

Technical Information

**Thermoplastic  
Polyurethane  
Elastomers (TPU)**

**Elastollan<sup>®</sup>-  
Material  
Properties**

**Elastogran is  
Polyurethanes**

**Elastogran**



**■ BASF Group**

# Contents

<b>Introduction</b>	<b>4</b>
<b>Chemical structure</b>	<b>5</b>
<b>Physical properties</b>	<b>6</b>
<b>Mechanical properties</b>	<b>6</b>
	<b>Rigidity</b> 7
	<b>Shore hardness</b> 9
	<b>Glass transition temperature</b> 10
	<b>Torsion modulus</b> 11
	<b>Tensile strength</b> 14
	<b>Tear strength</b> 21
	<b>Creep behaviour</b> 22
	<b>Compression set</b> 24
	<b>Impact strength</b> 24
	<b>Abrasion</b> 25
	<b>Friction</b> 25
<b>Thermal properties</b>	<b>26</b>
	<b>Thermal expansion</b> 26
	<b>Thermal deformation</b> 27
	<b>Vicat softening temperature</b> 27
	<b>Heat deflection temperature</b> 28
	<b>Thermal data</b> 29
	<b>Maximum service temperature</b> 30
<b>Gas permeability</b>	<b>31</b>
<b>Electrical properties</b>	<b>33</b>
	<b>Tracking</b> 33
	<b>Dielectric strength</b> 33
	<b>Surface resistivity</b> 33
	<b>Volume resistivity</b> 34
	<b>Dielectric constant</b> 34
	<b>Dielectric loss factor</b> 34

# Contents

<b>Chemical properties</b>	<b>35</b>
Swelling	35
Chemical resistance	36
Acids and alkaline solutions	36
Saturated hydrocarbons	36
Aromatic hydrocarbons	36
Lubricating oils and greases	37
Solvents	37
Microbiological resistance	38
Hydrolysis resistance	39
Radiation resistance	40
UV-radiation	40
High energy irradiation	40
Ozone resistance	40
Fire behaviour	41
<b>Quality management</b>	<b>42</b>
<b>Index of key terms</b>	<b>43</b>

# Introduction



Elastollan is the registered trade mark of our thermoplastic polyurethane elastomers (TPU), which are available in unplasticized form in a hardness range from 60 Shore A to 74 Shore D.

These materials are distinguished by the following properties:

- high wear and abrasion resistance
- high tensile strength and outstanding resistance to tear propagation
- excellent damping characteristics
- very good low-temperature flexibility
- high resistance to oils, greases, oxygen and ozone.

# Chemical structure

Elastollan is essentially formed from the inter-reaction of three components:

1. polyols (long-chain diols)
2. diisocyanates
3. short-chain diols

The polyols and the short-chain diols react with the diisocyanates through polyaddition to form linear polyurethane. Flexible segments are created by the reaction of the polyol with the diisocyanate. The combination of diisocyanate with short-chain diol produces the rigid component (rigid segment). Fig. 1 shows in diagrammatic form the chain structure of thermoplastic polyurethane.

The properties of the product depend on the nature of the raw materials, the reaction conditions, and the ratio of the starting materials. The polyols used have a significant influence on certain properties of the thermoplastic polyurethane.

Either polyester-based polyols (B, C, S, 500 and 600 grades) or polyether-based polyols (1100 grades) are used in the production of Elastollan.

The products are distinguished by the following characteristic features:

Polyester polyol:

- highest mechanical properties
- highest heat resistance
- highest resistance to mineral oils

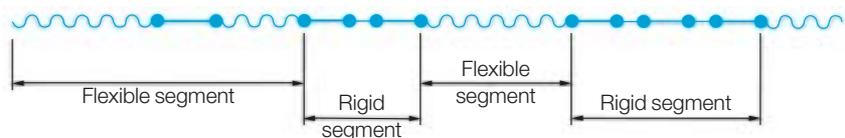
Polyether polyol:

- highest hydrolysis resistance
- best low-temperature flexibility
- resistance to microbiological degradation

In addition to the basic components described above, many Elastollan formulations contain additives to facilitate production and processability. Further additives can also be included to modify specific properties.

Such additives include mould release agents, flame retardants, UV-stabilizers and plasticizers for flexible grades. Glass fibres are used to increase rigidity (RTPU, Elastollan R grades).

## Structure of thermoplastic Polyurethane



-  = Residue of long-chain diol (ether/ester)
-  = Residue of short-chain diol
-  = Residue of diisocyanate
-  = Urethane group

Fig. 1

# Physical properties

## Mechanical properties



The physical properties of Elastollan are discussed below. The test procedures are explained in some detail. Typical values of these tests are presented in our Technical Information "Elastollan – Product Range" and in separate data sheets.

Tests are carried out on injection moulded samples using granulate which is pre-dried prior to processing. Before testing specimens are conditioned for 20 hours at 100 °C and then stored for at least 24 hours at 23 °C and 50 % relative humidity.

The values thus obtained cannot always be directly related to the properties of finished parts. The following factors affect the physical properties to varying degrees:

- part design
- processing conditions
- orientation of macromolecules and fillers
- internal stresses
- moisture
- annealing

Consequently, finished parts should be tested in relation to their intended application.

# Physical properties

## Mechanical properties

### Rigidity

The versatility of polyurethane chemistry makes it possible to produce Elastollan over a wide range of rigidity.

Fig. 2 shows the range of E-modulus of TPU and RTPU in comparison to other materials.

The **modulus of elasticity (E-modulus)** is determined by tensile testing according to DIN EN ISO 527-2 at a strain rate of 1 mm/min, using a type A test specimen according to DIN EN ISO 3167. The E-modulus is calculated from the initial slope of the stress-strain curve as ratio of stress to strain.

It is known that the modulus of elasticity of plastics is influenced by the following parameters:

- temperature
- moisture content
- orientation of macromolecules and fillers
- rate and duration of stress
- geometry of test specimens
- type of test equipment

Figs. 3–5 show the modulus of elasticity of several Elastollan grades as a function of temperature.

E-modulus values obtained from the tensile test are preferable to those from the bending test, since in the tensile test the stress distribution throughout the relevant test specimen length is constant.

**Comparison of E-modulus of TPU and RTPU with other materials**

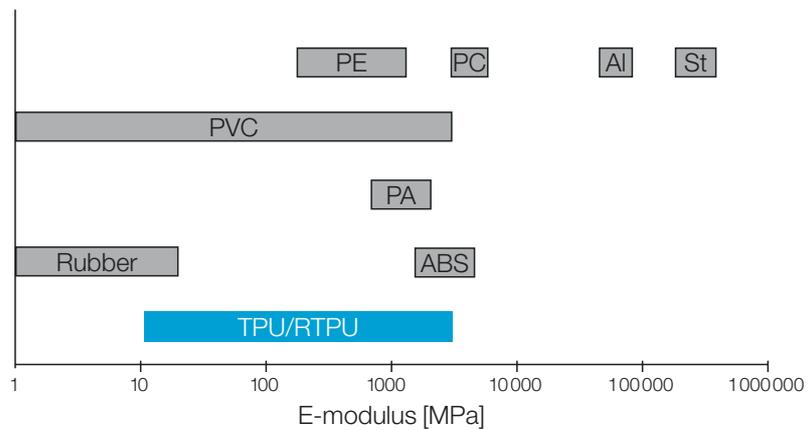
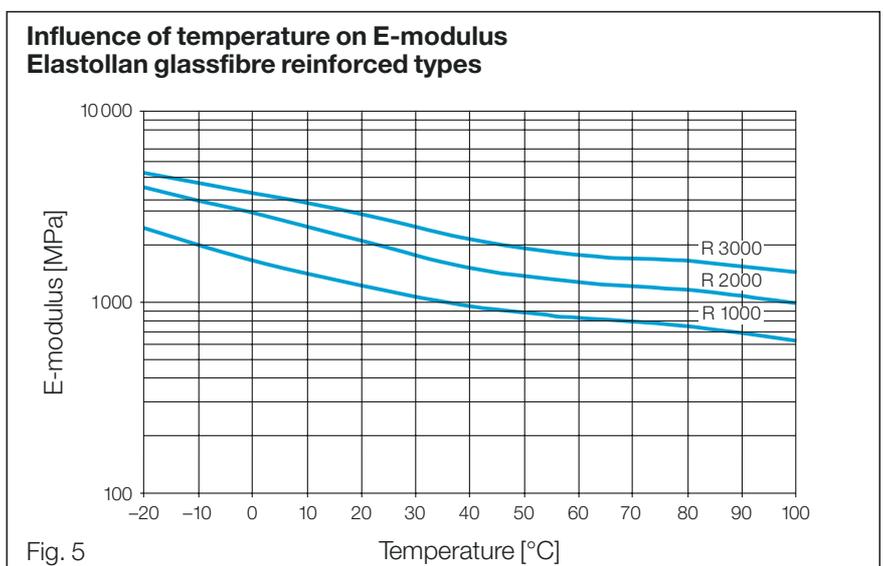
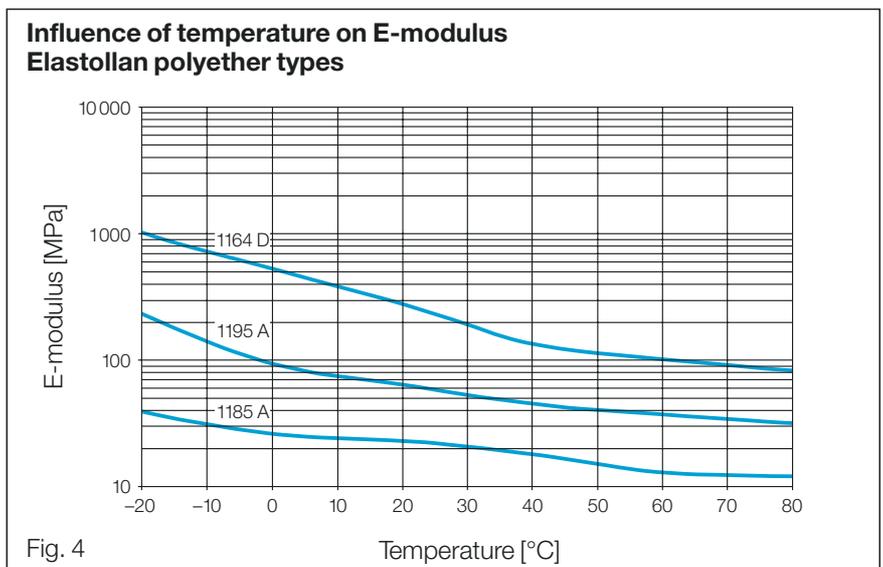
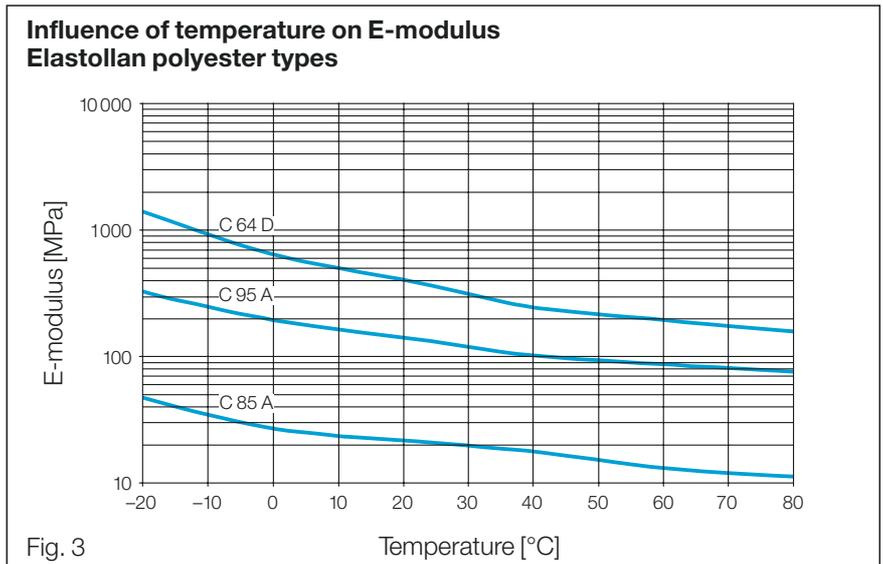


Fig. 2

# Physical properties

## Mechanical properties

### Rigidity



# Physical properties

## Mechanical properties

### Shore hardness

The hardness of elastomers such as Elastollan is measured in **Shore A** and **Shore D** according to **DIN 53505 (ISO 868)**.

Shore hardness is a measure of the resistance of a material to the penetration of a needle under a defined spring force. It is determined as a number from 0 to 100 on the scales A or D. The higher the number, the higher the hardness. The letter A is used for flexible types and the letter D for rigid types. However, the ranges do overlap.

Fig. 6 shows a comparison of the Shore hardness A and D scales for Elastollan. There is no general dependence between Shore A and D scales. Under standard atmospheric conditions (i.e. 23 °C, 50 % relative humidity), the hardness of Elastollan grades ranges from 60 Shore A to 74 Shore D.

**Relationship:  
Shore A to Shore D**

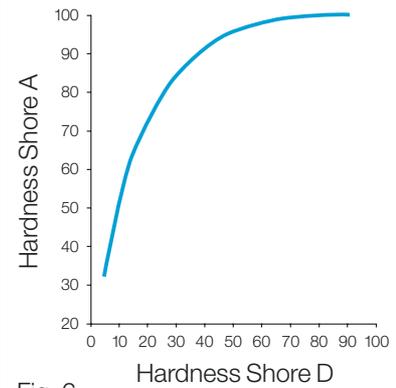


Fig. 6

Shore hardness reduces as temperature rises. Fig. 7 shows the variation of Shore hardness with temperature for various Elastollan grades.

**Influence of temperature on hardness  
Elastollan polyester types**

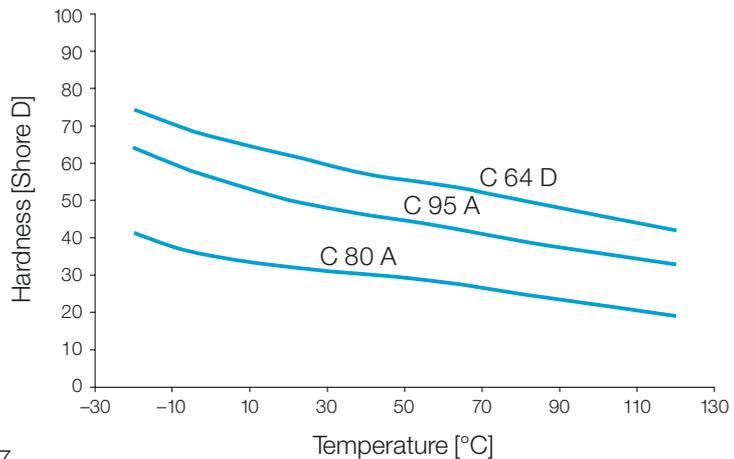


Fig. 7

# Physical properties

## Mechanical properties

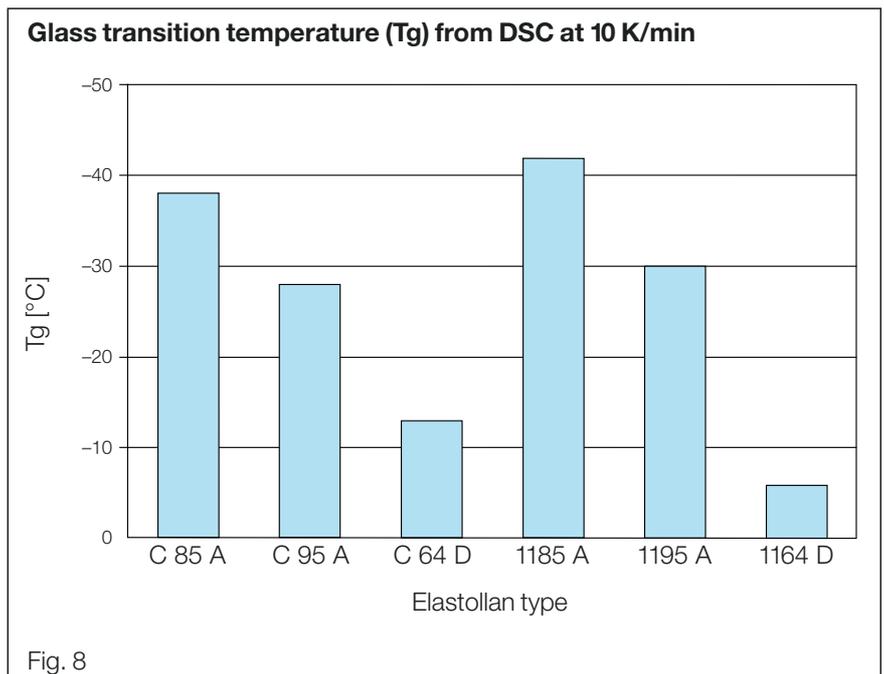
### Glass transition temperature

The glass transition temperature ( $T_g$ ) of a plastic is the point at which a reversible transition of amorphous phases from a hard brittle condition to a visco-elastic or rubber-elastic condition occurs. Glass transition takes place, depending on hardness or rather amorphous portion of a material, within a more or less wide temperature range. The larger the amorphous portion (softer Elastollan product), the lower is the glass transition temperature, and the narrower is this temperature range.

There are several methods available to determine glass transition temperature, each of them possibly yielding a different value, depending on the test conditions. Dynamic testing results in higher temperature values than static testing. Also the thermal history of the material to be measured is of importance. Thus, similar methods and conditions have to be selected for comparison of glass transition temperatures of different products.

Fig. 8 shows the glass transition temperatures of several Elastollan types, measured by differential scanning calorimetry (DSC) at a heating rate of 10 K/min. The  $T_g$  was evaluated according to DIN 51007 on the basis of the curve, the slope of which is stepped in the transition range.

The torsion modulus and the damping curves shown in figs. 9 to 14 enable  $T_g$ 's to be defined on the basis of the damping maximum. Since this is a dynamic test, the  $T_g$ 's exceed those obtained from the DSC measurements.



# Physical properties

## Mechanical properties

### Torsion modulus

The torsion vibration test as specified in **DIN EN ISO 6721-2** is used to determine the elastic behaviour of polymeric materials under dynamic torsional loading, over a temperature range. In this test, a test specimen is stimulated into free torsional vibration. The torsional angle is kept low enough to prevent permanent deformation. Under the test parameters specified in the standard, a frequency of 0.1 to 10 Hz results as temperature increases.

During the relaxation phase the decreasing sinusoidal vibration is recorded. From this decay curve, it is possible to calculate the torsion modulus and damping. The torsion modulus is the ratio between the torsion stress and the resultant elastic angular deformation.

Figs. 9–14 show the torsion modulus and damping behaviour over a temperature range for several Elastollan grades.

At low temperature torsion modulus is high and the curves are relatively flat. This is the so-called energy-elastic temperature range, where damping values are low.

With rising temperature, the torsion modulus curve falls and damping behaviour increases. This is the so-called glass transition zone, where damping reaches a maximum.

After the glass transition zone, the torsion modulus curve flattens. This condition is described as entropy-elastic (rubber-elastic). At this temperature the material remains solid with increasing temperature, torsion modulus declines more sharply and damping increases again. Here, the behaviour pattern is predominantly visco-elastic.

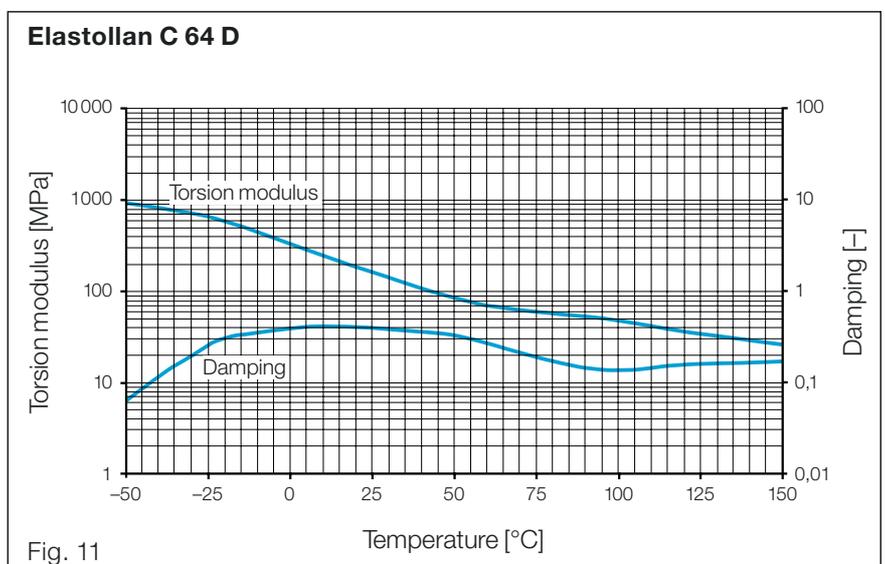
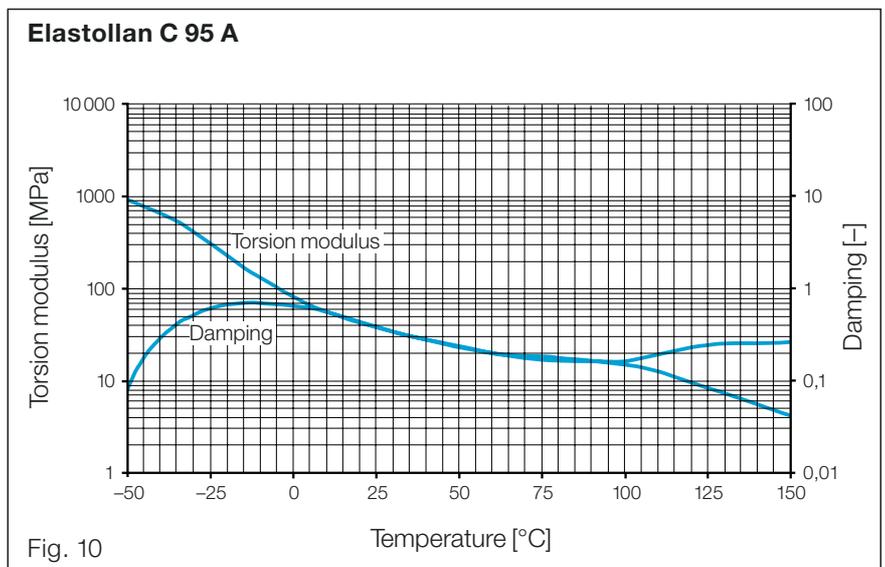
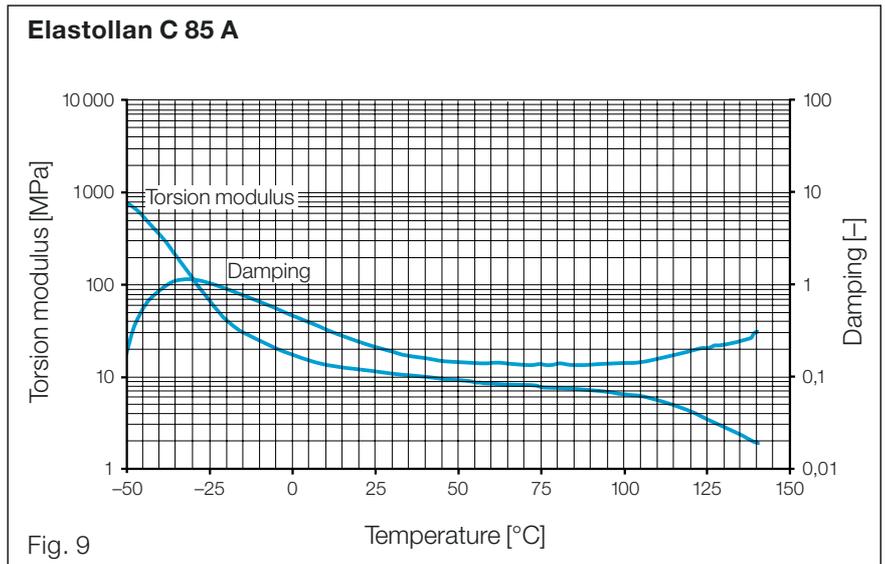
The extent of each zone varies according to Elastollan type.

However, as a general statement, the transition becomes more obvious with the lower hardness Elastollan grades.

# Physical properties

## Mechanical properties

### Torsion modulus



# Physical properties

## Mechanical properties

### Torsion modulus

**Elastollan 1185 A**

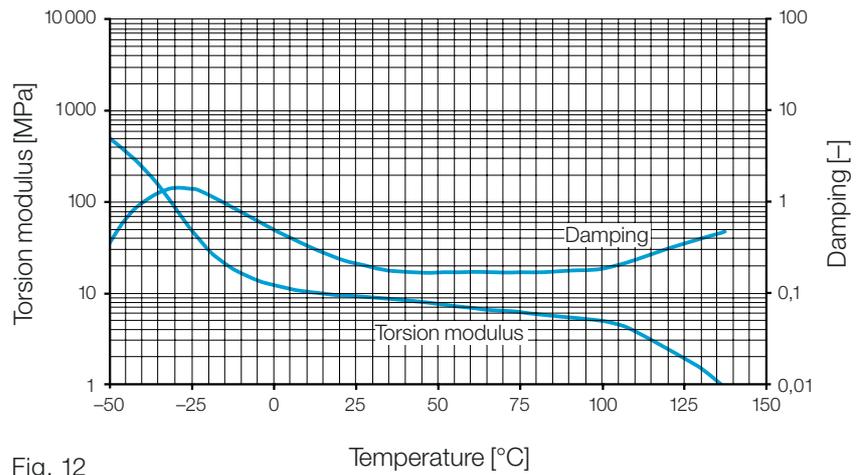


Fig. 12

**Elastollan 1195 A**

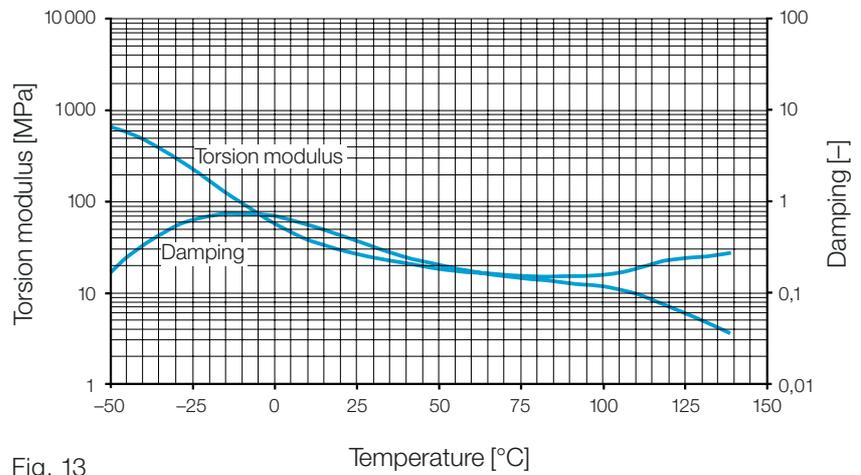


Fig. 13

**Elastollan 1164 D**

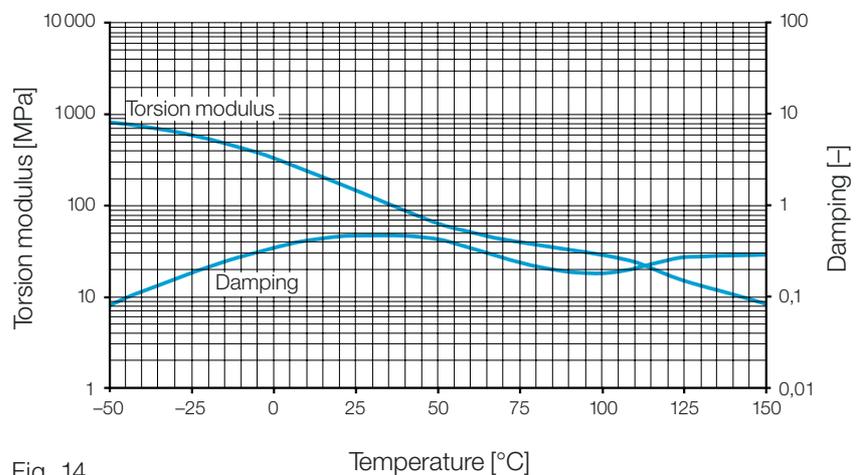


Fig. 14

# Physical properties

## Mechanical properties

### Tensile strength

The behaviour of elastomers under short-term, uniaxial, static tensile stress is determined by tensile tests as specified in **DIN 53504** and may be presented in the form of a stress-strain diagram. Throughout the test, the tensile stress is always related to the original cross-section of the test specimen. The actual stress, which increases steadily owing to the constant reduction in cross-section, is not taken into account.

Typical strength and deformation characteristics can be seen in the tensile stress-strain diagram (Fig. 15):

#### Strength characteristics:

- The yield stress  $\sigma_y$  is the tensile stress at which the slope of the stress-strain curve becomes zero.
- Tensile strength  $\sigma_{max}$  is the tensile stress at maximum force.
- Tear strength  $\sigma_B$  is the tensile stress at the moment of rupture of the specimen.

#### Deformation characteristics:

- The yield strain  $\epsilon_y$  is the elongation corresponding to the yield stress.
- Maximum force elongation  $\epsilon_{max}$  is the elongation corresponding to the tensile strength.
- Elongation at break  $\epsilon_B$  is the elongation corresponding to the tear strength.

In the case of unreinforced Elastollan grades at room temperature, differences are not generally observed, e.g., tear strength and tensile strength correspond (Fig. 16).

A yield stress is only observed with rigid formulations at lower temperatures.

For glass-fibre reinforced Elastollan grades (R grades), yield stress coincides with tensile strength (Fig. 17).

In one respect, the stress-strain diagrams on the following pages, determined according to DIN 53504 present the typical high elongation to break. On the other hand they include diagrams of lower deformations. These diagrams and the curves relating to the R-Types were determined according to DIN EN ISO 527-2 at a rate of 50 mm/min using a multipurpose test specimen according to DIN EN ISO 3167.

# Physical properties

## Mechanical properties

### Tensile strength

Typical stress-strain curve from tensile testing

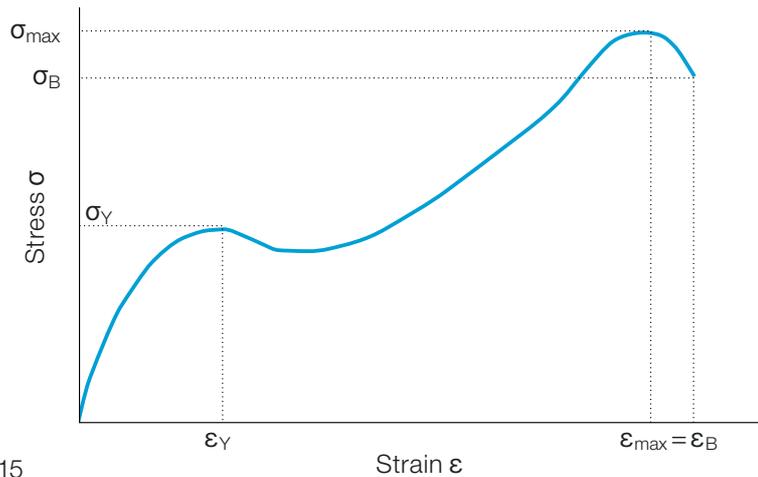


Fig. 15

Characteristic stress-strain curve for unreinforced Elastollan

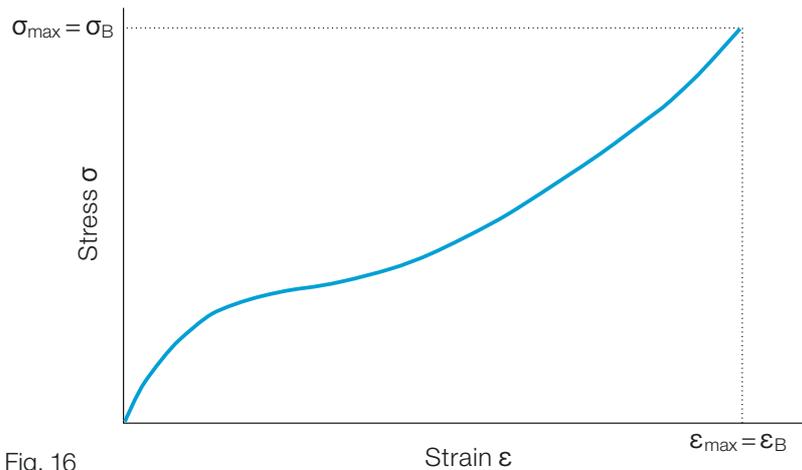


Fig. 16

Characteristic stress-strain curve for reinforced Elastollan

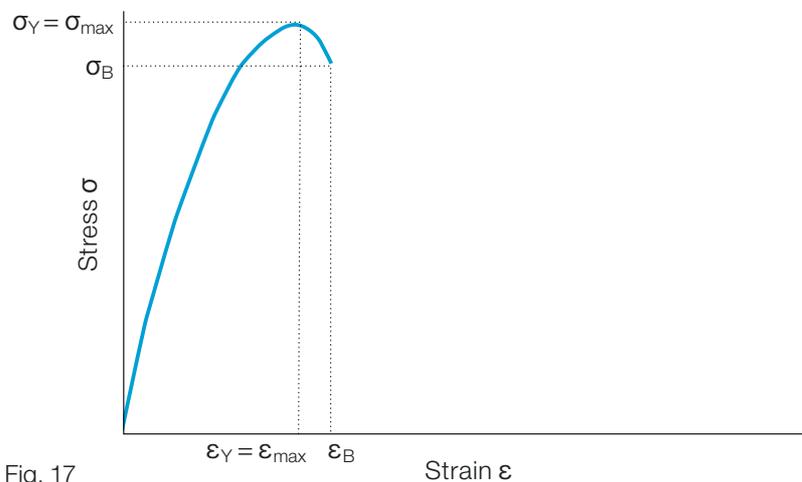
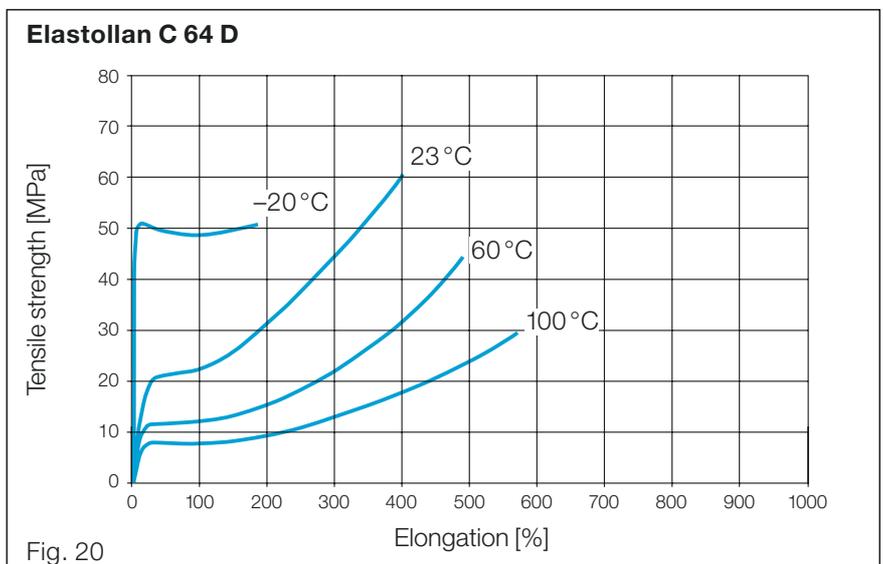
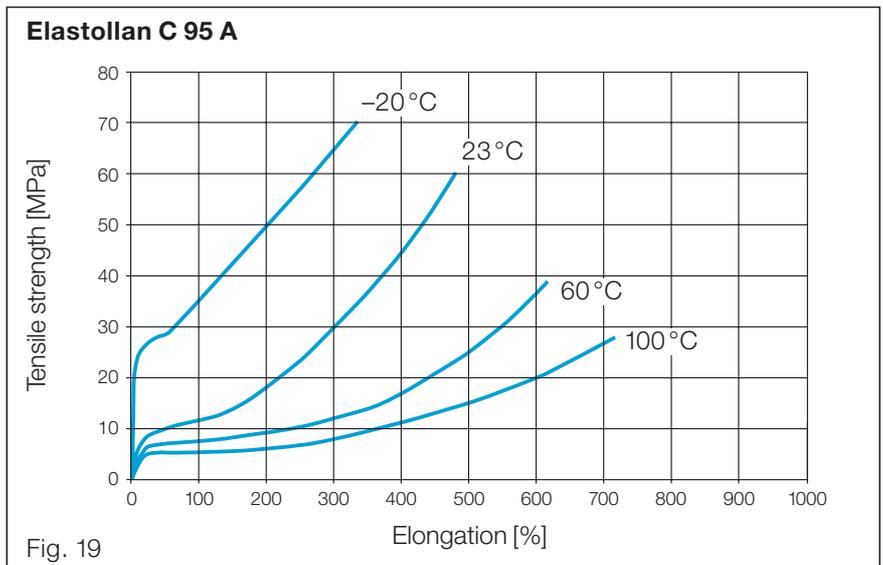
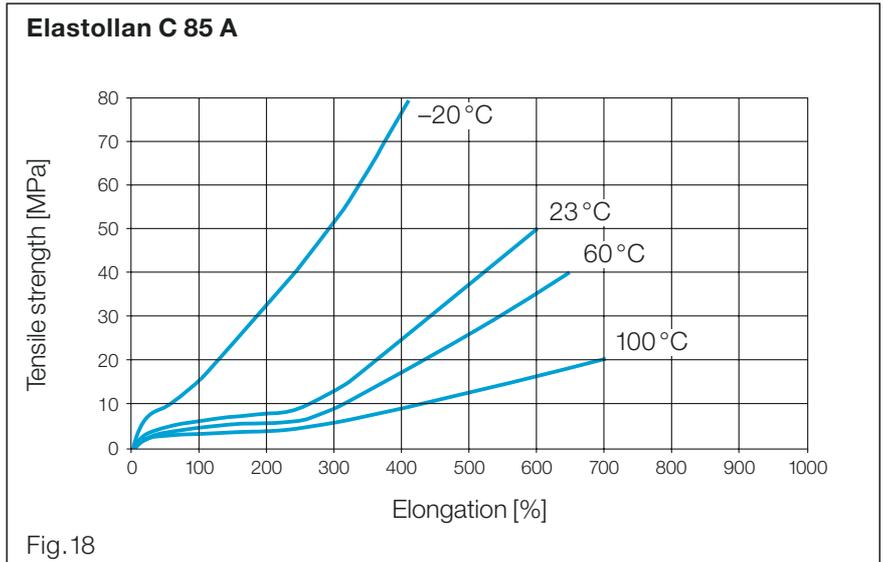


Fig. 17

# Physical properties

## Mechanical properties

### Tensile strength



Note:  
The graphs shown on pages 16 and 17 were determined according to DIN 53504 at a rate of 200 mm/min using test specimens of 2 mm thickness.

# Physical properties

## Mechanical properties

### Tensile strength

#### Elastollan 1185 A

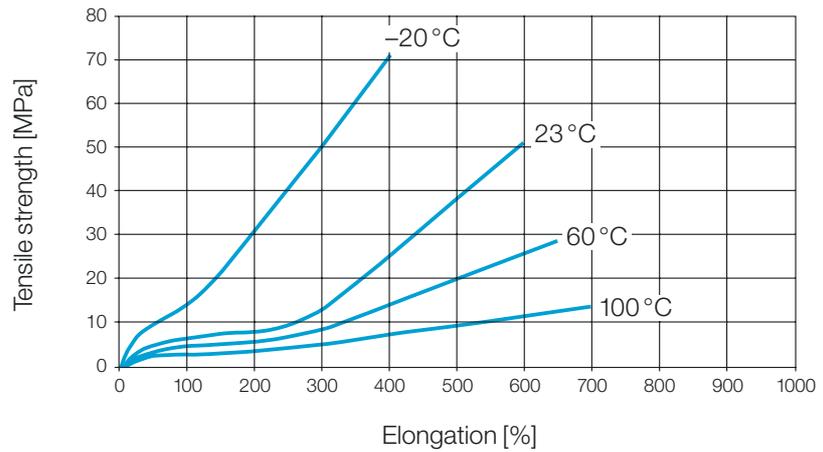


Fig. 21

#### Elastollan 1195 A

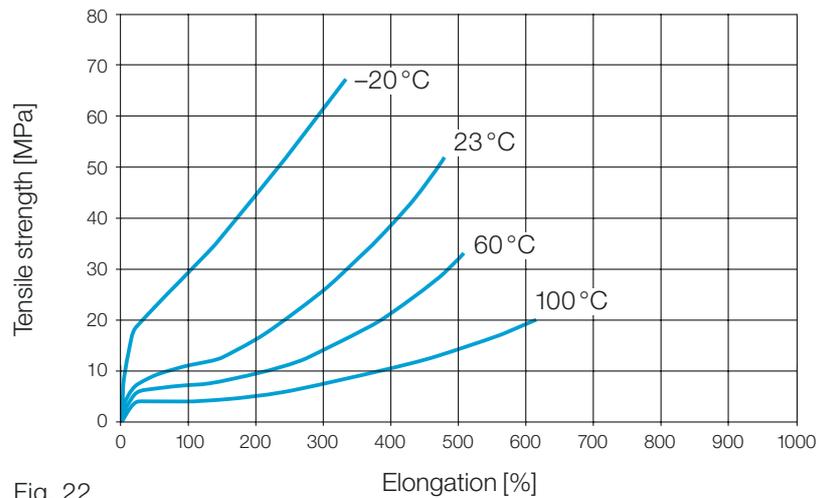


Fig. 22

#### Elastollan 1164 D

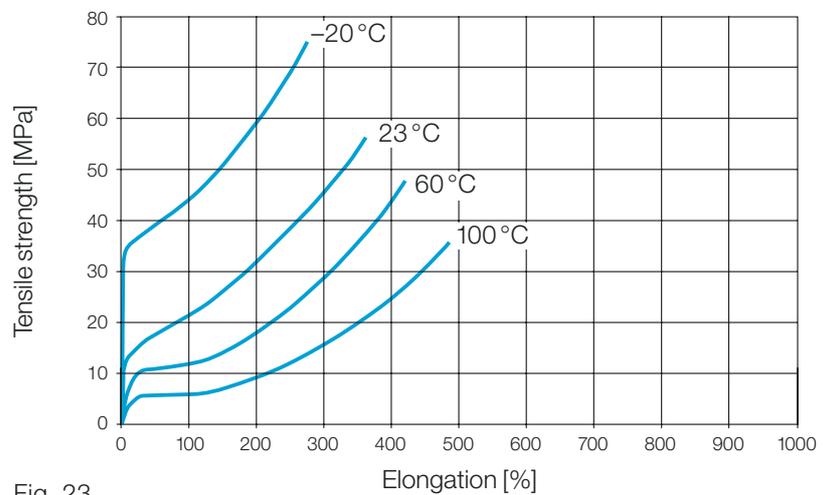
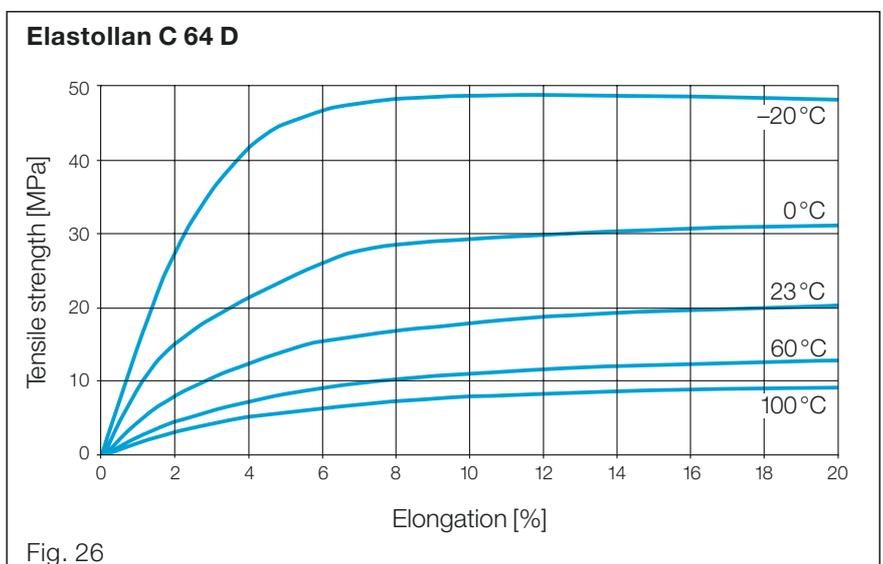
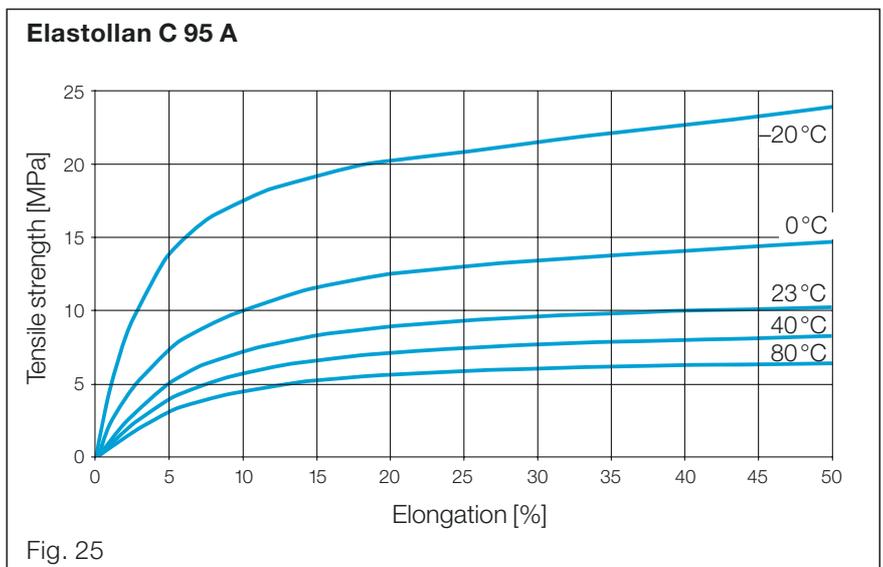
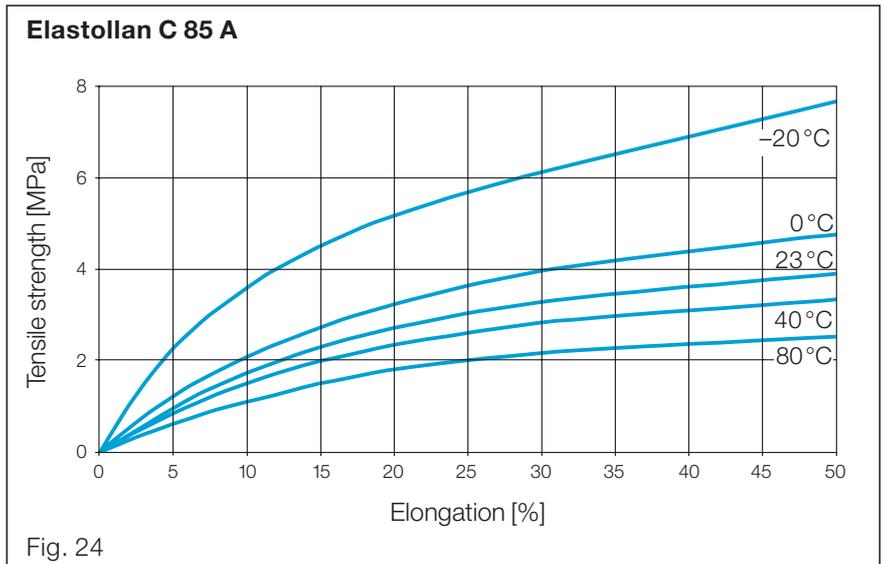


Fig. 23

# Physical properties

## Mechanical properties

### Tensile strength



Note:  
The graphs on pages 18 and 19 were determined according to DIN EN ISO 527-2 at a rate of 50 mm/min using multipurpose test specimens of 4 mm thickness according to DIN EN ISO 3167. These curves present in more detail stress-strain performance over the typical range of application.

# Physical properties

## Mechanical properties

### Tensile strength

**Elastollan 1185 A**

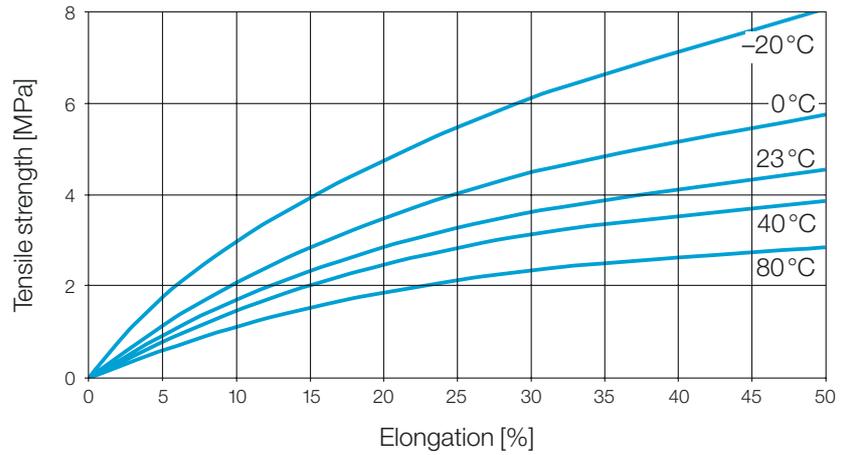


Fig. 27

**Elastollan 1195 A**

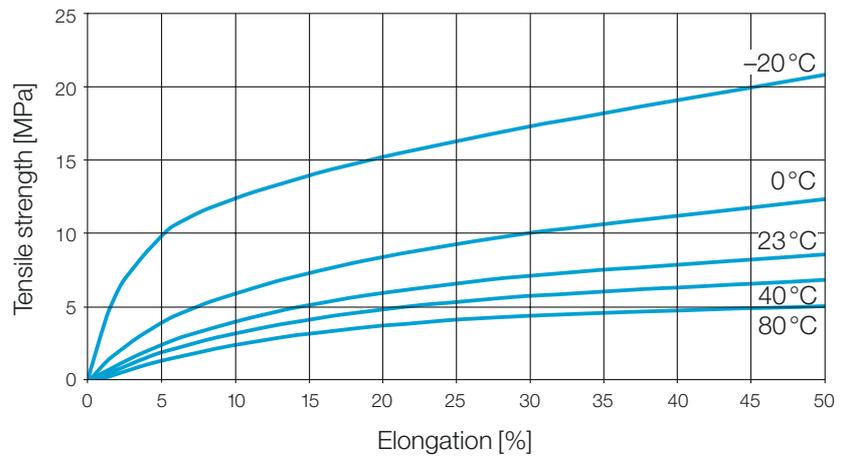


Fig. 28

**Elastollan 1164 D**

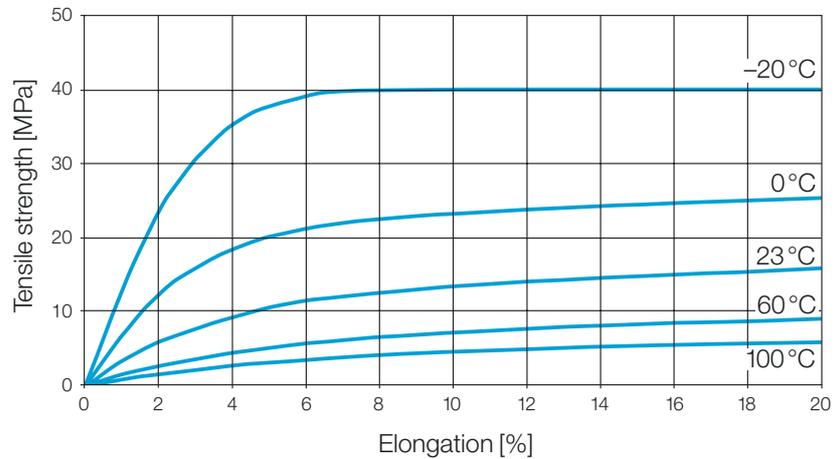
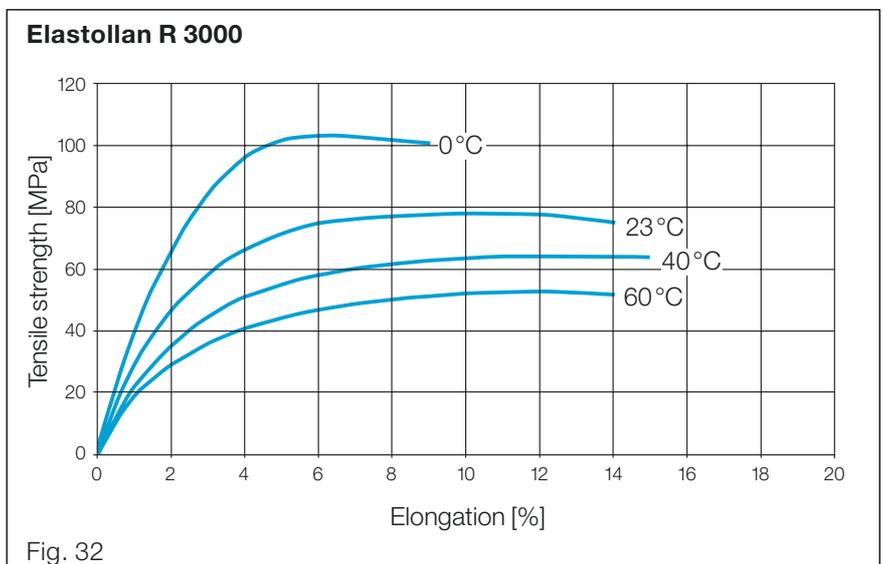
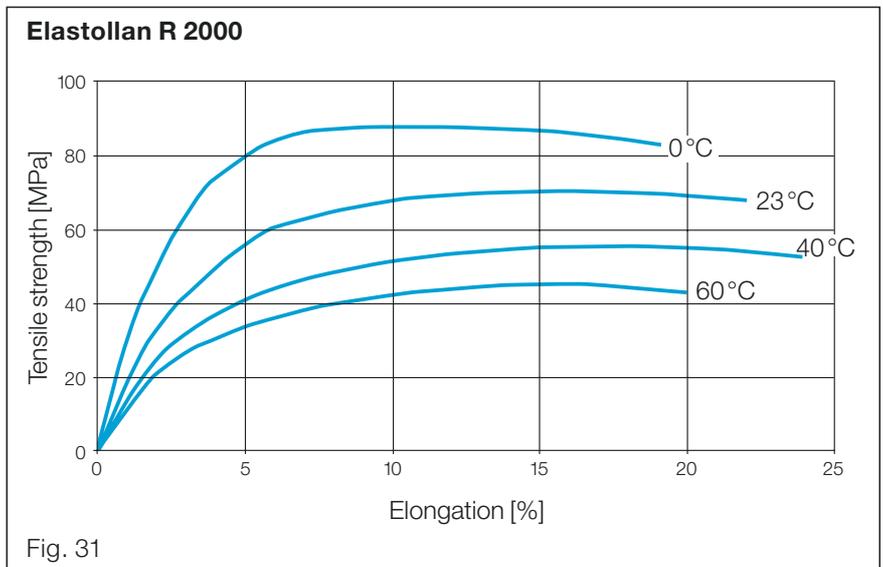
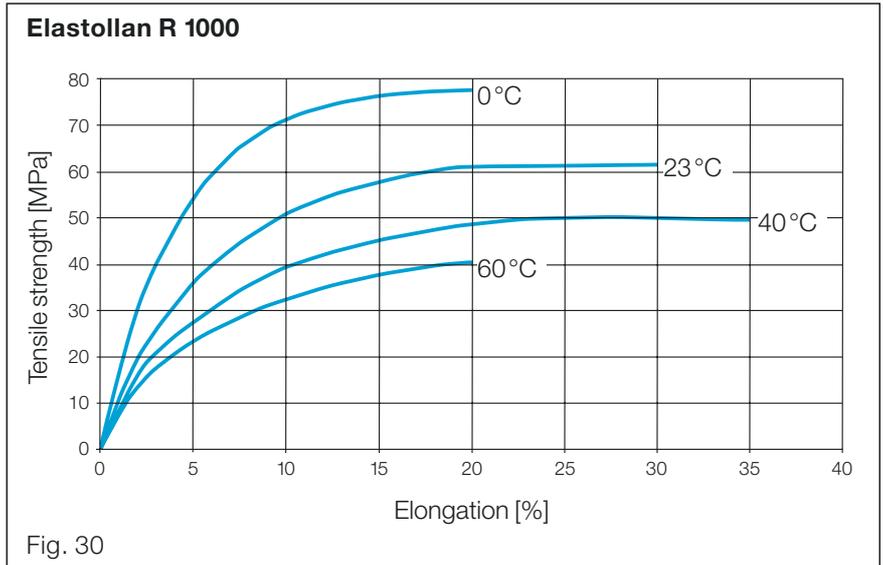


Fig. 29

# Physical properties

## Mechanical properties

### Tensile strength



Note:  
The graphs on page 20 were determined according to DIN EN ISO 527-2 at a rate of 50 mm/min using multipurpose test specimens of 4 mm thickness according to DIN EN ISO 3167.

# Physical properties

## Mechanical properties

### Tear strength

Tear strength is the term which defines the resistance of a notched test specimen to tear propagation. In this respect, Elastollan is far superior to most other of plastics.

The diagrams show tear strength for several Elastollan grades, relative to temperature.

The test is conducted in accordance with **DIN ISO 34-1Bb** using an angle specimen with cut. The specimen is stretched at right-angles to the incision at a rate of 500 mm/min until tear. The tear resistance [**kN/m**] is the ratio between maximum force and specimen thickness.

**Tear strength in relation to temperature  
Elastollan polyester types**

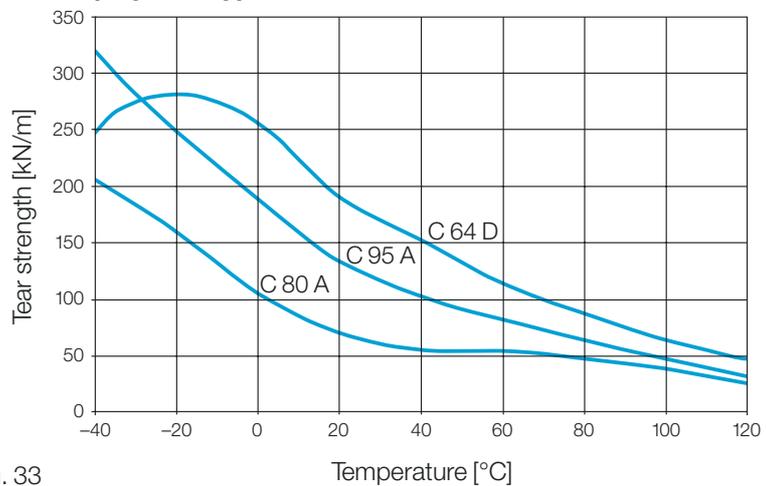


Fig. 33

**Tear strength in relation to temperature  
Elastollan polyether types**

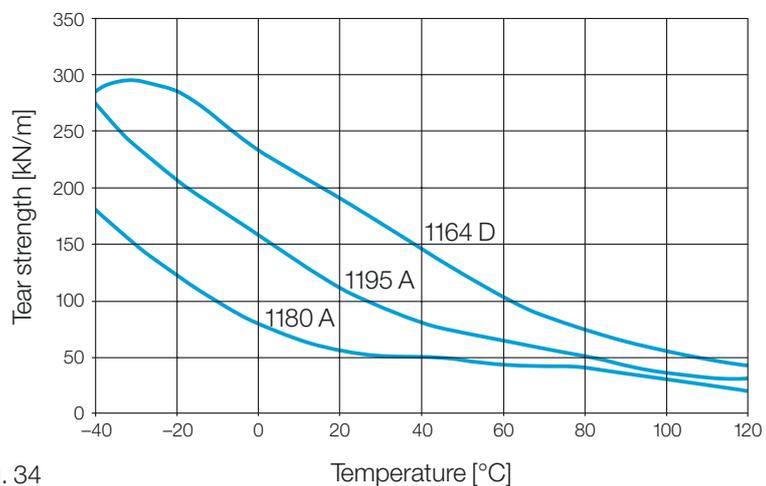


Fig. 34

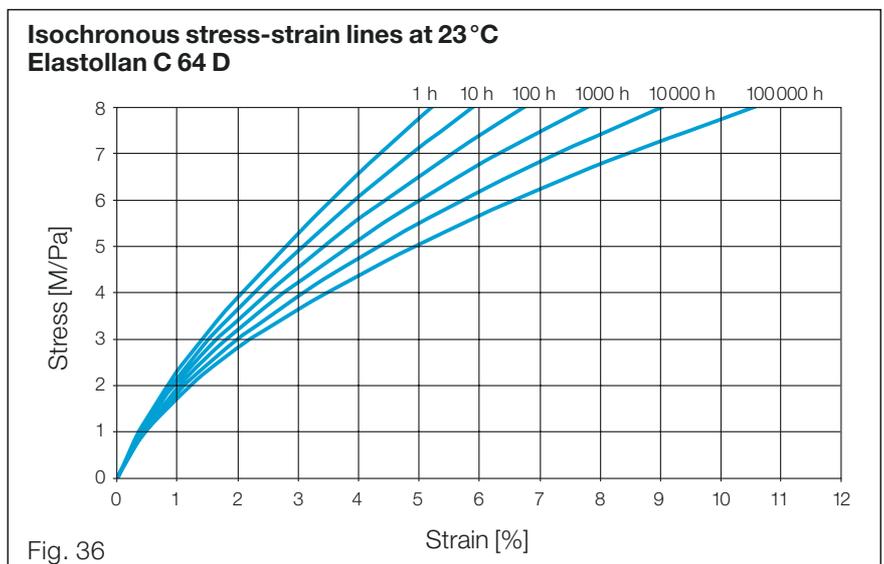
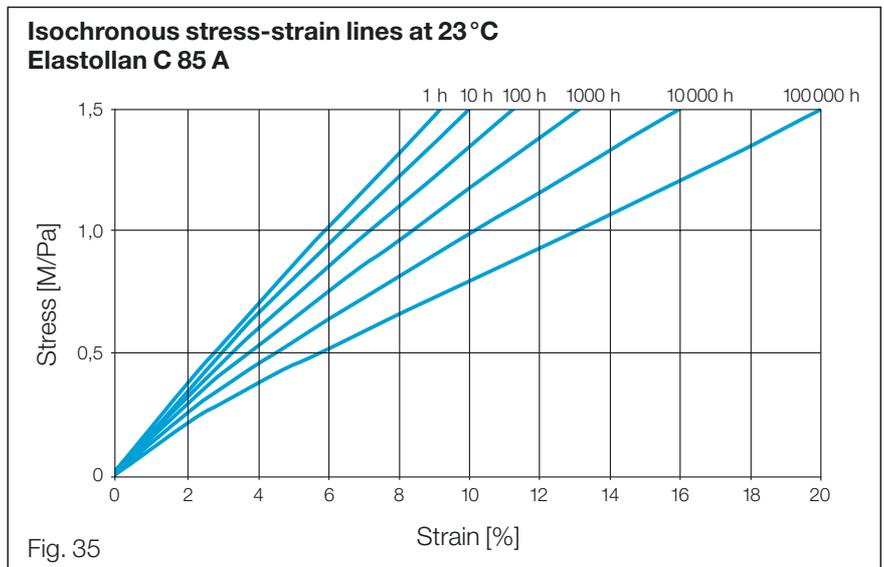
# Physical properties

## Mechanical properties

### Creep behaviour

A pure elastic deformation behaviour, whereby the elastic characteristic remains constant, does not occur with any material. Due to internal friction, there exist at any time both a visco-elastic and a viscous deformation portion, causing a dependence of the characteristic values on the stress duration and intensity. These non-elastic portions are considerably influenced by temperature and time. This dependence should be a pre-consideration in the case of plastics operating at ambient temperature under long term load.

Behaviour under long-term static stress can be characterized according to ISO 899 by means of creep tests, whereby a test specimen is subject to tensile stress using a load. The constant deformation thus caused is measured as a function of time. If this test is conducted applying different loads, the data yield a so-called **isochronous stress-strain diagram**. Such a diagram can be used to predict how a component deforms in the course of time under a certain load, and also how the stress in a component decreases with a given deformation (Figs. 35 to 39).



# Physical properties

## Mechanical properties

### Creep behaviour

**Isochronous stress-strain lines at 23 °C**

**Elastollan 1185 A**

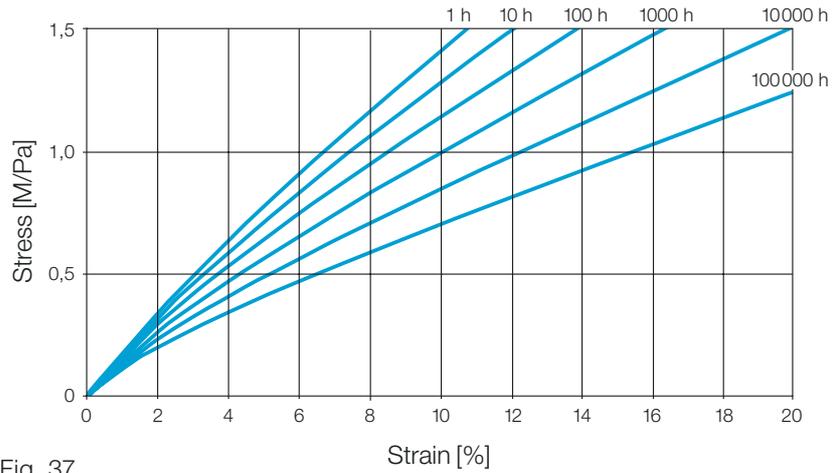


Fig. 37

**Isochronous stress-strain lines at 23 °C**

**Elastollan 1164 D**

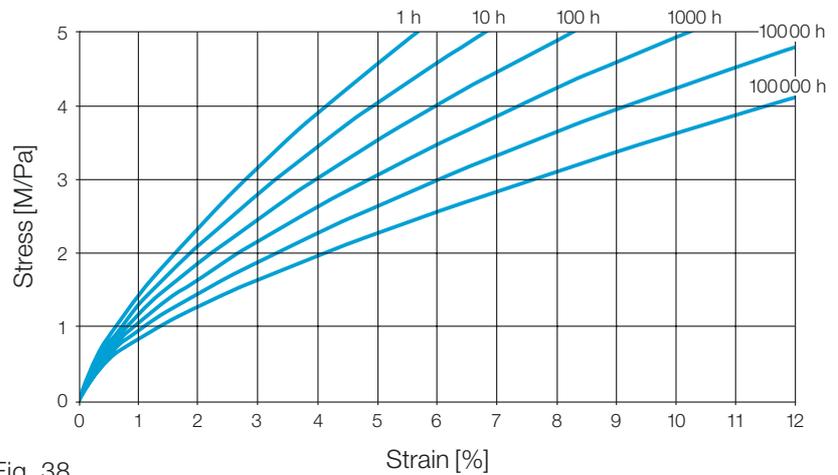


Fig. 38

**Isochronous stress-strain lines at 23 °C**

**Elastollan R 3000**

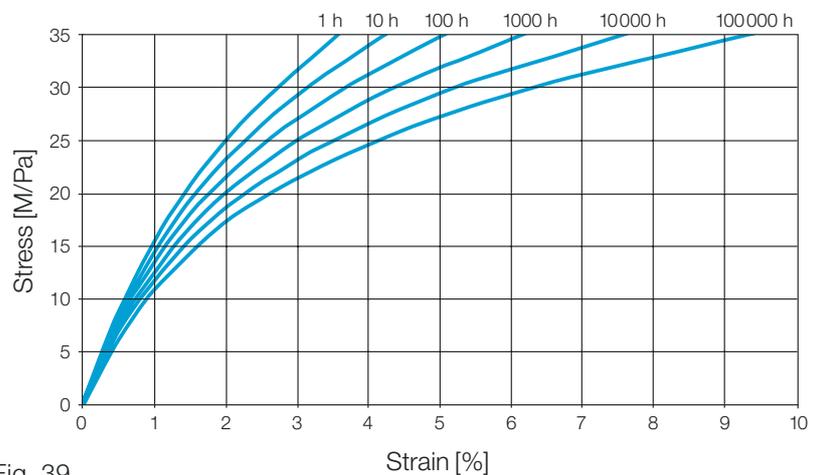


Fig. 39

# Physical properties

## Mechanical properties

### Compression set

**Compression set [%]** is determined by a constant deformation test over a period of 24 hours and is standardized in **DIN ISO 815**.

To achieve the best resistance to compression set annealing of the finished parts is recommended.

In application, in the event of compressive stress one should not exceed 5 % compression for the more rigid grades and 10 % for the more flexible grades, if noticeable compression set is to be avoided.

### Impact strength

Elastollan grades have outstanding low-temperature impact strength. The tables below give a survey of Charpy flexural impact tests according to **DIN EN ISO 179**.

	Impact strength	Notched impact strength
Elastollan C 85 A	down to -60 °C no fracture	fracture from -50 °C
Elastollan C 95 A	down to -60 °C no fracture	fracture from -40 °C
Elastollan C 60 D	down to -60 °C no fracture	fracture from -20 °C
Elastollan 1185 A	down to -60 °C no fracture	fracture from -60 °C
Elastollan 1195 A	down to -60 °C no fracture	fracture from -50 °C
Elastollan 1160 D	down to -60 °C no fracture	fracture from -30 °C
Table 1		

	Impact strength		Notched impact strength	
	23 °C	-30 °C	23 °C	-30 °C
Elastollan R 1000	no fracture	130	70	20
Elastollan R 2000	140	110	50	10
Elastollan R 3000	120	70	30	10
Values in kJ/m <sup>2</sup>				
Table 2				

# Physical properties

## Mechanical properties

### Abrasion

Abrasion [ $\text{mm}^3$ ] is determined in accordance with **DIN 53516 (ISO 4649)**. A test specimen is guided at a defined contact pressure on a rotating cylinder covered with abrasive test paper. The total frictional path is approx. 40 m. The mass loss due to abrasion wear is measured, taking into account the density of the material and the sharpness of the test paper. The abrasion is given as the loss of volume in  $\text{mm}^3$ . Elastollan shows very low abrasion.

Under practical conditions, TPU is considered to be the most abrasion resistant elastomeric material. Thorough predrying of the granulate prior to processing is however essential to achieve optimum abrasion performance.

### Friction

Any meaningful evaluation of the frictional behaviour of plastics is difficult since frictional processes in practice have side-effects which are difficult to define.

The frictional behaviour of Elastollan products depends upon hardness. Friction increases with reducing hardness and this can lead to „stick-slip“ effects for softer products.

# Physical properties

## Thermal properties

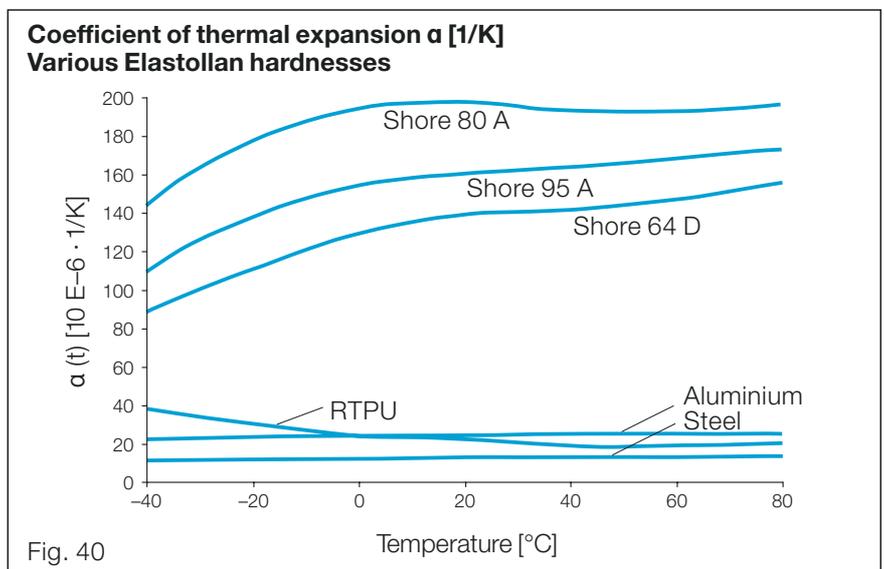
### Thermal expansion

As all materials, Elastollan is subject to a temperature-dependent, reversible variation in length. This is defined by the coefficient of linear expansion  $\alpha$  [1/K] in relation to temperature and determined in accordance with **DIN 53752**.

As shown the values for reinforced Elastollan (glass fibre content 20 %) are similar to those for steel and aluminium.

The influence of temperature is obvious and has to be considered for many applications!

Fig. 40 compares the coefficients of linear expansion of some Elastollan types with steel and aluminium and illustrates the dependence on temperature and Shore hardness.



# Physical properties

## Thermal properties

### Thermal deformation

Various tests can be used to compare the application limits of plastics at increased temperature. These include the determination of the **Vicat Softening Temperature (VST)** according to ISO 306 and the determination of the **Heat Deflection Temperature (HDT)** according to ISO 75.

### Vicat softening temperature

In the course of this test, a loaded needle (Vicat A: 10 N, Vicat B: 50 N) with a diameter of 1 mm<sup>2</sup> is placed on a test specimen, which is located on a plane surface within a temperature transfer medium. The temperature of the medium (oil or air) is increased at a constant heating rate (50 K/h or 120 K/h). The VST is the temperature at which the needle penetrates by 1 mm into the test material.

**Vicat temperature (VST) according to DIN EN ISO 306, method B 50**

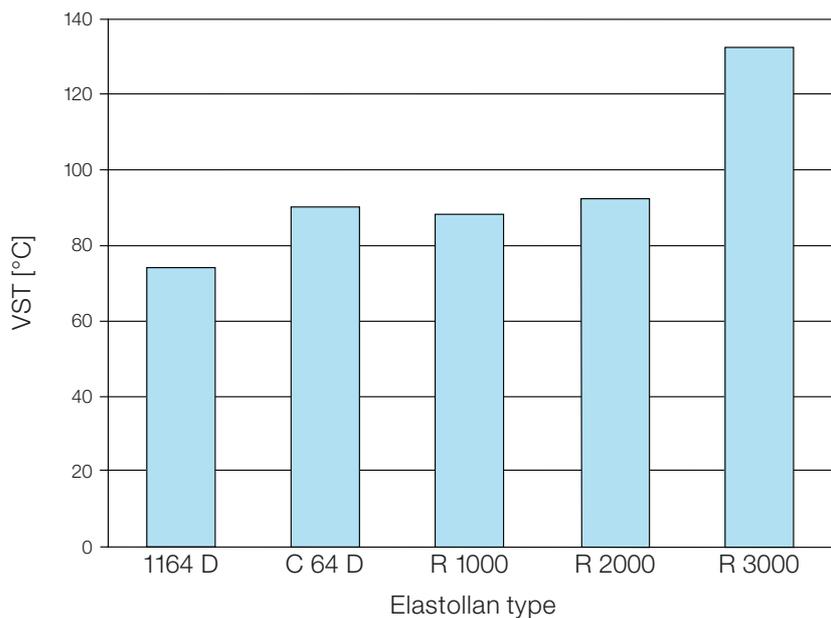


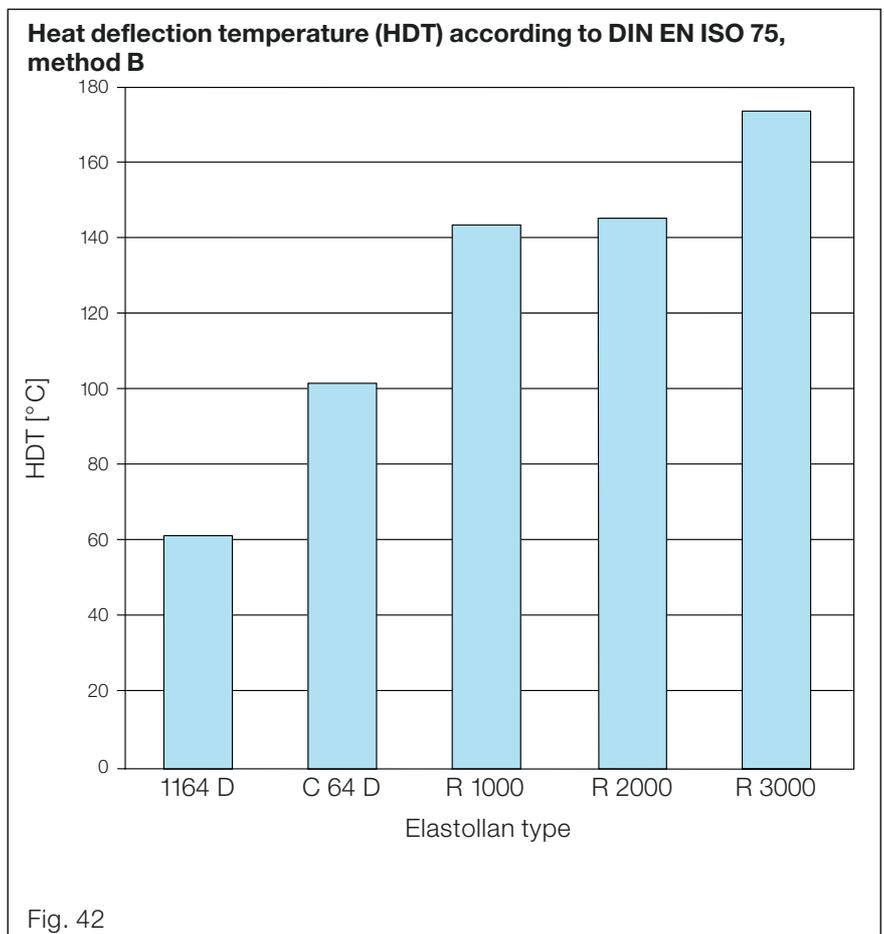
Fig. 41

# Physical properties

## Thermal properties

### Heat deflection temperature

Similarly to the Vicat test, the test set-up is heated in a heat transfer medium at a rate of 50 or 120 K/h. The arrangement is designed as 3-point bending test, the test piece being stressed at a constant load which corresponds to a bending stress of 0.45 MPa, 1.80 MPa or 8 MPa (method A, B or C), depending on the rigidity of the material. The temperature at which the test piece bends by 0.2 to 0.3 mm (depending on the height of the test piece) is indicated as HDT.



# Physical properties

## Thermal properties

### Thermal data

<b>Representative values of thermal data of Elastollan</b>			
Properties	according to	Unit	Values soft → hard
Thermal conductivity	DIN 52612	W/m K	0,19 → 0,25
Heat of combustion – heating value – burning value	DIN 51900	J/g J/g	25000 → 29000 26000 → 31000
Specific heat – room temperature – melt temperature	DIN 51005	J/g K J/g K	1,5 → 1,8 1,7 → 2,3
Table 3			

# Physical properties

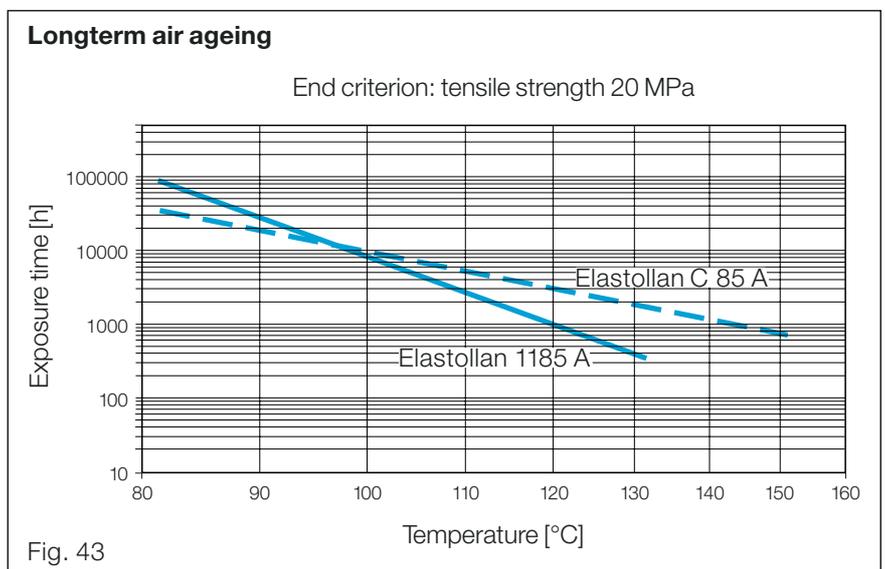
## Thermal properties

### Maximum service temperature

The life expectancy of a finished TPU part will be influenced by several factors and is difficult to predict exactly.

In the diagram below, the end criterion is taken as time for tensile strength to be reduced to 20 N/mm<sup>2</sup>.

The ageing behaviour of materials can however be compared by use of the so-called ARRHENIUS technique. Measurements conducted at higher temperatures can be extrapolated to predict performance at lower temperatures.



# Physical properties

## Gas permeability

The passage of gas through a test specimen is called diffusion. This takes place in three stages:

1. Solution of the gas in the test specimen.
2. Diffusion of the dissolved gas through the test specimen.
3. Evaporation of the gas from the test specimen.

The diffusion coefficient **Q [m<sup>2</sup>/(s · Pa)]** is a material constant which specifies the volume of gas which will pass through a test specimen of known surface area and thickness in a fixed time, with a given partial pressure difference. The coefficient varies with temperature and is determined in accordance with **DIN 53536**.

Table 4 shows the gas diffusion coefficients of Elastollan grades for various gases at a temperature of 20 °C.

The variation of diffusion coefficient with temperature using Elastollan 1185 A and nitrogen as example is illustrated in Fig. 44.

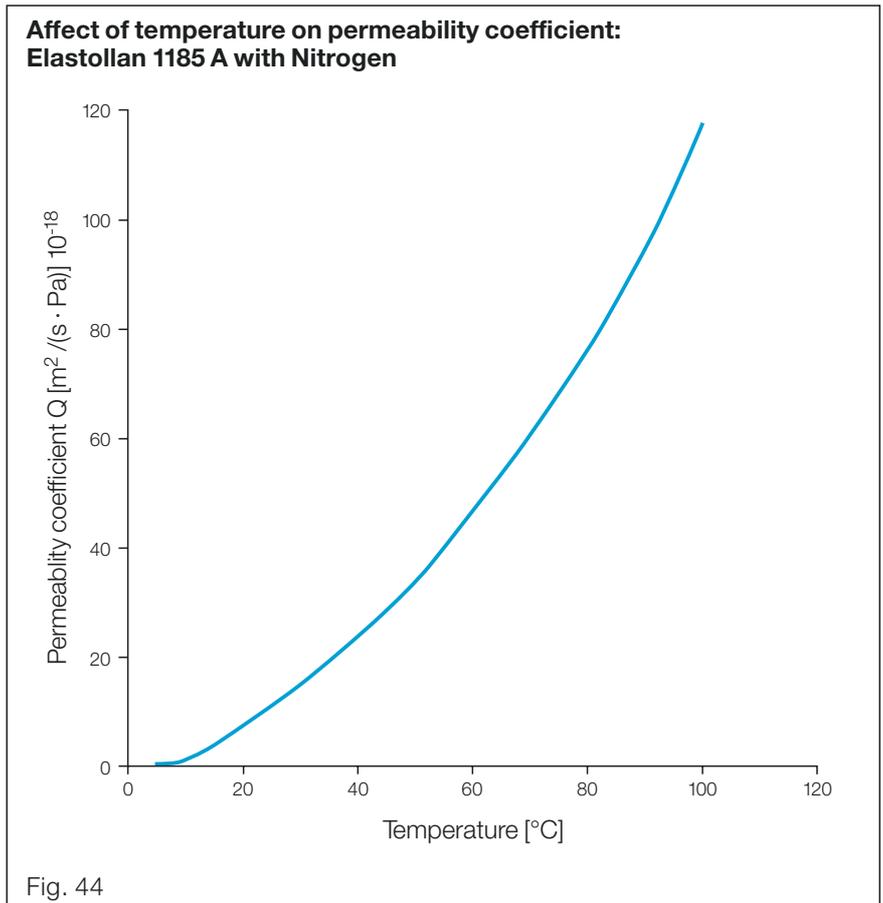
The water vapour permeability **WDD [g/(m<sup>2</sup> · d)]** of a plastic is determined in accordance with **DIN 53122** part 1. This is defined as the amount of water vapour passing through 1 m<sup>2</sup> of test specimen under set conditions (temperature, humidity differential) in 24 hours, and is roughly in inverse proportion to specimen thickness.

The figures shown in Table 5 were obtained with a temperature of 23 °C and a humidity differential of 93 % relative humidity. All values relate to a thickness of 1 mm.

Gas permeability coefficient Q [m <sup>2</sup> /(s · Pa)] · 10 <sup>-18</sup>							
Elastollan-type	Gas						
	Ar	CH <sub>4</sub>	CO <sub>2</sub>	H <sub>2</sub>	He	N <sub>2</sub>	O <sub>2</sub>
C 80 A	12	11	200	45	35	4	14
C 85 A	9	6	150	40	30	3	10
C 90 A	5	4	40	30	25	2	7
C 95 A	3	2	20	20	20	1	4
1180 A	14	18	230	70	50	6	21
1185 A	9	14	180	60	40	5	16
1190 A	7	9	130	50	30	4	12
1195 A	6	5	90	40	20	3	8
Table 4							

# Physical properties

## Gas permeability



**Water vapour permeability WDD [g/(m<sup>2</sup> · d)]  
measured at 1 mm section**

Elastollan type	WDD	Elastollan type	WDD
C 80 A	18	1180 A	21
C 85 A	15	1185 A	17
C 90 A	20	1190 A	15
C 95 A	8	1195 A	12

Table 5

# Physical properties

## Electrical properties

### General

The electrical conductivity of plastics is very low. They are, therefore, frequently used as insulating materials. Information on relevant properties for electrical applications must therefore be made available.

For Elastollan grades standard resistance measurements are made on conditioned test specimens (20 h, 100 °C) after storage in the standard conditioning atmosphere, i.e. 23 °C, 50 % relative humidity.

Allowance should be made for the fact that electrical properties are dependent on moisture content, temperature and frequency.

The results are presented in our technical information brochure "**Elastollan – Electrical Properties**".

### Tracking

Tracking results from the progressive formation of conductive paths on the surface of a solid insulating material. It is generated by the action of electrical loading and electrolytic impurities on the surface.

The **Comparative Tracking Index (CTI)** determined in accordance with **IEC 60112** is the maximum voltage at which a material will withstand 50 drops of a defined test solution without tracking.

### Dielectric strength

Dielectric strength according to **IEC 60243** is the ratio between disruptive voltage and the distance of the electrodes separated by the insulating material. Disruptive voltage is the a.c. voltage at which point the insulating material breaks down.

### Surface resistivity

The specific surface resistance is the resistance of the surface of a test piece. It is measured between two electrodes of dimensions prescribed in **IEC 60093**, fixed to the surface at a specified distance.

# Physical properties

## Electrical properties

### Volume resistivity

Volume resistivity as defined in **IEC 60093** is the electrical resistance of the bulk material measured between two electrodes, relative to the geometry of the test piece. The type of electrode arrangement makes it possible to ignore surface resistance.

### Dielectric constant

Dielectric constant is the ratio of capacity measured with the insulating material compared with that for air. This constant is determined in accordance with **IEC 60250** and is temperature and frequency dependent. Our technical information provides values for Elastollan grades for various frequencies at 23 °C.

### Dielectric loss factor

When an insulating material is used as dielectric in a capacitor, an adjustment of the phase displacement between current and voltage occurs. The displacement from the normal angle of 90° is known as the loss angle. The loss factor is defined as the tangent of the loss angle. As with dielectric constant, it varies with temperature and frequency. Values are provided for various frequencies at 23 °C.

# Chemical properties

## Swelling

### General

The suitability of a plastic for a particular application often depends on its resistance to chemicals. Depending on the type and chemical composition thermoplastic polyurethanes can behave very differently in interreaction with chemical substances.

It is therefore difficult in any case to make a clear distinction between the effects described below.

Our data sheet "**Elastollan – Chemical resistance**" provides a general guide. For critical applications, a detailed resistance test considering both swelling and the affect on mechanical properties is recommended.

### Swelling

Swelling is the fundamental physical process of the absorption of liquid substances by a solid.

In this process, the substance enters into the material without chemical interaction. This results in an increase in volume and weight with a corresponding reduction in mechanical values.

After evaporation a reduction in swelling occurs and the original properties of the product are almost completely restored.

Swelling is a reversible process.

# Chemical properties

## Chemical resistance



Chemical resistance depends on the period of exposure, the temperature, the quantity, the concentration and the type of the chemical substance.

In the case of chemical degradation of polyurethane the chemical reaction results in cleavage of the molecular chains. This process is generally preceded by swelling. In the course of degradation, polyurethane loses strength, and in extreme cases this can lead to disintegration of the part.

### Acids and alkaline solutions

Elastollan products are attacked by concentrated acids and alkaline solutions even at room temperature. Any contact with these substances should be avoided. Elastollan is resistant to short-time contact with dilute acids and alkali solutions at room temperature.

### Saturated hydrocarbons

Contact of Elastollan with saturated hydrocarbons such as diesel oil, isooctane, petroleum ether and kerosene, results in a limited swelling. At room temperature this swelling amounts to approx. 1–3 % and the resultant reduction in tensile strength is no more than 20 %. After evaporation and reversal of the swelling, the original mechanical properties are almost completely restored.

### Aromatic hydrocarbons

Contact of Elastollan with aromatic hydrocarbons such as benzene and toluene, results in considerable swelling even at room temperature. Absorption can result in a 50 % weight increase with a corresponding reduction in mechanical properties.

# Chemical properties

## Chemical resistance

### Lubricating oils and greases

Elastollan is in principal resistant to lubricating oils and greases, however irreversible damage can be caused by included additives.

Compatibility testing in each individual lubricant is to be recommended.

No reduction in strength occurs after immersion in ASTM oils 1, IRM 902 and IRM 903 at room temperature. No reduction in tensile strength is recorded after 3 weeks immersion at 100 °C.

### Solvents

Aliphatic alcohols, such as ethanol and isopropanol, cause swelling of Elastollan products. This is combined with a loss of tensile strength. Rising temperatures intensify these effects.

Ketones such as acetone, methyl-ethylketone (MEK) and cyclohexanone are partial solvents for thermoplastic polyurethane elastomers. Elastollan products are unsuitable for long-term use in these solvents.

Aliphatic esters, such as ethyl acetate and butyl acetate, cause severe swelling of Elastollan.

Highly polar organic solvents such as dimethylformamide (DMF), dimethylsulphoxide (DMSO), N-methylpyrrolidine and tetrahydrofuran (THF) dissolve thermoplastic polyurethane.

# Chemical properties

## Microbiological resistance

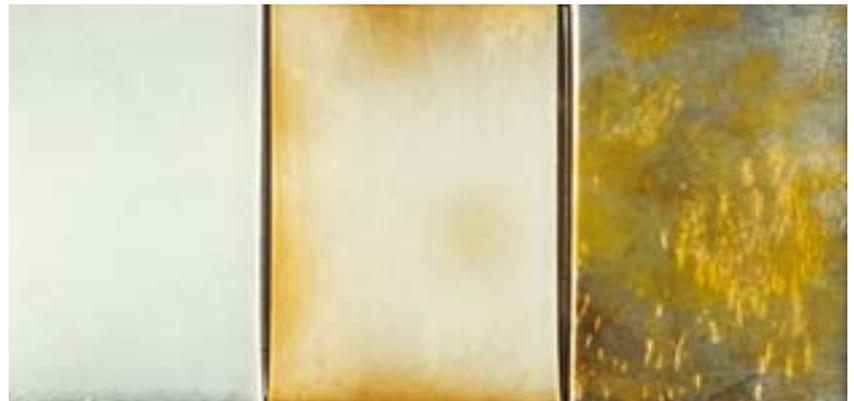
When using polyester-based thermoplastic polyurethane under climatic conditions of high heat and humidity, parts can be damaged by microbiological attack. In particular, micro-organisms producing enzymes are able to affect the molecule chains of polyester-based TPU. The microbiological attack initially becomes visible as discolouration. Subsequently, surface cracks occur which enable the microbes to penetrate deeper and to cause a complete destruction of the TPU (ref. Fig. 45).

Polyether-based thermoplastic polyurethane is resistant to microbiological attack.

The saponification number (SN) according to DIN VDE 0472, part 704 is an important criterion for microbiological resistance. Unfilled TPU is resistant to microbes up to a saponification number of 200 mg KOH/gm, which is the limiting value according to VDE 0282/10.

Depending on formulation and hardness, polyether-based TPUs achieve a saponification number of around 150, polyester-based TPUs around 450. With regard to polyether-polyester mixtures, the saponification number can be calculated from the quantitative portions. Small inclusions of up to approx. 10 % of ester urethane in ether urethane (e.g. addition of ester-based colour masterbatches) do not impair the microbiological resistance (SN remains < 200). Larger inclusions of ester-based TPU result in a reduction in the microbiological resistance.

### Progress of microbial degradation of polyester-based TPU



Left: reference sample  
Middle: mild discoloration  
Right: discoloration and distinctly visible cracks

Fig. 45

# Chemical properties

## Hydrolysis resistance

If polyester based polyurethanes are exposed for lengthy periods to hot water, moisture vapour or tropical climates, an irreversible break-down of the polyester chains occurs through hydrolysis. This results in a reduction in mechanical properties. This effect is more marked in flexible grades, where the polyester content is correspondingly higher than in the harder formulations. Degradation of polyester-based Elastollan is however rarely experienced at room temperature.

The following diagrams compare hydrolysis resistance of polyether- and polyester-based TPU.

Because of its chemical structure, polyether-based Elastollan is much more resistant to hydrolytic degradation.

### Long term hydrolysis resistance

End criterion: tensile strength 20 MPa

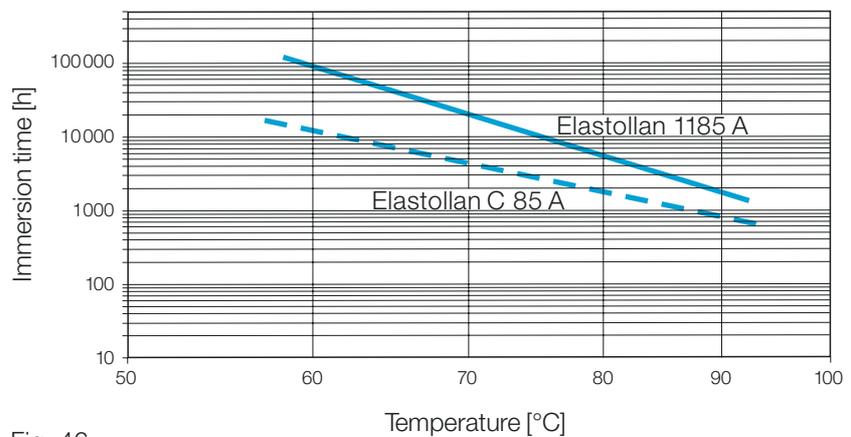


Fig. 46

### Long term hydrolysis resistance

End criterion: elongation 300%

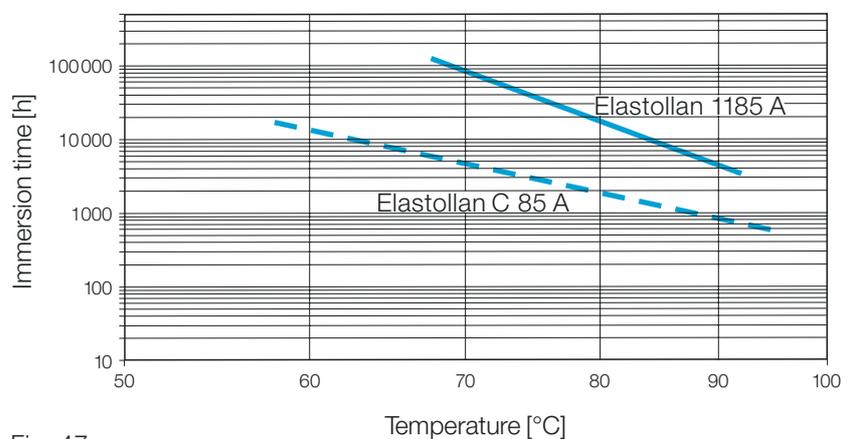


Fig. 47

# Chemical properties

## Radiation resistance · Ozone resistance

### UV-radiation

Plastics are chemically degraded by the effect of UV-radiation. The degree of ageing depends on duration and intensity. In the case of polyurethanes, the effect is seen initially as surface embrittlement. This is accompanied by a yellowing in colour and a reduction in mechanical properties.

It is possible to improve UV resistance by addition of colour pigments which prevent the deep penetration of UV-rays and thus mechanical destruction. Moreover, dark colour shades, in particular black, mask the surface discolouration. The ageing process can also be delayed by the addition of UV-stabilizers. Suitable masterbatches are available.

### High energy radiation

Elastollan is superior to most other plastics in its resistance to high energy radiation. Resistance to  $\alpha$ -,  $\beta$ - and  $\gamma$ -radiation is dependent on such factors as the intensity of the radiation, the shape and dimensions of the test specimen, and the atmosphere in the test area.

The addition of crosslinking agents and subsequent  $\beta$ - or  $\gamma$ -radiation can effect crosslinking of Elastollan. The maximum achievable degrees of crosslinking are around 90 %. This is a method to improve short-term heat deflection temperature and chemical resistance.

### Ozone resistance

The ozone molecule ( $O_3$ ) is formed by the union of three oxygen atoms. It is generated from reaction of oxygen in the atmosphere under the influence of high energy UV-radiation.

Ozone is highly reactive, especially with organic substances. Rubber-based elastomers are destroyed through cracking under the influence of ozone.

Elastollan, on the other hand, is resistant to ozone.

The test according to VDE 0472 part 805 results in „crack-free“, stage 0. There is neither a loss of elasticity nor an increase of surface hardness.

# Chemical properties

## Fire behaviour

Plastics are, like all organic substances, inflammable. Fire behaviour is influenced by the following characteristics:

- flammability
- flame propagation
- heat development
- smoke development (smoke density and toxicity of the combustion gases)
- surface/mass ratio of the combustible substances
- thermal-conductivity
- calorific value

The fire behaviour of a substance is not dependent on the material alone. Apart from the criteria listed above, it is also influenced by accompanying circumstances, such as:

- dispersion
- nature of storage
- quantity of material
- temperature
- ventilation
- duration and intensity of the source of ignition etc.

The complexity of the influencing factors makes it impossible to give a comprehensive and generally-valid description of the fire behaviour of plastics. Consequently, there are a number of standards and specifications, each simulating a representative case.

For the above reasons, in case of uncertainty it is recommended to consult our Technical Service Department. For certain applications, it is advisable to use flame-retardant Elastollan grades. These products provide increased protection against flame development and propagation.

No individual standard can cover every eventuality. The most important standards covering the behaviour of plastics in fire with typical results for Elastollan are described below:

### ● **UL 94** (Underwriters Laboratories)

Standard Elastollan grades are rated HB, grades containing plasticizer normally achieve classification V2. The flame retardant halogen free grade Elastollan 1185 A FHF is rated V0.

Yellow Cards for some grades are available on request.

### ● **ISO 4589** (Oxygen Index)

This test measures the minimum amount of oxygen required to maintain combustion. For Elastollan grades values between 22 and 25 are recorded.

### ● **FMVSS 302** (Federal Motor Vehicle Safety Standard)

All Elastollan grades comply with this standard, which permits a max. combustion rate of 4 inches/min. (101.6 mm/min) under the specified test conditions.

### ● **DIN EN 50267-2-2** (Corrosiveness of combustion gases)

Standard Elastollan grades as well as grades containing plasticizer fulfill the requirements of this test.

Additives can influence the result and must be considered separately.

Further details are to be found in our safety data sheets.

# Quality management



# Index of key terms

- A**
- Abrasion \_\_\_\_\_ 25
  - Acid and alkali solutions \_\_\_\_\_ 36
  - Ageing \_\_\_\_\_ 40
  - Air ageing \_\_\_\_\_ 30
  - Annealing \_\_\_\_\_ 6, 24
- B**
- Bending test \_\_\_\_\_ 7
- C**
- Chemical resistance \_\_\_\_\_ 36
  - Chemical structure \_\_\_\_\_ 5
  - Coefficient of linear expansion \_\_\_\_\_ 26
  - Cold flexibility \_\_\_\_\_ 20
  - Compression set \_\_\_\_\_ 24
  - Compressive stress \_\_\_\_\_ 24
  - Corrosiveness of combustion gas \_\_\_\_\_ 41
  - CTI, Comparative Tracking Index \_\_\_\_\_ 33
- D**
- Damping \_\_\_\_\_ 11
  - Deformation characteristics \_\_\_\_\_ 14
  - Dielectric constant \_\_\_\_\_ 34
  - Dielectric loss factor \_\_\_\_\_ 34
  - Dielectric strength \_\_\_\_\_ 33
  - Diffusion coefficient \_\_\_\_\_ 31
  - Disruptive voltage \_\_\_\_\_ 33
- E**
- Electrical properties \_\_\_\_\_ 33
  - Elongation \_\_\_\_\_ 14
  - Elongation at break \_\_\_\_\_ 14
  - Embrittlement \_\_\_\_\_ 40
  - E-modulus \_\_\_\_\_ 7
- F**
- Fire behaviour \_\_\_\_\_ 41
  - Flexural impact test \_\_\_\_\_ 24
  - FMVSS 302 \_\_\_\_\_ 41
  - Friction \_\_\_\_\_ 25
- G**
- Gas permeability \_\_\_\_\_ 31
  - Glass transition temperature \_\_\_\_\_ 10
  - Glass transition zone \_\_\_\_\_ 10
- H**
- Hardness \_\_\_\_\_ 9
  - Heat deflection temperature \_\_\_\_\_ 28
  - Heat deformation behaviour \_\_\_\_\_ 27
  - High energy irradiation \_\_\_\_\_ 40
  - Hydrocarbon, aromatic \_\_\_\_\_ 36
  - Hydrocarbon, saturated \_\_\_\_\_ 36
  - Hydrolysis resistance \_\_\_\_\_ 39
- I**
- Impact strength \_\_\_\_\_ 24
  - Isochronous stress-strain curves \_\_\_\_\_ 22
- L**
- Linear expansion \_\_\_\_\_ 22
  - Long-term performance \_\_\_\_\_ 22
  - Lubricating oils and greases \_\_\_\_\_ 37
- M**
- Maximum force elongation \_\_\_\_\_ 14
  - Maximum service temperature \_\_\_\_\_ 30
  - Mechanical properties \_\_\_\_\_ 6
  - Microbiological resistance \_\_\_\_\_ 38
  - Modulus of elasticity \_\_\_\_\_ 7
- N**
- Notched impact strength \_\_\_\_\_ 24
- O**
- Oxygen index \_\_\_\_\_ 41
  - Ozone resistance \_\_\_\_\_ 40
- P**
- Physical properties \_\_\_\_\_ 6
- Q**
- Quality management \_\_\_\_\_ 42
- R**
- Radiation resistance \_\_\_\_\_ 40
  - Rigidity \_\_\_\_\_ 7
- S**
- Saponification number \_\_\_\_\_ 38
  - Service temperature \_\_\_\_\_ 22
  - Shore hardness \_\_\_\_\_ 9
  - Solvents \_\_\_\_\_ 30
  - Specific heat \_\_\_\_\_ 29
  - Stick-slip effect \_\_\_\_\_ 25
  - Strength characteristics \_\_\_\_\_ 14
  - Stress-strain curves \_\_\_\_\_ 15
  - Surface resistance, specific \_\_\_\_\_ 35
  - Swelling \_\_\_\_\_ 35
- T**
- Tear strength \_\_\_\_\_ 21
  - Tensile strength \_\_\_\_\_ 14
  - Thermal conductivity \_\_\_\_\_ 29
  - Thermal data \_\_\_\_\_ 29
  - Thermal expansion \_\_\_\_\_ 26
  - Thermal properties \_\_\_\_\_ 29
  - Torsion modulus \_\_\_\_\_ 11
  - Torsion vibration test \_\_\_\_\_ 11
  - Tracking \_\_\_\_\_ 33
- U**
- Underwriters Laboratories \_\_\_\_\_ 41
  - UV-radiation \_\_\_\_\_ 40
- V**
- Vicat softening temperature \_\_\_\_\_ 27
  - Volume resistivity \_\_\_\_\_ 33
- W**
- Water vapour permeability \_\_\_\_\_ 32
- Y**
- Yield strain \_\_\_\_\_ 14
  - Yield stress \_\_\_\_\_ 14

## Elastogran is Polyurethane

With top quality products, a reputation for good customer service and continuous progress and development, Elastollan has secured a firm position in numerous markets.

We want to share our know-how and experience to contribute to your own success: The versatile Elastollan is the ideal material to fulfill your requirements.

For further information, the following detailed brochures are available upon request:

- Thermoplastic Polyurethane Elastomers: Elastollan
- Elastollan – Product Range
- Elastollan – Processing Recommendations
- Elastollan – Electrical Properties
- Elastollan – Chemical Resistance

### Elastogran GmbH

European Business Management  
Thermoplastic Polyurethanes  
Landwehrweg  
49448 Lemförde  
Germany  
Telephone ++49 (5443) 12-25 00  
Telefax ++49 (5443) 122555  
e-mail [elastomere@elastogran.de](mailto:elastomere@elastogran.de)  
[www.elastogran.de](http://www.elastogran.de)

# Elastogran



■ BASF Group

®= Registered Trademark of Elastogran GmbH

The data contained in this publication is based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, this data does not relieve processors from carrying out their own investigations and tests; neither does this data imply any guarantee of certain properties, or the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior notice and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed. (02/05)