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DEVELOPMENT OF IMPROVED RUBBER COMPOUNDS FOR USE IN WEAPON APPLICATIONS

Frank B. Testroet and William F. Garland

August 1974

TECHNICAL REPORT

U.S. ARMY ARMAMENT COMMAND

RESEARCH DIRECTORATE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Two rubber compounds were developed for use with the new flame-resistant synthetic hydraulic fluid, MIL-H-33282. A new rubber compound was developed for use in obturator pads for bag-loaded cannon. The effects of hydrazine on the physical properties of various elastomers were determined, and several compounds were developed for potential use in this medium. Fluorosilicone rubber inserts for machine gun springs were tested and an ECO for their use was initiated. Blending of conventional silicones with fluorosilicone rubber was

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20. studied with the goal of preparing vulcanizates having good low temperature performance and elastic recovery with only a small compromise in oil resistance. In general, the poorer properties of the elastomers involved predominated, although one blend (Silastics LS63U and 651) exhibited good potential for attaining the goal. Polyphosphazene vulcanizates exhibited good low-temperature flexibility and resistance to oils, fuels, ozones, and hydrolytic stability. Also, these vulcanizates are nonflammable.

CONTENTS

OBJECTIVE

The objective of this project was to provide elastomeric compounds for use in the fabrication of high-quality components of reasonable cost for Army weapon systems. Compounds need to be developed that are capable of functioning under the stringent conditions imposed by the increasing rates and ranges of fire of the current and future weapon systems. Nonmetallic materials that are compatible with fuels and oxidizers, and that satisfy the physical property requirements for elastomeric components in liquid gun systems also need to be developed. Improved compounds and field-fix techniques for end items that are deficient in field service were investigated. Another objective was to prolong the life of rubber items through the use of appropriate inhibitors and to protect against deteriorating elements such as heat, humidity, and ultraviolet radiation.

BACKGROUND

Many technological advances in the application of nonmetallic materials to Army end items have been made in recent years through improvements in the state of the art. These advances are of a continuous nature and only the best qualified materials are selected for use with new weapons involving novel fluids, chemicals and physical demands. An awareness of the up-to-date capabilities of nonmetallic materials is essential for proper selection of these materials for application in specific end items. Such awareness is best achieved through knowledge of the potential of new materials and technological methods by laboratory experimentation and prototype testing. Examination of items reported to be unsatisfactory in field service is also important so that appropriate remedial action can be taken. In summary, the purpose of this research project is to use the best available technology of nonmetallic materials to improve existing items and to develop only the most durable and functional nonmetallic materials for use in new military hardware, as the need arises.

APPROACH

Trade literature, D. D. C. bibliographies and foreign intelligence sources were reviewed for data on new elastomeric materials, new compounding techniques, and new methods of rubber technology.

All testing of materials was conducted in accordance with ASTM procedures where applicable.

RESULTS AND DISCUSSION

Rubber Seals for Hydraulic Fluid Use

Nitrile and fluorosilicone vulcanizates were tested for use with MIL-H-83282, "Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft." This is the fluid that is being considered by the Department of Defense as a replacement for MIL-H-6083, "Hydraulic Fluid, Petroleum Base, For Preservation and Testing." Compound formulations and physical properties of the vulcanizates tested in MIL-H-6083C and in MIL-H-83282 are listed in Tables 1 and 2, respectively. Fluid immersion was conducted for 70 hours at 212°F and at 275°F. Both rubber compounds showed good retention of tensile strength and moderate volume change after immersion in MIL-H-6083C and MIL-H-83282 at 212°F. However, MIL-H-6083C severely affected the strength of nitrile rubber at 275°F and also produced a somewhat higher volume change. Tensile strength of the nitrile compound was also lowered during immersion in MIL-H-83282 at 275°F, but it was not lowered to the extent of that noted in MIL-H-6083C. The fluorosilicone rubber maintained its integrity in both fluids at both temperatures. These elastomers could be used in the fabrication of seals or gaskets for use in contact with this new hydraulic fluid. However, additional compound development of nitrile elastomers for applications involving MIL-H-83282 at 275°F and above should be conducted.

Rubber Obturator Pads

It became necessary to seek a new elastomer for use in the fabrication of obturator pads for bag-loaded cannons since the currently used polyurethane elastomer, Genthane S, is no longer marketed and the Army supply of this rubber will soon be depleted. The high strength, fairly low compression set, and good flexibility at -40°F evidenced by Genthane S were considered important to the proper functioning of an obturator pad. For this reason, other commercially available millable polyurethane elastomers, as shown in Table 3, were evaluated. Examination of the physical property data in Table 4 reveals that none of the vulcanizates of these millable urethanes have the combination of high strength, low compression set, and low temperature flexibility equivalent to that of Genthane S (Compound 510-11). Furthermore, significant improvement of these physical properties is impossible by compounding since the deficiencies are inherent in the individual elastomers.

Because no urethane elastomer comparable to the one used in the current standard obturator pad was available, other oil resistant elastomers were investigated. Obturator pads were molded from Neoprene WD and Hydrin 200, and these pads were transported to Watervliet Arsenal[1] for subsequent test firing at Aberdeen Proving Ground. In addition, other compounds have been developed for laboratory testing and possible test firing; this action is dependent upon the performance of these compounds in the A ratio test developed at Watervliet Arsenal. In the A ratio test, cylindrical elastomeric specimens are inserted in a steel tube with cylindrical pistons at each end. The specimens are compressed at pressures up to 50,000 psi, and the applied and the normal pressures are measured. The A ratio is obtained by division of the normal pressure by the applied pressure; an A ratio of 0.92 or higher is considered necessary for a functional obturator pad.

This test can be conducted over a range of temperatures, and the results

[1] Watervliet Arsenal Correspondence, Subject: Production Engineering Measures Project Status Report (RCS AMCCPP-114), Project No: 6716784, Project Title: "Engineering Study and Materials Evaluation for Obturator Pads." 24 May 1972

TABLE 1

FORMULATIONS FOR COMPOUNDS COMPATIBLE WITH MIL-H-83282 HYDRAULIC FLUID

Compounding Ingredients	Parts by Weight N203	G40
Paracril AJ (nitrile)	100	
Silastic LS-63U (fluorosilicone)		100
Zinc oxide	5	
Stearic acid	1.5	
Sulfur	1.5	
Altax	1.5	
Age Rite Resin D	1	
Philblack N550	60	
Ferric oxide		2
Cadox TS-50		1.3
Compression mold, min/°F	30/307	5/240
Post cure, hrs/°F	-	8/392

TABLE 2

PHYSICAL PROPERTIES OF VULCANIZATES AFTER IMMERSION IN MIL-H-6083C AND MIL-H-83282

Properties Measured	Nitrile N203	Fluorosilicone G40
Original:		
Tensile strength, psi	2130	1070
Modulus @100% E, psi	1000	450
Elongation, %	190	180
Hardness, Shore A	70	54
70 Hrs/MIL-H-6083C/212°F:		
Tensile strength,psi	1590	1060
Modulus @ 100% E, psi	1020	580
Elongation,%	120	140
Hardness, Shore A	55	53
Volume change, %	+30	+ 5
70 Hrs/MIL-H-83282/212°F:		
Tensile strength, psi	1980	770
Modulus @ 100% E, psi	950	490
Elongation,%	180	140
Hardness, Shore A	63	55
Volume change, %	+17	+ 2
70 Hrs/MIL-H-6083C/275°F:		
Tensile strength, psi	750	1230
Modulus @ 100 % E, psi	560	520
Elongation, %	110	180
Hardness, Shore A	51	57
Volume change, %	+42	+ 5
70 Hrs/MIL-H-83282/275°F:		
Tensile strength, psi	1250	940
Modulus @ 100% E, psi	1250	470
Elongation, %	100	190
Hardness, Shore A	64	56
Volume change, %	+13	+ 2

TABLE 3

COMMERCIALLY AVAILABLE MILLABLE URETHANE ELASTOMERS FORMULATED FOR POTENTIAL OBTURATOR PAD USE

Parts by Weight

Compounding Ingredients	510-11	U88	U53	U58-1	U87-3	Z51	U75	U88-2	U34-9
Genthane S	100								
Vibrathane 5004		100							
Elastothane ZR625			100	100					
Elastothane 651M					100				
Adiprene C						100			
Adiprene CM							100		
Formrez MG2								100	
Formrez MG4									100
Stearic acid	2	0.2						0.25	
Di Cup 40C	5	4		3	2			3	3
PCD	4	4	4	4	4			4	4
Philblack N550	38	25						25	20
Philblack N110			30	30	30				
Altax			4			3			
Captax			2			1	1		
ZC 456			1						
Cadmium stearate			0.5				0.5		
Sulfur			1.5			1.5	0.75		
Philblack N330						30	30		
LD 395						0.35			
Cumar MH 2-1/2							10		
Caytur 4							0.35		
Test pads compression molded, Min/°F	30/320	30/307	40/310	40/310	30/307	45/281	60/287	30/307	30/320

TABLE 4

PHYSICAL PROPERTIES OF VULCANIZATES OF MILLABLE URETHANE ELASTOMERS

Properties Measured	510-11	U88	U58	U58-1	U87-3	251	U75	U88-2	U34-9
Tensile strength, psi	3870	3950	4300	3650	3310	5040	4480	3400	3310
Modulus@300%E,psi	2170	2670	2520			2410	1630		
Elongation, %	520	470	440	250	300	490	545	210	260
Hardness, Shore A	72	73	71	70	66	72	67	68	66
Compression set,Method B, 70 hrs/212°F,%	44	52	100	30	33	86	78	42	26
ASTMD746@-67°F	Pass	Fails ok-64	Fails ok-60	Fails ok-60	Pass	Pass	Pass		
70 hrs/212°F/ASTM#3 Oil:									
Volume change,%	+7	+8	+8	+8	+10	+32	+25	+3	+7
Hardness change,points	-6	-5	-3	-6	- 7	- 7	-17	-3	-3
70 hrs/212°F/Air:									
Tensile change,%	+3	- 6	+ 5	+ 9	- 4	-22	- 5	- 4	- 7
Elongation change,%	-2	-10	-29	0	-15	-40	-36	-19	-14
Hardness change,points	+2	0	+ 6	+3	+ 2	+ 4	+ 1	+ 2	+ 3
ASTMD1043,temperature at which Young's Modulus equals 10,000 psi,°F	-40	-25	+ 2	- 6	-19	-29	-25	- 6	-16

can be compared with those measured from the current Genthane S obturator pad. Any compounds exhibiting outstanding performance could be used for fabricating obturator pads for test firing. Formulations and physical properties of compounds developed for the A ratio test are given in Tables 5 and 6, respectively. A non-oil resistant elastomer, Nordel 1070, was included because its vulcanizate, coded Z140A1, exhibits high tensile strength, very good low-temperature flexibility and resistance to brittle fracture, low compression set and excellent resistance to aging without the use of special stabilizers. Two urethane compounds (U88 and U88-2) with poorer low temperature torsional flexibility than that of Genthane S were also included to determine whether correlation existed between the low temperature torsional flexibility and the A ratio tests. Results of the A ratio test made by Watervliet Arsenal are presented in Table 7 and are compared with the low temperature torsional flexibility data generated in this laboratory.

TABLE 7

Comparison of A Ratio and T_{200} Test Results on Rubber Compounds Developed for Obturator Pads

Compound No. and Base Polymer	A Ratio at -65°F	T_{200}, °F
U80-88 (Adiprene L42)	98	-67
Z140A1 (Nordel 1070)	85	-63
M118-3 (Neoprene WD)	83	-57
Z197 (Hydrin 200)	74	-36
U88 (Vibrathane 5004)	68	-25
510-11 (Genthane S)	67	-40
U88-2 (Formrez MG-2)	54	- 6

The data from the two tests indicate significant correlation. The A ratios are listed in descending order and, with the exception of the T_{200} for Genthane S, the corresponding T_{200} temperatures also rank in the same order. The two urethane compounds which have poor low temperature flexibility (U88 and U88-2) had poor A ratios.

On the basis of the A ratio and the T_{200} test results, compounds based on Adiprene L42, Nordel 1070, and Neoprene WD would appear to be likely candidates for use in obturator pads. However, as noted in Table 6, the very high compression-set of the Adiprene-based compound and the poor resistance to oil of the Nordel-based compound would seriously detract from their usefulness. The latter compound may prove to be usable in next year's program in which an attempt will be made to develop composite obturator pads consisting of an inner non-oil resistant elastomer and an outer oil resistant cover.

The obturator pad made of a Neoprene WD compound was successfully test-fired at APG at +125°F, at ambient temperature, and at -25°F. This pad (175mm) failed the firing test at -50°F. The Hydrin 200 - based pad was successfully test fired at +125°F and at ambient temperature, but failed at -25°F. These data show some correlation between the A ratios and the T_{200} values; however,

TABLE 5

FORMULATIONS OF POTENTIAL OBTURATOR PAD COMPOUNDS

Parts by Weight

	M118-3	Z197	U88-2	U88	U80-88	Z140A1
Neoprene WD	100					
Hydrin 200		100				
Formrez MG2			100			
Vibrathane 5004				100		
Adiprene L42					100	
Nordel 1070						100
Akroflex CD	3					
Maglite D	4					
Statex 125	55					
Plasticizer DOS	35					
Zinc oxide	5					
NA-22	1	1.5				
Philblack N550		40	25	25		
Red lead		5				
Age Rite Resin D		1				
Lithium stearate		1				
Di Cup 40C			3	4		
Stearic acid			0.25	0.2		
PCD			4	4		
MOCA					8.8	
Philblack E						50
Di Cup R						3.5
Tetrone A						1
Compression molded, minutes/°F	30/307	45/307	30/307	30/307		30/320
Cure, hrs/°F					3/212	
Post cure, days@75°F and 50% R.H.					14	

TABLE 6

PHYSICAL PROPERTIES OF POTENTIAL OBTURATOR PAD COMPOUNDS

Properties Measured	M118-3	Z197	U88-2	U88	U80-88	Z140A1
Tensile strength, psi	2260	2210	3060	3950	4000	3000
Modulus@100%E, psi	550	890	1010		490	
Modulus@200%E, psi	1470	1740			680	
Modulus@300%E, psi				2670	860	1850
Elongation, %	260	280	190	470	700	370
Hardness, Shore A	63	70	70	73	76	64
ASTM D1043, °F*	-57	-36	- 6	-25	-67	-63
ASTM D746@-67°F	Pass	Fail OK-60	Fail Fail-60	Fail OK-64	Pass	Pass
Compression set, Method B, 70 hrs/212°F, %	33	48	35	52	100	21
70 hrs/212°F/ASTM #3 Oil:						
Volume change, %	+40	+41	+ 4	+ 5	+13	Not sufficiently oil resistant to test
Hardness, Shore A	50	65	65	68	79	
70 hrs/212°F/Air:						
Tensile strength, psi	2180	2400	3740	3690	5730	3230
Elongation, %	260	210	210	420	700	390
Hardness, Shore A	67	73	72	73	79	64

*Temperature where Young's Modulus equals 10,000 psi what these two laboratory tests fail to provide is information relative to the thermal coefficient of expansion of the rubber compounds under test. For example, the Neoprene WD obturator pad was shown by the A ratio test to be sufficiently flexible at -65°F to function properly at that temperature, but it failed at -50°F in actual firing. Failure at -50°F was not caused by stiffness or brittleness, but was caused by the large shrinkage of the pad (high coefficient of thermal expansion). On the basis of this work, obturator pads made of Neoprene WD rubber (Compound M118-3) are being recommended as replacements for the standard polyurethane pads (Compound U89). The neoprene-based pad has three major advantages over the urethane: (1) Raw rubber costs have been reduced from $1.50 to $0.50 per pound. (2) The operating temperature range has been increased at the cold end of the scale from -10°F to -25°F. (3) The shelf life has been increased from five years to at least ten years. Furthermore, initial test firing of neoprene obturator pads in the XM198 Howitzer has proved successful. One obturator pad was used to fire 417 rounds of ammunition in the XM198 Howitzer without obturation problems. Another obturator pad of the same composition is being tested: this pad has performed satisfactorily for 170 rounds, and test firing is continuing at Jefferson Proving Ground (JPG). Five obturator pads are being tested for durability at JPG. Additional testing of the Neoprene obturator pads is planned for the near future at Yuma Proving Ground.

Rubber Inserts for Metallic Springs

It has been previously reported[2] that fluorosilicone rubber inserts significantly improve the service life of helical metallic extractor springs for the M16 rifle. Rubber inserts are also used in machine gun springs, but these are made of silicone rubber which does not have good resistance to lubricating oils, bore cleaner, and other fluids used on these weapons. Prototype inserts were fabricated from the fluorosilicone rubber which had been specially developed for the M16 rifle extractor spring and were test fired in machine guns. After 10,000 rounds, these inserts were much less severely degraded than inserts made of silicone rubber. Consequently, the Small Arms Weapons Systems Directorate has initiated an ECO to adopt the fluorosilicone inserts as standard for machine gun springs for both the extraction and ejection mechanisms.

Although rubber inserts have extended the service life of metallic extractor springs, replacement of the rubber insert - metallic spring combination with a one-component, all-rubber spring would be desirable. This action was attempted with the use of fluorosilicone rubber; however, this material displayed too great an increase in hardness at low temperatures and caused fracture of the M16 rifle extractor during firings at -40°F. Efforts were undertaken to improve the low-temperature performance of the fluorosilicone elastomer by means of blending this elastomer with various silicone elastomers possessing inherently better low temperature characteristics, but less resistance to oils and fluids. The objective was to develop compounds with good low temperature performance and good compression set, but with only a small compromise in fluid resistance. The compounds developed are listed

[2] US Army Weapons Command Technical Report SWERR-TR-72-67, "New and Improved Rubber Compounds For Weapons Systems." October 1972

in Table 8, and physical properties are shown in Table 9. These compounds were used to prepare cylindrical specimens, 0.675 inch in height and 0.600 inch in diameter (shape factor of 0.22), for dynamic laboratory testing. Testing consisted of the placing of a preload deflection of 20 percent on the cylinder and then the deflecting of an additional 20 percent at a rate of 650 cycles per minute, the approximate rate of fire for the M16 rifle. In general, the poorer properties of the elastomers involved in the blends tended to predominate. This is shown in compounds G60 and G60-1 which are blends of Silastic LS-63U and Silastic 432. Both compounds have the low tensile strength and poor resistance to fluids of Silastic 432. Again, with blends of Silastic LS-63U and SE555U (a phenyl siloxane elastomer with outstanding low temperature properties) in compounds G60-3, G60-4 and G60-5, high compression set and deterioration by oil and bore cleaner predominated. In a blend of Silastic LS-63U and Silastic 35U (a fairly oil-resistant elastomer), good low temperature properties were measured, but high compression set was evident. However, a 50/50 blend of Silastic LS-63U and Silastic 651 (G60-9) exhibits good tensile strength, low compression set, and good low-temperature properties accompanied only by a slight compromise in resistance to bore cleaner. This compound would be a good candidate for prototype springs for service testing. Cylindrical specimens of this blend, as previously cited, were cycled 500,000 cycles at a rate of 650 cycles per minute to determine if an all-rubber spring would perform under 40 percent deflection without exhibiting fatigue failure. All compounds completed 500,000 cycles without rupture or cracking, except for the 87 hardness compound G60-11, which ruptured within 34,000 cycles. This compound contained 15 pphr silicon dioxide filler and had very low initial elongation (40 percent). This dynamic test demonstrates that properly compounded rubber can function as a spring at high deflection over many cycles without failure.

Foreign Product Evaluation

A new Japanese nitrile elastomer was evaluated for comparison with a domestic product, Paracril D. Compound formulations and physical properties are listed in Tables 10 and 11, respectively. The Japanese nitrile rubber was somewhat more difficult to process than Paracril D, but it did show slightly higher original tensile strength. No significant advantages in low temperature properties, oil resistance or resistance to aging were noted for the Japanese elastomers.

Rubber For Use In Liquid Propellants

Results of a literature survey indicated that no one elastomer was satisfactory for use in all fuels and oxidizers which have been suggested for liquid propellant gun systems. However, EPDM, Hydrin, Butyl, EPR, Viton, and Nitroso rubbers were indicated as likely choices. Vulcanizates based on the last three of these elastomers were not selected for this study because EPR is limited in the manner in which it may be cured; Viton has very poor low-temperature properties and nitroso rubber is not commercially available. Compound formulations are listed in Table 12, and physical properties of the vulcanizates before and after immersion in hydrazine and

TABLE 8

FORMULATIONS OF POTENTIAL RUBBER SPRING COMPOUNDS

(Parts by Weight)

Compounding Ingredients	G60-6	G60	G60-1	G60-2	G60-3	G60-4	G60-5	G60-7	G60-8	G60-9	G60-10	G60-12	G60-13	G60-14	G60-15	G60-11
Silastic LS-63U		60	50	100	60	50		50		50	60	100	100	100	100	100
Silastic 432 Base	100	40	50													
SE 555 U					40	50	100									
Silastic 35 U								50								
Silastic 651									100	50	40					
Ferric oxide	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
Cadox TS-50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1	1.5	1.5		1.5	1.5	1.5	1.5	1.5
Hi-Sil 233	10	10	10									3	6	9	12	15
Hi-Sil-303																
Compression Mold minutes/°F	5/240	5/240	5/240	5/240	5/240	5/240	5/240	5/260	5/240	5/240	5/240	5/240	5/240	5/240	5/240	5/240
Post Cure, Hrs/°F	8/392	8/392	8/392	8/392	8/392	8/392	8/392	4/400	8/392	8/392	8/392	8/392	8/392	8/392	8/392	8/392

TABLE 9

PHYSICAL PROPERTIES OF POTENTIAL RUBBER SPRING COMPOUNDS

Properties Measured	G60-6	G60	G60-1	G60-2	G60-3	G60-4	G60-5	G60-7	G60-8	G60-9	G60-10	G60-12	G60-13	G60-14	G60-15	G60-11
Original:																
Tensile strength,psi	950	1130	1060	1210	1400	1450	1500	1150	1220	1320	1290	1230	1090	1000	790	800
Modulus@100%E,psi	260	360	330	410	300	190	180	180	240	310	400	680	750	850		
Modulus@200%E,psi	510	740	610	920	650	560	410	370	550	810	890					
Modulus@300%E,psi	770	1130	1060		1000	980	820	700	1010	1320						
Elongation,%	340	300	300	230	380	390	430	480	330	300	250	170	140	120	80	40
Hardness, Shore A	50	55	54	54	55	52	53	47	57	61	63	67	72	78	83	87
70 Hrs/392°F./Air:																
Tensile Strength,psi	910	1100	1040	1270	1220	1210	1170	1060	1280	1140	1230					
Modulus@100%E,psi	300	410	370	460	360	290	390	280	270	480	540					
Modulus@200%E,psi	540	930	790	1270	810	730	780	580	600	1140						
Elongation,%	290	220	240	200	260	280	280	310	330	200	180					
Hardness,Shore A	52	58	58	60	63	63	60	49	57	63	66					
Weight loss,%	1	1	1	1	1	1	1	1	1	1	1					
Compression set, Method B, 22 Hrs/392°F,%	33	46	44	43	64	67	68	50	16	19	21					
70 Hrs/Bore Cleaner/Rm.Temp:																
Tensile strength,psi	550	920	880	970	990	930	350	870	550	990	990					
Modulus@100%E,psi	230	290	290	270	240	240	170	170	160	340	360					
Modulus@200%E,psi	440	630	590	760	530	540		370	550							
Modulus@300%E,psi					910	860		610								
Elongation,%	210	300	260	220	310	310	160	420	200	240	230					
Hardness,Shore A	34	33	41	50	41	35	36	34	33	44	49					
Volume change,%	+37	+24	+21	+7	+ 29	+ 36	+ 71	+ 22	+ 58	+30	+ 22					
70 Hrs/ASTM#3 Oil/212°F:																
Tensile strength,psi	720	940	970	1140	960	1050	510	790	660	1000	960					
Modulus@100%E,psi	240	280	330	320	220	270	140	180	140	300	350					
Modulus@200%E,psi	460	710	660	910	590	690	510	400	360	750	810					
Modulus@300%E,psi								620								
Elongation,%	280	250	280	230	280	250	200	350	230	240	220					
Hardness, Shore A	35	43	42	47	40	39	27	34	28	42	45					
Volume change,%	+ 28	+16	+ 19	+ 4	+ 26	+ 33	+ 63	+ 23	+ 54	+ 29	+ 22					
ASTM D1043,T200,°F*	- 81	- 79	- 82	- 72	- 81	- 85	Below-90	- 84	Below-90	- 88	- 84	- 67	- 56	- 44	- 32	**
24 Hrs/-40°F **Compression set,%:**																
T_{10} seconds			71	95		82	41		13	70		100	100	100	100	
T_{30} minutes			31	60		52	31		12	44		75	84	92	94	
Load Compression@Rm.Temp.																
20% deflection,psi	146	162	156	144	197	180	174	102	157	179	194					
40% deflection,psi	346	442	418	470	533	456	452	264	350	435	474					
ASTM D2632,Resilience	42	32	36	18	29	31	36	28	37	27	14	12	12	6	6	10

* Temperature at which Young's Modulus equals 10,000 psi

** Above room temperature

TABLE 10

FORMULATIONS OF FOREIGN AND DOMESTIC NITRILE COMPOUNDS

(Parts by Weight)

Compounding Ingredients	N206	N206-1
Paracril D*	100	
FCM-30-9320-II**		100
Zinc oxide	5	5
Stearic acid	1	1
Age Rite Resin D	1	1
Sulfur	1.5	1.5
Altax	1.5	1.5
Philblack N550	50	50

Compression mold test pads 30 minutes @307°F
Compression mold set buttons 45 minutes @307°F

*Paracril D is a high acrylonitrile copolymer of butadiene and acrylonitrile manufactured in this country.

**Alternating copolymer of butadiene and acrylonitrile, oil resistant, brown, BRIDGESTONE (Japan).

TABLE 11

PHYSICAL PROPERTIES OF FOREIGN AND DOMESTIC BUTADIENE/ACRYLONITRILE VULCANIZATES

Properties Measured	N206	N206-1
Original:		
Tensile strength, psi	2770	3470
Modulus @100%E, psi	860	950
Modulus @200%E, psi	1710	2350
Modulus @300%E, psi	2350	3280
Elongation, %	400	320
Hardness, Shore A	73	72
Compression Set, ASTM D395, Method B, %:		
22 hours @158°F	27	17
70 hours @212°F	60	71
ASTM D1043, temperature at which Young's Modulus equals 10,000 psi, °F	+ 33	+27
70 hours/212°F/ASTM #3 Oil:		
Tensile strength, psi	2790	3600
Elongation, %	280	260
Hardness, Shore A	72	72
Volume change, %	+ 7	+ 7
70 hours/212°F/Air:		
Tensile strength, psi	2850	3800
Modulus @100%E, psi	1490	1800
Modulus @200%E, psi	2700	3400
Elongation, %	210	220
Hardness, Shore A	82	78

unsymetrical dimethyl hydrazine (UDMH) are listed in Table 13. Stress-strain properties were not measured after immersion in the hydrazine fluids because of the lack of a ventilating hood over the tensile tester.

Of the two EPDM elastomers tested, Nordel 1070 in compound Z140A1 had the best overall properties both before and after fluid immersion. The Hydrin 200 vulcanizate (compound Z197) had the highest volume swell in both test fluids. The Butyl compound (I74-5) tended to soften and became sticky during immersion in hydrazine and UDMH. Increasing carbon-black loading from 80 to 320 pphr in Compounds E35, E35-2, and E35-3 had no significant effect on volume swell in hydrazine, but did lower the volume change in UDMH.

In general, UDMH had a more rapid effect on the rubber specimens than did hydrazine. The Hydrin 200 compound swelled to almost double its original size in less than five hours in UDMH.

A great deal of bubble evolution was noted when specimens were immersed in hydrazine; also, the specimens swelled slowly. Some color change of the liquid occurred. A yellow condensate formed on the tube side walls and in condensors in less than three hours immersion of the rubber in UDMH. Liquid UDMH changed from water-clear to various shades of yellow. Some specimens swelled rapidly.

New Elastomer and Related Material Evaluation

Samples of polyphosphazene elastomer were received from Army Materials and Mechanics Research Center for evaluation. Evaluation of this new elastomer has been completed, and a technical report covering the evaluation has been prepared. In general, the adding of compounding ingredients to this elastomer on a two-roll rubber mixing mill was found difficult. However, calcium oxide and Dow Corning FS1265 fluid functioned as processing aids to facilitate incorporation of other compounding ingredients. Only low tensile strengths were obtained, but properly compounded vulcanizates exhibited good low temperature flexibility and resistance to a variety of fluids.

Two recently marketed nitrile elastomers, Ty Therm 510 and Ty Therm 511, were tested to determine whether they were superior to Paracril B. Paracril B has a nominal acrylonitrile content of 26 percent which is comparable to Ty Therm 510, while Ty Therm 511 is a medium high acrylonitrile nitrile elastomer. Compound formulations are listed in Table 14. Data shown in Table 15 indicate that the Ty Therm vulcanizates displayed higher original tensile strength and elongation than the Paracril B vulcanizate, but showed greater loss of elongation after aging in oil or air. The somewhat greater compression set of Ty Therm 511 (N201-2) can be attributed to the higher acrylonitrile content of the polymer.

Devcon's Flexane 95 Putty, which has been used for repairing damaged rubber coatings on the M60 machine gun, was removed from the market because of OSHA directives. A new material was sought that would have good adhesion

TABLE 12

FORMULATIONS OF RUBBER COMPOUNDS FOR IMMERSION IN HYDRAZINE AND UDMH

(Parts by Weight)

Compounding Ingredients	E35	E35-2	E35-3	I74-5	Z197	E35-4	Z140A1
Royalene 400	200	200	200			200	
Hydrin 200					100		
Butyl 325				100			
Nordel 1070							100
Zinc oxide	5	5	5	5		5	
Stearic acid	1	1	1	1		1	
Plasticizer TOF	20	20	20			80	
Captax	0.5	0.5					
Thionex	0.5	0.5				0.5	
Sulfur	1.5	1.5	1.5	1.5		1.5	
Tetrone A	1.5	1.5	1.5			1.5	
Philblack N550	80	180	320		40	80	
Philblack S315				60			
Philblack N110							50
Altax				1			
Di Cup R							3.5
Methyl Tuads				1			
Red lead					5		
NA-22					1.5		
Age Rite Resin D					1		
Lithium stearate					1		
Compression mold test pads, minutes/°F	30/307	30/307	30/307	30/307	45/307	30/307	30/302

TABLE 13

PHYSICAL PROPERTIES OF COMPOUNDS BEFORE AND AFTER IMMERSION
IN HYDRAZINE AND UDMH

Properties Measured	E35	E35-2	E35-3	I74-5	Z197	E35-4	Z140A1
Original:							
Tensile strength, psi	2010	1190	920	1990	2200	1010	3680
Modulus @300%E, psi	400		470	890	1990	170	1990
Elongation, %	870	80	670	590	350	980	390
Hardness, Shore A	36	87	57	64	67	21	68
ASTM D1043, Temp. at which Young's Modulus equals 10,000 psi, ^{o}F	- 71	- 46	+81	- 28	- 31	___	- 63
7 days/Rm. Temp./95% Hydrazine:							
Volume change, %	+ 6	+ 7	+ 2	- 26	+120	+ 5	+ 2
Hardness, Shore A	45	68	86	53	82	32	67
7 days/Rm. Temp./99% UDMH:							
Volume change, %	- 24	- 22	- 8	+ 9	+ 78	- 37	+ 3
Hardness, Shore A	67	88	94	53	45	67	65

TABLE 14

COMPOUND FORMULATIONS OF RECENTLY MARKETED NITRILE ELASTOMERS

(Parts by Weight)

Compounding Ingredients	N201-1	N201	N201-2
Paracril B	100		
Ty Therm 510		100	
TY Therm 511			100
Zinc oxide	5	5	5
Stearic acid	1	1	1
Age Rite Resin D	1	1	1
Philblack N550	50	50	50
Sulfur	1.5	1.5	1.5
Altax	1.5	1.5	1.5

Test pads compression-molded 30 minutes @307°F
Buttons compression-molded 45 minutes @307°F

TABLE 15

PHYSICAL PROPERTIES OF RECENTLY MARKETED NITRILE ELASTOMERS

Properties Measured	N201-1	N201	N201-2
Original:			
Tensile strength, psi	2170	2470	3020
Modulus @100%E,psi	1500	1300	1230
Modulus @200%E,psi		1980	2000
Elongation, %	260	370	450
Hardness, Shore A	67	65	65
Compression set, Method B, 70 hrs/212°F,%	50	54	61
70 Hrs/212°F/ASTM #3 Oil:			
Tensile strength,psi	2290	2050	2700
Modulus @200%E,psi	1600	1370	1540
Elongation,%	250	270	260
Hardness, Shore A	56	52	60
Volume change,%	+18	+22	+ 8
70 Hrs/212°F/Air:			
Tensile strength,psi	2420	2780	2860
Modulus@200%E,psi		2140	2140
Elongation,%	200	250	270
Hardness, Shore A	70	68	70
70 Hrs/250°F/Air:			
Tensile strength,psi	2580	2450	2930
Elongation,%	150	150	170
Hardness, Shore A	74	72	76

to metal and possess resistance to bore cleaner and other fluids associated with small arms. Eccobond 45 adhesive with Catalyst 15 mixed in a ratio of 100 parts to 150 parts, respectively, satisfied the desired requirements. This material can be applied to the damaged area, troweled to fit the contour of the piece being repaired, and cured at room temperature without shrinking. Excess material can be removed by the process of sanding or with a power-driven sanding block.

CONCLUSIONS:

Nitrile and fluorosilicone elastomers are compatible with MIL-H-83282 lubricant and could be used effectively in the fabrication of seals, O rings or packings for use in this lubricant at temperatures up to 212°F.

A newly developed obturator pad, based on Neoprene rubber, has been proved acceptable in limited firing tests at Aberdeen and Jefferson Proving Grounds. This neoprene obturator pad, which was developed as a replacement for the standard Genthane S compound, should be placed in production to replenish the very low supply of standard pads.

Fluorosilicone rubber inserts for use with machine gun springs exhibited better performance than the silicone rubber now specified. Blends of fluorosilicone and conventional silicones can produce compounds with improved compression set and low-temperature properties with only marginal sacrifice in fluid resistance. Rubber springs were cycled through 40 percent deflection without cracking, splitting, or evidence of any other sign of failure.

Recently introduced Japanese nitrile rubber and two domestic nitriles did not exhibit any highly significant improvement over nitrile rubber already in use.

An EPDM vulcanizate, Nordel 1070, could be used in liquid propellant gun systems in which hydrazine is used as an oxidizer.

Properly compounded polyphosphazene vulcanizates have good low temperature flexibility and resistance to oils and fuels. Mineral fillers produce greater reinforcement than carbon blacks. These vulcanizates exhibited excellent ozone resistance and hydrolytic stability, and they are nonflammable.

RECOMMENDATIONS:

An extensive research effort should be made to develop new compounds for bag loaded cannon obturator pads that have better low-temperature properties than the newly developed Neoprene obturator pads. New designs and composites of two rubbers should also be studied.

All-rubber springs should be considered for use with the extractor of small arms, replacing the metal helical spring with a rubber insert.

Additional research work should be conducted to optimize the compounds developed for use with hydrazine.

Efforts should be continued to enhance the heat resistance of rubber compounds, especially oil-resistant types often used for seals.

Additional compounding studies should be made to improve the strength and compression set of the polyphosphazene elastomer to provide an elastomer suitable for use as seals in Army applications.

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Development of Improved Rubber Compounds
For Use In Weapon Applications

Prepared By: Frank B. Testroet and William F. Garland

Technical Report: R-TR-74-044

26 Pages

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1. Obturator Pads
2. Fluorosilicone Rubber
3. Rubber Inserts For Springs
4. Fluorosilicone/Silicone Blends

I. Frank B. Testroet and William F. Garland
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