

Greases • Oil Compounds



Contents

● Facts about Silicone	P.2	● Safety Data	P.20
● Information on Silicone Greases · Oil Compounds...	P.3	● Packaging	P.22
● Product Selection Guides	P.4~	● Precautions Related to Handling, Safety and Hygiene...	P.22
● Product Introductions		● Packaging List	P.23
1. Greases	P.6~		
2. Oil Compounds	P.12~		

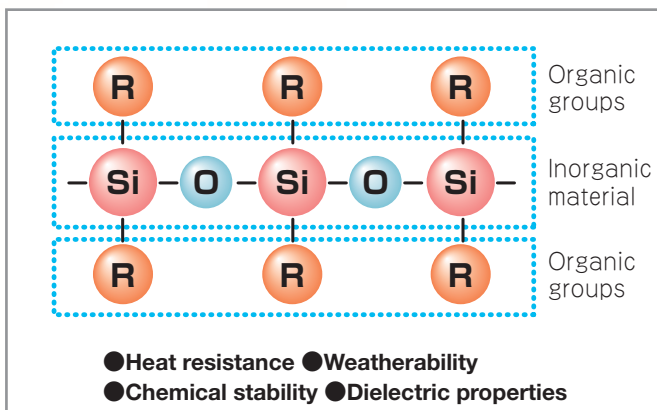
Facts about Silicone

[Chemical properties of silicones]

The main chain of a silicone is made up of inorganic siloxane linkages (Si-O-Si), to which are attached side chains which contain organic groups. Silicones are a sort of hybrid polymer with both inorganic and organic components.

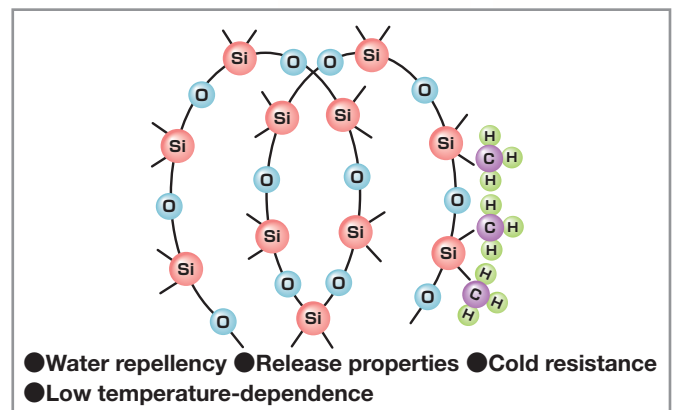
■ Features attributable to siloxane linkages

Silicones have a “backbone” of siloxane linkages, with attached side chains which contain organic groups.



■ Features attributable to molecular structure

The molecules of dimethyl silicone exhibit a twisted, helical structure.



● Compared to organic polymers, which have a carbon skeleton (C-C bond energy: 85 kcal/mol), silicones have superior heat resistance and weatherability (UV light, ozone resistance). This is due to the greater stability of siloxane bonds, which have a bond energy of 106 kcal/mol.

● Siloxane bonds have a bond length of 1.64 Å and bond angle of 134°. Compared to carbon bonds (bond distance: 1.54 Å, bond angle: 110°), they have a long bond distance and high bond angle, and a low rotational energy barrier. As a result, siloxane bonds move more freely and intermolecular forces are weak. These characteristics manifest themselves in the features of silicone materials, which include softness, gas permeability, cold resistance, and little change in viscosity due to temperature changes.

● The backbone of dimethyl silicone exhibits a helical structure.

Hydrophobic methyl groups cover almost the entire surface of the silicone polymer molecules, and surface energy is low. This gives rise to unique properties including water repellency and easy release.

● Moreover, silicones are low-polarity polymers, so they exhibit minimal moisture absorption.

Silicone Greases • Oil Compounds

Silicone greases are products which consist of a base oil of silicone fluid compounded with thickening agents (such as metallic soaps) and other additives. They can be used in a wide range of temperatures and are used primarily on moving parts to provide lubrication and adhesion.

Silicone oil compounds are products which consist of a base oil of silicone fluid compounded with fillers such as silica powder or metallic oxides. The intended application will dictate the type of filler used. They can be used in a wide range of temperatures and are used primarily on non-moving parts for thermal conduction, electrical insulation and sealing.

Features of Silicone Greases • Oil Compounds

Because they use silicone fluid as the base oil, Shin-Etsu silicone greases and oil compounds offer the following advantages.

- 1 Outstanding heat and cold resistance, so they perform well in extreme conditions and will continue to do so over prolonged use.
- 2 Electrically insulating, so they can be used with confidence.
- 3 Outstanding moisture resistance and water repellency.
- 4 Non-corrosive.
- 5 Effective in small amounts.



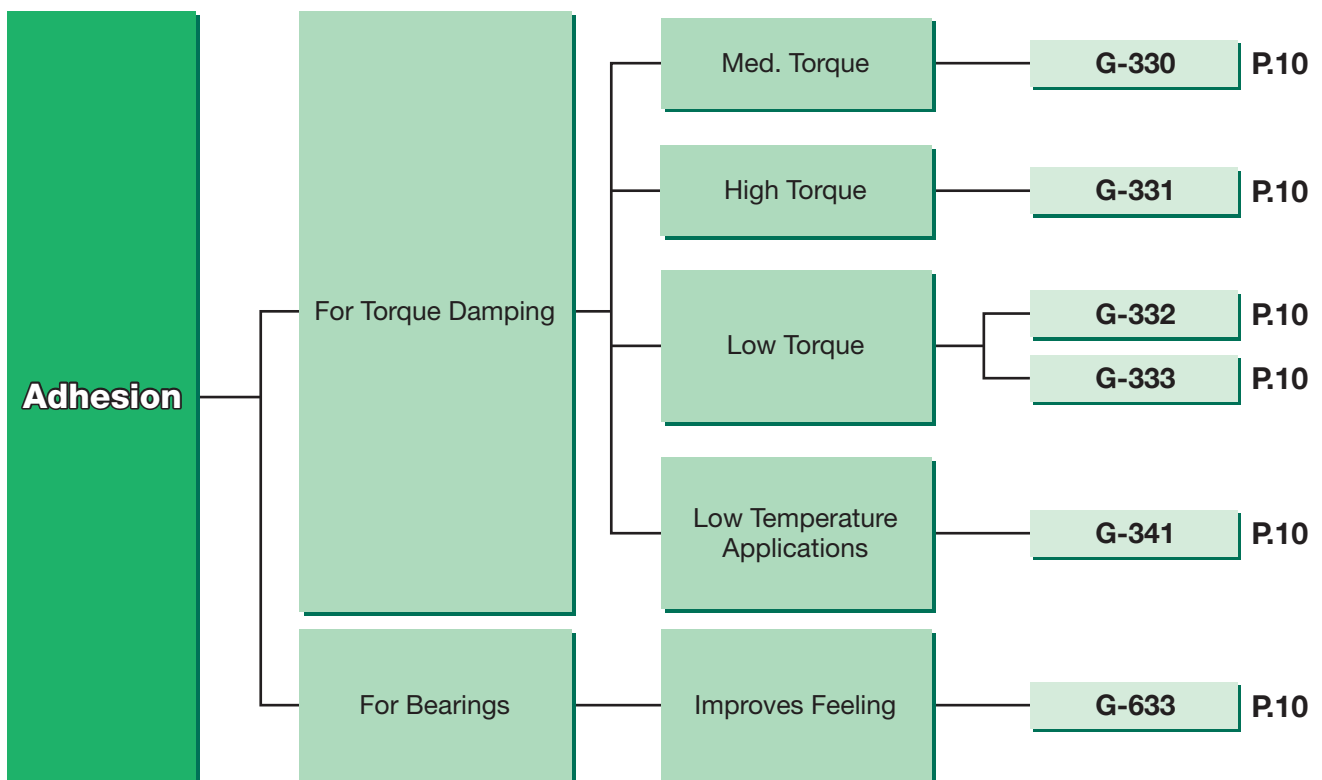
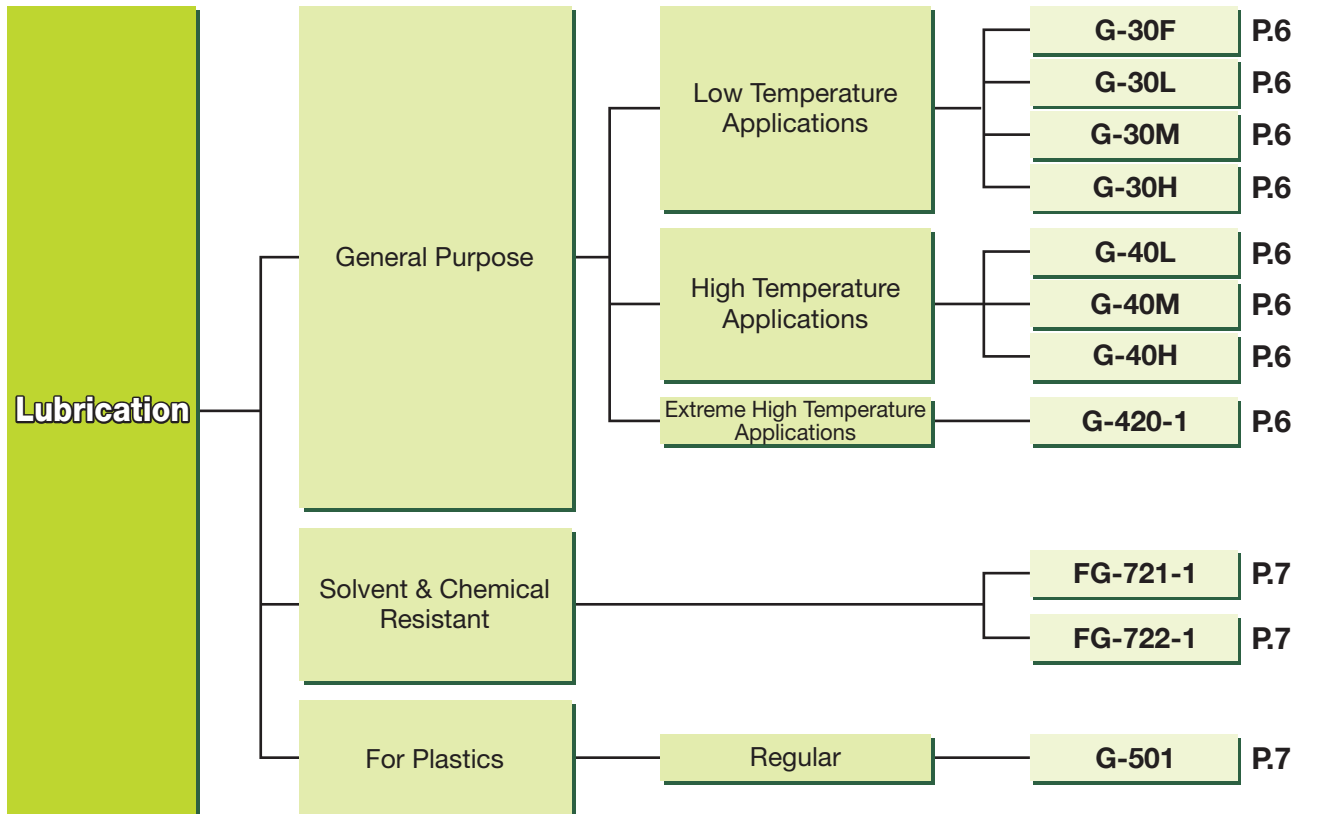
Heat resistance comparison (Left: mineral oil Right: silicone fluid)

※Before using any of these products, be sure to test beforehand to determine the product's suitability to the intended application.

Intended Use

Application/Feature

Product Name

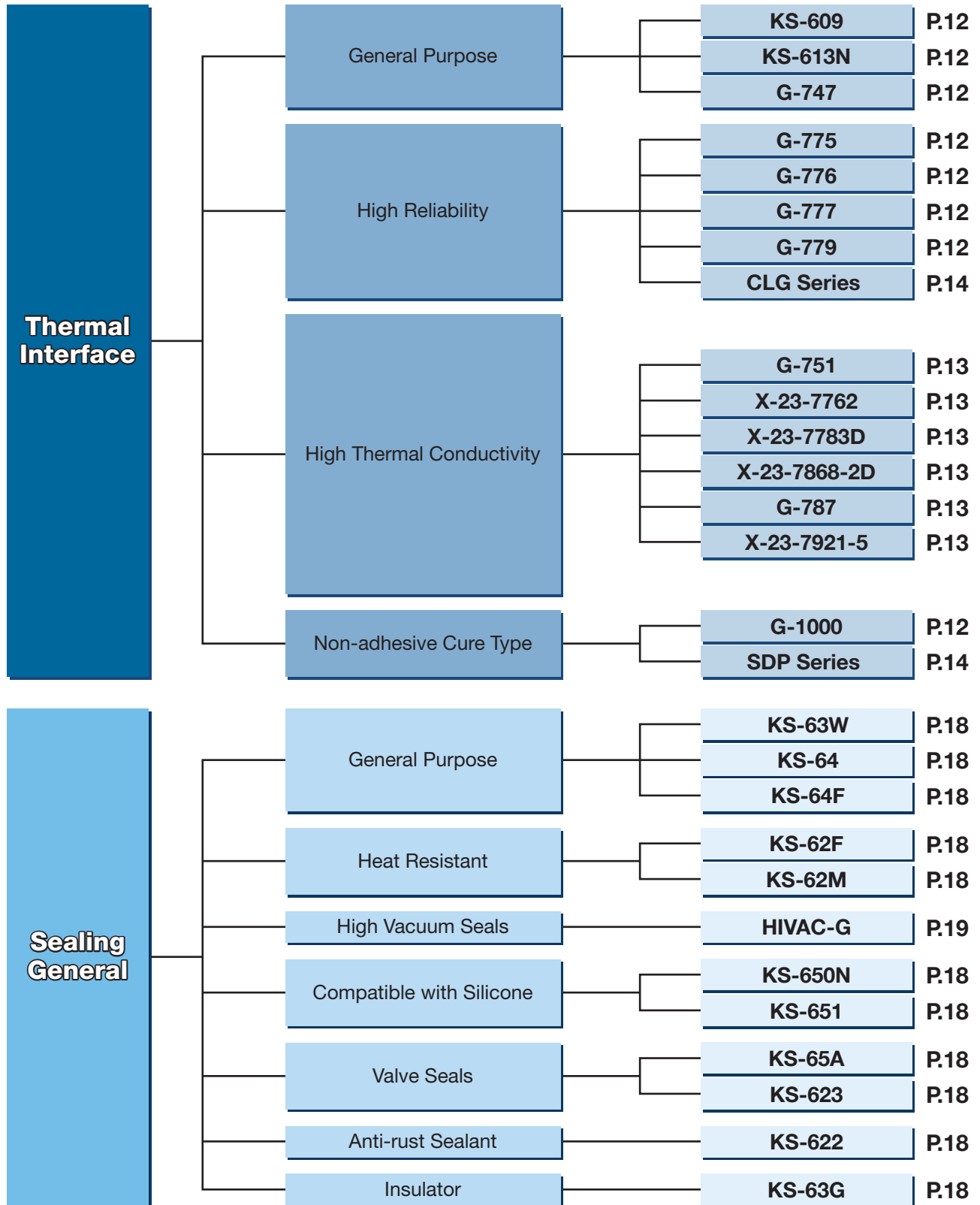




Intended Use

Application/Feature

Product Name



Properties of Grease Products

Silicone greases are made using a silicone fluid as the base oil. This is compounded with other materials such as thickeners, oiliness improvers and antioxidants. Compared to common mineral oil greases, silicone greases have greater thermo-oxidative stability and moisture resistance, and have a wider range of use temperatures. Silicone greases are also chemically inert, and so are compatible with almost all types of equipment.

◆ Low-temperature Lubrication Applications

■ G-30F G-30L G-30M G-30H

The greases in the G-30 series were specially designed to provide excellent lubrication at low temperatures. There are four grades of consistency : F, L, M and H.

■ Typical properties

Parameter		G-30F	G-30L	G-30M	G-30H	
Appearance		Grayish white paste		Grayish white grease		
Specific gravity	25°C	0.99	0.99	1.00	0.99	
JIS K2220 Test method	Consistency	25°C/worked	340 – 400	280 – 320	240 – 280	200 – 240
	Drop point	°C	—	200+	200+	200+
	Oil separation	150°C×100h %	—	5.7	2.3	0.5
	Oxidative stability	150°C×50h* ¹ kPa	—	30	30	30
	Moisture resistance	%	—	1	1	1
	Worked stability	100,000 strokes	—	400 (max.)	400 (max.)	400 (max.)
	Low-temperature torque (Starting/Running)	-60°C mN m	—	107/31	266/93	329/122
MIL-L15719A	Low-temperature torque	-60°C 2000 g-cm	—	Less than 1 sec	1 sec	1 sec
BTB	Free acid or free alkali	Neutral				
Use temperature range		°C -60 to +180				
Volatile content	150°C×100h %	—	0.35	0.41	0.35	
Low-molecular-weight siloxane content		ΣD ₃ -D ₁₀ ppm	≤100			

*1 The oxidative stability test conditions prescribed in JIS K 2220 indicate 99°C×100 hours, but in this case measurement was done at 150°C×50 h. (Not specified values)

*2 G-30 greases are suitable for speed factors (bearing bore in mm _ bearing shaft speed in rpm) up to 200,000.

◆ High-temperature Lubrication Applications

■ G-40L G-40M G-40H G-420-1

The greases in the G-40 series were specially designed to provide excellent lubrication at high temperatures, and are ideal for lubrication of sealed bearings.

There are three grades of consistency : L, M and H.

G-420-1 provides outstanding lubrication at very high temperatures.



Bearing lubrication

■ Typical properties

Parameter		G-40L	G-40M	G-40H	G-420-1* ¹	
Appearance		Beige grease		Brown grease	White grease	
Specific gravity	25°C	1.06	1.05	1.06	1.10	
JIS K2220 Test method	Consistency	25°C/worked	280 – 320	240 – 280	200 – 240	268
	Drop point	°C	200+	200+	200+	250+
	Oil separation	150°C×100h %	8.9	5.9	3.0	5.9* ²
	Oxidative stability	150°C×50h* ³ kPa	10	10	10	—
	Moisture resistance	%	1	1	1	<1
	Worked stability	100,000 strokes	400 (max.)	360 (max.)	320 (max.)	267
	Low-temperature torque (Starting/Running)	-20°C mN m	66/29	83/46	117/57	210/65
MIL-L15719A	Low-temperature torque	-20°C 2000 g-cm	Less than 5 sec.	Less than 5 sec.	Less than 5 sec.	—
BTB	Free acid or free alkali	Neutral				
Use temperature range		°C -30 to +200			-30 to +250	
Volatile content	150°C×100h %	0.4	0.3	0.3	0.15* ²	
Low-molecular-weight siloxane content		ΣD ₃ -D ₁₀ ppm	≤100		≤100* ⁴	

*1 For information on safety, see page 22 (Safety & hygiene).

*2 200°C×24h

*3 The oxidative stability test conditions prescribed in JIS K 2220 indicate 99°C×100 h, but in this case measurement was done at 150°C×50 h. (Not specified values)

*4 ΣD₄-D₁₀

*G-40 greases are suitable for speed factors (bearing bore in mm _ bearing shaft speed in rpm) up to 200,000.

◆ For Lubrication of Plastics

■ G-501

G-501 is compounded with a special silicone fluid as the base oil. This grease is ideal for blower bearings and plastic parts, where it provides both lubrication and noise reducing properties.

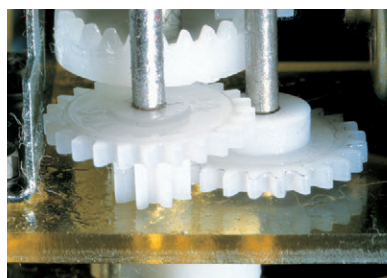
With its special formula, G-501 is much less likely to cause stress cracking of polycarbonate (PC), polyacetal (POM), ABS and other plastics.

It is also an excellent lubricant for steel/steel contacts.

■ Typical properties

Parameter		G-501	
Appearance		White to pale yellow grease	
Specific gravity	25°C	0.92	
JIS K2220 Test method	Consistency	25°C/worked	306
	Oil separation	150°C×24h %	2.5
	Low-temperature torque (Starting/Running)	-50°C mN m	211/103
Use temperature range	°C	-50 to +150	
Volatile content	150°C×24h %	0.1	
Low-molecular-weight siloxane content	ΣD3-D10 ppm	≤100	

(Not specified values)



Lubrication of plastic gears

◆ Solvent Resistant Greases

Fluorosilicone greases

■ FG-721-1 FG-722-1

The greases in the FG-72 series feature a fluorosilicone fluid as the base oil, compounded with fluoropolymer powder. These hybrid greases exhibit certain properties of both silicones and fluorine compounds, and offer outstanding heat resistance, solvent resistance and chemical resistance.

These greases provide excellent lubrication even in high speed, high load conditions.

■ Typical properties

Parameter		FG-721-1 *2	FG-722-1 *2	
Appearance		White grease		
Specific gravity	25°C	1.50	1.50	
JIS K2220 Test method	Consistency	25°C/worked	296	270
	Drop point	°C	259	>260
	Oil separation	200°C×24h %	3.4	0.6
	Oxidative stability	150°C×50h *2 kPa	10	0
	Low-temperature torque (Starting/Running)	-30°C mN m	250/77	1,800/710
	Copper strip corrosion	Room temp.×24h	Pass	
Use temperature range	°C	-30 to +200		
Volatile content	200°C×24h %	1.4	0.9	
Low-molecular-weight siloxane content	ΣD4-D10 ppm	≤100		

*1 For information on safety, see page 22 (Safety & hygiene).

*2 The oxidative stability test conditions prescribed in JIS K 2220 indicate 99°C×100 h, but in this case measurement was done at 150°C×50 h.

(Not specified values)

◆ Reference Data

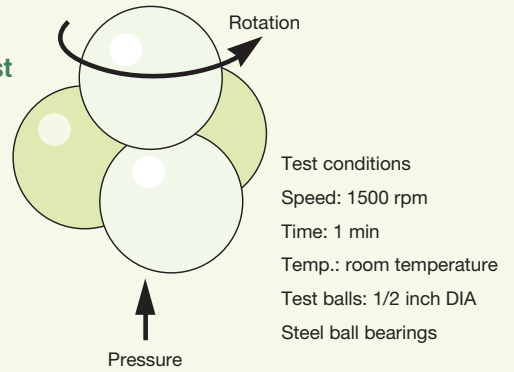
Boundary lubrication properties

● Properties of extreme-pressure greases

	4-ball weld load (kgf)
G-30M	102
G-40M	126
G-501	158
FG-721	348
Mineral oil type	183

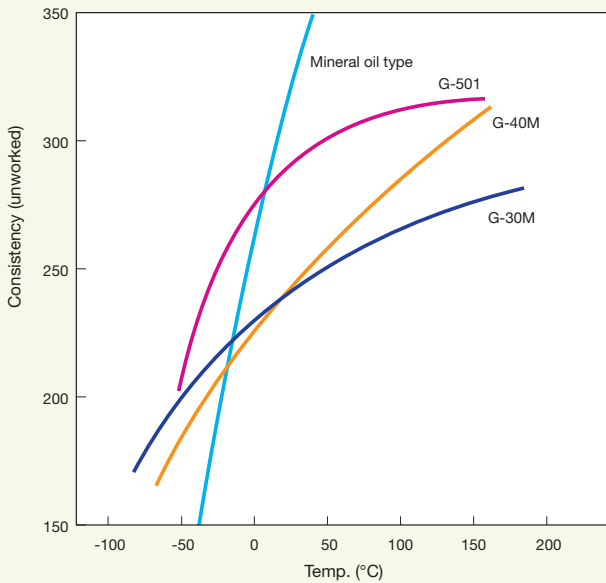
kgf values: 1500 rpm/1 min.

● 4-ball test

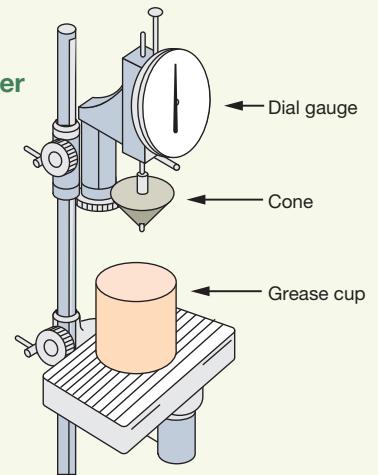


Consistency

● Effect of change in temperature on consistency



● Consistency tester

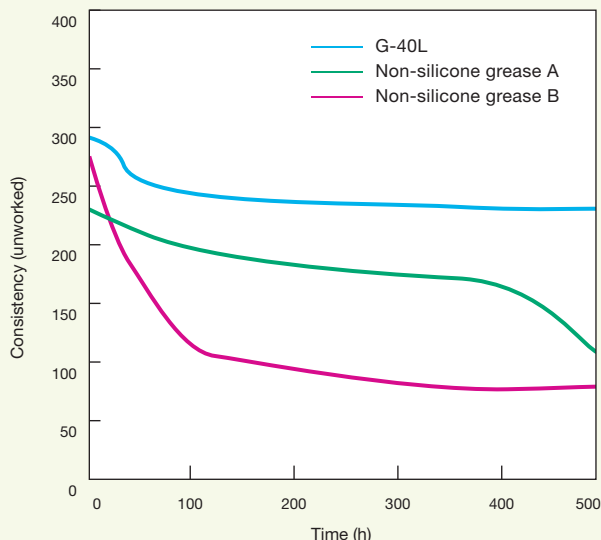


*Consistency test

A consistency tester of the type prescribed in the consistency test method in JIS K 2220 (grease) was used. For the test, a sample is put into the prescribed grease cup and the surface is leveled, then the sample is kept at 25.0 °C. The cone is then lowered and allowed to press vertically into the grease for 5 seconds. The penetration depth is measured to a precision of 0.1 mm, and this value is multiplied by 10 to get the consistency of the sample. Worked consistency is the consistency measured after the grease has been worked for 60 strokes over 1 minute using a mechanical grease worker of the prescribed type.

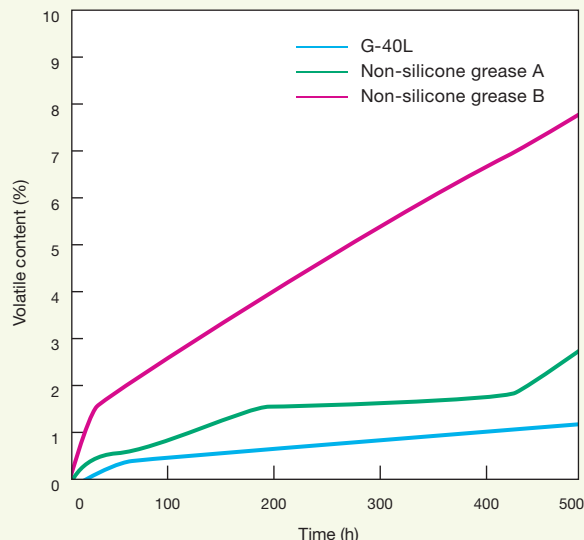
Reliability comparison: Silicone grease vs. Non-silicone grease

Consistency



Test conditions: 150°C × 500 h

Volatile content



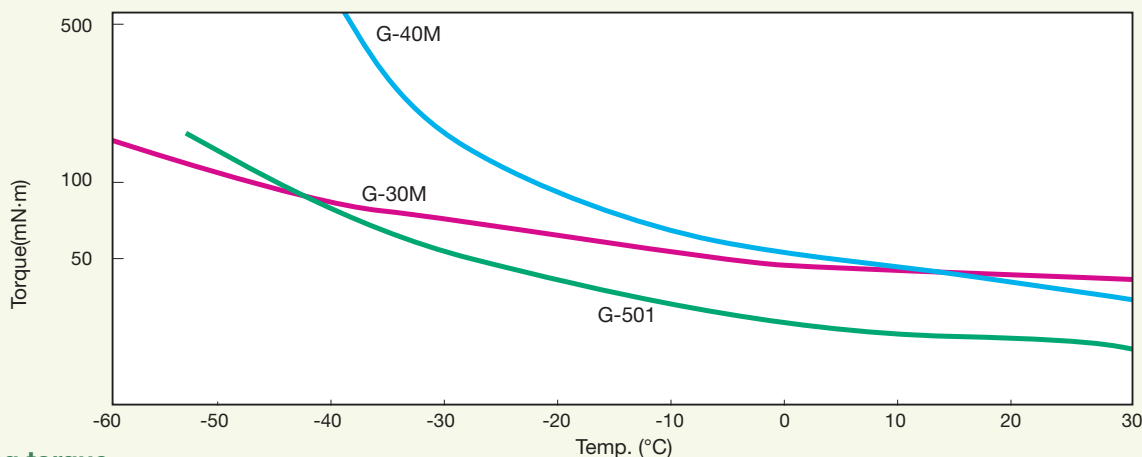
Test conditions: 150°C × 500 h

Torque (sliding resistance)

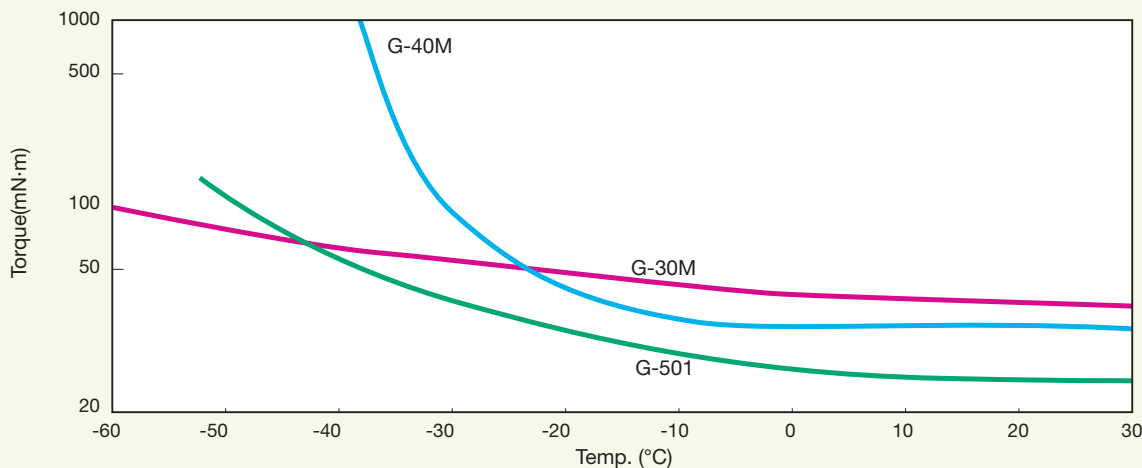
Measured in accordance with JIS K 2220. 6204 bearings, 1 rpm.

Grease is kept at a prescribed temperature for two hours, then starting torque is measured. Rotation is continued, and the torque value after 10 minutes is taken to be the running torque.

Starting torque



Running torque



◆ Tacky Greases (Torque, Damper Applications)

■ G-330 G-331 G-332 G-333

■ G-341

■ G-633

The products in the G-330 series and G-341 are highly tacky greases that exhibit little change in torque values due to changing temperatures.

These greases can be applied to sliding and rotating parts in a variety of equipment, where their high tackiness provides a superior damping effect.

G-330 has medium shear resistance (torque), while G-331 has high shear resistance. G-332 and G-333 are low-torque greases.

G-341 is specially formulated to ensure stable physical properties at low temperatures.

G-633 was developed as a bearing grease for variable resistors, and can also be used as a damping grease.

Note that G-633 is made using non-silicone base oils, and so the use temperature range will not be as wide as those of the other products.

■ Typical properties

Parameter			G-330	G-331	G-332	G-333
Appearance			White grease		Blue grease	White grease
Specific gravity	25°C		1.15	1.15	1.12	1.11
JIS K2220 Test method	Consistency	25°C/unworked	285	305	307	304
	Oil separation	105°C×24h %	0.01	0.01	0.12	0.38
Torque	After 50 turns	N·m×10 ⁻⁴ **	23	34	9	7
Use temperature range			-30 to +150			
Volatiles content	105°C×24h	%	0.05	0.05	0.06	0.06
Low-molecular-weight siloxane content			ΣD ₃ -D ₁₀ ppm ≤100			

※Torque meter: Torque Tester MDT2-AMP made by Shinmei Electric.

The sample is applied evenly to the shaft (4 mm DIA_8 mm) and in the bearing clearance (35 μm). The shaft is then turned 50 times (1 turn=360°) by hand at a rate of 1 turn per second. After 50 turns, the sample is loaded into the torque meter and the torque value is measured after rotation at 10 rpm for 1 minute. This value is taken as the test value.

(Not specified values)

■ Typical properties

Parameter			G-341
Appearance			Pale yellow grease
Specific gravity	25°C		1.02
JIS K2220 Test method	Consistency	25°C/unworked	182
	Oil separation	105°C×24h %	0.06
Torque	After 50 turns	N·m×10 ⁻⁴ **	9
Use temperature range			-40 to +100
Volatiles content	105°C×24h	%	0.08
Low-molecular-weight siloxane content			ΣD ₃ -D ₁₀ ppm ≤100

※Torque meter: Torque Tester MDT2-AMP made by Shinmei Electric.

The sample is applied evenly to the shaft (4 mm DIA_8 mm) and in the bearing clearance (35 μm). The shaft is then turned 50 times (1 turn=360°) by hand at a rate of 1 turn per second. After 50 turns, the sample is loaded into the torque meter and the torque value is measured after rotation at 10 rpm for 1 minute. This value is taken as the test value.

(Not specified values)

■ Typical properties

Parameter			G-633
Appearance			Pale yellow to creamy white translucent grease
Specific gravity	25°C		0.87
JIS K2220 Test method	Consistency	25°C/unworked	235
	Oil separation	105°C×24h %	0.04
Torque	After 50 turns	N·m×10 ⁻⁴ **	64
Use temperature range			0 to +80
Volatiles content	105°C×24h	%	0.07
Low-molecular-weight siloxane content			ΣD ₃ -D ₁₀ ppm ≤100

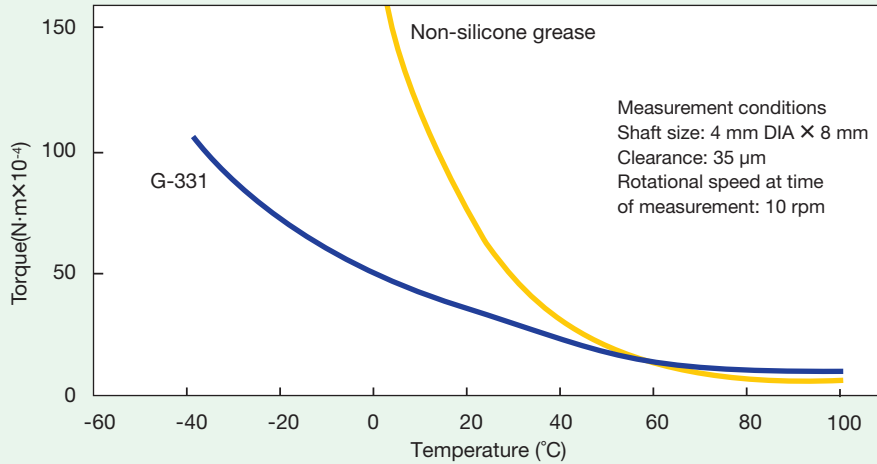
※Torque meter: Torque Tester MDT2-AMP made by Shinmei Electric.

The sample is applied evenly to the shaft (4 mm DIA_8 mm) and in the bearing clearance (35 μm). The shaft is then turned 50 times (1 turn=360°) by hand at a rate of 1 turn per second. After 50 turns, the sample is loaded into the torque meter and the torque value is measured after rotation at 10 rpm for 1 minute. This value is taken as the test value.

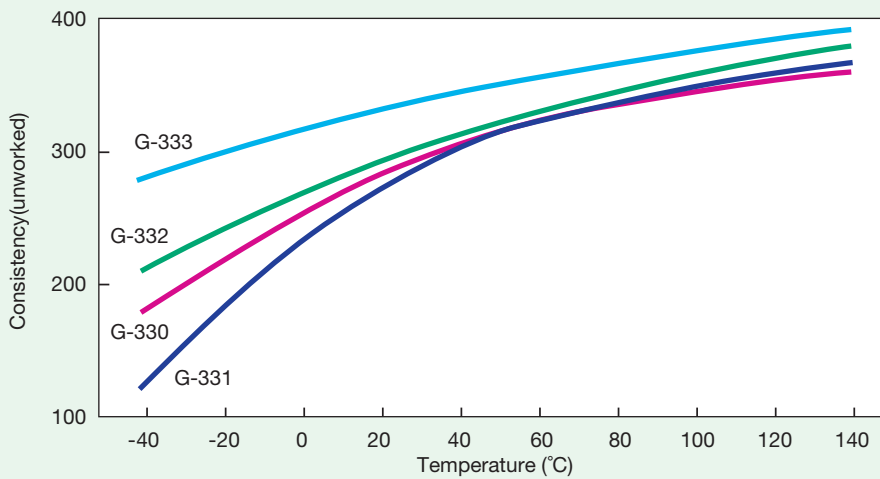
(Not specified values)

◆ Reference Data

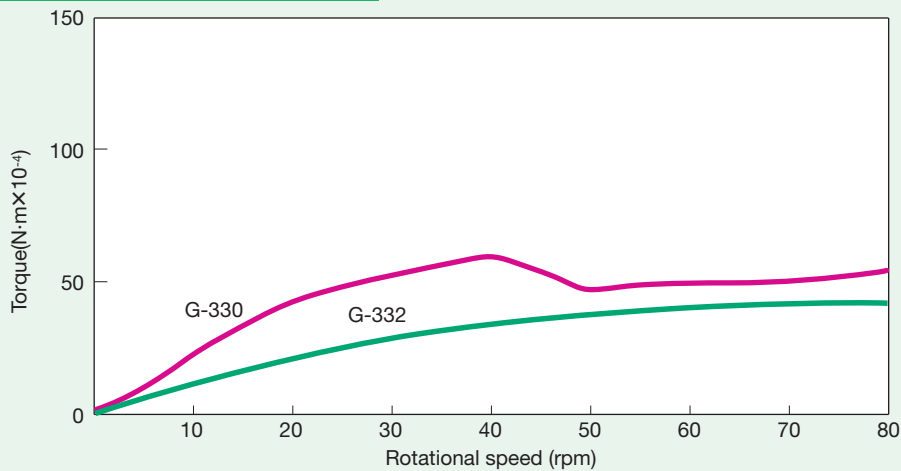
Temperature vs. Torque



Temperature vs. Consistency



Rotational speed vs. Torque



Properties of Silicone Oil Compounds

A silicone oil compound features a base oil of silicone fluid, compounded with silica or metal powders. Silicone oil compounds have superior electrical properties and water repellency and are exceptionally stable against heat and oxidation across a wide temperature range. These products are thus used extensively as a dielectric material, as a thermal interface material, for sealing, and to improve water repellency.

◆ Thermal Interface Compounds (General Purpose)

■ KS-609 KS-613N G-747

All three feature silicone fluid as the base oil, plus thermally conductive fillers. These oil compounds offer excellent thermal conductivity and electrical properties.

They are ideal for use as a thermal interface and insulator for semiconductor elements (transistors, thermistors) and various types of heatsinks.

KS-609 is a general purpose product, KS-613N has enhanced heat resistance for potting of thermistors, and G-747 can be used as a thermal interface material for resin-encapsulated power transistors.

■ Typical properties

Parameter	KS-609	KS-613N	G-747	
Appearance	White grease			
Specific gravity	25°C	2.50	2.41	2.65
Viscosity	25°C Pa·s	70	80	50
Consistency*2	25°C/worked	328	326	328
Oil separation*2	200°C×24h %	0.3	N/A	0.01 *1
Thermal conductivity	W/m·K	0.73	0.86	0.90
Volume resistivity	TΩ·m	2.3	0.05	2.5
Dielectric breakdown strength	0.25mm kV	3.5	5.4	3.7
Use temperature range	°C	-55 to +200	-50 to +250	-50 to +150
Volatile content	200°C×24h %	0.3	0.19	0.06 *1
Low-molecular-weight siloxane content	ΣD3-D10 ppm	≤100		

*1 Measured at 120°C×24 h. *2 Tested in accordance with JIS K 2220.

(Not specified values)

◆ Thermal Interface Compounds (High Reliability)

■ G-775 G-776 G-777 G-779 G-1000

All three feature a base oil of silicone fluid, compounded with thermally conductive fillers. These oil compounds offer excellent thermal conductivity and electrical properties.

Compared to general purpose products, these oil compounds offer better resistance against pump-out, creep and oil separation, meaning they can be used in spots where long-lasting reliability is required.

G-775 is high viscosity and offers the ultimate in creep resistance.

G-776 has been diluted with an isoparaffin solvent, to achieve properties which are normally at odds, namely low viscosity (ease of use) and low oil bleed.

G-777 is an all-purpose product that offers a balance of good working properties, heat resistance, thermal conductivity, and resistance against pump-out.

The all-purpose G-779 has all the reliability of G-777, and works great in low BLT applications.

The curable grease G-1000 has the low contact thermal resistance of a grease, and resists pump-out like a sheet.

■ Typical properties

Parameter	G-775	G-776	G-777	G-779	G-1000	
Appearance	White grease					
Specific gravity	25°C	3.4	2.9	3.2	3.2	3.04
Viscosity	25°C Pa·s	500	60	140	160	80
Consistency*2	25°C/unworked	250	354	190	190	—
Hardness after cured	Asker C	—	—	—	—	40
Thermal conductivity	W/m·K	3.6	1.3 *1	3.3	3.0	2.4
Dielectric breakdown strength	0.25mm kV	2.5	2.9	3.2	3.2	3.6
Use temperature range	°C	-40 to +150	-40 to +200	-40 to +200	-40~+200	-40~+180
Volatile content	150°C×24h %	0.26	3.10	0.1	0.18	0.58
Low-molecular-weight siloxane content	ΣD3-D10 ppm	≤300			≤100	

*1 Value after evaporation of solvent. *2 Tested in accordance with JIS K 2220.

(Not specified values)

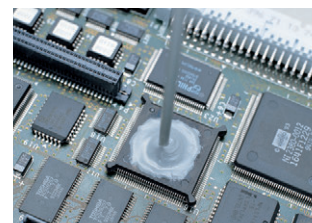
◆ Thermal Interface Compounds (High Thermal Conductivity)

■ G-751 X-23-7921-5

These oil compounds have excellent thermal conductivity. All feature a base oil of silicone fluid compounded with high thermal conductivity fillers.

In G-751 and X-23-7921-5 the emphasis is on thermal conductivity, and their dielectric strength is lower than that of other silicone products. Thus, G-751 and X-23-7921-5 are not recommended for applications that require a material with insulating properties.

G-751 and X-23-7921-5 are used as thermal interface materials and ideal for CPUs and MPUs.



Thermal interface for CPUs

■ Typical properties

Parameter		G-751	X-23-7921-5
Appearance		Gray grease	
Specific gravity	25°C	2.51	2.6
Viscosity	25°C Pa·s	420	363
Oil separation*	150°C×24h %	0.01	—
Thermal conductivity	W/m·K	4.5	6.0
Volume resistivity	TΩ·m	0.008	—
Dielectric breakdown strength	0.25mm kV	Below measurable limit	
Use temperature range	°C	-50 to +120	
Volatile content	150°C×24h %	0.10	0.44
Low-molecular-weight siloxane content	ΣD ₃ -D ₁₀ ppm	≤100	

* Tested in accordance with JIS K 2220.

(Not specified values)

◆ Thermal Interface (High Thermal Conductivity, Solvent Diluted Types)

■ X-23-7762 X-23-7783D X-23-7868-2D G-787

These oil compounds have excellent thermal conductivity. All feature a base oil of silicone fluid compounded with high thermal conductivity fillers.

They are compounded with around 2-3% isoparaffin based solvent so they not only have high thermal conductivity, but are also easier to work with. These products are ideal as a thermal interface for CPUs and MPUs.

X-23-7783D is essentially X-23-7762 compounded with a fine filler to give it a lower thermal resistance.

X-23-7868-2D has a lower viscosity than X-23-7783D, making it easier to work with and giving it an even higher thermal conductivity.

G-787 has thermal conductivity exceeding 3.0W/m · K, achieving excellent workability, heat resistance and insulation.

■ Typical properties

Parameter		X-23-7762	X-23-7783D	X-23-7868-2D	G-787
Appearance		Gray grease			White grease
Specific gravity	25°C	2.55	2.55	2.5	3.48
Viscosity	25°C Pa·s	180	200	100	70
Thermal conductivity	W/m·K	4.0(6.0*)	3.5(5.5*)	3.6(6.2*)	3.3(4.0*)
Dielectric breakdown strength	0.25mm kV	Below measurable limit			2.4
Use temperature range	°C	-50 to +120			-40~+200
Volatile content	150°C×24h %	2.58	2.43	2.70	0.93
Low-molecular-weight siloxane content	ΣD ₃ -D ₁₀ ppm	≤100			

* Value after evaporation of solvent.

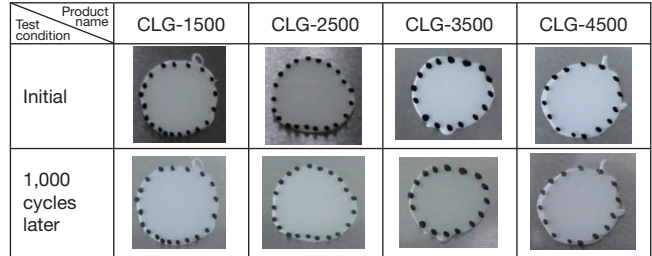
(Not specified values)

◆ TIM* Materials with Improved Resistance against Pump-out CLG Series

*TIM=Thermal Interface Material

■ CLG-1500 CLG-2500 CLG-3500 CLG-4500

- 1 Part ready to use
- No need to cure
- Resists against pump-out
- Owing to grease consistency, it is applicable on various surface shapes.
- Wide range of thermal conductivity



[Test method]

- 1 A sample is sandwiched between a microscope slide (glass) and an aluminum plate, which are separated by a 2.0mm spacer.
- 2 This test piece is stood vertically, and a heat cycle test is conducted (cycling between -40°C × 30 min and +125°C × 30 min).

■ Typical properties

Parameter	CLG-1500	CLG-2500	CLG-3500	CLG-4500
Appearance	White			
Specific gravity at 25°C	2.6	2.9	3.1	3.2
Viscosity at 25°C Pa·s	500	500	250	550
Thermal conductivity W/m·K	1.5	2.9	3.5	4.8
Dielectric breakdown strength kV/mm	9.6	6.2	8.9	4.7
Operation temperature range °C	-40 to +180			
LMW siloxane content ΣD_3-D_{10} ppm	≤ 300			

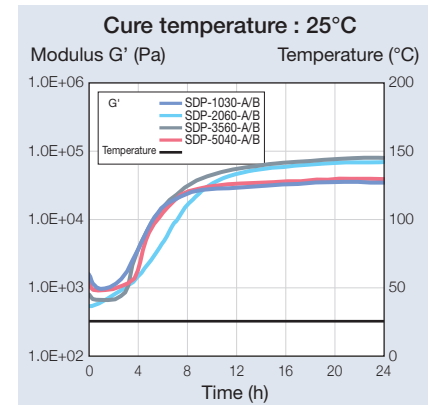
(Not specified values)

◆ Non-adhesive Curing TIM* Materials SDP Series

*TIM=Thermal Interface Material

■ SDP-1030-A/B SDP-2060-A/B SDP-3560-A/B SDP-5040-A/B SDP-6560-A/B

- Thermal interface materials that cure at room temperature when the two components are mixed.
- When applied, the materials have a grease-like consistency and get into the nooks and crannies of the substrate surface, which translates to lower contact thermal resistance.
- The materials have low hardness after curing, which means less stress on components.
- The materials can be reworked because they do not adhere to substrates.
- Owing to the addition reaction, curing time is shortened by heating.



■ Typical properties

Parameter	SDP-1030-A/B	SDP-2060-A/B	SDP-3560-A/B	SDP-5040-A/B	SDP-6560-A/B
Appearance	A:White B:Light blue	A:White B:Light blue	A:White B:Light blue	A:Grayish white B:Pink	A:Grayish white B:Pink
Specific gravity at 25°C	A/B:2.45	A/B:2.87	A:3.11 B:3.12	A:3.25 B:3.26	A/B:3.20
Mix ratio	100:100				
Viscosity after mixing at 25°C Pa·s	74	81	104	169	284
Pot life at 23°C min	240				
Standard curing conditions	25°C×24h				
Hardness after curing Shore OO	32	57	60	42	61
Thermal conductivity W/m·K	1.1	2.3	3.7	5.1	6.5
Dielectric break down strength kV/mm	19	18	15	21	20
Operation temperature range °C	-40 to +180				
LMW siloxane content ΣD_3-D_{10} ppm	≤ 300				

(Not specified values)

Heat Resistance: Evaluation & Measurement Methods

Thermal conductivity

At a given temperature, thermal conductivity is a value intrinsic to a particular substance. According to Fourier's Law, in a steady state, the proportionality constant is the thermal conductivity.

Thermal conductivity
 λ

$$Q = \lambda \frac{(T_1 - T_2) A}{L}$$

→

$$\lambda = \frac{Q}{A} \times \frac{L}{(T_1 - T_2)}$$

From this we get

Q: heat flow rate A: cross-sectional surface area L: Heat transfer distance
T1: temperature at high side T2: temperature at low side

Thermal resistance

Thermal resistance is the sum of contact resistance plus the resistance as heat flows (Q) from T₁ to T₂.

Thermal resistance
R

$$R_0 = \frac{T_1 - T_2}{Q} = \frac{L}{\lambda A}$$

→

$$R = R_0 + R_s$$

In reality

R₀: Intrinsic thermal resistance of substance R_s: Thermal contact resistance

Thermal conductivity measurement method(hot disk)

Two "pouches" were prepared by wrapping grease samples in kitchen wrap. A sensor was sandwiched between the pouches as shown in Figure 1, and a constant current was applied to the sensor so as to generate a specific amount of heat. Thermal conductivity was calculated from the rise in temperature of the sensor.

The sensor is constructed with a double spiral of nickel metal, and can detect temperature changes as the change in electrical resistance of the sensor. Figure 2 shows the signals obtained from the sensor when the constant current is applied.

If we take the graph showing temperature rise (Fig. 2) and scale the X-axis (function of time and thermal diffusivity (α) of the sample) to $D(\tau)$, we get the graph in Figure 3.

From Equation (1), we know that the slope of this straight line is inversely proportional to the thermal conductivity (λ) of the sample. The temperature rise (ΔT_{ave}) of the sensor may be theoretically expressed by the following equation.

$$\Delta T_{ave}(\tau) = \frac{P_0}{\pi^{3/2} r \lambda} \cdot D(\tau) \dots (1)$$

- P₀ : Total power (W) applied to the sensor
- r : Radius (m) of sensor
- λ : Thermal conductivity (W/m_K) of sample
- τ : Dimensionless parameter, defined by $\sqrt{\alpha \cdot t} / r^2$
- α : Thermal diffusivity (m²/s) of sample
- t : Test time (sec)
- D(τ) : Dimensionless function of

Fig. 1: Setup of samples

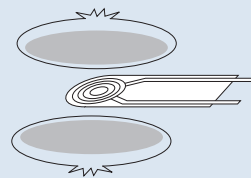


Fig. 2: Applied current and change in sensor signal over time

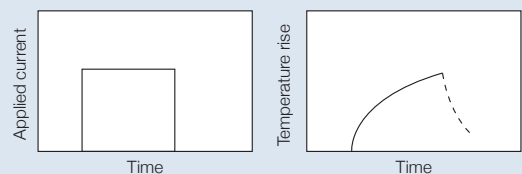
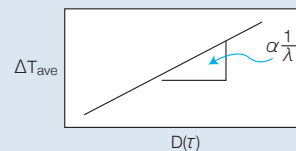


Fig. 3: Temperature rise curve vs. D(τ)

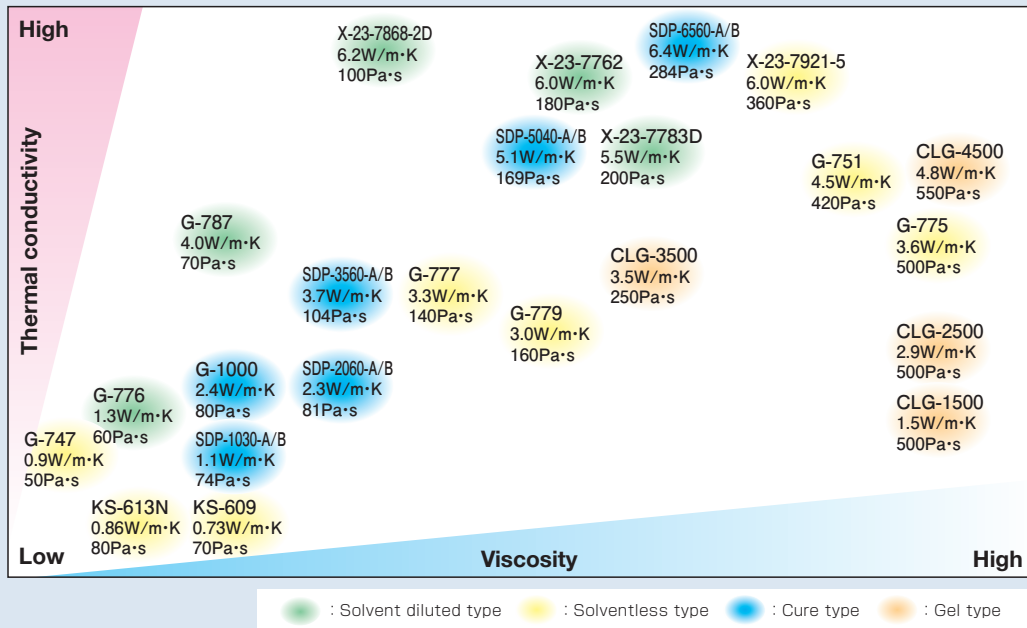


Method used to measure thermal resistance (laser flash)

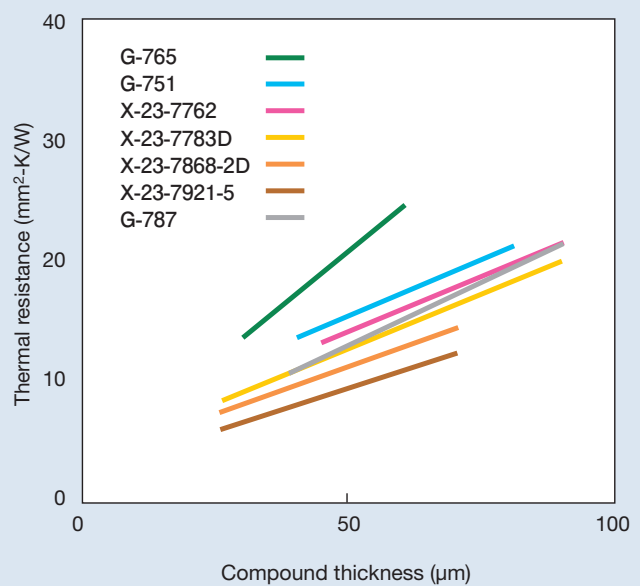
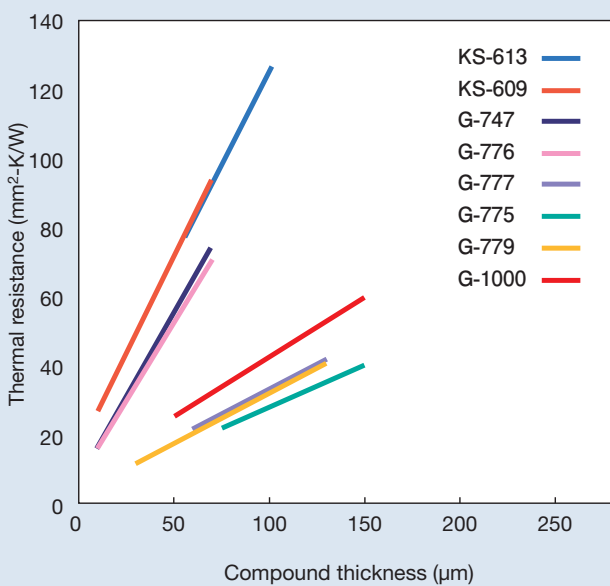
Thermal resistance was measured by the laser flash method, which is one method used to measure thermal constants. In this method, one face of a sample is irradiated with a pulse laser to heat it. The temperature rise at the opposite face is measured using an infrared sensor, which does not touch the sample.

◆ Reference Data

Correlation between thermal conductivity and viscosity

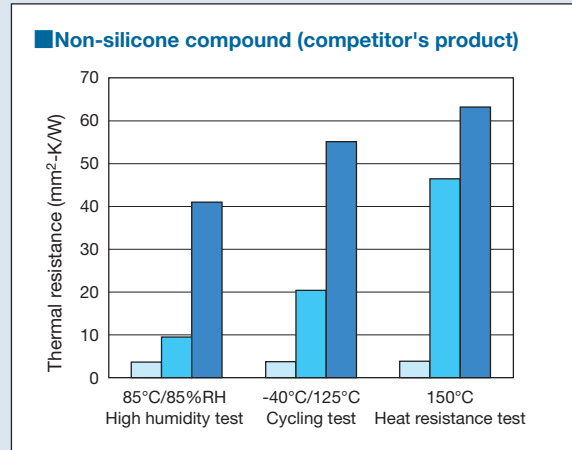
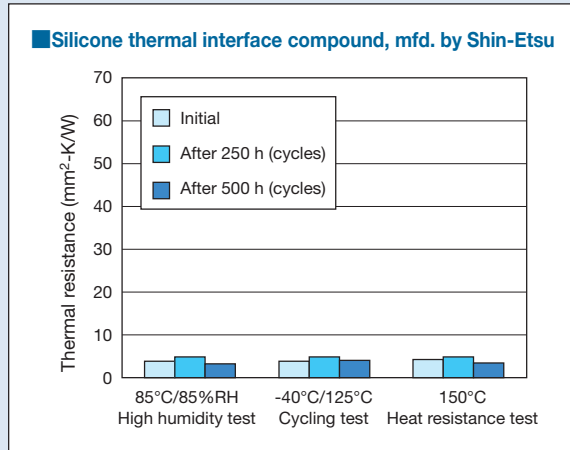


Correlation between thermal resistance and thickness of oil compound

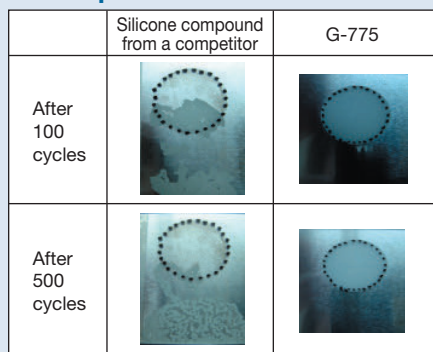


Reliability

● Reliability comparison: Silicone compound vs. Non-silicone compound



● Creep resistance of G-775



[Test method]

- 1 A 0.1cc sample is sandwiched between a microscope slide (glass) and an aluminum plate, which are separated by a 0.3mm spacer.
- 2 This test piece is stood vertically, and a heat cycle test is conducted (cycling between -40°C and +125°C).

● Resistance to oil-bleed of G-776

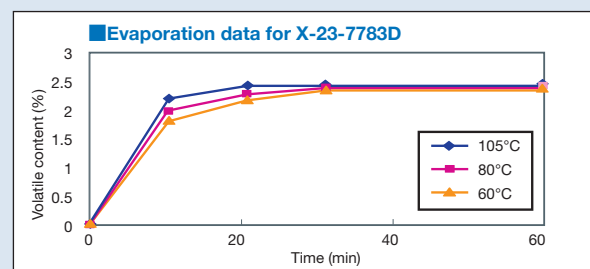
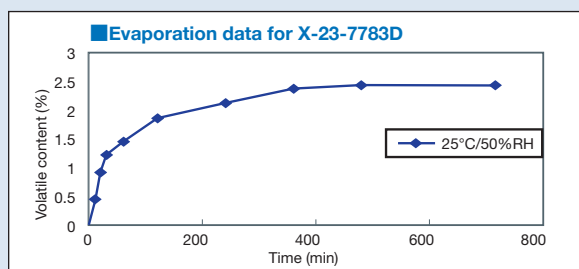
Conditions	23°C×64h		125°C×64h	
Sample	Conventional product	G-776	Conventional product	G-776
Photo				
Bleed distance mm	10.0	1.5	20.6	1.6

[Test method]

- 1 A 0.1 g sample is placed on a piece of frosted glass.
- 2 The oil bleed distance (radius of circle) is measured and oil separation is evaluated.
- 3 Bleed is measured after keeping samples at 23°C and 125°C.

Solvent evaporation time

● Solvent evaporation conditions (guide)



※Solvent diluted products: G-776, X-23-7762, X-23-7783D, X-23-7868-2D, G-787

[Test method]

- Using a metal screen, X-23-7783D was applied (application size: 25 mm long × 25 mm wide _ 120 μm thick) to aluminum plates.
- The samples were kept at various temperatures, and the change in weight was measured.

◆ For Dielectric & Sealing Applications (General Purpose)

■ KS-62F KS-62M KS-63W KS-64F KS-64

These oil compounds have superior electrical properties and water repellency, and are chemically inert. They are ideal for use as insulating and sealing materials for electric and electronic equipment.

KS-63W, KS-64 and KS-64F are general purpose products, while KS-62F and KS-62M are heat resistant products.

■ Typical properties

Parameter		KS-62F	KS-62M	KS-63W	KS-64F	KS-64
Appearance		Off-white paste	White translucent grease	White grease	White paste	White grease
Specific gravity 25°C		1.13	1.18	1.02	1.01	1.05
JIS K2220 Test method	Consistency 25°C/worked	—	229	225	385	246
	Oil separation 200°C×24h %	—	1.3	2.9*1	18*1	5.8
Dielectric breakdown strength 0.1mm	kV	3.4	3.5	3.8	3.6	4.0
Volume resistivity	TΩ·m	0.15	56	130	230	620
Permittivity	60Hz	2.96	2.88	2.84	2.80	2.80
Dissipation factor	60Hz	2.5×10 ⁻⁴	3.2×10 ⁻⁴	2.4×10 ⁻⁴	1×10 ⁻⁴	2.3×10 ⁻⁴
Thermal conductivity	W/m·K	0.17	0.20	0.19	0.17	0.19
Use temperature range	°C	-30 to +250		-50 to +200		
Volatile content 200°C×24h	%	≤1.0	0.3	0.1*1	0.1*1	0.1
Low-molecular-weight siloxane content	ΣD ₃ -D ₁₀ ppm	≤100				

*1 Measured at 150 °C×24 h.

(Not specified values)

◆ For Dielectric & Sealing Applications (Special Purpose)

■ KS-650N KS-651 KS-65A KS-623 KS-622 KS-63G

These oil compounds have superior electrical properties and water repellency, and are chemically inert. They are ideal for use as insulating and sealing materials for electric and electronic equipment.

KS-650N and KS-651 will not cause swelling of silicone rubber.

KS-65A and KS-623 are ideal for sealing valves, cocks and packing in common chemistry equipment.

KS-622 is specially formulated to prevent corrosion of copper, and is ideal for terminal protection for copper wiring.

KS-63G can be applied to insulators to help prevent flashover which can be caused by salt damage.



Protecting insulators from salt damage (application example for KS-63G)

■ Typical properties

Parameter		KS-650N	KS-651	KS-65A	KS-623	KS-622	KS-63G
Appearance		Creamy white translucent grease	Pale yellow to yellow grease	White grease	White grease	Creamy white grease	Green grease
Specific gravity 25°C		0.98	1.02	1.04	1.03	1.03	1.06
JIS K2220 Test method	Consistency 25°C/worked	263	258	221	211	268	209
	Oil separation %	0.7(105°C×24h)	2.0(150°C×24h)	1.1(200°C×24h)	1.9(200°C×24h)	2.74(150°C×24h)	0.8(150°C×24h)
Silicone rubber swelling (Weight change/volume change) 105°C×500h	%	+0.5/+1.1	+0.6/+1.3	—	—	—	—
Dielectric breakdown strength 0.1mm	kV	—	—	3.7	1.5≤	—	11*1
Volume resistivity	TΩ·m	208	1.3	2,600	1≤	—	2,300
Permittivity	60Hz	2.48	2.6	—	—	—	2.82
Dissipation factor	60Hz	3.3×10 ⁻⁴	4.7×10 ⁻⁴	—	—	—	—
Use temperature range	°C	-10 to +100	-50 to +170	-50 to +200		-50 to +160	-50 to +200
Volatile content	%	0.5(105°C×24h)	0.1(150°C×24h)	0.1(200°C×24h)	0.2(200°C×24h)	0.44(150°C×24h)	0.1(150°C×24h)
Low-molecular-weight siloxane content	ΣD ₃ -D ₁₀ ppm	≤100					

*1: 0.25mm

(Not specified values)

◆ For Dielectric & Sealing Applications (High Vacuum Seals)

■ HIVAC-G

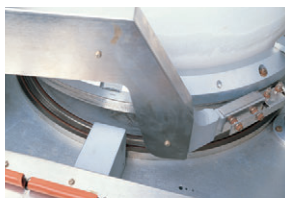
HIVAC-G features a base oil of specially refined silicone fluid, compounded with silica powder. This oil compound has excellent heat resistance, oxidative stability and chemical stability. Through an intensive refining process, volatile content has been reduced to very low levels, thereby making it possible to attain high vacuums of 10^{-6} Torr. HIVAC-G forms exceptionally tight seals on gaskets and sliding mechanisms, and is widely used as a sealing compound for high vacuum devices.

■ Typical properties

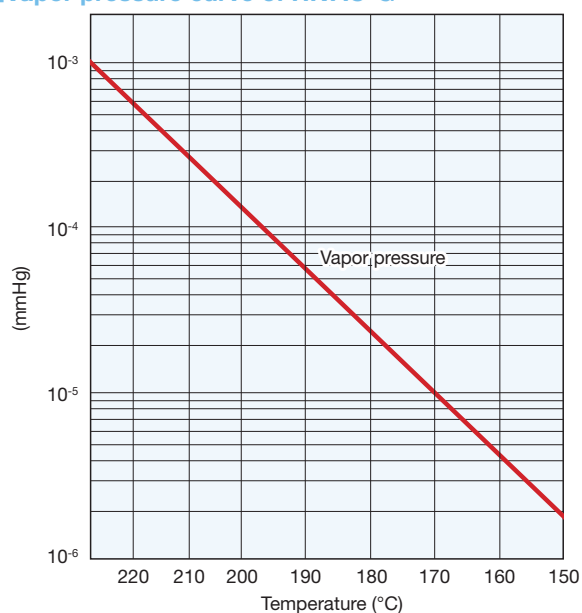
Parameter		HIVAC-G
Appearance		White grease
Specific gravity	25°C	1.03
JIS K2220 Test method	Consistency	25°C/worked
	Oil separation	200°C×24h %
	Copper strip corrosion	Room temp.×24h
Dielectric breakdown strength	0.1mm	kV
Volume resistivity		T·m
Permittivity	60Hz	
Dissipation factor	60Hz	
Use temperature range		°C
Volatile content	200°C×24h	%
Low-molecular-weight siloxane content	ΣD_3-D_{10}	ppm

(Not specified values)

Sealing of high vacuum devices



■ Vapor pressure curve of HIVAC-G



◆ Safety Data

Toxicity test results for silicone greases & oil compounds

Item Product name	Skin irritation (human)*1	LD50: Oral (rat) (unit: g/kg)
HIVAC-G	Negative	5≦
KS-64	Negative	5≦
G-30M	Negative	5≦
G-40M	Negative	5≦

*1 Tested by the Japanese Society for Cutaneous Health.

As the table at left shows, most silicone greases and oil compounds are highly safe. (See below for information on oral toxicity standards.) However, Shin-Etsu's special grades may differ in terms of safety, so please contact us for inquiries about products other than those shown at left.

Oral toxicity standards

● Acute toxicity test

Generally, an animal subject is exposed to a large quantity of a substance to determine the lethal dose.

This is normally expressed as LD50 (Lethal Dose, 50%). See the table below for information on degrees of toxicity.

● Categories of strength of toxicity

Degree of toxicity	LD50: Oral (rat) (unit: g/kg)
Extremely toxic	<0.001
Strongly toxic	0.001~0.05
Moderately toxic	0.05~0.5
Mildly toxic	0.5~5
Minimally toxic	5~15
Nearly non-toxic	15<

Source: Hodge, H.G. and Sterner, J.H.

: American Industrial Hygiene Association Quarterly, 10:4, 93, 1943

◆ Reference Data

Various silicone fluids and their swelling of synthetic rubbers

● Test of swelling tendencies of base oils on synthetic rubbers

(70°C, 120°C×240h)

Rubber type	Test item	KS-64 (base oil)		650N (base oil)		G-40 (base oil)		G-30 (base oil)		FG-721-1 (base oil)	
		70°C	120°C	70°C	120°C	70°C	120°C	70°C	120°C	70°C	120°C
IIR	Weight change (%)	-1.8	-3.7	-1.5	-2.1	-1.8	-2.8	-2.0	-3.6	-0.2	-0.9
	Volume change (%)	-3.1	-6.3	-2.4	-3.5	-3.0	-4.9	-3.3	-6.2	-0.4	-1.6
CR	Weight change (%)	-11.8	-12.1	-13.1	-14.1	-11.0	-11.6	-12.1	-12.4	-10.3	-11.1
	Volume change (%)	-18.5	-19.7	-20.1	-22.1	-17.4	-18.9	-19.0	-1.4	-16.1	-18.1
NR	Weight change (%)	-3.0	-4.2	-2.3	-5.0	-0.6	-3.0	-3.0	-4.6	-1.4	-2.0
	Volume change (%)	-5.1	-9.4	-3.5	-9.4	-1.4	-7.3	-5.1	-10.1	-2.2	-5.3
NBR	Weight change (%)	-5.4	-9.6	-6.3	-10.8	-6.1	-10.0	-5.8	-9.8	-4.9	-8.6
	Volume change (%)	-6.5	-12.9	-7.7	-13.9	-7.3	-13.0	-7.1	-13.2	-6.1	-11.6
EPDM	Weight change (%)	-17.6	-17.9	-14.7	-15.8	-17.7	-17.9	-18.1	-18.4	-11.3	-14.3
	Volume change (%)	-19.5	-20.5	-15.8	-17.4	-19.5	-20.4	-20.2	-21.1	-12.1	-16.3
Silicone	Weight change (%)	+32.0	+31.2	-0.2	-0.4	+7.2	+7.7	+33.2	+33.4	-0.6	-1.5
	Volume change (%)	+38.9	+38.5	+0.3	+0.2	+8.3	+9.4	+39.2	+39.8	-0.5	-1.2

Note: The data in the table above are the values observed in severe tests in which strips of rubber were immersed in the base oils, and do not represent results obtained with greases. The table should be taken as a guide with respect to compatibility with the materials shown. The same tests conducted with the actual greases tend to yield absolute values which are lower.

Compatibility with plastics

+ : No effect ± : Mild effects - : Significant effects

Plastic name Product name	ABS	POM	PBT	PVC	PS	PP	PC	HIPS	PMMA	AS	ASGF	Nylon 6	Nylon 66	Nory	Duranex
G-330	+	+	+	+	+	+	+	+		+	+	+	+	+	+
G-332	+	+	+	+	+	+	+	+		+	+	+	+	+	+
G-30M	± to +	+	+	+		+									+
G-40M	± to +	+	+	+	+	+	±	-	-	+	+	+	+	-	+
G-501	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
KS-63W	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
KS-64	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
KS-65A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
KS-62M	-	+	+	+	+	+	±	±	-	+	+	+	+	-	+
HIVAC-G	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
KF-96H-200,000CS mm ² /s	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

● Potential of silicone greases & oil compounds to cause stress cracking of plastics

When a stressed plastic is subjected to prolonged contact with certain chemicals, it may be more likely to crack at a much lower load than it would were it not in contact with the chemical. This phenomenon is commonly called stress cracking, and is characterized by glass-like cracking, usually with no whitening of the plastic.

Stress cracking of plastics can be a function of several factors which include stress, temperature, time and chemicals. Of these, exposure to chemicals is the most important factor. Silicone greases have also been known to cause stress cracking in plastics.

The particulars of the stress cracking will vary depending on the type of silicone grease and plastic involved. And even for molded pieces made using the same type of plastic, the effects of a grease may differ depending on the molding strain, orientation and other conditions.

Thus, before using a silicone grease where it will be in contact with a plastic, it is important to first determine how the grease will affect the plastic.

Shin-Etsu tests its products using the experimental method described below. The user should perform their own tests which simulate the conditions of actual use to make sure that the product will not cause problems when it is used.

[Test method]

1. A plastic test strip (140 mm long, 25 mm wide, 3 mm thick) is clamped in a jig set to a length of 130 mm.
2. Grease is applied evenly to the convex surface of the strip.
3. In this state, the strip is heated at 80°C for 16 hours.
4. After heating, the grease is wiped off and a visual inspection is made for cracking.
5. A visual check is done to look for cracking or surface deterioration.

The results are compared to those for a strip to which grease has not been applied.

◆ Packaging



Some of the available packaging options

◆ Precautions Related to Handling, Safety and Hygiene

Handling & storage

1. Store in a cool and dark place. Avoid direct sun light.
2. After prolonged storage, oil may have separated, but it does not mean there is a problem with product. Stir the product well before using.
3. As a general rule it is best to completely use up the product once the container has been opened. If any remains, be sure to seal completely.
4. Before applying the product to the intended area, clean and dry the area thoroughly.
5. Do not mix these products with other oils or greases.

Safety & hygiene

1. Wear gloves and other protective gear when using these products.
2. If product gets on the hands or other exposed skin, wipe off with a dry cloth and then wash thoroughly with soap and water. In case of eye contact, immediately flush eyes with plenty of running water, and consult a physician if necessary. Contact lens wearers must be careful to avoid contact between product and their contact lenses. If it comes into contact with the lens, the contact lens may become stuck to the eye.
3. Be sure there is adequate ventilation when handling these products at the time of heating in particular. Avoid handling in a poorly ventilated area causing inhalation of vapors. If you feel ill after breathing the vapors, move immediately to an area with fresh air.
4. Keep out of reach of children.
5. If product gets on the floor, it will become slippery. After wiping product up with a cloth, spread sand or other absorbent material, then wipe again to remove product completely.
6. Fluorosilicone greases (FG-72 series) are essentially harmless when used normally. However, if heated to temperatures above 150°C, trace amounts of toxic gas will be released. When using these products in high temperature conditions, be sure there is adequate ventilation.
7. Be sure to read the Safety Data Sheets (SDS) for these products before use. SDS are available from the Shin-Etsu Sales Department.

◆ Packaging List

Type	Product name	Packaging
Greases	G-30F	100g (tube) / 1kg (round can) / 18kg (pail)
	G-30L	100g (tube) / 1kg (round can) / 18kg (pail)
	G-30M	100g (tube) / 1kg (round can) / 18kg (pail)
	G-30H	100g (tube) / 1kg (round can) / 18kg (pail)
	G-40L	100g (tube) / 1kg (round can) / 20kg (pail)
	G-40M	100g (tube) / 1kg (round can) / 20kg (pail)
	G-40H	100g (tube) / 1kg (round can) / 20kg (pail)
	G-420-1	1kg (round can) / 20kg (pail)
	G-501	80g (tube) / 1kg (round can) / 16kg (pail)
	FG-721-1	100g (glass bottle) / 1kg (round can) / 20kg (pail)
	FG-722-1	100g (glass bottle) / 1kg (round can) / 20kg (pail)
	G-330	100g (glass bottle) / 1kg (round can) / 15kg (pail)
	G-331	100g (glass bottle) / 1kg (round can) / 20kg (pail)
	G-332	100g (glass bottle) / 1kg (round can) / 20kg (pail)
	G-333	1kg (round can) / 20kg (pail)
	G-341	100g (glass bottle) / 1kg (round can) / 18kg (pail)
	G-633	1kg (round can) / 18kg (pail)
Oil compound	KS-609	200g (tube) / 1kg (plastic container) / 20kg (pail)
	KS-613N	1kg (round can)
	G-747	200g (tube) / 1kg (plastic container) / 20kg (pail)
	G-775	100g (plastic bottle) / 90g (syringe) / 1kg (cartridge)
	G-776	100g (plastic bottle) / 1kg (plastic container)
	G-777	200g (plastic bottle) / 90g (syringe) / 1kg (plastic container)
	G-779	1kg (plastic container)
	G-1000	200g (tube) / 900g (cartridge)
	G-751	100g (plastic bottle) / 150g (syringe) / 1kg (plastic container)
	X-23-7762	100g (plastic bottle) / 1kg (plastic container)
	X-23-7783D	100g (plastic bottle) / 1kg (plastic container)
	X-23-7868-2D	100g (plastic bottle) / 1kg (plastic container)
	G-787	1kg (plastic container)
	X-23-7921-5	60g (syringe) / 1kg (plastic container)
	KS-63W	1kg (round can) / 20kg (pail)
	KS-64	100g (tube) / 1kg (round can) / 20kg (pail)
	KS-64F	100g (tube) / 1kg (round can) / 20kg (pail)
	KS-62F	1kg (round can) / 20kg (pail)
	KS-62M	1kg (round can) / 20kg (pail)
	HIVAC-G	100g (tube) / 50g (plastic bottle) / 1kg (round can) / 20kg (pail)
	KS-650N	100g (tube) / 1kg (round can) / 16kg (pail)
	KS-651	100g (plastic bottle) / 1kg (round can) / 18kg (pail)
	KS-65A	1kg (round can) / 20kg (pail)
	KS-623	1kg (round can) / 20kg (pail)
	KS-622	1kg (round can) / 15kg (pail)
	KS-63G	1kg (round can) / 20kg (pail)
	CLG-1500	900g (cartridge)
	CLG-2500	900g (cartridge)
	CLG-3500	900g (cartridge)
	CLG-4500	900g (cartridge)
	SDP-1030-A/B	50cc (double-barrel cartridge*) / 800g (cartridge) / 20kg (pail)
	SDP-2060-A/B	50cc (double-barrel cartridge*) / 900g (cartridge) / 20kg (pail)
	SDP-3560-A/B	50cc (double-barrel cartridge*) / 900g (cartridge) / 20kg (pail)
SDP-5040-A/B	50cc (double-barrel cartridge*) / 900g (cartridge) / 20kg (pail)	
SDP-6560-A/B	50cc (double-barrel cartridge*) / 900g (cartridge) / 20kg (pail)	

* For sample only

Silicone Division Sales and Marketing Department IV

Marunouchi Eiraku Bldg. , 4-1, Marunouchi 1-chome, Chiyoda-ku, Tokyo 100-0005, Japan
 Phone: +81-(0)3-6812-2410 FAX: +81-(0)3-6812-2415

Shin-Etsu Silicones of America, Inc.

1150 Damar Drive, Akron, OH 44305, U.S.A.
 Phone : +1-330-630-9860 Fax : +1-330-630-9855

Shin-Etsu do Brasil Representação de Produtos Químicos Ltda.

Rua Coronel Oscar Porto, 736-8º Andar-Sala 84,
 Paraíso São Paulo-SP Brasil CEP : 04003-003
 Phone : +55-11-3939-0690 Fax : +55-11-3052-3904

Shin-Etsu Silicones Europe B.V.

Bolderweg 32, 1332 AV, Almere, The Netherlands
 Phone : +31-(0)36-5493170 Fax : +31-(0)36-5326459
 (Products & Services: Products for Cosmetics Application)

Germany Branch

Kasteler str. 45, 65203 Wiesbaden, Germany
 Phone : +49-(0)611-71187290
 (Products & Services: Products for Industrial Applications)

Shin-Etsu Silicone Taiwan Co., Ltd.

Hung Kuo Bldg. 11F-D, No. 167, Tun Hua N. Rd.,
 Taipei, 105406 Taiwan, R.O.C.
 Phone : +886-(0)2-2715-0055 Fax : +886-(0)2-2715-0066

Shin-Etsu Silicone Korea Co., Ltd.

GT Tower 15F, 411, Seocho-daero, Seocho-gu,
 Seoul 06615, Korea
 Phone : +82-(0)2-590-2500 Fax : +82-(0)2-590-2501

Shin-Etsu Singapore Pte. Ltd.

1 Kim Seng Promenade #15-05/06 Great World City, Singapore 237994
 Phone : +65-6743-7277 Fax : +65-6743-7477

Shin-Etsu Silicones Vietnam Co., Ltd.

Unit 4, 11th Floor, A&B Tower, 76A Le Lai Street,
 Ben Thanh Ward, District 1, Ho Chi Minh City, Vietnam
 Phone : +84-28-35355270

Shin-Etsu Silicones India Pvt. Ltd.

Unit No. 403A, Fourth Floor, Eros Corporate Tower,
 Nehru Place, New Delhi 110019, India
 Phone : +91-11-43623081 Fax : +91-11-43623084

Shin-Etsu Silicones (Thailand) Ltd.

7th Floor, Unit 7F, Harindhorn Tower, 54 North Sathorn Road,
 Bangkok 10500 Thailand
 Phone : +66-(0)2-632-2941 Fax : +66-(0)2-632-2945


Shin-Etsu Silicone International Trading (Shanghai) Co., Ltd.

29F Junyao International Plaza, No.789,
 Zhao Jia Bang Road, Shanghai China 200032
 Phone : +86-(0)21-6443-5550 Fax : +86-(0)21-6443-5868

Guangzhou Branch

Room 2409-2410, Tower B, China Shine Plaza, 9 Linhexi Road,
 Tianhe, Guangzhou, Guangdong, China 510610
 Phone : +86-(0)20-3831-0212 Fax : +86-(0)20-3831-0207

- The data and information presented in this catalog may not be relied upon to represent standard values. Shin-Etsu reserves the right to change such data and information, in whole or in part, in this catalog, including product performance standards and specifications without notice.
- For detailed information regarding safety, please refer to the Safety Data Sheet (SDS).
- Users are solely responsible for making preliminary tests to determine the suitability of products for their intended use. Statements concerning possible or suggested uses made herein may not be relied upon, or be construed, as a guaranty of no patent infringement.
- The silicone products described herein have been designed, manufactured and developed solely for general industrial use only; such silicone products are not designed for, intended for use as, or suitable for, medical, surgical or other particular purposes. Users have the sole responsibility and obligation to determine the suitability of the silicone products described herein for any application, to make preliminary tests, and to confirm the safety of such products for their use.
- Users must never use the silicone products described herein for the purpose of implantation into the human body and/or injection into humans.
- Users are solely responsible for exporting or importing the silicone products described herein, and complying with all applicable laws, regulations, and rules relating to the use of such products. Shin-Etsu recommends checking each pertinent country's laws, regulations, and rules in advance, when exporting or importing, and before using the products.
- Please contact Shin-Etsu before reproducing any part of this catalog. Copyright belongs to Shin-Etsu Chemical Co., Ltd.



The Development and Manufacture of Shin-Etsu Silicones are based on the following registered international quality and environmental management standards.

Gunma Complex	ISO 9001 (JQA-0004)	ISO 14001 (JQA-E-0002)
Naoetsu Plant	ISO 9001 (JQA-0018)	ISO 14001 (JQA-E-0064)
Takefu Plant	ISO 9001 (JQA-0479)	ISO 14001 (JQA-EM0298)