SILICONE ELASTOMER EVALUATION FOR
CABLE JACKET APPLICATION

Published September 1976

Project Leader:
R. R. Crockett
Department 862

Project Team:
D. C. Powell
R. S. Sanders
L. A. Six

EP 04890700
Final Report

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Technical Communications

**Kansas City
Division**

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

SILICONE ELASTOMER EVALUATION FOR CABLE JACKET APPLICATION

BDX-613-1507 (Rev.), UNCLASSIFIED Final Report, Published
September 1976

Prepared by R. R. Crockett, D/862, under EP 04890700

A silicone elastomer manufactured by General Electric's Silicone Products Division was found to be adequate for use as a cable jacket compound. The elastomer has room temperature physical properties approximately equal to those of the currently used neoprene jacket compound and permits functional operations at temperatures both above and below those of neoprene.

WPC-pls

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

THE BENDIX CORPORATION
KANSAS CITY DIVISION
P.O. BOX 1159
KANSAS CITY, MISSOURI 64141

A prime contractor for the United
States Energy Research and
Development Administration
Contract Number E(29-1)-613 USERDA

CONTENTS

Section	Page
SUMMARY.	5
DISCUSSION	6
SCOPE AND PURPOSE.	6
ACTIVITY	6
<u>Preliminary Evaluation</u>	7
<u>Comprehensive Evaluation of SE4661 and SE9090.</u>	9
ACCOMPLISHMENTS.	19
FUTURE WORK.	20
DISTRIBUTION	21

ILLUSTRATIONS

Figure		Page
1	Tensile Strength and Elongation Data Plots. .	11
2	Tear Strength and Hardness Data Plots	12
3	Effects of Catalyst on Tensile Strength and Elongation.	18

TABLES

Number		Page
1	Preliminary Test Data	8
2	Silicone to Catalyst Mix Ratio and Cure Schedule for SE4661 and SE9090	10
3	Physical Test Results for SE4661 and SE9090.	13
4	Results of Dual-Catalyzed SE9090 Tests. . . .	16
5	Peel Strength Data.	19
6	Effects of Heat Aging on SE9090	20

SUMMARY

A silicone elastomer manufactured by General Electric's Silicone Products Division has been evaluated as a cable jacket compound and found to be adequate for use through a temperature range of -76°F (-60°C) to 500°F (260°C). This compound has room temperature physical properties approximately equal to those of the currently used neoprene jacket compound and it will permit functional operation at temperatures both above and below those of neoprene.

The silicone elastomer, known as SE9090, is commercially available and cable manufacturers have the experience and knowledge to fabricate cables using it. The SE9090 compound has good moldability characteristics and has excellent adhesion to itself and fair to good adhesion to bare brass, which previously has been coated with a primer.

DISCUSSION

SCOPE AND PURPOSE

Increased temperature limits with better mechanical properties are required to assure the functional reliability of electrical cables. This project was undertaken to evaluate some potential materials for use as cable jackets.

ACTIVITY

The operating and environmental temperature limits imposed for this study were from -65°F (-54°C) to 400°F (204°C) with a possible upper limit increase to 450°F (232°C).

Currently used cable jacket materials such as polyurethane, neoprene, SBR, polyvinyl chloride, and polyethylene, all have inherent shortcomings which make them unacceptable for elevated temperature pullout cable applications. Silicones did look promising; however, the physical properties in the past have always been very marginal at best. A review of manufacturer's data on silicone elastomers indicated that some of them have been improved to the extent that their physical properties are approximately equal to those of the neoprene currently used for jackets of pullout cable assemblies.

Six silicone elastomers were selected for preliminary evaluation. It was decided that the two which showed the most promise would undergo a comprehensive evaluation.

The six chosen for preliminary study were

- GE SE4661, Mechanical Grade Silicone Compound,
- GE PSE780, Mechanical Grade Silicone Compound,
- GE SE9073, Electrical Grade Silicone Compound,
- GE SE9090, Electrical Grade Silicone Compound,
- GE SE9092, Electrical Grade Silicone Compound, and
- GE SE9095, Electrical Grade Silicone Compound.

The preliminary evaluation was based on the results of the following physical tests:

- Tensile strength,
- Elongation,
- Tear strength, and
- Hardness.

The two elastomers selected as the most promising, based on the preliminary testing, were then subjected to the following more comprehensive tests:

- Tensile strength,
- Elongation,
- Hardness,
- Tear strength,
- Brittleness (cold) temperature,
- Heat aging effects on tensile, elongation, hardness and tear,
- JP-4 fuel oil immersion,
- Ozone resistance, and
- Adhesion of the elastomer to itself and to bare and tinned brass.

All testing was conducted on standard ASTM press cured slabs of each elastomer.

Preliminary Evaluation

The preliminary testing was conducted on 6 by 6 by 0.075 inch (152.4 by 152.4 by 1.91 mm) slabs of each silicone compound prepared, molded, and cured by GE's Silicone Products Division at Waterford, New York.

The slabs received a 10 minute press cure at 260°F (127°C). One group was then postcured 1 hour at 300°F (149°C) and another group was postcured 1 hour at 400°F (204°C). The press cure temperature is related to the catalyst selected for use in the elastomer compound.

Five specimens of each compound with each cure schedule were tested for each parameter. The data is reported in Table 1. The value for each test shown in Table 1 is the mean of the five values obtained. The test methods used are also reported in Table 1.

Table 1. Preliminary Test Data

Compound and Postcure Temperature	Tensile Strength* (psi) (MPa)	Elongation* (Percent)	Tear Strength** (lb·in.) (N·m)	Hardness (Shore A)
SE4661				
300°F (149°C)	1125 (7.756)	686	241 (27.22)	56
400°F (204°C)	1097 (7.563)	622	245 (27.59)	56
PSE 780				
300°F	984 (6.784)	254	114 (12.87)	74
400°F	980 (6.755)	240	107 (12.09)	76
SE9073				
300°F	931 (6.418)	426	139 (15.70)	60
400°F	904 (6.232)	380	132 (14.91)	63
SE9090				
300°F	1290 (8.894)	392	155 (17.51)	67
400°F	1310 (9.032)	370	128 (14.45)	74
SE9092				
300°F	828 (5.708)	586	181 (20.44)	55
400°F	937 (6.460)	552	190 (21.45)	61
SE9095				
300°F	1310 (9.032)	402	136 (15.36)	55
400°F	1266 (8.728)	375	123 (13.89)	55

*In accordance with ASTM D412 Die C.

**In accordance with ASTM D624 Die B.

Two of the silicone compounds, SE9090 and SE4661, appeared to possess a better balance of properties than the others. The first is an electrical grade and the other a mechanical grade silicone.

Inherent to the process of preparing and curing the ASTM test slabs for the preliminary testing was an evaluation of the processibility of each compound. All the slabs were readily milled, catalyzed, molded, and cured to the degree that none of them was superior to the others.

Comprehensive Evaluation of SE4661 and SE9090

The comprehensive evaluation was conducted on standard 6 by 6 by 0.075-inch (152.4 by 152.4 by 1.91 mm) slabs of GE silicone compounds SE4661/U and SE9090/U procured from the manufacturer as base stock pigmented a medium green. The SE9090 is supplied with part of the catalyst already in it. It contains 0.4 pph of 2, 5-bis (tert-butylperoxy)-2, 5-dimethylhexane. The SE4661 is supplied without any catalyst.

The silicone compound to catalyst mix ratio and cure schedule used in preparation of the test slabs are shown in Table 2.

Test specimens were prepared from the cured slabs and tested for the following physical properties:

- Tensile strength (to ASTM D412 Die C),
- Elongation (to ASTM D412 Die C),
- Hardness (Shore A Durometer),
- Tear Strength (to ASTM D624 Die B), and
- Brittleness (to ASTM D746).

Specimens were heat aged for 25, 50 and 100 hours at 350°F (177°C), 400°F (204°C), and 450°F (232°C), allowed to stabilize at room temperature, and then checked for

- Tensile strength,
- Elongation,
- Hardness, and
- Tear strength.

Specimens were immersed in JP-4 fuel oil for 4 and 24 hours at room temperature and then analyzed to determine the following properties:

Table 2. Silicone to Catalyst Mix Ratio and Cure Schedule for SE4661 and SE9090

Variable	SE4661	SE9090
Silicone Compound	100 pbw	100 pbw
Luperco 101XL Powder (50 Percent Active)	0.9 pbw	0.5 pbw
Luperco 101 Liquid (100 Percent Active) Added by Manufacturer		0.4 pbw
Press Cure	10 minutes at 340°F (171°C)	10 minutes at 340°F (171°C)
Post Cure	1 hour at 400°F (204°C)	1 hour at 400°F (204°C)

- Volume change,
- Tensile strength, and
- Elongation.

Ozone resistance was determined in accordance with ASTM D1149 at 100 pphm of ozone at 122°F (50°C) for 7 days. The specimen was bent 180 degrees during the test.

Compression set was determined in accordance with ASTM D395 Method B, conditioned for 22 hours at 350°F (177°C).

The data obtained on the compounds is reported in Table 3 for each parameter tested. The value shown is the mean value of 10 specimens tested for each characteristic.

The data for tensile strength and elongation are plotted in Figure 1. The data for tear strength and hardness are plotted in Figure 2.

A review of the data in Table 3 shows that the SE9090 compound has the better physical properties over the temperature range of 350 to 450°F (177 to 232°C). The initial room temperature properties show the SE4661 with a slight edge over the SE9090, but this is lost as soon as heat aging is introduced into the testing.

Figure 1. Tensile Strength and Elongation Data Plots

Figure 2. Tear Strength and Hardness Data Plots

Table 3. Physical Test Results for SE4661 and SE9090

Parameter	SE4661	SE9090
Tensile Strength (psi)(MPa)	1260 (8.687)	1190 (8.294)
Elongation (Percent)	540	520
Hardness (Shore A)	60	70
Tear Strength (lb·in.) (N·m)	213 (24.06)	198 (22.37)
Brittleness (°C)	Below -75	Below -75
Heat Aging 25 Hours at 350°F (177°C)		
Tensile Strength (psi) (MPa)	1150 (7.928)	1160 (7.997)
Elongation (Percent)	480	470
Hardness (Shore A)	64	75
Tear Strength (lb·in.) (N·m)	188 (21.24)	178 (20.11)
Heat Aging 50 Hours at 350°F (177°C)		
Tensile Strength (psi) (MPa)	1140 (7.860)	1150 (7.928)
Elongation (Percent)	470	460
Hardness (Shore A)	65	77
Tear Strength (lb·in.) (N·m)	180 (20.33)	190 (21.46)
Heat Aging 100 Hours at 350°F (177°C)		
Tensile Strength (psi) (MPa)	1060 (7.308)	1160 (7.997)
Elongation (Percent)	430	420
Hardness (Shore A)	69	78
Tear Strength (lb·in.) (N·m)	117 (19.99)	186 (21.01)
Heat Aging 25 Hours at 400°F (204°C)		
Tensile Strength (psi) (MPa)	1050 (7.239)	1130 (7.791)
Elongation (Percent)	440	410
Hardness (Shore A)	67	76
Tear Strength (lb·in.) (N·m)	186 (21.01)	182 (20.56)
Heat Aging 50 Hours at 400°F (204°C)		
Tensile Strength (psi) (MPa)	880 (6.067)	1120 (7.722)
Elongation (Percent)	350	380
Hardness (Shore A)	70	82
Tear Strength (lb·in.) (N·m)	134 (15.14)	150 (16.94)
Heat Aging 100 Hours at 400°F (204°C)		
Tensile Strength (psi) (MPa)	760 (5.240)	1100 (7.584)
Elongation (Percent)	280	340
Hardness (Shore A)	75	83
Tear Strength (lb·in.) (N·m)	110 (12.42)	126 (14.23)

Table 3 Continued. Physical Test Results for SE4661 and SE9090

Parameter	SE4661	SE9090
Heat Aging 25 Hours at 450°F (232°C)		
Tensile Strength (psi) (MPa)	810 (5.584)	1050 (7.239)
Elongation (Percent)	320	340
Hardness (Shore A)	71	81
Tear Strength (lb·in.) (N·m)	109 (12.31)	123 (13.89)
Heat Aging 50 Hours at 450°F (232°C)		
Tensile Strength (psi) (MPa)	620 (4.274)	940 (6.481)
Elongation (Percent)	200	290
Hardness (Shore A)	74	84
Tear Strength (lb·in.) (N·m)	94 (10.62)	103 (11.63)
Heat Aging 100 Hours at 450°F (226°C)		
Tensile Strength (psi) (MPa)	580 (3.998)	800 (5.515)
Elongation (Percent)	130	210
Hardness (Shore A)	82	84
Tear Strength (lb·in.) (N·m)	115 (12.99)	90 (10.16)
Immersion in JP-4 for 4 Hours at Room Temperature		
Volume Change (Percent)	+77	+93
Tensile Strength (psi) (MPa)	360 (2.482)	250 (1.723)
Elongation (Percent)	140	140
Immersion in JP-4 for 24 Hours at Room Temperature		
Volume Change (Percent)	+94	+138
Tensile Strength (psi) (MPa)	330 (2.275)	240 (1.654)
Elongation (Percent)	120	130
Ozone Resistance 7 Days at 122°F (50°C) in 100 pphm Ozone	No Cracks	No Cracks
Compression Set, 22 Hours at 350°F (177°C) (Percent)	42	62

Both compounds were equally good, within the limits of the test equipment used, on low temperature brittleness and ozone resistance. None of the test specimens developed any cracks during testing.

Because neither compound developed physical properties as good as anticipated, a discussion was held with the manufacturer. GE expressed the opinion that the properties of the SE4661 were

about as good as they would expect of that compound. However, they believe that figures obtained on the SE9090 compound were low. They suggested the use of a dual catalyst system on the compound, which, in their words "would result in a closer knit or better cross-linked" material.

The SE9090 was milled and catalyzed and new test slabs press cured and post cured to GE suggestions as follows.

SE9090 (with 0.40 pph Lupersol 101 catalyst as supplied by GE)	99.40 percent
Cadox BS (Benzol Peroxide)	<u>0.60</u> percent
Total	100 percent

Press Cure, 10 minutes at 255°F (124°C)

Post Cure, 1 hour at 400°F (204°C)

The test slabs with the dual catalyst system were tested to the same physical tests and methods as were used in the original testing of the SE9090 compound. The data obtained on the retest and the amount of change from the original test data are shown in Table 4.

The comparison of tensile strength and elongation of the single and dual catalyst systems of the SE9090 compound is plotted in Figure 3.

Adhesion strength of the unvulcanized SE9090 compound to cured slabs of SE9090 and to bright dipped naval brass was determined using the dual catalyst compound. The peel specimens were press cured 10 minutes at 250°F (121°C) followed by a post cure of 1 hour at 400°F (204°C).

The silicone-to-silicone specimens were pulled at a 180 degree angle at a rate of 10 inches per minute peel. The silicone-to-brass specimens were pulled at a 90 degree angle at a rate of 10 inches per minute peel.

The data in Table 5 is the mean of 10 specimens each.

To determine if a primer would improve the adhesion of the unvulcanized SE9090 compound to bare brass, the brass substrate was coated with Chemlok 607, a proprietary material of Hughson Chemicals.

Table 4. Results of Dual-Catalyzed SE9090 Tests

Test	Value Obtained	Change From Original Data
Tensile Strength (psi) (MPa)	1270 (8.756)	+80
Elongation (Percent)	590	+70
Hardness (Shore A)	72	+2
Tear Strength (lb·in.) (N·m)	193 (21.80)	-5
Brittleness (°C)	Below -75	0
Heat Aging 25 Hours at 350°F (177°C)		
Tensile Strength (psi) (MPa)	1290 (8.894)	+130
Elongation (Percent)	530	+60
Hardness (Shore A)	76	+1
Heat Aging 50 Hours at 350°F (177°C)		
Tensile Strength (psi) (MPa)	1310 (9.032)	+160
Elongation (Percent)	530	+70
Hardness (Shore A)	78	+1
Heat Aging 100 Hours at 350°F (177°C)		
Tensile Strength (psi) (MPa)	1320 (9.101)	+160
Elongation (Percent)	520	+100
Hardness (Shore A)	80	+2
Heat Aging 25 Hours at 400°F (204°C)		
Tensile Strength (psi) (MPa)	1300 (8.963)	+170
Elongation (Percent)	500	+90
Hardness (Shore A)	78	+2
Heat Aging 50 Hours at 400°F (204°C)		
Tensile Strength (psi) (MPa)	1260 (8.687)	+140
Elongation (Percent)	460	+80
Hardness (Shore A)	82	0
Heat Aging 100 Hours at 400°F (204°C)		
Tensile Strength (psi) (MPa)	1180 (8.135)	+80
Elongation (Percent)	410	+70
Hardness (Shore A)	81	-2
Heat Aging 25 Hours at 450°F (232°C)		
Tensile Strength (psi) (MPa)	1160 (7.997)	+110
Elongation (Percent)	440	+100
Hardness (Shore A)	80	-1

Table 4 Continued. Results of Dual-Catalyzed SE9090 Tests

Test	Value Obtained	Change From Original Data
Heat Aging 50 Hours at 450°F (232°C)		
Tensile Strength (psi) (MPa)	1020 (7.032)	+80
Elongation (Percent)	340	+50
Hardness (Shore A)	82	-2
Heat Aging 100 Hours at 450°F (232°C)		
Tensile Strength (psi) (MPa)	850 (5.860)	+50
Elongation (Percent)	260	+50
Hardness (Shore A)	85	+1
Immersion in JP-4 for 4 Hours at Room Temperature		
Volume Change (Percent)	133	+40
Tensile Strength (psi)(MPa)	310 (2.137)	+60
Elongation (Percent)	160	+20
Immersion in JP-4 for 24 Hours at Room Temperature		
Volume Change (Percent)	140	+2
Tensile Strength (psi) (MPa)	240 (1.654)	0
Elongation (Percent)	130	0

Chemlok 607 is a colorless, water thin, very low solids coating and was applied to the bare brass substrate by brush and allowed to air dry approximately 20 minutes. The peel specimens were press cured 10 minutes at 250°F (121°C) followed by a post cure of 1 hour at 400°F (204°C).

The peel strength of SE9090 silicone to bare brass coated with Chemlok 607 at a 90 degree pull was 15.51 pounds per inch (1.752 N·m) mean maximum average and 11.6 pounds per inch (1.310 N·m) mean sustained average.

The Chemlok 607 coated specimens increased the peel strength of the SE9090 silicone to brass on the order of threefold. A 30X magnification inspection of the silicone peel tabs displays minute particles of brass imbedded in it, which indicates that the nature of the failure is probably cohesive within the primer coating.

Figure 3. Effects of Catalyst on Tensile Strength and Elongation

Table 5. Peel Strength Data

Material Combination	Pull Angle (Degrees)	Strength (lb·in.) (N·m)
Silicone to Silicone	180	23.20 (2.62) mean*
Silicone to Bare Brass	90	5.24 (0.59) mean**
Silicone to Tin Coated Brass	90	0***

*Average pull; the adhesion of five specimens exceeded the tensile strength of the material and broke rather than peeling.

**Maximum pull

***Failure within the tin coating

Additional testing was conducted to ascertain the degradation of 500°F (260°C) heat aging on the physical properties of the SE9090 silicone compound.

The test specimens were compounded using the dual catalyst system, press cured 10 minutes at 255°F (124°C), and post cured 1 hour at 400°F (204°C). The heat aging was for periods of 25, 50, and 100 hours at 500°F (260°C) in an air circulating oven to assure that reversion of the silicone compound was not a factor.

The data in Table 6 is the mean of 5 specimens each.

The physical properties after 100 hours at 500°F (260°C) have been degraded approximately 55 percent from the original unaged properties. However, the compound is still a tough, flexible, coherent, abrasion resistant, and servicable material as a cable jacket.

ACCOMPLISHMENTS

General Electric's silicone elastomer SE9090 was extensively analyzed and found to be adequate for use as a cable jacket compound through a temperature range broader than that of neoprene, the current cable jacket material. SE9090 was also found to have room temperature physical properties approximately equal to those of the current neoprene cable jacket compound.

Table 6. Effects of Heat Aging on SE9090

Parameter	Result
Heat Aging 25 Hours at 500°F (260°C)	
Tensile Strength (psi) (MPa)	760 (5.240)
Elongation (Percent)	220
Hardness (Shore A)	83
Tear Strength (lb·in.) (N·m)	84 (9.491)
Heat Aging 50 Hours at 500°F (260°C)	
Tensile Strength (psi) (MPa)	680 (4.688)
Elongation (Percent)	160
Hardness (Shore A)	83
Tear Strength (lb·in.) (N·m)	78 (8.812)
Heat Aging 100 Hours at 500°F (260°C)	
Tensile Strength (psi) (MPa)	700 (4.826)
Elongation (Percent)	110
Hardness (Shore A)	85
Tear Strength (lb·in.) (N·m)	71 (8.02)

FUTURE WORK

No further work in evaluating the properties of the silicone compound SE9090 is planned.

A material specification will be written for a multiconductor cable using the SE9090 silicone as the jacket material. The property values defined for the cable jacket will be lower than the values obtained in this evaluation of the SE9090 because the test specimens used here have the ideal configuration and molding controls to develop optimum values. Test specimens prepared from jacket removed from a cable do not possess these attributes.

DISTRIBUTION

	Copy
R. Bulcock, ERDA-KCAO, 1D49	1
V. C. Vespe, ERDA-ALO	2
J. A. Freed, LASL	3
S. J. Buginas, LLL	4
H. M. Brinkmeier, Monsanto	5
G. H. Donaldson, SLA	6
R. S. Nelson, SLA	7
G. Volda, SLA	8-15
J. D. Corey, D/554, BD50	16-17
L. Stratton, D/554, 2C44	18-20
R. F. Pippert, D/700, 1A42	21
R. P. Frohmberg, D/800, 2A39	22
D. H. Hax, D/800, 2A38	23
R. R. Crockett, D/862, MC39	24-28
J. C. McCoy, D/862, MC39	29
G. A. Yocum, Jr., D/862, MC39	30
R. E. Kessler, D/865, 2C40	31