Technical Data

SILICONE rubber provides the maximum in reliability – whether exposed to adverse environmental conditions, stored for indefinite periods, or used under normal conditions. Resisting conditions which normally cause rubber to deteriorate, silicone rubber offers a useful life which is unmatched by other known elastomers. It resists temperature extremes, ozone, corona, radiation, moisture, compression set, weathering, and chemical attack.

Silicone has been with us since 1944, and has gone through hundreds of improvements. Originally sacrificing physical strength and elongation, we now have a large variety of compounds available which provide resistance to a broad range of temperatures with excellent electrometric physical properties.

When comparing elastomers for an application, one should not only consider the physical requirements. The "Total Cost", or the cost of the part including purchase price, installation, maintenance, and service life, should also be considered. Many elastomers are available at a much lesser cost than silicone, but fail to provide the user the reliability, and durability over an extended period of time. Users should consider the "Total Cost" package when selecting or specifying silicone rubber parts for an application.

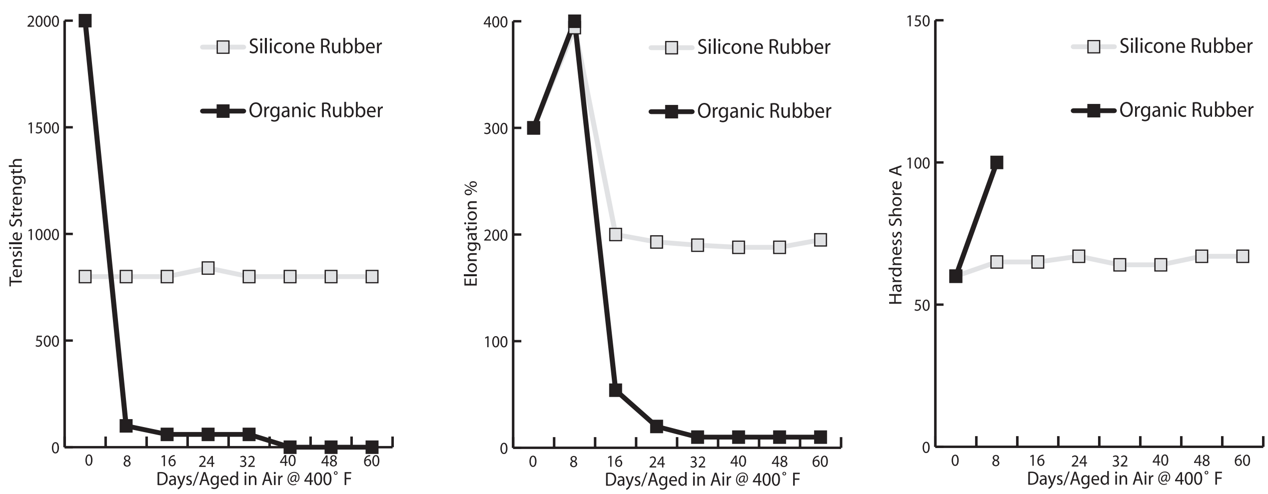
CHEMICALLY, silicone rubber is quite different from other elastomers. It is this difference, which gives them their unique combination of properties and permit silicone to perform in many applications where no other elastomer can be used. The basic difference between silicone polymers and "Organic" polymers is in the molecular make-up. Silicone or Dimethyl Polysiloxane, is made up of silicone/oxygen linkages, the same found in high temperature materials such as quartz, glass, and sand. Natural rubbers, or Organic polymers, are made up of carbon/carbon linkages. Many organic polymers witness "unsaturation" where carbon atoms are joined together by double bonds, making them susceptible to the adverse affects of ozone.

Through altering the chemical make-up of the silicones by adding phenyls, vinyl and, fluorine's, significant variations in physical properties can be achieved. The addition of phenyls improves low temperature flexibility and resistance to gamma radiation. Vinyl side groups improve the vulcanization characteristics and the compression set of the cured material. Fluorosilicones enable the user to witness the physical properties inherent in standard silicone and maintain resistance to solvents and fuels.

TEMPERATURE EXTREME STABILITY is silicones most outstanding property. Under normal operating conditions, temperatures as high as 500°F and as low as -150°F do not destroy the physical and electrical properties of silicone. At elevated temperatures, the tensile, elongation, and abrasion resistance of silicone is far superior to that of most organic elastomers. The advantages of silicone over natural rubbers is readily apparent in Figure 16A, which compares the effects of heat aging at 400°F. To show the true superiority of silicone, we have shown the effects in increments of DAYS for silicone, while the increments for organic rubber are shown in HOURS. Before aging, the organic rubber had higher tensile and elongation characteristics, but after only an hour into the test the silicone shows to be the elastomer of choice. As shown in Figure 16A, silicone shows stability throughout the term of the test. The estimated Useful Life of silicone at different temperatures is shown in Table 16B We consider the useful life to be the elastomer's ability to retain flexibility (measured here in elongation). In many applications, such as electrical cables, and insulator pads, the flexibility requirement may not be as critical, extending the "Useful Service Life" far beyond that indicated.

FIGURE 16A

Heat Aging Characteristics



FLAMMABILITY: Certain silicone rubber products inherently posses a profile of fire hazard characteristics which make them useful for applications where good flame retardation and minimum fire hazard is desired. For example most silicone rubber products will pass MIL-STD-417A horizontal resistance to flame (test method M). However, to pass the more stringent vertical flame retardant specification, flame retardant ingredients are essential. Silicone rubber can be compounded and fabricated to meet many specifications, including:

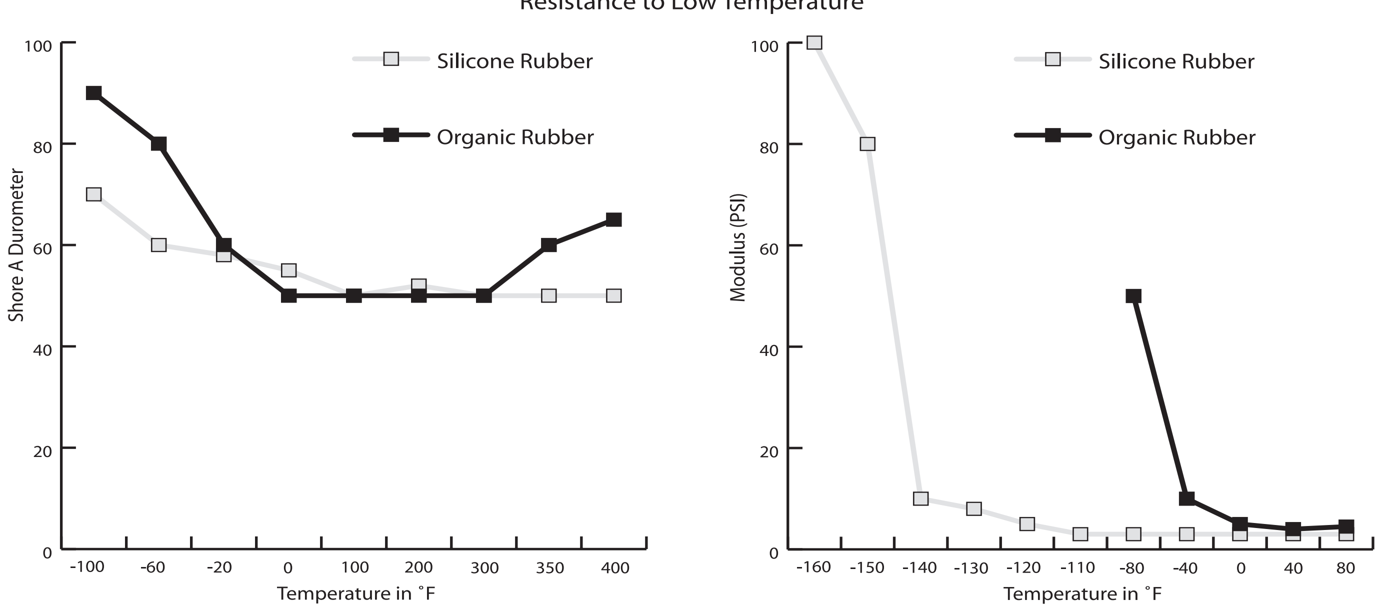
- UL-94, V-1 or V-0
- UL Code 62
- BMS 159-C

LOW TEMPERATURE FLEXIBILITY is yet another advantage silicone has over most organic rubbers. Silicone's durometer and modulus show little change at temperatures as low as -100°F. Extreme low temperatures require the addition of PHENYLS, which exhibit brittle points as low as -150°F, and remain serviceable at -120 to -130°F. In Figure 16C, we show a comparison between commonly used "low temperature" organic rubbers and standard (methyl) silicones when exposed to temperature variations.

TABLE 16B

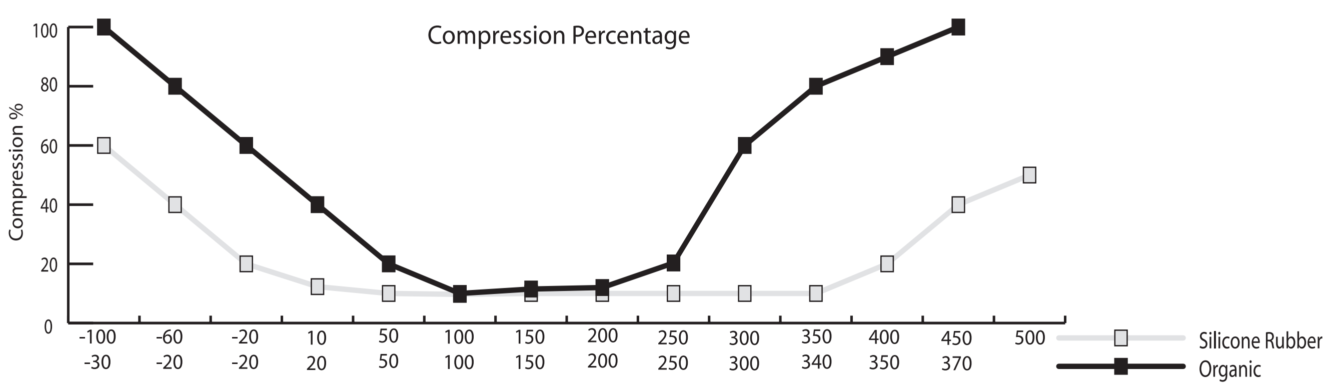
Service Temperature	Useful Life (Retention of 50% Elongation)
200°F	10 to 20 years
300°F	5 to 10 years
400°F	2 to 5 years
500°F	3 months to 2 years
500–600°F	1 week to 2 months
600–700°F	6 hours to 1 week
700–800°F	10 minutes to 2 hours.
800–900°F	2 to 10 minutes

FIGURE 16C



COMPRESSION SET and deformation resistance of silicone is superior to that of organic rubber, as shown in Figure 16D, which depicts the compression set values over a range of temperatures, when both elastomers are subjected to the same compressive forces.

FIGURE 16D



THE PHYSICAL STRENGTH of elastomers is measured by testing the Tensile, Tear, Elongation, and Compression Set. In general, silicone rubber is strong, resilient, and stretchable at temperatures where organic rubber fails. When compared with many popular organic rubbers at room temperature, silicone is relatively weak. But, as shown previously, silicone shows far superior stability when subjected to temperature fluctuations. When specifying an elastomer for a specific application, one must consider the environments in which the elastomer is asked to perform, and the expected life of the unit into which the elastomer is installed. The typical values one can expect of silicone at room temperature are shown in Table 16E.

WEATHERING RESISTANCE is another important concern when specifying material to be used. Silicone rubber resists the deteriorating effects of sunlight, ozone, and gasses, which cause weathering. Inherently water repellent, silicone is not affected by moist operating conditions. Very dry conditions and low humidity will not leach, dry out, or affect silicone in any way.

GOOD FUNGUS RESISTANCE When rubber is used in any warm, damp environment, its properties resist attack by mold or fungus. And, although silicone rubber is not antifungicidal, its not a nutrient for fungi nor is it adversely affected by fungus or mold.

RESISTANCE TO WATER Silicone also resists the deteriorating effects of the agents found in rainwater: nitrates, sulfates, chloride, and hydrogenous. Surface water containing minerals, acids, bases, and salts from the soil normally have no detrimental effect on silicone. We show in Table 16F the minimal effects long term immersion have on silicone due to it's resistance to moisture absorption. In fact, testing performed by the Navy Applied Science Lab, showed that silicone rubber did not change in appearance or physical properties after four years of undersea exposure (comparisons made with control samples shelf-aged at ambient temperatures).

TABLE 16E SUMMARY OF PHYSICAL PROPERTIES AT ROOM TEMPERATURE

Durometer Hardness, Shore A	25-90
Tensile Strength, psi	Up to 1600
Elongation, %	Up to 700
Tear Resistance, lb/in	Up to 250
Compression Set, %	Down to 5

TABLE 16F INFLUENCE OF 23°C WATER IMMERSION

	Original Values	After 125 Months Immersion
Volume Resistivity, (ohm-cm)	$1x10^{16}$	$5.5 X 10^{15}$
Dielectric Constant, 60 Hz	3.0	3.2
Power Factor, 60 Hz	0.0011	0.0011

Immersion Condition	Swell, Percent	Hardness change, Shore A Scale Points
7 Days at 73.4°F	+1	-1
7 Days at 158°F	+1	-3
7 Days at 212°F	+1	-5
1 Day at 249.8°F	+5	-6
3 Days at 249.8°F	+6	-6
1 Day at 350.6°F	+15	-16
3 Days at 350.6°F	Sample Broke Up	Sample Broke Up

TABLE 16G SUMMARY OF ELECTRICAL PROPERTIES-SILICONE RUBBER

Volume Resistivity, ohm-cm	$1x10^{14}$ - $1x10^{16}$
Electric Strength volts/Mil	400-700
Dielectric Constant 60 Hz	2.95-4.0
Power Factor, 60 Hz	0.001-0.0100

OZONE and CORONA, as stated, cause most organic rubbers to break down rapidly, and loose their inherent physical properties. Silicone on the other hand can withstand high concentrations of ozone (200ppm) with comparable effects resembling that of heat aging on silicone. The corona resistance of silicone approaches that of mica with the added advantage of silicone's flexibility.

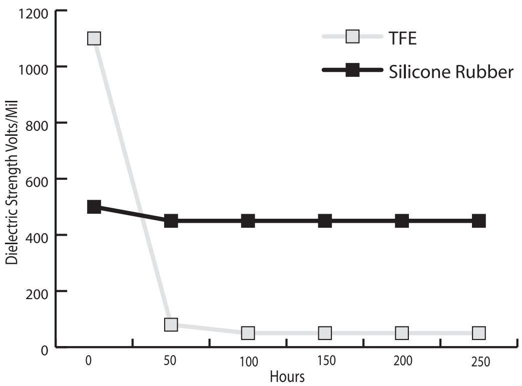
ELECTRICAL PROPERTIES of silicone compare favorably with the best insulating organic materials. Table 16G depicts the typical electrical properties to expect from silicone. Silicone rubbers fatigue life under continuous stress is high, allowing it to outperform organic rubbers when subjected to voltage for a prolonged period of time.

TABLE 16H INFLUENCE OF FREQUENCY ON DIELECTRIC CONSTANT AND POWER FACTOR

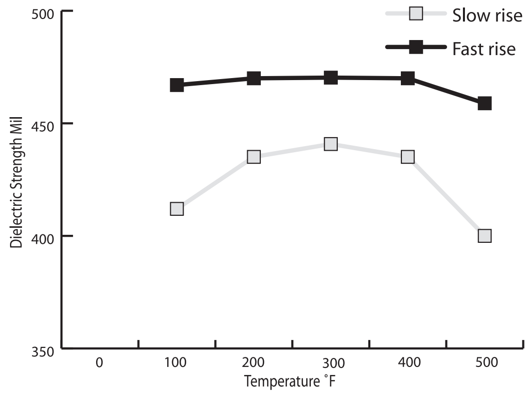
Frequency	Dielectric Constant	Power Factor
60 Hz	2.96	0.0004
10 Hz	2.96	0.0004
10 Hz	2.95	0.0010
10 Hz	2.91	0.0051

DIELECTRIC FATIGUE and ELECTRICAL STRENGTH stability are two more attributes silicone provides where organic rubbers often fail. At normal temperatures the electrical strength of silicone rubber is in the same order as the values for organic elastomers. Figure 16G shows that there is very little change in voltage resistance over the operating temperature range for which silicones are used. When continuously subjected to high voltage stresses for prolonged periods of time, other elastomers will evidence a drop-off in electric strength or show dielectric fatigue. Values shown in Figure 16G, depict those of silicone rubber. Dielectric constant and power factor vary in different compounds. The absolute values in Table16H will also be influenced by current frequency. For this reason silicone rubber is not used for applications where constancy in these properties as a function of frequency are essential.

Dielectric Fatique Measured on 50- Mil Sheets



Dielectric Strength vs Temperature of a Typical Stock



Silicone rubbers can also meet CHEMICAL RESISTANCE requirements in elevated temperature applications.

Table 16J shows the effect of a variety of materials on a low compression set silicone compound after one week's immersion at 77°F. At elevated temperatures, organic rubbers loose their effectiveness to resist these types of chemicals, and begin to break down.

Note: The figures for volume and durometer change, can help determine the suitability of silicone rubber, in your application

THERMAL CONDUCTIVITY compared to most other elastomers, silicone rubber has a high thermal conductivity. Values range 0.330 to 0.515 x 10^3 gr-cal/sec/cm^2/cm/°C

ADDITIONAL THERMAL PROPERTIES: Thermal expansion- the coefficient of volumetric thermal expansion for silicone rubber is in the range of 5.9 to 7.9 x 10^{-4}/°C. The linear coefficient of thermal expansion is roughly one-third of the volumetric coefficient of thermal expansion, and can be used to calculate the total linear thermal expansion of a silicone rubber part over a temperature range.

RADIATION RESISTANCE: The ability of silicone rubber to resist radiation damage at normal Temperature is comparable to many other synthetic polymers. However, at temperatures extremes, silicone rubber offers a combination of thermal, oxidation, and radiation resistance superior to most polymers.

RELEASE CHARACTERISTICS: Silicone rubber provides better release from sticking than any other rubber. One example of an application utilizing these release properties is the use of silicone rubber for rollers used in processing sticky materials such as hot polyethylene and adhesive.

TABLE 16J CHEMICAL RESISTANCE- SILICONE RUBBER

MATERIAL	WEIGHT CHANGE %	VOLUME CHANGE %	DUROMETER CHANGE %
ACIDS			
Nictric conc.	+10	+10	-30
Nictric 7%	<1	<1	-2
Sulfuric conc.	*	Disintegrates	*
Sulfuric 10%	<1	<1	-2
Acetic conc.	+2	+3	-4
Acetic 5%	+4	+4	+8
Hydrochloric conc.	+1	+1	-6
Hydrochloric 10%	+2	+4	-4
Hydrochloric 3%	<1	+1	-2
BASES			
Sodium Hydroxide 20%	<1	<1	-2
Sodium Hydroxide 1%	<1	<1	-4
Ammonium Hydroxide conc.	+2	+2	-4
Ammonium Hydroxide 10%	+3	+2	-6
SALTS			
Sodium Chloride 10%	<1	<1	-2
Sodium Carbonate 2%	<1	<1	0
SOLVENTS			
Ethal Alcohol	+5	+6	-10
Acetone	+5	+15	-15
Toluene	+75	+120	-30
Gasoline, Regular	+65	+130	-25
Gasoline, Aviation	+60	+110	-30
Mineral Spirits Carbon	+65	+110	-30
Tetrachloride	+130	+110	-25
HYDRAULIC FLUIDS			
Hollingshead H-2	+4	+5	-10
Hollingshead H-2 (1)	+9	+12	-15
Skydrol	+4	+4	-8
Skydrol (1)	+7	+8	-10
PRL3161	+5	+7	-8
PRL3161(1)	+9	+9	-15
OILS			
Castor Oil	<1	<1	-4
Lard Oil	<1	<1	-4
Linseed Oil	<1	<1	-2
Mineral Oil	+5	+6	-6
ASTM # 1 Oil (2)	+3	+5	-6
ASTM # 3 Oil (2)	+20	+31	-20
Silicone Oil SF 96 (100) 2	+25	+35	-25
Silicone Oil 42,000 cstk (2)	+9	+10	-12
OTHER			
Water	<1	<1	<1
Hydrogen Peroxide 3%	<1	<1	<1
Pyanol 1476	+4	+4	-8

(1) 70 hours @ 212ºF (2) 70 hours @ 300ºF