 2 Friction Test Machine.

**C2.1.2 Clutch Plate Head Assembly.** Greening Associates, Incorporated or equivalent.

**C2.1.3 Drive Motor.** Delco 22 kW, 3600 min<sup>-1</sup> (3600 rpm), 3-Phase, 326-UZ frame or equivalent.

**C2.1.4 Flywheel Assembly.** Flywheel to provide 15.7 kJ ± 0.3 kJ total energy, attached to motor shaft with taper-lock adaptor.

**C2.1.5 Lubricant Reservoir.** A 1 L stainless steel lubricant reservoir with cover, vented to the atmosphere, mounted above the housing and connected to the housing at the 12 o'clock position (as viewed from cover end of machine) with a 9.5 mm Outside Diameter (OD) x 8.0 mm Inside Diameter (ID) x 100 mm long teflon tube (with stainless steel fittings).

#### C2.2 Test Hardware.

**C2.2.1 Friction Clutch Plate.** Standard SAE Number 2 size plates and BorgWarner 4329 material. All parts must be ordered from GM Racing under the part number GMPT-0506.

#### C2.3 Instrumentation and Recording Equipment.

**C2.3.1 Torque Transducer.** Lebow Load Cell, Model Number 3397, or equivalent.

**C2.3.2 Pressure Transducer.** Sensotech, Model Number TJU708-12, or equivalent.

**C2.3.3 Speed Transducer.** Electro Corporation, Model Number 3010AN, or equivalent.

**C2.3.4** Data acquisition system with the capability of recording speed, torque, and pressure. Data is to be recorded at 1000 Hz without filtering.

**C2.3.5 Temperature Measurement.** Thermosensor, Iron-Constantan thermocouple, Type 22J34-E-4-TGFS36, or equivalent. Leeds and Northrup Speedmax 165, Model Number 168-10-001-0010-6-C0000-000, chart J68-F, or equivalent. If using a digital recording device, data will be collected at 1 Hz.

**C2.4 Control Equipment.** For installation information contact Southwest Research Institute or PerkinElmer Automotive Research.

**C2.4.1 Temperature Control.** Precision Products and Control Research Control Valve (pneumatic-activated water-temperature control), Type 755, Diaphragm 3-15, Trim J, Action Air-To-Close (ATC), or equivalent.

**C2.4.2 Timer.** Texas Instruments, Model Number 510, or equivalent.

**C2.4.3 Cycle Counter.** General Controls, Model Number CE600 BS 602, or equivalent.

**C2.4.4 Controller.** Allen-Bradley, Model Number 712 DAB 26-43, K-Series, or equivalent.

**C2.4.5 Four-Way Solenoid Valve.** Automatic Switch Company, Number 83441, 115 V, 60 Hz, 10.5 W or equivalent.

**C2.4.6 Regulator Controls.** C. A. Norgen Company, Number 11-042-003, or equivalent, for engaging clutch plates. C. A. Norgen Company, Number 11-009-041, or equivalent, for disengaging clutch plates.

**C2.4.7 Quick Release Valve.** Bendix-Westinghouse, Number 224417, or equivalent.

**C2.4.8 Pressure Gauges.** Ashcroft gauges, 0 kPa to 400 kPa for apply pressure, 0 kPa to 100 kPa for release pressure, or equivalent.

**C2.4.9 Calibrated Rotameter.** Aalborg Instrument Company, Model Number FM032-15, or equivalent. To be calibrated before each test.

**C2.4.10 Micrometering Valve.** Nupro Company, or equivalent.

**C2.4.11 Air Source.** Supply of hydrocarbon-free, dry (minimum -59 °C dew point) compressed air with regulator controls.

## C2.5 Connections.

**C2.5.1 Imperial-Eastman Poly-Flo Tubing.** A 44-P-1/4, 6.4 mm OD x 4.8 mm ID, or equivalent, to connect air cylinder to metering valve near flow meter.

**C2.5.2 Tygon Tubing.** A 6.4 mm ID x 125 mm length to connect micrometering valve to the flow meter.

**C2.5.3 Tygon Tubing.** A 6.4 mm ID x 250 mm length to connect flow meter to Swagelok fitting at the housing.

**C2.5.4 Stainless Steel Orifice.** A 0.90 mm ID, as shown in Figure C1. To be fitted to test head in the 7 o'clock position. Connected to flow meter output with 6.4 mm ID Tygon Tubing. Tubing should be long enough to create a low point so that any test fluid that leaks into the tubing does not go back into the flow meter.

## C3 Test Procedure

### C3.1 Cleaning Procedure.

**C3.1.1** Remove the front cover, spacer, retainer ring, and hub to clean.

**C3.1.2** Clean fixture with Stoddard solvent, prior to each test. Flush the inside of the test housing, attached ports and thermocouple connections with solvent. Thoroughly clean all crevices and ports in the housing where fluid is likely to be, trapped.

**C3.1.3** Air blow dry the cleaned parts and test housing.

**C3.1.4** Install new Tygon tubing to the flow meter before each test.

### C3.2 Assembly Procedure.

**C3.2.1** Inspect rotating shaft seal and lip seal for deterioration and replace if necessary.

**C3.2.2** Install clutch plate hub, snap ring, and clutch plate retainer.

**C3.2.3** Mark clutch plates so that their order of installation is known. Mark plates in an area unaffected by the friction contact, e.g., on the steel plate tangs and composition plate splines.

**C3.2.4** Pre-soak clutch plates in test fluid for 5 minutes and then install clutch plates in the clutch plate retainer (Figure C2).

**C3.2.5** Install spacer.

**C3.2.6** Check clutch plate pack free movement. Clearance is  $1.02 \text{ mm} \pm 0.13 \text{ mm}$ . This measurement, conveniently made, with a depth micrometer, is with the clutch pack and spacer installed and compressed at the sites of measurements.

**C3.2.7** Install thermocouple at 4 o'clock position, relative to cover, to within 1 mm of steel clutch plate annulus OD.

**C3.2.8** Install new O-rings on cover.

**C3.2.9** Attach cover and fasten with ring-bearing support and cover retainer.

**C3.2.10** Connect compressed air cylinder to micrometering valve with Poly-Flo tubing. Connect micrometering valve to flow meter with Tygon tubing with C2.5.2 and from the flow meter to the Swagelok fitting on the housing at the 7 o'clock port with C2.5.3. At the housing, insert 25 mm length of stainless steel capillary tubing (0.90 mm ID) into the Swagelok fitting.

**C3.2.11** Fill test head with 650 mL of test fluid. Release trapped air from head.

### C3.3 Test Startup.

**C3.3.1** Check and calibrate torque, pressure, motor-speed, and thermocouple signals.

**C3.3.2** Set, apply air pressure at 345 kPa.

**C3.3.3** Set release air pressure at 70 kPa.

**C3.3.4** Open, cooling water valve.

**C3.3.5** Set timer to provide test-cycle sequence shown in Table C1.

**C3.3.6** Start temperature recorder, chart speed at 50 mm/h or collect data at 1 Hz.

**C3.3.7** Meter cylinder air into the housing at a rate of 50 mL/minute. Adjust airflow while motor is not running.

**C3.3.8** Set, apply air pressure at 345 kPa. Set apply rate to go from 30 kPa to 345 kPa in  $0.15 \text{ s} \pm 0.02 \text{ s}$ . Pressure should increase linearly from 50 kPa to 250 kPa in  $70 \text{ ms} \pm 5 \text{ ms}$ .

**C3.3.9** Start test cycle.

**C3.3.10** Check for air, fluid and water leaks, operation of transducers and cycling event times.

**C3.4 Test Operation.**

**C3.4.1** Continue to repeat test-cycle sequence until failure or for 200 h without any scheduled shutdowns.

**C3.4.2** Maintain average test fluid temperature during operation at  $140\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ . Within each cycle, the temperature may vary by  $\pm 6\text{ }^{\circ}\text{C}$ .

**C3.5 Test Startup After Unscheduled Shutdown.**

**C3.5.1** Ascertain and correct cause of shutdown. Record test duration at shutdown, duration of shutdown, and whether or not aeration was, continued during shutdown.

**C3.5.2** Repeat C3.3 Test Startup (see C3.3).

**C3.5.3** Resume recording test time when fluid reaches test temperature.

**C3.6 Required Recordings.**

**C3.6.1** Record fluid temperature continuously.

**C3.6.2** Record torque, apply pressure, and motor speed during test-cycle sequence Event 2 of Table C1 at 10 cycles to confirm proper test operation.

**C3.6.3** Record torque, apply pressure, and motor speed during test-cycle sequence Event 2 of Table C1 at test hours; 1 h, 2 h, 3 h, 4 h, 5 h, and every 5 h thereafter until the end of the test at 200 test hours.

**C4 Test Results**

**C4.1** Report required recordings per C3.6.

**C4.2** Lockup is the time when the speed reaches zero.

**C4.2.1** If a Direct Current (DC) tachometer is, used for speed, then there should be no delay between the zero speed and zero voltage from the DC tachometer.

**C4.2.2** When a magnetic pickup and Frequency to Voltage Converter (FVC) are, used for speed, there will be delays and non-linear response near zero. The following steps will reduce these errors. As an example for a 200 pulse per revolution speed signal, use the average ( $\pm 5$  scans) speeds at  $300\text{ min}^{-1}$  (300 rpm) and the  $300\text{ min}^{-1}$  (300 rpm) plus 10 scans to find a delta speed for projecting the speed through zero. Lockup scan will be the closest point to zero speed adjusted for the delay factor caused by the FVC. This delay is typically 8 scans but needs to be determined for each specific FVC unit.

**C4.2.3** Project the Frequency to Voltage Converter speed from  $1000\text{ min}^{-1}$  (1000 rpm) to zero at the adjusted lockup scan found in C4.2.2. All speed data from lockup scan to end of data should be set to a value of zero.

**C4.3** End Torque is determined by the North-East Corner (NEC) method. Starting at the lockup scan, point search forward and find the first negative torque value. Calling this point N, back up 41 scans and calculate the product of  $\text{TORQUE}_{(N \text{ minus } 41)} \times 1$ ,  $\text{TORQUE}_{(N \text{ minus } 40)} \times 2$ , etc., up to  $\text{TORQUE}_{(N \text{ minus } 1)} \times 40$ . The NEC point will be the scan, which has the largest product from these calculations.

**C4.4** Stop Time is the elapsed time in milliseconds (ms) between the start of engagement, when applied pressure reaches 30 kPa, and the lockup scan.

**C4.5** Midpoint Torque is a 48-point average centered about a point in time halfway between the start of engagement and the lockup scan.

**C4.6** Maximum Torque is the largest torque value found between  $500\text{ min}^{-1}$  (500 rpm) and the lockup scan.

**C4.7** Delta Torque equals Maximum Torque minus Midpoint Torque.

**C4.8** Energy is integrated power in Watts per Second (W/s) from the start of engagement to the lockup scan.

**C4.9** Apply pressure is, recorded at the Midpoint scan.

**C4.10** Report test results in Appendix C, Table C2. Sample analysis of test results is, shown in Appendix C, Figure C2. Report all required torque values as three (3)-point running averages.

**C5 Test Criteria**

**C5.1** Between 10 h and 200 h of operation: