

Technical Library

Product Technology For Silicone Heat Cured Elastomers

Silicone Rubber is a specialty synthetic elastomer that provides a unique balance of chemical and mechanical properties required by many of today's more demanding industrial applications. From its original development in the 1940's using a laboratory Grignard process, to its final commercial form today, silicone rubber excels in such areas as:

- High temperature stability
- Low temperature flexibility
- Chemical resistance
- Weatherability
- Electrical performance
- Sealing capability

In addition, because of its relative purity and chemical makeup, silicone rubber displays exceptional biocompatibility which makes it suitable for many health care and pharmaceutical applications. Compared to many organic elastomers, silicone rubber offers superior ease of fabrication resulting in high productivity and cost effectiveness for extended service reliability. Good examples of this are automotive gasketing and connectors which provide long term sealability under a variety of temperature and environmentally severe operating conditions.

Workshop Index

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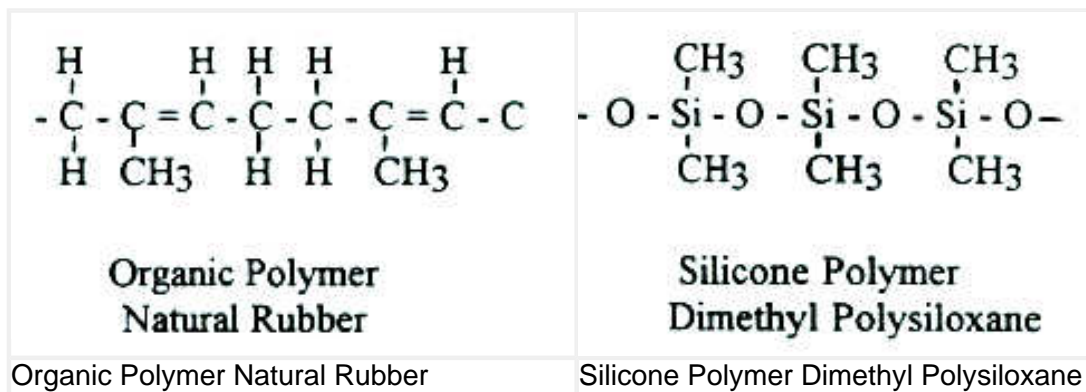
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The Chemistry of Silicone Rubber

Within the field of specialty elastomers, silicone rubber reserves the distinction of having evolved from the inorganic origins of ordinary beach sand. The unique chemistry resulting from the silicon-oxygen (Si-O) polymer backbone is responsible for the extended service temperature capability of silicone rubber as well as its extraordinary resistance to oxidation and ozone degradation. This basic difference between silicone polymers (also known as polysiloxanes) and organic polymers is illustrated below.



This silicon-oxygen linkage is identical to the chemical bond found in highly stable materials such as quartz, glass, and sand, and is responsible for the outstanding high temperature performance of silicones and their general resistance to deterioration factors such as ozone, corona, weathering, and radiation. Many organic polymers contain unsaturated double bonds in their primary backbone which are particularly susceptible to oxidation and ozone attack. The absence of any unsaturation in the silicone backbone makes them extremely resistant to these environmental factors.

The silicone molecule can be customized by the chemist to optimize certain attributes required by the particular application. Of the several organic side groups which can be used along the polymer chain, methyl, vinyl, phenyl, and trifluoro propyl are the most common which have commercial significance.

The inclusion of vinyl groups (generally at less than 1 mole %) greatly increases crosslinking efficiency with organic peroxides and yields elastomers with lower compression set and improved hot oil resistance. Today, almost all commercially available silicone rubber polymers contain some level of vinyl.

Although dimethyl silicone rubber remains flexible at temperatures as low as -60°C , the partial substitution of phenyl groups extends the low temperature performance to -93°C by sterically hindering association of polymer chains. Such phenyl silicone rubber compounds are typically used in aerospace applications where low temperature performance is critical.

Finally, inclusion of the trifluoro propyl side group imparts a polar nature to the silicone molecule which results in a fuel resistant variation of silicone rubber called fluorosilicone rubber. Fluorosilicone rubber combines the high and low temperature advantages of "ordinary" silicone with resistance to many harsh chemicals and is, thus, used in the most demanding applications.

More than one chemical side group can be included in the same polymer to combine the advantages of each. For example, a polymer containing both vinyl and phenyl groups would exhibit improved crosslink efficiency and extended low temperature flexibility. The chemical structure of these different classes of silicone polymers along with their respective ASTM D-1418 classifications are shown in [Figure 1](#). [Figure 2](#) indicates areas of strengths and

weaknesses for each of the polymer classes relevant to final physical and chemical properties.

Figure 1

Silicone Polymer Classifications

ASTM D-1418

Classification	Description	Polymer Structure
MQ	Dimethyl Silicone General Purpose, Sponge	
PMQ	Methyl Phenyl Silicone Low Temperature	
VMQ	Methyl Vinyl Silicone Low Compression Set	
FVMQ	Fluorosilicone Solvent Resistance	

Polymer Information

Molecular Weight Range: 300,000 to 800,000
Viscosity Range: 2×10^6 to 2×10^7 cps
Penetration: 2×10^{10}
 Viscosity (cps)

Figure 2

Silicone Polymer Comparative Properties

Relative Effect

	Dimethyl	Vinyl	Phenyl	Fluoro
High Elongation	+	-	0	-
High Tensile	+	-	0	-
High Modulus	-	+	0	0
High Resilience	0	+	-	-
Low Compression Set	-v	+	-	0
Oil Resistance	-	+	-	+
Thermal Stability	0	0	+	-
Reversion Resistance	-	+	-	-
Low Temperature Flex	0	0	+	-
Fuel Resistance	-	0	-v	+
Radiation Resistance	0	0	+	0
Clarity	0	0	+	-
Fast Cure Rate	-	+	0	-

Note: This table indicates individual effects only. Inclusion of two or more classes of side group can optimize the overall property profile.

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Commercial Preparation of Silicone Polymer

Most silicone products including fluids, RTV's, and rubber are derived from the same chemical starting materials and are later differentiated by viscosity or degree of polymerization. The process begins with the reduction of silica (sand) to elemental silicon metal which is then mechanically ground and reacted with methyl chloride at 300°C in the presence of a copper catalyst.

This results in the formation of reactive methylchloro silanes which are fractionally distilled and separated into their mono, di, and tri counterparts. Note that the dichloro species is most important for forming long linear polymer chains since its bifunctionality allows it to "grow" chemically in two dimensions. The trichloro species forms three dimensional crosslink networks and, although important for rigid, nonelastomeric molding resins, must be separated from the di stream to avoid gelling the polymer.

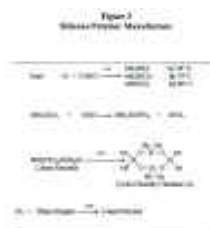
After distillation, the dimethyldechlorosilanes are hydrolyzed to form silanols which rapidly condense to cyclic siloxanes and low molecular weight linear siloxanes. The latter are reacted with caustic to produce cyclic siloxanes, specifically dimethyl tetramer or D₄ which

is the primary input for all dimethyl silicone rubber polymer and which is a clear, low viscosity liquid. Ring opening polymerization of the cyclic D₄ is then accomplished via

strong base resulting in linear polymer whose molecular weight (viscosity) is controlled by the addition of monofunctional siloxanes which function as chain stoppers. This process is diagrammed in [Figure 3](#):

Figure 3

Silicone Polymer Manufacture



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Silicone Rubber Compounding

Unlike organic polymers, silicone polymer by itself is relatively weak and produces tensile strengths of only 1.0 Mpa when crosslinked. To achieve useful engineering properties, it is necessary to reinforce the polymer by the addition of very fine, high surface [fillers](#) which are compatible chemically with the silicone polymer. In addition, functional fluids called [process aids](#) are required for adequate shelf life control as well as processability, and [curing agents](#) are needed for vulcanization. [Figure 4](#) lists the various formulation ingredients for silicone rubber compounds and their primary function. The following sections will treat these in more detail.

Fillers

The most common reinforcing filler used in silicone rubber compounds is fumed silica which is manufactured by burning silicon tetrachloride in the presence of hydrogen and oxygen. The smoke-like silica particles produced are extremely fine and spherical in shape with surface areas as high as $325 \text{ m}^2/\text{gm}$. These particles are amorphous but associate in string-like clusters which chemically interact with the Si – O polymer backbone, yielding the desirable reinforcement properties.

Crosslinked silicone rubber compounds containing fumed silica typically have tensile strengths in excess of 10 Mpa, i.e., a factor of ten higher than the pure polymer.

Precipitated silicas made through the acidification and precipitation of sodium silicate can also be used as reinforcing fillers in silicone compounds but usually give weaker mechanical properties compared to fumed silica. In addition, because salt is a by-product of the manufacturing process, compounds based on precipitated fillers tend to be poorer in terms of electrical properties. These compounds are, however, extremely good in terms of low compression set and high resilience, and are more cost effective than their fumed silica counterparts.

Because precipitated silica holds absorbed water on its surface, sponging may occur during curing unless pressure can be maintained on the part. For this reason, precipitated fillers are primarily utilized in compounds intended for molding processes.

The degree of reinforcement of a filler in silicone polymer can be categorized according to its incremental effect on Shore A durometer ([Figure 5](#)) which strongly correlates to filler surface area.

In the semi-reinforcing category, diatomaceous earths are often added to improve oil resistance.

A third category of essentially non-reinforcing or extender fillers include ground quartz which reduces cost, reduces shrinkage, and improves thermal conductivity.

Other fillers which are useful in silicone rubber formulations include iron oxide and titania for heat stability, aluminum trihydrate for tracking resistance in insulators, and various carbon blacks for conductivity. ([Figure 6](#))

Figure 4

Formulation

Component	Primary Function
Silicone Polymer	Inherent Chemical Properties
Reinforcing Filler	Physical and Rheological Properties
Extender Filler	Cost Reduction and Oil Resistance
Process Aid	Processability and Shelf Life Stability
Organic Peroxide	Crosslinking Agent
Metallic Oxide	Oil and Reversion Resistance
Platinum Complex	Addition Cure Catalyst and/or Flame Retardant
Iron Oxide, Titania	High Temperature Heat Stability
Coupling Agent	Lower Compression Set and Increase Modulus
Phenyl Silicone Fluid	Self-Bleed or Self Lubrication
Teflon Powder	Increase Green Strength

Figure 5

Fillers Suitable For Use With Silicone Polymers

Type	Reinforcement	Sp. Gravity	Particle Diameter (Millimicron)	Surface Area (m ² /gm)	1 Duro Pt. Loading (parts per 100)
Fumed Silica	High	2.20	17 10	200 325	1 – 1.5 0.5 – 1.0
Precipitated Silica	High	2.00	22	160	1 – 1.5
Diatomaceous Earth	Semi	2.15 – 2.30	3000	5	2.0
Ground Quartz	Low	2.65	5000 – 30,000	---	3.0 – 5.0
Red Iron Oxide	Low	4.95	1000	---	---
Titania	Semi	3.90	300	9	---

Figure 6

Comparative Properties Of Conductive Carbon Blacks For Silicone Rubber Compounding

	Acetylene Black (Shawinigan)	Furnace Black (Ketjen EC)	Graphite (Lonza KS15)
% Volatiles	0.3	1.0	0.1
Particle Size (millimicrons)	420	30	15,000
BET Surface Area (m ² /gm)	64	950	14
Degree of Structure	High	Medium	Low
Microstructure	Highly Ordered	Medium	Extremely Ordered
Degree of Porosity	Medium	Very High	Very Low

Effect Of Extender Filler On 35 Durometer General Purpose

Compound

Formulation	A	B	C	D	E
SE6035	100	100	100	100	100
5 Micron Minusil	----	25	50	100	150
DBPH-50	0.8	0.8	0.8	0.8	0.8

Press Cured 10' @ 177° C**+ 1 Hour @ 200° C Post Bake**

Shore A	34	38	42	56	66
Tensile, psi	1320	1065	950	730	700
Elongation, %	780	750	690	500	210
Tear Die B, ppi	95	90	90	95	75
Compression Set, %	35	37	36	38	42
Specific Gravity	1.10	1.25	1.37	1.55	1.69

Heat Aged 70 Hours @ 225° C

Shore A Change	+2	+4	+4	+5	+9
Tensile Change, %	-16	-12	-6	-4	-4
Elongation Change, %	-30	-30	-28	-45	-30

Process Aids

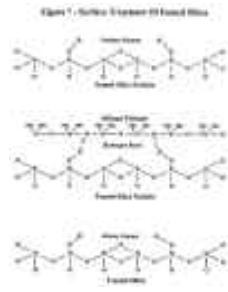
Process aids, also known as softeners, are reactive silicone fluids which chemically modify the surface of the silica fillers to reduce their association with the silicone polymer. Most process aids are liquids which can either be prereacted with the silica filler in a pretreatment process, or can be introduced during the compounding/mixing phase to effect “in-situ” treatment. In many cases, both techniques are employed.

To understand the need for this critical ingredient, reference is made to (Figure 7). The upper schematic shows the surface of a typical fumed silica particle. Note that the pendant hydroxyl (OH) groups on the filler surface form secondary bonds with the oxygen (O) in the polymer backbone (Center schematic in Figure 7). This is called hydrogen bonding and increases as a function of time so that an uncured compound containing only silicone polymer and untreated fumed silica will harden or structure as it ages. This adversely affects the processability of the compound such that it crumbles and cracks on the mill instead of forming a smooth, continuous band.

Process aids react with the pendant hydroxyl groups, thereby reducing the level of polymer-filler interaction and improving processability and shelf life of the silicone compound. This is shown in the lower schematic of (Figure 7) in which the hydroxyl groups have been replaced with a nonreactive alkoxy group designated by –R. Process aids typically are hydroxyl stopped fluids or chemicals which hydrolyze during compounding to produce hydroxy functional fluids which then react with the filler surface.

In addition to processability improvements, the proper amount of process aids can aid dispersion of extender filler, improve physical properties, and enhance clarity. Too much process aid can adversely impact compression set and high temperature aging.

Figure 7 – Surface Treatment Of Fumed Silica



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Vulcanization/Curing Of Silicone Rubber

Traditional curing agents for silicone rubber compounds are organic peroxides which, when heated, decompose to form free radicals that react with the pendant organic groups on the silicone polymer. This results in crosslinks between the polymer chains, the number and distribution of which greatly influence the final physical property profile of the cured rubber.

Cure time is a function of the activation temperature of the particular peroxide and the thickness of the part.

The crosslinking mechanism is illustrated in [Figure 8](#) for both methyl and vinyl sidegroups, with the higher reaction rate of the vinyl group responsible for its importance to crosslink density and cure rate.

Organic peroxides fall into two broad categories according to their ability to crosslink just vinyl groups or both methyl and vinyl groups. The dialkyl peroxides such as dicumyl peroxides fall into the former category and are termed “vinyl specific” while the diacyl peroxides such as benzoyl peroxide fall in the latter category.

Most peroxides are available as a liquid (90% - 98% active), as powders (40% - 50% active), or as pastes made from silicone fluids and gums (20% - 80% active) to facilitate handling and dispersion. [Figure 9](#) lists the organic peroxides commonly used to cure silicone rubber with recommended cure temperatures and general application areas. [Figure 10](#) is a further checklist to differentiate the use of diacyl and dialkyl peroxide types.

Figure 8

Peroxide Crosslinking Mechanism



Figure 9

Organic Peroxides For Silicone Rubber

Typical Curing Agents

Peroxides	Commercial Grades	Form	%	Typical Molding Temperature	Recommended Use
Bis (2,4 Dichlorobenzoyl) Peroxide DCBP-50	Cadox® TS-50 Or Luperco® CST	50% Active Paste	1.2	104-132°C (220-270°F)	Hot Air Vulcanization

Benzoyl Peroxide BP-50	Cadox® BS Or Luperco® AST	50% Active Paste	0.8	116-138°C (240-280°F)	Molding Steam Curing
DiCumyl Peroxide	Di-Cup® 40C	40% Active Powder	1.0	154-177°C (310-360°F)	Molding Thick Sections, Bonding, Steam Curing
2,5-DiMethyl- 2,5-Di (t-butyl peroxy) Hexane	Varox® Or DBPH-50 Lupersol® 101	50% Active Powder 100% Active Liquid	0.8 0.4	166-182°C (330-360°F)	Molding Thick Sections, Bonding, Steam Curing

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Figure 10

Comparison Of Diacyl And Dialkyl Peroxides

	DCBP-50	BP-50	Dicumyl	DBPH
Type	Diacyl	Diacyl	Dialkyl	Dialkyl
Vinyl Specific	No	No	Yes	Yes
HAV Curable	Yes	No	No	No
Acid By-products	Yes	Yes	No	No
Low Compression Set	No	No	Yes	Yes
Post-bake Recommended	Yes	Yes	No	No
Carbon Black Compatible	No	No	Yes	Yes
Low Temperature Cure	Yes	Yes	No	No
Thick Section Cure	No	No	Yes	Yes
Optimum Bondability	No	No	Yes	Yes
Non-Blooming	No	Yes	Yes	Yes
Optimum Fire Retardance	Yes	No	No	No

Addition Cure

An alternative method for curing silicone rubber utilizes a silicone hydride (SiH) crosslinking agent in conjunction with methylvinyl silicone polymer. In the presence of a precious metal catalyst such as platinum, a true addition reaction occurs resulting in a uniformly vulcanized rubber without curative by-products ([Figure 11](#)). Since this reaction proceeds quite actively at room temperature, inhibitors play a crucial role in assuring adequate mixed shelf life and cure rate control at fabrication temperatures.

Both hydride spacing in the crosslinker and vinyl level and distribution in the polymer determine the physical property profile of the cured elastomer, and addition cured materials are able to achieve extremely high levels of tear strength (50 – 60 KN/M) as a result. [Figure 12](#) further compares the properties of addition cure and peroxide cure systems.

Compounding Additives

Silicone polymer, reinforcing filler, and process aids are the three major components of every silicone rubber formulation. Other compounding ingredients may also be used to enhance specific properties such as heat, age and oil resistance ([Figure 4](#)). These materials are often supplied as separate additive packages to meet the custom requirements of

specific applications.

Since certain additives may be problematic in certain silicone base compounds, it is recommended that the silicone supplier be consulted to ensure compatibility.

Figure 11

Addition Cure Mechanism



Figure 12

Peroxide Cure vs Addition Cure

	Peroxide Cure	Addition Cure
Tight Surface		X
Low SurfaceTack		X
Hot Air Cure	DCBP only	X
Low Coefficient Of Friction		X
Best Hot Tear Strength		X
Low Compression Set	X	
Optimum High Temperature	X	
Fast Cure Rate		X
Long Shelf Life	X	
Non-Blooming Extrusion		X
No Decomposition By-products		X
Lower Cost	X	
Easy Flash Removal		X
Catalyst Sensitivity		X
Potential Cure Inhibition		X

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The Compounding Process

Silicone rubbers are most commonly mixed in an internal mixer such as a doughmixer or Banbury type mixer which provides additional shear through action of the ram. Typically, the polymer is loaded first, followed by the liquid components, reinforcing filler, and additives, although this sequence can be modified to provide more initial shear by partial addition of the filler up front.

Incorporation of the high surface area reinforcing filler is usually the rate controlling step in achieving satisfactory mix. In-situ filler treatment usually requires a cook or heating cycle which also serves to devolatilize the compound and stabilize properties. Pretreated filler and devolatilized polymer allows the use of a “cold mix” to similarly achieve stable properties and is generally a more cost effective process. A schematic of a typical Banbury mix process is illustrated in Banbury [Figure 13](#).

Freshening and Milling

Freshening is the process of mechanically plasticizing or softening a rubber compound to develop consistency in fabrication. Even with the use of process aids, most silicone compounds show some degree of structure with time and benefit from freshening prior to fabrication.

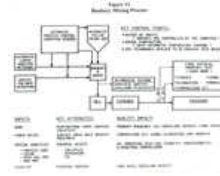
Silicone compounds are easily freshened on a two roll rubber mill equipped with a scraper blade on the fast roll to facilitate stock removal. A speed ratio on the rolls of 1.2 – 1.4 to 1 is required to shear the rubber as it passes through the nip which helps to promote good dispersion.

Milling is also utilized to add minor ingredients such as pigment and catalyst to the compound as it provides temperature control to prevent premature volatilization or decomposition of the catalyst. A typical mill mix cycle is as follows:

- Begin with a clean mill and turn on the cooling water.
- Set the nip spacing to approximately ¼” and pass the compound through the nip several times.
- Gradually tighten the nip until the compound transfers to the fast roll. Continue milling until the material forms a smooth band which indicates the material is freshened.
- When mixing additives on the mill, first fully freshen the base compound, and then add the other components. Cross-blend by removing the material from the mill using the scraper blade or a mill knife and turning 90 ° before feeding it back through the nip. Cross-blending a minimum of 10 times will assure a uniform mix.
- When blending compounds of different consistencies, freshen the firmer stock first, and then add the softer stock and cross-blend. Prefreshening pigment masterbatches is recommended before adding to the base compound.
- The mill should be cleaned PRIOR to changing the compound formulation. A stiff, highly filled silicone stock makes a good cleanout compound for removing any material that may have adhered to the mill rolls from prior batches.

Figure 13

Banbury Mixing Process



Key Control Points:

- Ratio of Inputs (amounts are controlled by the computer)
- Mixing Temperature (have automatic temperature control)
- SPC Techniques Applied to in Process Test Results

Inputs	Key Attributes	Quality Impact
Gums	Penetration, Vinyl Content Volatiles	Product Rheology, S.G. Crosslink, Density, Final Physicals
Fumed Silica	Surface Area, Bulk Density, Treatment	Compression Set, Shore, Elongation, 100% Modulus
Special Additives Process Aids Color Heat-Age MBX MgO MBX	Chemical Assays Volatiles Dispersion S.G.	Oil Immersion, Heat-Age Stability, Processibility, Elongation, Compression
Catalyst	Peroxide Content	Cure Rate, Crosslink Density

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Fabrication Methods & Curing

Silicone rubber can be fabricated by all standard methods for thermoset elastomers including [compression molding](#), [transfer molding](#), [extrusion](#), and [calendaring](#). Compared to many organic elastomers, silicone is relatively easy to process and often needs no secondary post cure operations. It is especially suited to detailed molding applications such as automotive connectors and provides rapid cure times and relatively low odor during fabrication. The following summarize these various Fabrication and Curing techniques:

Fabrication Techniques:

- [Compression Molding](#)
- [Transfer Molding](#)
- [Injection Molding](#)
- [Extrusion](#)
- [Calendaring](#)

Cure Techniques:

- [Curing Methods for Extrusion](#)
- [Oven Curing](#)

Compression Molding

Compression molding is the most widely used method for molding silicone rubber parts. The stock is usually preformed first to the approximate size and weight of the final part and then placed in the heated cavity of the mold where it is cured under heat and pressure.

The process is labor intensive due to its manual nature and necessity to remove flash, but requires the lowest expenditure for tooling and equipment.



Transfer Molding

Transfer molding is a process by which uncured rubber compound is transferred from a holding vessel (transfer pot) to the mold cavities using a hydraulically operated piston. Transfer molding is especially conducive to multicavity designs and can produce nearly flashless parts.

Older designs using hot transfer pots resulted in considerable cured waste. Newer designs using water-cooled transfer pots have significantly overcome this problem so that transfer molding now can compete comfortably with injection molding for certain applications.



Injection Molding

Silicone rubber's low relative viscosity and fast cure rate make it an excellent material for injection molding. Although the screw can be directly fed with preformed strip, many prefer to use a stuffer box which insures constant feed and minimizes handling of the uncured compound.

Injection molding cure cycles are typically in the range of 0.5 – 3 minutes depending on part size, and mold shrinkage tends to be lower than other molding methods due to high injection pressures. Balanced gates and venting are required to avoid air entrapment and insure complete fill in multi-cavity molds.



Extrusion

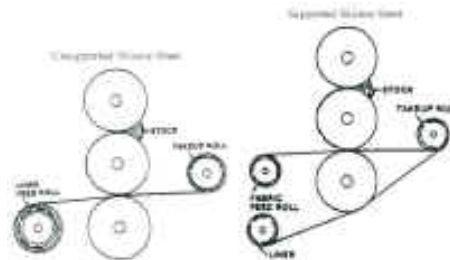
Extrusion is the fabricating technique to produce continuous profile shapes and preforms such as tubing and wire & cable insulation.

Standard rubber extruders with water cooling and roller feeds can be used to fabricate silicone rubber. The barrel should be constructed of abrasion-resistant, surface-hardened steel such as nitrided 4140 to minimize wear. Typically, the screw should have a compression ratio in the range of 2:1 to 4:1 and an L/D (length/diameter) ratio of 8:1 to 12:1. Deep flights in the feed section facilitate feeding of the compound. Stainless steel screens of 40 to 150 mesh are recommended to remove contamination, increase back pressure, reduce porosity, and provide better dimensional control. Also see [Curing Methods For Extrusion](#).

Calendering

Calendering is the process for producing long runs of uniform thickness sheets of silicone rubber either unsupported or on a fabric backing. A standard 3 or 4 roll calender with linear speed range of 2 to 10 feet/minute is typical for silicone rubber. Firm compound with good green strength and resistance to overmilling works the best for calendering. Soft stocks should be aged a minimum of 24 hours after milling to build up some structure prior to calendering. Unsupported sheet can be partially cured by passing over a heated drum or through a hot air vulcanization unit, and then post-cured in an air circulating oven. Both supported and unsupported sheet can be cured on a roll in a steam autoclave.

Typical Calender Set Ups



Curing Methods For Extrusion

Extruded profile may be cured by hot air vulcanization (HAV), steam vulcanization (CV) or liquid-medium cure. HAV consists of a heated tunnel through which the profile is fed continuously on a moving conveyor. Air temperature reaches 600°F to 1200°F, and cure times are usually short, on the order of 3 to 12 seconds. The recommended curing agents are DCBP-50 or addition cure, both of which provide rapid cure with no porosity.

Steam cure commonly refers to the steam curing systems used by the wire and cable industry and consists of chambers 4" – 6" in diameter and 100 – 150 feet in length. Steam pressure varies from 50 psig to 225 psig depending on wall thickness of the insulation and line speed. A typical cure with benzoyl peroxide is 13 seconds or 400 feet/minute at 125 psig.

For liquid-medium cure, continuous lengths of extruded profile are fed into a bath of molten material (salt or lead) which cures the extrudate. This technique requires DCBP-50 to prevent porosity.

Oven Curing

Oven curing or post-baking is the process of heating cured silicone rubber parts in an oven to remove volatiles and peroxide decomposition by-products. This process improves dimensional stability and high temperature performance. It is especially recommended for parts cured with either 2,4 dichlorobenzoyl peroxide or benzoyl peroxide since acidic by-products of these materials cause reversion at high temperature unless removed by post-baking.

Electric and indirectly-fired gas air circulating ovens have been used successfully for post-baking silicone rubber parts. Fresh airflow should be maintained at a minimum of 2 cubic feet per minute, per pound of silicone rubber, and parts should be supported on open trays to maximize exposure. Generally, post-bake temperature should be a minimum of 50°F higher than the service temperature of the part. Sections thicker than 0.075" may require a stepped post-bake (gradually increasing temperatures) to avoid sponging of the part.

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Technical Library

Troubleshooting Guide for Silicone Rubber Fabrication

- [Milling and Freshening Troubleshooting Chart](#)
- [Molding Troubleshooting Chart](#)
- [Extrusion – Wire and Cable – Troubleshooting Chart](#)

Milling and Freshening

Problem	Probable Cause	Recommended Action
Lumps	Improper freshening technique	Gradual reduction of mill nip during freshening. Lengthen milling time at original wide nip setting. Avoid addition of unfreshened crumbs to freshened stock.
Stickiness	Over-freshening	Shorten milling time after stock has knit on mill.
Porosity	Entrapped air due to over-freshening	Shorten milling time after stock has knit on mill. Pass stock through wide nip to gently squeeze out entrapped air.
Brown Spots	Entrapped air	Shorten milling time after stock has knit on mill. Pass stock through wide nip to gently squeeze out entrapped air.
Flow Lines	Under-freshening	Extend milling of stock after mill.
Specks in Compound	Contamination from handling and/or milling	Keep compound in closed container when in storage both before and after freshening. Clean all traces of organic rubber fillers, etc. from mill pan, roll guides, etc.

Molding

Problem	Probable Cause	Recommended Action
Back Rind	Usually encountered in flash-type molds as a result of a combination of high shrinkage, high thermal expansion and compressibility of silicone.	Lower mold temperature. Bump press as charge heats. Use accurately weighed perform. Reduce mold pressure. Cool mold before opening.
Brown Spots	Entrapped air	Add masking color. Make sure stock is freshened properly for reasonable flow. Use weighed preform, shaped and loaded to most effectively sweep out air. Close mold completely and then bump several times. Avoid excess release agent. Use even mold temperature. Lower temperature if charge is heavy. Raise mold temperature if charge is light. Venting of mold may be necessary.

Gassing and Decomposition	Contamination	Check for contamination. See <i>Brown Spots</i> , above.
Flow Marks	Some hindrance to plastic flow. More likely to appear on light-gauge, deep draw or highly complicated moldings.	Stock should be well freshened. Fast loading and closing of the mold is essential to prevent premature curing. Reduce the molding temperature. Conditions may be such that elimination of flow lines may not be possible unless process or stock are modified.
Shrinkage Variation	Variations of more than +1% can come from improper molding procedures.	Check plasticity of stock. Check mold temperature. Check preform weight. Check molding time.
	Insufficient age after compounding	Increase shelf age. Use low shrink gum base.
White Spots	Under-curing	Raise mold temperature. Increase oven temperature, time, and air circulation.
	Storing too long between press and oven cure.	Raise mold temperature. Shorten storage time.
“Windows” (Clear spots in a pigmented stock)	Improper freshening	Make sure freshening is not started on tight mill rolls. Make sure crumbs from the mill pan are not added after the stock has been broken down.

Extrusion-Wire and Cable

Problem	Probable Cause	Recommended Action
Rough Surface	Structured compound Scorched compound Die land too long Surface imperfections	Freshen compound. Check cooling water screw speed, catalyst type, etc. Maintain 1:1 land to orifice ratio. Polish die surface.
Wavy insulation Fluctuating Diameter	Die orifice too small or too large Die land too short	Orifice should approximate desired wire diameter. Maintain 1:1 land to orifice ratio. Install diameter control device.
Blisters	Moisture on conductor Oil or other contaminant on conductor HAV temperature too high	Preheat conductor (125-150°C). Clean, dry, preheat conductor. Reduce HAV temperature or increase extrusion speed.
	Entrapped air	Increase pressure in extruder (screens, die design). Apply vacuum to extruder.
	Humid atmosphere	Minimize moisture condensation as much as possible.

Poor Cure	HAV temperature too low Catalyst level too low	Increase HAV temperature or reduce extrusion speed. Run Mooney scorch test. Compare with O.C. limits. Adjust as necessary.
	Contamination on conductor or in compound Too much air circulation in HAV tunnel.	Clean, dry, pre-heat conductor. Reduce air circulation.
Porosity	Wrong catalyst Entrapped air or moisture	Replace material. Add additional or finer mesh screens. Preheat conductor.
Brittle Insulation	HAV temperature too high Excessive dwell time in HAV	Reduce HAV temperature. Increase production speeds.
Misfeeding	Poor design of extruder throat Poor screw design Wrong preform size Soft and sticky compound Operator carelessness	Redesign throat. Try single-flight screw. Adjust preform size. Dust lightly with talc.
Inadequate Delivery	Misfeeding Poor screw design	See above. Increase compression ratio or use deeper flight screw.
	Blocked screen packs Compound scorching	Change screen packs. Reduce back pressure and frictional heat build-up. Change to high temperature catalyst for CV cures.
	Inadequate gum space	Increase clearance between tip and die.
Adhesion to Conductor	Organic lubricant on strand High lead content in lead/tin alloy Too high post cure	Clean conductor prior to use. Reduce lead content or use separator. Adjust post cure temperature to conform to conductor plating. Bare Copper-125°C Tin Copper-150°C Silver Plate-200°C Stainless Steel or Nickel Clad-232°C
	Soft insulation buried into strand interstices	Reduce extrusion and curing pressure or use separator.

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Testing Of Silicone Rubber

New section

Testing Of Silicone Rubber

Silicone rubber is tested according to standard ASTM methods with few exceptions. The following section summarizes mechanical and process related testing for silicone rubber. Figures 14 – 16 show the cure rate dependence of rheology and compression set for injection molded automotive gasketing compounds and demonstrate the relationship between state of cure and optimum properties.

- [Tensile Testing](#)
- [Tear Strength](#)
- [Cold Temperature retraction](#)
- [Processing Test Equipment](#)
- [Cure Profile](#)
- [Compression Stress Relaxation](#)

Tensile Testing, Die C

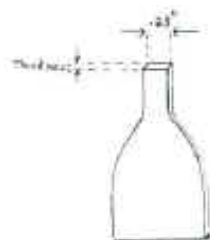


Tensile: Force to break sample

Modulus: Force at a given elongation

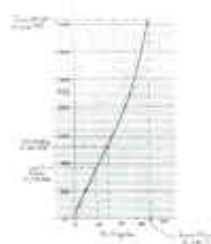
Elongation: Distance in percent that sample stretches

Durometer Shore A: A measure of hardness by indentation on 3 plied dumbbells. Silicone Rubber 20-85 Shore A



$$\text{Tensile Strength} = \frac{\text{Force}}{\text{Area}} = \frac{\text{Force}}{.25 \times \text{thickness}}$$

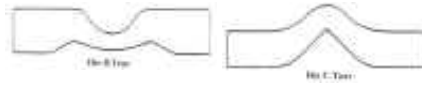
Tensile Strength, Elongation, Modulus Chart



Tear Strength

Die B: Measures tear propagation in pounds. Pull on tensile testing equipment.

Die C: Measures initiation in pounds. Pull on tensile testing equipment



William Plastometer: Measures deformation of silicone rubber or compound to determine molecular weight on structuring (hydrogen bonding of filler).

Penetration: Measure of viscosity or molecular weight using a foot as shown in a polymer.

Cold Temperature Retraction

Comparison of the TR-10 cold temperature retraction of typical silicone automotive sealing compounds with those of ethylene acrylic elastomers and clearly demonstrates the superiority of silicones under extreme cold temperature conditions, not uncommon to many parts of the country.

TR-10 Cold Temperature Retraction For Silicone And VAMAC Ethlene Acrylic Elastomer



Processing Test Equipment

Mooney Viscometer (ASTM D-1646)

The Mooney is a shearing disk viscometer which is used for measuring the viscosity of rubber compounds. A steel rotor disk, centrally embedded in the uncured rubber specimen, is caused to rotate at low speed within the confines of a tight cavity. The greater the resistance of the rubber to shear, the higher the viscosity.

The value obtained after a specified time is called "The Mooney".

Williams Plastometer (ASTM D-926)

The Williams consists of two parallel steel plates, the lower of which is stationary, and the upper free to descend under a standard weight. A 2 cc cylindrical shaped sample of uncured compound is placed between the plates, and the upper plate is released. At the end of three minutes, the thickness of the resulting squashed cylinder is measured in mm, multiplied by 100, and recorded as the Williams Plasticity value.

This empirical measurement is often a useful tool in differentiating "good" from "bad" material for a particular piece of rubber processing equipment such as an extruder.

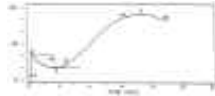
Cure Profile

- Oscillating Disc Rheometer (graph)
- Cure Profile vs. Cure Temperature (graph)
- Temperature Dependence of Cure (graph)
- Compression Set vs. Cure Time and Temperature (graph)

Oscillating Disk Rheometer

Description...Oscillation of a biconical disk embedded in the rubber specimen confined in a heated square cavity exerts a sinusoidal shear strain on the specimen. The force

(torque) needed to oscillate the disk is directly proportional to the stiffness (shear modulus) of the specimen. As the specimen cures, modulus increases, and torque is recorded as a function of time yielding the following characteristic curve:



1. Preheat
2. Initial Torque
3. Minimum Torque
4. Structure
5. Scorch Time
6. 90% Cure
7. Maximum Torque

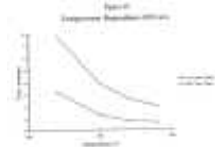
Cure Profile vs Cure Temperature

**Cure Profile vs Cure Temperature Graph -- Figure 14
Durometer Gasketing Compound
Monsanto R100 Rheometer**



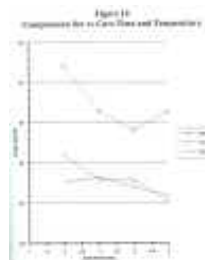
Temperature Dependence Of Cure

Temperature Dependence Of Cure Graph -- Figure 15



Compression Set vs Cure Time and Temperature

Compression Set vs Cure Time and Temperature Graph-- Figure 16



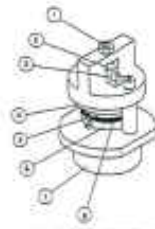
Compression Stress Relaxation

A relatively new test which measures the actual force on a compressed elastomer as a function of time and environmental exposure is compression stress relaxation. The standard test specimen is a 0.75" OD flat O-ring which is compressed between parallel steel plates. The initial compressive force is measured, and the test jig with specimen in place is then subjected to environmental aging such as thermal cycling or oil immersion. The compressive force is then measured again at several time intervals such that a stress decay curve is obtained. This test more closely resembles the actual sealing environment of a static gasket and is now called out on several OEM specifications. [Figure 17](#) shows the test jig, and [Figure 18](#) compares the ethylene acrylic elastomer as a function of immersion

time in IRM903 oil at 150°C.

Test Jig For Compression Stress Relaxation -- Figure 17

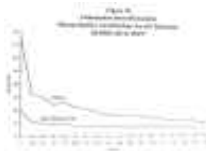
Figure 17
Test Jig For Compression Stress Relaxation



The entire jig fits in a test instrument equipped with a load cell. The test instrument has a U-shaped adapter to apply a force to the load arms, number 3. Loss of electrical continuity when the sealing force is marginally exceeded is measured between the underside of number 1 and the top side of number 2.

An actual jig for measuring sealing force -- The two upper plates are numbers 4 and 5, the lower plate is number 6, and the test specimen is number 8. Number 7 is an adjusting screw for initial compression of the test specimen. The entire jig fits in a test instrument equipped with a load cell. The test instrument has a U-shaped adapter to apply a force to the load arms, number 3. Loss of electrical continuity when the sealing force is marginally exceeded is measured between the underside of number 1 and the top side of number 2.

Compression Stress Relaxation Graph -- Figure 18 Compression Stress Relaxation Graph Silicone Rubber And Ethylene Acrylic Elastomer IRM903 Oil At 150°C



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Compounding Guidelines

- Consider several alternatives.
- Understand the specification requirement(s).
- Understand the fabrication requirements.
- Understand dimensional/shrinkage requirements.
- Use pound volume costs to compare alternatives.

Example: The following describes and compares three alternative examples of how to design a silicone compound which meets the following Specification Requirements and Fabrication Needs (physical profile) to be used as an automotive exhaust hanger.

Specification Requirement		Fabrication Needs
Shore A	60 +/- 5	Injection Moldable
Tensile, psi	800 min.	Thick Section Cure
Elongation, %	300 min.	Rounded Corners
Tear B, ppi	45 min.	
Sp. Gravity	<1.45	

Alternative 1 -- Purchase 60 durometer general purpose compound with following profile:

Shore A	60 +/- 5
Tensile, psi	1200 min.
Elongation, %	500 min.
Tear B, ppi	90 min.
Sp. Gravity	1.18
Price	\$3.00/lb.

$$\text{Pound Volume Cost} = \text{Sp. Gravity} \times \text{Price} = 1.18 \times \$3.00 = \$3.54$$

Alternative 2 -- Purchase 45 durometer general purpose compound and add minusil (ground quartz) to achieve 60 durometer.

Step 1... Calculate the amount of minusil needed.

We need (60 – 45) or 15 points increase in durometer. Assume 1 point increase in durometer requires 5 parts of minusil per 100 parts of compound. We need 5 X 15 or 75 parts of minusil.

Step 2... Calculate the specific gravity at the required minusil loading.

$$\text{Resultant Specific Gravity} = \frac{\text{Total Weight}}{\text{Total Volume}} = \frac{\sum W}{\sum V}$$

For each component, $V = W / SG$

$$\therefore \text{Resultant Specific Gravity} = \frac{\sum W}{\sum W/SG}$$

We have a two component system:

Component A = 45 durometer compound

Component B = minasil

Where:

$$W_A = 100$$

$$W_B = 75$$

$$SG_A = 1.12$$

$$SG_B = 2.65$$

$$V_A = W_A / SG_A = 100 / 1.12 = 88.5$$

$$V_B = W_B / SG_B = 75 / 2.65 = 28.2$$

$$\therefore \text{Resultant Specific Gravity} = \frac{W_A + W_B}{V_A + V_B} = \frac{(100 + 75)}{(88.5 + 28.3)} = 1.50$$

Since this is higher than the max. specification limit of 1.45, this alternative is not feasible.

Alternative 3: Purchase 50 durometer compound and add minasil to achieve 60 durometer.

Step 1: Calculate the amount of minasil needed.

$$(60 - 50) \times 5 = 50 \text{ parts}$$

Step 2: Calculate the Specific Gravity. (SG = 1.16 for compound)

$$\text{Resultant Specific Gravity} = \frac{(100 + 50)}{(100/1.16 + 50/2.65)} = 1.43$$

\therefore Since 1.43 < 1.45, specific gravity meets the specification.

Step 3: Mix compound, press sheets, and obtain physicals.

Results:	
Shore A:	61

Tensile, psi:	950
Elongation, %:	380
Tear B, ppi:	65

∴ *Extended compound meets physical requirements*

Step 4: Calculate the extended compound material cost.

50 Durometer Compound	\$3.00 / lb
5 micron minusil	\$0.20 / lb

$$\text{Cost} = \frac{(100 \times \$3.00 + 50 \times \$0.20)}{(100 + 50)} = \$2.07 / \text{lb}$$

Step 5: Calculate the pound volume cost

$$\text{Pound Volume Cost} = 1.43 \times \$2.07 = \$2.96$$

Step 6: Calculate incremental mixing cost for adding minusil.

Since the original 60 durometer compound (alternative 1) is uncatalyzed, it also requires additional mixing. Therefore, the incremental cost for adding one additional component is small...

Assume \$0.15 / lb

Step 7: Compare Alternatives

Alternative 1:	\$3.54
Alternative 2:	\$3.11 (\$2.96 + \$0.15)
Alternative 3:	\$2.96

∴ **Select Alternative 3**

- Meets Specification Requirements.
- Meets Fabrication Requirements.
- Saves \$0.43 or 12%.

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Silicone Rubber Properties

[Advantages Silicone Elastomers](#)

[Linear Thermal Expansion For Silicone Rubber \(graph\)](#)

[Thermal Conductivity For Silicone Rubber \(graph\)](#)

[Effects of Thermal Degradation On Siloxanes](#)

[Non-Catalytic Siloxane Reversion \(diagram\)](#)

[Heat Aged Results \(graphs\)](#)

Advantages Silicone Elastomers

[High Temperature Resistance](#)

[Low Temperature Flexibility](#)

[Compression Set Resistance](#)

[Electrical Properties](#)

[Fire Resistance](#)

[Smoke Generation](#)

[Radiation Resistance](#)

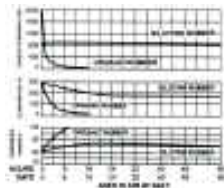
[Chemical Resistance](#)

[Ozone and Corona Resistance](#)

[Strength](#)

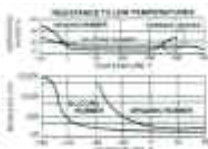
High Temperature Resistance

Silicone elastomers outperform organics with proven temperature resistance up to 600°F. Even under extreme heat, these compounds provide superior tensile strength, elongation and abrasion resistance.



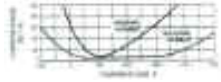
Low Temperature Flexibility

Despite extreme temperatures as low as -100°F, most GE silicone elastomers retain durometer and modulus. They also perform reliably for prolonged periods at -75°F. Special grades have brittle points below -150°F and remain serviceable at temperatures as low as -130°F.



Compression Set Resistance

Compared to other elastomers, our silicone elastomers offer incomparable resistance to compression set deformation, even at temperatures as low as -120°F or as high as 500°F .



Electrical Properties

Silicone elastomers provide unequalled electrical properties over a wide range of temperatures. They rival mica in terms of resistance to high-voltage ionization and corona. Plus, they show far less dielectric fatigue than TFE resins or organic elastomers.

Summary of Electrical Properties - Silicone Rubber	
Volume Resistance	$1.0 \times 10^{14} \text{ } \Omega\text{-cm}$
Surface Resistance	$1.0 \times 10^{12} \text{ } \Omega$
Dielectric Constant	2.9 to 3.5
Dielectric Loss	0.001 to 0.002

Fire Resistance

Underwriters Laboratories Flame Test (UL94) is the standard measure of a material's resistance to burning. This UL test is performed on a test sample 5" by $\frac{1}{2}$ ". (Sample thicknesses vary but have a direct bearing on test results.) A $\frac{3}{4}$ " Bunsen flame is applied for 10 seconds to a vertically supported sample immersed $\frac{3}{4}$ " into the flame. The time for burning to cease following the initial 10-second exposure is noted. The flame is applied again for 10 seconds and the time for burning to cease, including glowing, is noted. A total of 5 samples are tested in this manner. Five additional samples aged for 7 days at 70°C are also tested in this manner.

UL Flame Test Ratings and Results

Rating	Required Test Results
94 V-0	5 specimens with 10 flame applications, with none exceeding 10-second flame or 50-second total burn.
94 V-1	5 specimens with 10 flame applications, with none exceeding 30-second flame or 250-second total burn
94 V-2	Same criteria as for 94 V-1, except some dripping allowed.
94 HB	3 specimens, none of which has either a burn rate exceeding 3 inches per minute or ceases to burn before reaching reference point.

Smoke Generation

Silicone polymers yield low levels of smoke under normal

service or fire conditions. In the table below, D_m represents Maximum Specific Optical Density, or maximum total smoke accumulation over a 20-minute test period. T_C is the time required to reach a Specific Optical Density of 16, which corresponds to a light transmittance of 16% over the viewing distance. This is considered the minimum value for visibility and safety.

Smoke Test Values

Material	D_m	T_c (min)	Gases Evolved			
			yes	no	no	no
Silicone Rubber	43	7	yes	no	no	no
Polyvinyl Chloride	180	1.4	yes	yes	Trace	no
Neoprene=	161	1.6	yes	yes	Trace	no
Hypalon=	196	1.1	yes	yes	no	yes

*Tests run under non-flaming conditions.
 =Registered Trademarks of E.I. DuPont deNemours & Co., Inc.,

Radiation Resistance

Room temperature, GE silicone elastomers outperform TFE resin and conventional fluoroelastomers on exposure to 10/8 roentgens. Special compounds provide even greater radiation resistance.

Radiation Resistance-Silicone Rubber

Dosage (Rads)	Methyl-Vinyl		Methyl-Phenyl-Vinyl	
	Elongation (%)	Tensile Strength (psi)	Elongation (%)	Tensile Strength (psi)
None	5 X 10 ⁶	5 X 10 ⁷	1 X 10 ⁸	200 130 50 20
	200	1200	1000	900 600 600 450 225 75 1200 1100 900 850

Chemical Resistance

Many GE elastomers fulfill specific requirements. However, only GE fluorosilicones provide outstanding fuel and solvent resistance plus the wide-ranging temperature performance of silicones.

High/Low Temperature, Chemical-Resistant Fluorosilicone



Ozone and Corona Resistance

Silicone elastomers, including fluorosilicones, provide excellent resistance to both ozone and corona. On the other hand, while fluorocarbon materials offer good heat and ozone resistance, they degrade rapidly when exposed to corona.

Silicone Rubber* Resistance to 200 PPM Ozone

Exposure Time	Change in Physical Properties		
	Hardness Shore A Points	Tensile Strength	Elongation
7 days 14 days 28 days	+3 +4 +7	-5% -15% -15%	0 -5% -5%

Strength

High-strength silicone elastomers offer strength comparable to many organic elastomers for almost any application. Physical properties of general purpose components are usually equal to or superior to organics in the 200-350°F range.

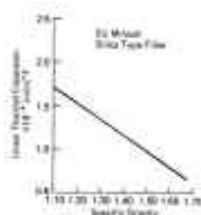
Summary of Physical Properties at Room Temperature

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



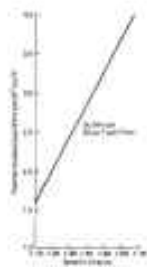
Linear Thermal Expansion For Silicone Rubber

Linear Thermal Expansion For Silicone Rubber



Thermal Conductivity For Silicone Rubber

Thermal Conductivity For Silicone Rubber



Effects of Thermal Degradation On Siloxanes

Crosslinked Silicones at 400°F (204°C):

- Drop in Tensile
- Drop in Elongation
- Build in Shore A
- Small Build in Specific Gravity
- Small Change in Crosslink Density

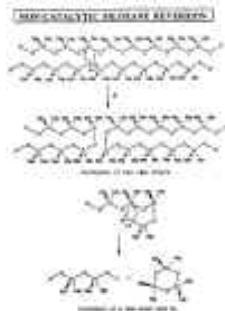
Crosslinked Silicones at 480°F (250°C):

- Large Drop in Tensile
- Total Loss of Elongation
- Embrittlement
- Large Increase in Shore A
- Build in Specific Gravity
- Large Change in Crosslink Density

-Test System

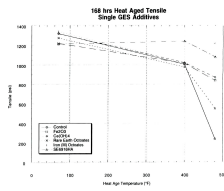
Temperature	M_C
70 °F	8317
480 °F	476

Non-Catalytic Siloxane Reversion

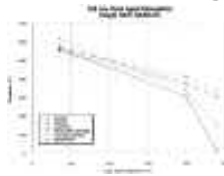


Heat Aged Test Results

168 hrs Heat Aged Shore A Single GES Additives



168 hrs Heat Aged Tensile Single GES Additives



168 hrs Heat Aged Elongation Single GES Additives

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GE Silicones Silplus® Properties and Specifications

Grade	Shore A, points		Tensile, psi		Elongation, %		Tear B, ppi		Comp. Set, %		Sp. Gravity	
	Ave.	Spec.	Ave.	Spec.	Ave.	Spec.	Ave.	Spec.	Ave.	Spec.	Ave.	Spec.
SE 6035	35.1	30-40	1345	900 min.	764	400 min.	100	35 min.	---	---	1.10	1.07-1.13
SE6075	73.8	70-80	1329	1000 min.	398	150 min.	150	70 min.	---	---	1.22	1.18-1.24
SE6740	40.5	35-45	863	700 min.	456	300 min.	61	40 min.	15	35	1.10	1.07-1.13
SE6160	61.9	55-65	1385	1000 min.	364	250 min.	117	70 min.	18	35	1.17	1.15-1.21
SE6180	77.9	75-85	1305	1000 min.	184	100 min.	114	70 min.	23	45	1.29	1.27-1.33
SE6740	42.7	37-47	820	650 min.	462	350 min.	66	35 min.	13	25	1.11	1.09-1.13
SE6750	51.6	45-55	1036	900 min.	443	380 min.	85	35 min.	22	30	1.14	1.12-1.17
SE6770	73.9	67-77	1066	900 min.	244	200 min.	89	50 min.	25	40	1.22	1.19-1.23
SE6335	34.3	30-40	1207	1000 min.	786	500 min.	231	150 min.	14	45	1.11	1.07-1.13
SE6350	49.7	45-55	1448	1200 min.	676	400 min.	229	150 min.	11	45	1.15	1.13-1.16
SE6370	69.1	65-75	1220	1100 min.	589	400 min.	242	150 min.	22	55	1.22	1.19-1.25
SE6260	45.5	42-52	1419	950 min.	590	425 min.	111	65 min.	40	REC	1.14	1.09-1.15

Ave. Value Calculated From 5/92 – 5/93 Production Batches

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Catalyst and Test Conditions

Grade	Catalyst / Level	Press Cure	Post Bake	Compression Set	
SE6035	Varox Paste	1.2 pph	10'/177°X	1 Hr/200°X	-----
SE6075	Varox Paste	1.2 pph	10'/177° X	1 Hr/200°X	-----
SE6140	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177°X
SE6160	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177° X
SE6180	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177° X
SE6740	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177° X
SE6750	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177° X
SE6770	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177° X
SE6260	Varox Paste	1.2 pph	10'/177° X	-----	22 Hrs/177° X
SE6335	TS-50	1.0 pph	15'/142° X	4 Hrs/200° X	70 Hrs/100° X
SE6350	TS-50	1.0 pph	15'/142° X	4 Hrs/200° X	70 Hrs/100° X
SE6370	TS-50	1.0 pph	15'/142° X	4 Hrs/200° X	70 Hrs/100° X

1.2 pph Varox Paste Is Equivalent To 0.4 pph Lupersol 101 Or 1.8 pph DTBPH-50

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Chemical Resistance Of Silicone Rubber Chart

Material	Weight Change %	VMQ	FVMQ	Volume Change %	Durometer Change Points
		Volume Change %	Durometer Change Points		
Acids					
Nitric conc.	+10	+10	-30	+5	0
Nitric 7 %	<1	<1	-2	0	0
Sulfuric conc.	Disintegrates	Disintegrates			
Sulfuric 10%	<1	<1	-2	0	0
Acetic conc.	+2	+3	-4	+20	-
Acetic 5%	+4	+4	+8	-	-
Hydrochloric conc.	+1	+1	-6	+10	-5
Hydrochloric 10%	+2	+4	-4	0	-5
Hydrochloric 3%	<1	+1	-2	-	-
Bases					
Sodium hydroxide 20%	<1	<1	-2	0	-5
Hydroxide 1%	<1	<1	-4	0	0
Ammonium hydroxide conc.	+2	+2	-4	+5	-5
Ammonium hydroxide 10%	+3	+2	-6	0	0
Salts					
Sodium chloride 10%	<1	<1	-2	-	-
Sodium carbonate 2%	<1	<1	0	-	-
Solvents					
Ethyl alcohol	+5	+6	-10	+5	0
Acetone	+5	+15	-15	+180	-20
Toluene	+75	+120	-30	+20	-10
Gasoline, regular	+65	+130	-25	+20	-12
Gasoline, aviation	+60	+110	-30	+10	-5
Mineral spirits	+65	+110	-30	0	0
Carbon tetrachloride	+130	+110	-25	+20	-5
Hydraulic Fluids					
Hollingshead H-2	+4	+5	-10	-	-
Hollingshead H-2	+9	+12	-15	-	-
Skydrol	+4	+4	-8	+25 ^c	-10
Skydrol ^a	+7	+8	-10	-	-
PRL3161	+5	+7	-8	-	-
PRL3161 ^a	+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 ^b	+3	+5	-6	0	-5
ASTM #3 oil ^b	+20	+31	-20	+5	-5
Silicone oil SF96 (100) ^b	+25	+35	-25	0	-5
Silicone oil 42,000 cstk. ^b	+9	+10	-12	0	-5
Other					
Water	<1	<1	<1	0	0
Hydrogen peroxide 3%	<1	<1	<1	0	0

Pyranol 1476	+4	+4	-8	-	-
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a70 hr @ 212° F 100° C.

b70 hr @ 300° F 149° C.

c7 days 128f (49° C).

VMQ data from General Electric Silicones
Technical Data Book S-1E.

Data on FVMQ from Dow Corning Bulletin 17-052.

Courtesy: W. Lynch, Handbook of Silicone
Rubber Fabrication; Van Nostrand; Reinhold
Company, New York, 1978.

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Comparison with Other Elastomers

Property	Units	Silicone Rubber	Polytetrafluoroethylene	SBR Rubber	Butyl Rubber	Oil-Base Rubber	Polyvinyl-chloride	Poly-Ethylene
Temperature rating	°F °C	300-480 150-250	480 250	170 75	190 90	170 75	140-220 60-105	170 75
Mechanical Water absorption	Mg/sq in. Mg/sq cm	10 1.6	0.5 .08	15 2.3	8 1.2	20-30 3.9	8-10 1.4	0.5 .08
Insulation resistance	Megohm Constant	30,000	50,000	2000	30,000	21,000	2000	50,000
Dielectric Constant		3.0	2.1	5.0	3.5	5.0	5 to 8	2.3
Power Factor	%	0.1	0.1	4.5	3.0	5.0	5 to 8	0.1
Dielectric Strength		Excellent	Excellent	Very Good	Very Good	Excellent	Excellent	Excellent
Tensile Strength	Lb/sq in. Kg/sq cm	1200 84	2000 140	800 56	800 56	1200 84	1500 105	1500 105
Elongation	%	400+	150	350	400	300	200	400
Heat Aging 5 days @ 200C	% retention	Tensile 75 Elongation 60	Tensile 85 Elongation 75	Fails	Fails	Fails	Fails	Melts
Cold bend @ -55C	-	Passes	Passes	Fails	Passes	Fails	Fails	Passes
Ozone and Corona Resistance	-	Excellent	Good	Fails	Good	Good	Very Good	Good
Radiation Resistance	Ergs/ gram (gamma radiation)	10 ⁸	4 X 10 ⁵	4 X 10 ⁸	3 X 10 ⁸	2 X 10 ⁹	10 ¹⁰	10 ¹⁰
Flammability	-	Burns to Non-Conducting ash	Self-Extinguishing	Burns	Burns	Burns	Self-Extinguishing	Burns
Chemical Resistance	-	Good	Excellent	Fair	Fair	Poor	Very Good	Good
Processibility		Good	Poor	Good	Good	Good	Very Good	Very Good
Weathering		Excellent	Excellent	Poor	Excellent	Fair	Excellent	Must be Pigmented

Courtesy: W. Lynch, Handbook of Silicone Rubber Fabrication; Van Nostrand; Reinhold Company, New York, 1978.

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