BRITISH STANDARD

BS 3463:1975

Specification for

Observation and gauge glasses for pressure vessels

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Co-operating organizations

The Glass Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following scientific and industrial organizations.

British Glass Industry Research Association
British Lampblown Scientific Glassware Manufacturers' Association
British Plastics Federation
Department of the Environment
Flat Glass Manufacturers' Association*
Glass Manufacturers' Federation
Scientific Instrument Manufacturers' Association
Society of Glass Technology
University of Sheffield (Department of Glass Technology)

The industrial organization marked with an asterisk in the above list, together with the following, was directly represented on the committee entrusted with the preparation of this British Standard:

British Valve Manufacturers' Association
Chemical Industries Association
Council of British Manufacturers of Petroleum Equipment
Department of Trade
Electricity Supply Industry in England and Wales
Engineering Equipment Users' Association
Institution of Mechanical Engineers
Society of Chemical Industry

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Contents

Foreword

This British Standard was first prepared in 1962 at the request of the steam using (power) and chemical industries and with the support and participation of manufacturers and users of observation and gauge glasses fitted to pressure vessels containing steam and water or other fluids.

The Technical Committee representing these interests which prepared the standard based the requirements on the characteristics of glasses which had been shown to meet adequately the demands of service under conditions of high pressure and temperature in contact with corrosive fluids. Attention was drawn to the requirements of the Factories Act, 1961, Section 32 (2) (d) in relation to protector glasses for gauge glasses.

Recommendations for the use of observation and gauge glasses on pressure vessels are given in Appendix A, but no attempt has been made to deal exhaustively with this subject, for which both reference to suitable modern textbooks and practical experience are indispensable.

The main changes incorporated in this revision as compared with the 1962 edition are the following.

a) In the 1962 edition, ranges of standard dimensions for each type of glass were specified with the object of reducing the number of such sizes to be manufactured and kept in stock. In this revision, the need to increase the number of sizes has been recognized.

b) Since 1962, liquid level indicators of the through-vision type having circular ports (referred to for example in BS 759 "Valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers"), have gained worldwide acceptance, and specifications for the circular glasses used therein have now been included.

c) The use of soda-lime glass for tubular glasses and annealed borosilicate glass for through-vision and reflex glasses is no longer permitted.

d) The section on inspection and thermal shock testing of toughened glasses (which was originally given in an appendix) now contains mandatory methods and criteria and accordingly this material has been incorporated into the main body of the standard.

e) Dimensions and units have been converted to metric units. For design stress the MN/m^2 [1)] has been used; for fluid pressure, however, the bar[2)] has been adopted.

f) At the time of preparation of this British Standard, much borosilicate glass was still being supplied in imperial measure. In view of the stocks of these glasses and the expectation of their use continuing for a period before the changeover to metric sizes is complete, the thicknesses of borosilicate circular sight and light glasses are given in the former inch sizes but expressed in millimetres. In some cases the difference between the imperial and nearest metric equivalent is too large to ignore in design calculations, and it was therefore thought important in this revision to give (in Appendix A) recommended maximum pressures in graphical form to facilitate interpolation.

g) Appendix B now lists separately the information to be provided with an order or enquiry.

[1)] 1 MN/m^2 = 1 MPa.

[2)] 1 bar = 10^5 N/m^2 = 100 kPa.

Certification. It is strongly recommended that in view of the nature of this specification manufacturers and purchasers should make use of the certification facilities described on the inside back cover of this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This British Standard specifies requirements for the main types of observation and gauge glasses for pressure vessels, and also specifies inspection and testing techniques for toughened glasses, under the following main headings.

Section 1	General
Section 2	Tubular glasses for level gauges
Section 3	Protector glasses for tubular gauge glasses
Section 4	Through-vision and reflex glasses
Section 5	Circular sight and light glasses
Section 6	Port gauge glasses as used in fittings for steam boilers
Section 7	Inspection and thermal shock testing of toughened glasses and tubular glasses

2 References

The title of the British Standard referred to in this standard is given on the inside back cover.

3 Definitions

For the purposes of this British Standard, the following definitions apply.

3.1
annealed glass

glass which has had objectionable stresses removed by controlled heating and cooling

3.2
toughened glass (heat-treated glass, tempered glass, hardened glass)

glass, the surface of which has been rapidly cooled from near its softening point, so that after cooling a residual compressive stress remains in the surface and is balanced by tensile stresses below the surface. This increases the mechanical strength and thermal shock resistance of the glass and also, when it breaks, causes it to shatter into smaller and less angular fragments than an annealed glass. Chemically toughened glass is not permitted within the scope of this British Standard

3.3
"as drawn" glass

glass tubing in the "as made" state, not having been furnace annealed, and containing certain desirable residual stresses, in particular compression stress in the outer surface. For design purposes, stress values for annealed glasses (see **A.3.2**) may be used

3.4
soda-lime glass

glass in which the main constituents are silica, soda and lime. Soda-lime glass has a relatively high coefficient of expansion and hence in the annealed state has only little resistance to thermal shock but its strength and thermal resistance can be greatly increased by toughening

3.5
borosilicate glass

silicate glass containing boron as a characteristic constituent. Borosilicate glass has a relatively low coefficient of expansion and hence has considerable resistance to thermal shock. Because it has a low coefficient of expansion, it does not develop as much stress as soda-lime glass under comparable toughening treatments. Because of its higher softening temperature, borosilicate glass withstands higher duty temperatures than does soda-lime glass without de-toughening. Because it is more resistant to corrosion than soda-lime glass, borosilicate glass is recommended for all reflex glasses

3.6
defects

defects that may occur in glass and affect its performance, as listed and defined in BS 3447

3.7
corrosion

chemical and mechanical attack of glass surfaces by the contents of the pressure vessel

NOTE Owing to the difficulty of distinguishing corrosion and erosion as separate processes, the term corrosion is used to cover both processes.

4 Marking

Glasses for which compliance with this standard is claimed shall be permanently marked with the following inscriptions:

a) The manufacturer's identification or trade mark.

b) The number of this British Standard, i.e. "BS 3463".

These markings shall not interfere with the function of the glass and preferably shall be placed so as to be visible when mounted. This latter requirement does not apply to through-vision and reflex glasses as described in section 4 nor to port gauge glasses as described in section 6.

Section 2. Tubular glasses for level gauges

5 Material

Tubular glasses shall be made of borosilicate glass. It is recommended that for steaming conditions, tubular glasses should not be used above 18.5 bar[3)] For non-steaming conditions higher pressures are allowable up to a limit of 30 bar. Tubing used for steaming conditions shall be in the "as drawn" state and not annealed. Tubing used for non-steaming conditions may be "as drawn" or annealed.

NOTE Requirements are not specified for toughened tubular glasses, as the manufacture of these is not practicable at present.

6 Quality of glass

Tubular glasses shall be free from defects that would interfere with vision or service.

7 Dimensions

7.1 Diameters and wall thicknesses of tubular glasses shall be as specified in Table 1. Each of the three sizes is available with two different tolerances on diameter, the two grades being designated "selected grade" and "ordinary grade".

7.2 The lengths of tubular glasses are determined by the design of the fittings into which they are assembled. For steaming applications, such fittings should not be further than 505 mm apart if the glass is unsupported, or 600 mm apart if an intermediate support is used. For non-steaming applications, the corresponding distances should be 1 000 mm and 1 200 mm. For the purposes of this British Standard the respective lengths of tubular glasses shall be 505 mm, 600 mm, 1 000 mm and 1 200 mm. Unless otherwise agreed between purchaser and manufacturer, the tolerance on length shall be ± 2.0 mm.

8 Finish of ends

The ends of tubular gauge glasses shall be cut at right angles to the axis, then fused and flame cooled to prevent severe ring stress.

9 Straightness

Tubular glasses shall be straight within limits agreed between purchaser and manufacturer.

Table 1 — Diameters, thicknesses and tolerances of tubular glasses

Nominal external diameter	Tolerance on external diameter		Wall thickness
	Selected grade	Ordinary grade	
mm	mm	mm	mm
13	+ 0 − 0.8	+ 0.4 − 0.8	1.8 to 2.5
16			2.6 to 3.3
19			2.8 to 3.5

10 Ovality

The maximum and minimum external diameters of any cross section at right angles to the axis of tubular glasses shall not differ by more than 3 % of the nominal diameter.

11 Thermal shock requirements

Manufacturers shall certify that tubular glasses for steaming conditions will pass the thermal shock test and acceptance conditions described in section 7. In the event of a purchaser requiring tests to be made on any consignment, the sampling procedure described in section 7 shall be adopted.

NOTE With tubular glasses, it is not practicable to require destructive tests on small batches (10 glasses or fewer) because a sampling procedure is not considered appropriate at this level.

Glasses subjected to the test shall be destroyed after the test to prevent them being inadvertently put into service.

Section 3. Protector glasses for tubular gauge glasses

12 Material

Protector glasses shall be made of toughened soda-lime clear glass. Annealed or chemically toughened glass shall not be used.

13 Quality of glass

Protector glasses shall be free from defects that would interfere with vision or service.

14 Dimensions

14.1 Protector glasses should preferably be 57 ± 0.5 mm wide, and 12 ± 0.5 mm thick.

14.2 The length of protector glasses should preferably be as specified in Table 2 with a tolerance in each case of ± 0.8 mm.

[3)] 1 bar = 10^5 N/m^2 = 100 kPa.

When desired, protector glasses may be supplied in sets of three, having an overall tolerance on length of 0.4 mm, and being otherwise in accordance with Table 2.

14.3 Glasses of other dimensions and tolerances are acceptable provided that they comply with the other requirements of this British Standard.

Table 2 — Lengths of protector glasses for tubular gauge glasses

mm			
150	255	370	480
175	280	380	505
190	305	405	
200	330	430	
230	355	455	

15 Finish of edges

15.1 The edges of protector glasses shall be bevelled in accordance with one of the designs shown in Figure 1.

15.2 The finish on edges and bevels shall be by agreement between purchaser and manufacturer.

16 Inspection under polarized light

Each protector glass shall be examined under polarized light as described in section 7. Any glass which does not show a polarization pattern indicative of toughening shall be rejected.

17 Thermal shock requirements

Manufacturers shall certify that protector glasses will pass the thermal shock test and acceptance conditions described in section 7.

In the event of a purchaser requiring tests to be made on any consignment the sampling procedure described in section 7 shall be adopted. Glasses subjected to and passing the test may be put into service.

Table 3 — Dimensions and tolerances for through-vision and reflex glasses

Sizes	Nominal dimensions	Tolerances
	Length	
	mm	mm
0	95	± 1 for all sizes
1	115	
2	140	
3	165	
4	190	
5	220	
6	250	
7	280	
8	320	
9	340	
10	370	
	Width	
All sizes	34	+ 0.5 – 1.0
	Thickness	
All sizes	17.5	+ 0.5 – 1.0
NOTE Particular design requirements may necessitate manufacture to closer tolerances, which shall be subject to agreement between purchaser and manufacturer.		

Section 4. Through-vision and reflex glasses

18 Material

Through-vision and reflex glasses shall be made of toughened borosilicate or toughened soda lime glass, as required.

19 Quality of glass

Through-vision and reflex glasses shall be free from defects that would interfere with vision or service.

20 Dimensions and shape

20.1 The lengths, widths and thicknesses of 11 standard sizes of through-vision and reflex glasses shall be as specified in Table 3.

20.2 Gauges incorporating reflex glasses to these dimensions and tolerances shall not be used for steaming applications at gauge pressures above 25 bar[4)]. Gauges incorporating through-vision glasses can be used for steaming applications at gauge pressures up to 25 bar without mica protection of the face and up to 80 bar with mica protection of the face.

[4)] 1 bar = 10^5 N/m^2 = 100 kPa.

20.3 Glasses for use on steam boilers operating at pressures higher than those specified in **20.2** shall be to dimensions and tolerances as agreed between purchaser and manufacturer.

20.4 The thickness of any one glass shall not vary by more than 0.08 mm.

20.5 The ends shall be semi-circular within the tolerances specified in Table 3 for length and width.

21 Flatness

All working flat faces of through-vision and reflex glasses shall be plane within the limits specified in Table 4 as determined by the use of an inspection table and feeler gauges or other suitable method.

Table 4 — Flatness limits for through-vision and reflex glasses

Size	Flatness limit
	mm
0	0.05
1	0.05
2	0.05
3	0.05
4	0.08
5	0.08
6	0.15
7	0.15
8	0.25
9	0.25
10	0.25

22 Joint faces and edges for reflex glasses

22.1 The minimum width of glass face in contact with the packing shall be 6 mm.

22.2 The grooves shall be formed so as to produce a marked contrast in appearance between the liquid and gaseous phases to be viewed through the glass.

22.3 The thickness of glass between the bottom of each groove and the opposite face shall not be less than 12.5 mm.

22.4 All glasses, including cut and moulded glasses, shall be radiused or arrised to remove sharp corners.

23 Inspection under polarized light

Each toughened through-vision or reflex glass shall be examined under polarized light as described in section 7. Any glass which does not show a polarization pattern indicative of toughening shall be rejected. Hoop stress as seen in the strain viewer shall be of similar intensity at all edges and shall not be interrupted by the incidence of surface cracks.

24 Thermal shock requirements

Manufacturers shall certify that toughened through-vision and reflex glasses will pass the thermal shock test and acceptance conditions described in section 7. In the event of a purchaser requiring tests to be made on any consignment, the sampling procedure described in section 7 shall be used. Glasses subjected to and passing the test may be put into service.

Section 5. Circular sight and light glasses

25 Material

Circular sight and light glasses shall be made of soda-lime glass or borosilicate glass, either annealed or toughened, as required.

26 Quality of glass

Circular sight and light glasses shall be free from defects that would interfere with vision or service; in particular, both faces shall be free from irregularities within the area required for jointing.

27 Dimensions

27.1 The preferred diameters of circular sight and light glasses shall be 50 mm, 65 mm, 75 mm, 100 mm, 125 mm, 150 mm, 175 mm and 200 mm for which the tolerance shall be ± 1 mm for all thicknesses; and 255 mm and 305 mm, for which the tolerance shall be + 1 mm – 2 mm for all thicknesses.

27.2 The preferred thicknesses and appropriate tolerances of circular sight and light glasses shall be as given in Table 5.

Table 5 — Preferred thicknesses of circular sight and light glasses

Soda lime glass	Borosilicate glass
mm	mm
6 ± 0.2	6.35 ± 0.8 (nominally 6)
10 ± 0.3	9.53 ± 1.6 (nominally 10)
12 ± 0.3	12.70 ± 1.6 (nominally 12)
15 ± 0.5	15.7 ± 1.6 (nominally 15)
19 ± 1.0	19.0 ± 1.6 (nominally 19)
25 ± 2.0	25.40 ± 2.4 (nominally 25)

27.3 Other dimensions and tolerances as agreed between purchaser and vendor are permitted within this British Standard, provided that the glasses comply with the other clauses of the specification.

27.4 Glasses shall be flat (i.e. free from bow) within the limits specified in Table 6.

Table 6 — Limits of bow for circular sight and light glasses

Material	50 mm to 100 mm diameter	101 mm to 150 mm diameter	151 mm to 200 mm diameter	201 mm to 305 mm diameter
	mm	mm	mm	mm
Annealed glass (all thicknesses)	0.05	0.08	0.10	0.13
Toughened glass up to 12 mm thickness	0.13	0.25	0.38	0.64
Toughened glass above 12 mm and up to 25 mm thickness	0.10	0.20	0.25	0.38

27.5 When glasses are required with thicknesses other than those given in Table 5, or diameters outside the range given in **27.1**, the limits of bow shall be as given in Table 6 for the next size smaller and next size thinner in the same material.

28 Finish of edges

All glasses including cut and moulded glasses shall be radiused or arrised to remove sharp corners; edges of cut glasses shall be ground smooth.

29 Inspection under polarized light

Each toughened circular sight and light glass shall be examined under polarized light as described in section 7. Any glass which does not show a polarization pattern indicative of toughening shall be rejected. Hoop stress as seen by rotation of the glass in the strain viewer shall be of similar intensity around the complete periphery and shall not be interrupted by the incidence of surface cracks, heavy cord or other defects.

30 Thermal shock requirements

Manufacturers shall certify that toughened circular sight and light glasses will pass the thermal shock test and acceptance conditions described in section 7. In the event of a purchaser requiring tests to be made on any consignment, the sampling procedure described in section 7 shall be used. If annealed glasses are required to be tested for resistance to thermal shock, the temperature difference for the tests (see Table 7) shall be agreed between purchaser and manufacturer. Glasses subjected to and passing the test may be put into service.

Section 6. Port gauge glasses as used in fittings for steam boilers

31 Material

Port gauge glasses shall be made of toughened borosilicate glass.

32 Quality of glass

Port gauge glasses shall be free from defects that could interfere with vision or service.

33 Dimensions

33.1 Port gauge glasses shall be right cylinders within the tolerances specified.

33.2 The diameters of port gauge glasses shall be as agreed between purchaser and manufacturer, but shall not exceed 52 mm for working gauge pressures up to 80 bar[5)] nor 34 mm for working gauge pressures up to 206 bar.

33.3 The thickness of port gauge glasses shall not be less than:

12.00 mm for diameters up to 29 mm

12.6 mm for diameters over 29 mm and up to 32 mm

14.0 mm for diameters over 32 mm and up to 34 mm

17.0 mm for diameters over 34 mm and up to 52 mm

33.4 All sharp edges shall be uniformly bevelled at 45° around the periphery. The width of the bevels is a function of the design of the fitting and shall be the subject of agreement between purchaser and manufacturer.

[5)] 1 bar = 10^5 N/m^2 = 100 kPa.

34 Tolerances

34.1 Particular design requirements may necessitate manufacture to closer tolerances than those given in **34.2** to **34.4** in which case they shall be subject to agreement between purchaser and manufacturer.

34.2 The diametral tolerance shall not exceed a total of 0.4 mm for diameters up to 34 mm nor a total of 0.8 mm for diameters over 34 mm and up to 52 mm.

34.3 The thickness tolerance, subject to the additional limitation of **34.4**, shall be as follows:

a) For applications up to a working gauge pressure of 80 bar, the total tolerance shall not exceed 0.25 mm.

b) For applications above a working gauge pressure of 80 bar and up to 206 bar, the total tolerance shall not exceed 0.10 mm.

34.4 The parallelism of surfaces shall be assessed by measuring the variation of thickness around the perimeter of a circle having a diameter 3 mm less than that of the glass. A minimum of 6 measurements shall be taken; variation in thickness in any one glass shall not exceed the following.

For applications up to a working gauge pressure of 80 bar: 0.075 mm.

For applications above a working gauge pressure of 80 bar and up to 206 bar: 0.025 mm.

35 Finish of faces and edges

The faces of port gauge glasses shall be polished; their edges may be smooth ground or as moulded.

36 Inspection under polarized light

Each toughened port gauge glass shall be examined under polarized light as described in section 7. Any glass which does not show a polarization pattern indicative of toughening shall be rejected. Hoop stress, as seen by rotation of the glass in the strain viewer, shall be of similar intensity around the complete periphery and shall not be interrupted by the presence of surface cracks, heavy cord or other defects.

37 Thermal shock requirements

The manufacturer shall subject, or cause to be subjected, toughened port gauge glasses to a thermal shock test as described in section 7.

The number of glasses so subjected shall be 2 % of the consignment, but not less than 10 glasses nor more than 30 glasses, selected at random.

A failure of a single glass shall cause the whole of the consignment to be rejected.

Glasses subjected to and passing the test may be put into service.

Section 7. Inspection and thermal shock testing of toughened glasses and tubular glasses

38 Inspection

Every toughened glass covered by sections 3 to 6 of the specification shall be examined, by means of a polarized light strain viewer, for adequacy of toughening.

39 Thermal shock testing

39.1 Requirements. Tubular gauge glasses covered by section 2 of this specification and toughened glasses described in sections 3, 4 and 5 shall be certified as capable of passing the appropriate thermal shock test. A thermal shock test may also, by agreement between purchaser and manufacturer, be specifically requested to be carried out on a particular consignment. Toughened glasses covered by section 6 of the specification shall be subjected to the appropriate thermal shock test, as specified in **39.4** and as required by clause **37**.

39.2 Grouping of toughened glasses. All the glasses in the consignment shall be examined in the strain viewer and divided into groups of similar strain pattern, and any glass not showing a pattern indicative of toughening shall be rejected. Each group shall then be subjected to the sampling procedure described in **39.3**.

39.3 Sampling of tubular glasses and groups of toughened glasses. 2 % of the glasses (but not less than 10 or more than 30 glasses) shall be taken by random selection from each consignment of tubular glasses, or each group of toughened glasses. These glasses shall be subjected to the thermal shock test described below. With the exception of glasses covered by clause **37**, if more than 10 % but not more than 20 % of the glasses in the sample fail the test, a further sample of 2 % (but not less than 10 glasses or more than 30 glasses) shall be taken by random selection from the consignment or group and subjected to a second test.

Where a group of toughened glasses consists of 10 glasses or less, all the glasses shall be taken as the sample for test.

NOTE The requirement to test all glasses in a group of 10 or less is not applicable to tubular glasses; see note to clause **11**.

39.4 Thermal shock test

39.4.1 ***Apparatus***

39.4.1.1 *Cold bath* for use with water, capacity at least 4.5 litres (or for large articles at least 10 litres for each 1 kg mass of glass), maintained at a temperature (t_2) and provided with means of agitation and a thermometer graduated at each 1 °C.

39.4.1.2 *Hot bath* for use with oil (up to 180 °C), or *air oven.* Each shall be provided with means of agitation and of maintaining the temperature (t_1) uniform and constant to 1 °C.

39.4.2 *Procedure.* The cold bath (temperature t_2) and the hot bath or oven (temperature t_1) shall be adjusted to give the required thermal shock $t_1 - t_2$, given in Table 7, for the articles under test.

The samples selected as in **39.3** or clause **37** shall be placed in the hot bath or oven and maintained at the temperature t_1 for 15 minutes. The articles shall be taken one at a time and plunged into the cold bath maintained at temperature t_2.

39.4.2.1 Tubular glasses shall enter the water vertically.

39.4.2.2 Toughened glasses, other than port gauge glasses, shall enter the water with an observation face parallel to the water surface.

39.4.2.3 Port gauge glasses, being small, shall be supported above the base of the oven while being heated. Individual wire frames, with the glass resting on its edges on two thin wires shall be used. After reaching the specified temperature, the glass shall be transported in the frame as quickly as possible to the quenching bath, but the glass only shall be tipped into the water. These small glasses may enter the water edges first.

39.5 Examination. All glasses shall be examined with unaided vision (other than spectacles if worn) after subjecting them to the test described in **39.4**. A glass is deemed to pass the thermal shock test if it shows no signs of damage, cracks, surface cracks, scaling or other defects.

Tubular glasses which have been subjected to the test shall not be put into service, and shall be destroyed. Toughened glasses of other types subjected to and passing the test may be put into service.

39.6 Acceptance. Acceptance of glasses covered by sections 2 to 5 of this standard depends on whether one test or two tests have been carried out according to the requirements of **39.3**.

If *either* not more than 10 % of the first sample fail the test *or*

more than 10 % and not more than 20 % of the first sample, and not more than 10 % of the second sample fail the test

then the consignment (or group in the case of toughened glass) (see **39.2**) is deemed to comply with the standard.

Glasses covered by section 6 are deemed not to comply with the standard if a single glass fails the test (see clause **37**).

Table 7 — Summary of thermal shock testing

Type		Tubular glasses (for steaming conditions)	Protector glasses	Through-vision and reflex glasses	Circular sight and light glasses	Port gauge glasses
Clause numbers		**11**	**17**	**23**	**30**	**37**
Material		Borosilicate ("as drawn")	Toughened soda-lime	Toughened soda-lime or toughened borosilicate[a]		Toughened borosilicate
Inspection under polarized light		Not applicable	Inadequate toughening: reject Adequate toughening: sort into groups			
No. selected for test sample	No. in group or consignment					
	1–10	Not practicable	All of group or consignment			
	11–499	10	10	10	10	10
	500–1 500	2 % of group or consignment				
	over 1 500	30	30	30	30	30
Temperature differential °C for test	Up to 13 mm thick	160	160	160	160	280
	Over 13 mm thick	160	160	160	125	250
Acceptance of whole group or consignment	No. in test sample damaged					
	Nil	Pass				
	One glass up to 10 %	Pass				Fail
	Over 10 % up to 20 %	Retest once only, then: Up to 10 % (of retest) Pass Over 10 % (of retest) Fail				Fail
	Over 20 %	Fail				Fail
Manufacturer's assurance of conformity with the thermal shock clauses of BS 3463		May be given without testing sample glasses from the consignment				May be given only after testing sample glasses from the consignment
Disposal of samples after test		Shall be destroyed	May be put into service			

[a] Annealed circular sight and light glasses may also be thermal shock tested (see clause **30**).

Appendix A Information and recommendations on glasses for pressure vessels

A.1 Effects of temperature and pressure. Limits of working pressure on tubular gauge glasses depend on freedom from stress induced by badly aligned fittings, the length of glass, and the presence of any corrosive conditions. In steaming applications, users should establish a permissible life dependent on feed water and pressure conditions, which permits no more than half the tubular wall thickness to be corroded away in the area of the gauge cone or packing

Tubular glasses for boilers, and for other vessels where conditions of pressure, temperature and corrosion are similar to those for boilers, should not be longer than 505 mm unsupported or 600 mm supported. For non-steaming conditions, lengths up to 1 000 mm unsupported and 1 200 mm supported may be used. Where a gauge length above these limits is required, it should consist of a combination of shorter glasses.

Reflex glasses, and through-vision glasses without mica protection, are not recommended for use above 25 bar[6] in steam installations, or above 80 bar for other purposes (see **20.2**). For installations at higher pressures, manufacturers' recommendations should be obtained.

Through-vision and reflex glasses and circular sight and light glasses are not recommended for greater maximum working temperature and temperature differentials (ambient to fluid) than those set out in Table 8. These figures have been adjusted so that they apply to the differential between the ambient and fluid temperatures, because of the impracticability of measuring actual glass surface temperatures under operational conditions. The temperatures stated, however, ensure that, within the conditions covered by this standard, the glasses will not be overstressed.

Glasses suitable for work at higher temperatures are obtainable; information regarding special applications should be obtained from the manufacturers.

Table 8 — Recommended maximum working temperatures and temperature differentials for through-vision and reflex glasses and circular sight and light glasses

Type of glass	Maximum working temperature	Maximum temperature differential (ambient to fluid)
	°C	°C
Annealed soda-lime	350	40
Toughened soda-lime	300	265
Annealed borosilicate	400	110
Toughened borosilicate	360	265

A.2 Recommended maximum pressures for circular sight and light glasses. Circular sight and light glasses are not recommended for pressures greater than those indicated in Figure 2 to Figure 5. The range of application of these graphs should be considered as limited to the largest preferred glass diameter (305 mm) and greatest preferred thickness (25 mm) of the circular sight and light glasses covered in this British Standard. For applications outside these limits, the manufacturer should be consulted.

A.3 Strength formulae used for circular sight and light glasses

A.3.1 The graphs given in Figure 2 to Figure 5 are based on calculations of the "worst case" arising from the situations governing the stresses acting within a circular glass disc when a uniform pressure difference is exerted across its faces. The "worst cases" adopted are based on the following considerations.

a) The maximum pressure adopted is the maximum pressure the glass will withstand, calculated (for the type of glass and specified design stress) under bending stress and under shear stress, whichever gives the lower result. This gives rise to the discontinuity of the graphs, with bending stress limited on the low pressure side and shear stress on the high pressure side of the change in slope.

b) For bending stress, the calculation is for simply supported discs, i.e. without edge clamping.

c) For both bending stress and shear stress, the thickness is taken as the minimum allowed within the tolerances specified in **27.2** and Table 5.

[6] 1 bar = 10^5 N/m^2 = 100 kPa.

d) Although adopting the overall glass diameter would lead to a lower pressure, the committee which prepared this British Standard considered that specifying the maximum unsupported diameter was more logical.

e) Although the recommended design bending stresses for toughened glasses are higher than those for annealed glasses, for design shear stress the same value is adopted for glasses in the annealed and toughened states.

f) A small margin for thermal stresses corresponding to the maximum temperature gradients permitted in Table 8 has been allowed for in the design stresses stated on the graphs.

A.3.2 Strength under bending stress has been calculated according to the formula given by *Timoshenko* and *Woinowsky-Kreiger*, "Theory of plates and shells" (McGraw Hill, 1959) for the strength of a simply supported disc.

$$p\frac{d^2}{2} = \frac{8}{3\ (3+v)}\ \sigma_b t^2$$

where

p is the maximum pressure the disc will withstand,

d is the diameter of the disc,

v is the Poisson ratio of the glass type;

σ_b is the design bending stress for the glass type;

t is the thickness of the disc.

On substituting 0.23 as the accepted value of the Poisson ratio for glass, the formula becomes:

$$pd^2 = 3.30\ \sigma_b t^2$$

The values of design bending stress σ_b used are as follows.

Annealed soda lime	7 MN/m^2.
Toughened soda lime	35 MN/m^2.
Annealed borosilicate	7 MN/m^2.
Toughened borosilicate	14 MN/m^2.

A.3.3 Strength under shear stress has been calculated according to the formula:

$$pd = 4\ \sigma_s t$$

where σ_s is the design shear stress for the glass type.

The value of design shear stress used is 7 MN/m^2 for all glass types.

A.4 Corrosion. Corrosion of glass on pressure vessels is sometimes a problem requiring consideration, because of the faster rate of chemical reactions at temperatures and pressures above atmospheric. Borosilicate glass is more resistant than soda-lime glass to attack by hot water and acids. Toughening does not increase the corrosion resistance of glass. For use under severe conditions, for instance in the presence of alkalis where the consequences of failure would be serious, the use of two glasses (each capable of withstanding the full pressure) is to be preferred. In boiler practice, the glass is frequently protected by mica; alternatively, corrosion may be minimized by control of the fluid circulation. The glass manufacturer should be consulted regarding the possible effect of corrosion on the properties of glass for pressure vessels wherever particularly adverse conditions are likely to be encountered.

Appendix B Information to be given when ordering

The following information should be provided with any order or enquiry to manufacturers of glasses for pressure vessels, and the recommendations in this appendix should be consulted in compiling this information.

All the information listed should be provided when first ordering or when seeking the manufacturer's advice on the suitability of glasses for a particular application. When ordering replacements, the information in items **B.8** to **B.12** may be omitted.

B.1 Compliance. A statement as to whether the glass is to comply with this British Standard.

B.2 Types

B.2.1 Tubular gauge glasses.

B.2.2 Protector glasses.

B.2.3 Through-vision glasses.

B.2.4 Reflex glasses.

B.2.5 Circular sight and light glasses.

B.2.6 Port gauge glasses.

B.3 Materials

B.3.1 Soda-lime glass.

B.3.2 Borosilicate glass.

B.4 Condition

B.4.1 Annealed.

B.4.2 Toughened.

B.4.3 "As drawn".

B.5 Grade (for tubular glasses, see **7.1**)

B.5.1 Ordinary (this will be supplied unless otherwise stated).

B.5.2 Selected.

B.6 Dimensions

B.6.1 Tubular gauge glasses: length, external diameter.

B.6.2 Protector glasses: length, width and thickness if non-standard.

B.6.3 Through-vision and reflex glasses: size number or length.

B.6.4 Circular sight and light glasses: diameter, thickness.

B.6.5 Port gauge glasses: diameter, thickness.

B.7 Manufacturer's catalogue reference (where applicable).

B.8 Application

B.8.1 Type of vessel.

B.8.2 Fluid in contact with the glass and any known corrosive effect it has on glass.

B.9 Pressure

B.9.1 Nominal working pressure (and/or vacuum) on the glass.

B.9.2 Maximum pressure (and/or vacuum) on the glass, e.g. under test conditions.

B.10 Temperature

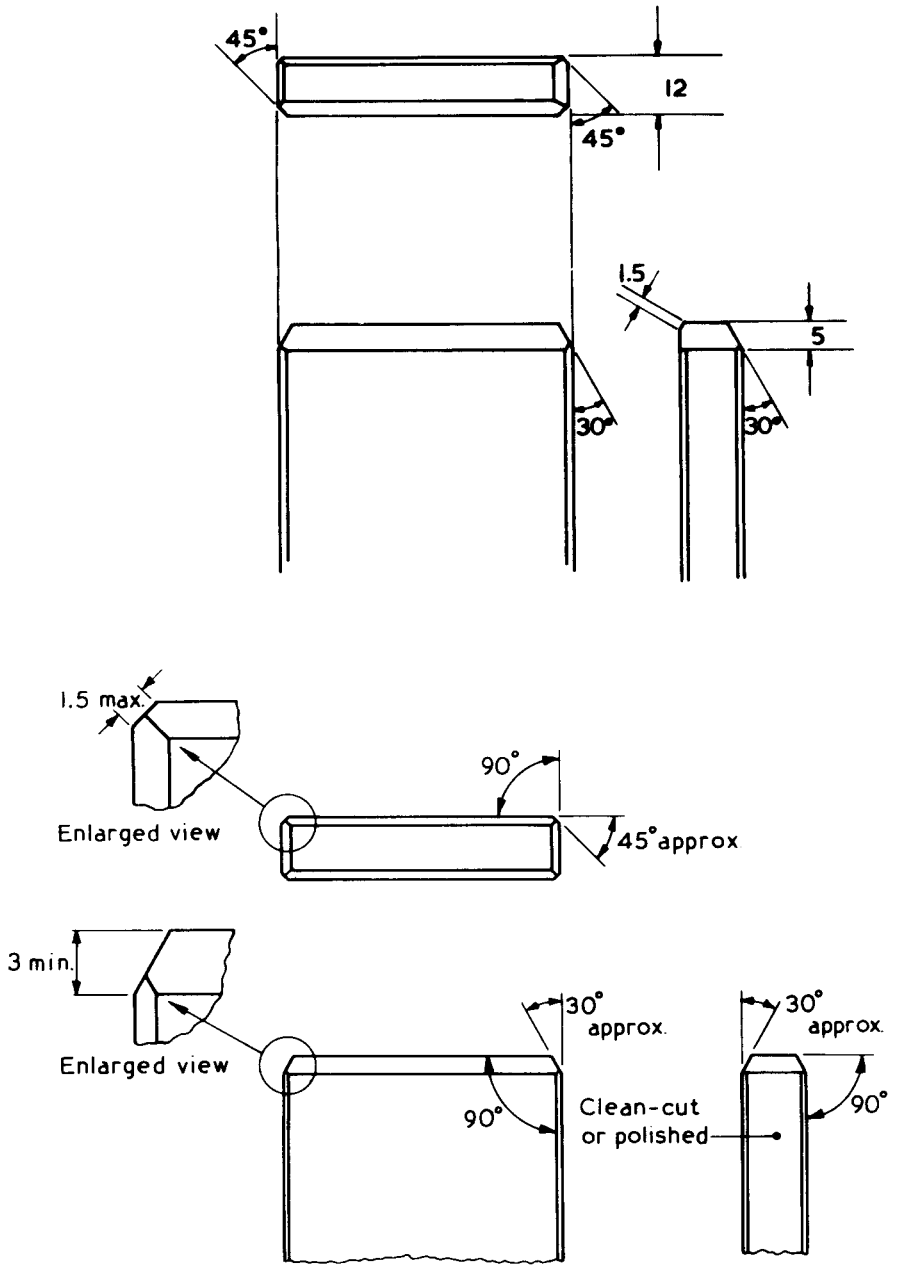
B.10.1 Maximum temperature inside the vessel.

B.10.2 Ambient temperature.

B.10.3 Any sudden thermal shock the glass is likely to be subjected to, and whether this is an up-shock or a down-shock.

B.11 Mounting. Details of how it is proposed to mount the glass.

B.12 Work on the glass. Details of all work to be done on the glass. (In the case of toughened glass, all work must be done before toughening.)



Dimensions in millimetres

Figure 1 — Designs for edges of protector glasses

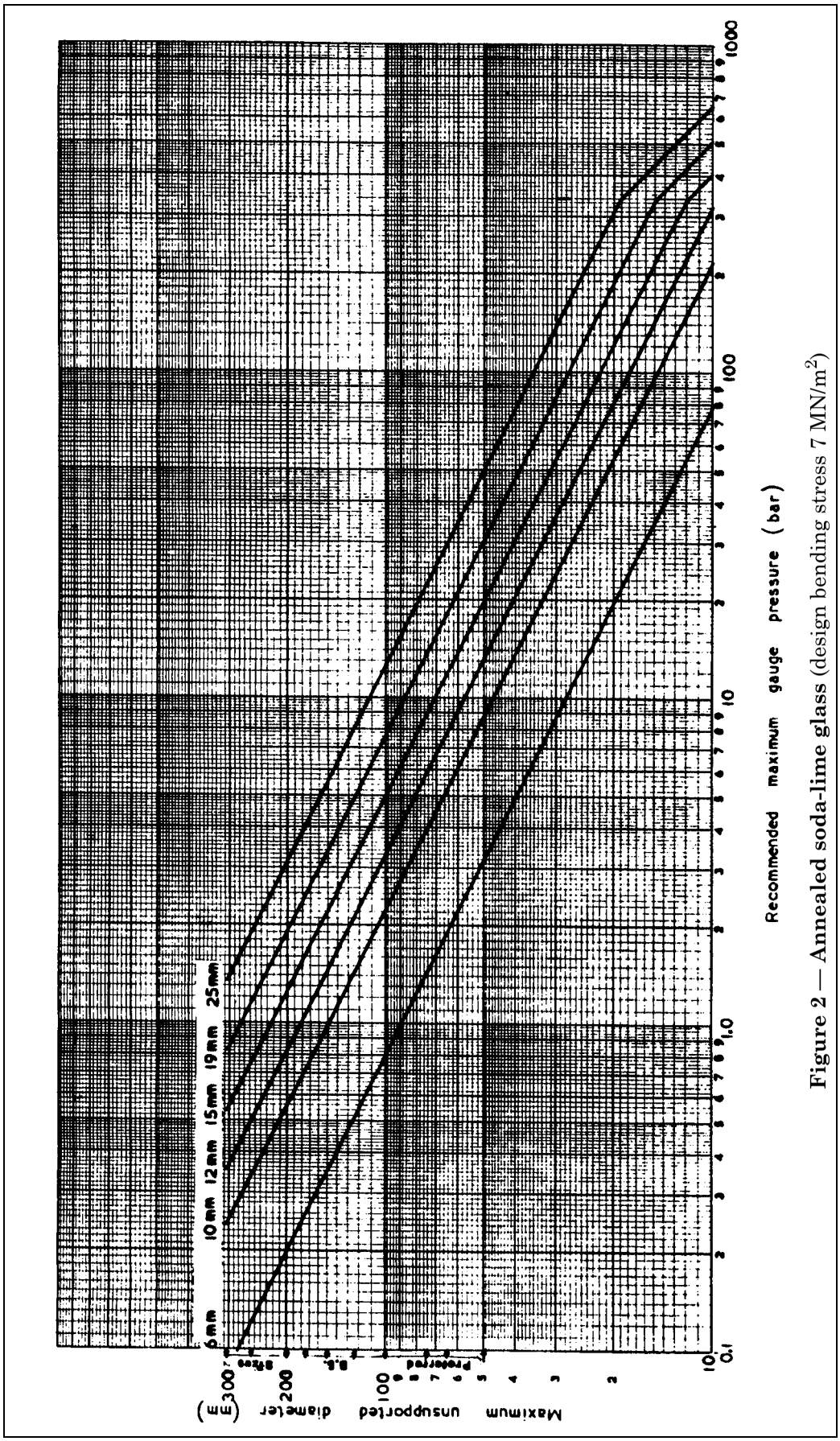


Figure 2 — Annealed soda-lime glass (design bending stress 7 MN/m^2)

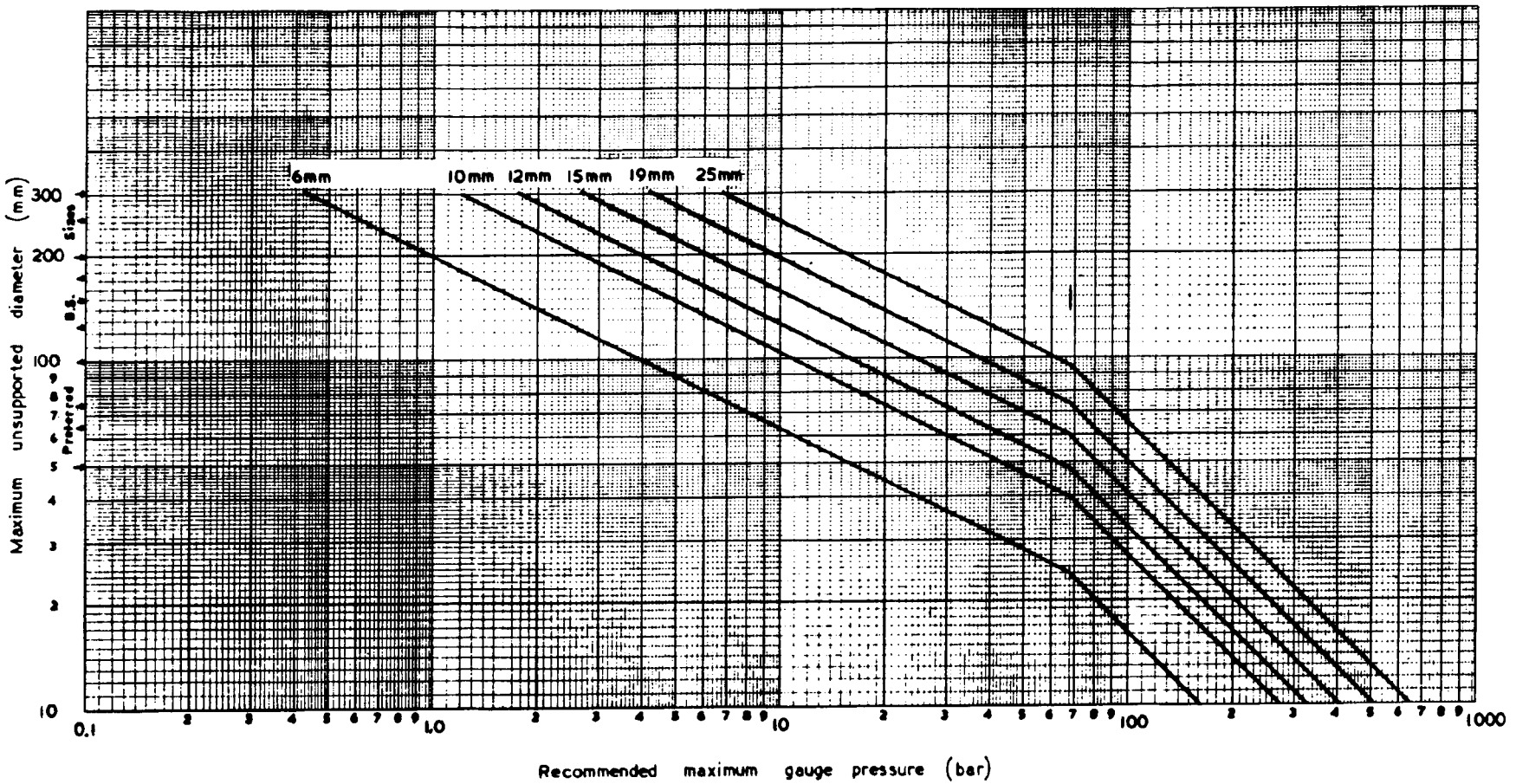


Figure 3 — Toughened soda-lime glass (design bending stress 35 MN/m^2)

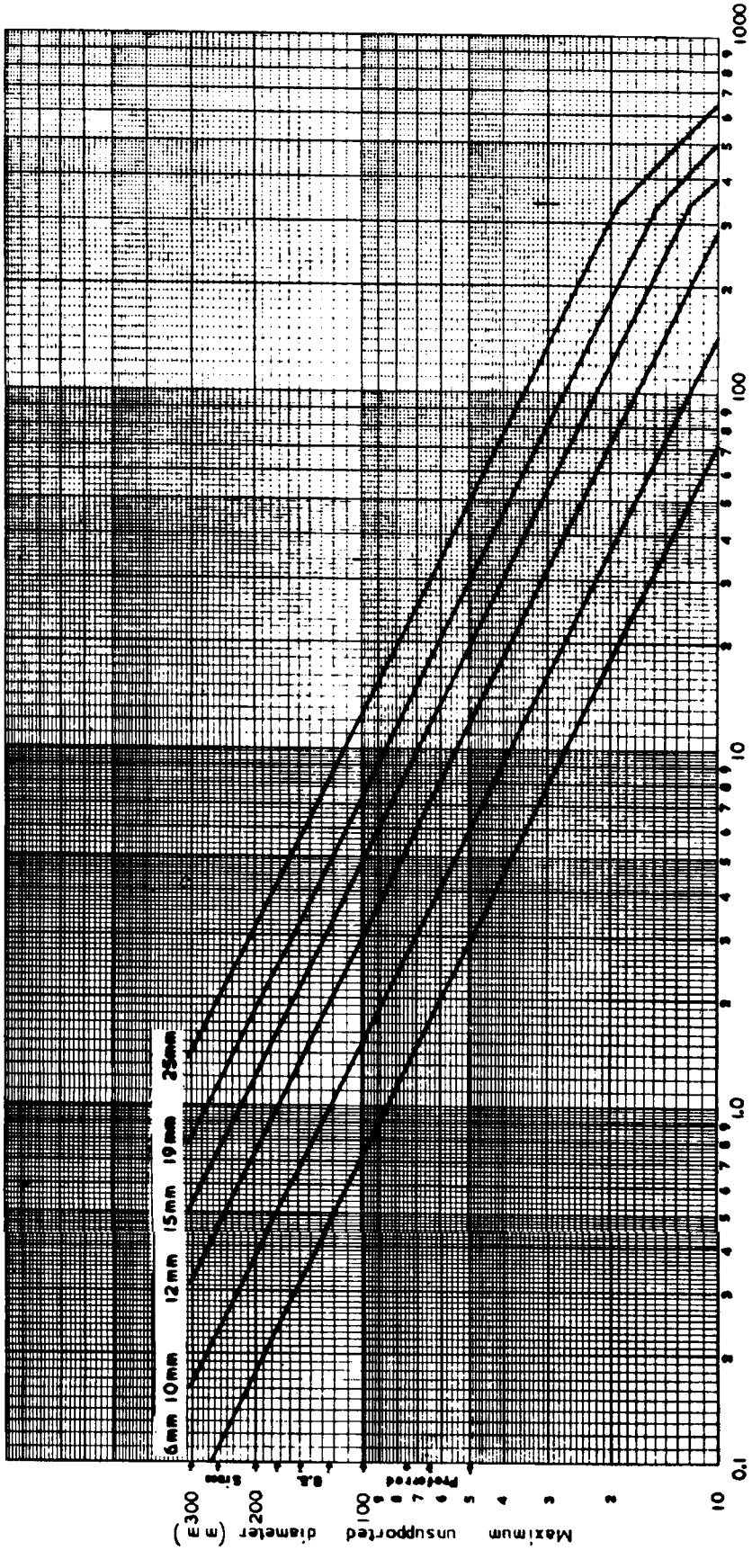


Figure 4 — Annealed borosilicate glass (design bending stress 7 MN/m^2)

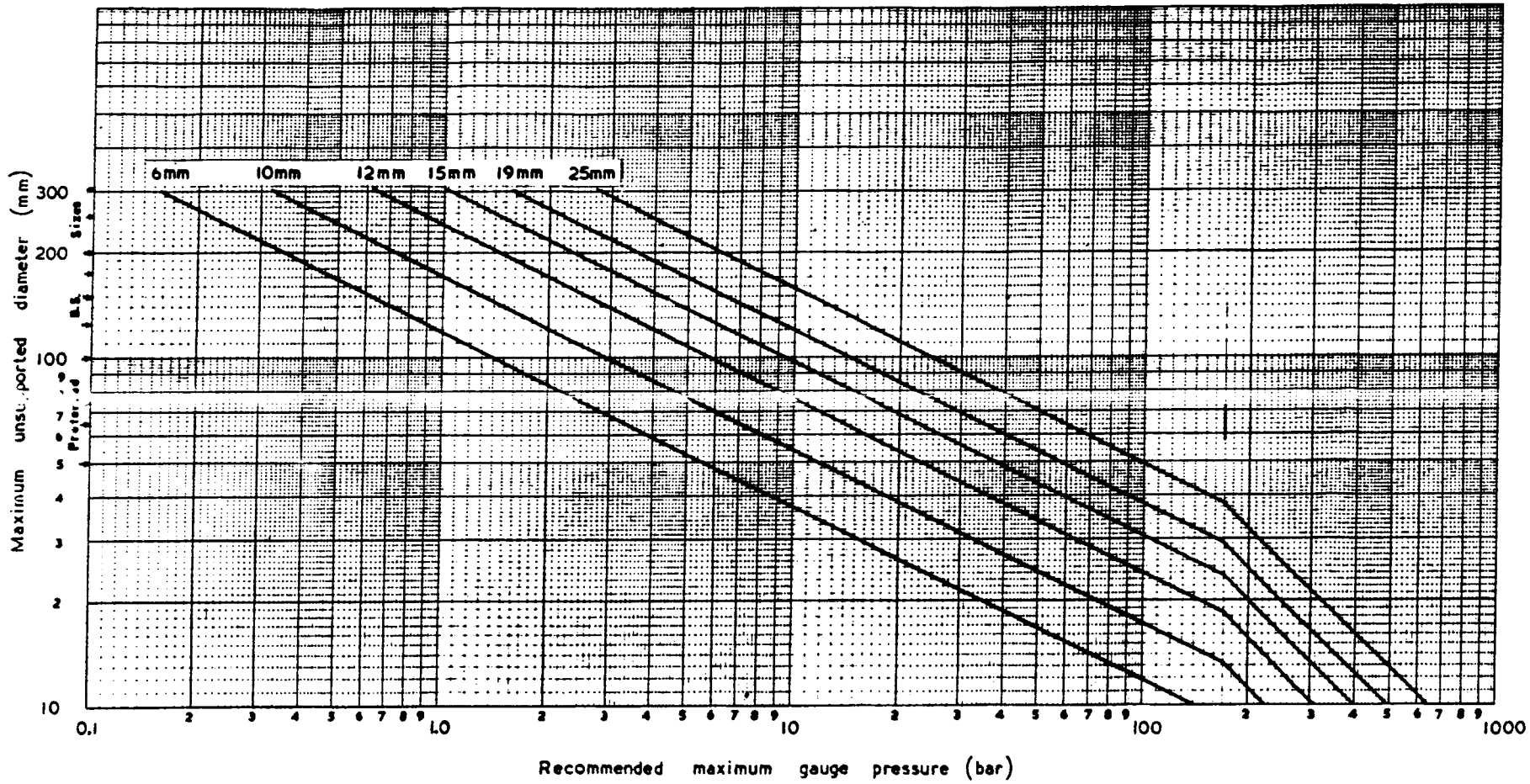


Figure 5 — Toughened borosilicate glass (design bending stress 14 MN/m^2)

Publications referred to

This standard makes reference to the following British Standard:
BS 3447, *Glossary of terms used in the glass industry*.

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