

## Technical Information

The chemical composition and properties of BOROSILICATE glass place it in "group 3.3" of clear "hard" borosilicate glasses, characterised by their high heat-resistance and chemical stability. It fully complies with the requirements which these standards place on its properties.

BOROSILICATE glass is used to produce a wide range of technical and laboratory glass products, industrial apparatus and heat-resistant household glassware, whose characteristics and practical value have made them much sought-after products in many countries throughout the world.

Because of its properties, BOROSILICATE glass is used in situations which place the highest demands on the heat-resistance and chemical stability of products as well as their neutrality with respect to the substances or preparations with which they come into contact, i.e. in chemistry, petrochemistry, the food, energy and metalworking industries, health care, microbiology, pharmacy, mechanical engineering and laboratories.

Products made from BOROSILICATE glass are smooth, non-porous and perfectly transparent, with no catalytic action, and are corrosion-resistant even in demanding operating conditions up to 300°C without sudden changes of temperature.

BOROSILICATE glass is an environment-friendly product and is completely harmless from an ecological point of view.

Chemical composition of BOROSILICATE glass

<b>Component</b>	<b>Amount (% by mass)</b>
SiO <sub>2</sub>	80,4
B <sub>2</sub> O <sub>3</sub>	13,0
Al <sub>2</sub> O <sub>3</sub>	2,4
Na <sub>2</sub> O + K <sub>2</sub> O	4,2

## Chemical Properties of BOROSILICATE Glass

Products made from BOROSILICATE glass are chemically stable, practically inert and characterised by high resistance to the effects of water, water vapour, acids and salt solutions and relatively high resistance to alkalis.

The glass is etched by hydrofluoric acid and concentrated trihydrogenphosphoric acid and corroded by hot concentrated alkaline solutions. Constant alternation of acid and alkaline environments increases corrosion.

The chemical resistance of BOROSILICATE glass is specified by the ISO 3585 and CSN ISO 3585 standards and is evaluated precisely by the international standard testing methods defined by ISO and DIN ISO standards.

Chemical resistance of BOROSILICATE glass to	
<b>water at 98 °C (in accordance with ISO 719)</b>	HGB 1
<b>water at 121 °C (in accordance with ISO 720)</b>	HGA 1
<b>acids (in accordance with ISO 1776)</b>	1
<b>effects of a boiling aqueous solution of mixed alkalis (in accordance with ISO 695)</b>	A2 or better

## Physical Properties of BOROSILICATE Glass

The physical properties of BOROSILICATE glass are evaluated precisely by the international standard testing methods defined by ISO and DIN ISO standards.

The physical properties of Borosilicate glass, as shown in the following table, comply with the ISO 3585 standards.

Mean coefficient of linear thermal expansion (ISO 7991) $A_{20/300}$	$3,3 \times 10^{-6} \text{ K}^{-1}$
Density $\rho$	$2,23 \text{ g} \times \text{cm}^{-3}$
Thermal conductivity (at 100 °C) $\lambda_w$	$1,2 \text{ W} \times \text{m}^{-1} \times \text{K}^{-1}$
Specific heat capacity at constant pressure $c_p$	$0,8 \times 10^3 \text{ J} \times \text{Kg}^{-1} \times \text{K}^{-1}$
Temperatures of main points in terms of viscosity $\eta$ in dPa $\times$ s	
<ul style="list-style-type: none"><li>• <math>10^4</math> working temperature (ISO 7884 -- 2, ISO 7884--5) ..... 1260 °C</li><li>• <math>10^{7,5}</math> softening point - Littleton point (ISO 7884--6) ..... 820 °C</li><li>• <math>10^{13,2}</math> upper cooling temperature (ISO 7884-7) ..... 560 °C</li><li>• <math>10^{14,7}</math> lower cooling temperature (ISO 7884-7) ..... 510 °C</li></ul>	
Transformation temperature (ISO 7884-8)	525 °C
Modulus of elasticity E	$64 \times 10^3 \text{ MPa}$
Poisson constant $\mu$	0,20
Tensile strength $R_m$	35 to 100 MPa

Viscosity is also an important property of glass, and is significant in all stages of glass production and working. It also affects electrical properties through its effect on the mobility of ions.

BOROSILICATE glass is counted among viscously "shorter" glasses, i.e. it has a relatively narrow temperature range for working.

## Mechanical stability of BOROSILICATE glass

The mechanical properties and service life of products made from BOROSILICATE glass are largely determined by the condition of the surface, especially its integrity, i.e. the depth of damage to the surface in handling and secondary heat treatment.

Scratch hardness of glass on Mohs scale 6	
Allowable tensile stress	3,5 MPa
Allowable bending stress	7 MPa
Allowable compressive stress	100 MPa

## Thermal Properties of BOROSILICATE Glass

The high resistance of products made from BOROSILICATE glass to sudden changes of temperature - their heat resistance - is due to a low coefficient of linear thermal expansion, a relatively low modulus of tensile elasticity E and relatively high thermal conductivity.

When the glass product is heated or cooled, unwanted internal stress arises.

Breaking on rapid cooling of the product occurs when the unwanted internal stress exceeds the allowable limit. Values of resistance to thermal shock ( $\Delta$  °C) for Borosilicate glass products are shown in the following table against the thickness of the wall.

**Wall thickness (mm) Resistance to thermal shock ( $\Delta$ °C)**

1	303
3	175
6	124
10	96

**Cooling of BOROSILICATE glass**

Cooling is a thermal process whose purpose is to prevent unwanted and unacceptable thermal stress from appearing in the glass, which would weaken the product, or to remove stress which is already present.

The cooling cycle consists of three stages:

**Temperature increase** (heating of the product) at a given heating rate from the initial temperature to the upper cooling temperature.

**Maintenance of temperature** (hold, tempering, stabilisation) - the product is kept at the upper cooling temperature for some time while the temperature differences within the product equalise and stress decreases to an acceptable level.

**Temperature decrease** (initial and final cooling) at a given cooling rate from the upper cooling temperature to the lower cooling temperature (this stage is important, as permanent stress may arise) and from the lower cooling temperature to a final temperature or to the ambient temperature (important for subsequent practical handling of the product).

A specific cooling cycle is shown in the table

**Temperature Ranges**

Temperature increase Max. wall thickness	hold 20 -- 550 °C	decrease 560 °C	560 -- 490 °C	490 -- 440 °C	440 -- 40 °C
3 mm	140 °C/min	5 °C/min	14 °C/min	28 °C/min	140 °C/min
6 mm	30	10	3	6	30
9 mm	15	18	1,5	3	15
12 mm	8	30	0,6	1,6	8

**Optical Properties of BOROSILICATE Glass**

Borosilicate glass is transparent and colourless and does not show significant absorption in the visible spectrum. Its transmittance at ultraviolet wavelengths allows products to be used for photochemical reactions.

Refractive index of Borosilicate glass ( $\lambda = 589,30$  nm)  $n_d$  1,472

Photoelastic constant B  $3,6 \cdot 10^{-6}$  MPa<sup>-1</sup>.

The optical transmittance of BOROSILICATE glass in the visible area of the spectrum is between 90 and 92% for a wall thickness of 3 mm, and is shown in the following graph.

## Electrical Properties of BOROSILICATE Glass

BOROSILICATE glass is non-conductive at normal temperatures - it is an insulator.

Electrical resistivity in a humidity-free environment (20 °C)	greater than $10^{13}$ - $10^{15} \Omega \times \text{cm}$
Permittivity $\epsilon$ (20 °C, 1 MHz)	4,6
Loss angle $\text{tg } \delta$	$4,9 \times 10^{-3}$

Dielectric losses rise sharply with increasing temperature and change with frequency.

## Standard tolerance of dimensional parameters of tubes, rods and capillary tubes BOROSILICATE

### Lengths and the end treatment

<b>Tubes - outside diameter</b>	<b>length</b>	<b>end treatment</b>
$4 \text{ mm} \leq \emptyset \leq 7 \text{ mm}$	$1500 \pm 20 \text{ mm}$	cut only
$7 \text{ mm} < \emptyset \leq 10 \text{ mm}$	$1500 \pm 10 \text{ mm}$	cut only
$10 \text{ mm} < \emptyset \leq 48 \text{ mm}$	$1500 \pm 10 \text{ mm}$	trimmed and glazed
$48 \text{ mm} < \emptyset \leq 150 \text{ mm}$	$1500 \pm 5 \text{ mm}$	trimmed and glazed
<b>Capillary tubes and rods</b>		
$3 \text{ mm} \leq \emptyset \leq 7 \text{ mm}$	$1500 \pm 20 \text{ mm}$	cut only
$8 \text{ mm} < \emptyset \leq 17 \text{ mm}$	$1500 \pm 10 \text{ mm}$	cut only
$18 \text{ mm} < \emptyset \leq 30 \text{ mm}$	$1500 \pm 30 \text{ mm}$	cut only

Special lengths of tubes in range of 1000-3000 mm can be delivered on demand in dependence on outside diameter.

Tubes cut in special way in length of 15-3500 mm can be delivered in dependence on outside diameter.

### Out-of-roundness

Out-of-roundness of tubes, rods and capillary tubes is related to outside diameter.

### Tubes

In any place of tube there the difference of maximum and minimum diameter must not exceed 2 % of nominal outside diameter.

### Rods and capillary tubes

In any place of rod or capillary tube there the difference of maximum and minimum

diameter must not exceed 3 % of nominal outside diameter.

## Siding

Siding in any place of the tube cut must not exceed the values as follows:

- 25 % of nominal wall thickness for the thin-wall tubes
- 15 % of nominal wall thickness for the medium and thick wall tubes medium wall thickness or these thick-wall ones

## Deflection

The tube deflection is related to nominal length  $L = 1500$  mm

### Tubes

$\varnothing \leq 6$ mm	0,6 % of the tube length
$6 \text{ mm} \leq \varnothing \leq 10$ mm	0,4 % of the tube length
$10 \text{ mm} < \varnothing \leq 150$ mm	0,3 % of the tube length

### Rods and capillary tubes

$\varnothing \leq 6$ mm	0,6 % of the tube length
$6 \text{ mm} \leq \varnothing \leq 16$ mm	0,5 % of the tube length
$16 \text{ mm} < \varnothing \leq 30$ mm	0,15 % of the tube length

## Stones

For tubes with outside diameter of 4 - 20 mm incl. are allowed the following dimensions and numbers of stones in 1 kg of glass :

$\varnothing < 0,3$ mm	allowed
$0,3 \text{ mm} \leq \varnothing \leq 1$ mm	4 pieces in maximum per 1 kg of glass
$1 \text{ mm} < \varnothing \leq 2$ mm	2 pieces in maximum per 1 kg of glass

For tubes with outside diameter over 20 mm are allowed the following dimensions and numbers of stones in 1 kg of glass :

$\varnothing < 0,3$ mm	allowed
$0,3 \text{ mm} \leq \varnothing \leq 1$ mm	2 pieces in maximum per 1 kg of glass
$1 \text{ mm} < \varnothing \leq 2$ mm	1 piece in maximum per 1 kg of glass

For rods and capillary tubes are allowed the following dimensions and number of stones in 1 piece of product with length of 1 500 mm :

$\varnothing < 0,3$ mm	allowed
$0,3 \text{ mm} \leq \varnothing \leq 1,0$ mm	3 pieces in maximum per 1 piece of tube $\varnothing < 24$ mm
$0,3 \text{ mm} < \varnothing \leq 1,0$ mm	4 pieces in maximum per 1 piece of tube $\varnothing \geq 24$ mm

## Knots, stringy knots

### **Tubes**

$\varnothing < 0,3 \text{ mm}$	allowed
$0,3 \text{ mm} \leq \varnothing \leq 1,0 \text{ mm}$	4 pieces in maximum per 1 kg of glass
$1,0 \text{ mm} < \varnothing \leq 3,0 \text{ mm}$	2 pieces in maximum per 1 kg of glass

### **Rods and capillary tubes**

$\varnothing < 0,3 \text{ mm}$	allowed
$0,3 \text{ mm} \leq \varnothing \leq 1,5 \text{ mm}$	3 pieces in maximum per 1 piece of tube or rod $\varnothing < 24 \text{ mm}$
$0,3 \text{ mm} < \varnothing \leq 1,5 \text{ mm}$	4 pieces in maximum per 1 piece of tube or rod $\varnothing \geq 24 \text{ mm}$

### **Capillary bubbles**

Capillary bubbles to length  $\leq$  are allowed.

Total length of capillary bubbles with length  $> 20 \text{ mm}$  is allowed in maximum 1,5 m per 10 m of the tube length.

Width of capillary bubbles is allowed:

for tubes  $4 \text{ mm} \leq \varnothing \leq 40 \text{ mm}$  max. 0,2 mm

for tubes  $\varnothing > 40 \text{ mm}$  max. 0,7 mm

for rods and capillary tubes max. 0,3 mm

### **Notes**

- Tubes up to  $\varnothing 43 \text{ mm}$  are delivered in the not cooled stage, if it is not agreed in other way.  
Tubes of  $\varnothing 44 \text{ mm}$  and bigger are standardly delivered in the cooled stage.  
Rods and capillary tubes are delivered in the not cooled stage, if it is not agreed in other way.
- If it is not agreed with customer in other way, tubes of outside diameter 8 – 40 mm are protected on surface with PE cover to increase their resistance against scratches.
- In additional to the standard forms of profiled tubes mentioned in catalogue it is possible to ask for other forms of profiled tubes.