COMPARATIVE VALUES OF BOROSILICATE GLASSES

Glass Code Source Trade Name	7740 Corning Pyrex	8330 Schott Duran	KG-33 Kimble Kimax	Kavalier Simax
Expansion 10^{-7}/ °C	32.5	33.0	32.0	33.0
Strain Point °C	510	525	513	510
Annealing Point °C	560	560	565	560
Softening Point °C	821	820	827	820
Working Point 0C	1252	1260	1255	1260
Density gm / cm^3	2.23	2.23	2.23	2.23
Vol.Rest Log 10				
At 250 °C ohm/cm	8.1	8.0	7.9	
At 350 °C ohm/cm	6.6	6.5	6.4	
Dielectric 1MHz	At 20°C	At 25°C	At 25°C	At 20°C
K	4.6	4.6	4.6	4.6
Loss Factor 1%	2.6		2.2	
Refractive Index	1.474	1.473	1.470	1.472
Loss Factor tan d		37×10^{-4}		
Stress Optical Coef.				
$10^{-6} mm^2/N$	3.94	4.00	3.70	3.60
Melt Availability	Continuous melt (6-8 week cycles)			
Composition App Wt %				
SiO_2	80.6	81.0	80.0	80.4
B_2O_3	13.0	13.0	13.0	13.0
Na_2O+K_2O	4.0	4.0	4.0	4.2
Al_2O_3	2.3	2.0	3.0	2.4

This form should be used for reference only. Data for design and product application should be taken from the respective company's technical glass data.

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PHYSICAL PROPERTIES

Physical properties of Simax® Glass are set down by ISO standard 3585, or DIN ISO 3585 and 3585, or DIN ISO 3585 and _SN ISO 3585. They are exactly certified by approved international testing methods defined by the standards ISO, DIN ISO a _SN ISO, as shown in the table below.

PHYSICAL PROPERTIES		TESTING METHOD	CONDITIONS	SYMBOL	VALUE	DEVIATIONS	UNIT
MEAN COEFFICIENT OF LINEAR THERMAL EXPANSIVITY		ISO 7991	20°C to 300°C	a	**3.3**	±0.1	**$x10^{-6}K^{-1}$**
DENSITY		_SN 7005 13	20°C	r	**2.23**	±0.02	**$g.cm^{-3}$**
THERMAL CONDUCTIVITY			20°C a_ 100°C	l	**1.2**		**$Wm^{-1}K^{-1}$**
SPECIFIC HEAT AT CONSTANT PRESSURE			20°C a_ 100°C	C_p	**0.98**		**$x10^{3}$ $Jkg^{-1}K^{-1}$**
REFERENCE VISCOSITY POINTS	WORKING TEMPERATURE	ISO 7884-2 ISO 7884-5	$h_{f1}=10^{4}$ dPa.s	J_{f1}	**1260**	±20	**°C**
	SOFTENING POINT *(Littleton point)*	ISO 7884-2 ISO 7884-6	$h_{f2}=10^{7.5}$ dPa.s	J_{f2}	**820**	±10	**°C**
	UPPER COOLING TEMPERATURE	ISO 7884-7	$h_{f3}=10^{13.2}$ dPa.s	J_{f3}	**560**	±10	**°C**
	LOWER COOLING TEMPERATURE	ISO 7884-7	$h_{f4}=10^{14.7}$ dPa.s	J_{f4}	**510**	±10	**°C**
	TRANSFORMATION TEMPERATURE	ISO 7884-8		t_g	**525**	±15	**°C**
MODULUS OF ELASTICITY				E	**64**		**$x10^{3}MPa$**
POISSON CONSTANT				m			
TENSILE STRENGTH					**35 to 100**		**MPa**

Simax Glass has an expansion coefficient of 33 x 10^{-7}°C. Simply put, a 1.0m long rod will expand 0.33mm when heated an additional 100° C. Even with such a low rate of expansion care must be taken when designing long pipeline runs.

Density is affected by chemical composition and decreases with rising temperature of the molten glass.

MECHANICAL RESISTANCE

Generally, glass is a brittle material and fractures occur as a result of tensile stress. Mechanical properties and service life of a given product from Simax® glass are to a major part determined by surface condition. Particularly important is surface damage caused by handling (scratching) and secondary thermal treatment (cracks from handling with already cooled surface flaws). A failure can result even from a damage of 5 to 10 µm in depth. Scratch hardness of Simax® Glass is close to grade 6 (feldspar) according to the Mohs scale. Consequently, a material of the same or higher hardness can cause mechanical damage to the surface. Therefore, the glass must be handled with care!

Maximum permitted stress is 3.5 MPa, 7.0 MPa and 100 MPa in tension, bending and compression, respectively. Module of elasticity in shear G is 26,500 MPa.

TECHNICAL PROPERTIES OF SIMAX GLASS

Simax Glass® , because of its chemical composition and properties, belongs to the group of clear "hard" borosilicate glasses "3.3" characterized by high thermal and chemical stability, as defined by the international standard ***ISO 3585: Borosilicate glass 3.3*** - Properties (or by identical Czech version of the standard ***_N ISO 3585: Borosilicate glass*** - Properties, or German ***DIN ISO 3585***). The glass fully meets the requirements set down by these standards. Pyrex 7740 and Duran 8330 belong to this same class.

Simax® Glass is used in applications where the highest demands are put on products regarding their thermal and chemical stability. Its neutral formulation will not interfere with substances or preparations coming into contact with them, i.e. in chemistry, petrochemistry, food industry, cooling technologies, power engineering, metallurgy, health service, microbiology, pharmacy, engineering, laboratories, home preparation of foods.

The drawn tubing and rod products are manufactured using the latest technology that yields pristine surfaces that are smooth and pore-free, perfectly transparent, and corrosion-resistant. The quality is not only on the surface and in the glass but is also in the production methods and philosophy of Kavalier Glassworks. This process and dedication produces consistent and clearly superior results.

CHEMICAL COMPOSITION

The glass formulation is SiO_2-Al_2O_3-B_2O_3-Na_2O-K_2O.

The relative chemical composition of Simax® Glass is expressed in glass-forming oxides that are given in the table to the right.

Testing method	Content [% by weight]
SiO_2	80.4
B_2O_3	13.0
Al_2O_3	2.4
$Na_2O + K_2O$	4.2

CHEMICAL PROPERTIES

Products from Simax Glass are chemically stable, and relatively inert. They exhibit excellent resistance against the effects of water, steam, acids, and salt solutions. Their resistance to alkalis is also excellent.

The chemical resistance of Simax® Glass is determined by the ISO standard
3585 or DIN ISO 3585 and 3585 or DIN ISO 3585 and _SN ISO 3585. It is diligently certified by approved international testing methods as defined by the ISO standards DIN ISO a _SN ISO, as shown in the following table:

Chemical resistance against	Testing method	Class of resistance	Loss of	Maximum permitted value
water at 98 °C	ISO 719	HGB 1	Na_2O [mg/g]	31
water at 121 °C	ISO 720	HGA 1	Na_2O [mg/g]	62
Acids	ISO 1776	1	weight [mg/dm^2]	100
Effect of boiling water solution of mixed alkalis	ISO 695	A2	weight [mg/dm^2]	175

mechanical damage to the surface. Therefore, the glass must be handled with care!

Maximum permitted stress is 3.5 MPa, 7.0 MPa and 100 MPa in tension, bending and compression, respectively. Module of elasticity in shear G is 26,500 MPa.

THERMAL PROPERTIES

The high thermal shock resistance of Simax® Glass is afforded by its low coefficient of expansion. The excellent thermal conductivity of the material also prevents high temperature gradients from forming within the walls of the product.On cooling and heating, undesirable internal stresses can develop in the glass. Fracture of the glass by temperature change results from tensile stress on the product surface caused by linear thermal expansion of the glass during rapid cooling of the product surface. Therefore, thermal resistance of the glass object is always higher on rapid heating than on rapid cooling. Quick cooling is far more dangerous as tensile stress is generated on the surface and, with synergetic effect of mechanical damage of the product surface, fracture can take place. Mechanical damage of the product surface dramatically reduces thermal resistance! During use, the products should not be exposed to temperatures exceeding 450°C or else they should be annealed afterwards.

ANNEALING

Annealing is a thermal process whereby the strain induced in the glass from forming the glass into products is removed.

The annealing cycle is a theoretically calculated time-controlled procedure of heating and slowly cooling the glass in an annealing oven. The thermal cycling consists of three stages:

Temperature increase of the ware at a controlled rate. This ramp up will vary depending on thickness of glassware and the total mass of material in the oven.

Dwell at temperature of the product for a certain time period at the proper annealing temperature. The purpose is to allow all strain previously induced in the glass to dissipate. The "soaking period" will also vary according to product thickness and oven load.

Cool Down of the product at the cooling rate from lower annealing temperature to final temperature or to the surrounding temperature (this is important for subsequent practical handling of products).

A typical cooling cycle is given in the following table:

Temperature range [°C]	20 - 550	560	560 - 490	490 - 440	440 - 40
MAXIMUM COOLING CYCLE THICKNESS OF WALL [mm]	TEMPERATURE INCREASE [°C.min^{-1}]	DWELL AT TEMPERATURE [min]	TEMPERATURE DROP [°C.min^{-1}]		
3	140	5	14	28	140
6	30	10	3	6	30
9	15	18	1.5	3	15
12	8	30	0.6	1.6	8

OPTICAL PROPERTIES

Wavelength [nm]	Refractive index	Value
404.66	n_h	1.48419
486.13	n_f	1.47724
546.07	n_e	1.47403
589.30	n_d	1.47231
656.27	n_c	1.47011

Simax® Glass is clear and colourless, it does not show any marked absorption in the visible spectrum. Transmittance of ultraviolet rays is higher than that of common sheet glass which makes it possible to use glass products for photochemical reactions.

The ***Refractive index*** of Simax® Glass is close to that of pure quartz and is lower than that of common alkaline lime-silicate glasses. The values of refractive index for main spectral lines are shown in the following table. Photoelastic constant is $3.6.10^{-6}$ MPa^{-1}.

Irradiation of the glass Simax® with UV light and hard radiation causes solarization (browning) which fades away by heating up to 400°C to 450C.

ELECTRIC PROPERTIES

Under normal temperatures Simax® Glass is non-conductive - it acts as an insulator. Specific electric resistance of the glass Simax® at room temperature (20°C) and in a humidity-free environment is higher than 10^{13} to 10^{15} Ω.cm (specific resistance of insulants should be higher than 10^{10} to 10^{12} Ω.cm).

Due to atmospheric humidity at temperatures up to 100°C, glasses are generally covered with an adsorbed thin layer of water, a very weak surface conductivity occurs, surface resistance is reduced with rising relative humidity of the atmosphere and, up to 100°C, also with rising surface temperature of the insulant.

Surface resistance in a humidity-free environment is 10^{15} per square, at the relative humidity of 50% it is 10^{10} to 10^{13} Ω per square which fully meets the conditions put on insulants.

Electric strength is given by two aspects: Either dielectric breakdown takes place when actual electric strength of the material is reached and an electric impulse wave is generated, or thermal breakdown occurs when the insulant is locally heated up and, at the same time, electric resistance is reduced which results in a spontaneous passage of electric current.

Electric strength is approximately 1000 $kVcm^{-1}$ in air and 10 $kVcm^{-1}$ in oil. The limit value of 10 000 $kVcm^{-1}$ is seldom reached because of rupture of the insulant after localized heating caused by dielectric losses at higher frequencies. .

Generally, dielectric losses are expressed by a loss factor as the product of permittivity ε (ratio of capacitance of the capacitor with the glass dielectric to the ideal one) and loss angle tg δ (δ is angle vector of total current with respect to charging ideal capacitor). The losses increase steeply with rising temperature and change with frequency. in such a way that their minimum is at about 10^6 Hz. More detailed data are given in the following table:

Dependence	Frequency [Hz] (20°C)			Temperature [C] (1MHz)			
Value	10^3	10^6	3.10^9	20	100	200	300
x	4.7	4.6	4.5	4.6	4.7	5.1	5.7
tg * $.10^3$	8.6	4.9	6.4	4.9	9.0	30.0	150.0

Neither Simax® Glass nor other glasses of the group "3.3" are glasses of low losses (max. loss factor is $50x10^{-4}$, for Simax® Glass at 1MHz and 20°C is $184x10^{-4}$). Nevertheless, low values of permittivity render this glass ideally suited as an insulator.