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RUBBER COMPOUNDS AS ENERGY-STORING DEVICES FOR WEAPONS

BY

JAMES D. RUBY

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4. Blends

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Compounds based on fluorovinyl silicone and blends of fluorovinyl silicone with a phenyl vinyl silicone or a vinyl silicone were evaluated as materials for use in energy-controlling devices. Several test compounds exhibited properties such that further tests under actual end-use conditions were deemed necessary. The opportunity for such tests became available through an urgent request as to the feasibility of the use of rubber as a replacement of the helical extractor spring currently used in the Mechanized Infantry Combat

20. ABSTRACT (continued)

Vehicle, Firing Port Weapon. The metallic extractor springs were manifesting premature failure due to fatigue. Springs fabricated in several sizes from three of the most promising rubber compounds were subjected to firing tests. A spring fabricated from the fluorovinyl silicone compound remained functional after more than 15,000 rounds. A preliminary investigation of the effect of various spring shapes was undertaken. The frustum of a right circular cone configuration produced results that warrant further investigation.

CONTENTS

OBJECTIVE:

The object of this project was to develop rubber compounds suitable for use in the fabrication of springs, buffers, and vibration isolators for small arms and aircraft armament.

BACKGROUND:

Rubber is a versatile and adaptable material which has been used in dynamic applications for many years. Rubber is not only flexible and an ideal material for the accommodation of unwanted movement, but it can also support high stresses without damage. Unlike almost all other engineering materials, rubber can be made with a wide range of elastic moduli that enables one to make changes in elastic behavior obtainable without changes in dimensions. This and other properties make rubber a likely choice for use as springs and buffers where space limitations are of importance. However, the inability of rubber to rapidly and completely recover from deformation at low temperatures restricts its use in such applications to moderate temperature ranges.

APPROACH:

The elastic moduli of vulcanized rubber are material constants which alter elastic behavior. Their magnitude is dependent upon the manner in which the rubber is compounded and manufactured. The specific thrust of this program was to develop compounds having rapid and complete recovery from elastic deformation at low temperature. However, the expectation was that improvement in other properties would result. The maximum energy absorption of vulcanized rubber occurs over a narrow temperature range on each side of its glass transition temperature. The blending of polymers with different glass transition temperatures should result in vulcanizates with several areas of maximum energy absorption. Also, more uniform spring rates should result from this approach. Physical configurations were investigated to determine the effect of shape on load deflection curves.

RESULTS AND DISCUSSION:

The formulations for compounds developed in connection with this study are presented in Table 1. Mixing was accomplished on a 13 by 6 inch two-roll mill and the following procedure followed for the preparation of blended compounds:

(1) Each polymer was softened separately on a two-roll mill.
(2) While the vinyl silicone was being mixed, the desired amount of fluoro silicone was slowly added.
(3) The polymer mixture was thoroughly cross-blended.
(4) Ferric oxide and fine particle silica (if used) were added.
(5) Vulcanizing agent was added, mixed thoroughly and stock-sheeted off from the back roll of mill.

TABLE 1

COMPOUND FORMULATIONS

INGREDIENTS	Parts By Weight G40-1	G60-9	G66-1	G67	G67-1	G67-2	G67-3	G67-4	G67-5
FLUOROVINYL SILICONE	100	50	50	100	80	60	40	20	
PHENYLVINYL SILICONE		50	50						
VINYL SILICONE					20	40	60	80	100
FERRIC OXIDE	2	1	1	2	2	2	2	2	2
FINE PARTICLE SILICA	5		5						
2, 4 DICHLOROBENZOYL PEROXIDE	1.3	1.5	1.5						
2,5 DIMETHYL-2,5 DI (t-BUTYL PEROXY) HEXANE				0.7	0.9	1.02	1.18	1.34	1.5
PRESS CURE, min/°F	5/240	5/240	5/240	10/310	10/340	10/340	10/340	10/340	10/340
POST CURE, hrs/°F	8/392	8/392	8/392	4/400	4/400	4/400	4/400	4/400	4/400

Specimens were molded in a 12 by 12 inch electrically heated press and post cured in an air oven. Times and temperatures for the press and post cures are given in Table 1.

Physical properties of the developed compounds were determined according to ASTM procedures and are given in Table 2. The most important points revealed by the results are as follows:

a. The inadequacy of the fluorovinyl silicone rubber (cured with 2,4 dichlorobenzoyl peroxide) at -67°F is shown by the small difference between the required and the measured twists (ASTM D1053). This compound (G40-1) also had quite high-compression set.
b. Blends of the fluorovinyl silicone and phenylvinyl silicone (G60-9 and G66-1)showed marked improvements in low-temperature behavior due to the inherently excellent low-temperature characteristics of the phenylvinyl polymer. However, the resistance of these blends to ASTM #3 oil was inferior to that of the fluoro polymer because of the poor oil resistance of the phenylvinyl silicone.
c. The fluorovinyl silicone cured with peroxy hexane (G67) has much more desirable properties than the same polymer cured with benzoyl peroxide (G40-1); the set was much lower, as was the modulus at -67° F.
d. Blends of the fluorovinyl silicone with 20 and 40 parts of vinyl silicone (G67-1 and G67-2) were the best compounds developed, having low set, excellent resistance to petroleum oil, and good flexibility at -67° F.
e. Similar blends in which the vinyl silicone content was increased to 60 or 80 parts (G67-3 and G67-4) exhibited a decrease in resistance to oil.

The compound development portion of this study was discontinued at this point because several of the compounds, shown in Table 2, were believed suitable for potential use in weapon applications.

The belief was that these rubber compounds needed to be tested under actual firing conditions to test for adequacy. Fortunately, the opportunity for such testing occurred as an urgent request for assistance with a problem relating to the Mechanized Infantry Combat Vehicle (MICV) Firing Port Weapon, XM231. This gun was designed to use the same metallic helical extractor spring that is used in the M16A1 rifle. These springs were failing at the 2000-3000 round level during firing tests of the MICV; this failure level was far short of the 10,000 round goal. The feasibility of using an all-rubber extractor spring was demonstrated by preliminary firing tests on fluorosilicone springs molded in the shape of a right cylinder. Results of the firing tests are given in Table 3. On the basis of these results, initial design criteria and spring configurations were selected and are presented in Table 4.

TABLE 2

Physical Properties of Materials Developed for Spring Applications

Property Tested	G40-1	G60-9	G66-1	G67	G67-1	G67-2	G67-3	G67-4	G67-5
Tensile strength, psi	1100	1200	1030	940	1170	1140	1240	1230	1220
Modulus @ 100% E, psi	270	150	180	370	270	320	310	420	340
Modulus @ 200% E, psi	910	490	620	840	730	690	640	690	580
Modulus @ 300% E, psi	--	950	990	--	--	1020	990	990	890
Elongation, %	235	370	310	215	290	330	400	395	410
Hardness, Shore A	65	56	66	63	62	68	70	68	70
Compression Set, 70 hrs. @ 347°F, %	50	24	28	25	17	17	14	15	16
Air-Aged 70 Hrs @ 392°F:									
Tensile, % change		-14		-7	-15	-10	-32	-13	-3
Elongation, % change		-33		+9	-24	-27	-40	-24	-15
Hardness, points change		+2		-2	+5	+2	+1	+4	+4
Oil-Aged 70 Hr @ 212°F ASTM#3 Oil:									
Tensile, % Change		-24		-13	-25	-12	-24	-2	+2
Elongation, % change		-20		-9	-21	-14	-24	-5	-9
Volume, % change	+4	+27	+24	+3	+10	+14	+21	+24	+29
Hardness, points change	-4	-14	-19	-9	-6	-11	-17	-16	-17
ASTM D1053 @ -67°F:									
Min twist required, deg.*	49	61	52	55	50	55	67	61	55
twist measured, deg.	75	153	127	120	134	140	150	137	134
ASTM D2632, Resilience, % rebound	21	35	34	21	26	32	35	39	43
Spring Rate:									
at 20% deflection, lbs.	92		146	121	131	173	191	193	205
at 40% deflection, lbs.	375		450	461	513	714	740	715	740

* In many dynamic applications involving rubber, 10,000 psi is usually selected as the maximum value for Young's modulus of elasticity. Higher moduli rubbers are generally too stiff to function. The "minimum twist required" is the twist that corresponds to a 10,000 psi modulus.

TABLE 3

Preliminary Firing Test on All-Rubber Springs

Fluorosilicone Rubber Springs 0.150 In. Diameter, 0.233 In. Long

Extractor No.	No. Rounds Fired	Total Failures To Extract Or Eject	No. Rounds Between Failures
1	5514	6	919
2	7078	4	1770
3	5517	33	168
4	7535	2	3767
5	4780	15	319
TOTALS	30,424	60	507 (average)

TABLE 4

DESIGN CRITERIA AND CONFIGURATION FOR ALL-RUBBER EXTRACTOR SPRINGS

Design Criteria

1. Average expected life of at least 10,000 rounds.

2. Should fit the current bolt and extractor design.

3.

Maximum assembled height (in.)	0.142
Minimum load at max. assembled height (lb.)	1.5 to 2.0
Minimum operating height (in.)	0.092
Load at Min. operating height (lb.)	6.5 to 9.5

4. Should operate over the temperature range from -65 F to 400 F, but a range of -30 F. to 400 F. is acceptable.

Spring Configurations

Right Cylinder with the Following Dimensions:

Spring No.	Diameter (in.)	Length (in.)	Shape Factor
1	0.130	0.170	0.19
2	0.142	0.170	0.21
3	0.180	0.170	0.26
4	0.135	0.190	0.18

Molds to produce extractor springs conforming to the configurations given in Table 4 were fabricated, and compound G67-2, Tables 1 and 2, was selected as the material for molding the extractor springs.

Extractor springs conforming to the four sizes in Table 4 were delivered to the Small Arms Systems Directorate of the Rodman Laboratory for firing tests.

Compression deflection tests were performed on the four sizes of springs, and the curves are given in Figure 1. Springs 1 and 2 come closest to matching the load requirements of Table 4.

The all-rubber extractor springs furnished for firing tests were returned after testing had been completed. The results of the firing tests are given in Table 5.

Extractor springs were fabricated from a second blended compound (G67-3) in sizes 0.142 by 0.170 in. and 0.135 by 0.190 in., and firing test results are also given in Table 5.

After review and assessment of results from the firing tests, the decision was made to conduct future testing on springs made from the original fluorosilicone compound G40-1, in the original size of 0.150 by 0.223 in., and one of the best compounds of the fluorosilicone/vinyl silicone blends (G67-2). Results of the firing tests on these springs are given in Table 6.

Load deflection curves were determined for these springs, but in a different manner from that previously used. Each spring was installed in a breech bolt complete with extractor, and load-deflection tests were conducted under conditions nearer to those encountered in actual use. These curves are given in Figures 2 and 3.

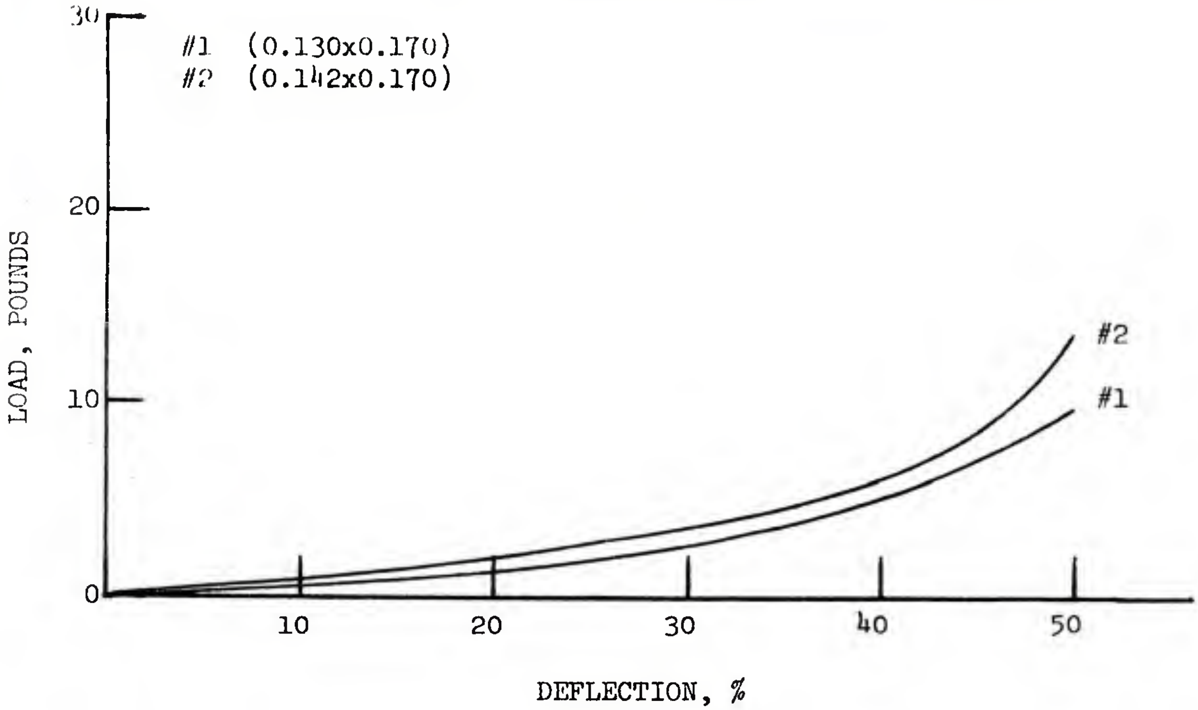
Firing test data, shown in Table 6, indicate that the best extractor performance was apparently provided by an all-rubber spring 0.150 inch in diameter, 0.223 inch long, fabricated from a fluorosilicone rubber (G40-1). Figure 2 shows that the load-deflection characteristics of this spring do not match the load requirements of Table 4. For example, the design criterion load was 6.5 to 9.5 pounds for a maximum allowable deflection of 0.050 inch (maximum allowable height minus minimum allowable height). The observed deflection of 0.018 inch was obtained at a load of 45 pounds.

Perhaps the most important point to be drawn from Figures 2 and 3 is that the load-deflection curve for the best performing spring is more nearly linear than are the curves for the other, poorer performing springs. Furthermore, the curve for the metallic helical spring is the most non-linear.

The firing test data for the spring made from the blend (G67-2) were inconclusive because of bolt breakage.

FIGURE 1

COMPRESSION DEFLECTION CURVES FOR EXTRACTOR SPRINGS



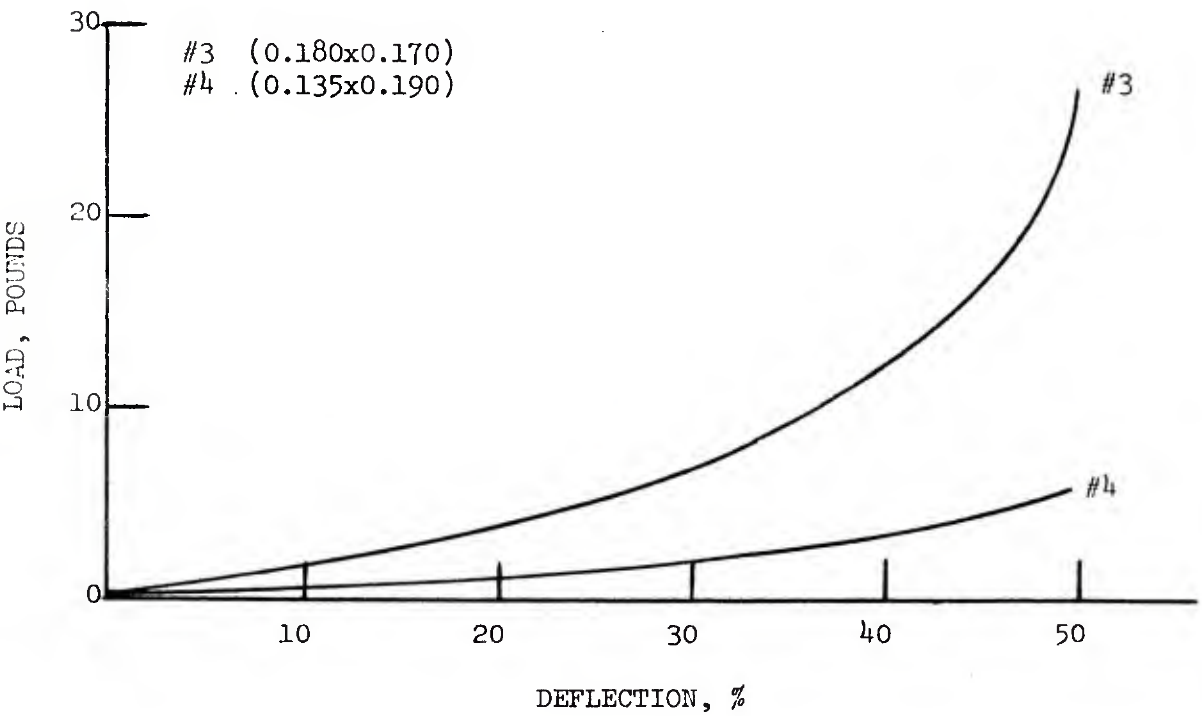


TABLE 5

FIRING TEST RESULTS FOR ALL-RUBBER EXTRACTOR SPRINGS

Spring size, in. Compound G67-2	Total Rounds Fired	Failure to Extract	Failure to Eject	Total Failures	Approximate No. Rounds Between Failures
(0.130 x 0.170)	This spring was too light and failed to function properly from the beginning.				
(0.142 x 0.170)#1	10,153	3	68	71	143
#2	2,984	23	16	39	76
(0.135 x 0.190)#1	6,759	3	26	29	233
#2	4,389	58	66	124	35
(0.180 x 0.170)	This spring was for use with a modified extractor. The modification weakened the extractor and it broke during first firing test.				
Compound G67-3					
(0.142 x 0.170)#1	10,247	2	4	6	1708
#2	2,987	18	25	43	69
#3	796	10	16	26	31
#4	9,060	21	81	102	89
(0.135 x 0.190)#1	3,590	26	27	53	68
#2	5,440	50	42	92	59

TABLE 6

FINAL FIRING TEST RESULTS ON ALL-RUBBER EXTRACTOR SPRINGS

Spring Sizes, Inches	Total Rounds Fired	Failure to Extract	Failure to Eject	Failures Attributed to Extractor Springs	No. Rounds Between Failures
Compound G40-1					
(0.150 x 0.223 in.)#1	4,712	0	0	0	4,712
#2	8,171	0	2	2	4,086
#3	11,622	1	3*	1	2,906
#4	12,281	0	7*	0	1,765
#5	7,237	0	0	0	7,237

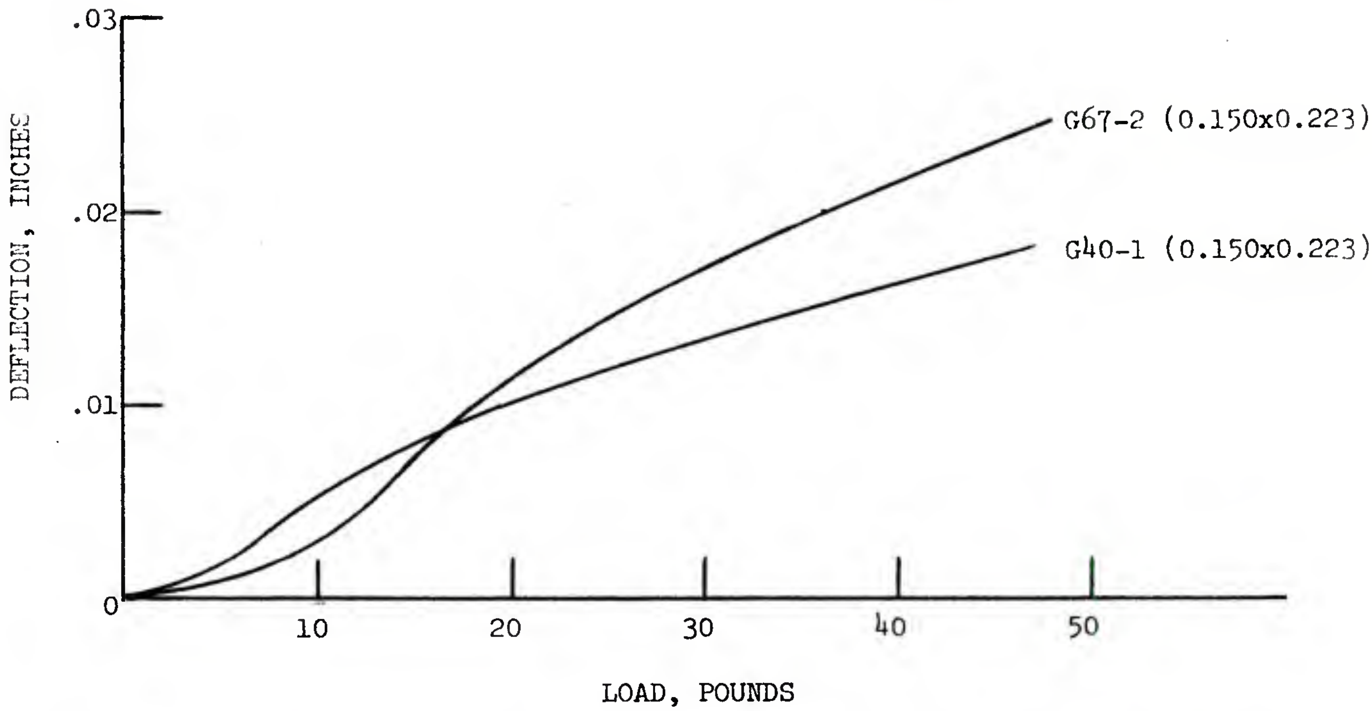
*Failures attributed to ejector spring, not extractor spring. All-rubber extractor springs were still serviceable when retired from test.

Spring Sizes, Inches	Total Rounds Fired	Failure to Extract	Failure to Eject	Failures Attributed to Extractor Springs	No. Rounds Between Failures
Compound G40-1					
(0.150 x 0.203)#1	2,012	10	16	10	201
#2	1,096	0	11	0	1,096
Compound G67-2					
(0.150 x 0.223)	3,760	0	53	53	71

All but 9 failures to eject occurred in last 1260 rounds. Broken bolt & bolt cam pin replaced at 2500 rounds. Number of failures attributed to all-rubber spring unknown.

FIGURE 2

LOAD-DEFLECTION CURVES-BOLT AND EXTRACTOR



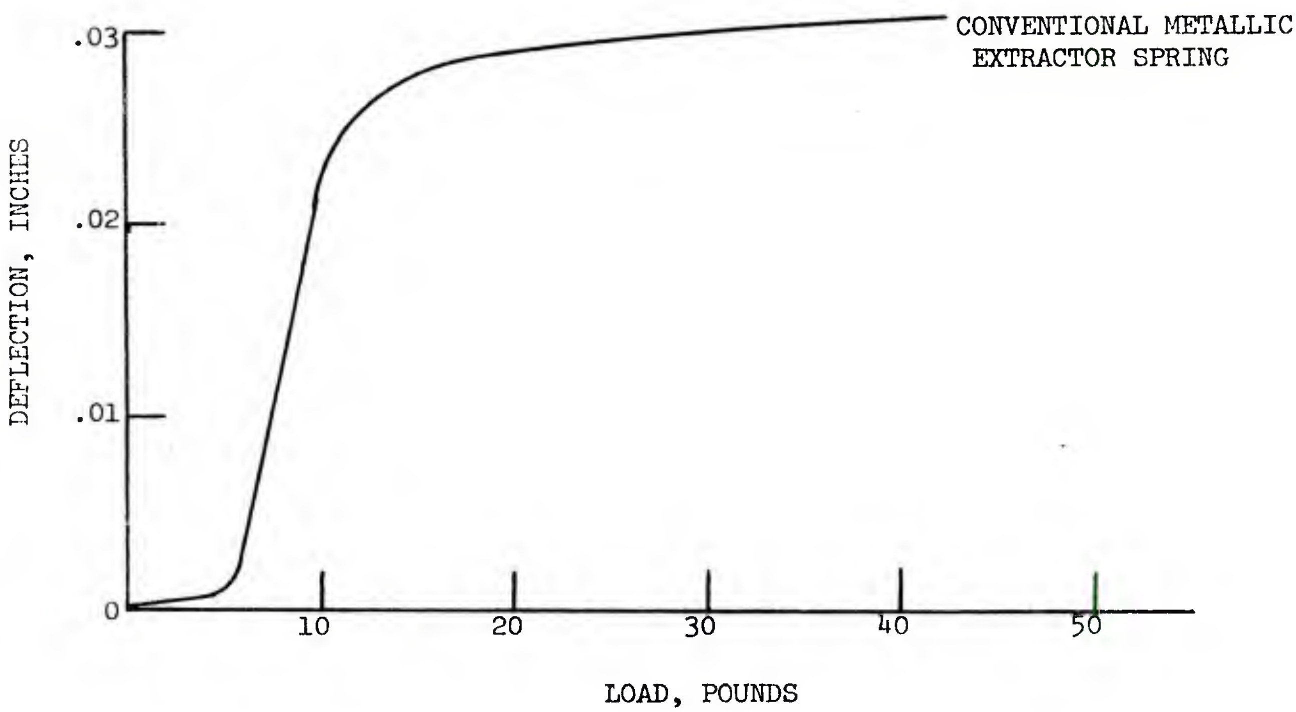
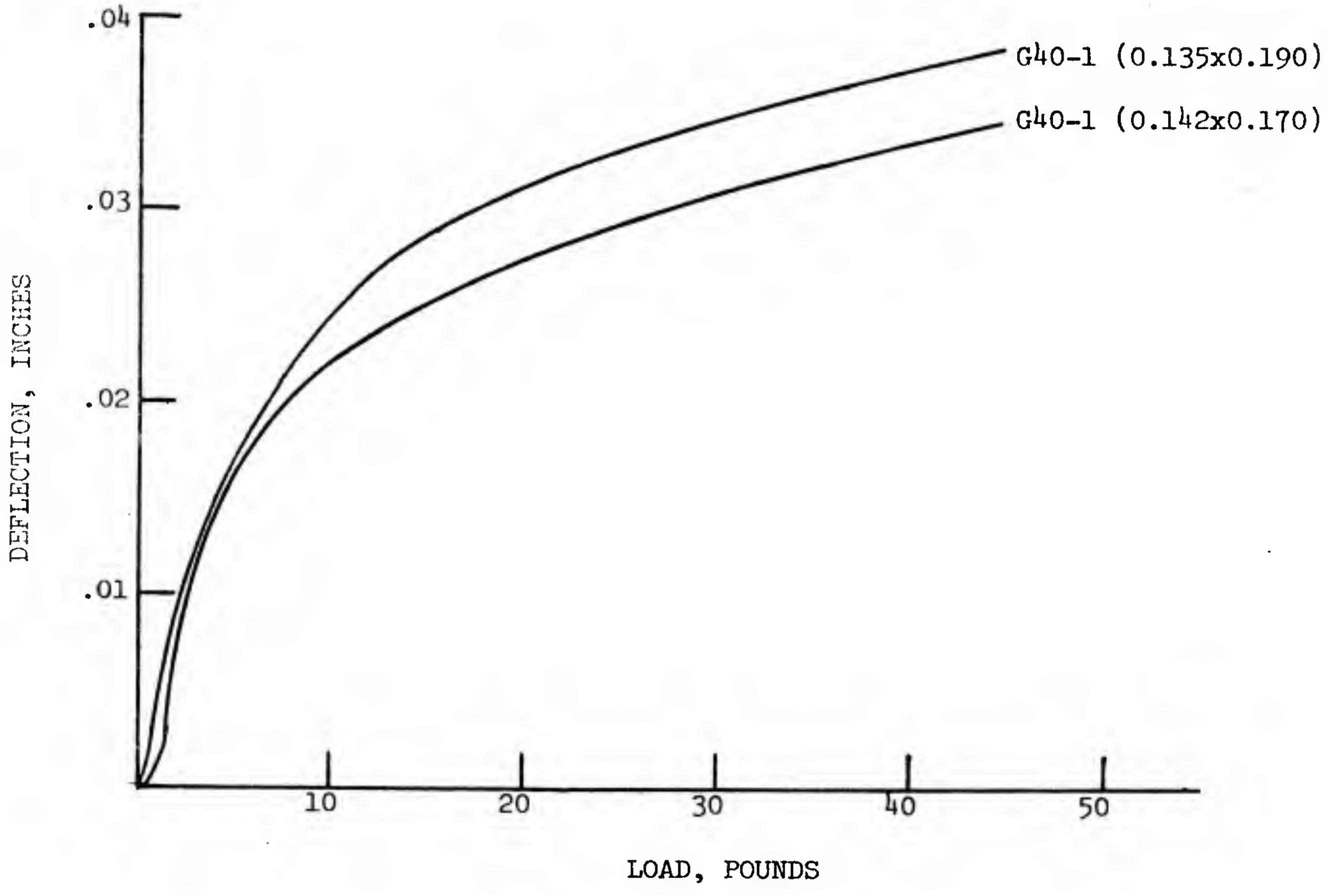


FIGURE 3

LOAD DEFLECTION CURVE-BOLT AND EXTRACTOR



Late in the development of all-rubber springs, an investigation of spring shapes other than the right cylinder was undertaken. Load-deflection curves for three different shapes are given in Figure 4. Note that the load deflection curve for the frustum of a right circular cone is linear to about 40 percent deflection. A mold is being fabricated for use in producing two different sizes of the right circular cone frustum for testing.

CONCLUSIONS:

The feasibility of using rubber springs in high cyclic small arms applications has been clearly demonstrated. All-rubber extractor springs functioned satisfactorily for over 10,000 rounds in actual firing tests.

From a physical property standpoint, blends of fluorovinyl silicone and vinyl silicone should have all the characteristics needed to provide reliable performance as springs in small arms. Resistance to dynamic fatigue at room temperature and above is provided by the inherent ozone and heat resistance of the silicone and fluorosilicone polymers. The tear strength and the hardness of these compounds are apparently also adequate to resist dynamic failure. The resistance to fatigue at low temperature has not been determined, but should be excellent on the basis of a low temperature flex test.

RECOMMENDATIONS:

Firing tests should be conducted at low temperature to determine suitability of rubber springs over a broad temperature range.

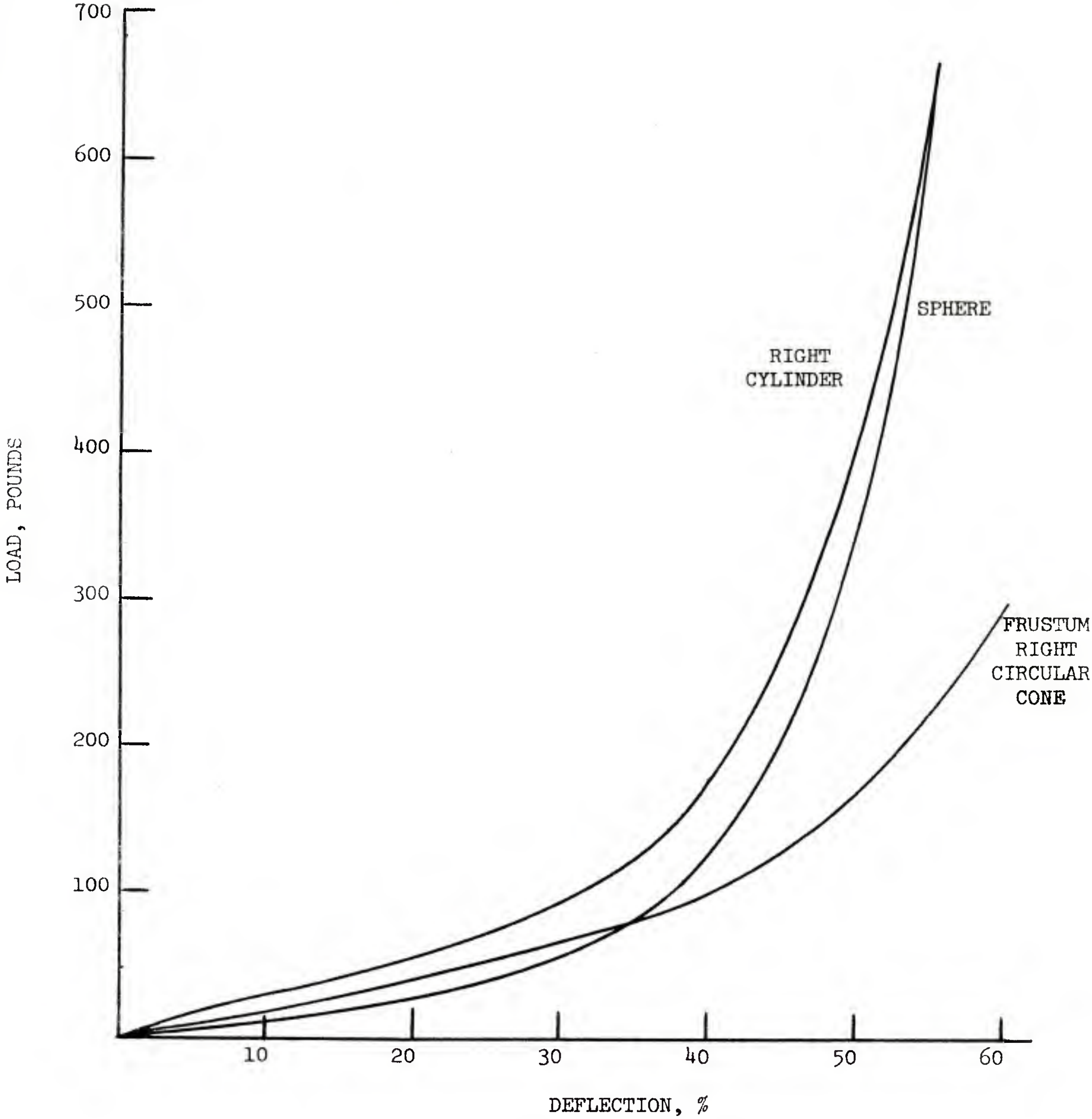
The load-deflection test with the use of an actual bolt and extractor is a much more meaningful test than the conventional ASTM test. The former test should be modified to permit the measurement of change in load during cyclic performance.

The effect that linearity in load-deflection characteristics plays in producing reliable springs should be investigated.

Firing tests should be conducted on springs produced in the configuration of a frustum of a right circular cone with the use of a fluorosilicone compound (G40-1) and the fluorosilicone-vinyl silicone blend (G67-2).

FIGURE 4

EFFECT OF SHAPE ON LOAD-DEFLECTION



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Report R-TR-77-016, May 76, 22 p. incl. illus. tables, (DA 1T162105AH84, AMS Code 612105.11.H8400) Unclassified report.

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