



SURFACE VEHICLE INFORMATION REPORT

J3200™

OCT2022

Issued

2022-10

Fluid for Automotive Electrified Drivetrains

RATIONALE

Automotive manufacturers are turning to electrification to meet new regulatory requirements and consumer expectations to reduce greenhouse gases, in particular carbon dioxide. Electric-Mobility (e-Mobility) is becoming a larger and more prominent part of the transportation industry and by 2030 the majority of light vehicles will include some form of electrification. E-Mobility encompasses powertrain technologies that include hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV), and fuel cell electric vehicles (FCEV). In many of these powertrains, the lubricant is in contact with the electric motor (e-motor), and this architecture is anticipated to continue. While the first e-Mobility vehicles were designed around current lubricants, these technologies are evolving rapidly, and newer designs require new lubricant performance attributes. This information report provides lubricant guidance for electrical and mechanical component designers, component and/or vehicle manufacturers, and users of e-Mobility powertrains. The information will also be useful for lubricant formulators, fluid manufacturers, and marketers who supply fluid for e-Mobility drivetrain components. This area is evolving rapidly, and this report will be revised accordingly.

1. SCOPE

This SAE Information Report details the important new performance properties and suggested test methods for lubricants used in e-Mobility drivetrain components. The lubricants under discussion are those used in electrified drivetrains, mainly electric-transmissions and axles (e-transmissions and e-axles). The scope is limited to those geared systems in which an electric motor (e-motor) is immersed in the powertrain lubricant or comes in contact with the powertrain lubricant. Though the report focuses on new lubricant attributes, some information on conventional lubricant attributes is included. The information presented here will be helpful in understanding the similarities and differences between conventional (i.e., internal combustion engine (ICE)) and e-Mobility powertrain systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 Applicable Scientific and Engineering Publications

2.1.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

Gahagan, M., "Lubricant Technology for Hybrid Electric Automatic Transmissions," SAE Technical Paper 2017-01-2358, 2017, <https://doi.org/10.4271/2017-01-2358>.

Hunt, G., "New Perspectives on Lubricant Additive Corrosion: Comparison of Methods and Metallurgy," SAE Technical Paper 2018-01-0656, 2018, <https://doi.org/10.4271/2018-01-0656>.

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Documents

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Hunt, G., "New Perspectives on the Temperature Dependence of Lubricant Additives on Copper Corrosion," SAE International Journal of Fuels and Lubricants, Vol. 10, No. 2, June 2017, 521-527.

Kwak, Y., Cleveland, C., Adhvaryu, A., Fang, X. et al., "Understanding Base Oils and Lubricants for Electric Drivetrain Applications," SAE Technical Paper 2019-01-2337, 2019, <https://doi.org/10.4271/2019-01-2337>.

McFadden, C., Hughes, K., Raser, L., and Newcomb, T., "Electrical Conductivity of New and Used Automatic Transmission Fluids," SAE International Journal of Fuels and Lubricants, Vol. 9, No. 3, November 2016, 519-526.

Morgan, C., Cummings, J., Fewkes, R., and Jackson, J., "A New Method of Measuring Aeration and Deaeration of Fluids," SAE Technical Paper 2004-01-2914, 2004, <https://doi.org/10.4271/2004-01-2914>.

Tang, T., Devlin, M., Mathur, N., Henly, T., and Saathoff, L., "Lubricants for (Hybrid) Electric Transmissions," SAE International Journal of Fuels and Lubricants, Vol. 6, No. 2, June 2013, 289-294.

2.1.1.2 Relevant Journal Publications

Beyer, M., Brown, G., Gahagan, M.P. et al., "Lubricant Concepts for Electrified Vehicle Transmissions and Axles," Tribology Online, Vol. 14, No. 5, 2019.

Gahagan, M. and Einertshofer, C., "Lubricant Technology for Hybrid Electric Vehicle Automatic Transmissions," Liebl J. (eds) Reibungsminimierung im Antriebsstrang 2017. Proceedings. Springer Vieweg, Wiesbaden, 2017, 9-28.

Gahagan, M.P. and Hunt, G.J., "New Insights on the Impact of Automatic Transmission Fluid (ATF) Additives on Corrosion of Copper - The Application of a Wire Electrical Resistance Method." International Journal of Automotive Engineering, 7, 2016, 115-120.

Hunt, G.J., Gahagan, M.P., and Peplow, M.A., "Wire resistance method for measuring the corrosion of copper by lubricating fluids," Lubrication Science, 2017, 29:279-290.

2.1.1.3 Patent Publications

Tang, H., Devlin, M., Mathur, N., Henly, T., and Saathoff, L., "Hybrid Electric Transmission Fluid," US 8,400,030 B1 / EP 2650348 B1 (2013).

Watts, R. and Noles, J., "Methods for lubricating a transmission," US20080194442A1 (2017).

Watts, R., "Lubricant Test Method," US 9,488,612 B2 (2016).

Watts, R., "Power transmitting fluids with improved materials compatibility," US 9,732,301 B2 (2017).

2.1.2 Applicable Testing and Standards Publications

2.1.2.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester

ASTM D97 Standard Test Method for Pour Point of Petroleum Products

ASTM D130 Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension

ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D664	Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
ASTM D877	Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
ASTM D892	Standard Test Method for Foaming Characteristics of Lubricating Oils
ASTM D971	Standard Test Method for Interfacial Tension of Insulating Liquids Against Water by the Ring Method
ASTM D1169	Standard Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids
ASTM D1816	Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes
ASTM D2809	Standard Test Method for Cavitation Corrosion and Erosion-Corrosion Characteristics of Aluminum Pumps with Engine Coolants
ASTM D2983	Standard Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer
ASTM D3427	Standard Test Method for Air Release Properties of Hydrocarbon Based Oils
ASTM D4052	Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
ASTM D4951	Standard Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry
ASTM D5185	Standard Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
ASTM D5704	Standard Test Method for Evaluation of the Thermal and Oxidative Stability of Lubricating Oils Used for Manual Transmissions and Final Drive Axles (L-60-1)
ASTM D6082	Standard Test Method for High Temperature Foaming Characteristics of Lubricating Oils
ASTM D6147	Standard Test Method for Vulcanized Rubber and Thermoplastic Elastomer - Determination of Force Decay (Stress Relaxation) in Compression
ASTM D6304	Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fisher Titration
ASTM D6417	Standard Test Method for Estimation of Engine Oil Volatility by Capillary Gas Chromatography
ASTM D6443	Test Method for Determination of Calcium, Chlorine, Copper, Magnesium, Phosphorus, Sulfur, and Zinc in Unused Lubricating Oils and Additives by Wavelength Dispersive X-ray Fluorescence Spectrometry (Mathematical Correction Procedure)
ASTM D7214	Standard Test Method for Determination of the Oxidation of Used Lubricants by FT-IR Using Peak Area Increase Calculation
ASTM D7279	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids by Automated Houillon Viscometer
ASTM D7546	Standard Test Method for Determination of Moisture in New and In-Service Lubricating Oils and Additives by Relative Humidity Sensor
ASTM D7896	Standard Test Method for Thermal Conductivity, Thermal Diffusivity, and Volumetric Heat Capacity of Engine Coolants and Related Fluids by Transient Hot Wire Liquid Thermal Conductivity Method

- ASTM D8047 Standard Test Method for Evaluation of Engine Oil Aeration Resistance in a Caterpillar C13 Direct-Injected Turbocharged Automotive Diesel Engine
- ASTM E168 Standard Practices for General Techniques of Infrared Quantitative Analysis
- ASTM E1269 Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
- ASTM E2716 Standard Test Method for Determining Specific Heat Capacity by Sinusoidal Modulated Temperature Differential Scanning Calorimetry

2.1.2.2 CEC Publications

Available from The Coordinating European Council, Kellen Europe, Avenue de Tervueren 188 A, Postbox 4, 1150 Brussels, Belgium, Tel: +32 2 761 16 84, <https://cectests.org>.

- CEC L-45 Viscosity Shear Stability of Transmission Lubricants (Taper Roller Bearing Rig)
- CEC L-48 Oxidation Stability of Lubricating Oils used in Automotive Transmissions by Artificial Ageing (Laboratory Test)

2.1.2.3 IEC Publications

Available from IEC Regional Centre for North America, 446 Main Street, 16th Floor, Worcester, MA 01608, Tel: +1 508-755-5663, www.iec.ch.

- IEC 60156 Insulating liquids - Determination of the breakdown voltage at power frequency - Test method
- IEC 60247 Insulating liquids - Measurement of relative permittivity, dielectric dissipation factor (tan d) and d.c. resistivity
- IEC 60819-2 Non-cellulosic papers for electrical purposes - Part 2: Methods of test

2.1.2.4 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

- ISO 527 Plastics - Determination of tensile properties - Part 1: General principles

2.1.2.5 Japanese Industrial Standards Publications

Available from Japanese Industrial Standards, 1-3-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8901, Japan, www.jisc.go.jp/eng/.

- JIS K 2514 Lubricating oils - Determination of oxidation stability - Part 1: Oxidation stability of internal combustion engine oils (Indiana Stirring Oxidation Stability Test (ISOT))

2.1.2.6 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- SAE J1715 Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

3. DEFINITIONS/ABBREVIATIONS

AUTOMATIC TRANSMISSION FLUID (ATF): 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.

BATTERY ELECTRIC VEHICLE (BEV): A vehicle that uses batteries as an energy source coupled with an electric motor for propulsion.

ELECTRIC DRIVE UNIT (EDU): A powertrain which consists of an electric motor, a power electronics module, and a transmission.

ELECTRIC DRIVETRAIN FLUIDS (EDF): Liquids that are used in vehicle powertrains containing electric motors. Such fluids include transmission oils, battery coolants, and motor coolants.

ELECTRIC MOBILITY (e-MOBILITY) OR ELECTRIC VEHICLE (EV): A general term used to describe a vehicle using electric propulsion devices.

HYBRID ELECTRIC VEHICLE (HEV): A vehicle that uses both internal combustion engine (ICE) and electric propulsion devices.

INTERNAL COMBUSTION ENGINE (ICE): An engine that uses combustion as a propulsion method. Typically uses energy-dense fuels, such as gasoline, diesel or other liquid fuels from fossil fuel.

MANUAL TRANSMISSION FLUID (MTF): A lubricant used in manual transmissions.

ORIGINAL EQUIPMENT MANUFACTURER (OEM): The manufacturer responsible for the design and final assembly of a piece of equipment, such as a battery electric vehicle.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV): A vehicle that uses an internal combustion engine as well as batteries for propulsion sources. The battery can be charged by the ICE or by plugging into an electric power source.

POLYAMIDE (PA): A polymer with repeating units linked by amide bonds. This engineering thermoplastic has a number of automotive uses, such as engine covers and electrical connectors.

POLYETHER ETHER KETONE (PEEK): A thermoplastic polymer used in demanding applications such as electrical insulation.

POLYPHENYLENE SULFIDE (PPS): An organic polymer consisting of aromatic rings linked by sulfides. Because of its high thermal resistance, PPS is used in lithium-ion batteries, electric motor wires, insulating films, and other parts.

POLYPROPYLENE (PP): A polymer consisting of repeating propylene units. It is widely used in automotive parts such as battery cases and trays.

4. GENERAL FLUID PERFORMANCE PROPERTIES

Conventional vehicles (i.e., those without e-motors) employ a transmission and a drive axle (differential) which takes input torque and speed from the internal combustion engine (ICE) and delivers the selected output torque and speed to the drive wheels. The transmissions in these vehicles can be broadly classified as manual or automatic, and the fluids used in these applications are quite different and correspondingly classified. Axle fluids comprise another unique category and their characteristics depend on whether they utilize a hypoid gear. Regardless of the specific requirements unique to a particular design, such as friction specifications for the various shifting clutches, torque converter clutches, metal pulley, and belt combinations, etc., all these lubricants must meet several basic performance requirements. The list below highlights the major common lubricant requirements.

Conventional Powertrain Lubricant Performance Properties:

- Ability to lubricate mechanical components such as gears, bushings, and bearings
- Ability to transfer heat away from working components
- Anti-wear protection
- Hydraulic control medium for actuation of valve body and clutch systems
- Resistance to thermal and oxidative breakdown, including the formation of sludge and/or varnish
- Ability to protect from deposits
- Operation from very low temperatures to very high temperatures
- Protection against rust
- Protection against copper corrosion
- Protection against aeration and foaming
- Compatibility with elastomeric and other non-ferrous materials
- Proper engagement characteristics when friction couples are incorporated to transfer torque
- Miscibility with fluids used for initial OEM factory fill and with other OEM qualified fluids
- Shear stability

5. SPECIFIC PERFORMANCE REQUIREMENTS FOR ELECTRIFIED POWERTRAINS

E-Mobility vehicles employ an electric drive unit (EDU) which consists of an electric motor, an inverter (the power electronics), and a gear box (transmission or axle). There is a trend to integrate these parts. Electric motors can be positioned in several locations along the powertrain, as illustrated in Figure 1.