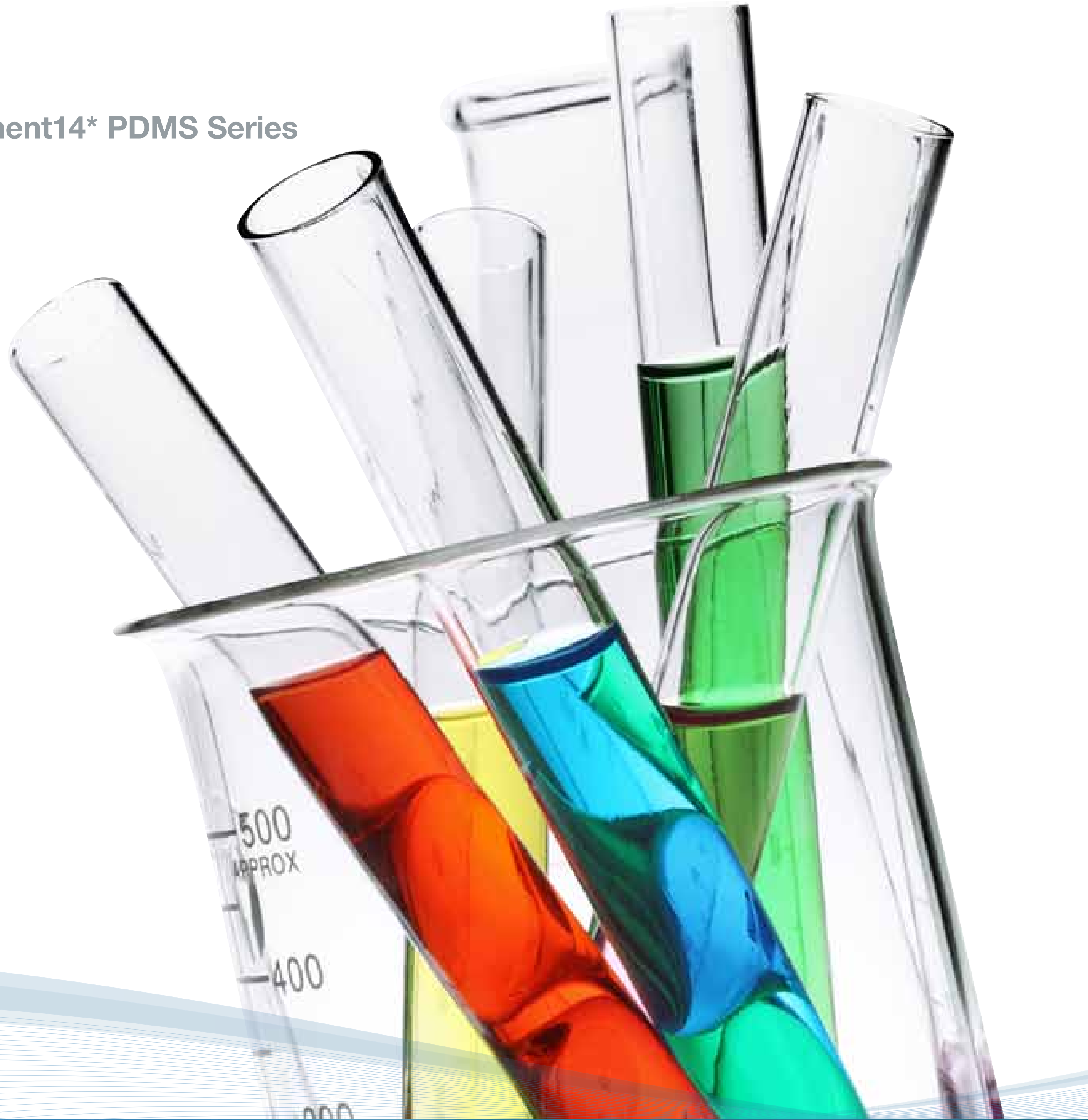
MOMENTIVE™

# Element14* PDMS Series





*Silwet is a trademark of Momentive Performane Materials Inc.

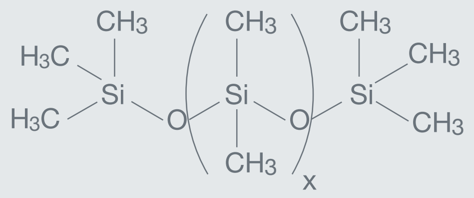
## Contents



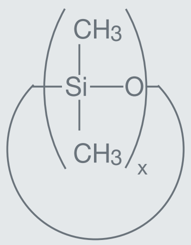

## Element14* PDMS series

The Element14 PDMS fluids series comprises a portfolio of products globally available from Momentive Performance Materials. In their chemical structure, our Element14 PDMS fluids are quite different from other synthetic materials. The products of the Element14 PDMS line belong to the class of the methyl terminated polydimethylsiloxane

### Element14* PDMS



### Element14* D



The silicon-to-oxygen bond is much stronger than the carbon-to-carbon bond. Additionally, the inorganic backbone - inherited from quartz – is saturated with organic methyl groups. As a result of this structure silicones exhibit:

- Unusually low viscosities at high molecular weight
- Excellent low temperature fluidity
- Outstanding high and low temperature stability
- Low vapor pressure
- Oxidation stability
- Chemical stability
- Very low interfacial tensions of down to ~20mN·m-1

As a result of these properties, Element14 PDMS fluids are used in many applications, e.g. as:

- Heat transfer media
- Hydraulic Fluids
- Liquid dielectrics
- Water repellents
- Polish ingredients
- Mold release agents
- Lubricants
- Antifoams
- Damping fluids
- Slipping Acids

A more detailed overview of application areas is displayed in the application grid (please consult Table 2).

Intermediate values are obtained by blending in accordance with the blending chart shown in Figure 3. More detailed information on blending techniques and the use of the chart are to be found in the blending section. Temperature has very little effect on the viscosity. Figure 2 shows the effect of temperature on Element14 PDMS fluids as compared with mineral oils of similar viscosity.

The range of Element14* PDMS fluids comprises various grades which differ in their viscosity and in related properties. The adjacent list constitutes a survey of the entire range of Element14 PDMS fluids, their typical physical properties are comprehensively shown in Table 1.

| Element14 PDMS | Viscosity [$mm \cdot s^{-1}$] | Viscosity Class |
|---|---|---|
| 0.65 | 0.65 | Low viscosity oil (LVO) |
| 3 | 3 | |
| 5 | 5 | |
| 10 | 10 | |
| 20 | 20 | |
| 50 | 50 | Medium viscosity oil(MVO) |
| 100 | 100 | |
| 350 | 350 | |
| 500 | 500 | |
| 1000 | 1000 | |
| 5K | 5000 | High viscosity oil(HVO) |
| 10K | 10000 | |
| 12.5K | 125000 | |
| 60K | 60000 | |
| 100K | 100000 | |
| 500K | 500000 | Ultra high viscosity oil(UVO) |
| 1000K | 1000000 | |
| 2000K | 2000000 | |

Note: Typical data are average data and actual results may vary. Typical data shall not be used as product specifications.

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| PolyDimethylsiloxanes | Kinematic Viscosity at 25°C | Molecular Weight (average) | Viscosity Temperature Coefficient | Specific Gravity | Refractive Index at 25°C | Pour Point DIN 51597 | Flash Point °DIN 51376 | Fire Point DIN 51376 | Surface Tension at 25°C | Thermal Expansion Coefficiant [-104] 0-150°C | Thermal Conductivity 50°C | Maximum Volatility Weight loss at 150°C after 24 hrs. | Specific Heat | Dielectric Strength | Dissipation Factor tan δ | Dielectric Constant δr | Volume Resistivity δD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $mm^2 \cdot s^{-1}$ | $g \cdot mol^{-1}$ | | | | °C | °C | °C | $mN \cdot m^{-1}$ | $cm^3 \bullet (cm^3 \bullet °C)^{-1} \bullet 10^{-4}$ | $W \cdot K^{-1} \cdot m^{-1}$ | % | $J \bullet g^{-1} \bullet K^{-1}$ | KV | | | Ω·cm |
| **Low Viscosity Oils (LVO)** | | | | | | | | | | | | | | | | | |
| Element14 PDMS 0.65 | 0.65 | 162 | 0.32 | 0.761 | 1.375 | -68 | -1[a)] | | 15.9 | — | 0.10 | 100 | — | 35.00 | 0.0001 | 2.18 | $1 \cdot 10^{15}$ |
| Element14 PDMS 3 | 3 | 530 | 0.51 | 0.898 | 1.394 | < -90 | > 62 | > 110 | 19.2 | 10.5 | 0.11 | 100 | | 35.00 | 0.0001 | 2.35 | $1 \cdot 10^{14}$ |
| Element14 PDMS 5 | 5 | 800 | 0.53 | 0.916 | 1.397 | < -90 | > 120 | >160 | 19.7 | 10.5 | 0.12 | 90 | | 35.00 | 0.0001 | 2.50 | $1 \cdot 10^{14}$ |
| Element14 PDMS 10 | 10 | 1,250 | 0.56 | 0.939 | 1.399 | < -80 | > 160 | >230 | 20.2 | 10.6 | 0.13 | 15 | | 35.00 | 0.0001 | 2.65 | $1 \cdot 10^{14}$ |
| Element14 PDMS 20 | 20 | 2,000 | 0.58 | 0.953 | 1.401 | < -70 | > 230 | > 290 | 20.6 | 10.7 | 0.14 | 10 | | 35.00 | 0.0001 | 2.69 | $1 \cdot 10^{14}$ |
| Element14 PDMS 50 | 50 | 3,800 | 0.59 | 0.963 | 1.402 | < -55 | > 250 | > 350 | 20.8 | 10.6 | 0.15 | 0.5 | 1.55 | 35.00 | 0.0001 | 2.73 | $1 \cdot 10^{14}$ |
| **Regular Viscosity Oils (RVO)** | | | | | | | | | | | | | | | | | |
| Element14 PDMS 100 | 100 | 6,000 | 0.59 | 0.966 | 1.403 | -50 | > 275 | > 370 | 20.9 | 9.24 | 0.15 | 0.5 | 1.55 | 35.00 | 0.0001 | 2.73 | $1 \cdot 10^{14}$ |
| Element14 PDMS 350 | 350 | 13,700 | 0.6 | 0.97 | 1.4032 | -50 | > 300 | > 380 | 21.0 | 9.23 | 0.15 | 0.5 | 1.55 | 35.00 | 0.0001 | 2.73 | $1 \cdot 10^{14}$ |
| Element14 PDMS 500 | 500 | 17,300 | 0.6 | 0.971 | 1.4033 | -50 | > 300 | > 380 | 21.1 | 9.23 | 0.15 | 0.5 | 1.55 | 35.00 | 0.0001 | 2.74 | $1 \cdot 10^{14}$ |
| Element14 PDMS 1000 | 1,000 | 28,000 | 0.6 | 0.974 | 1.4035 | -50 | > 320 | > 390 | 21.2 | 9.2 | 0.15 | 0.5 | 1.55 | 35.00 | 0.0001 | 2.74 | $1 \cdot 10^{14}$ |
| **High Viscosity Oils (HVO)** | | | | | | | | | | | | | | | | | |
| Element14 PDMS 5K | 5,000 | 49,300 | 0.6 | 0.974 | 1.4035 | -50 | > 320 | > 390 | 21.4 | 9.2 | 0.15 | 2.0 | 0.36 | 35.00 | 0.0001 | 2.74 | $1 \cdot 10^{14}$ |
| Element14 PDMS 10K | 10,000 | 62,700 | 0.6 | 0.975 | 1.4035 | -50 | > 320 | > 390 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | 35.00 | 0.0001 | 2.75 | $1 \cdot 10^{14}$ |
| Element14 PDMS 12.5K | 12,500 | 67,700 | 0.6 | 0.975 | 1.4035 | -50 | > 320 | > 390 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | 35.00 | 0.0001 | 2.75 | $1 \cdot 10^{14}$ |
| Element14 PDMS 30K | 30,000 | 91,700 | 0.6 | 0.976 | 1.4035 | -50 | > 320 | > 390 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | 35.00 | 0.0001 | 2.76 | $1 \cdot 10^{14}$ |
| Element14 PDMS 60K | 60,000 | 116,500 | 0.6 | 0.977 | 1.4035 | -50 | > 320 | > 390 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | | | 2.76 | |
| Element14 PDMS 100K | 100,000 | 139,000 | 0.6 | 0.977 | 1.4035 | -50 | > 320 | >400 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | | | 2.76 | |
| Element14 PDMS 300K | 300,000 | 143,000 | 0.6 | 0.977 | 1.4042 | -40 | > 320 | >400 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | | | 2.76 | |
| Element14 PDMS 500K | 500,000 | 155,000 | 0.6 | 0.977 | 1.4042 | -40 | > 320 | >400 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | | | 2.76 | |
| Element14 PDMS 600K | 600,000 | 160,000 | 0.6 | 0.978 | 1.4042 | -40 | > 320 | >400 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | | | 2.76 | |
| Element14 PDMS 1000K | 1,000,000 | 175,000 | 0.6 | 0.978 | 1.4042 | -40 | > 320 | >400 | 21.5 | 9.2 | 0.15 | 2.0 | 0.36 | | | 2.76 | |
| Element14 PDMS 2000K | 2,000,000 | 190,000 | 0.6 | 0.978 | 1.4042 | -40 | > 320 | >400 | 21.5 | 9.25 | 0.15 | 2.0 | 0.36 | | | | |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications. ^) Flash Point closed cup

Table 1: Typical physical properties of Element14* PDMS fluids.

*Element 14 is a trademark of Momentive Performance Materials.

| Element14* PDMS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 10 | 20 | 50 | 100 - 5M | 10K to 30K | 60K - 100K | 300K - 1000K |
| | LVO | | | | MVO | | HVO | | UVO |
| **MECHANICAL** | | | | | | | | | |
| Damping | | | | | • | • | • | • | • |
| Heat transfer | | | | | • | • | | | |
| Power transmission | | | | | • | | • | | |
| Hydraulic fluids | | | | | | • | | | |
| **LUBRICATION** | | | | | | | | | |
| Aluminium | please check our alkyl- and pheny-functional silicone fluids | | | | | | | | |
| Rubber & Plastic | | | | | | • | • | • | • |
| Base fluid for grease | | | | | | • | • | | |
| Fod Application | | | | | | | | | |
| Metal on Metal | please check our alkyl- and pheny-functional silicone fluids | | | | | | | | |
| **ELECTRICAL** | | | | | | | | | |
| Dielectric fluid* | | | | | • | | | | |
| **CONSUMER CARE** | | | | | | | | | |
| Polishes | | | | | | • | • | | |
| Cosmetic & Toiletries | • | • | • | | | • | • | | |
| Particle hydrophobization | | | | | | • | | | |
| **MOLD RELEASE** | | | | | | | | | |
| Tires | | | | | | • | • | • | |
| Rubber & Plastic | | | | | • | • | • | • | • |
| Food applications | | | | | | • | • | | |
| Paintable releases | please check our alkyl- and pheny-functional silicone fluids | | | | | | | | |
| **ANTIFOAMS** | | | | | | | | | |
| Petroleum | | | | | • | • | • | • | • |
| Food applications | | | | | | • | • | | |
| Formulation of defoaming products | | | | | | • | | | |
| **TEXTILES** | | | | | | | | | |
| Thread & Fiber lubricants | | • | • | • | • | | | | |
| Softners/Modifiers | | | | • | • | | | | |
| Water repellent | please check our reactive and amino functional silicone fluids | | | | | | | | |
| **PAINT ADDITIVES** | | | | | | | | | |
| Flow control | | | | | | • | | | |
| Mar resistance | | | | | | • | | | |
| Gloss | | | | | | • | | | |
| Particle hydrophobization | | | | | | • | | | |

*Oil M50EL - SF97 - 50 & TSF41I - 50E are specified for that use. Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

Table 2: Typical application areas of Element14* PDMS fluids.

## Viscosity

Element14* PDMS fluids have low viscosities at high molecular weights and do remain liquid where organic polymers are already greases, waxes or solids. The main reason lies in the combination of very low inter-molecular interaction with a high flexibility of the polymer chain. Above a molecular weight of about 2500g/mol the polymers start to coil and entangle, leading to a lower slope.

### Temperature dependence

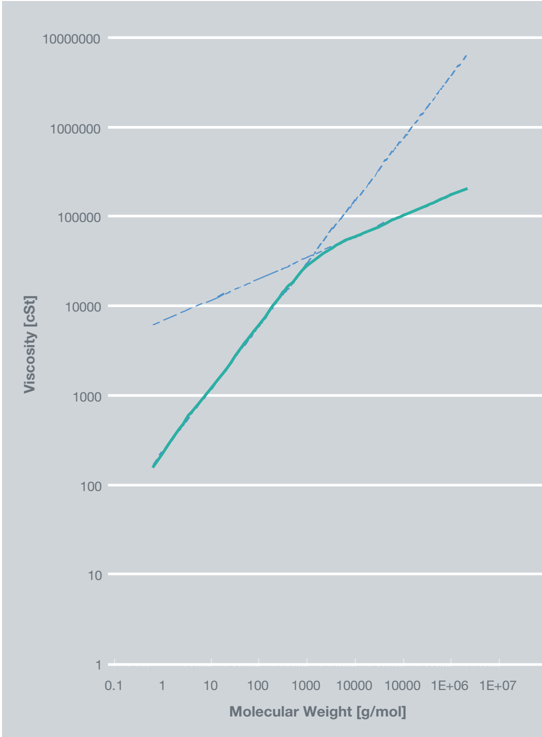
An important property of Element14 PDMS fluids is their low dependence of the viscosity on temperature, compared to other fluids. The viscosities of several Element14 PDMS fluids as a function of temperature are displayed in Figure 2 in comparison to two mineral oils.

The relatively limited viscosity increase of silicone fluids at low temperature, the low pour points and the flat viscosity temperature profile are important in many applications. The latter is expressed by the viscosity temperature coefficient (VTC), which is calculated per the formula below:

$$\text{VTC-A-} \frac{\text{Viscosity [ mm2/s ] at 99°C}}{\text{Viscosity [ mm2/s ] at 38°C}}$$

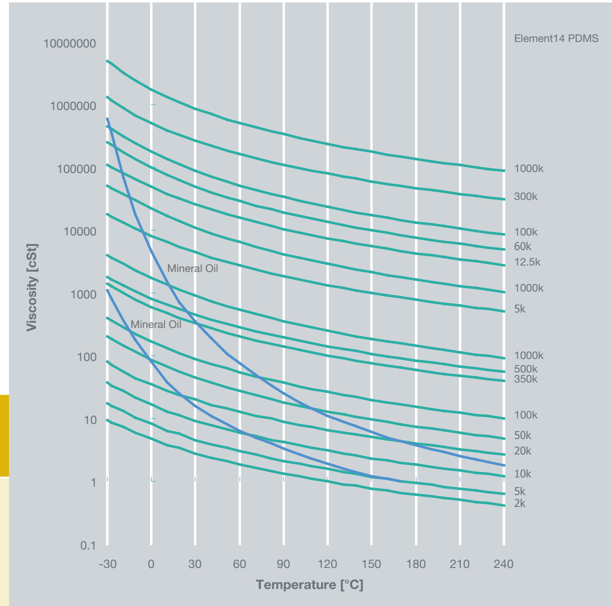
Respective VTC Values for Element14 PDMS fluids are listed in Table 1 and are ~0.6 for fluids of higher viscosities, of 350 mm2/s -1 or higher.

Figure 1: Viscosity dependence as function of the molecular weight.




Note: Test data. Actual results may vary.

Figure 2: Viscosity dependence as function of the temperature compared to two mineral oils.




Note: Test data. Actual results may vary.

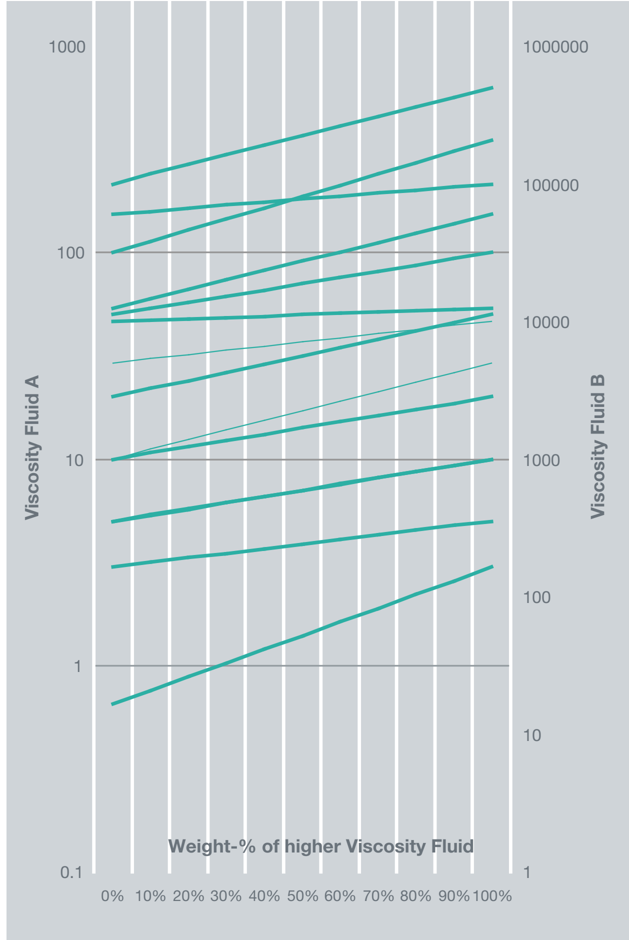
## Miscibility & Viscosity adjustment

Element14* PDMS fluids are essentially freely miscible with one another. They are also miscible with the PD 5 and PK 20 grades of the P fluids range, but not with the Fluid PN 200, PN 1000, PH 300 and PH 1000 grades of the same range.

In cases where silicone fluids with a viscosity differing from the grades described here are required, these can easily be obtained by blending. This, of course, only holds true for those viscosities which are within the range of the Element14 PDMS fluids. Blends of Element14 PDMS fluids of adjacent viscosities exhibit a linear viscosity dependency on blend ratio if the viscosity is plotted on logarithmic scale. The requisite mixing proportions can be seen from the graph Figure 3.

If, for example, it is desired to obtain a fluid with a viscosity of 6000 mm2·s–1 by blending Element14 PDMS 5000 (viscosity 5000 mm2·s–1) and grades Element14 PDMS 10M (viscosity 10000 mm2·s–1) at 25°C, the value 5000 mm2·s–1 should be marked on the left and the value 10000 mm2·s–1 on the right ordinate, and the two values should be connected by a straight line. As marked with the red-dotted line in Figure 3, the intersection of the connecting line with the abscissa parallel, which is drawn through the ordinate value 6000 mm2·s–1, gives the blending proportions in per cent on the abscissa, namely 25% Element14 PDMS 10000 and 75% Element14 PDMS 5000.

Figure 3: Intermediate viscosities can be achieved by blending Element14 PDMS fluids of viscosities adjacent to the targeted value.




Note: Test data. Actual results may vary.



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## Shear characteristics

The viscosity of a fluid is defined as the ratio of shear stress to shear rate. In the ideal of a Newtonian fluid this ratio is constant and independent of the shear rate. In a non-Newtonian fluid, the ratio is not constant and the apparent viscosity at high shear rates is less than the true viscosity.

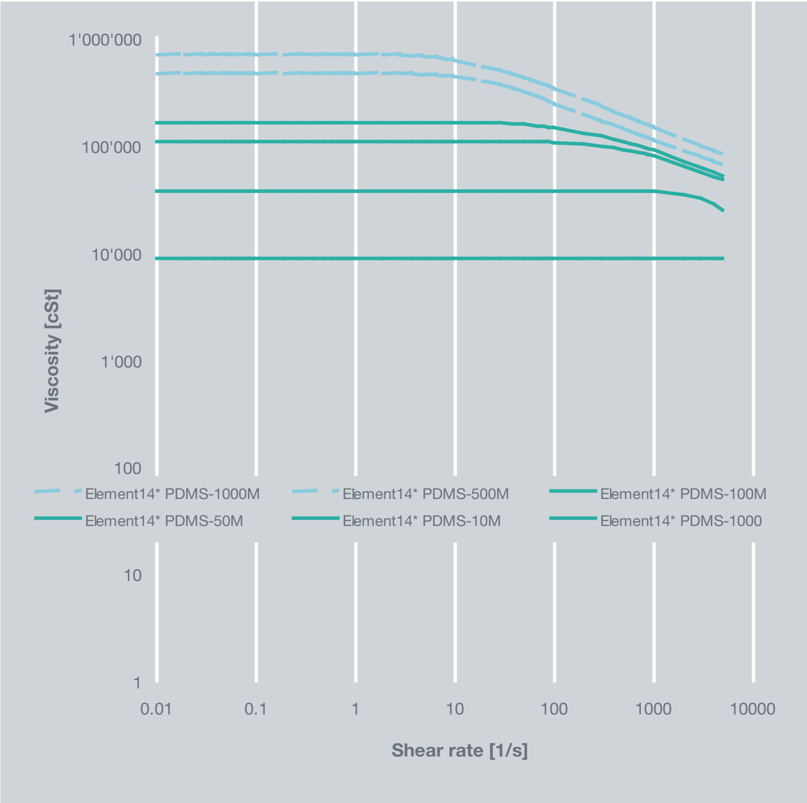
Element14* PDMS fluids are an excellent candidate to approach the Newtonian ideal. The lower the viscosity the more Newtonian like the fluids behave. At higher viscosities the pseudo plasticity is noticeable even at low shear rates. When lowering shear rate again, the fluid will recover its original viscosity.

If the temperature of a fluid is increased, the range of Newtonian behavior shifts to higher shear rates. Figure 4 shows the viscosity of Element14 PDMS fluids as a function of the shear rate.

Many organic fluids show a drop in nominal viscosity after prolonged shearing action. This is a permanent loss in viscosity resulting from poor shear stability and different from the recoverable drop in viscosity demonstrated by Element14 PDMS fluids.

The permanent viscosity change results from the molecules being torn apart by the mechanical action. Element14 PDMS fluids typically show extremely good shear stability and retain their original viscosity characteristics as they are less affected by mechanical stress.

Figure 4: The flow properties of Element14 PDMS fluids at 25 °C.




Note: Test data. Actual results may vary.

## The Effect of pressure

The viscosity of Element14* PDMS fluids, unlike that of mineral oils, is scarcely affected by pressure. A pressure of 2,000 bar at 25°C causes the viscosity of mineral oil to increase 50 to 5,000 times, depending on the grade, whereas the viscosity of Element14 PDMS 1000, for example, increases only 14 times under the same conditions. Even when subjected to extreme pressures, at which mineral oils solidify, Element14 PDMS fluids remain liquid.

Figure 5 shows the viscosity of Element14 PDMS-100 and -1000 at different temperatures as a function of pressure.

## Interfacial tension

As a result of the polar Si-O based backbone structure that is confronted with an unpolar shell based on methyl groups, silicones can exhibit unusually low interfacial tensions, resulting in unique performance in applications where high surface activity and great spreading or penetration

power is required.

Element14 PDMS fluids have low surface tension values - largely independent of viscosity - of down to ~20mN·m-1.

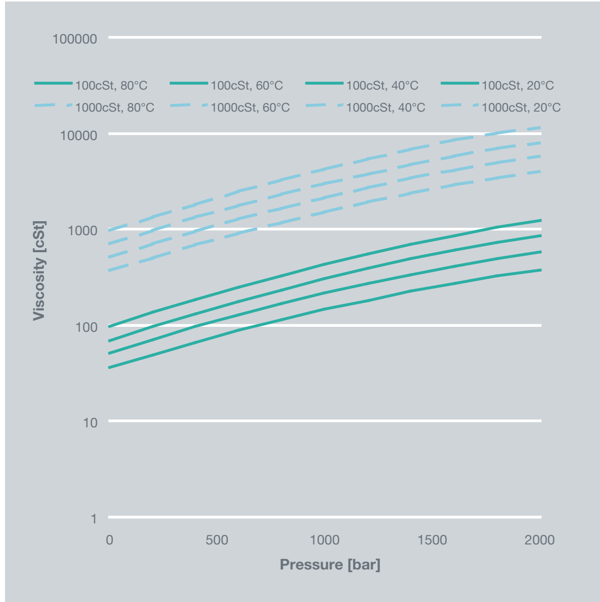
The surface tensions of organic fluids are typically in the range of 35 to 40mN·m - 1. The value for water at room temperature is about 72mN·m-1.

## Refractive index

The refractive index of Element14 PDMS fluids rises from nD 25 = 1.3941 for Element14 PDMS 3 through 1.4000 for Element14 PDMS 20 until it reaches a virtually constant value of 1.4042 for M 1000 and above

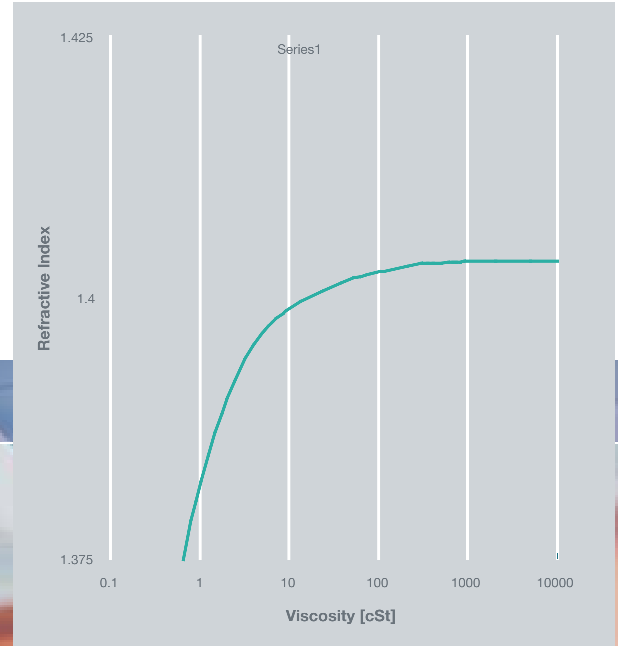
(see Figure 6).

Figure 5: The effect of pressure on the viscosity of Element14 PDMS fluids 100 and 1000 at 25, 40, 60 and 80°C (according to F. Kuss and GG. R. Schultze).




Note: Test data. Actual results may vary.

Figure 6: The Refractive Index of Element14 PDMS fluids as a function of the viscosity.




Note: Test data. Actual results may vary.

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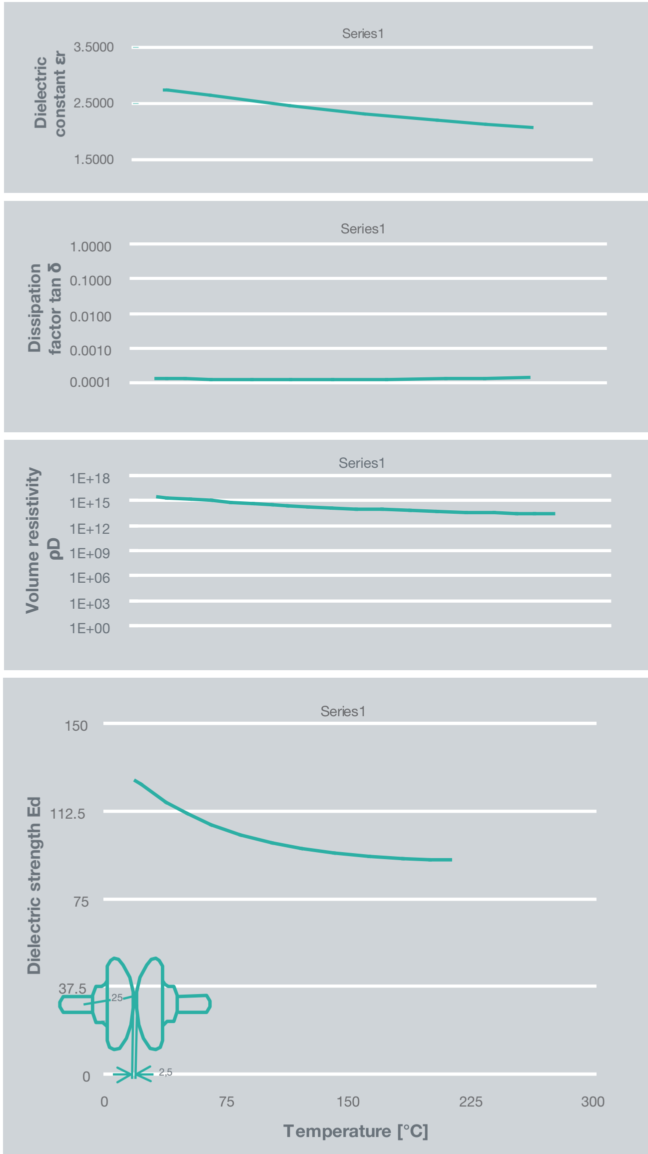
## Dielectric performance

Because of their satisfactory dielectric characteristics, Element14 PDMS fluids are useful dielectrics. Measurements have revealed that the dielectric strength, volume resistivity, dielectric constant and dissipation factor are little affected by temperatures over a wide range. Similarly, there is very little change in the dielectric constant and the dissipation factor over a frequency range from 102 to 107Hertz. The relevant data for Element14 PDMS 350 can be seen in Figure 7. The dielectric characteristics of other Element14 PDMS fluids are listed in Table 1 and are also contained in the "Oil M 50 EL" brochure, the SF97-50 and TSF451-50E technical bulletins.


Figure 7: The effect of temperature on the dielectric and electrical characteristics of Element14 PDMS 350.




Note: Test data. Actual results may vary.

## Lubrication & Slip properties

The low pour points, high flash points, excellent thermal stability, shear and pressure resistance or the low temperature dependency of the viscosity make the Element14 PDMS fluids excellent candidates for slip and lubrication agents.

However, despite these beneficial properties of Element14 PDMS fluids versus mineral oil based materials, their usage as lubricants is only recommended for a limited set of applications.

The following information on the lubricating properties of Element14 PDMS fluids is intended primarily to serve as a reference for applications where Element14 PDMS fluids are to be used as hydraulic fluids, heat transfer media and the like, and where their lubricating properties are valuable extra assets.

Element14 PDMS fluids have limited load carrying capability, thus their applicability depends to a large extent on the particular bearing materials used in the equipment. The best results are obtained with plastics, e.g. polyamides, polystyrene and phenolic resins, as well as with rubber or sewing yarns. Element14 PDMS fluids are also suitable as lubricants for certain combinations of metals, e.g. steel with bronze, brass, chrome and zinc, and chrome with bronze. They have no lubricating properties, however, in the case of steel/steel contact within the range of limit friction. It is therefore necessary to decide in each individual case whether the use of Element14 PDMS fluids in a pure form is appropriate where there are lubricating problems. In cases where Element14* PDMS fluids are formulated with additions of thickening components to give greases, the lubricating properties are improved, since a part of the lubricating function is taken over by the additive.

The lubricating properties of the fluids must not be confused with their slip properties. Element14 PDMS fluids can help constitute excellent slip agents in many applications, e.g. in the processing of certain plastics and synthetic fibers. In this function, the effectiveness of Element14 PDMS fluids is attributable more to their release action than to the formation of a load-carrying lubricating film.

### Solubility

The Element14 PDMS and D fluid are non-polar and insoluble in water or lower alcohols, as well as higher hydrocarbons, lube oils, waxes, fatty acids, vegetable oils and animal oils.

They are completely miscible with aromatic and lower aliphatic hydrocarbons, higher alcohols, ethers, esters and chlorinated hydrocarbons.

Element14 PDMS fluids of 20mn·s-1 and lower are still soluble in more polar solvents, like dioxane, butanol and isopropanol, whereas the higher viscosities become increasingly insoluble in these. Water contamination dramatically reduces the solubility.

| Solvent | Solubility |
|---|---|
| Aliphatic Hydrocarbon [spetroleum spirits, hexane, heptane] | Soluble in all ratios |
| Aromatic Hydrocarbons [toluene, xylene, benzene] | Soluble in all ratios |
| Chlorinated Hydrocarbons carbon [tetrachloride, chloroform, trichloroethane, perchloroethylene, acetylene tetrachloride] | Soluble in all ratios |
| Higher Alcohols [(> $C^5$)2-ethylhexanal, butyl-, amyl- & lauryl alcohol] | Soluble in all ratios |
| Higher Ketones [methyl ethyl ketone, methyl isobutyl ketone] | Soluble in all ratios |
| Ethersethyl [ether, isopropyl ether] | Soluble in all ratios |
| Higher Esters [ethyl acetate, butyl acetate] | Soluble in all ratios |
| Water | Insoluble |
| Lower Alcohols [methanol, ethanol, isopropanol] | Insoluble |
| Higher Hydrocarbons [lube oils, white oils, petroleum, waxes, vegetable oils, fatty acids] | Insoluble |
| Glycols [ethylene glycol, propylene glycol, glycerin] | Insoluble |

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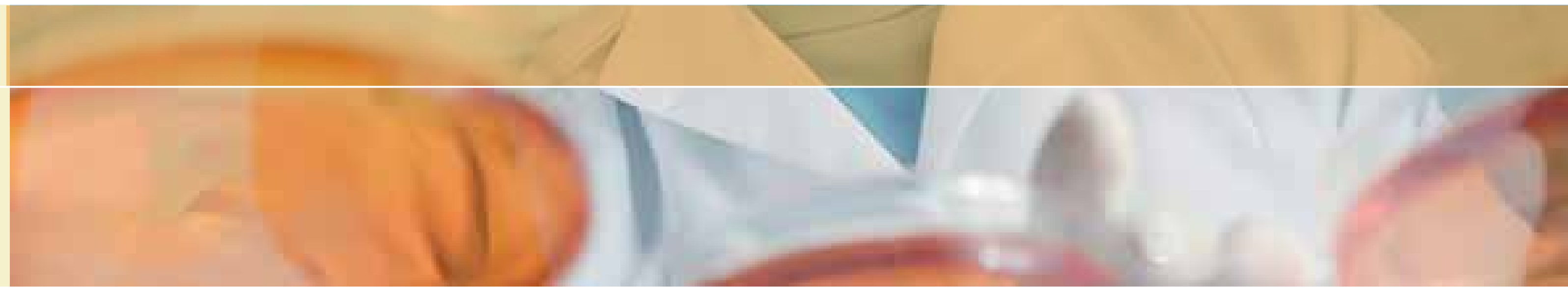

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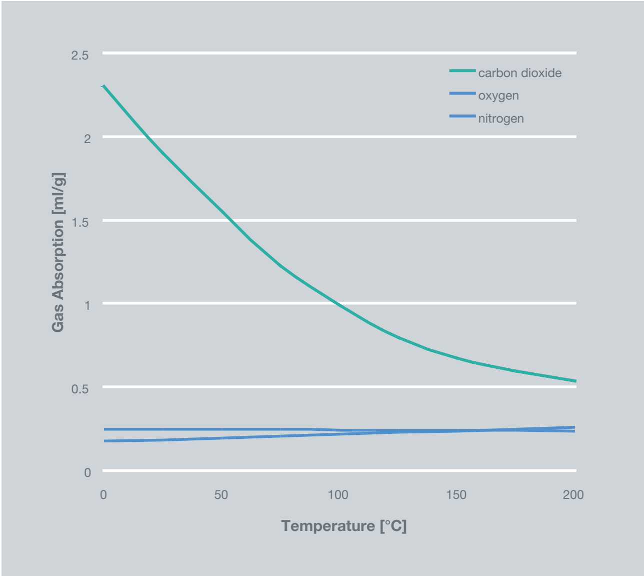
Gases have a relatively high solubility in Element14 PDMS fluids. In case of nitrogen and oxygen this is scarcely affected by temperature, whereas carbon dioxide shows a strong dependency as displayed by Figure 8. The differences in solubility between the individual Element14 PDMS fluids are also relatively small.

Figure 8: Gas absorption rate of Element14* PDMS-50 fluid of carbon dioxide, oxygen and nitrogen as function of the temperature.




Note: Test data. Actual results may vary.

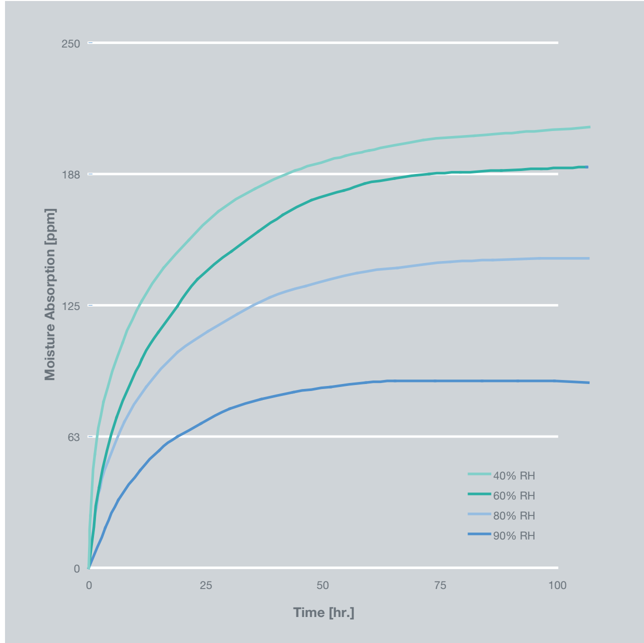
## Storage stability

Climatic changes have no influence on the properties of Element14 PDMS fluids. When properly stored, they are stable for many years; they neither precipitate any solids, even after long periods of time, nor undergo any changes in color or acid value. As a result of their extremely low vapor pressure, their low pour point and their absolute inertness to packaging materials, there are no special requirements with regards to storage vessels and conditions. As with any other oily fluid, contact with water generally results in emulsion turbidity, or phase seperation.

"The shelf life and use-before date are stated on the respective Element 14 container labels. Due to the remarkable chemical and thermal stability physical or chemical decomposition is unlikely to occur, if stored in tightly sealed containers within the recommended temperature range. Repeated reopening of containers increases the risk of moisture uptake from the surrounding atmosphere, which might impact e.g. low termperature applications or uses sensitive to water. Re-testing of application relevent performance properties is strongly recommended for quality ensurance."

Although polydimethylsiloxanes are generally insoluble in water, they can absorb up to 200ppm of water (see Figure 9). Thus they are hygroscopic and have to be stored in tightly closed containers to prevent water uptake up to the above mentioned limit from air moisture.

Figure 9: Moisture absorption rate of Element14 PDMS-50 fluid at various degrees of relative humidity (RH) and a temperature of 25°C.

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## Vapor pressure

Since Element14* PDMS fluids of 50 centistokes and above are polymers of mixed molecular weights, they have no true boiling points or reproducible vapor pressure curves. These properties are only applicable to chemical compounds with a single molecular weight. With silicone fluids, volatility and measurable vapor pressure come from the lower molecular weight fraction present.

The vapor pressure of medium and high viscosity Element14 PDMS fluids is very low. At temperatures between 25°C and 175°C, it is between 10-5 and 10-4 mbar. Only the low viscosity grades possess a noticeably higher vapor pressure. The flash point can be taken as an indication of this.

When exposed to relatively high temperatures or high vacuums, the small quantities of lower molecular weight polymers will escape leaving a fluid which will undergo no further weight loss at that temperature and pressure. At very high temperatures beyond the thermal stability of the Si-O-band more volatiles will be given off because of molecular rearrangement which forms volatile short-chain molecules.

In order to determine the volatile constituents of Element14 PDMS fluids at 250°C, the Noack Test (heating a 65 g sample for one hour at atmospheric pressure reduced by 20 mbar and at 250°C) was used. The weight losses which occurred were as follows:

Table 3: Typical results of Element14 PDMS fluids with the Noack Test (heating a 65 g sample for one hour at atmospheric pressure reduced by 20 mbar and at 250°C).

| Noack test for Element14* PDMS fluids at 250°C | Weight loss [%] |
|---|---|
| Element14* PDMS 50 | less than 5.0 |
| Element14* PDMS 100 | less than 3.0 |
| Element14* PDMS 350 | less than 1.0 |
| Element14* PDMS 500 | less than 1.0 |
| Element14* PDMS 1000 | less than 1.0 |
| Element14* PDMS 5K and higher | less than 0.3 |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

## Thermal stability

Excellent thermal and thermo-oxidative stability are among the most characteristic and technically most important properties of the Element14* PDMS fluid series. In general these products withstand higher temperatures and longer exposure times than comparable organic counterparts.

In the presence of air, Element14 PDMS fluids are stable at temperatures of up to 150°C for a very long time. At higher temperatures oxidation leads to a change of viscosity and finally gelling (see section chemical stability).

The fluids will also stand up well to higher temperatures if the access of air is restricted, e.g. by reducing the exposed surface of the fluid or by sealing off the fluid completely using a narrow pressure-equalizing connection pipe.

Where air is totally excluded by using the fluids in completely enclosed systems or in an inert atmosphere, e.g. under a nitrogen or carbon dioxide cushion, the fluids may even be exposed to temperature peaks of approx. 200°C.

Within these temperature ranges the fluids mostly maintain their initial properties without decomposition or change of appearance. Outside these ranges two general degradation pathways have to be distinguished:

Oxidative degradation:

As mentioned, presence of air or pure oxygen does lead to oxidation of the organic groups of the Element14 PDMS fluids at elevated temperatures. This leads to the formation of volatile organic compounds and cross linkage of the silicone molecules. In the final phase the fluids start to gel.

Thermal degradation:

In absence of air, breakage of the Si-O bond is the major decomposition pathway. This leads to formation of shorter silicone chains and cyclic components and thus to a reduction of viscosity. Finally, volatile silicone compounds are formed.

## Chemical stability

Element14 PDMS fluids are in general remarkably stable towards chemical attack. They are usually resistant to water, organic solvents, pure oxygen and many chemicals, even at elevated temperatures.

As many applications are in presence of air, oxidation stability becomes an important factor in the high temperature performance of Silicones. In oxidative breakdown, oxygen reacts with the organic groups of the molecules causing the fluids to lose volatiles and increase in viscosity until gelation occurs. The reaction is dependent on the temperature and supply of air.

A useful differentiator is the oxygen threshold, which is defined as the temperature at which a significant amount of oxidation by-products start to appear. Below this temperature some oxidation will occur which will not adversely affect the useful life of the product. In Table 4 the oxidation threshold of several silicone and organic fluids are compared.

Table 4: Typical oxygen threshold of various products. This information is offered for comparison degrees of relative humidity (RH) and a temperature of 25°C.

| Fluid | Oxygen Threshold Temperature [°C] |
|---|---|
| Diphenyl-Dimethyl Silicones (Fluid SF1154, PH 300) | 250 |
| Element14 PDMS 350 | 150 |
| Element14 PDMS 60M | 150 |
| Dibasic Acid Ester | 70 |
| Petroleum Oil | 70 |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

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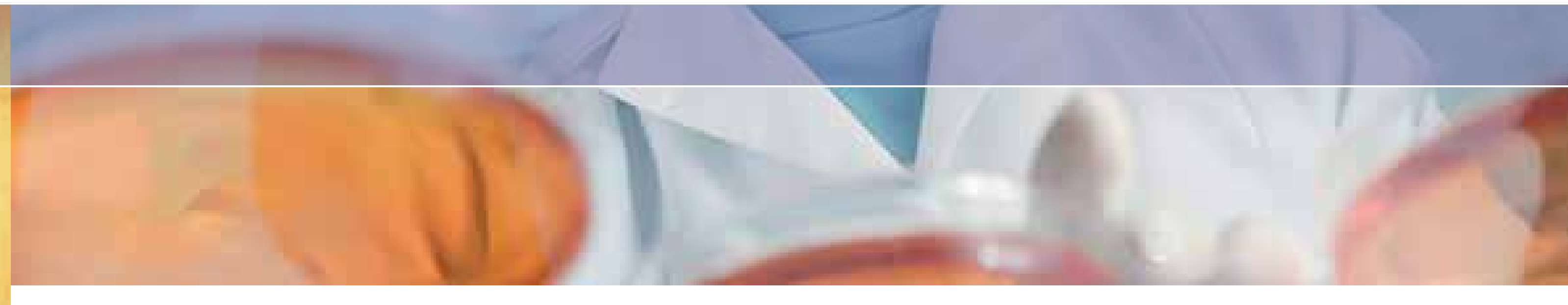
However, low molecular weight fluids (10mm2•s-1 or less) may behave as solvents and damage the surface of plastics or resin coatings. The table below shows how Element14* PDMS fluids are affected by a number of materials known for their aggressive nature. It gives the % change in viscosity after 12 hours' exposure at 25°C and 100°C respectively to a variety of acids and alkalis. Strong oxidants, such as concentrated nitric acid and elementary chlorine, cause Element14 PDMS fluids

| % Change of Viscosity after 12 hr | Element14 PDMS 50 | | Element14 PDMS 100 | |
|---|---|---|---|---|
| | 25° | 100° | 25° | 100° |
| **In Sodium Hydronide Solution** | +1.1 | +1.0 | +0.1 | -2.0 |
| In Hydrochloric Acid | +2.2 | +0.6 | +0.2 | -5.0 |
| 36% Hydrychloric Acid | +29.2 | +30.5 | +12.1 | -4.2 |
| 13% Nitric Acid | +7.6 | +4.0 | +3.8 | -18.8 |
| 30% Sulfuric Acid | - | +5.8 | - | +6.0 |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.



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## Thermal conductivity, thermal capacity, specific heat

The thermal conductivity of Element14* PDMS fluids is not affected by temperature. Even the level of viscosity has only a slight effect. Thus, although the coefficient of thermal conductivity λ increases somewhat from the low to the medium-viscosity oils, it undergoes no further change when the high-viscosity grades are reached.

The following values for the coefficient of thermal conductivity λ were determined at both 25°C and 250°C.

Table 5: Typical values of Element14* PDMS fluids for the coefficient of thermal conductivity λ, determined at both 25°C and 250°C.

| Element14 PDMS | $W·K^{-1}·m^{-1}$ |
|---|---|
| 3 | 0.105 |
| 5 | 0.116 |
| 10 | 0.140 |
| 20 | 0.140 |
| 100 | 0.163 |
| 1000 | 0.174 |
| 12.5M | 0.174 |
| 100M | 0.174 |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

When determining the mean specific heat c of Element14* PDMS 50 to 12500, there were no appreciable differences between the individual fluids; the same holds true for the thermal capacity W20. The relationship between the values obtained is shown in the table below.

Table 6: Typical results for the mean specific heat c and the thermal capacity W20 of Element14 PDMS fluids.

| t [°C] | c $[J·g^{-1}·K^{-1}]$ | N20 $[J·g^{-1}]$ |
|---|---|---|
| 20 | 1.51 | 0 |
| 40 | 1.51 | 30.6 |
| 60 | 1.55 | 62.0 |
| 80 | 1.55 | 93.4 |
| 100 | 1.55 | 123.5 |
| 120 | 1.59 | 157.8 |
| 140 | 1.59 | 192.2 |
| 160 | 1.63 | 229.0 |
| 180 | 1.67 | 267.5 |
| 200 | 1.73 | 309.0 |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

## Coefficient of expansion, specific volume

The mean cubic expansion coefficient λ of Element14* PDMS fluids in the range 25°C to 175°C is between 99 and M·10-5·K-1. The differences are slight among the individual types of fluids; a slight increase in the coefficients of expansion is only observed towards the lower viscosities.

The volume Vt , taken up by a given quantity of fluid m at a temperature t, can be calculated by means of the equation

Vt = m·Vspec. (t).

The specific volume Vspec. (t) of Element14 PDMS fluids is given below in Table 7 for certain temperatures. Figure 11 shows the volume of Element14 PDMS fluids as a function of temperature.

Table 7: Mean cubic expansion coefficients and specific volume values at certain temperatures for Element14 PDMS fluids.

| Element14 PDMS | Cubic expansion coefficiant $[10^{-5} · K^{-1}]$ | Specific volume at $[cm^3 · g^{-1}]$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | -40°C | 0°C | 25°C | 50°C | 100°C | 175°C |
| 3 | 111 | 1.03 | 1.08 | 1.11 | 1.14 | | |
| 5 | 108 | 1.01 | 1.05 | 1.09 | 1.11 | | |
| 10 | 103 | 0.98 | 1.03 | 1.06 | 1.09 | | |
| 20 | 101 | 0.98 | 1.02 | 1.05 | 1.08 | | |
| 50 | 100 | 0.97 | 1.01 | 1.04 | 1.06 | 1.11 | 1.19 |
| 100 | 99 | 0.96 | 1.00 | 1.03 | 1.05 | 1.10 | 1.18 |
| 350 | 99 | 0.96 | 1.00 | 1.03 | 1.05 | 1.10 | 1.18 |
| 500 | 99 | 0.96 | 1.00 | 1.03 | 1.05 | 1.10 | 1.18 |
| 1000 | 99 | 0.96 | 1.00 | 1.03 | 1.05 | 1.10 | 1.18 |
| 5K | 99 | 0.96 | 1.00 | 1.03 | 1.03 | 1.10 | 1.18 |
| 12.5K | 99 | 0.96 | 1.00 | 1.03 | 1.03 | 1.10 | 1.18 |
| 30K | 99 | | | 1.03 | 1.03 | 1.10 | 1.18 |
| 60K | 99 | | | 1.03 | 1.03 | 1.10 | 1.18 |
| 100K | 99 | | | 1.03 | 1.03 | 1.10 | 1.18 |
| 300K | 99 | | | 1.03 | 1.03 | 1.10 | 1.18 |
| 1000K | 99 | | | 1.03 | 1.03 | 1.10 | 1.18 |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

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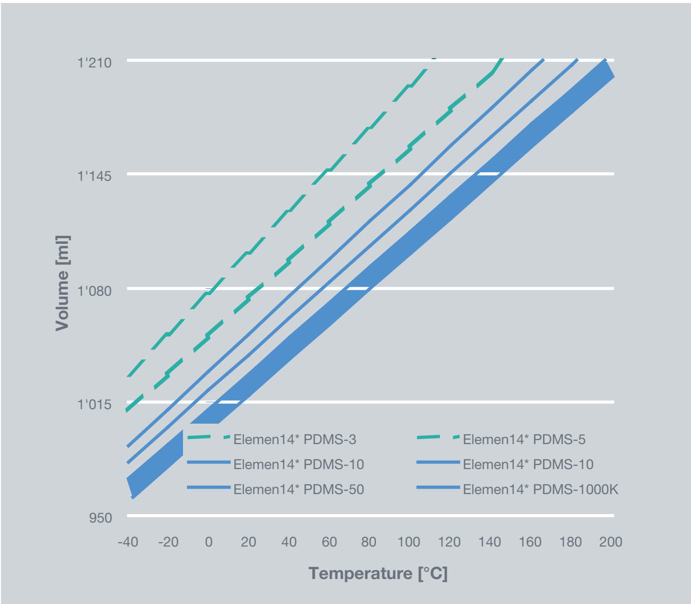
The volume of Element14 PDMS 1000 decreases by 15% under a pressure of 3500 bar, and by about 30% under a pressure of 25000 bar. The low-viscosity fluids have even higher compressibility. As can be seen from the values given below in Table 8, the compressibility is relatively high; Element14 PDMS fluids are therefore suitable for use in fluid spring systems.

Table 8: Adiabatic compressibility values for certain Element14* PDMS fluids.

| Element14 PDMS | Adiabatic compressibility Kad[$m^2 \cdot N^{-1}$] |
|---|---|
| 50 | $101.6 \cdot 10^{-11}$ |
| 100 | $100.8 \cdot 10^{-11}$ |
| 350 | $100.0 \cdot 10^{-11}$ |
| 500 | $99.8 \cdot 10^{-11}$ |
| 10000 | $99.8 \cdot 10^{-11}$ |

Typical data are average data and actual values may vary. Typical data shall not be used as product specifications.

Figure 10: The effect of temperature on the volume of Element14 PDMS fluids. The highlighted area covers the viscosities Element 14 PDMS 50 to 1000M.




Note: Test data. Actual results may vary.

### Patent Status

Technical subject matter in this publication is described and protected by one or more of the following U.S. Patents and their foreign counterpart patents and/or patent applications: U.S. Patent Nos. 7,507,775, 7,645,720, 7,652,072, 7,700,797, 5,968,872, 5,504,054, 7,081,436 5,558,806 and 5,811,482. Other U.S. and foreign patents and/or patent applications not listed covering the subject matter may be relevant.

### Product Safety, Handling and Storage

Customers considering the use of this product should review the latest Material Safety Data Sheet and label for product safety information, handling instructions, personal protective equipment if necessary, and any special storage conditions required. Material Safety Data Sheets are available at www.momentive.com or, upon request, from any Momentive Performance Materials representative. Use of other materials in conjunction with Momentive Performance Materials products (for example, primers) may require additional precautions. Please review and follow the safety information provided by the manufacturer of such other materials.

### Limitations

Customers must evaluate Momentive Performance Materials products and make their own determination as to fitness of use in their particular applications.

### Emergency Service

Momentive Performance Materials maintains an around-the-clock emergency service for its products. Ther American Chemistry Council (CHEMTREC) and CareChem24 International also maintain an around-the-clock emergency service for all chemical products:

| Location | Momentive Performance Materials Products | All Chemical Products |
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