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THE AUTOMOBILE INDUSTRY has recognized for many years that there are certain disadvantages to glycol brake fluids. These fluids pick up water during their service life, producing a corresponding decrease in their boiling point and an increase in their low temperature viscosity and corrosion tendencies. Until recently, there has not been a material available which does not possess these disadvantages, while remaining compatible with current brake systems.

Modified dimethylpolysiloxanes (silicone based brake fluids) have demonstrated performance characteristics in bench tests and field tests that make them excellent candidates for use as automotive brake fluids. These performance characteristics offer improvements over current brake fluids while retaining compatibility with current brake systems. Consequently, their use will benefit not only the automobile industry, but also the vehicle owner. This paper will demonstrate these improved performance characteristics.

WATER ABSORPTION

Over a six month period, glycol brake fluid samples were removed from 25 cars in use near Waterford, New York (1)*. These cars ranged in ages of 1-13 years and were both domestic and imported. Table 1 illustrates the amount of water present in the brake fluid as a function of the car's age. The reason for peak values in three year old cars is not clear. Possible explanations are poor statistical sample or servicing (replacing brakes and brake fluids) after about three years' service. It is clear from these data that the water content of automotive brake fluids increases with length of service. Harvey, Milliken, and Forthofer (2) also observed the increase in water content of brake fluid with time in service. Work by the Office of Vehicle Systems Research of the National Bureau of Standards (now the Safety Systems Laboratory of DOT) has demonstrated that permeation of water through the brake hoses is responsible for the majority of water transmission into the brake fluid (3).

Since highways in the northeastern states are liberally treated with salt during the winter months, tests were run to determine the extent of water and salt diffusion through automobile brake hoses. Salt on the highways causes severe corrosion of car bodies and could accelerate corrosion in the brake systems.

Two tests were run wherein a commercial glycol base brake fluid and a silicone brake fluid were placed in elastomeric brake hoses (4). Both ends of the liquid-filled hoses were capped, the hoses bent into a U shape and immersed in water or a 5% NaCl aqueous solution. Table 2 illustrates that both water and salt penetrate the brake hose filled with glycol fluid. In 65% of the samples taken from in-use automobiles at Waterford, New York, the average amount of chloride found was 36 ppm with an overall range of 22-50 ppm. Table 3 illustrates the water pickup of fluids in a controlled field test at Waterford, New York (5). The glycol fluids picked up

*Numbers in parentheses designate References at end of paper.

ABSTRACT

Silicone based brake fluids have demonstrated performance characteristics that are improvements over current brake fluids. They do not absorb water through elastomeric brake hoses, and their boiling point and low temperature viscosity do not change in service. The tendency toward brake system corrosion and the vapor pressure of silicone brake fluids are minimal. Silicone brake fluids are compatible with brake system components and will function as an effective brake fluid even when mixed with glycol brake fluids.

Table 1 - Glycol Brake Fluid Water Content versus Auto Age

Auto Age, years	Water Content, %
1	1.1, 1.3, 1.5, 1.6, 1.8 Average 1.5
2	2.2, 3.0, 3.9 Average 3.0
3	2.3, 4.1, 8.8, 9.3, 11.1 Average 7.1
4	1.6, 2.2, 2.8, 4.1 Average 2.6
5	3.0, 4.2, 5.7 Average 4.3
7	2.9, 4.8 Average 3.9
9	4.8, 5.0 Average 4.9
13	4.0

Table 2 - Water and Chloride Penetration of Automotive Brake Hoses

Analytical Results–Water

	Before Test	Immersion, 7 days	Immersion, 35 days
Glycol Base Fluid	0.15%	3.03%	6.9%
Silicone Base Fluid	0.01%	0.03%	0.03%

Analytical Results–Chloride

	Before Test	Immersion, 6 days
Glycol Base Fluid	<1 ppm Cl	143 ppm
Silicone Base Fluid	<1 ppm Cl	<1 ppm Cl

from 3-7% water in this test, while the highest water pickup for a silicone brake fluid was less than two tenths of a percent.

Silicone brake fluids are nonhygroscopic and will not solublize water; therefore, they do not act as a reservoir to water and salt diffusing through an elastomeric brake hose. This lack of water and salt acceptance through a brake hose is a definite advantage for silicone brake fluids.

EQUILIBRIUM REFLUX BOILING POINT

The National Highway Traffic Safety Administration has shown (6) that brake fluid can reach temperatures as high as 129-146°C (265-295°F) on long downgrades with frequent brake applications. Thus, the equilibrium reflux boiling point of the brake fluid becomes very important as a measure of its vapor-locking tendencies. As can be seen from Fig. 1, the boiling point of conventional fluids changes with the amount of absorbed water. Silicone brake fluids, on the other hand, are

Table 3 - Water Pick-up in Service

Vehicle No.	Fluid	Vehicle Mileage	Length of Service, months	% Water
8	Glycol	51,961	28	4.4
10	Glycol	27,531	23	6.7
16	Glycol	22,931	22	3.2
21	Glycol	10,318	21	3.7
24	Silicone	22,972	18	0.07
25	Silicone	5,712	17	0.07
29	Silicone	25,422	13	0.16
31	Silicone	28,158	10	0.05
32	Silicone	4,181	14	0.03

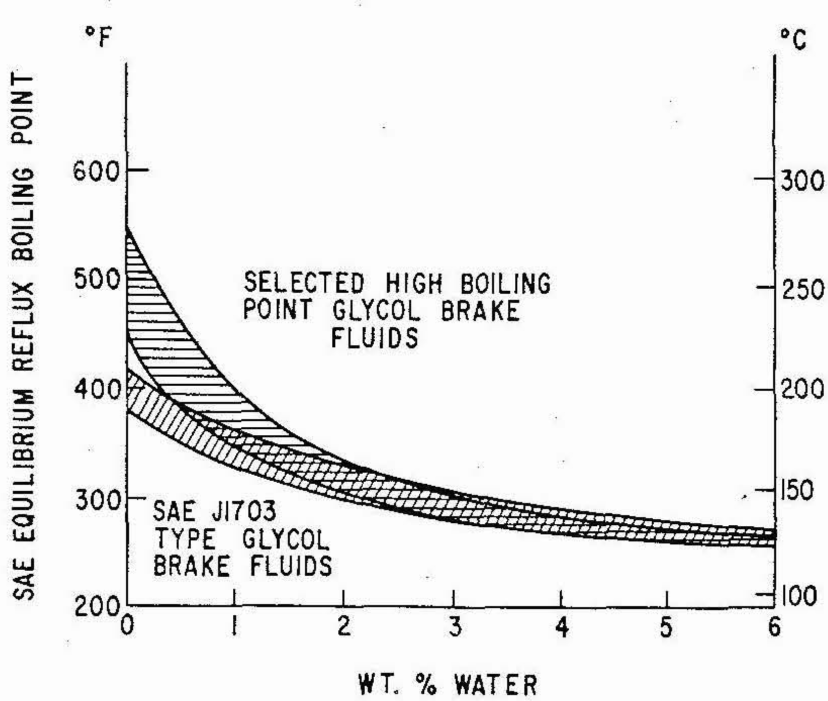

Fig. 1 - SAE ERBP versus water content

made up largely of nonvolatile high molecular weight species which do *not* absorb water and do not boil at temperatures below 260°C (500°F).

Field test results (5) have also shown that the equilibrium reflux boiling point of glycol fluids decreases in service, while silicones maintain their original high boiling point (Table 4).

LOW TEMPERATURE VISCOSITY

Harvey, Milliken, and Forthofer (2) illustrate the effect that water has on the -40°C (-40°F) viscosity of conventional fluids (Fig. 2). Viscosities in the range of 1500-2500 centistokes and higher are possible at -40°C (-40°F) with as little as 3% water in the brake fluid. These high viscosities can have an effect on vehicle braking performance. Silicone brake fluids, on the other hand, do not absorb water and their low temperature viscosity is not affected in this way. Silicone brake fluids do offer a relatively small viscosity change with temperature as illustrated by Fig. 3. Because of its low viscosity temperature coefficient (about 0.6 or less), the low temperature viscosity of silicone brake fluids can be changed by changing the room temperature viscosity. A silicone brake fluid with a viscosity of 50 centistokes at 25°C (78°F) will exhibit a viscosity of less than 500 centistokes at -40°C (-40 °F) while the viscosity of a 100 centistoke brake fluid at 25°C (78°F) will be less than 1000 centistokes at -40°C (-40°F).

CORROSION RESISTANCE

Present fluids are satisfactory as far as resistance to corrosion is concerned. A silicone brake fluid should certainly be no worse than the present fluid. Table 5 illustrates the results of the SAE J1703 corrosion test with two typical silicone brake fluids. These data indicate that in-service corrosion of brake components may be decreased by the use of silicone brake fluids. As shown earlier, these fluids do not absorb water and salt through the elastomeric brake hoses and, therefore, the tendency for corrosion and gumming, especially during standby storage, should be reduced.

VAPOR PRESSURE

The concept of vapor pressure has little significance when applied to polymers such as silicones. A single chemical compound has a distinct boiling point at a given pressure and a single characteristic vapor pressure curve. However, silicone brake fluids are polymers of mixed high molecular weights and, therefore, have no true boiling point and no true reproducible vapor pressure curve. Volatility and measurable vapor pressure come from the lower molecular weight fractions present. Generally, at temperatures below 200°C (392°F) silicone brake fluids exhibit vapor pressure of less than 50 mm and, at temperatures below 100°C (212°F), vapor pressure of less than 10 mm.

Table 4 - ERBP in Service

Vehicle No.	Fluid	Vehicle Mileage	Length of Service, months	In Service ERBP °C	In Service ERBP °F
8	Glycol*	51,961	28	155	311
10	Glycol	27,531	23	127	260
16	Glycol	22,931	22	135	275
21	Glycol	10,318	21	148	298
24	Silicone**	22,972	18	>300	>572
25	Silicone	5,712	17	>300	>572
29	Silicone	25,422	13	>300	>572
31	Silicone	28,158	10	>300	>572
32	Silicone	4,181	14	>300	>572

*All glycol fluids are DOT-3 type fluid. Minimum ERBP 205°C (401°F).

**All silicone fluids had an original ERBP of >300°C (>572°F).

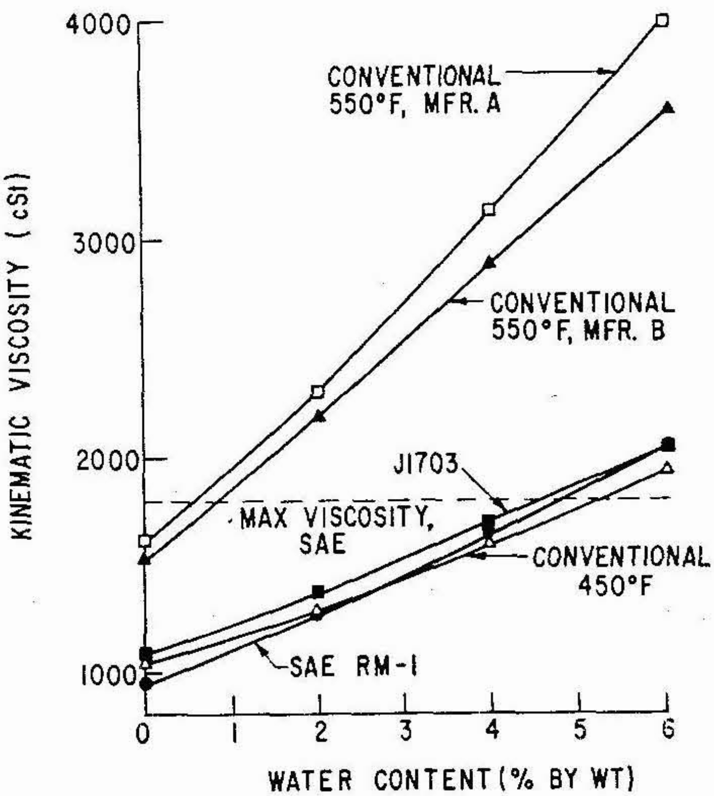

Fig. 2 - Effect of water on -40°C (-40°F) viscosity

Table 5 - SAE J1703 Corrosion Test Coupon Weight Change in mg/cm²

	Silicone A	Silicone B
Tinned iron	+0.03	+0.02
Steel	+0.03	+0.03
Aluminum	+0.07	+0.07
Cast iron	+0.04	+0.06
Brass	+0.03	+0.02
Copper	+0.01	+0.01

COMPATIBILITY

Compatibility can be separated into two distinct categories: compatibility between the fluid and the existing components of a brake system—particularly the elastomeric seals—and compatibility of silicone brake fluid with glycol brake fluid.

The SAE Nonconventional Brake Fluids Task Group has established a tentative specification SAE J1705 for silicone based brake fluids. This specification spells out the requirements of compatibility between the elastomeric components of a brake system and the silicone fluid (Table 6). The current silicone based brake fluids meet the established swelling requirements with SBR cups, ethylene propylene (EP) seals, natural rubber cups, and Neoprene brake hose stock. Table 7 shows some of the elastomer compatibility results obtained in a round robin evaluation conducted by the SAE Nonconventional Brake Fluids Task Group (7).

Fluid tests have also been performed with mixtures of silicone and glycol brake fluids in automotive brake syst These two fluids are not miscible and form two l[illegible]s w allowed to stand. This phenomenon does not de[illegible] fr the ability of such a two phase system to act as an effect brake fluid. In one field test (Table 8), over 40,000 mile driving has been reported using a 50/50 silicone/glycol t phase system in the brake system with no reported diffi (5).

FIELD TESTS

The amount of data collected from field tests could be subject of another paper. However, in one field test (5) has been at least 500,000 miles of driving experience wi silicone-based brake fluids in many types of domestic an

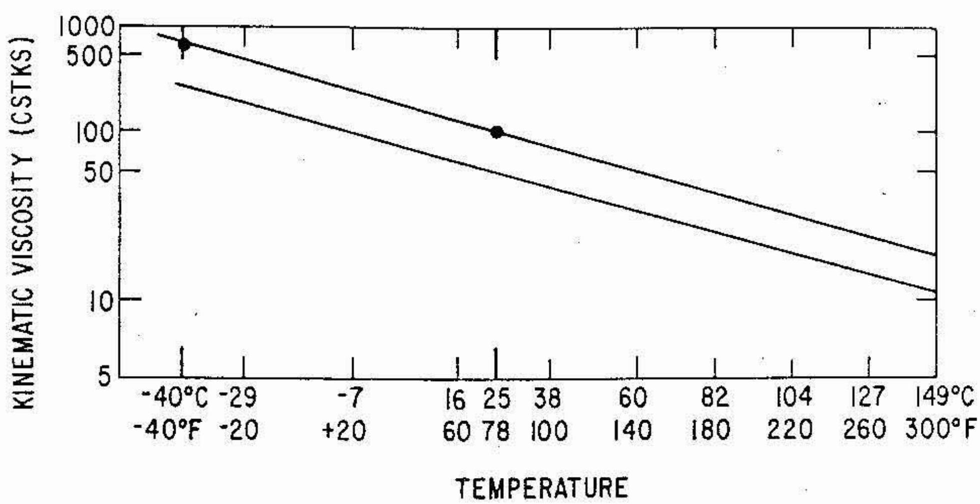

Fig. 3 - Silicone brake fluid viscosity versus temperature

Table 6 - Summary of SAE J1705 Effect on Rubber Requirements

Elastomer Type	Test Specimen	Volume Change	Hardness Change
SBR	SAE RM-3 CUP	+5 to +20	0 to -15
Neoprene	SAE RM-68 Neoprene slab stock	0 to +6	+3 to -10
EPDM	SAE RM-69 EPDM slab stock	0 to +10	0 to -10
Natural	SAE natural rubber cup	+5 to +20	0 to -10

Table 7 - Typical Silicone Brake Fluid Effect on Rubber

Elastomer Type	Volume Change		Hardness Change	
	Silicone A	Silicone B	Silicone A	Silicone B
SBR	+11.4	+12.1	-10	-11
Neoprene	+ 2.3	+ 1.1	- 4	- 2
EPDM	+ 7.7	+ 8.3	- 6	- 7
Natural	+13.5	+14.0	- 7	- 7

Table 8 - Fleet Test with 50/50 Silicone/Glycol in the Brake

Vehicle No. 1
- Fluid-50/50 Silicone/Glycol
- ERBP of mixed fluid
  - New 178C
  - After 11 months, 12,680 miles 163C
  - Test terminated-car sold
- No problems reported during test. All samples from the car separated into 2 phases on standing.

Vehicle No. 22
- Fluid-50/50 Silicone/Glycol
- ERBP of mixed fluid
  - New 208C
  - After 20 months, 32,750 miles 200C
- Car still running
- No problems reported
- All samples from the car separated into two phases [illegible]and

foreign automobiles under the sometimes severe weather conditions found in upstate New York. There has not been one single reported brake system failure due to silicone brake fluids in the three year test period. Most participants in the test report faster braking system response in cold weather.

SUMMARY

The performance characteristics of silicone based brake fluids can be summarized by the following statements.

1. Silicones do not absorb water and salt through automotive brake hoses.
2. Silicone brake fluids do not show a decrease in boiling point or a large increase in low temperature viscosity due to water absorption.
3. Brake systems filled with silicone brake fluids should be less susceptible to corrosion than those filled with conventional brake fluids.
4. Silicone brake fluids have very low vapor pressure.
5. Silicone brake fluids are compatible with the elastomers in the current brake systems and also with current conventional brake fluids.
6. Field tests have shown silicone based brake fluids to perform satisfactorily in many types of automobiles.

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