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## European Brake Fluid Technology

**Foreword**—The SAE has established engineering guidelines which describe the tests and minimum performance properties for motor vehicle brake fluids. Such information is contained within SAE J1703 (Motor Vehicle Brake Fluid), SAE J1704 (Borate Ester Based Brake Fluid), and SAE J1705 (Low Water Tolerant Brake Fluids). Brake fluids which meet the criteria set forth by these documents are non-mineral oil based. Common compositions may include synthetic glycol ethers, borate esters, or silicone.

The requirements for brake fluids are further described within the Federal Motor Vehicle Safety Standard 116, prepared by the National Highway Traffic Safety Administration. Within this Standard, motor vehicle brake fluids are classified as DOT 3, DOT 4, DOT 5, or DOT 5.1 based upon minimum wet and dry boiling points, viscosity characteristics, and in the DOT 5/5.1 case, base fluid chemistry.

Developments in Europe have resulted in the introduction of brake fluids which offer enhanced wet and dry boiling point performance. Employing both conventional and novel chemistry, these fluids are becoming an increasingly important factor in the European marketplace. The purpose of this document is to provide an overview of the performance and characterization of these fluids and the general trend toward the utilization of such technology. In utilizing the information provided, it should be recognized that field experience and engineering knowledge is greatest for DOT 4 followed by Super DOT 4. DOT 5.1 fluids have more recently been introduced and application experience continues to be gained. Additionally, the silicon ester technology described has well-established experience in racing and continues to be evaluated for use in passenger cars.

1. **Scope**—This SAE Information Report provides an overview of brake fluid technology developed and marketed in Europe which offers enhanced wet and dry boiling point performance. The information contained within this document applies to hydraulic brake fluids utilized in automotive braking systems which are designed to be compatible with SAE J1703 (DOT 3) and SAE J1704 (DOT 4) fluids. The report reflects details received as of September 1998.

### 2. References

2.1 **Applicable Publications**—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 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1703—Motor Vehicle Brake Fluid  
SAE J1704—Borate Ester Based Brake Fluid  
SAE J1705—Low Water Tolerant Brake Fluids

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2.1.2 FMVSS PUBLICATION—Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FMVSS No. 116—Motor Vehicle Brake Fluids

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

SAE 740126—Brake Fluid Temperatures Obtained in Alpine Vehicle Trials

2.2.2 ISO PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 4925—Road vehicle—Non petroleum based brake fluids

**3. Background**—Borate ester based DOT 4 brake fluids developed between 1960 to 1970 have been commonplace in Europe, and to a lesser extent North America, for many years. The requirements established within the FMVSS 116 dictate that these fluids possess a higher dry and wet equilibrium reflux boiling point than fluids classified as DOT 3. Introduction of DOT 4 fluids in Europe was designed to better accommodate the engineering trends and service requirements of European vehicles which are operated more often at high-speed conditions and are subject to regular safety inspections.

Since 1970, there has been an extension of the borate ester technology such that a wide range of fluids is now available offering higher wet and dry boiling point performance compared to DOT 4. Brake fluids are now being manufactured and marketed in Europe with properties which bridge the gap between DOT 4 and DOT 5 fluids.

These so called Super DOT 4 fluids are gaining increased acceptance and are now utilized by some original equipment manufacturers in Europe for initial and service fill applications.

In the 1980's, brake fluids based upon silicon esters were introduced which offer further improvement to the boiling point properties beyond Super DOT 4 fluids. Such fluids possess very high wet and dry boiling point performance and have been utilized successfully in racing applications.

Also in the 1980's, fluids were developed in Europe which meet the performance requirements of DOT 5, but do not utilize silicone-based chemistry. These fluids are now classified as non-silicone-based fluid DOT 5.1. Such fluids employ borate ester bases resulting in formulations which are miscible with SAE J1703 fluids and meet the performance criteria of all established DOT categories. Non-silicone-based DOT 5.1 brake fluids are being offered in the aftermarket in small but increasing quantities.

**4. European Market Trends**—It is estimated that over three-quarters of the European market for brake fluid is represented by DOT 4 product. In Germany close to 100% of the brake fluid market is covered by DOT 4, Super DOT 4, and DOT 5.1 fluids. DOT 4 fluids are recommended by most European vehicle manufacturers. DOT 3 fluids represent a minor percentage and are utilized in commercial applications and in certain passenger car vehicles.

DOT 5 fluid is not widely used in Europe. Usage is confined to some US, OEM, and military recommendations and some special applications such as in classic cars that are kept for occasional use. DOT 5.1 fluids are more increasingly used but the low temperature performance properties of DOT 3 or DOT 4 are generally viewed as satisfactory for existing applications.

The largest growth area for brake fluid performance in Europe is the Super DOT 4 category. This type of fluid is used by some original equipment manufacturers as an initial fill and service fill fluid. Super DOT 4 fluids are considered by certain manufacturers as being necessary to cope with the high temperatures attained in braking systems under European driving conditions, in cars of modern design and to extend service intervals.

5. **Brake Fluid Characteristics**—Table 1 presents the respective performance and characterization of brake fluid technology in Europe versus established DOT 3, DOT 4, and DOT 5 benchmarks. The primary points of differentiation are dry and wet boiling point and low-temperature viscosity.

TABLE 1—BRAKE FLUID PARAMETERS

Property	DOT 3 Requirement	DOT 4 Requirement	Super DOT 4 Accepted Limit	Super DOT 4 (Typical)	DOT 5 Requirement	Silicone <sup>(1)</sup> DOT 5 (Typical)	DOT 5.1 Requirement	Borate Ester DOT 5.1 (Typical)	Silicon Ester (Typical)
Dry ERBP (°C)	>205	>230	>260	270	>260	>310	>260	>265	310
Wet ERBP (°C)	>140	>155	>180	185	>180	>310	>180	185	260
Kinematic Viscosity, mm <sup>2</sup> /s -40 °C	<1500	<1800	<1800	1350	<900	250	<900	850	1350

1. Silicone fluids do not possess a true boiling point.

- 5.1 **Super DOT 4 Fluids**—Super DOT 4 brake fluids are commonly based upon mixtures of glycol ether and borate ester chemistry. Although an official specification has not been established to date (and is not planned), it is commonly accepted that such fluids should attain a minimum dry boiling point of 260 °C and a minimum wet boiling point of 180 °C as required by the DOT 5 (silicone brake fluid) or DOT 5.1 (non-silicone brake fluid) category. Low-temperature viscosity requirements are that of DOT 4. Super DOT 4 fluids in the European market are typically higher in dry and wet boiling point (270 °C ERBP/185 °C wet ERBP) with low-temperature viscosity meeting DOT 3 criteria. Additionally, Super DOT 4 fluids have recently been introduced which achieve 200 °C wet ERBP and DOT 3 low-temperature viscosity characteristics.
- 5.2 **Borate Ester DOT 5.1 Fluids**—Revisions to FMVSS 116 have been published to accommodate non-silicone based DOT 5 fluids. The fluids are categorized as DOT 5.1 and, unlike DOT 5 fluids which are dyed purple, can vary from colorless to amber in color. DOT 5.1 brake fluids are based predominantly on borate ester chemistry. Such fluids typically possess wet/dry boiling points and low-temperature viscometric properties within the DOT 5 specification limits. Borate ester chemistry allows for SAE J1703 DOT 3 and DOT 4 fluid miscibility.
- 5.3 **Silicon Ester Fluids**—Silicon ester based brake fluids typically achieve boiling point characteristics above the requirements of the DOT 5 specification. Silicon esters do not have the same chemical structure as silicones and differ in physical properties. Silicon esters are similar in structure to borate esters. Figure 1 reflects the respective compositions of silicone and borate/silicon ester based fluids.

Silicon esters are miscible with glycol ethers and borate ester type fluids and achieve all performance criteria established by SAE J1703, SAE J1704, and FMVSS 116 for DOT 3 and DOT 4 fluids. At present, these fluids are not utilized by manufacturers but are employed in racing.

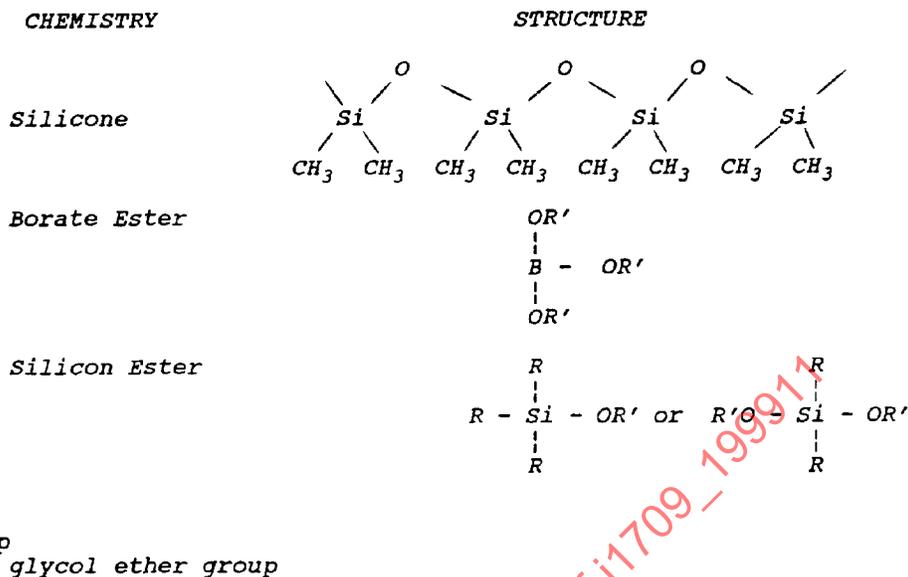


FIGURE 1—RESPECTIVE COMPOSITIONS OF SILICONE AND BORATE/SILICON ESTER BASED FLUIDS

6. **Performance and Testing**—Borate Ester Super DOT 4 and DOT 5.1 brake fluid manufactured in Europe all meet the minimum performance requirements set forth within SAE J1703, J1704, and FMVSS 116 for the respective DOT categories. Along with boiling point and viscometric requirements, this includes evaluations for chemical stability, high- and low-temperature stability, evaporation, water tolerance, fluid and elastomer compatibility, oxidation resistance, corrosion protection, and stroking properties.

In addition to the evaluation previously described, testing beyond SAE and Federal requirements has been conducted within Europe to support advanced brake fluid technology. This includes the following:

- a. Testing to motor manufacturers' specifications
- b. Alpine Trials
- c. Fleet Trials
- d. Water ingress into different hose/fluid combinations
- e. Hose Burst Tests
- f. Additional corrosion testing

Evaluation of fluid performance versus motor vehicle manufacturers' specifications will generally impose additional requirements beyond those established by SAE J1703, SAE J1704, and FMVSS 116. These can include additional stroking tests and corrosion protection performance to provide improved safety margin during actual field use. Vehicle manufacturer specifications which include performance limits and test procedures are proprietary to equipment and fluid manufacturers.

Alpine trials are commonly conducted within Europe to monitor brake fluid temperatures and brake system protection under arduous mountain descent conditions. Such conditions have been found to result in extremely high brake fluid temperatures in passenger cars and supported the movement to brake fluid formulations possessing improved boiling point performance.