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Report 2164

SILICONE BRAKE FLUIDS: TWO-YEAR FIELD TEST

January 1976

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fluid with respect to metal corrosion. At ATC, tests on the two water intolerant silicone fluids were discontinued because of possible crystallization at low temperatures and were replaced midway through the first year with fluids having improved low-temperature properties. These fluids were superior to the MIL-H013910 arctic brake fluid after one year's service.

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SILICONE BRAKE FLUIDS: TWO-YEAR FIELD TEST

I. INTRODUCTION

The Army uses three types of automotive hydraulic fluids. These are covered by Specifications VV-B-680, "Brake Fluid, Automotive," for operations ranging from plus 55°C to minus 30°C; MIL-H-13910, "Hydraulic Fluid, Polar Type, Automotive, All Weather," for operation to minus 55°C; and MIL-P-46046, "Preservative Fluid, Automotive Brake System and Components," for brake systems of vehicles in storage and as a packaging fluid for wheel and master cylinders.

In 1967, because of the success of silicone fluids in hydraulic applications, makers of these fluids became interested in developing a single all-purpose fluid to overcome the water sensitivity of current fluids as well as to provide all-weather and preservative properties. The producers were encouraged to develop such a fluid since it would reduce maintenance and logistics costs substantially by providing increased brake system reliability; eliminating the need to change fluids for CONUS, Arctic, or storage conditions; and replacing the three existing fluids with one. During the next three years, deficiencies such as poor lubrication properties and rubber incompatibility which showed up in laboratory testing were lessened by the incorporation of small amounts of additives to the fluids. Laboratory evaluation, including stroking tests based on SAE specifications and storage tests for packaging and preservative properties, established that a silicone fluid could be formulated to provide heavy-duty and arctic-type performance and the preservative properties required by the current brake fluids and packaging fluid. The remaining question of suitability under all operating conditions required the conduct of a field test. During March and April 1973, therefore, tests were initiated to obtain experience with silicone fluids in operational vehicles.

Three silicone fluids (two water-intolerant and one water-tolerant) and a conventional specification fluid were installed in the brake systems of vehicles operated by Army units in three areas representing climatic extremes: tropical (Tropic Test Center, Panama Canal Zone); extreme cold (Arctic Test Center, Fort Greeley, Alaska); and desert (Yuma Proving Ground, Arizona).

The first year inspection was covered in USAMERDC Report 2132.* This portion of the test showed that the silicone brake fluids will equal or exceed the performance obtained from current specification fluids. The most significant improvement was found in Panama where numerous malfunctions due to corrosion occurred with brake systems using the specification fluid. There were no malfunctions with the silicone brake fluids.

* James H. Conley, Robert Jamison, and Charles B. Jordan, "Silicone Brake Fluids: One-Year Field Test," USAMERDC Report 2132, AD A012849 (Feb 75).

In Yuma the general appearance of the systems with silicone fluids was somewhat better than those with the conventional fluids. However, no malfunctions occurred which were attributable to the fluids.

The same situation held true for the Alaskan portion of the test where the performance of the system which was operated with the silicone fluid for one year was comparable to those systems with the specification fluid.

This report contains the final results of the two-year field test of silicone brake fluids operating at TTC and YPG and the one-year test of two low-temperature fluids operating at ATC.

II. DETAILS OF TEST

Three silicone fluids (two water-intolerant and one water-tolerant) and a conventional specification fluid (VV-B-680) were used in Panama and Yuma. These silicones were used initially in Alaska. Testing on the water-intolerant fluids was discontinued midway through the test, however, because of possible crystallization at temperatures below minus 46°C (50°F), and two new silicones with improved low-temperature properties were substituted and compared to conventional MIL-H-13910 arctic brake fluid.

For these tests, new brake cylinder sets were packaged with fluid in the laboratory and shipped with new brake hoses to the appropriate area for installation on M 151, ¼-ton cargo vehicles and M 715, 1¼-ton vehicles. After one year, half the cylinders from Panama and Yuma were torn down on site and examined for condition of the metal parts and rubber compounds and for appearance of the fluid. Samples of the fluids were sent back to the laboratory. The cylinders were then reinstalled and brought back to level with fresh fluid, and the vehicles were returned to operation. Cylinders of the other vehicles were left undisturbed. After two years' operation all cylinders, hoses, and samples of the fluid were returned to the laboratory for final evaluation. In Alaska, all cylinders were returned for examination after one year's operation. In addition to visual examination of the fluids, water pick-up was determined by the Karl Fisher Method.

III. DISCUSSION

In Panama (Table 1), three of the four vehicles using the VV-B-680 fluid completed the second year of operation without a brake malfunction (numerous failures occurred during the first year) even though the cylinders were severely corroded. The fourth vehicle was reported missing in February 1975, and no data are available. During examination of the brake parts, a strong odor of gasoline and swelling of the

Table 1. Panama Inspection

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-7 USA2A055369 ¾-Ton	VV-B-680	May 75/24	3980	Cylinder bore--satisfactory Piston--satisfactory Spring--satisfactory Secondary Cup--slight scuffing Primary Cup--slight scuffing	All cylinders--heavy rusting under pistons Pistons--heavy rust and gum Cups--light scuffing All springs--slight rusting	Moderate sediment % H ₂ O 10.4	Moderate-to-heavy sediment % H ₂ O 15.7 12.2 10.3 7.8
HQ-37 USA03M83668 1½ Ton	VV-B-680	May 75/24	3084	Cylinder--heavy rusting under secondary cup Piston--satisfactory Secondary cup--slight scuffing; appears to be swollen; hard to remove Primary cup--slight scuffing; odor of gasoline	Cylinders--1 wheel cylinder heavy rust under both pistons 1 wheel cylinder heavy rust under 1 piston; slight-to-moderate rusting under 1 piston 2 wheel cylinders--moderate rusting under both pistons; more under cups Pistons--3 pistons heavy gumming; 3 pistons moderate; 2 pistons light gumming Cups--2 moderate; 6 light scuffing Springs--satisfactory	Slight sediment Gasoline odor % H ₂ O 5.3	Heavy sediment % H ₂ O 11.6 4.8 10.1 4.1

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-3B USA03MB2568 1 1/2-Ton *	V.V.-B-680	May 75/24	1829	Cylinder heavy rusting under secondary cup	Cylinders heavy rusting in 3 cylinders.	Slight sediment	Moderate-to-heavy sediment
				Piston satisfactory	moderate rusting under pistons in 1 wheel cylinder	Gasoline odor	% H ₂ O 7.6
				Spring satisfactory		% H ₂ O 6.8	2.5
				Secondary cup slight scuffing; appears to be swollen; hard to remove	Pistons heavy rusting and gumming on piston in 3 wheel cylinders; moderate rusting and gumming on pistons in 1 wheel cylinder		5.3
				Primary cup moderate scuffing; light scoring at base	Cups slight scuffing		10.3
Gasoline odor							
HQ-21 USA02AJ1069 3/4-Ton *	U.C.	May 75/24	5100	Cylinder satisfactory	Cylinder satisfactory	Slight sediment	Slight sediment
				Piston satisfactory	Pistons satisfactory	% H ₂ O 0.5	% H ₂ O 0.0
				Spring satisfactory	Springs satisfactory		0.1
				Secondary cup satisfactory	Cups light scuffing		0.0
				Primary cup slight scoring			0.0
Gasoline odor							
HQ-40 USA03MB6468 1 1/2-Ton	U.C.	May 75/24	681	Cylinder satisfactory	Cylinder satisfactory	Clear	Clear
				Piston satisfactory	Piston slight scoring and wear; no corrosion	Gasoline odor	% H ₂ O 0.0
				Secondary cup slight scuffing	Cups slight scuffing and scoring	% H ₂ O 0.3	0.1
				Primary cup moderate scoring and scuffing over secondary port; both cups swollen	Springs satisfactory		0.0
							0.3

Table 1 Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-29 USA03M00968 1 1/2-Ton *	U.C.	May 75/24	5150	Cylinder--satisfactory Piston--satisfactory Springs--satisfactory Secondary cup--slight scuffing Primary cup--slight scuffing; both cups swollen	Cylinder--normal wear Pistons--slight scoring Cups--slight scuffing Springs--satisfactory	Clear Gasoline odor 1/2 H ₂ O 0.0	Clear 1/2 H ₂ O 1.4 0.7 0.1 0.2
HQ-8 USA2D6897 1/2-Ton	D.C.	May 75/24	4747	Cylinder--satisfactory Piston--satisfactory Secondary cup--satisfactory Primary cup--slight scoring and moderate scuffing Spring and check valve--slight corrosion	Cylinders--2 wheel cylinders show heavy corrosion in center bottom with normal wear in piston area. 2 wheel cylinders show slight corrosion in center bottom with normal wear in piston area	Clear 1/2 H ₂ O 0.0	Moderate sediment 1/2 H ₂ O 0.0 0.0 0.0 0.0
HQ-17 USA250738 1/2-Ton *	D.C.	May 75/24	3718	Cylinder--overall staining Piston satisfactory Secondary cup--satisfactory Primary cup--slight scoring	Cylinder--3 wheel cylinders satisfactory; 1 wheel cylinder stain in center Pistons--1 moderate scoring; 3 slight scoring; 4 normal wear Cups--1 moderate scuffing; 7 slight scuffing Springs--satisfactory	Clear 1/2 H ₂ O 0.0	Slight sediment 1/2 H ₂ O 0.5 0.0 0.1

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date:		Visual Inspection		Fluid Appearance	
		Months of Service	Total Mileage	Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-17 (Continued) USA250738 1/4-Ton				Spring and check valve slight-to-moderate corrosion	6 normal wear Cups--all slight scuffing		
HQ-27 USA03M02168	D.C.	May 75/24	1378	Cylinder--satisfactory Piston--satisfactory Cups swollen; secondary had to be forced out Strong odor of gasoline present Spring--satisfactory	Springs--satisfactory Cylinders--2 satisfactory; 2 show slight corrosion in bottom center Pistons--2 moderate scoring; 6 normal wear Cups--satisfactory Springs--satisfactory	Clear Gasoline Odor % H ₂ O 0.5	Clear % H ₂ O 0.0 0.0 0.3 0.0
HQ-35 USA03M74468 1/4-Ton	D.C.	May 75/24	10,733	Cylinder--satisfactory Piston--satisfactory Cups swollen; secondary had to be forced out Strong odor of gasoline present Spring--satisfactory	Cylinders 1 wheel cylinder slight pitting on bottom center; 1 wheel cylinder slight scoring at outside edge of one end; 2 wheel cylinder--satisfactory Pistons--5 moderate scoring 3 normal wear Cups--5 slight scuffing; 3 satisfactory Springs--satisfactory	Clear Gasoline Odor % H ₂ O 0.0	Clear % H ₂ O 0.1 0.0 0.0 0.3

*

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-1 USA250771 ¼-Ton *	G.E.	May 75/24	3245	Cylinder bore - satisfactory Piston - satisfactory Spring - moderate corrosion Secondary cup - satisfactory Primary cup - slight scuffing	2 Wheel Cylinders - slight stain; 1 wheel cylinder - slight stain at one end; moderate stain at the other end. 1 wheel cylinder - heavy rust both ends and center 2 Pistons - slight stain and scoring; 4 pistons moderate stain; 2 pistons heavy corrosion	Slight sediment Clear % H ₂ O 1.5	Moderate sediment Amber % H ₂ O 6.7 1.8 0.4 1.3
HQ-2 USA250730 ¼-Ton	G.E.	May 75/24	5328	Cylinder bore - moderate scoring left bottom Piston - satisfactory Secondary cup - satisfactory Primary cup - satisfactory Spring - heavy corrosion	2 Cylinders - heavy rust both ends; 1 cylinder heavy rust one end; 1 cylinder - moderate rust and stain both ends Cups - satisfactory 2 Springs - heavy corrosion; 2 springs - slight corrosion	Heavy sediment % H ₂ O 4.7 0.1 0.5 0.0 4.2	Heavy sediment % H ₂ O 1.1 0.5 0.0 4.2
HQ-31 USA03M156068 ¼-Ton *	G.E.	May 75/24	2766	Cylinder - heavy rusting at secondary Piston - satisfactory Secondary cup - heavy scuffing	All cylinders - heavy rust in piston area All pistons - heavy corrosion Cups - 4 moderate scuffing; 4 slight scuffing	Slight sediment % H ₂ O 1.9	Moderate sediment % H ₂ O 3.2 0.7 1.6 1.6

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-31 (Continued) USA03M56068 1½-Ton				Primary cup—slight scuffing and scoring Spring—satisfactory	Springs—moderate rusting		
HQ-36 USA03M82668 1½-Ton	G.E.	May 75/24	4753	Cylinder—slight rusting in secondary cup area Piston—covered with black residue Secondary cup—slight scuffing Primary cup—slight scuffing Spring—completely detuned	Cylinder—3 heavy rust both ends; 1 moderate rust both ends Pistons—3 heavy corrosion; 4 moderate corrosion; 1 light corrosion Cups—slight scuffing and scoring Springs—slight corrosion; 4 boots show polymer buildup	Black Gasoline Odor Cr H ₂ O: 2.1	Heavy sediment Cr H ₂ O: 6.2 3.0 1.3 0.4

* Vehicle inspected at one year. New fluid added.

secondary cup were noted in the master cylinders from the two 1/4-ton vehicles. Water pick-up in the fluid ranged from 2.5 to 15 percent.

The vehicles using the silicone fluids continued to operate trouble free during the second year. The cylinders with the Union Carbide (U.C.) and Dow Corning (D.C.) water-intolerant fluids were satisfactory, with the latter showing a tendency to stain and have slightly more corrosion of metal parts. The cylinders with the General Electric (G.E.) water-tolerant fluid showed considerably more corrosion than those with other silicone fluids but were still substantially better than those with the VV-B-680 fluid. The odor of gasoline and swelling of the secondary cup in the master cylinder were also noted in the 1/4-ton vehicles using the U.C. and D.C. fluids. It was not present in the vehicles using the G.E. fluid. The rubber cups had a slight-to-moderate scoring and scuffing with all the fluids under test.

In an investigation to determine the cause for the gasoline odor in the master cylinders of some of the 1/4-ton vehicles, test personnel learned from TTC personnel that the affected vehicles had been equipped with deep water fording kits. These kits vent the master cylinder into the air breather which, in turn, allows gasoline vapors to enter the master cylinder and cause the rubber cup swelling that was noted.

At Yuma Proving Ground, Arizona, all vehicles except one containing U.C. silicone fluid completed the second year of operation without a brake malfunction. Those brake parts were discarded inadvertently and the cause of malfunction could not be determined. Fluid performance was comparable to the Panama portion of the test. Visual inspection and pertinent data are shown in Table 2.

At Fort Greeley, Alaska, the vehicle containing MIL-H-13910, Arctic Brake Fluid, showed heavy corrosion of the wheel cylinders and scoring of the pistons. All the vehicles with the water-intolerant silicones gave comparable results, showing only slight stain of the cylinders and, with the exception of one vehicle using the D.C. fluid, showed no piston scoring (Table 3).

Photographs illustrating representative cylinders from each climatic area are shown in Figures 1 through 8.

Table 2. Yuma Inspection

Vehicle Number and Type	Fluid	Inspection Date/		Total Mileage	Visual Inspection		Fluid Appearance	
		Months of Service	Oct 74/18		Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
SP-208 03B00469 1 1/4-Ton	VV-B-680	Oct 74/18	6986	No master cylinder returned	All cylinders show very heavy rust and corrosion	Heavy sediment	% H ₂ O-5.1 5.3	
03J02268 1 1/4-Ton	VV-B-680	Apr 75/24	4255	Moderate-to-heavy rust at bottom of cylinder bore	All cylinders show heavy rust and corrosion	Heavy sediment	% H ₂ O-3.9 3.0 1.9 2.3	
*				Rust in reservoir	All pistons--heavy corrosion and gum deposit			
				Secondary cup--heavy scuffing	Cups--moderate scuffing			
				Primary cup--heavy scuffing	Springs--2 satisfactory; 2 detinned			
MS-6 2J8585 1/4-Ton	VV-B-680	May 75/24	8069	Cylinder--moderate stain at forward end of bore	All cylinders show heavy rusting	Moderate sediment	Two drops recovered	
*				Piston--satisfactory	All pistons show heavy gumming	% H ₂ O-3.7	% H ₂ O-5.8 11.5	
				Secondary cup--heavy scuffing	All springs--detinned			
				Primary cup--heavy scuffing				
				Spring--satisfactory				

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MIS-2 2K6397 ¾-Ton	VV-B-680	May 75/24	9117	Cylinder showed slight sludge	All cylinders—heavy rust and corrosion	Heavy sediment	Moderate sediment
				Piston—satisfactory	All pistons—heavy corrosion and gumming	% H ₂ O—3.0	% H ₂ O—4.5
				Secondary cup—moderate scuffing			3.9
				Primary cup—slight scuffing and scoring	All cups—slight-to-moderate scuffing		8.4
					All springs—detinned		3.7
				Spring—partially detinned			
03J43568 1½-Ton	U.C.	Vehicle turned in for salvage; date not known; 12 months +	3347+	Cylinder—satisfactory	Left front cylinder—slight stain	Moderate sediment	Slight sediment in two wheels.
				Piston—satisfactory	Pistons—slight scoring	Fluid clear	clear amber in the other two
				Secondary cup—moderate scuffing	Cups—satisfactory	% H ₂ O—0.5	% H ₂ O—0.6
				Primary cup—moderate scuffing and scoring	Spring—satisfactory		0.0
				Spring—satisfactory	Right front cylinder—slight stain		0.0
					Pistons—1 normal wear, 1 slight scoring		0.4
					Cups—slight scuffing		
					Spring—satisfactory		
					Left rear cylinder—slight stain		
					Piston—slight scoring		
					Cups—slight scuffing		
					Spring—satisfactory		

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
03J43568 (Continued) 1/4-Ton							
TP-593 3D67368 1/4-Ton	U.C.	Apr 75/24	1104	Cylinder bore--satisfactory Piston--satisfactory Secondary cup--slight scuffing Primary cup--moderate scuffing Spring--satisfactory	Right rear cylinder--slight stain Pistons--slight scoring Cups--slight scuffing Springs--satisfactory	Moderate sediment % H ₂ O--0.0	Fluids clear, slight sediment % H ₂ O--0.2 0.1 0.0 0.0
					Left front cylinder--heavy stain in fluid area Pistons--slight scoring Cups--slight scuffing Spring--satisfactory Right front cylinder--slight stain Pistons--1 slight scoring 1 slight-to-moderate scoring Cups--moderate scuffing Spring--satisfactory Left rear cylinder--small area near bleeder valve shows heavy rust Pistons--normal wear Cups--slight scuffing Spring--satisfactory		

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
TP-593 (Continued)							
3D67368							
1 1/4-Ton							
					Right rear cylinder— slight stain		
					Pistons—slight scoring		
					Cups—satisfactory		
					Spring—partially detinned		
MS-1	U.C.	May 75/24	6797	Cylinder—moderate stain at top of bore	Left front cylinder— slight stain and wear on both ends	Clear	Clear
2N1756				Piston—satisfactory		% H ₂ O-0.4	% H ₂ O-0.7
1/4-Ton				Secondary cup—slight scuffing	Pistons—slight stain		0.2
*				Primary cup—moderate scuffing	Cups—slight scuffing		0.2
				Spring—satisfactory	Spring—satisfactory		0.4
					Right front cylinder— same as left front		
					Left rear cylinder—same as left front		
					Right rear cylinder— same as left front		
MS-5	U.C.	May 75/24	6463	Cylinder—moderate stain at top of bore	Left front cylinder— slight stain and slight wear both ends	Clear	Clear
2J8403				Piston—satisfactory		% H ₂ O-0.4	% H ₂ O-0.3
1/4-Ton				Cups—satisfactory	Pistons—1 slight stain and scoring		0.2
				Spring—satisfactory	Cups—slight scuffing		0.3
					Spring—satisfactory		

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection		Total Mileage	Visual Inspection		Fluid Appearance	
		Date/ Months of Service	Master Cylinders		Wheel Cylinders	Master Cylinders	Wheel Cylinders	
MS-5 (Continued) 2J8403 1/4-Ton				6317*	Master cylinder and right rear wheel cylinder replaced at 21 1/2 months; parts not returned	Right front cylinder-- same as left front Pistons-- 1 satisfactory; 1 slight scoring Cups--slight scuffing Spring--satisfact ; Left rear cylinder-- same as left front except both pistons show slight scoring Right rear cylinder-- slight stain		
MS-25 03F50668 1 1/4-Ton	D.C.	Apr 75/24		4413	Cylinder--satisfactory Piston--satisfactory Secondary cup--severe cracking at base Primary cup--slight scuffing and scoring Spring--satisfactory	Spring--satisfactory Left front cylinder-- moderate stain in fluid area. Slight scoring at one end Pistons-- 1 slight scoring; 1 heavy scoring Cups--satisfactory Spring--satisfactory Right front cylinder-- slight stain in fluid area	Clear % H ₂ O 0.1 0.1 0.3 0.0	

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-25 (Continued) 03F50668 1½-Ton				Pistons—normal wear	Pistons—normal wear		
				Cups—slight scuffing	Cups—slight scuffing		
				Spring—satisfactory	Spring—satisfactory		
				Left rear cylinder— slight stain overall	Left rear cylinder— slight stain overall		
				Pistons—normal wear	Pistons—normal wear		
				Cups—slight scuffing	Cups—slight scuffing		
				Spring—satisfactory	Spring—satisfactory		
				Left rear cylinder— slight stain overall	Left rear cylinder— slight stain overall		
				Piston—normal wear	Piston—normal wear		
				Cups—slight scuffing	Cups—slight scuffing		
				Spring—satisfactory	Spring—satisfactory		
				Right rear cylinder— slight stain in fluid area	Right rear cylinder— slight stain in fluid area		
				Pistons—1 satisfactory 1 slight scoring	Pistons—1 satisfactory 1 slight scoring		
				Cups—satisfactory	Cups—satisfactory		
				Spring—satisfactory	Spring—satisfactory		
MS-8 2P8730 ¾-Ton	D.C.	May 75/24	8462	Cylinder—satisfactory	Left front cylinder— slight stain and scoring in piston area	Clear	Clear
				Piston—satisfactory		% H ₂ O—0.1	% H ₂ O—1.3 0.2

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-8 (Continued) 2F8730 ¼-Ton				Secondary cup--moderate scuffing	Pistons--slight stain		
				Primary cup--slight scuffing	Cups--slight scuffing		
				Spring--satisfactory	Spring--satisfactory		
					Right front cylinder-- slight stain		
					Piston--slight scoring		
					Cups--satisfactory		
					Spring--satisfactory		
					Right rear cylinder-- slight scoring on both ends		
					Pistons--1 slight scoring; 1 slight stain		
					Cups--slight scuffing		
MS-70 2R0799 ¼-Ton					Spring--satisfactory		
					Left front cylinder-- slight stain	Moderate sediment	Clear
					Pistons--moderate scoring	Fluid clear	% H ₂ O--0.0 0.1
					Cups--slight scuffing	% H ₂ O--0.3	
					Primary cup--moderate scuffing and scoring		
					Spring--satisfactory		
					Right front cylinder-- slight stain on both ends		

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-70 (Continued) 2R0799 1/4-Ton							
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
					Pistons—1 slight stain; 1 moderate stain		
					Cups—slight scuffing		
					Spring—satisfactory		
					Left rear cylinder—slight wear both ends		
					Pistons—slight scoring		
					Cups—slight scuffing		
					Spring—detinned		
					Right rear cylinder—spot of corrosion on bottom in fluid area		
					Pistons—moderate stain		
					Cups—slight scuffing		
					Spring—satisfactory		
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-21 03M41668 1/4-Ton	G.E.	Apr 75/24	11514	Cylinder—slight overall rusting	Left front cylinder—slight scoring both ends	Heavy sediment	Moderate sediment
				Piston—satisfactory	Pistons—heavy scoring	Fluid green	Fluid amber
				Secondary cup—satisfactory	Cups—moderate scuffing	% H ₂ O—0.8	% H ₂ O—0.3
				Primary cup—slight chipping; 3 blisters	Spring—detinned		0.9
				Spring—detinned	Right front cylinder—		1.1
							0.1

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance																																		
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders																																	
MS-21 (Continued) 03M41668 1/4-Ton					Wheel Cylinders slight stain																																			
					Pistons--1 heavy scoring 1 slight scoring																																			
					Cups--slight scuffing																																			
					Spring--detinned																																			
					Left rear cylinder-- slight overall stain; light pitting on one end																																			
					Pistons--1 moderate scoring; 1 light scoring																																			
					Cups--slight scuffing																																			
					Spring--detinned																																			
					Right rear cylinder-- moderate scoring on end; slight scoring on other																																			
					Pistons moderate to heavy scoring																																			
					Cups--slight scuffing																																			
					Spring--detinned																																			
	MS-26 03E92768 1/4-Ton	G.E.	Apr 75/24	8751	Cylinder--moderate overall rusting in bore	Left front cylinder-- slight pitting at one end; other satisfactory	Heavy sediment	Moderate-to- heavy sediment																																
Piston--satisfactory									Fluid black	Fluid dark amber																														
											Secondary cup--slight scuffing	% H ₂ O--0.0	Fluid dark amber																											
															% H ₂ O--0.9	Fluid dark amber																								
																		1.4	Fluid dark amber																					
																					0.0	Fluid dark amber																		
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Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-26 (Continued) 03E92768 1 1/2-Ton				Primary cup slight scuffing	Cups- slight scuffing		
				Spring- partially detuned	Spring- partially detuned		
					Right front cylinder slight pitting both ends		
					Pistons- moderate scoring		
					Cups- satisfactory		
					Spring- detuned		
					Right rear cylinder- slight scoring one end; other satisfactory		
					Pistons- 1 heavy scoring; 1 slight-to-moderate scoring		
					Cups- satisfactory		
					Spring- satisfactory		
				Left rear cylinder- slight pitting one end; slight scoring both ends			
				Pistons- heavy scoring			
				Cups- satisfactory			
				Spring- detuned			

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-3 2F0458 ¼-Ton	G.E.	May 75/24	6606	Cylinder - slight overall stain Piston - satisfactory Secondary cup - very slight scuffing Primary cup - moderate to heavy scoring Spring - partially detinned	Left front cylinder - slight overall stain Pistons - 1 heavy etch, 1 slight scoring Cups - slight scuffing Spring - detinned Right front cylinder - moderate stain in fluid area Pistons - normal wear Cups - slight scoring Spring - detinned	Two drops Clear C ₁ H ₂ O 0.0	
					Left rear cylinder - slight overall stain Pistons - moderate scoring Cups - slight scuffing Spring - detinned		
					Right rear cylinder - slight overall stain Pistons - slight scoring Cups - slight scuffing Spring - detinned		

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-7 2J8621 ¼-Ton	G.E.	Apr 75/24	7599	Cylinder—slight overall stain Piston—satisfactory Secondary cup—satisfactory Primary cup—slight scuffing and scoring Spring—partially detinned	Left front cylinder—moderate stain in fluid area Piston—1 moderate scoring; 1 slight scoring Cups—light scuffing Spring—detinned Right front cylinder—moderate to heavy rusting in fluid area and under one piston Piston—1 slight scoring; 1 moderate scoring Cups—1 slight scuffing; 1 moderate scuffing Spring—detinned Left rear cylinder—moderate rust in fluid area Pistons—1 light scoring; 1 moderate scoring Cups—slight scuffing Spring—detinned Right rear cylinder—moderate rusting in fluid area Pistons—1 light scoring; 1 moderate scoring Cups—slight scuffing Spring—detinned	Heavy sediment ¼ H ₂ O 0.3 0.0 0.0	Slight sediment ¼ H ₂ O 0.0 0.0 0.0

* Vehicle inspected at one year. New fluid added.

Table 3. Alaska Inspection

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
USA03N36068 1/4-Ton	MIL-H-13910	Dec 75/12	3319	Cylinder bore - ring of corrosion under secondary cup.	2 cylinders - heavy corrosion and sludge in fluid area	Dark	Dark
				Overall stain of bore	1 cylinder - moderate to heavy corrosion; one spot on side and top. Heavy spots under one cup	% H ₂ O - 1.1	Moderate sediment
				Piston - heavy corrosion and stain			% H ₂ O - 2.4
				Secondary cup - moderate scuffing	1 cylinder - moderate stain and heavy sludge in fluid area		1.9
				Primary cup - slight scoring and scuffing. Slight chipping at base	3 pistons - normal wear		2.4
				Spring - detuned	2 pistons - moderate to heavy scoring		2.6
					2 pistons - slight scoring		
					1 piston - pitted (13 spots)		
					2 cups - moderate scuffing and scoring		
					1 cup - moderate scuffing		
					1 cup - slight scuffing and scoring		
					3 cups - slight scuffing		
					1 cup - satisfactory		

Table 3. Alaska Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/		Total Mileage	Visual Inspection		Fluid Appearance	
		Months of Service	Service		Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
USA03N36068 (Continued) 1 1/4-Ton					2 springs--detuned			
2K6108 1 1/4-Ton	U.C.	Apr 75/8	3191	Cylinder bore--satisfactory	2 springs--satisfactory	All cylinders--slight stain	Slight sediment	Slight sediment
				Piston--satisfactory		7 pistons--slight stain	% H ₂ O--0.2	% H ₂ O--0.6
				Spring--satisfactory		1 piston--slight etch		0.3
				Secondary cup--slight scuffing		All cups--satisfactory		-1
				Primary cup--satisfactory		Springs--satisfactory		0.0
219248 1/4-Ton	U.C.	Apr 75/9	1920	Cylinder bore--satisfactory		All cylinders--slight stain	Amber	Clear amber
				Piston--satisfactory		All pistons--slight stain	Slight sediment	% H ₂ O--0.3
				Spring--satisfactory		Cups--satisfactory	% H ₂ O--0.5	0.3
				Secondary cup--satisfactory		Springs--satisfactory		0.1
				Primary cup--slight scuffing and scoring at base				0.6
219374 1/4-Ton	U.C.	Apr 75/9	3082	Cylinder bore--satisfactory		All cylinders--slight stain	Slight sediment	Clear
				Piston--satisfactory		All pistons--slight stain	% H ₂ O--0.2	% H ₂ O--0.2
				Spring--satisfactory		Secondary cup--satisfactory		0.2
				Primary cup--moderate scuffing; slight scuffing				0.0
								0.1

Table 3. Alaska Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
2J9202 1/2-Ton	D.C.	Apr 75/9	2045	Cylinder bore--satisfactory	All cylinders--slight stain	Clear	Clear
				Piston--satisfactory	All pistons--slight stain	% H ₂ O--0.2	% H ₂ O--0.0 0.5
				Spring--satisfactory			0.2 0.5
				Secondary cup--satisfactory	Cups--satisfactory		
2J9490	D.C.	Apr 75/9	5000	Primary cup--slight scuffing	Springs--satisfactory	Clear	Clear
				Cylinder bore--dark ring about 1 inch from push rod end	2 cylinders--slight stain	Clear	% H ₂ O--0.0 0.5
				Piston--satisfactory	1 cylinder--slight scoring and stain	% H ₂ O--0.2	0.5 0.2 0.5
				Spring--satisfactory	1 cylinder--slight corrosion one end		
				Secondary cup--satisfactory	2 pistons--slight stain		
				Primary cup--slight scuffing and chipping	1 piston--moderate scoring		
					1 piston--heavy scoring		
					1 piston--slight scoring		
					1 piston--slight to moderate scoring		
					1 piston--moderate etch		
	1 piston--moderate to heavy etch						

Table 3. Alaska Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
219490 (Continued)							
				4 cups- slight scuffing			
				1 cup- moderate scuffing			
				3 cups- satisfactory			
02H80172 ¼-Ton	D.C.	Apr 75/9	1206	Cylinder bore- satisfactory	All cylinders- slight stain	Clear	Clear
				Piston- satisfactory	All pistons- slight stain	% H ₂ O- 0.7	% H ₂ O- 0.6 1.8
				Spring- satisfactory			0.1
				Secondary cup- satisfactory	7 cups- satisfactory		0.2
				Primary cup- moderate scuffing and scoring	1 cup- slight scoring		
					Springs- satisfactory		

IV. CONCLUSIONS

This program has shown that silicone brake fluid will equal or exceed the performance obtained from current specification fluids in conventional hydraulic brake systems. The water-intolerant silicones show considerably less corrosion than either the conventional fluids or the water-tolerant silicone fluid after the two-year period. After one year in the arctic, both the water-intolerant and the water-tolerant silicones were comparable in performance.

Based on this study and previous laboratory evaluations, silicone brake fluids have demonstrated their potential for use in the bulk of the Army fleet, which is composed of vehicles under 10,000 pounds gross weight and equipped with conventional hydraulic brake systems.

During this test period, however, laboratory tests conducted by a brake parts manufacturer indicated a potential problem with silicone fluids in vacuum over hydraulic brake systems used on vehicles of over 10,000 pounds gross weight. Since the Army fleet includes vehicles with this type of hydraulic brake system, further studies and tests are being conducted to resolve the problem.

The swelling of the rubber cups in the master cylinders of vehicles equipped with the deep-water fording kit can produce brake system failures regardless of the fluid used.

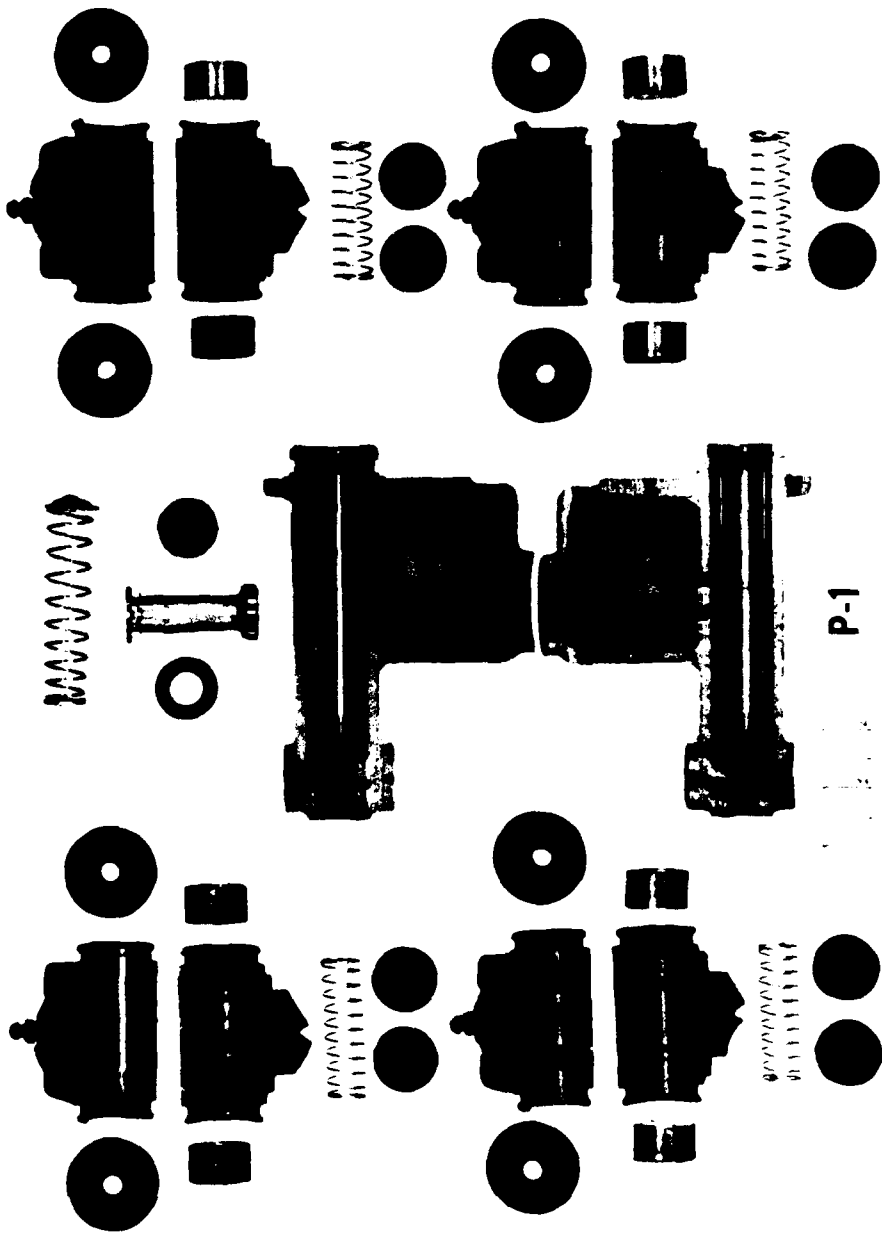


Figure 1. Typical set of cylinders after 2 years' operation at TTC with VV-B-660 fluid.

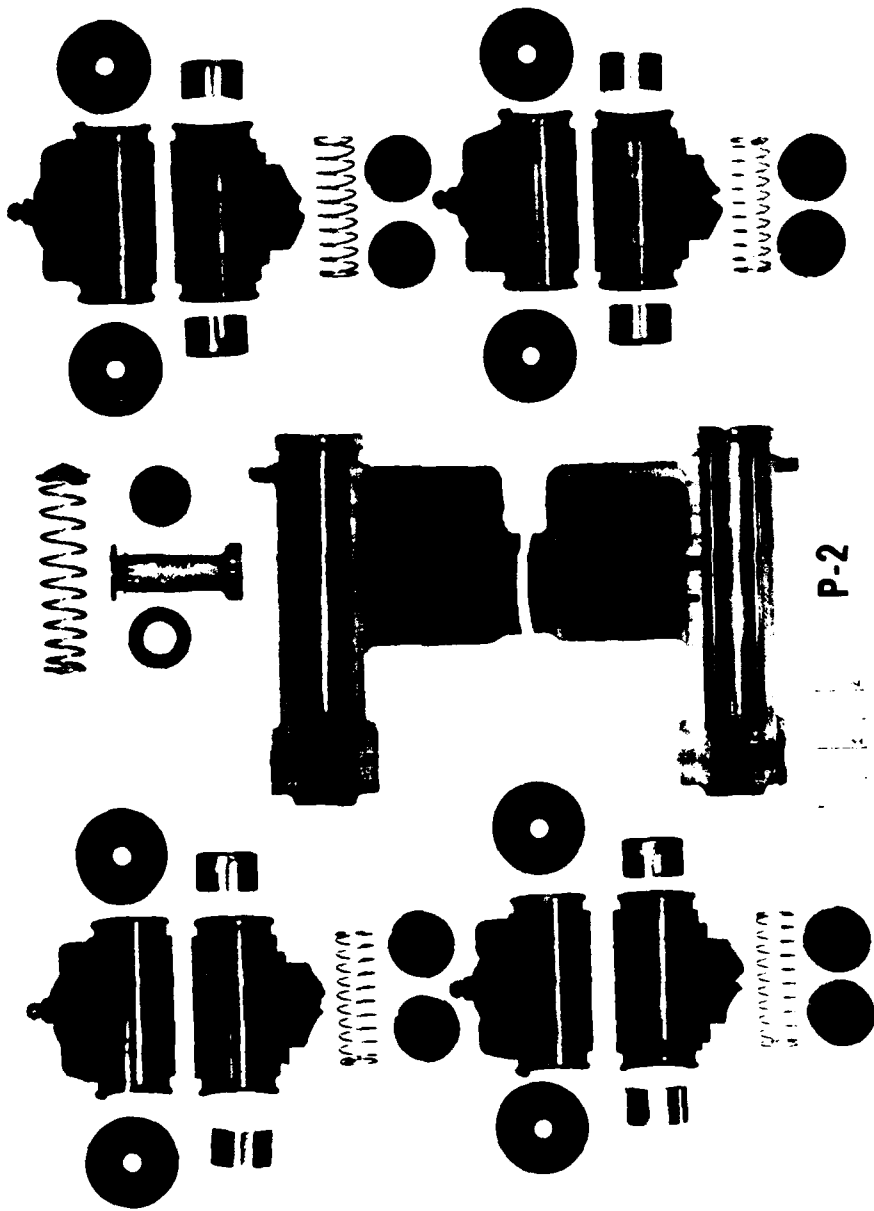


Figure 2. Typical set of cylinders after 2 years' operation at TTC with water-intolerant silicone.

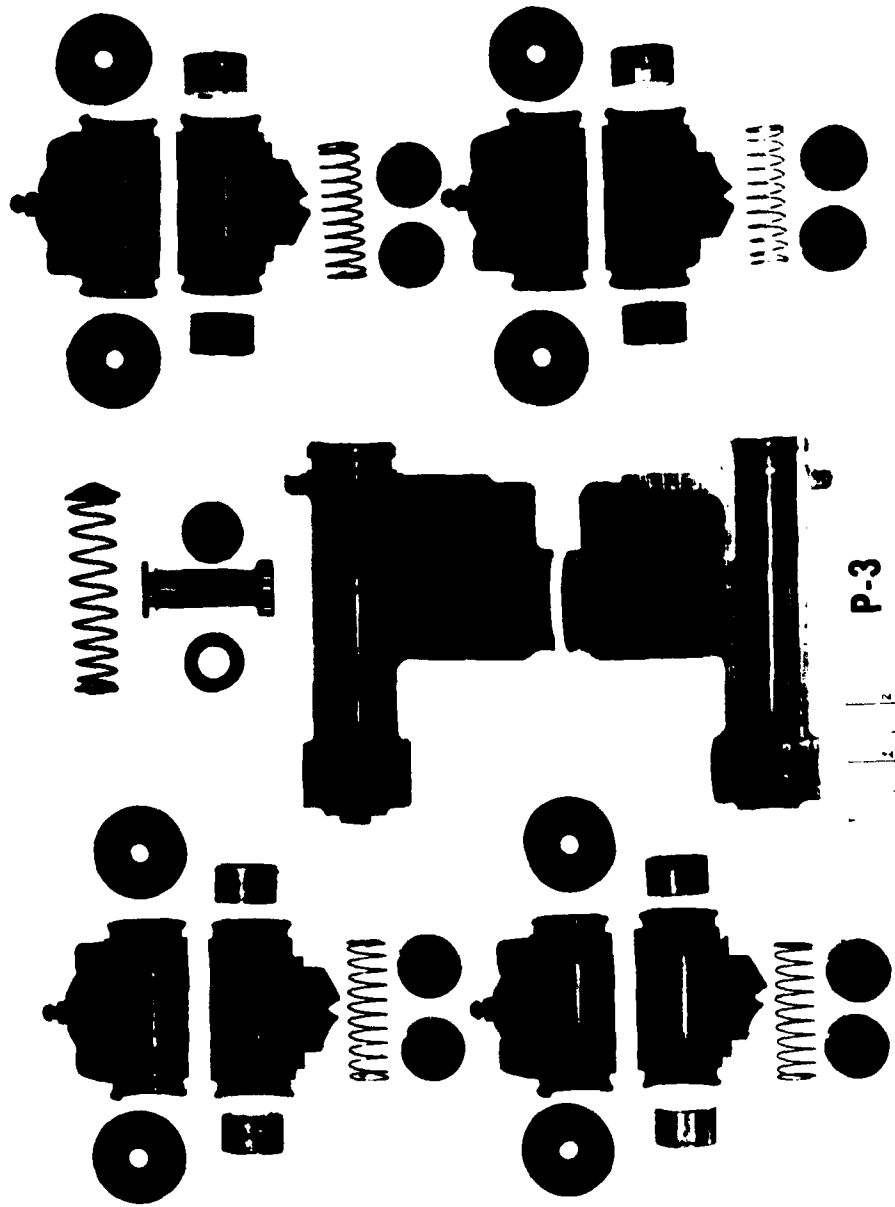


Figure 3. Typical set of cylinders after 2 years' operation at TTC with water-tolerant silicone.

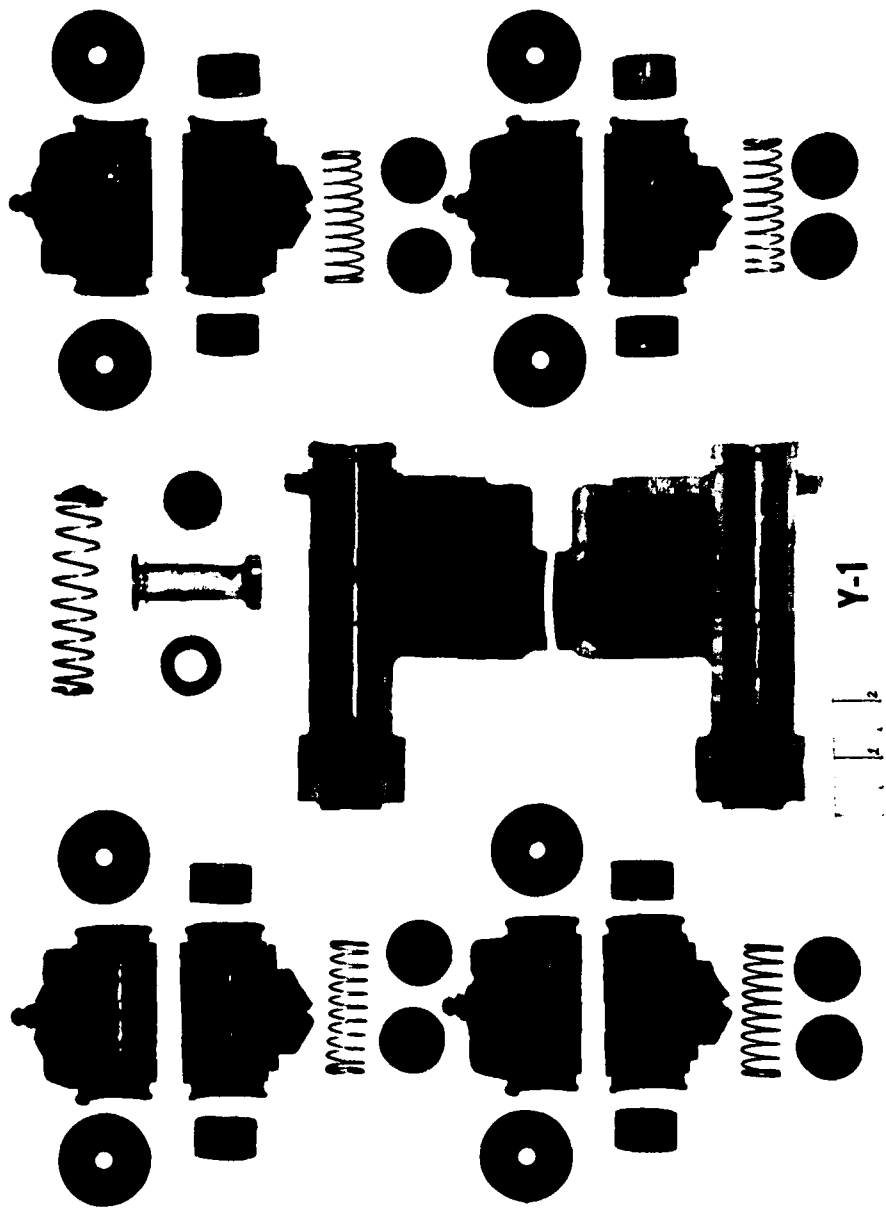


Figure 4. Typical set of cylinders after 2 years' operation at YPG with VV-B-680 fluid.

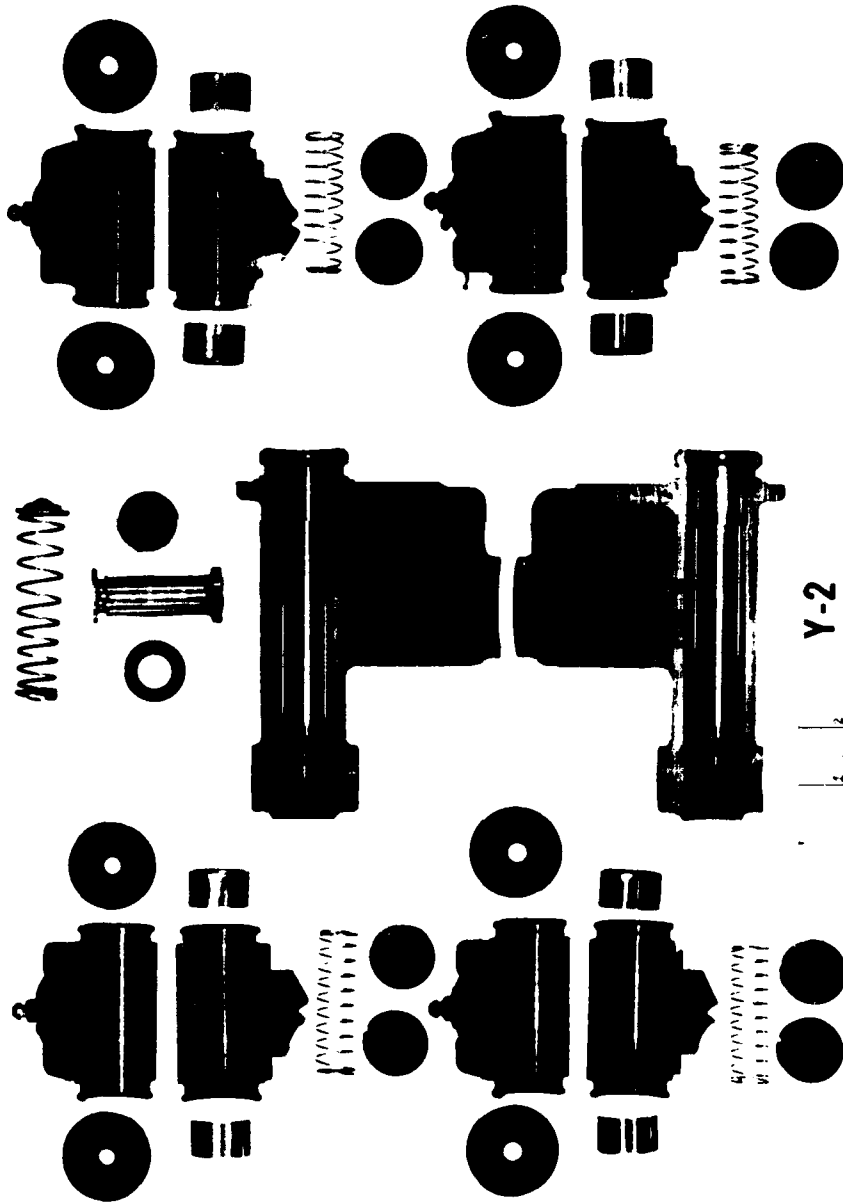


Figure 5. Typical set of cylinders after 2 years' operation at YPG with water-intolerant silicone.

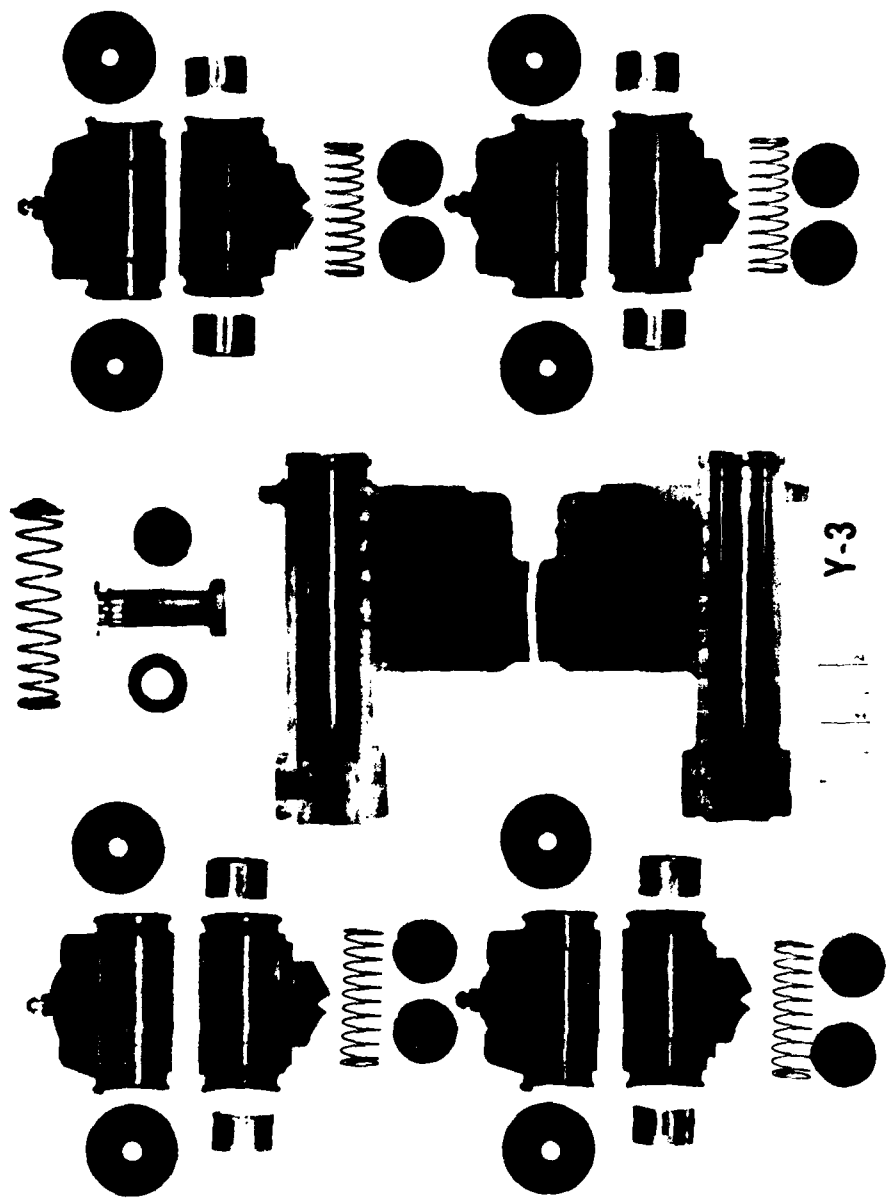


Figure 6. Typical set of cylinders after 2 years' operation at YPG with water-tolerant silicone.

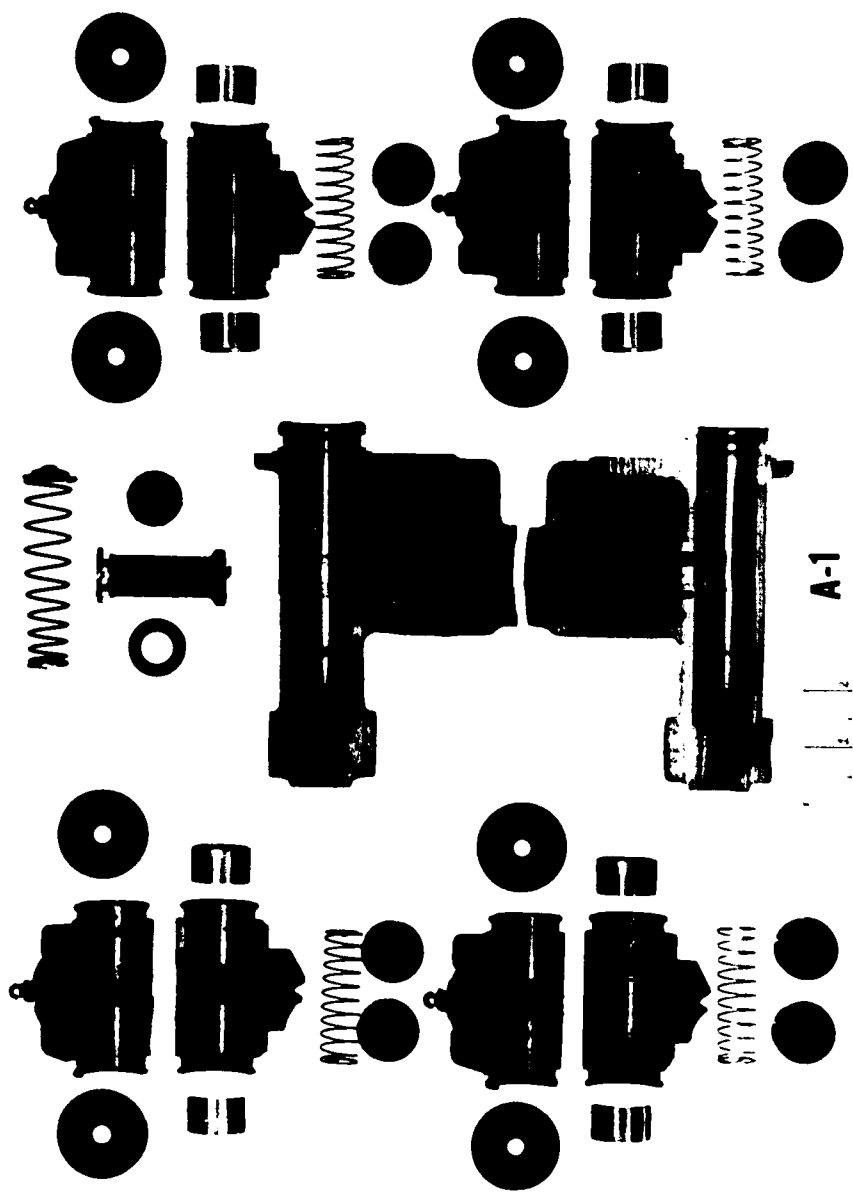


Figure 7. Typical set of cylinders after 1 year's operation at ATC with MIL-H-13810 fluid.

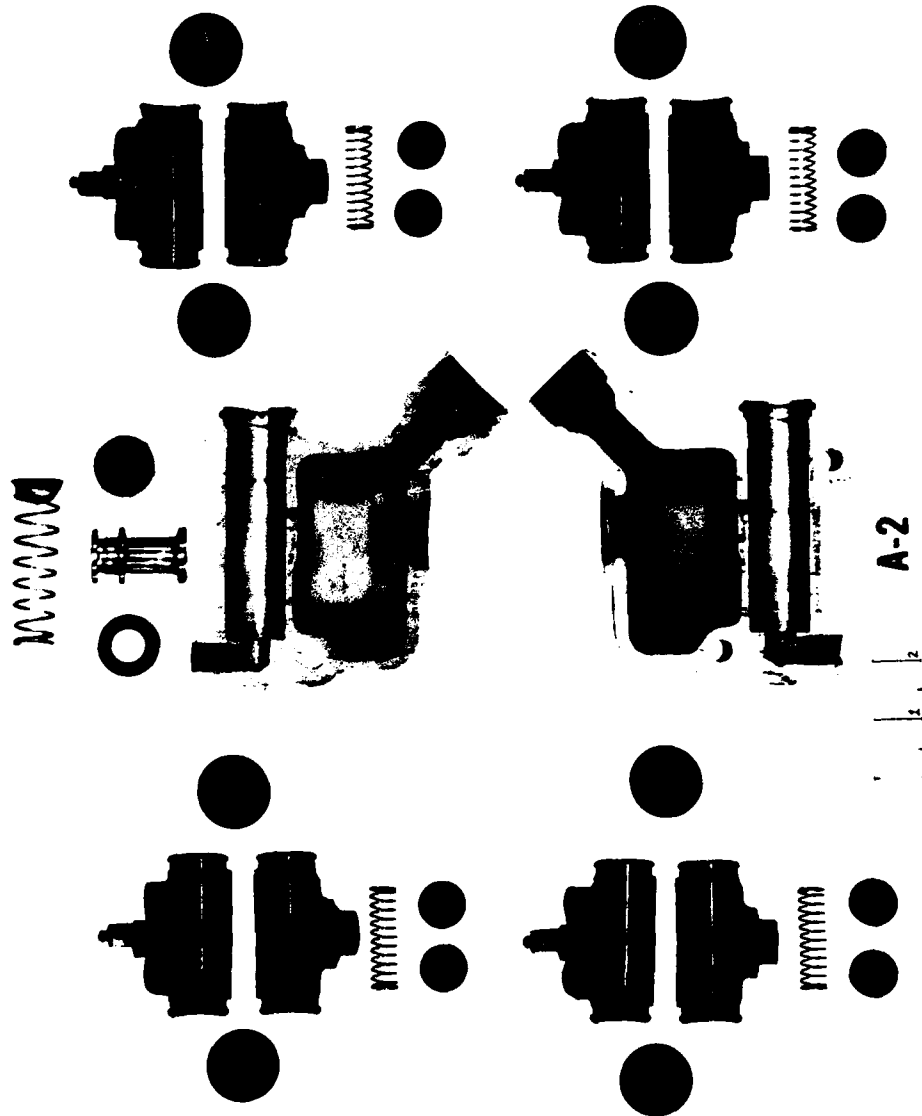


Figure 8. Typical set of cylinders after 1 year's operation at ATC with water-intolerant silicone.

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