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Fluid for Passenger Car Type Automatic Transmissions

1. ***Scope***—This SAE Information Report details some of the equipment and procedures used to measure critical characteristics of automatic transmission fluid (ATF) used in current automatic transmissions. It is intended to assist those concerned with the design of transmission components, and with the selection and marketing of automatic transmission fluids for the use in passenger car and light-duty truck automatic transmissions. The information contained herein will be helpful in understanding the terms related to properties, designations, and service applications of automatic transmission fluids.

2. *References*

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J110—Seals—Testing of Radial Lip

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 130—Method of Test of Copper Strip Corrosion by Petroleum Products
ASTM D 665—Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water
ASTM D 892—Foaming Characteristics of Lubricating Oils
ASTM D 1275—Method of Test for Corrosive Sulfur in Electrical Insulating Oils
ASTM D 1748—Method of Test for Rust Protection by Metal Preservatives in the Humidity Cabinet
ASTM D 2882—Indicating the Wear Characteristics of Petroleum and Non-Petroleum Hydraulic Fluids in a Constant Volume Vane Pump

2.1.3 GM PUBLICATIONS—Available from General Motors Corporation, GM ATF Committee, 30500 Mound Road, M/C 480-106-160, Warren, MI 48090.

GM-6137M—DEXRON®-IIE Automatic Transmission Fluid Specification, General Motors Corporation, August 1992
GM-6417M—DEXRON®-III Automatic Transmission Fluid Specification, General Motors Corporation, December 1998

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2.1.4 FORD MOTOR PUBLICATION—Available from Ford Motor Company, ATF Committee, 36200 Plymouth, Livonia, MI 48150.

MERCON®—Automatic Transmission Fluid Specification, Ford Motor Company, September 1, 1992
MERCON®-V—Automatic Transmission Fluid Specification, Ford Motor Company, February, 1996

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

Design Practices—Passenger Car Automatic Transmissions, SAE Advances in Engineering, Vols. 1 and 2
SAE Paper 710838—Automatic Transmissions Fluid Viscosity Requirements, E. D. Davison and M. L. Haviland, presented at St. Louis, MO, 1971
SAE Paper 740051—Automotive Transmission Fluids—Some Aspects on Friction, E. J. Friihauf, presented at SAE Automotive Engineering Congress, Detroit, MI, February, 1974
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SAE Paper 690768—Engine and Transmission Lubricant Viscosity Effects on Low Temperature Cranking and Starting, M. L. Haviland, SAE Transactions, Vol. 78 (1969)
SAE Paper 740053—DEXRON®-II Automatic Transmission Fluid Performance, M. L. Haviland, et al, presented at SAE Automotive Engineering Congress, Detroit, MI, February, 1974
SAE Paper 881673—The Aluminum Beaker Oxidation Test for MERCON® World-Wide Service ATF, P. A. Willermet and S. K. Kandah, 1988
SAE Paper 801363—The Prediction of ATF Service Life from Laboratory Oxidation Test Data, in SP 473, "Deterioration of Automotive Lubricants in Service," P. A. Willermet, et al; SAE Fuels and Lubricants Meeting, Baltimore, MD, October, 1980
SAE Paper 680438—Laboratory Methods for Predicting Viscosity Loss of Polymer Thickened Hydraulic Fluids, p. 74, R. L. Stambaugh and A. L. Preuss, Fuels and Lubricants, 1968 Paper, SAE Activity Proceedings, A P-1
SAE Paper 902148—Physical and Chemical Properties of a Typical Automatic Transmission Fluid, S. P. Kemp and J. L. Linden, 1990
SAE Paper 870356—Improving Transaxle Performance at Low Temperature with Reduced-Viscosity Automatic Transmission Fluids, J. L. Linden and S. P. Kemp, 1987
SAE Paper 922371—The Oxidation Stability of General Motors Proposed Factory-Fill Automatic Transmission Fluid, S. P. Kemp and J. L. Linden, 1992
SAE Paper 841214—Automatic Transmission Fluids—Properties and Performance, H. E. Deen and J. Ryer
SAE Paper 982674—Development and Introduction of Chrysler's New Automatic Transmission Fluid, D. W. Florkowski, T. E. King, A. P. Skrobul, J. L. Sumiejski, 1998

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2.2.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 92—Flash and Fire Points by Cleveland Open Cup
ASTM D 445—Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D 808—Chlorine in New and Used Petroleum Products (Bomb Method)
ASTM D 971—Interfacial Tension of Oil Against Water by the Ring Method
ASTM D 1298—Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D 2717—Thermal Conductivity of Liquids
ASTM D 2766—Specific Heat of Liquids and Solids
ASTM D 2780—Solubility of Fixed Gases in Liquids
ASTM D 2983—Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer
ASTM D 4951—Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry

2.2.3 DAIMLER CHRYSLER CORPORATION PUBLICATION—Available from Daimler Chrysler Corporation, Auburn Hills, MI 48326.

MS-9602—Automatic Transmission Fluid Specification, October, 1998

2.2.4 OTHER PUBLICATIONS

"Petroleum Refinery Engineering," 4th Edition by W. L. Nelson, New York, McGraw Hill Book Co., 1958, pp. 189–190
CRC Handbook of Lubrication, Volume II, Theory and Design, CRC Press, Inc., Boca Raton, Florida, 1984
J. B. Maxwell, "Data Book on Hydrocarbons," D Van Nostrand, New York, 1950

3. Definitions

3.1 Automatic Transmission Fluid—Automatic transmission fluid is a lubricating oil specifically designed for use in fully automatic transmissions. ATF consists of a base oil and an additive package which is added to enhance the properties of the base oil.

4. Basic Performance Requirements—Automatic transmission fluids are complex because they are intended to provide good transmission performance and durability, and serve a variety of functions: power transfer medium, hydraulic control fluid, heat-transfer medium, lubricant for sliding surfaces, gear lubricant, and lubricant for frictional surfaces. In order to ensure satisfactory performance in all intended applications under normal use and severe operating conditions, the fluid must satisfactorily meet the following requirements:

a. Miscibility with fluids used for initial OEM factory fill and with other OEM qualified fluids
b. Resistance to oxidation, including the formation of sludge and/or varnish
c. Operation from very low temperatures to very high temperatures
d. Component lubrication
e. Anti-foam performance
f. Protection against corrosion or rusting
g. Compatibility with elastomeric materials
h. OEM shift-feel characteristics
i. Stability of band and plate clutch friction characteristics over time and duty cycle at various temperatures
j. Anti-wear protection

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5. Properties of Automatic transmission Fluids

5.1 Physical and Chemical Properties—The physical and chemical properties of an automatic transmission fluid are important transmission design criteria. The transmission design engineer must have data on these properties to solve the many momentum and heat transfer calculations required to design today's complex automatic transmissions. In general, air solubility, thermal expansion, and specific heat increase with increasing temperature; whereas, surface tension, specific gravity, viscosity, bulk modulus, density, thermal conductivity, and electrical conductivity decrease with increasing temperature.

5.1.1 TYPICAL VALUE

a. Brookfield Viscosity, cP

–20 °C	600 to 1200
–40 °C	8000 to 20 000

b. Kinemtic Viscosity, cSt

40 °C	33
100 °C	7.0

c. Thermal Conductivity, W/m·K

40 °C	0.158
1000 °C	0.149

d. Coefficient of Thermal Expansion, mL/mL C

6×10^{-4}

e. Specific Gravity (Relative Density)

40 °C	0.8534
100 °C	0.8116

f. Specific Heat, J/kg·K

40 °C	2018
100 °C	2244

g. Density, g/cm^3

40 °C	0.853
100 °C	0.816

h. Bulk Modulus (Tangent Isothermal), MPa

37.8 °C @ 6.9 MPa	1372
37.8 °C @ 55.16 MPa	2034
37.8 °C @ 137.9 MPa	2930
93.3 °C @ 6.9 MPa	1110
93.3 °C @ 55.16 MPa	1613
93.3 °C @ 137.9 MPa	2530

i. Electric Resistivity, Ohms/cm

40 °C	$8.05 \cdot 10^9$
100 °C	$1.44 \cdot 10^9$

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j. Surface Tension, dynes/cm

93 °C	28.9
135 °C	25.5

k. Flash Point, °C — 190

l. Fire Point, °C — 210

5.2 Viscosity—Viscosity is the measure of a fluid's resistance to flow, and is one of the most important physical properties of a lubricant. The viscosity must be low enough at all operating temperatures to ensure adequate fluid flow and minimize viscous drag, but high enough at high temperatures to provide adequate fluid-film strength and prevent excessive internal transmission fluid leakage.

Viscosities chosen vary with the individual manufacturer, but are generally within the range of 6.5 to 8.5 cSt at 100 °C for fresh fluid. Both kinematic (centistokes) and absolute (centipoises) viscosities are determined on these fluids. The absolute viscosity divided by the density of the fluid equals the kinematic viscosity.

Fluid kinematic viscosity shall not fall below what is required for proper operation of the automatic transmission for which the fluid is used. Typical minimum viscosities during transmission operation range from 5 to 5.5 cSt at 100 °C.

Detailed discussion of fundamental principles and measuring equipment is available in current literature.

5.3 Chemical Content—An automatic transmission fluid consists of 85 to 90% base oil and 10 to 15% of a performance additive package containing chemical compounds necessary to impart the desired characteristics. The base oil may be naphthenic, paraffinic, hydro-treated or synthetic (or any combination) depending on the type of service, the needs of the transmission manufacturer and the oil company marketing plans for the automatic transmission fluid. The chemical compounds which form the additive package contain, in general: *dispersants* to control sludge and varnish; *corrosion inhibitors* to prevent the corrosion of bushings; thrust washers, and any other copper-based components; *anti-wear additives* to prevent wear of gears, bushings, washers, and other rubbing components; *friction modifiers* to improve shift-feel and friction material durability; *anti-oxidants* to control fluid degradation and increase fluid useful life; *pour point depressants* to lower the fluid pour point; *anti-foam additives* to reduce fluid foaming tendencies; *viscosity modifiers* to increase the viscosity index of the fluid; *seal swell additives* to insure elastomer compatibility and performance; and a *red dye* to identify the fluid as an automatic transmission fluid.

6. Oxidation and Thermal Stability—Oxidation is the chemical reaction of a substance with oxygen and is a major cause of automatic transmission fluid deterioration. The oxidation process involves the formation of free radicals, acidic compounds, and polar compounds which attack and degrade the ATF additive package, the ATF base oil, transmission elastomeric compounds, copper alloy components, and other sensitive transmission parts. Degrading an ATF can change the properties of the ATF significantly. Transmission designers must take such changes into consideration in the design of transmission components and fluid change interval recommendations.

The oxidation stability of ATF is affected by many parameters, such as: fluid temperature, aeration rate, additive system effectiveness, base oil type, and the presence of catalysts. Fluid temperature is probably the most critical parameter. Fluids used in automatic transmissions must be capable of operating at temperatures in excess of 150 °C in services such as trailer towing, and under conditions encountered in hot-weather high-density urban traffic.

Full-scale tests such as the DEXRON®-III Cycling Test and Oxidation Test, as well as bench tests such as the MERCON® Aluminum Beaker Oxidation Test (ABOT) are used for evaluating oxidation resistance of fluids.

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7. ***Friction Characteristics—***Fluid friction characteristics are important in automatic transmissions that utilize lubricated friction clutches and bands to change gear ratios. Extensive performance and durability testing is performed in actual transmissions and bench friction test apparatus. The General Motors and Ford Motor Company automatic transmission fluid specifications both require SAE No. 2 Friction Machine bench tests, dynamometer cycling tests, and vehicle shift-feel tests to characterize the fluid frictional properties and friction durability. No single fluid is known to provide the optimum friction requirements of all existing transmission types. The transmission designer must realize that the automatic transmission fluid formulator must compromise fluid friction properties of one clutch system to benefit another clutch system. For example, shifting clutches, in general, require a lower static coefficient of friction to maximize customer acceptance of the shift feel, whereas a holding clutch system (such as a forward clutch which is always engaged during forward motion) requires a higher static coefficient of friction to provide the necessary friction torque capacity and minimize clutch slippage. Maximizing the performance in one type of system compromises the performance in the other system.

Evolution of friction materials and consequent changes in reaction member surfaces, both clutch and band, has emphasized the friction-controlling role of automatic transmission fluid. Matching fluid friction characteristics properly with clutch and band materials is an important design consideration in all currently produced automatic transmissions.

8. ***Anti-Foam Characteristics—***Suppression of the foaming tendency of fluids in an automatic transmission is essential to proper operation. Foaming of the transmission fluid can produce erratic pump, converter, and hydraulic control response; foaming frequently results in fluid loss through the vent or fill tube. Measurement of foaming tendency and foam stability is used for evaluating fluid suitability. Techniques for evaluation fluid foaming tendencies include transmission tests, bench tests such as ASTM D 892, and the DEXRON®-III Foam Test.

9. ***Fluid/Seal Compatibility—***Automatic transmission fluid and transmission elastomeric materials must be compatible. Accepted design procedure involves the use of a reference elastomer to determine swell, shrink, and hardening tendencies of a candidate fluid. Seal materials must be selected to meet transmission performance requirements with established fluid formulations. Bench test procedures such as those outlined in the MERCON® and DEXRON®-III specifications are of value for screening purposes. Bench test devices for seal assemblies are also useful for determining compatibility; see SAE J110.

10. ***Score and Wear Resistance—***Current automatic transmission fluids contain anti-wear additives which inhibit scoring and wear of rubbing surfaces. Anti-wear additives must be effective and compatible with the variety of materials used in transmissions. Many bench test devices exist for evaluation of fluid anti-wear performance. The most popular tests among OEMs are ASTM D 2882 using a Vickers Pump and the FZG test apparatus.

11. ***Corrosion Properties—***Automatic transmission fluids generally contain corrosion inhibitors to assure protection of transmission components. As a result of the many components and materials involved, a variety of tests are used for evaluating moisture and/or chemical corrosion resistance of transmission fluids: ASTM D 1748, ASTM D 665, ASTM D 130, and ASTM D 1275.

12. ***Notes***

12.1 **Marginal Indicia—**The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

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Rationale—Not applicable.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Information Report details some of the equipment and procedures used to measure critical characteristics of automatic transmission fluid (ATF) used in current automatic transmissions. It is intended to assist those concerned with the design of transmission components, and with the selection and marketing of automatic transmission fluids for the use in passenger car and light-duty truck automatic transmissions. The information contained herein will be helpful in understanding the terms related to properties, designations, and service applications of automatic transmission fluids.

Reference Section

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ASTM D 892—Foaming Characteristics of Lubricating Oils

ASTM D 1275—Method of Test for Corrosive Sulfur in Electrical Insulating Oils

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SAE Paper 881673—The Aluminum Beaker Oxidation Test for MERCON® World-Wide Service ATF, P. A. Willermet and S. K. Kandah, 1988

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