BRITISH STANDARD

BS EN 1595 : 1997

Pressure equipment made from borosilicate glass 3.3 — General rules for design, manufacture and testing

The European Standard EN 1595 : 1997 has the status of a British Standard

ICS 71.120.10; 81.040.30

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PSE/13, Glass piping, upon which the following bodies were represented:

British Glass Manufacturers' Confederation
Chemical Industries Association
Institution of Chemical Engineers
Society of Glass Technology
Coopted members

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National foreword

This British Standard has been prepared by Technical Committee PSE/13, and is the English language version of EN 1595 : 1997, published by the European Committee for Standardization (CEN). It supersedes BS 2598 : Part 1 : 1991 which is withdrawn.

Cross-references

Publication referred to	Corresponding British Standard
	BS 3473 *Chemical resistance of glass used in the production of laboratory glassware*
ISO 695 : 1991	Part 1 : 1991 *Method for determination of resistance of glass to attack by a boiling aqueous solution of mixed alkali*
ISO 719 : 1985	Part 2 : 1987 *Method for determination of hydrolytic resistance of glass grains at 98 ˚C*
ISO 720 : 1985	Part 3 : 1987 *Method for determination of hydrolytic resistance of glass grains at 121 ˚C*
ISO 1776 : 1985	Part 5 : 1987 *Method for determination of resitance of glass to attack by 6 mol/L hydrochloric acid at 100 ˚C*
	BS 7034 *Viscosity and viscometric fixed points of glass*
ISO 7884-8 : 1987	Part 8 : 1988 *Method for the determination of (dilatometric) transformation temperature*
ISO 7991 : 1987	BS 7030 : 1988 *Method for determination of the coefficient of mean linear thermal expansion of glass*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 8, an inside back cover and a back cover.

EUROPEAN STANDARD

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English version

Pressure equipment made from borosilicate glass 3.3 — General rules for design, manufacture and testing

Equipement sous pression réalisés en verre borosilicate 3.3 — Règles générales pour calculs, fabrication et essais

Druckgeräte aus Borosilicatglas 3.3 — Allgemeine Grundsätze für Berechnung, Herstellung und Prüfung

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CEN

European Committee for Standardization

Comité Européen de Normalisation

Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN 1595 : 1997 E

Foreword

This European Standard has been prepared by CEN/CS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 1997, and conflicting national standards shall be withdrawn at the latest by July 1997.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

It has been assumed in the drafting of this European Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

1 Scope

This European Standard specifies material, design, inspection, testing and marking requirements of pressure equipment (e.g. vessels, pipes, valves) made from borosilicate glass 3.3 with a coefficient of mean linear thermal expansion of $(3,3 \pm 0,1) \times 10^{-6}\ K^{-1}$.

It is not applicable to:

– circular, flat and tubular sight glasses;

– equipment made from borosilicate glass with another coefficient of thermal expansion.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

ISO 695	*Glass — Resistance to attack by a boiling aqueous solution of mixed alkali — Method of test and classification*
ISO 719	*Glass — Hydrolytic resistance of glass grains at 98 degrees C — Method of test and classification*
ISO 720	*Glass — Hydrolytic resistance of glass grains at 121 degrees C — Method of test and classification*
ISO 1776	*Glass — Resistance to attack by hydrochloric acid at 100 degrees C — Flame emission or flame atomic absorption spectrometric method*
ISO 7884-8	*Glass — Viscosity and viscometric fixed points — Part 8: Determination of (dilatometric) transformation temperature*
ISO 7991	*Glass — Determination of coefficient of mean linear thermal expansion*

3 Symbols and units

For the purposes of this European Standard the following symbols and their definitions apply:

c_p	specific heat capacity	$kJ \cdot kg^{-1} \cdot K^{-1}$
$c_{p20/100}$	mean specific heat capacity between 20 °C and 100 °C	$kJ \cdot kg^{-1} \cdot K^{-1}$
$c_{p20/200}$	mean specific heat capacity between 20 °C and 200 °C	$kJ \cdot kg^{-1} \cdot K^{-1}$
E	modulus of elasticity	$kN \cdot mm^{-2}$
K	strength characteristic	$N \cdot mm^{-2}$
S	safety factor	—
$\frac{K}{S}$	permissible stress to be employed for calculations	$N.mm^{-2}$
ΔT	temperature difference between inner and outer surface of the wall	K
θ_a	temperature of the medium around the pressure equipment	°C
θ_B	maximum temperature of the medium in contact with glass	°C
θ_g	transformation temperature	°C
θ_i	temperature of the medium in the pressure equipment	°C
α	coefficient of linear thermal expansion	K^{-1}
$\alpha_{20/300}$	coefficient of mean linear thermal expansion over the range between 20 °C and 300 °C	K^{-1}
λ	thermal conductivity	$W \cdot m^{-1} \cdot K^{-1}$
$\lambda_{20/200}$	mean thermal conductivity between 20 °C and 200 °C	$W \cdot m^{-1} \cdot K^{-1}$
ν	Poisson's ratio (transverse contraction ratio)	—
ρ	density	$g \cdot cm^{-3}$
σ_T	thermal wall stress, stress as a consequence of linear temperature gradient	$N \cdot mm^{-2}$
$\Delta\theta$	temperature difference $\theta_i - \theta_a$	K

4 Material

4.1 Properties

For the construction of glass pressure equipment borosilicate glass 3.3 having the properties specified in table 1 shall be used.

Table 1. Characteristic values, application limits and chemical resistance of borosilicate glass 3.3

Coefficient of mean linear thermal expansion Test method: ISO 7991	$\alpha_{20/300} = (3{,}3 \pm 0{,}1)\ 10^{-6}\ K^{-1}$
Mean thermal conductivity between 20 °C and 200 °C	$\lambda_{20/200} = 1{,}2\ W{\cdot}m{\cdot}^{-}K^{-1}$
Mean specific heat capacity between 20 and 100 °C	$c_{p20/100} = 0{,}8\ kJ{\cdot}kg^{-1}{\cdot}K^{-1}$
Mean specific heat capacity between 20 and 200 °C	$c_{p20/200} = 0{,}9\ kJ{\cdot}kg^{-1}{\cdot}K^{-1}$
Density at 20 °C	$\rho = (2{,}23 \pm 0{,}02)\ g{\cdot}cm^{-3}$
Modulus of elasticity	$E = 64\ kN{\cdot}mm^{-2}$
Poisson's ratio (transverse contraction ratio)	$\nu = 0{,}2$
Transformation temperature Test method: ISO 7884-8	$\theta_g = (525 \pm 15)$ °C
Maximum temperature of the medium in contact with glass[1)]	$\theta_B \leq 300$ °C
Hydrolytic resistance at 98 °C Test method: ISO 719	Hydrolytic resistance grain class ISO 719-HGB1
Hydrolytic resistance at 121 °C Test method: ISO 720	Hydrolytic resistance grain class ISO 720-HGA1
Acid resistance Test method: ISO 1776	Sodium oxide (Na_2O) $\leq$ 100 µg per 1 dm^2 of glass when the glass 'as a material' is tested (including preliminary acid treatment)
Resistance to attack by a boiling aqueous solution of mixed alkali Test method: ISO 695	Alkali resistance class ISO 695-A2 or better

[1)] With temperatures $\theta_B \leq$ 200 °C special precautions shall be taken for the prevention of abrupt temperature fluctuations.

4.2 Quality

The glass shall be annealed to commercially acceptable quality and shall be homogeneous enough to be free from imperfections, which can affect the mechanical strength.

Types of imperfections and criteria for acceptability shall be as given in table 2.

Table 2. Types of imperfections and criteria for acceptability

Types of imperfections	Description	Criteria for acceptability
Solid inclusions	Solid inclusions are non-transparent inclusions in the solidified glass. The solid inclusions may be both undissolved constituents of the glass batch, and also foreign bodies, e.g. particles from the refractory lining of the furnace or constitutents of glass that have crystallized out.	Solid inclusions which lie in the vicinity of the surface of the glass, and which therefore deform or interrupt the line of the surface and can thus be detected by touch, are not permissible. Solid inclusions from which cracks extend into the surrounding glass are not permissible. Solid inclusions within the glass wall are permissible: – if their diameter is no greater than 50 % of the wall thickness, but does not exceed 4 mm; – and if the distance between them is at least ten times the diameter of the smaller inclusion.
Bubbles	Bubbles are gaseous inclusions. They may be closed or open. Open bubbles are bubbles that have opened up at the surface of the glass wall, or bubbles sited at such a short distance beneath the surface that they can be made to collapse easily.	Open bubbles or bubbles which can be made to collapse easily are not permissible. Closed bubbles are permissible if the sum of their breadth and length is no greater than 30 mm, the breadth is no greater than 10 mm and the bubbles thickness is less than 50 % of the wall thickness but does not exceed 4 mm.
Knots	Knots are roundish integrated inhomogeneities within the glass. They have a different refractive index and are therefore visible.	Knots from which cracks extend into the surrounding glass are not permissible.
Cords	Cords are filamentary or threadlike inhomogeneities in the glass which for the most part follow a twisting path. They have a different refractive index and are therefore visible.	Cords from which cracks extend into the surrounding glass are not permissible.
Cracks	Cracks are breaks in the glass body which propagate right through or partly through the wall thickness.	Cracks are not permissible.
Scratches	The term scratches is used to describe damage to the surface of the glass which follows a linear path, is rough and which as a rule has a dull appearance.	Scratches which can be detected clearly by touch, and those associated with cracking, are not permissible.
Knocks	Knocks are points at the surface of the glass which have been chipped as a consequence of impacts or blows.	Knocks are not permissible.

5 Certification of quality characteristics

By marking as defined in clause **8**, the manufacturer certifies the following:

1) that the type of glass designated through the application of his brand name has the specified physical and chemical properties of borosilicate glass 3.3;

2) that the shape, dimensions and wall thickness requirements have been met.

6 Strength characteristics for design

6.1 If the surface is ground and polished or simply ground, or if an initially flame-polished undamaged surface is altered as a result of mechanical effects (e. g. scratches) when being utilized in the manner intended, or if it is possible for it to be altered under service conditions, the permissible tensile stress shall be:

$$\frac{K}{S} = 7\ \mathrm{N{\cdot}mm^{-2}}$$

6.2 If the flame-polished surface produced during the hot-forming process has neither been subjected to further mechanical processing, nor has been altered as a consequence of mechanical effects (e.g. scratches), and if this flame-polished state can be prevented from undergoing any alterations during the planned service period through the application of a protective surface finish firmly bonded to the glass, or through the adoption of other safety measures, the permissible tensile stress shall be:

$$\frac{K}{S} = 10\ \mathrm{N{\cdot}mm^{-2}}$$

6.3 The permissible compressive stress shall be:

$$\frac{K}{S} = 100\ \mathrm{N{\cdot}mm^{-2}}$$

6.4 The characteristics given in **6.1** to **6.3** already embrace a safety factor S, for which no figure has been specified, which makes allowance for practical experience and for the theoretical finding relating to the strength behaviour of borosilicate glass 3.3 determined in experiments. Even with the application of a continuous maximum permissible load under unfavourable ambient conditions, a sufficiently low failure probability is ensured.

7 Design calculations

7.1 Thermal wall stresses

When there is a temperature difference between the outer and inner surfaces, stresses are established in the glass wall. The allowable temperature difference shall be stated by the manufacturer.

7.2 Design principles

The required wall thickness shall be determined by appropriate calculation methods using the design characteristics given in clause **6**.

7.3 Calculation of thermal wall stresses

7.3.1 Thermal stresses in the wall vary in proportion with the temperature difference across the wall. Account shall be taken of thermal stresses perpendicular to the wall, observing **7.3.2** to **7.4**. Thermal stresses parallel to the wall do not need to be taken into consideration if, through the adoption of a suitable configuration or mode of operation, it is ensured that they cause the stresses in the wall to increase only slightly. It is important that deformations of thermal origin are not inhibited by the manner in which the equipment is installed and the means employed for its restraint.

7.3.2 In the case of a linear temperature gradient perpendicular to the surface of the wall of the equipment, the stress in axisymmetrical hollow bodies shall be calculated as follows:

Stress at the wall surface $\sigma_T = \dfrac{\alpha{\cdot}E{\cdot}\Delta T}{2\,(1 - \nu)}$

where:

σ_T is the tensile stress at the colder surface and also the compressive stress at the hotter surface.

7.3.3 With a non-linear temperature gradient, e.g. during the heating and cooling of glass components, σ_T can assume larger values depending on the rate of temperature variation, and may increase to a maximum of twice the above value.

7.4 Superposition of stresses of thermal and mechanical origin

If the stresses attributable to the service pressure are increased simultaneously by thermal wall stresses σ_T in accordance with the equation given in **7.3.2**, then the values:

$\frac{K}{S} - \sigma_T$ instead of $\frac{K}{S}$ shall be substituted in the appropriate calculations.

8 Marking

8.1 The glass component shall be marked permanently with the name of the manufacturer or processor, the type of glass or brand name, the maximum allowable service pressure and the maximum allowable service temperature difference ΔT or $\Delta\theta$.

8.2 For glass components included in catalogues or lists and those which, in respect of their principal dimensions (including nominal diameter) and their external shape, correspond to dimensions specified in catalogues, there is no need for the maximum allowable service pressure and the maximum allowable temperature difference to be indicated on the glass component provided, in his catalogue or in his list, the manufacturer specifies this pressure as a function of the temperature difference ΔT or $\Delta\theta$ for the nominal size.

Through appropriate marking, it shall be possible to establish a clear correlation between the component and the relevant edition of the catalogue or list.

8.3 For heat exchangers made of glass which are included in catalogues or lists, it is sufficient to specify ΔT or $\Delta\theta$ for the exchange surface in the catalogues or lists.

8.4 Pressure vessels which are made up from glass components shall be provided with a permanent and prominently sited maker's nameplate which gives the following particulars:

– name of the manufacturer or processor;

– year of manufacture;

– serial number or drawing number;

– maximum allowable service pressure;

– maximum allowable service temperature;

– maximum allowable service temperature difference ΔT or $\Delta\theta$;

– volume.

9 Inspection and testing

9.1 Inspection

Glass components shall be assessed for compliance with wall thickness requirement, visually inspected as to freedom of imperfections which can affect the mechanical strength and examined by means of stress optical methods as to sufficient freedom from residual stress.

9.2 Leak-tightness test

A leak-tightness test on assembled components shall be performed in accordance with **9.2.1** or **9.2.2** at ambient temperature using a test pressure which shall be no higher than the maximum allowable service pressure.

9.2.1 The hydraulic pressure shall be applied preferably as a static liquid head. If it is not practical to do this, then it can be applied steadily through a hydraulic pump.

9.2.2 Should it not be practical to use a hydraulic test, then an air or inert gas test shall be carried out at a pressure of 0,1 bar using a water seal and joints examined for leakage. If a leak is located, the air or inert gas pressure shall be released before work is carried out on the plant. Plant for use under vacuum shall be evacuated so that any leakage can be measured by pressure rise against a known internal volume.

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List of references

See national foreword.

BSI — British Standards Institution

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London
W4 4AL