section 8:
ruBBer solutions a–Z
Facts anD Figures aBout silicone

Content

A list of frequently used technical terms is given below.

8. Rubber Solutions A–Z

Facts and Figures About Silicone

Coefficient of expansion

– Linear coefficient of expansion of tool steel is approx. $1.5 \cdot 10^{-6}$ K^{-1}, and leads to shrinkage of the final parts.

– Typical values: approx. 2 - 4 • 10^{-4} K^{-1}.

Compression set

– Determination of the compression set as per ISO 815-B (ASTM D395 B-2) by storage for 22h/175 °C, or 22h/125 °C in the case of self-adhesive grades.

– Compression set describes the elastic recovery of a cured rubber, an important characteristic for gasket applications.

– Typical values for silicone rubber: 5 – 25%.

Density

– Determination as per ISO 1183-1 A (buoyancy method).

– Typical range for specific weight 1.05 – 1.60 g/cm^3.

– When using additional inactive fillers (e.g. quartz), values up to $1.75\ g/cm^3$ can be achieved, e.g. to improve swelling resistance.

Dielectric constant ε

– Determination of dielectric constant ε as per DIN 53 482 or VDE 0303.

– Typical values for silicone rubber: ε = 2.7 - 3.3 (at 25 °C and 50 Hz).

– This property can be increased up to 150 by the use of suitable fillers.

Dielectric strength

– Determination of dielectric strength per IEC 60243-1.

– Typical value for ELASTOSIL® silicone rubber > 20 kV/mm (measured on a 1 mm sheet).

Dissipation factor tan δ

– Determination of the dissipation factor as per VDE 0303.

– Typical values for loss tangent tan δ ~ 10^{-3}.

– tan δ is raised by increasing the filler content/density.

Fire behavior

– The auto-ignition temperature of cured products is about 430 °C.

– The flashpoint is about 750 °C.

– Silicone rubber burns to form a white non-toxic ash of silicon dioxide

– The resultant combustion gases are usually non-corrosive.

– Specialty grades for high-safety cables form a ceramic layer in a fire.

Flame resistance

– Determination of the flame resistance acc. to test standard ASTM D 2863 by determining the limiting oxygen index (LOI) or acc. to Underwriters Laboratory fire standard (UL 94).

– Typical LOI values of flame retardant grades 27 to 35%

– Standard grades normally achieve UL 94 HB (0.5 – 1.0 mm thickness*)

– Specialty grades with additives reach UL 94 V0 (1.0 – 4.0 mm thickness*).

– In the case of solid silicone rubber, the addition of 2.2% ELASTOSIL® AUX Batch SB-2 improves the flame resistance considerably.

* dep. on grade

Gas permeability

– Determination as per DIN 53 536
– Very high gas permeability compared to other elastomers, e.g. for air 30 times higher than for natural rubber (NR) or 400 times higher than butyl rubber (IIR) (measured at 25 °C)
– The absolute value of a 50 Shore A grade for air at 20 °C and 80 °C is 570 and 1.330 $cm^3 \cdot mm \cdot m^{-2} \cdot h^{-1} \cdot bar^{-1}$ (volume of air measured in cm^3, that penetrates a membrane of 1 m^2 area per hour at a pressure difference of 1 bar and 1 mm thickness)
– Technical advantage, e.g. for contact lenses, textile coatings and for some medical applications
– At high temperatures, silicone has similar values to organic elastomers

Hardness

– Determination of the hardness of silicone rubber in Shore A (DIN 53 505) or in IRHD units (DIN 53 519).
– Typical bandwidth 3 – 90 Shore A.

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Gas	relative permeability at 25 °C
Air	100
Hydrogen	190
Oxygen	170
Nitrogen	80
Carbon dioxide	1.000
Ethylene	390

High-energy radiation

– Outstanding resistance of silicone rubber (MVQ, PMVQ) to high-energy radiation in combination with hot-air resistance in comparison to other elastomers.
– With VMQ silicone rubber grades, only high radiation doses of 400 – 800 kGy lead to a reduction of 50% in the elongation at break.
– Phenyl-containing PVMQ silicone rubber, such as ELASTOSIL® R 490/55, has higher resistance.
– Properties not severely affected by gamma and beta radiation (25 – 75 kGy), as widely used for sterilization of medical equipment.
– Very good resistance to microwaves, since silicone parts are not microwave-active and therefore not heated.

Hot-air resistance

– The mechanical properties of WACKER silicone rubber are retained even at high temperature loading (hot air).
– The hot-air resistance is thereby clearly superior to that of most organic elastomers (cf. ASTM Charta D2000)

Rebound resilience

– Determination of rebound resilience as per DIN 53 512
– Also commonly known as “snap”
– Measured on 6-mm samples as a ratio of rebound height to the failling height of a pendulum
– Typical values 30 – 70%.

Reversion

- By reversion is meant in general degradation of the crosslinking network in the cured rubber as a result of chemical or thermal effects, which leads to a permanent decrease of hardness (softening)
- In silicone rubber, at high temperatures (> 200 °C) traces of moisture or free hydroxyl groups in fillers cause cleavage of the Si-O bond in the polymer chain and ultimately the above-mentioned decrease in hardness due to depolymerization
- This process is inhibited by the presence of air
- High heat resistance therefore requires unrestricted access of atmospheric oxygen, and must be taken into account in the design of gasket parts
- In the case of thick parts, where oxygen diffusion is difficult, this process is inhibited by the use of Stabilizer R.

Solvent and chemical resistance

- The chemical resistance of WACKER silicone rubber generally depends on the crosslinking density, filler used, and filler content.
- With higher filler levels in the silicone rubber, swelling tendency decreases and resistance is therefore improved.
- High swelling tendency to non-polar liquids such as hydrocarbons, mineral oils and greases.
- Low swelling tendency to polar liquids, such as polyhydric alcohols, low-molecular ketones, and therefore no negative effect on seal quality.
- Strongly attacked by concentrated acids and alkalis, particularly by oxidizing acids such as sulfuric or nitric acid.
- Silicone rubber has good resistance to aqueous solutions of weak acids, alkalis or salts, which are commonly used as cleaning solutions for lines / tubing at 70 – 80 °C in the food industry.

Shrinkage

- Linear shrinkage of approx. 2 – 4% falls with increasing Shore hardness and lower vulcanization temperature
- The higher the filler content or density, the less is the shrinkage of the cured parts.
- Very strong dependency on processing parameters and material grades
- For precision parts, fine tuning is necessary by means of preliminary tests

Surface resistence

- Determination of the surface resistivity per VDE 0303
- Typical values for insulating ELASTOSIL® LR compounds: approx. 10^{12} – 10^{13} Ω.

Tear propagation and notch resistance

- Tear strength depends on which particular standard is used.
- Typical values when determined as per ASTM D 624 B (crescent): 5 – 55 N/mm.
- Values are up to 30% lower when measured by ISO 34-1, method B-b (Graves).
- ISO 34-1 method A (trouser) yields values about 50% lower.

Tear strength and elongation at break

- Determination as per DIN 53 504
- Standard test on S1 bar. In exceptional cases also measurements on small S2 and S3 test specimens, though the values deviate correspondingly
- Typical values for tensile strength: approx. 5 – 11 N/mm² (or MPa) Typical values for elongation at break: approx. 100 – 1.100%

Temperature behavior

- Mechanical properties of silicones determined at 23 °C (RT) as per DIN 53503 or DIN 53505 respectively.
- The change in the mechanical properties is only small compared to organic elastomers. ASTM D2000.
- Typical service temperature range: –50 to +250 °C.
- The material hardens at very low temperatures (–40 °C) due to reversible crystallization.
- There is a slow increase in hardness at very high temperatures (> 200 °C) as a result of heat aging.
- At high temperatures (> 180 °C), the organic side groups attached to the silicon atom undergo free-radical cleavage. The resulting free radicals cause post-curing of the polymer chains, with an increase in hardness to-gether with a decrease of tensile strength and elongation at break (embrittlement).
- The simultaneous weight decrease of the vulcanizate leads to shrinkage.
- The lifetime of the vulcanizate can be increased by the use of heat stabilizers H1 – H6 (usually oxides of multi-valent elements).
- The increased crosslinking density as a result of prolonged thermal loading has a positive effect on the compression set and rebound resilience.
- Excellent stable long-term behavior for insulation at high temperatures is obtained, as oxidative degradation produces quartz-like properties.

Thermal conductivity and specific heat capacity

- Determined as per DIN 52 612
- The thermal conductivity depends on the type and amount of fillers used.
- Typical value at 100 °C: approx. 0.2 – 0.3 W • m^{-1} • K^{-1}.
- Special thermally conductive compounds achieve values of about 0.1 – 1.2 W • m^{-1} • K^{-1}.
- Typical values for specific heat capacity: approx. 1.25 kJ • kg^{-1} • K^{-1}.

Volume resistivity

- Determination as per VDE 0303
- Typical values for insulating silicone rubber grades approx. 1015 Ω • cm.
- Typical values for conductive grades approx. 2 - 150 Ω • cm.
- Lower temperature dependency in the case of platinum-catalyzed grades compared to peroxide-cured systems.

Water- and steam resistance

- Excellent resistance to boiling water.
- Volume decrease in boiling water below 1%, even after prolonged action.
- Resistance to superheated steam is higher for elastic grades than for notch-resistant grades.
- Steam sterilization (as per ISO 17665, DIN EN 868-8 at 500 cycles at 134 °C, 5 min.) leads to only a slight worsening of mechanical properties.

Weathering and UV resistance

- Silicone rubber articles are generally insensitive to UV radiation.
- Properties only change slightly even in long-term tests (several years of weathering).
- Unlike with organic elastomers, weathering resistance can be achieved without additives (e.g. organic antioxidants, UV stabilizers, etc.).