



DEXRON® - VI Automatic Transmission Fluid

1 Scope

1.1 Material Description. This specification covers DEXRON® - VI 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. 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.

1.5 This specification uses the International System of Units (SI) as standard per Institute of Electrical and Electronics Engineers/ASTM International SI 10 (IEEE/ASTM SI 10), except for certain components, which are commercially available only in American conventional units.

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

1.7 Unless otherwise noted, part numbers of this specification refer to those of General Motors Powertrain.

2 References

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

2.1 External Standards/Specifications.

ASTM D92	ASTM D1193	ASTM D4683	ASTM D7043
ASTM D130	ASTM D1418	ASTM D4927	ASTM E29
ASTM D412	ASTM D1500	ASTM D4951	ASTM E168
ASTM D445	ASTM D1748	ASTM D5185	CEC L-45-99
ASTM D471	ASTM D2240	ASTM D5293	CEC L-48
ASTM D659	ASTM D2270	ASTM D5800	CEC L-084-02
ASTM D664	ASTM D2983	ASTM D6082	FED-STD-791
ASTM D665	ASTM D4052	ASTM D6304	IEEE/ASTM SI 10
ASTM D892	ASTM D4289	ASTM D6443	ISO 37
ASTM D893	ASTM D4629	ASTM D6922	SAE J2643

2.2 GM Standards/Specifications.

GMW3059

2.3 Additional References.

- Donaldson Duramax Part Number P165354.
- Donaldson Duramax Part Number P169310.
- FVA-2/IV (Pitting Test Procedure) - Forschungsvereinigung Antriebstechnik (Germany)
- GM Customer Care and Aftersales (CCA) Part Number 1050026.
- GM CCA Part Number 8654654.
- GM CCA Part Number 24214202.
- GM CCA Part Number 24218069.
- GM CCA Part Number 24219551.
- GM CCA Part Number 24221347.
- GM CCA Part Number 24223118.
- GM Part Number 7000081 – Tech 2.
- GM Part Number 08681295.
- GMPT CAH0404.
- GMPT HX010751A.
- GM Powertrain (GMPT-0506).
- GM Powertrain Procedure Matrix.
- ITT Standard Company Part Number SN5-160-02-008-002.
- ITT Standard Company Part Number SN5-160-03-014-002.
- Morgan, C., Cummings, J.M., Fewkes, R., Jackson, J.M. A New Method of Measuring Aeration and Deaeration of Fluids, SAE Paper 2004-01-2914. (See Appendix K).
- Morgan, C., Fewkes, R., McCombs, T., Tersigni, S.H., Jackson, J.M. Low-Speed Carbon Fiber Torque Capacity and Frictional Properties Test for ATFs, SAE Paper 2004-01-3026.
- Part drawings, including material specifications, are available from Southwest Research Institute (San Antonio, Texas). (See Appendix K).
- TMC003 Material Safety Data Sheet (MSDS) guidance documents (available at gmsupplypower.com).
- VW PV 1454 (Volkswagen test procedure).

2.3.2 Test Method Sources.

- ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania, 19428-2959, U.S.A. (Available at: www.enterprise.astm.org).
- EHDPROC_11 is available from Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas U.S.A.
- LR4 procedure is available from Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas, U.S.A.
- MERCON SP Procedure 3.14 Specification. Ford Motor Company, ATF Committee, 36200 Plymouth Road, Livonia, Michigan, 48150, U.S.A.
- Test Methods CEC L-45-99 Coordinating European Council, Madou Plaza, 25th Floor, Place Madou 1, B-1030 Brussels, Belgium. (Available at: www.cectests.org).
- VWR Grade 417, 25.0 cm Diameter, Part Number 28313-160.

2.3.3 Forms.

- A spreadsheet is available from the GM ATF Committee that contains all report formats. (See Appendix K.)

- All GM DEXRON® testing forms, 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. Folders/ENGINEERING/Powertrain Product Engineering/Transmission.
(gmsupplypower.covisint.com/c/document_library/get_file?p_l_id=4211828&folderId=4501165&name=DLF E-188908.docx).
- Chevrolet Service Manual ST368-92.

3 Requirements

3.1 Test Requirements. Form A, (2.3.3) is required for testing to be started on ATF pursuing DEXRON® - VI approval.

3.2 Mechanical Requirements. Test procedures shall be conducted as specified, with no deviation, unless express written authorization is obtained from the General Motors ATF and Gear Oil Committee. Test transmissions and parts are to be used as received. Replacement or modification of any part shall be made only if directed in this specification or 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® - VI Additive Chemistry Combinations.

3.5 Requirements for New DEXRON® - VI Additive Chemistry Combinations.

3.5.1 Successful completion of a complete DEXRON® - VI Qualification Program (Table 1).

3.5.2 Successful completion of a complete DEXRON® - VI Qualification Program (Table 1) using the following fluid blends from **a** to **d**.

- Seventy-Five Percent (75%) Candidate, 25% Reference Fluid.
- Fifty Percent (50%) Candidate, 50% Reference Fluid.
- Twenty-Five Percent (25%) Candidate, 75% Reference Fluid.
- 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. A proposal for the fleet test shall be submitted to and approved by the GM ATF and Gear Oil Committee before commencing the fleet test.

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 to be applied 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 any additional tests that may be deemed necessary to ensure satisfactory performance of fluids submitted for qualification as DEXRON® - VI Automatic Transmission Fluids.

Table 1: DEXRON®- VI Test Methods and Requirements

TEST	METHOD	REQUIREMENT
A. Color	ASTM D1500	6.0 to 8.0
B. 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
C. Fluid Profile	Proprietary GM Test	Report
D1. Miscibility and Homogeneity	ASTM D6922	No separation or color change at end of test using Reference Fluid
D2. FED-STD-791	3430-Compatibility 3440-Storage Solubility	Pass Pass
Water Content	ASTM D6304	0.10% weight
E. Density	ASTM D4052: 15 °C	Report
F. Kinematic Viscosity	ASTM D445	32 cSt at 40 °C (maximum)
		6.4 cSt at 100 °C (maximum)
		150 °C (Report)
		4.5 cSt at 100 °C (minimum) for base oil blend
G. Viscosity Index	ASTM D2270	145 °C (minimum)
H. Flash Point	ASTM D92	180 °C (minimum)
I. Fire Point	ASTM D92	195 °C (minimum)
J. Brookfield Viscosity	ASTM D2983	Report, cP at -10 °C 1500 cP (maximum) at -20 °C 5000 cP (maximum) at -30 °C 15 000 cP (maximum) at -40 °C
K. Copper Strip Corrosion Test	ASTM D130 Modified: 3 h at 150 °C	1B
L. Corrosion Test	ASTM D665: Procedure A; 4 h	Pass
M. Rust Protection Test	ASTM D1748 Sandblasted Surface 40 °C 50 h New coupon for each test	No rust or corrosion on any test surface
N. Wear Test	ASTM D7043 Modified: 80 °C ± 3 °C 6.9 MPa 11.356 L (3 gal) Conestoga pump parts	10 mg weight loss (maximum)
Forschungstelle Fur Zahnrad und Getriebbau (FZG) - Scuffing	CEC L-084-02	A10/16.6R/90C, load stage 5
O. Cold Crank Simulation	ASTM D5293: -30 °C	3200 cP (maximum)
P. High Temperature, High Shear	ASTM D4683: 150 °C	2.00 cP (minimum)
Q. Noack Evaporation	ASTM D5800	10% evaporation (maximum) 1 h at 200 °C
R. Film Thickness	EHDPROC_11 at Imperial College 60 °C, 80 °C, 100 °C, 120 °C	Report, Committee Decision
S. Tapered Roller Bearing Shear	CEC L-45-99 Modified: 3 480 000 revolutions, approximately 40 h at 100 °C	KV100, 5.5 cSt (minimum) at End of Test (EOT), 10% decrease (maximum) at EOT (Base Oil Viscosity (BOV) + End of Test Viscosity (EOTV)) /2 >5.0 cSt at 100 °C

TEST	METHOD	REQUIREMENT
T. Foam Test	Appendix A ASTM D892 Modified	New Fluid: Sequence I, ASTM D892; 50/0 (maximum) Sequence II, ASTM D892; 50/0 (maximum) Sequence III, ASTM D892; 50/0 (maximum) Sequence IV, ASTM D6082; 50/0 (maximum) After cycling test filtered fluid: Sequence I, ASTM D892; 50/0 (maximum) Sequence II, ASTM D892; 50/0 (maximum) Sequence III, ASTM D892; 50/0 (maximum) Sequence IV, ASTM D6082; 150/0 (maximum) After Thermal Aging at 135 °C for 100 h Sequence I, ASTM D892; 50/0 maximum Sequence II, ASTM D892; 50/0 maximum Sequence III, ASTM D892; 50/0 maximum Sequence IV, ASTM D6082; 50/0 maximum After Thermal Aging at 150 °C for 100 h Report results for all four (4) sequences After Tapered Roller Bearing Shear Test Report results for all four (4) sequences
U. Elastomer Test	Appendix B	Pass
V. Plate Friction Test	Appendix C	Satisfactory operation for 200 h No unusual wear or flaking on test parts Between 10 h and 200 h of operation: Midpoint dynamic torque between 80 Nm and 105 Nm Maximum Torque >90 Nm Delta Torque <30 Nm Stop Time between 0.85 s and 1.05 s Report End Torque, Newton meters (Nm) Report Shift Energy, kilojoules (kJ)
W. Band Friction Test Only for new chemistry or if requested by GM fluid team	Appendix D	Satisfactory operation for 150 h on 4L60-E drums with Modified Friction Material band No unusual wear or flaking on test parts Between 10 h and 150 h of operation: Midpoint Torque between 180 Nm and 290 Nm End Torque >200 Nm Delta Torque <120 Nm Stop Time between 0.30 s and 0.45 s Report Maximum Torque, Nm Report Shift Energy, (15.7 kJ to 16.3 kJ is typical)
X. Deutscher Koordinierungsausschuss (DKA) Oxidation Stability Test	CEC L-48 modified 175 °C for 192 h Method B Appendix E	Delta Kinematic Viscosity (KV) 40, 13% Maximum Delta KV 100, 12% Maximum Peak Arrival Interval (PAI) (unit) Report Delta Total Acid Number (TAN) (mg KOH/g fluid), report (Typical 1 to 3) Sludge rating of flask, maximum 1.0 Blotter, report with photo
Y. Cycling Test	Appendix F	Satisfactory operation for 42 000 cycles Condition of transmission parts must be equal to or better than that obtained with the Reference Fluid TAN Increase <2.0 Carbonyl Absorbance increase <0.30 Used fluid viscosity at 100 °C >5.0 cSt Used fluid viscosity at -20 °C <2000 cP Used fluid viscosity at -40 °C <15 000 cP 1 to 2 shift time between 0.30 s and 0.75 s 2 to 3 shift time between 0.30 s and 0.75 s 3 to 4 shift time, seconds (s) (Report) No expulsion of ATF from vent (Appendix F, Table F3)

TEST	METHOD	REQUIREMENT
Z. Vehicle Performance Test	Appendix G	Shift performance essentially equal to that obtained with the Reference Fluid (Appendix G, Table G1)
AA. Electronically Controlled Capacity Clutch (ECCC) Vehicle Performance Test	Appendix H	Equal to or better than Reference Fluid (Appendix H, Table H1)
AB. Achsial-Rillen-Kugal-Lager (ARKL)	VW PV 1454	Report in C, Committee Decision
	No Appendix I	
AC. Low-Speed Carbon Fiber Friction Test	Appendix J	New and used fluid from Cycling Test must be equal to or better than Reference Fluid (Appendix J, Table J1)
AD. Aeration Test (RDL) 3434 Reference shall be run before every candidate fluid	Appendix K	New and used fluid from Cycling Test must have the following limits: <2% above RDL 3434 reference - Aeration percent (%) 60 °C <2% above RDL 3434 reference - Aeration percent (%) 90 °C <2% above RDL 3434 reference - Aeration percent (%) 120 °C <5 s above RDL 3434 reference - Deaeration 60 °C <5 s above RDL 3434 reference - Deaeration 90 °C <2 s above RDL 3434 reference - Deaeration 120 °C RDL 3434 Reference shall be run before every candidate fluid (Appendix K, Table K1)

Table 2: DEXRON® - VI Approved Chemistry Combinations

Company	Chemistry Name	Treat Rate Weight Percent (wt %)
1 Afton Chemical Corporation	HiTEC 3491 HiTEC 5738	7.18 1 to 5
2 Infineum	Infineum T4760 Infineum T4163	7.25 0 to 6
3 Lubrizol	Lubrizol AT1210 Lubrizol VL240E	8.48 0 to 6

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

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

Test	Method	Requirement
3A. Hunting Behavior	LR4 4.8L 4L60-E	No Hunting
3B. Pitting	FVA-2/IV (Pitting Test Procedure)	Equal to or better than Reference Fluid
3C. Carbon Fiber Durability	MERCON SP Procedure 3.14 Modified: 1) Low Speed Carbon Fiber plates	Equal to or better than Reference Fluid
3D. Fleet Test	See 3.5.4	See 3.5.4

Note: Reference = Something of known performance characteristics, designated by the GM ATF and Gear Oil Committee.

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 TMC003 Material Safety Data Sheet/Safety Data Sheet guidance documents where available.

5.6 All materials supplied to this standard must comply with the requirements of GMW3059, **Restricted and Reportable Substances for Parts.**

5.7 Trademark Licensing.

5.7.1 Licenses to use the trademark DEXRON® and related "J" identification numbers are issued for fluids which have been tested by an independent laboratory and/or by General Motors and subsequently approved by the General Motors Automatic Transmission Fluid and Gear Oil Committee.

Note: For information on qualification of service replacement fluids for use in General Motors axles, contact, the Team Leader for Service Parts Engineering and DEXRON® Licensing or the GM ATF and Gear Oil Committee Chairman, via GM Supply Power. Folders/ENGINEERING/Powertrain Product Engineering/Transmission.

(gmsupplypower.covisint.com/c/document_library/get_file?p_l_id=4211828&folderId=4501165&name=DLFE-188908.docx).

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.

7 Notes

7.1 Glossary.

α : Level of significance for hypothesis tests (0.01 for this procedure).

n_1 : Number of candidate fluid data points (typically, 24 for shudder and 12 for hunting).

n_2 : Number of reference fluid data points (typically, 24 multiplied by number of reference fluids for shudder and 12 multiplied by number of reference fluids for hunting).

P_{av} : Average Apply Pressure.

Reference: Something of known performance characteristics, designated by the GM ATF and Gear Oil Committee.

R_{sa} : Ratio of the shudder averages.

R_{sv} : Ratio of the shudder variances.

s_1 : Standard deviation of the candidate fluid.

$$s_1 = \sqrt{\frac{1}{n_1 - 1} \sum_{i=1}^{n_1} (x_{1i} - \bar{x}_1)^2}$$

s_2 : Standard deviation of the reference fluid.

$$s_2 = \sqrt{\frac{1}{n_2 - 1} \sum_{i=1}^{n_2} (x_{2i} - \bar{x}_2)^2}$$

s_1^2 : Variance of the candidate.

s_2^2 : Variance of the reference fluid.

s_p : Pooled standard deviation (for pooling 2 groups).

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 - 1) + (n_2 - 1)}}$$

T_{avg} : Average Torque.

$\bar{x}_1$: Average response of the candidate fluid.

$$\bar{x}_1 = \frac{\left(\sum_{i=1}^{n_1} x_{1i} \right)}{n_1}$$

$\bar{x}_2$: Average response of the reference fluid.

$$\bar{x}_2 = \frac{\left(\sum_{i=1}^{n_2} x_{2i} \right)}{n_2}$$

7.2 Acronyms, Abbreviations, and Symbols.

ACM	Acrylic Monomer
AEM	Ethylene Acrylate Elastomer
Al	Aluminum
AN	Acid Number
ARDL	Akron Rubber Development Laboratory
ARKL	Achsial-Rillen-Kugal-Lager
ASTM	ASTM International
ATC	Air-To-Close
ATF	Automatic Transmission Fluid
BOV	Base Oil Viscosity
CCA	Customer Care and Aftersales
CEC	Coordinating European Council
Cu	Copper
CVT	Continuously Variable Transmission
DC	Direct Current
DKA	Deutscher Koordinierungsausschuss
DoF	Degrees of Freedom
ECCC	Electronically Controlled Capacity Clutch

ECM	Electronic Control Module
EHD	Elastohydrodynamic
EOT	End of Test
EOTV	End of Test Viscosity
ES	Elastomers Standard
Fe	Iron
FED	Federal
FFT	Fast Fourier Transform
FKM	Fluorocarbon
FTP	Federal Test Procedure
FVA	Forschungsvereinigung Antriebstechnik (Germany Company)
FVC	Frequency to Voltage Converter
FZG	Forschungstelle Fur Zahnrad und Getriebebau
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
GMPT	General Motors Powertrain
GSSLT	Global Subsystem Leadership Team
HNBR	Highly Saturated Nitrile Halogenated Acrylonitrile Butadiene
HP	Horsepower
HP-ATF	High Performance Automatic Transmission Fluid
ID	Inside Diameter
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
KRL	Kugel Rollen Lager
KV	Kinetic Viscosity
LDTHL	Long Duration Test High Load
MSDS	Material Safety Data Sheets
MY	Model Year
NEC	North East Corner
No.	Number
NPT	National Pipe Tapered Thread
OD	Outside Diameter
PAI	Peak Area Interval
Pb	Lead
PCM	Powertrain Control Module
PO	Peroxide
PPAP	Production Part Approval Process
Ppm	Parts per Million
PTFE	Polytetrafluoroethylene
RDL	Petrol Canada Internal Laboratory Code
SAE	SAE International
SDS	Safety Data Sheets
SI	International System of Units
SOT	Start of Test
SRE	Standard Reference Elastomer

STD	Standard
Std. Dev.	Standard Deviation
TAN	Total Acid Number
TCC	Torque Converter Clutch
TCM	Transmission Control Module
Temp.	Temperature
TPS	Throttle Position Sensor
UHP	Ultra-High Purity
VTi:	An electronically controlled Continuously Variable Transmission (CVT)
VWR	VWR is the name of a laboratory supply company
WOT	Wide Open Throttle
W/s	Watts per Second

8 Coding System

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

Material per GMW16444

9 Release and Revisions

This standard was originated in October 2010. It was first approved by the GM ATF and Gear Oil Committee in August 2011. It was first published in August 2011.

Issue	Publication Date	Description (Organization)
1	AUG 2011	Initial publication.
2	APR 2014	New tests added and revised other tests. (Fuels, Fluids and Lubricants Global Subsystem Leadership Team)

Appendix A: Foam Test

A1 Objective

A1.1 To 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 U.S.A. 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 ASTM D892 shall be followed exactly as written, with the following points included.

A3.1.1 As indicated in Note 4 of ASTM D892, only liquid baths (i.e., silicone oil) shall be used for Sequences I, II, and III.

A3.2 Run ASTM D6082.

A3.3 Repeat A3.1 through A3.2 for ATF taken from the end of the Cycling Test. This step should be performed within 24 h of completion of the GM Aeration Test. The fluid is to be filtered through the filtration system described in A2.2 before testing commences.

A4 Test Results

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

A4.2 Report the foam stability (in milliliters) 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 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 Table A2.

Table A1: New Fluid Limits

Test	Tendency (milliliters)	Stability (milliliters)
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 (milliliters)	Stability (milliliters)
ASTM D892, Sequence I	50	0
ASTM D892, Sequence II	50	0
ASTM D892, Sequence III	50	0
ASTM D6082, Sequence IV	150	0

Appendix B: Elastomers Test

B1 Objective

B1.1 To determine the compatibility of ATF with elastomeric seal materials.

B2 Test Equipment

B2.1 ASTM D2240 Equipment.

B2.1.1 Shore Durometer A. As described in ASTM D2240, available from The Shore Instrument and Manufacturing Company, Model CV.

B2.1.2 Conveloader. Preloaded to 822 g, mounted on a Durometer stand, available from The Shore Instrument and Manufacturing Company, Model CV.

B2.2 ASTM D412 Equipment.

B2.3 Heating Device. Aluminum heating block or oil bath. Each heating device must be approved by the General Motors ATF Committee.

B2.4 Heat-Resistant Test Tubes. Per Figure B1, with air inlet, condenser connection, condenser, and elastomer hanger insert. Dimensions to match those specified in ASTM D659.

B2.5 Analytical Balance. Sartorius, Model Number 2402, or equivalent.

B2.6 Suspension Wire. Stainless steel, approximately 0.25 mm diameter.

B2.7 Reagent Water. Conforming to ASTM D1193, Type IV.

B2.8 Reference Fluids. DEXRON® - VI ATF.

B2.9 Elastomeric Compounds. ASTM standard slabs of Standard Reference Elastomers (SRE) can be ordered from Akron Rubber Development Laboratory Inc. (ARDL), the only SAE approved organization for SAE SRE. (See Table B1).

Table B1: Standard Reference Elastomers (SRE)

Compound Description					
GM No.	SAE J2643	FKM	ASTM D-1418		Compounds
ES-1	FKM-2		Type 1	Bisphenol AF 66%	DuPont ,A401C, Tg -16 °C
ES-2	FKM-3		Type 2	PO (Peroxide) 68%	DuPont ,GBL 600S, Tg -17 °C
			Type 3		
ES-4	FKM-5	AEM		Low temp, Tg at -30 °C	Solvay ,PL855 64% F
ES-7	AEM-2		G	DuPont , with 10 mph TP759, EM08A 49-2	
ES-8	AEM-3		GLS	DuPont , with 10 mph TP759, EM08A49-4	
ES-10	ACM-1	ACM	Traditional	ACM-1, SAE J2643, Zeon	
ES-11	ACM-2		AR 12	ACM-2, New cure technology, Zeon	
ES-14	HNBR	HNBR		HNBR-1, SAE J2643, Zeon	

Note: No. = Number, FKM = Fluorocarbon, AEM = Ethylene Acrylate Elastomer, ACM = Acrylic Monomer, HNBR = Highly Saturated Nitrile Halogenated Acrylonitrile Butadiene, PO = Peroxide, Temp. = Temperature

B2.10 Wetting-Agent Solution. A 0.5 mass percent (approximately) dioctyl sodium sulfosuccinate, made by dilution of concentrated solution with reagent water. (Concentrated solutions, such as Aerosol OT (Sodium Bisulfate), are available from laboratory supply companies.) Preparation of the wetting solution from the solid reagent is not recommended.

B2.11 Prepare test specimens using ASTM D471, longitudinally with the grain, and punch a nominal 3 mm hole in specimen for hanging on stainless steel support bracket in test tube. All specimens are cut with Die Number 2 (ISO 37). A total of eight (8) specimens are prepared for aging in each fluid. An additional eight (8) specimens are prepared for initial tensile strength and elongation measurements to be done side by side with posttest measurements.

B2.12 Maintain heating device so that fluid temperature in test tubes is controlled at $150\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$.

B2.13 Air flow with dry house air, ultra-high purity (UHP) air or the equivalent, into test tube at 5 L/h.

B3 Qualification of Elastomeric Compounds

B3.1 Each batch of elastomeric compound shall meet the percent volume change and Durometer A hardness change limits with DEXRON®- VI ATF oils as shown in Table B2. Each batch of seal materials will be tested at both independent laboratories using a minimum of five (5) coupons from five (5) different slabs of material in the two (2) oils previously mentioned, as well as the Reference Fluid.

B3.2 No elastomeric compound shall be used after one (1) year from the date of manufacture.

B3.3 Elastomeric compounds shall be stored in a sealed, non-reactive container, below $25\text{ }^{\circ}\text{C}$.

B3.4 ARDL (Akron Rubber Development Lab) is the only approved source for mixing SRE and Elastomers Standard (ES) compounds.

B3.5 Test specimens shall be cut in the grain direction.

B4 Test Procedure

B4.1 Determine the original volume measurement, tensile strength, elongation, and Durometer readings of each specimen per ASTM D4289. Durometer reading must be taken instantaneously, $1.0\text{ s} \pm 0.1\text{ s}$. Dip each specimen in the wetting-agent solution before weighing specimen in water. Dislodge bubbles.

B4.2 Hang the eight (8) specimens in the tubes as shown in Figure B1, making sure the specimens do not touch each other or the tube walls. They should be completely suspended and surrounded by the fluid. Add 300 ml of test fluid to each tube. Assemble the tube as shown with air tube extending through the bottom of the support hanger.

B4.3 Age the seals for 504 h at $150\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ fluid temperature.

B4.4 Remove the specimens from the test tubes and immediately place them on a clean absorbent pad or laboratory grade paper towels and cover with the same material. Cool to room temperature at least 30 minutes before working with the elastomers. Final measurements must be taken within 120 minutes of the end of B4.3.

B4.5 Wipe specimens dry with a clean, lint-free, laboratory grade paper towel or equivalent.

B4.6 Determine the final volume, tensile strength, elongation, and Durometer readings of each specimen as described in B4.1.

B5 Test Results

B5.1 Report the percent volume change, percent tensile change, percent elongation, and points Durometer A hardness change for each test specimen.

B5.2 Report the average values and standard deviation for the test specimens in the candidate fluid and reference fluid.

B6 Test Criteria

B6.1 Reference oils percent volume change, tensile change, elongation change, and points Durometer A hardness change must meet the limits shown in Table B2, for each batch of seal material.

B6.2 Candidate fluid percent volume change, tensile change, elongation change, and points Durometer A hardness change must meet the limits shown in Table B3 for the candidate fluid to pass.

Figure B1: Specimen Setup



Note: A spreadsheet is available from the GM ATF Committee that contains all report formats.

Table B2: Elastomer Batch Certification Values

GM No./ SAE J2643	Reference Fluid	Volume Change Limits (%)	Durometer A Change Limits	Tensile MPa	Elongation (%)
ES-1/FKM-2	DEXRON® - VI ATF	0 to 4	-2 to +5	Report	Report
ES-2/FKM-3	DEXRON® - VI ATF	0 to 4	-3 to +2	Report	Report
ES-4/FKM-5	DEXRON® - VI ATF	0 to 4	-6 to 0	Report	Report
ES-7/AEM-2	DEXRON® - VI ATF	12 to 20	-14 to -2	Report	Report
ES-8/AEM-3	DEXRON® - VI ATF	4 to 10	-6 to +8	Report	Report
ES-10/ACM-1	DEXRON® - VI ATF	0 to 5	-4 to +3	Report	Report
ES-11/ACM-2	DEXRON® - VI ATF	9 to 14	-9 to -2	Report	Report
ES-14/HNBR	DEXRON® - VI ATF	0 to 4	1 to 10	Report	Report

Table B3: Elastomers Test Specification Limits

GM No./ SAE J2643	Volume Change Limits (%)	Durometer A Change Limits	Tensile MPa	Elongation (%)
ES-1/FKM-2	0 to 4	-2 to +5	Report	Report
ES-2/FKM-3	0 to 4	-3 to +2	Report	Report
ES-4/FKM-5	0 to 4	-6 to 0	Report	Report
ES-7/AEM-2	12 to 20	-14 to -2	Report	Report
ES-8/AEM-3	4 to 10	-6 to +8	Report	Report
ES-10/ACM-1	0 to 5	-4 to +3	Report	Report
ES-11/ACM-2	9 to 14	-9 to -2	Report	Report
ES-14/HNBR	0 to 4	1 to 10	Report	Report

Appendix C: Plate Friction Test

C1 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 SAE Number 2 Friction Test Machine.

C2.1.1 Clutch Plate Head Assembly. Greening Associates, Inc., or equivalent.

C2.1.2 Drive Motor. Delco 22 kW, 3600 rpm, 3-Phase, 326-UZ Frame, or equivalent.

C2.1.3 Flywheel Assembly. Flywheel, to provide $15.7 \text{ kJ} \pm 0.3 \text{ kJ}$ total energy, attached to motor shaft with taper-lock adaptor.

C2.1.4 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) $\times$ 8.0 mm Inside Diameter (ID) $\times$ 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 GM Powertrain (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 Micro Metering 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 × 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 × 125 mm length, to connect micro metering valve to the flow meter.

C2.5.3 Tygon Tubing. A 6.4 mm ID × 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 Presoak 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 micro metering valve with Poly-Flo tubing. Connect micro metering valve to flow meter with Tygon tubing with Step C2.5.2 and from the flow meter to the Swagelok fitting on the housing at the 7 o'clock port with Step C2.5.4. 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 air flow 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 $140^\circ\text{C} \pm 3^\circ\text{C}$. Within each cycle, the temperature may vary by $\pm 6^\circ\text{C}$.

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 Test Startup 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, 2, 3, 4, 5, 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 (± 5 scans) speeds at 300 rpm and 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 eight (8) scans, but needs to be determined for each specific FVC unit.

C4.2.3 Project the Frequency to Voltage Converter (FVC) speed from 1000 rpm to zero at the adjusted lockup scan found in Step 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 the preceding calculations.

C4.4 Stop Time is the elapsed time in milliseconds 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 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 Table C2. Sample analysis of test results is shown in 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:

C5.1.1 Midpoint Torque must be between 80 Nm and 105 Nm.

C5.1.2 Report End Torque.

C5.1.3 Delta Torque must be less than 30 Nm.

C5.1.4 Stop Time must be between 0.85 s and 1.05 s.

C5.1.5 Maximum Torque must be >90 Nm.

C5.2 Steel clutch plate and composition plate condition shall be equal to or better than that obtained with the Reference Fluid.

C5.3 Submit the following parts: Direct clutch fiber plates, Direct clutch steel plates.

Table C1: Test-Cycle Sequence

Event	Duration (s)	Cumulative Time (s)	Operation
1	10	0 to 10	Motor On, Clutch Plates Disengaged
2	5	10 to 15	Motor Off, Clutch Plates Engaged
3	5	15 to 20	Motor Off, Clutch Plates Disengaged

Table C2: Sample Record of Test Results

DEXRON®-VI Plate Friction - 200 HOURS

Program Code:
Status:
Test Cycles:
Test Performance:

Start Date:
EOT Date:
Run Number:
EOT Parts Condition:

Fiber Plates:
Steel Plates:
Delta Travel [mm]:

Test Time [h]	Cycles	Stop Time [s]		Midpoint Torque [N·m]		End Torque [N·m] Report	Maximum Torque [N·m] > 90	Max - Mid Torque [N·m] < 30		Shift Energy [kJ] 15.4 - 16.0
		0.85	1.05	80	105					
0.1	10									
1	180									
2	360									
3	540									
4	720									
5	900									
10	1,800									
15	2,700									
20	3,600									
25	4,500									
30	5,400									
35	6,300									
40	7,200									
45	8,100									
50	9,000									
55	9,900									
60	10,800									
65	11,700									
70	12,600									
75	13,500									
80	14,400									
85	15,300									
90	16,200									
95	17,100									
100	18,000									
105	18,900									
110	19,800									
115	20,700									
120	21,600									
125	22,500									
130	23,400									
135	24,300									
140	25,200									
145	26,100									
150	27,000									
155	27,900									
160	28,800									
165	29,700									
170	30,600									
175	31,500									
180	32,400									
185	33,300									
190	34,200									
195	35,100									
200	36,000									

Note: A spreadsheet is available from the GM ATF Committee that contains all report formats.

Figure C1: Stainless Steel Orifice (all dimensions are in millimeters (mm))

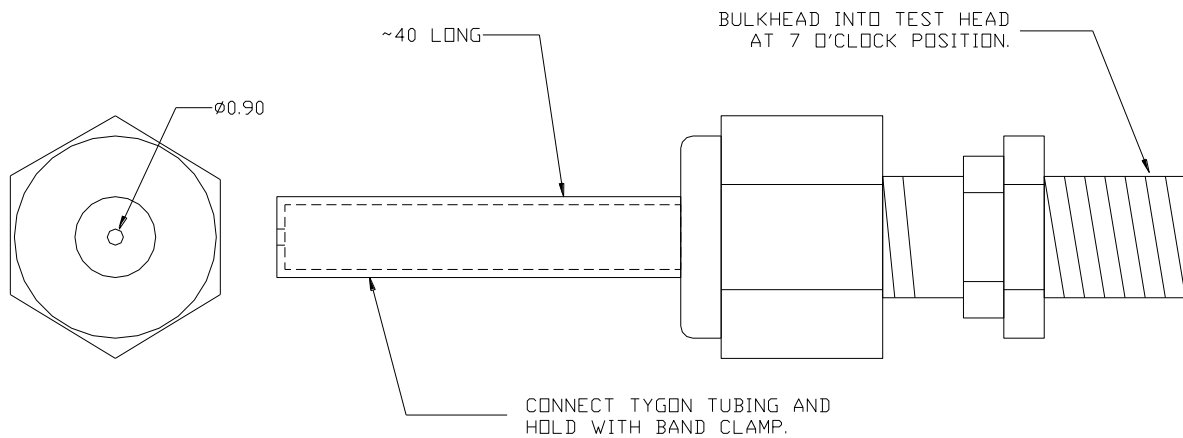
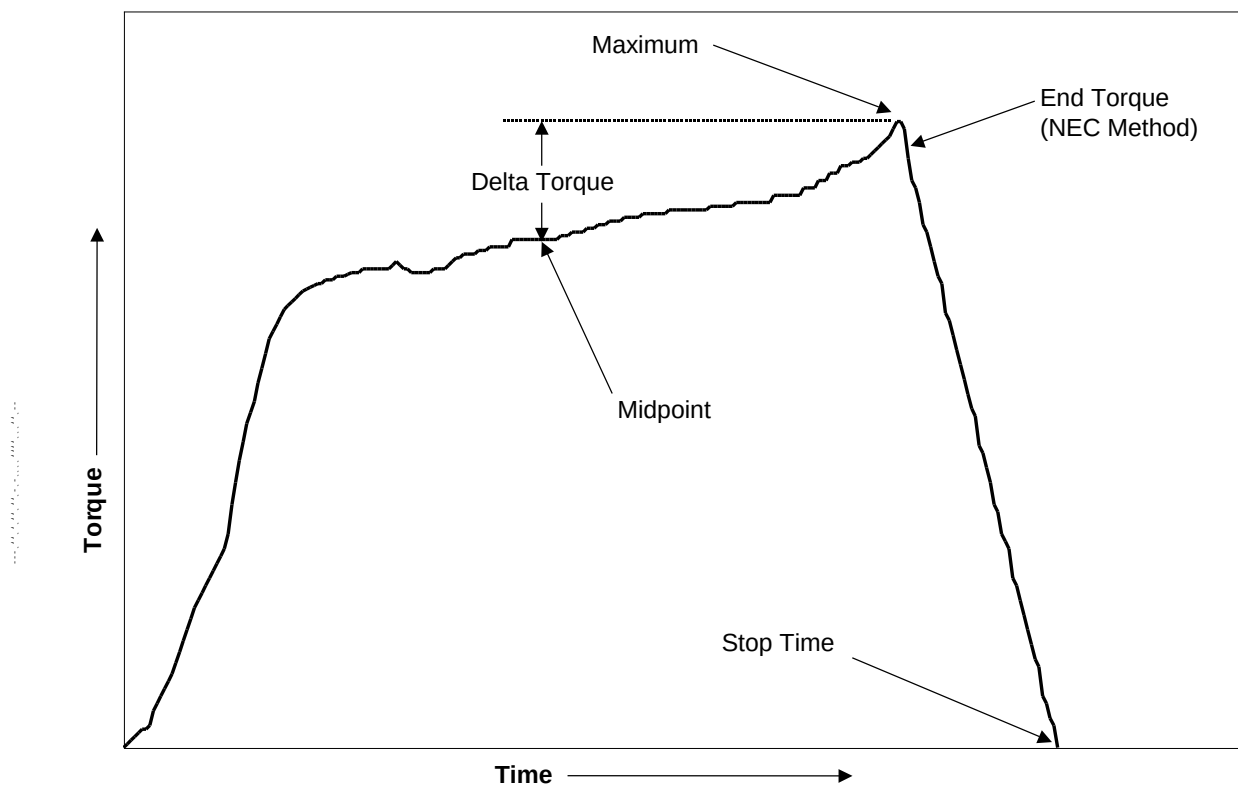


Figure C2: Sample Analysis of Test Results



Appendix D: Band Friction Test

Test should be conducted only for new chemistry or if requested by GM ATF Committee.

D1 Objective

D1.1 To determine the friction characteristics and durability of an automatic transmission fluid in a band friction test.

D2 Test Equipment

D2.1 SAE Number 2 Friction Test Machine.

D2.1.1 Band Head Assembly and Ring Force Gauge. Greening Associates, Incorporated, or equivalent.
Note: Ring Force Gauge used only for troubleshooting the test head.

D2.1.2 Drive Motor. Delco 22 kW, (3600 rpm, 3-phase, 326-UZ Frame, or equivalent).

D2.1.3 Flywheel Assembly. Flywheel, to provide $16.0 \text{ kJ} \pm 0.3 \text{ kJ}$ total energy, attached to motor shaft with Taper-Lock adaptor.

D2.1.4 Band Clutch Housing and Adaptors. Housing and adaptors to accommodate 4L60-E band and drum.

D2.2 Test Hardware.

D2.2.1 Band. A 4L60-E modified band, unsoaked, available from BorgWarner Automotive (Frankfort, Illinois).

D2.2.2 Drum. A 4L60-E Reverse Input Clutch Housing, Part Number 08681295, available from GM dealerships.

D2.3 Instrumentation and Recording Equipment.

D2.3.1 Torque Transducer. Lebow load cell, Model Number 3397 or equivalent.

D2.3.2 Pressure Transducer. Sensotech, Model Number TJU708-12, or equivalent.

D2.3.3 Data acquisition system with the capability of recording speed, torque, and pressure. Data is to be recorded at 1000 Hz without filtering.

D2.3.4 Speed Transducer. Electro Corporation, Model Number 3010AN, or equivalent.

D2.3.5 Temperature Measurement. Thermo-sensor, Iron-Constantan Thermocouple, Type 22TJ34-E-4-TGFS36, or equivalent. Leeds and Northrup Speedomax 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.

D2.4 Control Equipment. For installation information, contact Southwest Research Institute or PerkinElmer Automotive Research.

D2.4.1 Temperature Control. Precision Products and Control Research Control Valve (pneumatic-activated water temperature control), Type 755, Diaphragm 3 to 15, Trim J, Action ATC or equivalent.

D2.4.2 Timer. Texas Instruments, Model Number 510, or equivalent.

D2.4.3 Cycle Counter. Model Number CE600 BS 602, Automated Control Division, General Controls or equivalent.

D2.4.4 Controller. Allen-Bradley, Model Number 712 DAB 26-43, K-series, or equivalent.

D2.4.5 Time Delay Relay. Agastat Type NE-12 or equivalent.

D2.4.6 Regulator Air Apply. C. A. Norgren Company, Model Number 11-042-003 relieving type, or equivalent.

D2.4.7 Pressure Gauges. Ashcroft gauges, 0 kPa to 400 kPa for apply pressure, or equivalent.

D2.4.8 Micro Metering Valve. Nupro Company or equivalent.

D2.4.9 Calibrated Rotameter. Aalborg Instrument Company, Model Number FM032-15, or equivalent. Calibrate before each test.