200 S. Hallock Drive
Santa Paula, CA 93003
(805)525-4902 • (805) 525-8604 Fax

BOROFLOAT® Borosilicate Float Glass

Schott offers a highly chemically resistant borosilicate glass with a low thermal expansion that is being manufactured by the float method. BOROFLOAT® is a technologically significant development, achieving unsurpassed quality for flat borosilicate glass. It replaces TEMPAX®, a drawn flat borosilicate glass. The high quality resulting from the float glass process opens up new applications for borosilicate flat glass, which has proven itself over time in laboratories, chemical process plants and in the home appliance and lighting industries.

BOROFLOAT® flat glass is highly resistant to water; neutral, acidic and saline solutions; as well as to chlorine, bromine, iodine and organic substances. Even over long periods of time and at high temperatures that exceed 100°C, BOROFLOAT® exceeds the chemical resistance of most metals and other materials.

Chemical Data

- Hydrolytic Resistance (ISO-719-HGB) 1
- Hydrolytic Resistance (ISO 720-HGA) 1
- Acid Resistance (ISO 1776) 1
- Alkali Resistance (ISO 695-A) 2

Mechanical Properties

- Density (@ 25°C/77°F) 2.23 g/cm^3
- Modulus of Elasticity 63 kN/mm^2
- Knoop Hardness HK 0.1/20 (according to E DIN/ISO 9385) 480
- Poisson's Ratio 0.2

Electrical Properties

- Dielectric Constant (@ 1 MHz & 25°C) 4.6
- Loss Tangent (@ 1 MHz & 25°C) 37 x 10^{-4}
- Dielectric Strength(@ 50 Hz & 25°C) 16 kV/mm
- Electric Volume Resistivity (log ρ)
  @ 250°C 8.0
  @ 350°C 6.5

Physical Impact

The resistance of BOROFLOAT® to physical impact depends on the type of installation, the size and thickness of the glass panel, the type of physical impact, in addition to other parameters.

Optical Properties

- Refractive Index (n_d) 1.472
- Dispersion ($n_F - n_C$) 71.9 x 10^{-4}

Thermal Properties

- Linear Thermal Coefficient of Expansion α
  (20-300°C/ 68-572°F) 3.25 x 10^{-6}/°K
- Transformation Temperature T_g 530°C/986°F
- Annealing Point (10^{13} dPa•s) 560°C/1040°F
- Softening Point (10$^{7.6}$ dPa•s) 815°C/1508°F
- Thermal Conductivity k
  @ 90°C 1.12 W/(m•°K)
  @ 194°F 0.65 Btu•ft/h•ft^2•°F
- Mean Specific Thermal Capacity c_p
  20-100°C 0.83 kJ/(kg•°K)
  68-212°F 0.19 Btu/lb•°F
- Maximum Operating Temperature
  (Considering RTD[1])
  Short term 500°C/932°F
  Long term 450°C/842°F
- Resistance to Temperature Differences (RTD[1])
  Short term exposure
  (1 hour) 110°K/198°R
  (1-100 hours) 90°K/162°R
  Long term exposure
  (>100 hours) 80°K/144°R
- Resistance to Thermal Shock (RTS[2])
  Thickness <4 mm 175°K/315°R
  Thickness 4-6 mm 160°K/288°R
  Thickness 6-15 mm 150°K/270°R
  Thickness >15 mm 140°K/252°R

0204
Supersedes All Previous Releases

Sheet Sizes and Tolerances

Stock sizes (standard) ±2.0 mm
1150 x 850 mm^2 (45.3 x 33.5 $in.^2$) [0.7 - 21 mm]
1700 x 1300 mm^2 (66.9 x 51.2 $in.^2$) [16 - 21 mm]
2300 x 1700 mm^2 (90.5 x 66.9 $in.^2$) [3.3 - 15 mm]

Standard Thickness

Nominal Thickness (mm)	Tolerance (mm)
0.7	±0.07
1.1	±0.1
1.75	±0.2
2.0	±0.2
2.25	±0.2
2.75	±0.2
3.3	±0.2
3.8	±0.2
5.0	±0.2
5.5	±0.2
6.5	±0.2
7.5	±0.3
9.0	±0.3
11.0	±0.3
13.0	±0.3
15.0	±0.3
16.0	±0.5
19.0	±0.5
21.0	±0.7
25.4	±1.0

[1]RTD = Resistance to Temperature Differences
Panels measuring 25 x 25 cm^2 (10 x 10 inches) are heated in the center of the panel to a defined temperature, and the edges are maintained at room temperature. An RTD value is the difference in temperature between the hot center of the panel and the cool panel edge, at which breakage occurs to less than or equal to 5% of the samples.

Before the testing, the samples are abraded with sandpaper of grain size 40. This simulates extreme damage which is possible in usage.

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[2]RTS - Resistance to Thermal Shock
Panels measuring 20 x 20 cm^2 (8 x 8 inches) are heated in an oven with circulating air and afterwards are doused in the center with 50 ml of cold (room temperature) water.

The RTS value is the difference in temperature between the hot panel and the cold (room temperature) water, at which breakage occurs to less than or equal to 5% of the samples.

Before being heated, the samples are abraded with emery paper of grain size 220. This simulates a typical state of the surface in practical use.

All data are intended to be used as guidelines, unless otherwise stated. Please contact Schott should you have additional technical questions.

CONTENTS

SCHOTT JENA^{er} GLAS GmbH

1. General Information

1.1. Area of Application

This product specification applies to the quality assurance of BOROFLOAT® 33 at SCHOTT JENA^{er} GLAS GmbH and at the customer's facility. It describes the quality parameters of BOROFLOAT® 33 in standard sheet sizes (raw glass).

1.2. Validity

This product specification is valid with receipt of a written agreement by SCHOTT JENA^{er} GLAS GmbH and supercedes all previous versions with the same title. Amendments to the specification will be valid only if presented in writing and after a written agreement has been issued by SCHOTT JENA^{er} GLAS GmbH.

2. Material Properties

BOROFLOAT® 33 is a product exclusively manufactured by SCHOTT JENA^{er} GLAS GmbH via a float process from SCHOTT DURAN®, a borosilicate glass 3.3 (material properties per DIN ISO 3585 - section 5 and material nomenclature per DIN 1259).

The floating process produces BOROFLOAT® 33 with mirror-like surfaces on both sides, as well as outstanding optical quality. Compared to conventional soda-lime glass (e.g. common window glass) BOROFLOAT® 33 offers greater chemical resistance and a lower thermal expansion coefficient, whereby it can withstand higher temperature differences across the surface and through the thickness of the sheet.

The composition of BOROFLOAT® 33 consists of very special raw materials that are difficult to melt. This may lead to the formation of minor inhomogeneous features such as bubbles, stones, cords, etc.
BOROFLOAT® 33 is subjected to strict quality control procedures assuring that any inhomogeneous features present will affect only the visual appearance and not the product' s general function or suitability for a specific application.

BOROFLOAT® 33 complies with the demands of the EN standard 1748-1 "Glass in the construction industry - special base products - part 1: Borosilicate glasses". It corresponds to section 8, standard class 1, category A.

BOROFLOAT® 33 is offered in a thickness range between 0.7 – 25.4 mm and in several different standard sheet sizes. Due to the wide thickness range available and the variety of end use applications it is difficult to assign one standard specification for all thicknesses. Therefore, this specification contains three appendixes (Thin glass - Appendix 1, Medium thickness glass - Appendix 2 and Thick glass - Appendix 3).

2.1. Chemical, Physical and Transmission Data

The following chemical and physical data for SCHOTT DURAN®, a borosilicate glass 3.3, corresponds to the International Standard ISO 3585, edition October 1999.

2.1.1. Chemical Resistance Data

Hydrolytic Resistance class at 98 °C
Class 1
Test method ISO 719-HGB

Hydrolytic Resistance class at 121 °C
Class 1
Test method ISO 720-HGA

Acid Resistance
Class 1
Test method: ISO 1776

Alkali Resistance
Class 2
Test method: ISO 695-A

2.1.2. Physical Data

Linear thermal expansion coefficient
$\alpha_{(20 - 300°C)} = (3.3 \pm 0.1) \times 10^{-6}$/°K according to test method: ISO 7991

Density
$\rho = 2.23\ g/cm^3 \pm 0.02\ g/cm^3$

Mean thermal conductivity (20°C to 200°C)
k = 1.2 W/m°K

Mean specific heat capacity at a constant pressure (20°C to 100°C)
c_p= 0.8 x 10_ J/kg°K

Viscosity temperature behavior
$\eta_1 = 10^4$ dPa· s at a temperature T1 = 1,260°C ± 20°C
$\eta_2 = 10^{7.6}$ dPa· s at a temperature T2 = 825°C ± 10°C
$\eta_3 = 10^{13}$ dPa· s at a temperature T3 = 560°C ± 10°C

Measuring procedures:

Rotation Viscometer	according to ISO 7884-2
Tensile Viscometer	according to ISO 7884-3
Bending Viscometer	according to ISO 7884-4

Transformation temperature
T_g = 525°C ± 15°C
Test method: according to ISO 7884-8

Elasticity Modulus
E = 64 kN/mm_ = 64 x 10_ MPa

Poisson`s Ratio
ν = 0.20

Maximum value of the tensile strength*
R_m = 35 to 100 N/mm^2 (35 to 100 MPa)

*This data is for reference only and not to be used as standard values for calculating glass strength.

2.1.3 Transmission Data

BOROFLOAT®33 is a clear transparent glass. The following light transmission measurements were performed according to DIN EN 410 using a standard D 65 light source. These measurements were conducted in Schott's testing laboratory.

Table 1: Standard values for light transmission (τ_v)

Nominal Thickness (mm)	Light Transmission τ_v (%)
0.70	92.8
1.10	92.7
1.75	92.6
2.00	92.6
2.25	92.5
2.75	92.5
3.30	92.4
3.80	92.3
5.00	92.1
5.50	92.0
6.50	91.8
7.50	91.6
9.00	91.4
11.00	91.0
13.00	90.7
15.00	90.4
16.00	90.2
19.00	89.7
21.00	89.3
25.40	88.7

3. Quantitative Properties

3.1. Sheet thickness

BOROFLOAT® 33 is offered in the following standard thicknesses:

Table 2: Nominal thickness and tolerance

Nominal Thickness (mm)	Thickness Tolerance (mm)
0.70	± 0.07
1.10	± 0.1
1.75	± 0.1
2.00	± 0.2
2.25	± 0.2
2.75	± 0.2
3.30	± 0.2
3.80	± 0.2
5.00	± 0.2
5.50	± 0.2
6.50	± 0.2
7.50	± 0.3
9.00	± 0.3
11.00	± 0.3
13.00	± 0.5
15.00	± 0.5
15.30	± 0.5
16.00	± 0.5
19.00	± 0.5
21.00	± 0.7
25.40	±1.0

The sheet thickness is monitored online with a laser thickness measuring device. Requests for other nominal thicknesses and tolerances should be discussed with the manufacturer.

3.2. Squareness

The tolerances for squareness of delivered sheets are illustrated in the figure and table below and comply with DIN-EN 1748-1, section 6.2.

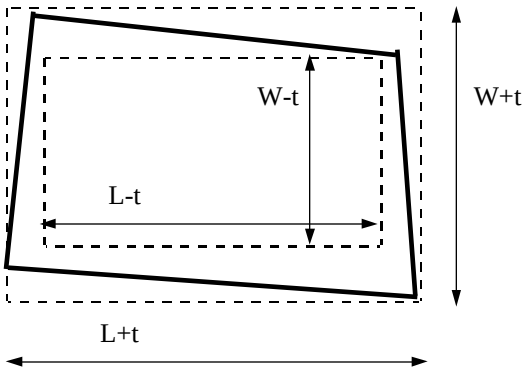

Table 3: Tolerance for squareness

Tolerance (t)	Nominal size (L) or (W)
± 5.0 mm	≤ 1,000 mm
± 10.0 mm	> 1,000 mm

Explanation concerning tolerance for squareness (DIN-EN 1748-1)

The nominal dimensions for the length (L) and the width (W) of a standard size sheet will reside within the tolerance band defined by the larger and smaller "dotted" reference squares. The sides of the reference squares must run parallel to one another and both must have a common center point.

Squareness is limited by the tolerance band created between the larger and smaller reference squares. The squareness of standard size sheets is controlled by a computerized cutting process.

3.3. Optical distortion

Optical distortion is described as the appearance of objects when viewing the sheet at an angle less than (90°) perpendicular to the surface.
The distortion is determined by measuring the zebra angle according to (DIN EN 572-2, "Base glass products, floated glass"). This is a standard test procedure for float glass manufacturing.

The test sheet is placed in front of a zebra wall (illuminated wall with black and white strips running diagonally at 45°) and viewed from a defined distance. Possible distortions will appear by rotating the test sheet from the initial viewing position (90°- zebra angle) to the parallel viewing position (0°- zebra angle).

Standard values for the zebra angle of several glass thicknesses have been measured via DIN EN 572-2 and are indicated in the table below.

Table 4: Standard values for zebra angle

Nominal Thickness (mm)	Zebra Angle
2.00 – 2.75	45 °
3.30 – 3.80	50 °
5.00 – 7.50	55 °

Excluded from the viewing is a 100 mm wide strip on the left and right edges.
Lower zebra angles can be achieved. Requests for the zebra angles of other thicknesses should be discussed with the manufacturer.

3.4. Tin Residue

As with the production of soda-lime float glass, a tin residue will appear on BOROFLOAT® during manufacturing. Tin residue on the topside of the glass may result from the condensation of evaporated tin present in the atmosphere of the float bath. For BOROFLOAT® 33, the amount of tin on either the tin contact side (top) or the atmosphere side (bottom) is substantially lower than that found on soda-lime glass. The tin content in BOROLFOAT® has been found to have no effect on properties in comparison to TEMPAX® drawn borosilicate glass, and should not result in any disadvantages, e.g. for coatings. However, it is

recommended that the topside be used for coatings. The manufacturer labels the topside (atmosphere side) of the float glass.

4. Qualitative Characteristics

4.1. Visible Defects

Visible defects change the visual quality of the product. An online detection system automatically locates the defects during production. Unacceptable defects are sorted and removed.

The glass is inspected and defects are evaluated as follows: the glass sheet is placed in front of a matte black background and inspected by the naked eye at a distance of 2 meters (6.5 feet) with a diffused light (2 kLux), similar to daylight. The form of the defect is determined without regard to the surrounding defect region.

A distinction is made between point and line defects. Point defects are gas bubbles, solid inclusions, knots and spot deposits on the surface. Line defects are scratches, streaks, marks or deposits which are inside the glass or on the surface and take up a certain length or area.

4.1.1. Unacceptable Defects

Unacceptable defects reduce the usability of the product, which leads to a reduction in the quality of the sheets for transportation and inventory. They are sorted and removed by a quality detection and selection system.

Table 5: Types of unacceptable defects

Defect	Visibility
Scratches	deep, visible and can be felt
Cracks	all visible sizes
Broken sheet	unacceptable
Drip*	all visible sizes
Open bubbles	all visible sizes
Stones	all visible sizes

* A drip is produced by the condensation of alkali-borates, released from the float bath, on the glass surface.

4.1.2. Acceptable Defects

Acceptable defects do not impair the usability of the glass. The allowable size and quantity of these defects will not adversely affect the use of the glass in normal applications.

Acceptable defects are considered to be small closed blisters, knots, and streaks. Acceptable defects may not appear in clusters; the minimum distance between any two acceptable defects must be at least 50 mm (approx. 2”). Defects less than 0.5 mm (0.020”) are not considered unless they occur in clusters.

Refer to the appendixes for more information regarding acceptable defects for different glass thicknesses.

5. Quality assurance

The BOROFLOAT® 33 flat glass sheets are continuously checked during the manufacturing process in order to ensure compliance with the product specification. Should defects appear in the material delivered, however, SCHOTT JENA^{er} GLAS GmbH requires the following information for processing a rejection claim:

- Glass dimensions (length, width, thickness)
- Quantity of material
- SCHOTT - order number
- Customer purchase order number
- Order date
- Crate tag
- Written statement regarding the type, quantity and size of defect(s) found

If material is rejected because defects covered (or not covered) in this specification are found, an agreement regarding remedial action between SCHOTT JENA^{er} GLAS GmbH and the customer must be made prior to any further processing. Rejected material will not be credited or replaced until the

glass has been evaluated by SCHOTT JENA[er] GLAS GmbH. Therefore, the glass is treated as acceptable material until the evaluation has been completed.

Appendix 1

Thin Glass

BOROFLOAT® 33 thin glass is becoming more important in the following high tech applications:

- substrate glass for electronics
- substrate glass for optical filters
- substrate glass for coatings
- substrate glass for sensors
- substrate glass for genetic analysis

In order to fulfill the demands of these applications, BOROFLOAT® 33 thin glass sheets are manufactured almost defect free with extremely low warp and excellent waviness characteristics.

Special process modifications are required when manufacturing thin float glass. For instance, the throughput must be reduced in comparison to classical thicknesses.

A1-1 Sheet Thickness and Tolerance

BOROFLOAT® 33 thin glass is offered in the following standard thicknesses:

Table A1-1: Nominal thickness and tolerance

Nominal Thickness (mm)	Thickness Tolerance (mm)
0.70	± 0.07
1.10	± 0.1
1.75	± 0.1

Requests for tighter tolerances among and within sheets are to be coordinated with the manufacturer.

A1-2 Sizes

BOROFLOAT® 33 thin glass is offered in the following standard sizes:

Table A1-2: Standard sizes and packaging

Size Length (L) x Width (W)	Packaging Type
1,150 mm x 850 mm	Wooden case or tri-wall container

Special sizes and packaging should be coordinated with the manufacturer.

A1-3 Acceptable Defects

Table A1-3: Allowable quantity of acceptable defects

Sizes	Acceptable Defects per m_	Maximum Number of Defects per m_
> 0.5 mm < 2.5 mm	2	2
> 2.5 mm < 5.0 mm	1	

The definition for acceptable defects can be found in section 4.1.2.

A1-4 Surface Morphology

For many thin glass applications, the surface quality is important. The surface is often characterized by the degree of warp and waviness present. The surface morphology can be measured and the data will be provided upon request for an additional charge. The following values serve as a reference only.

A1-4.1 Warp

For BOROFLOAT® 33 thin glass, the warp can be controlled to < 200 µm along a glass sheet length of 400 mm. S-waves (concave and convex curves in sequence) can be avoided. The extrapolation of the warp values for larger sheet sizes is limited because the measured results will be influenced by how the sheet is stored and the amount of pressure applied to the sheet, causing it to bend, while the measurement is taken.

The warp of BOROFLOAT® 33 thin glass sheets is measured by a set of feelers while the sheets are supported on a flat plain (e.g. granite plate).

A1-4.2 Waviness

The waviness of float glasses is not constant. The value depends on the processing speed, glass thickness and location within the ribbon. An essential difference exists between the topside (atmosphere side) and the bottom side (tin side). Typically, the bottom side shows lower degrees of waviness, which could be important for further processing (e.g. polishing or coating).

An average production period of BOROFLOAT® 33 thin glass sheets shows waviness values of < 0.150 µm (top side) and < 0.100 µm (bottom side) for a thickness of 0.7 mm.

The waviness values of BOROFLOAT® 33 thin glass sheets are measured with a surface tactile scanner (e.g. Taylor Surfe). The selection for the measuring parameters complies with the International Standards of Thin Glass Suppliers.

Different waviness requirements can be achieved and measurements can be provided for an additional charge and should be coordinated with the manufacturer.

A1-4.3 Roughness

The roughness values for both surfaces, the tin side and the atmosphere side, are relatively minor as a result of the float process. Typical values for roughness are < 2 nm and are therefore comparable to an optically polished surface. Roughness measurements can be provided for an additional charge and should be coordinated with the manufacturer.

Appendix 2

Medium Thickness Glass

BOROFLOAT® 33 medium thickness glass is used for applications such as:

- oven baking trays
- lamp covers
- glazing for home fireplaces
- microwave oven trays
- substrates for electronic applications
- substrates for microscopy and measuring scales
- chemical reactor trays
- other applications that require excellent thermal and chemical resistance.

BOROFLOAT® 33 medium thickness glass satisfies many diverse applications with a variety of thicknesses offering high surface quality. Other borosilicate glasses in this thickness range are commonly manufactured by the Top Rolling Method.

A2-1 Sheet Thickness and Tolerance

BOROFLOAT® 33 medium thickness glass is offered in the following standard thicknesses:

Table A2-1: Nominal thickness and tolerance

Nominal Thickness (mm)	Thickness Tolerance (mm)
2.00	± 0.2
2.25	± 0.2
2.75	± 0.2
3.30	± 0.2
3.80	± 0.2
5.00	± 0.2
5.50	± 0.2
6.50	± 0.2
7.50	± 0.3

9.00	± 0.3
11.00	± 0.3

A2-2 Sizes

BOROFLOAT® 33 medium thickness glass is available in the following standard sizes:

Table A2-2: Standard sizes and packaging

Size Length (L) x Width (W)	Packaging Type
2,300 mm x 1,700 mm	Wooden case
1,150 x 850 mm	Wooden case or tri-wall container

Special sizes and packaging should be coordinated with the manufacturer.

A2-3 Acceptable Defects

Table A2-3: Allowable quantity of acceptable defects

Sizes	Acceptable Defects per m_	Maximum Number of Defects per m_
> 0.5 mm < 2.5 mm	4	4
> 2.5 mm < 5.0 mm	2	

The definition for acceptable defects can be found in section 4.1.2.

Appendix 3

	Initiated	Approved	Approved	Released
Organization	FJQ/UL	FJF/Ltr	FJV/Kls	FJ/KSc
Date				
Signature				

Thick Glass

BOROFLOAT® 33 thick glass sheets are used for applications such as:

- sight and gauge glasses for vessels and instrumentation
- support material for wafer polishing
- support material for microscopy
- glazing for iron and steel plants
- trays for distillation columns
- other applications where excellent thermal and chemical resistance, mechanical integrity, and high transparency are required.

Compared to the standard float process for BOROFLOAT® 33, thick glass sheets are manufactured by using additional carbon fenders. This modified technology, along with higher operating temperatures and lower production speeds, will result in sheets with greater thickness tolerances and smaller band widths.

A3-1 Sheet Thickness and Tolerance

BOROFLOAT® 33 thick glass is offered in the following standard thicknesses:

Table A3-1: Nominal thickness and tolerance

Nominal Thickness (mm)	Thickness Tolerance (mm)
13.00	± 0.5
15.00	± 0.5
16.00	± 0.5
19.00	± 0.5
21.00	± 0.7
25.40	±1.0

A3-2 Sizes

The cut (raw) edges can show irregular breaks at the starting points of the cutting or breaking tools. Higher thicknesses can show positive or negative deviations within the first 30 mm of a maximum length of 100 mm per side. This will not reduce glass quality.

BOROFLOAT® 33 thick glass is available in the following standard sizes:

Table A3-2: Standard sizes and packaging

Sizes Length (L) x Width (W)	Thickness	Packaging Type
2,300 x 1,700 mm	13.0 – 16.0	Wooden case
1,700 x 1,300 mm	17.0 – 21.0	Wooden case
1,150 x 850 mm	13.0 – 25.0	Wooden case or tri-wall container

Special sizes and packaging should be coordinated with the manufacturer.

A3-3 Acceptable Defects

Table A3-3: Allowable quantity of acceptable defects

Sizes	Acceptable Defects per m_	Maximum Number of Defects per m_
> 0.5 mm < 2.5 mm	10	10
> 2.5 mm < 5.0 mm	3	

The definition for acceptable defects can be found in section 4.1.2.