BRITISH STANDARD

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Recommendations for

Design of glass vacuum vessels (including desiccators) for laboratory use

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Committees responsible for this British Standard

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British Laboratory Ware Association
British Lampblown Scientific Glassware Manufacturers' Association Ltd.
Chemical Industries Association
Department of Health and Social Security
Department of Trade and Industry (Laboratory of the Government Chemist)
Glass Manufacturers' Federation
Institute of Medical Laboratory Sciences
Institute of Science Technology
Royal Society of Chemistry

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Contents

Foreword

This British Standard has been prepared under the direction of the Laboratory Apparatus Standards Committee and was first published in 1962 as "Recommendations for the design of glass vacuum desiccators". This revision has been prepared to cover a wider range of glass vacuum vessels for laboratory use because the same basic principles are relevant to all such vessels. There has been a reduction in the number of different types of vacuum desiccators commercially available and, therefore, a number of the figures in the earlier edition have not been included in this revision; an O-ring type of seal for the lids of desiccators and similar vessels has been introduced.

In this standard, glass vacuum vessels are considered as pressure vessels subject to an external pressure of 1 atm. Suitable structures and thicknesses of glass are recommended for each part of the vessel. The standard gives equations which should be applied in calculating the thickness of glass vacuum vessels for laboratory use where the external pressure will not exceed 1 atm. The calculated glass thickness, however, is sometimes less than that considered adequate for ordinary handling hazards; in these cases, the recommended minimum thicknesses given in this standard take these hazards into account and are greater than the calculated values.

Appendix A gives equations for calculation of minimum thickness. Appendix B to Appendix D describe methods for the hydraulic testing of glass vacuum vessels, for examining them in polarized light under a strain-viewer and for testing the grinding of the flanges.

It is not at present the purpose of this British Standard to specify a range of sizes of desiccators, and the sizes mentioned in the tables are given merely by way of example. The size of desiccators is designated by the internal diameter measured at the flange, which gives a better indication of the usable space compared with the practice in some countries of designating by the outside diameter of the flange.

The use of a safety cage to contain the glass vacuum vessel is strongly recommended.

At the time of publication of this British Standard, no corresponding International Standard exists.

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 and ii, pages 1 to 14, 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.

1 Scope

This British Standard recommends minimum thicknesses and safety considerations for the design and construction of glass vessels for use under vacuum in a laboratory, including desiccators and filter flasks. Other configurations of desiccating vessels which are not for use under vacuum are outside the scope of this standard.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Glass quality

The vessels should be free from defects that will weaken the glass, and substantially free from blisters, seed, striae, cord, etc. They should be well annealed.

3 Design features

Figure 1 and Figure 2 indicate by the letters A to H the features included in this standard for vacuum vessels in common use.

Recommendations for these features are given in the clauses listed below.

Feature	Clause
A Flat base with radiused or sharp lower corners	**5**
B Lower and upper parts of side-wall	**6**
C Step to carry perforated plate	**7**
D Flange of body or lid	8
E Lid form	**9**
F Opening for vacuum	**10**
G Flange, ground finish	8
H Flange, grooved with elastomeric insert	8

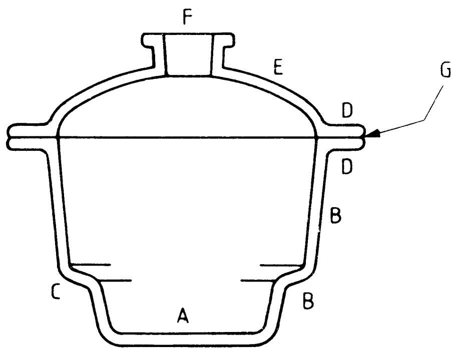


Figure 1 — Common design of vacuum desiccator with flat ground flange

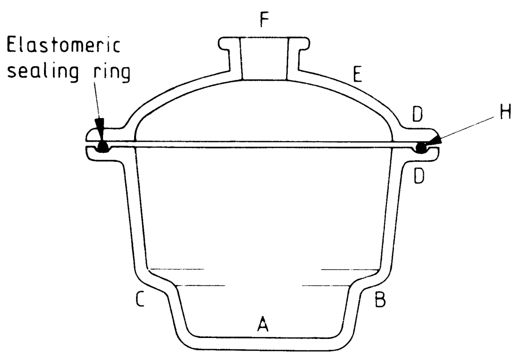


Figure 2 — Common design of vacuum desiccator with grooved flange

4 Symbols

The letter symbols used in this standard together with the quantities to which they refer are listed in Table 1.

Table 1 — Letter symbols

Symbol	Unit	Quantity
p	kPa	Maximum pressure differential (i.e. excess of external pressure over internal pressure) to which the vessel is subjected when in use
f	N/mm^2	Design tensile stress
f_c	N/mm^2	Maximum compressive stress
E	N/mm^2	Modulus of elasticity of glass
k_1, k_2, etc.		Factors for various forms of construction as defined in clauses **5** to **10**
d_i	mm	Internal diameter
d_o	mm	External diameter
t_e	mm	Lid, base or step thickness
t_w	mm	Wall thickness
t_f	mm	Flange thickness
r	mm	Internal corner radius
r_1	mm	Internal radius of vessel or lid
r_2	mm	External radius of vessel or lid
h_o	mm	External height of lid
h_i	mm	Internal height of lid
l	mm	Cantilever length, i.e. the width of the flange face external to body or lid
γ	degree	Angle between the sloping side and the vertical axis
β	degree	Angle between the axis and the tangent to the curve of a part-spherical lid where it meets the flange
α	degree	Half-angle of a conical lid or section

5 Base thickness (design features A and F)

5.1 Flat base with radiused or sharp lower corners

5.1.1 *Recommendations*. The minimum thickness t_e of a flat base should be not less than the larger of the two values given by the following equations.

$$t_e = 0.05\, d_i \qquad [1(a)]$$

$$t_e = d_i \left(\frac{p}{k_1 f}\right)^{0.5} \qquad [1(b)]$$

where

d_i is the internal diameter measured at the base (in mm);

k_1 is a factor derived from equation 2;

p and f are defined in Table 1.

In the construction shown in Figure 3, where the internal corner radius r is greater than $3t_e$, k_1 is derived from the following equation.

$$k_1 = \frac{4}{\left(1 - \frac{r}{d_i} - \frac{2r^2}{d_i^2}\right)^2} \qquad (2)$$

In the construction shown in Figure 4, where the internal corner radius r is less than $3t_e$, k_1 is given the value 5.25. It is recommended that, for desiccator bases, r should be not less than t_e.

NOTE Equation 1, with $k_1 = 5.25$, is applicable in the calculation of the minimum thickness of flat plates.

5.1.2 *Calculations of minimum values of* t_e. Using equation 1, with an example of a 150 mm diameter base, of different corner radii, where $t_e = 0.05d_i$, the following values are obtained.

a) *Base with radiused corners*

r = 32 mm, k_1 = 8.0, t_e = 6.5 mm

r = 25 mm, k_1 = 6.6, t_e = 7.4 mm

b) *Base with sharp corners*

r = 13 mm, k_1 = 5.25, t_e = 8.0 mm

NOTE 1 Desiccators having well-radiused corners (see Figure 3) are generally in accordance with the recommendations of **5.1.1**, the base thickness being not less than $0.05d_i$; those of smaller corner radius require a base thickness greater than $0.5d_i$.

NOTE 2 Extra glass may be provided externally, as shown in Figure 5(a), to form a protective rim or to increase the stability of the vessel, or internally in the form of lugs to support a perforated plate, for example, as shown in Figure 5(b).

NOTE 3 When the side-wall makes an obtuse angle with the base, as shown in Figure 3 and Figure 4, the angle between the side-wall and the vertical axis of the vessel being γ, an extra compressive stress is exerted about the corner, proportional to sec γ; this can generally be ignored.

5.2 Semi-ellipsoidal base

A base of semi-ellipsoidal form should be designed as described in **9.2** for a semi-ellipsoidal lid.

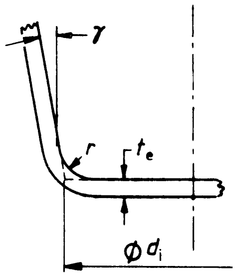


Figure 3 — Base with radiused corners

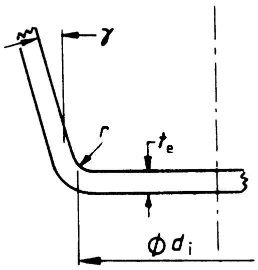


Figure 4 — Base with sharp corners

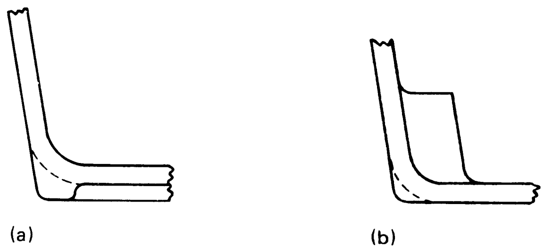


Figure 5 — Methods of reinforcing radiused corners

6 Body thickness and shape (design feature B)

6.1 Straight and stepped side-walls

The side-wall of the vessel should be either stepped or straight and the design principles are the same in each case. The body should be cylindrical or conical with a cone half-angle of less than 15°.

6.2 Part-spherical body

The form of body shown in Figure 6, having a curved sidewall terminating at an angle γ to the axis of the vessel, should be designed as recommended in **9.3** for a part-spherical lid with an extra thickness allowance adjacent to the flange as given by equation 8 in Appendix A, or with the appropriate safe-handling minimum thickness given in Table 2.

Table 2 — Minimum side-wall thickness

Internal diameter	Recommended thickness
mm	mm
150	4
200	5
250	6
300	7

7 Step thickness and radius of curvature (design feature C)

7.1 Recommendations

The internal corners of each step should be radiused as shown in Figure 7. The radii r_1 and r_2 should each be not less than t_e as shown in Figure 7.

NOTE To obtain a significant increase in strength, r_1 and r_2 need to be not less than 3 t_e.

If the angle γ in Figure 7 is less than 60° the step should be treated as a short conical section or swage and the thickness needed at any point should be not less than the value of t_e (in mm) given by the following equation.

$$t_e = \frac{1.66pd_c}{\cos\gamma\,(2f-p)} \quad (3)$$

where

d_c is the diameter of the cone at the point under consideration (in mm);

γ is the half-angle of the conical section (in degrees);

f and p are as defined in Table 1.

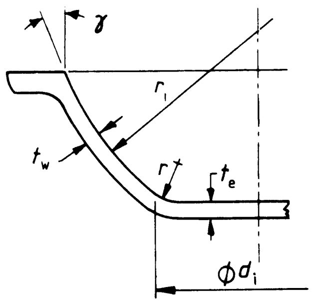


Figure 6 — Curved side-wall with subsidiary curve at corner

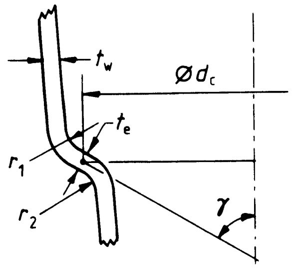


Figure 7 — Form of step (for example, for supporting a perforated plate in a desiccator)

7.2 Examples

Table 3 gives values of t_e for various values of d_c, with $\alpha = 55°$.

Table 3 — Minimum step thickness t_e for $\alpha = 55°$ calculated using equation 3

d_c	t_e **minimum**
mm	mm
150	3.5
200	4.5
250	5.5
300	6.8

8 Flange thickness and shape (design feature D)

8.1 Recommendations

8.1.1 For a flange of the form shown in Figure 8(a), Figure 8(b) and Figure 8(c), the flange thickness t_f (in mm) should be not less than the value given by equation 4(a) if $d_o > d_i$ or not less than the value given by equation 4(b) if $d_o < d_i$.

$$t_f = \left(\frac{2ld_op}{k_2 f}\right)^{0.5} \qquad [4(a)]$$

$$t_f = \left(\frac{2ld_ip}{k_2 f}\right)^{0.5} \qquad [4(b)]$$

where

k_2 is the factor, equal to 2.25, for the flanges shown in Figure 8(a), Figure 8(b) and Figure 8(c);

d_o is the external diameter of the lid or body at the flange (in mm);

d_i is the internal diameter measured at the flange where the joint faces meet (in mm);

l is the cantilever length (in mm);

f and p are as defined in Table 1.

NOTE 1 For the construction shown in Figure 8(a) and Figure 8(b) the width of flange face is equal to the cantilever length l plus the wall thickness t_w.

NOTE 2 Equation 4 indicates that it is an advantage to make the flange as narrow as is compatible with obtaining a good joint.

If the tangent at the flange to the curve described by the inside of the lid meets the flange at an angle γ to the vertical axis as shown in Figure 8(b), the thickness t_f calculated in equation 4 should be increased by the amount given in equation 8 to counter the radial stress introduced.

For the construction in which the flange terminates outside the line of the wall, the angle β shown in Figure 8(d) should not exceed 130°.

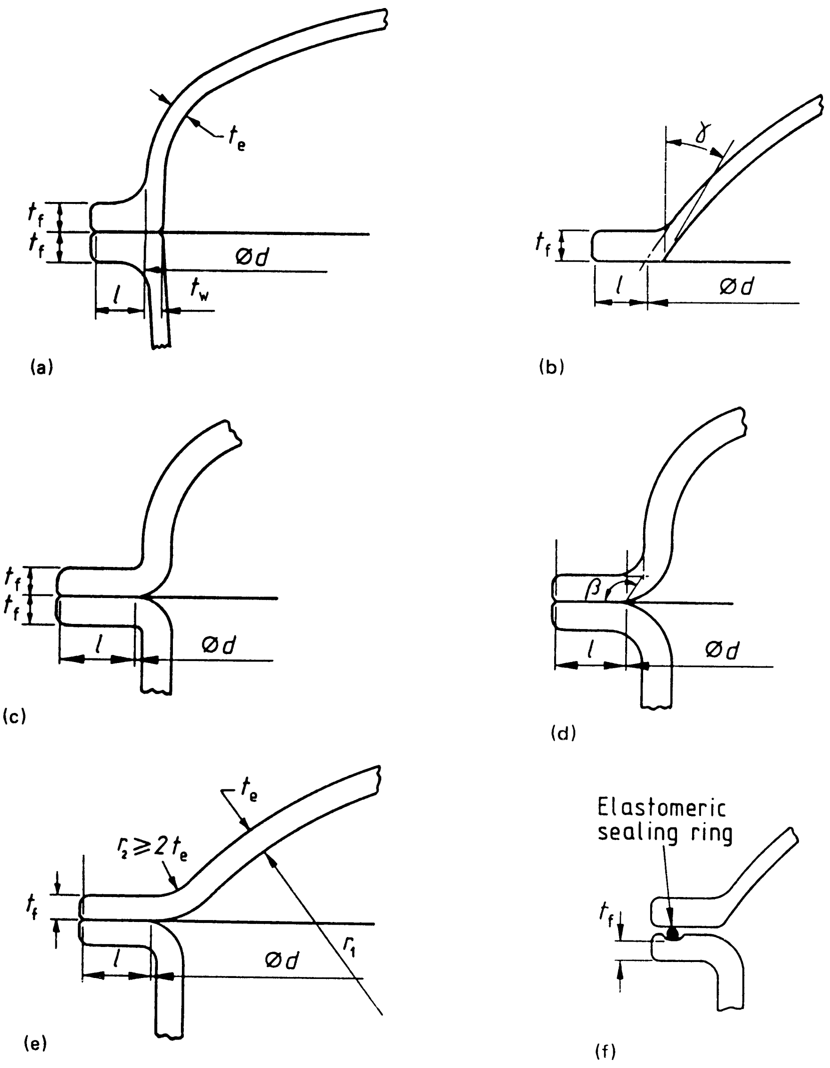


Figure 8 — Alternative flange designs

8.1.2 For a vessel in which the flange and lid take the form shown in Figure 8(e) and Figure 9, the lid being part-spherical and the flange and lid being of substantially the same thickness, the thickness t_f (in mm) of the flange and of the lid should be not less than the value given by the following equation.

$$t_f = k_3 \left[1 + \left(\frac{6ld}{k_3 r_1} \right)^{0.5} \right] \qquad (5)$$

where

$$k_3 = \frac{pr_1 (d + l)}{4f (d + 7l)}$$

d is the internal diameter (in mm) measured at the flange where the joint faces meet.

If the ground face of the lid extends inwards from the point at which the two faces meet as shown in Figure 8(e), it should not do so by more than $0.5t_e$, and r_1 should be not greater than d and the corner radius r not less than $2t_e$.

NOTE For flanges with a recess to accommodate an elastomeric sealing ring the calculated flange thickness t_f is that shown in Figure 8(f) measured from the bottom of the recess.

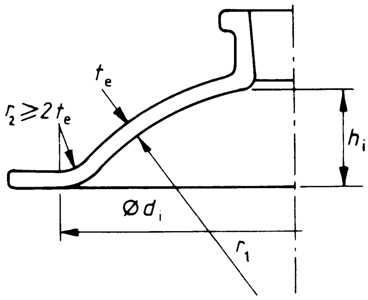


Figure 9 — Part-spherical form lid

8.2 Examples

8.2.1 Table 4 gives examples of flange thickness calculated from equation 4 for a flange face 25 mm in width.

Table 4 — Examples of flange thickness t_f calculated using equation 4

d	t_f	
	Figure 8(a) and Figure 8(b) l **= 19.1 mm**	**Figure 8(c)** l **= 25.4 mm**
mm	mm	mm
150	6.5	7.0
200	7.0	8.5
250	8.0	9.5
300	9.0	10.0
NOTE Width of flange face 25 mm: wall thickness about 6 mm.		

8.2.2 Table 5 gives examples of lid and flange thickness calculated from equation 5 for a flange face 25 mm in width and with two different radii of curvature for the lid, the larger being the limiting value in each case.

Table 5 — Examples of lid and flange thicknesses t_f calculated using equation 5

d	r_1	t_f
mm	mm	mm
150	90	7.0
	150	7.0
200	115	8.5
	200	9.0
250	140	10.0
	250	10.5
300	165	11.5
	300	11.5
NOTE Width of flange face 25 mm.		

9 Lid thickness and curvature (design feature E)

9.1 General

Lids are subject to considerable stresses under vacuum and should be made to one of the forms which lend themselves to simple design calculation. Of these the best are hemispherical (see Figure 10), semi-ellipsoidal (see Figure 11), dished (see Figure 12) and part-spherical (see Figure 9 and Figure 13).

NOTE 1 The term "dished" is the accepted description of the lid whose profile is formed by two radii and which has similar design characteristics to those of an ellipse.

For both the semi-ellipsoidal and dished forms the outer part of the curve should terminate perpendicular to the plane of the flange and the internal radii should be appropriately related to the internal diameter.

NOTE 2 The lid forms described in **9.2** are dealt with fully in BS 5500. However, it is found that when the equations in that standard are applied to desiccator lids, and the lids comply with the recommendations on curvature, the calculated thicknesses are less than those required for the safe-handling of glass fabrications. The relevant equations are therefore given for information in Appendix A but only the safe-handling thicknesses given in **9.2** are recommended.

9.2 Thickness

The thickness of hemispherical, semi-ellipsoidal, dished, part-spherical and conical lids designed in accordance with **9.3** should be not less than the appropriate value given in Table 6.

NOTE The values given in Table 6 are the recommended minimum values for safe-handling. Equations for calculating the minimum thickness of lids based on stress considerations alone are given for information in Appendix A.

The thickness of lids that are not in accordance with the recommendations given in **9.3** should be not less than the value given by equation 1, with $k_1 = 5.25$.

9.3 Curvature

For semi-ellipsoidal lids the ratio of the major axis to the minor axis of the ellipse formed by the lid in cross section should be not greater than 2.6 : 1 (see Figure 11).

For dished lids the crown radius r_1 should be not greater than d_i and the inside corner radius should be not less than $0.1d_i$ (see Figure 12).

For both the semi-ellipsoidal and dished forms the tangent to the curve described by the outer surface of the lid at the ground flange face should be at a right angle to the horizontal axis (see Figure 11 and Figure 12).

For part-spherical lids in which the lids and the flange are of substantially the same thickness, the lid should be in accordance with **8.1.2**. For part-spherical lids in which the lid and flange thicknesses are different, r_1 should be not greater than d_i (see Figure 13).

For conical lids the half-angle of the cone should not exceed 60°.

Table 6 — Minimum safe-handling thicknesses (t_e minimum) for lids

d_o	t_e **minimum**
mm	mm
150	4
200	5
250	6
300	7

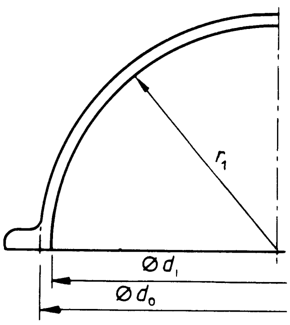


Figure 10 — Hemispherical form lid

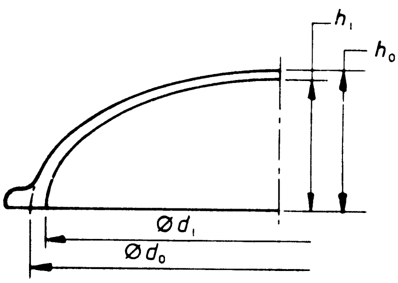


Figure 11 — Semi-ellipsoidal form lid

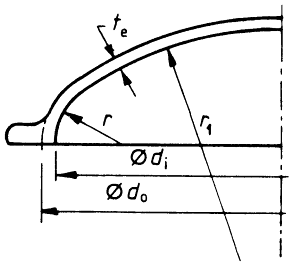


Figure 12 — Dished form lid

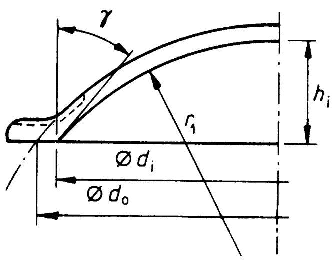


Figure 13 — Part-spherical form lid

10 Opening for vacuum (design feature F)

The vacuum adaptor should be constricted in some part, e.g. below the cone, so that sudden opening to a vacuum pump or the atmosphere will not cause too abrupt a change in pressure.

If the opening for vacuum is in the lid it should be at the apex, but if required in the side of the body, it should be at a position of adequate thickness and well removed from the flange and the step. Provided that this opening is small, there need be no extra allowance for thickness in the lid or in the side of the body.

It is recommended that a 34/35 (B34) joint complying with BS 572 is the largest size that should be fitted to the apex of a lid, owing to the danger of seizure under vacuum, but the largest size that should be fitted to the side is 19/26 (B19). The use of non-interchangeable joints is not recommended.

It is essential that any fitment, e.g. a stopcock, should be of adequate strength to resist being pulled into the vessel when a vacuum is applied.

11 Grinding of flanges (design feature G)

If ground flanges are used, the two faces should be separately ground plane so that they are interchangeable; non-interchangeable grinding is not recommended. The ground surface should have a roughness not exceeding 1 μm R_a when assessed in accordance with BS 1134-1.

NOTE A meter cut-off of 0.76 mm is suitable for roughness measurement of most ground surfaces.

12 Elastomeric joint seals (design feature H)

If the vacuum seal between two parts of the vessel is achieved by means of an elastomeric sealing ring (O-ring or similar), it is recommended that a suitable synthetic elastomer (e.g. chloroprene) is used.

13 Tests

If it is desired to confirm the strength of the structure of a vessel, the methods described in Appendix B, Appendix C and Appendix D are recommended. Methods for hydraulic pressure tests are outlined in Appendix B, and a method for observation using polarized light in the strain-viewer in Appendix C. Appendix D describes methods for examining the flange faces for flatness and fineness of grinding.

14 Size description of desiccators

It is recommended that the nominal internal diameter at the flange be used as a size designation of vacuum desiccators.

NOTE Designation by the diameter of the perforated plate for which the desiccator has been designed is also customary.

It is recommended that the following dimensions should be stated in describing the size of desiccators.

a) Internal diameter at the flange.

b) Nominal diameter of the designed usable space.

c) Nominal height of the designed usable space.

Appendix A Equations for calculation of minimum thickness of lids based on stress considerations only

A.1 Hemispherical, semi-ellipsoidal and dished lids

The general equation for determining the thickness t_e of hemispherical lids (see Figure 10), semi-ellipsoidal lids (see Figure 11) and dished lids (see Figure 12) is as follows.

$$t_e = \frac{p\, d_o\, k_4}{2.3\, f_c} \qquad (6)$$

where

d_o is the external diameter of the developed shape (in mm);

k_4 is a factor derived from the graph Figure 14 from the ratio h_o/d_o, with the following conditions:

a) for the semi-ellipsoidal form, the ratio of major axis to minor axis of the ellipse formed by the lid in cross section is not greater than 2.6 : 1;

b) for the dished form, the crown radius r_1 is not greater than d_i and the inside corner radius not less than $0.1d_i$;

f_c and p are as defined in Table 1.

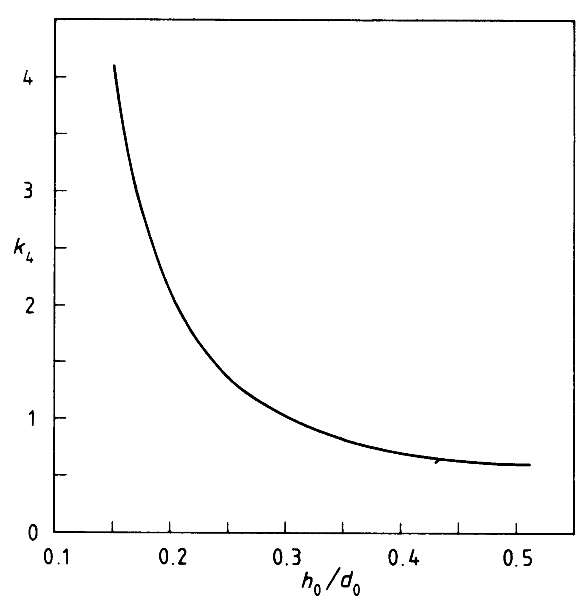


Figure 14 — Factor k_4 for hemispherical and semi-ellipsoidal lids

Calculate the thickness from equations 6 and 7 and take the larger value.

$$t_e = r_1 \left(\frac{p}{0.8\,E}\right)^{0.4} \qquad (7)$$

where

E is as defined in Table 1.

NOTE This formula may here be simplified to $t_e = 0.0051\, r_1$.

A.2 Part-spherical lids

Part-spherical lids are generally of one of two forms of construction, either as shown in Figure 9, in which the lid and the flange are of substantially the same thickness, or as shown in Figure 13, when the thicknesses of the flange and the lid may be separately controlled.

Part-spherical lids of the form shown in Figure 9 are dealt with fully in **8.2**.

For part-spherical lids of the form shown in Figure 13, provided that r_1 is not greater than d_i, the minimum thickness of the curved part is given by equations 6 and 7. The additional cross-sectional area of glass, A, which has to be provided either in the flange or in that part of the lid adjacent to the flange, is given by equation 8.

$$A = \frac{p d_i^2 \tan\beta}{8f} \qquad (8)$$

where

β is the angle between the axis, and the tangent to the curve of the lid where it meets the flange (in degrees) (see Figure 8).

A.3 Conical lids

For conical lids, provided that the half-angle of the cone does not exceed 60°, the minimum thickness t_e is given by equation 9.

$$t_e = \frac{0.83\, p\, d}{f \cos\alpha} \qquad (9)$$

where

α is the half-angle of the cone.

Owing to the radial stress set up about the flange, an additional thickness has to be provided, as described in **A.2**.

Appendix B Hydraulic external pressure tests

B.1 Apparatus

The vacuum vessel is tested in a pressure vessel connected to a suitable water supply and fitted with a pressure gauge of appropriate range, complying with BS 1780. Alternatively, pressure may be applied by means of a ram pump connected to a water reservoir with a release valve discharging back to the reservoir. A suitable arrangement is shown in Figure 15.

B.2 Procedure

Clean the vessel and assemble for use in accordance with the manufacturer's instructions. Close the stopcock at atmospheric pressure. Ensure that the vessel is submerged, either by means of some suitable device or by placing cloth-wrapped weights in it. Fill the pressure vessel with water and raise the pressure to 400 kPa gauge and maintain this pressure for 1 min.

A test of this duration indicates that a vessel capable of sustaining the applied pressure without damage could be expected to withstand indefinitely a pressure differential (external-internal) of 100 kPa, provided the glass is not abraded, bruised or otherwise damaged in subsequent service. However, the design recommendations in this British Standard incorporate a maximum permissible tensile stress of 6.89 N/mm^2 and provide a safety factor of at least 3.

Appendix C Polarized light test

Examine the evacuated vessel under polarized light in a strain-viewer and assess the strain produced in different portions of the desiccator by matching the colours with those produced in a specimen of the same glass strained in a tensometer as shown in Figure 16, or a vessel made from the same batch and known to be satisfactory, while viewed in the same strain-viewer.

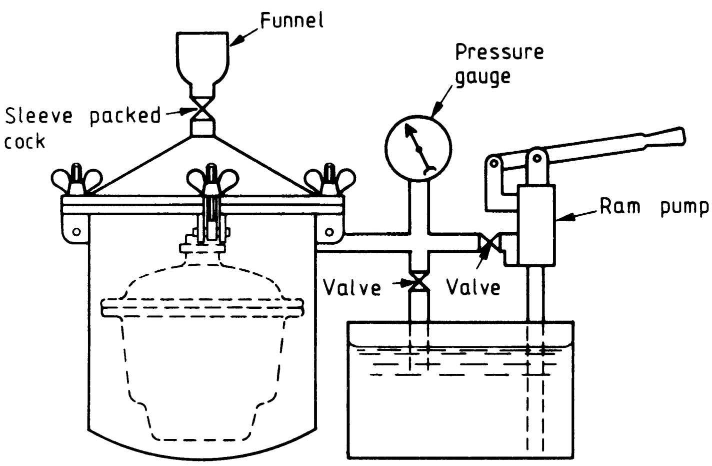
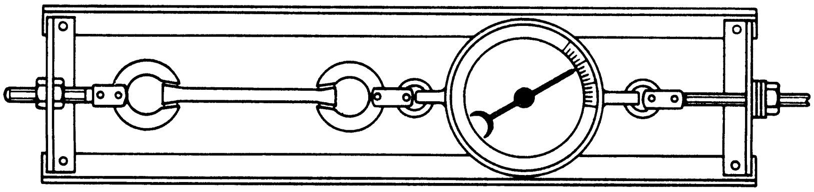
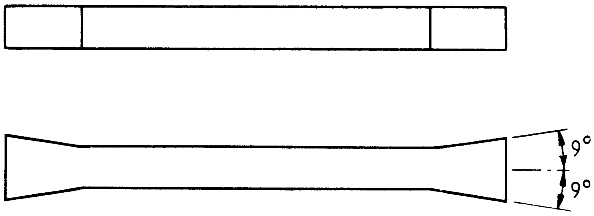


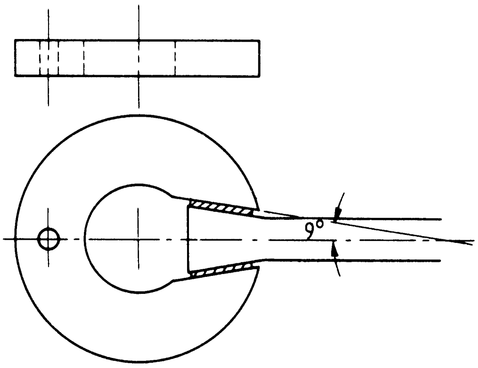
Figure 15 — Hydraulic test rig



(a) General arrangement



(b) Glass test-piece



(c) Clamp for glass test-piece

Figure 16 — Tensometer for polarized light test

Appendix D Test for ground flat flanges

D.1 Principle

This test may be applied either to an assembled vessel or to either part against a flat reference plate. Vessels of the elastomeric sealing ring type should be tested as an assembly. The test assesses the rate of leakage of the clean dry flange under a small controlled reduced pressure. The sensitivity of the test is independent of the volume of the vessel and, for practical purposes, independent of the dimensions of the flange.

D.2 Apparatus

The apparatus is shown in Figure 17(a), and consists of a vacuum pump connected by a T-piece B to a reduced pressure regulator A, which comprises a cylindrical vessel containing water that is closed by a rubber bung and carries the tube C, one end of which is open to the atmosphere and the other end immersed in the water to a depth of 300 mm. The depth of immersion h of this tube determines the controlled reduced pressure head. The T-piece B is further connected to a conventional form of flowmeter D, having a manometer height greater than h, and containing coloured water as the manometric liquid, and a control capillary E. For this purpose a 30 mm length, clean cut at both ends, of 0.5 mm precision-bore tubing is suitable, but for more critical use the bore may be decreased to 0.4 mm. The flowmeter is also provided with a by-pass cock F of not less than 5 mm bore, and a release cock G. The article under test is connected by rubber tubing to J. For the suction pump a small vacuum pump is suitable.

To test the surface finishes of flanges a small test probe is used [see Figure 17(c)]. This is made from a 15 mm pipe-end complying with BS 2598, the face of which is carefully finished to maximum diameter and finely lapped flat.

D.3 Procedure

D.3.1 ***Complete vacuum vessel***

Connect end J to its opening by rubber bung or greased joint, the flanges being clean and dry.

With tap G closed, tap F open, and the air tube C bubbling freely, allow a few seconds to elapse to stabilize the pressure, close tap F and read the manometer. At the conclusion of the test, open taps F and G in this order. Acceptable vessels show a manometer reading of less than 20 mm.

D.3.2 ***Lids and bases separately***

Connect end J to the centre of a test plate as shown in Figure 17(b). Plate glass not less than 2.7 mm thick is suitable.

D.3.3 ***Surface finish of flanges***

Connect end J to the test probe as shown in Figure 17(c) and press its face in succession to any section of the flange under test and on to a reference plate. Compare the manometer readings.

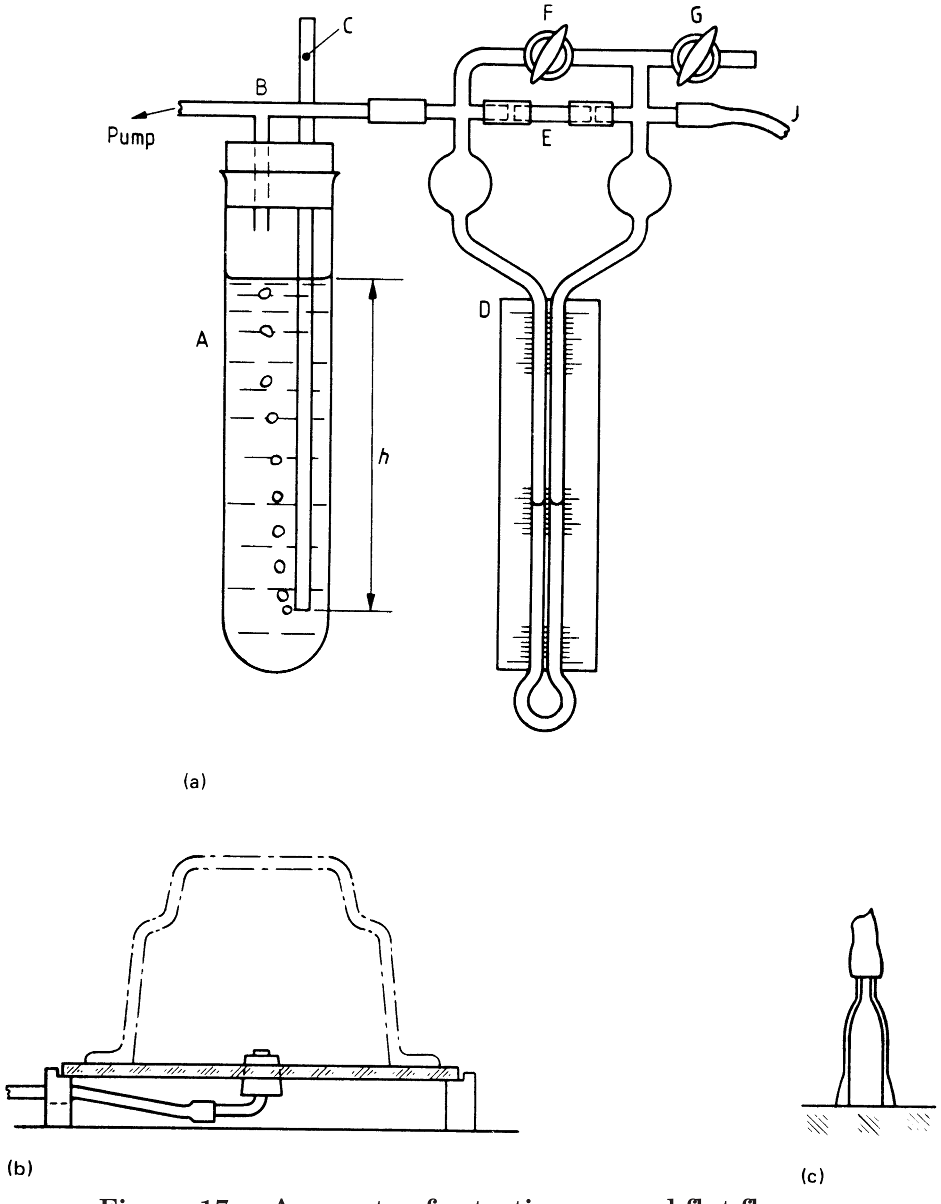


Figure 17 — Apparatus for testing ground flat flanges

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Publications referred to

BS 572, *Specification for interchangeable conical ground glass joints.*
BS 1134, *Method for the assessment of surface texture.*
BS 1134-1, *Method and instrumentation.*
BS 1780, *Specification for Bourdon tube pressure and vacuum gauges.*
BS 1780-2, *Metric units.*
BS 2598, *Glass plant, pipeline and fittings.*
BS 2598-3, *Pipeline and fittings of nominal bore 15 to 150 mm; compatibility and interchangeability.*
BS 5500, *Specification for unfired fusion welded pressure vessels.*

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