BRITISH STANDARD

BS 5276-2:
2003

Pressure vessel details (dimensions) —

Part 2: Specification for saddle supports for horizontal cylindrical pressure vessels

ICS 23.020.30

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PVE/1, Pressure vessels, upon which the following bodies were represented:

Air Conditioning and Refrigeration Board (ACRIB)
British Chemical Engineering Contractors' Association
British Compressed Gases Association
British Refrigeration Association
British Valve and Actuator Manufacturers' Association (BVAMA)
Department of Trade and Industry (Standards and Technical Regulations Directorate)
Electricity Association
Energy Industries Council
Engineering Equipment and Materials Users' Association
Health and Safety Executive
LP Gas Association
Lloyd's Register of Shipping
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The Welding Institute

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Contents

Foreword

This part of BS 5276 has been prepared by Technical Committee PVE/1 to cover the dimensions of pressure vessel details. It supersedes BS 5276-2:1983, which is withdrawn. This new edition of BS 5276-2 incorporates technical changes only. It does not reflect a full review or revision of this standard, which will be undertaken in due course.

BS 5276 is published in the following Parts:

— Part 1: *Specification for davits for branch covers of steel vessels;*

— Part 2: *Specification for saddle supports for horizontal cylindrical pressure vessels;*

— Part 4: *Standardized pressure vessels.*

Part 3 has been withdrawn without being replaced.

This Part provides data for evaluating the maximum permissible loads on shells of vessels, this data being based upon the requirements of PD 5500. Attention is drawn to PD 6497 which indicates the derivation of the basic equations and constants used in PD 5500. Maximum permissible loads for support parts are also specified.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 15 and a back cover.

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1 Scope

This Part of BS 5276 specifies dimensions and materials for saddle supports welded to stationary horizontal vessels with internal diameters between 600 mm and 3 000 mm, conforming to PD 5500 and having ellipsoidal or torispherical dished ends. This British Standard is applicable to saddle supports welded to vessels manufactured from carbon, carbon manganese and austenitic steels having a permissible design stress not exceeding 210 N/mm^2 at 50 °C, with corresponding values at higher temperatures.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 21, Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).

BS 449-2, Use of structural steel in building — Part 2: Metric units.

PD 5500:2003, Specification for unfired fusion welded pressure vessels.

BS EN 10025, Hot rolled products of non-alloy structural steels — Technical delivery conditions.

BS EN 13000 (all parts), Plastics — Polytetrafluoroethylene (PTFE) semi finished products.

3 Materials

3.1 Saddle supports

The materials used for the construction of the supports shall be as follows.

a) The saddle plate, which is welded to the vessel, shall be made from material in accordance with the same material specification as the material used for the vessel.

b) Parts of the supports which are not welded to the vessel shall either be made from material in accordance with the same material specification as used for the vessel, or from material of grades 1.0038, 1.0044, 1.0114 or 1.0143 in accordance with BS EN 10025, providing they are suitable at the predicted temperature.

3.2 Anti-friction materials for sliding supports

When polytetrafluoroethylene (PTFE) is specified for sliding supports (see **6.1**) it shall conform to BS EN 13000. PTFE shall not be used for applications at temperatures in excess of 200 °C.

4 Dimensions

4.1 The dimensions of the supports shall be in accordance with Figure 1 or Figure 2, according to the diameter of the vessel.

4.2 Saddle supports shall fit closely, and the gap at all exposed edges to be welded shall not exceed 2 mm or one-twentieth of the thickness of the attachment at the point of attachment, whichever is the greater.

5 Manufacture

Saddle supports shall normally be welded to the vessel before any post-weld heat treatment, but in exceptional circumstances, the saddle shall be attached following post-weld heat treatment, provided that the saddle plate is continuously welded to the shell before post-weld heat treatment.

NOTE This standard does not specify a procedure for welding the saddle supports to the vessel after post-weld heat treatment and the full procedure, including the welding of the saddle, should be subject to agreement between the manufacturer and the purchaser.

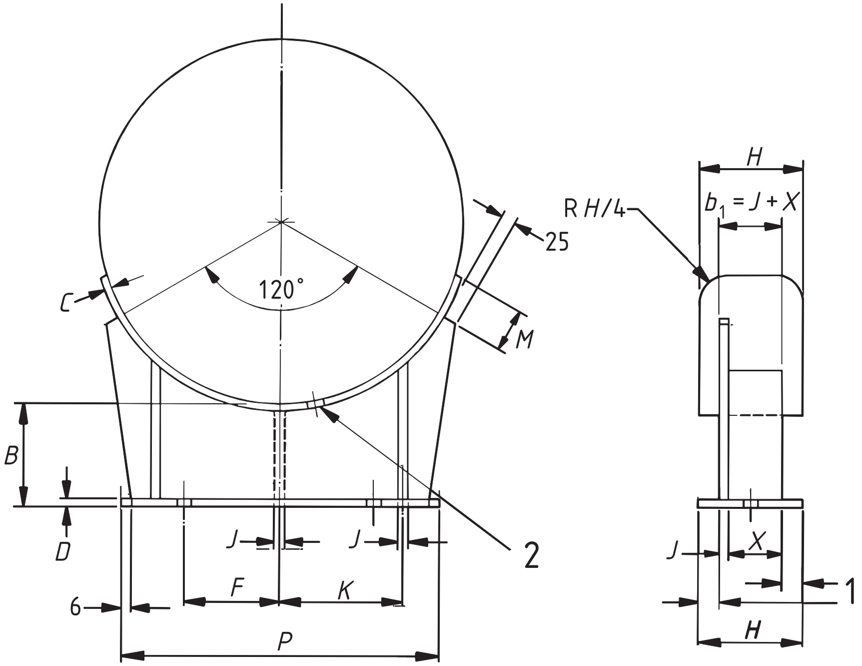
6 Design considerations

6.1 Provision for axial movement

One support shall be fixed and the other shall be restrained laterally but able to move axially to accommodate movement resulting from thermal effects and axial strain.

The sliding support shall be determined from Figure 3 as either the steel-on-steel type (see Figure 4) or of low friction material (see Figure 5).

NOTE It is assumed that the coefficient of friction is 1 for steel-on-steel sliding supports and 0.1 for sliding supports of low friction material. On this basis, the use of the steel-on-steel type is to be limited to those applications where the load on the saddle support falls below the curve on Figure 3 and is also less than 0.1 W_v (see Clause **7**). In cases where either of these limitations is exceeded, low friction material should be used. The choice of sliding support to be used is further influenced by consideration of the horizontal forces imposed upon the foundations or supporting steelworks.



Weld details:

(a) *Fabrication of saddle supports*: continuous fillet welds on both sides of the plate with leg lengths of 6 mm.

(b) *Connecting saddle plate to shell*: continuous fillet welds with leg lengths equal to the saddle plate thickness or 10 mm, whichever is the lesser.

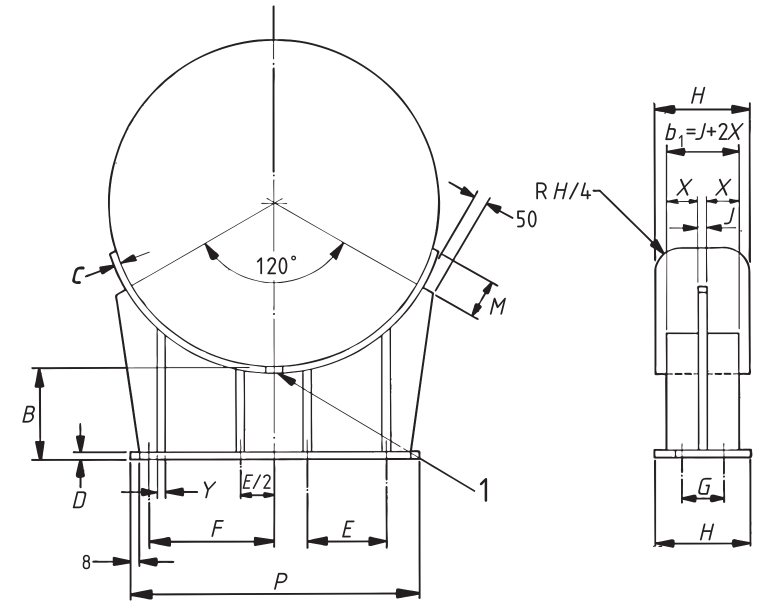
Key
1 Equally spaced.
2 At least one hole drilled through saddle plate and tapped ¼ in B.S.P. (R_c ¼ conforming to BS 21).

All dimensions are in millimetres unless stated otherwise

Internal diameter of vessel	**Dimensions as shown in Figure 1**										**Centre rib required**	**Holding down bolts**[a]		**Approximate mass of saddle support**[b]	**Maximum load,** W_s (see Clause **7**)
	P	***B***	***C***	***D***	***F***[a]	***H***	***X***	***J***	***K***	***M***		**Diameter of holes**	**Size of bolts**	kg	kg
600 to 750	600		To be equal to vessel shell thickness (t) up to a maximum of 15		225	180	130		260	60	No			22	2 500
800 to 950	750	200		12	300			6	336			26	M20	28	5 000
1 000 to 1 150	900				375	250	190		410	80	Yes			42	9 000

[a] Details of holding down bolts are applicable to fixed supports and are not applicable to sliding supports (see **6.1**).
[b] Mass of saddle support given is without saddle plate (this varies according to vessel shell thickness).

Figure 1 — Saddle supports for horizontal vessels of internal diameter of 600 mm to 1 150 mm



Weld details:

(a) *Fabrication of saddle supports:* continuous fillet welds on both sides of the plate with leg lengths of 6 mm for vessels with internal diameters from 1 200 mm to 1 900 mm, inclusive and with leg lengths of 8 mm for vessels with internal diameters from 2 000 mm to 3 000 mm, inclusive.
(b) *Connecting saddle plate to shell:* continuous fillet welds with leg lengths equal to the saddle plate thickness or 10 mm, whichever is the lesser.

Key
1 At least one hole drilled through saddle plate and tapped ¼ in B.S.P. (R_c ¼ conforming to BS 21).

All dimensions are in millimetres unless stated otherwise

Internal diameter of vessel	Dimensions as shown in Figure 2												Holding down bolts[a]		Approximate mass of saddle support[b] kg	Maximum load, W_s (see Clause **7**) kg
	P	***B***	***C***	***D***	***E***	***F***[a]	***H***	***G***[a]	***J***	***M***	***X***	***Y***	**Diameter of holes**	**Size of bolts**		
1 200 to 1 500	1 150		To be equal to vessel shell thickness (*t*) up to a maximum of 15		290	500	250	180		85	90		26	M20	100	20 000
1 600 to 1 900	1 450			15	380	650			12.5	110		12	30	M24	145	40 000
2 000 to 2 300	1 750	226			470	775	300	220		130	120				220	65 000
2 400 to 2 700	2 050			20	550	900			15	150		15	36	M30	300	100 000
2 800 to 3 000	2 300				630	1 025	400	300	20	160	160				350	130 000

[a] Details of holding down bolts are applicable to fixed supports and are not applicable to sliding supports (see **6.1**).
[b] Mass of saddle support given is without saddle plate (this varies according to vessel shell thickness).

Figure 2 — Saddle supports for horizontal vessels of internal diameter of 1 200 mm to 3 000 mm

6.2 Holding down bolts

The position and sizes of holding down bolts shall be in accordance with the fixed support shown in Figure 1 and Figure 2.

NOTE The position and sizes of holding down bolts specified are adequate to resist overturning without the need for holding down bolts in the sliding support. They are designed for empty vessels of minimum thickness (6 mm) and maximum length derived from $L_t/D_i = 5$ (see Clause **7**), with a basic wind speed of 31 m/s, see BS 6399-2. The resultant tensile forces in the holding down bolts on the windward side resulting from the above consideration are as shown in Table 1.

The tensile forces given in Table 1 shall be used to assess the margin in hand to cater for additional overturning moments from pipework, platforms, etc.

Table 1 — Tensile forces in holding down bolts

Vessel diameter mm	**Tensile force per bolt** N
750	2 240
950	2 720
1 150	3 120
1 500	1 890
1 900	2 530
2 300	3 380
2 700	4 330
3 000	6 610

Holding down bolts shall be provided at the sliding support if flotation is to be guarded against.

6.3 Special considerations

Special additional consideration shall be given to the following:

a) cyclic conditions which can lead to fatigue, see PD 5500:2003, Annex C;

b) saddle supports not welded to the shell;

c) saddle supports located at positions, relative to the domed ends, different to those indicated in Figure 6;

d) subsidence occurring at one support relative to the other, which can result in loading and structural implications.

e) vessels installed on a slope, e.g. to cater for drainage.

7 Maximum permissible loads

The maximum permissible load which may be supported on each saddle support shall be the lesser of the following.

a) The load relevant to the structural design of the supports, which is equivalent to the force exerted by a mass of W_s. Values of W_s, in kilograms, are given in Figure 1 and Figure 2.

b) The load relevant to the strength of the vessel shell, which is equivalent to the force exerted by a mass of W_v. Values of W_v in kilograms, are determined in accordance with the following formula:

$$W_v = Kf$$

where

K is the coefficient given in Table 2 (see **A.2** for derivation);
f is the permissible design stress in the vessel shell, in N/mm^2.

NOTE 1 Information provided for evaluating the maximum permissible load on shells of non-cyclically loaded vessels is based on the method given in PD 5500:2003, **G.3.3** for shells not stiffened by rings at the saddles, and applies to the direct load of the weight of the vessel and its contents reacting through the supports positioned at specified locations on the shell cylinder.

NOTE 2 Attention is drawn to the need to consider all external forces and superimposed loads. For vessels which are to be hydraulically tested, the weight of water should be taken into account.

The following conditions apply.

1) The coefficient K shall be applicable only to steel shell materials having a permissible design stress not exceeding 210 N/mm^2 at 50 °C, with corresponding values at higher temperatures.

2) In calculating coefficient K, it shall be assumed that the shell thickness has been reduced by corrosion by 1.5 mm.

NOTE 3 Corrosion allowance has not been allowed for in the saddle plate.

3) Domed ends shall be either of ellipsoidal or torispherical shape conforming to the shape limitations of PD 5500:2003, **3.5.2.2**.

4) The location of supports relative to domed ends shall be as follows.

i) For vessels of internal diameter from 600 mm up to and including 750 mm, the supports shall be located where:

$$A = \frac{L_t}{5}$$

where

A is the distance from the centreline of the saddle support to the tangent line of the domed end;
L_t is the length of the cylindrical portion of the vessel between the tangent lines of the domed ends.

NOTE 4 The shell cylinder is not stiffened by the vessel ends.

ii) For vessels of internal diameter of 800 mm and larger, the supports shall be located where:

$$b_1 \leq A \leq \frac{D_i}{4}$$

where

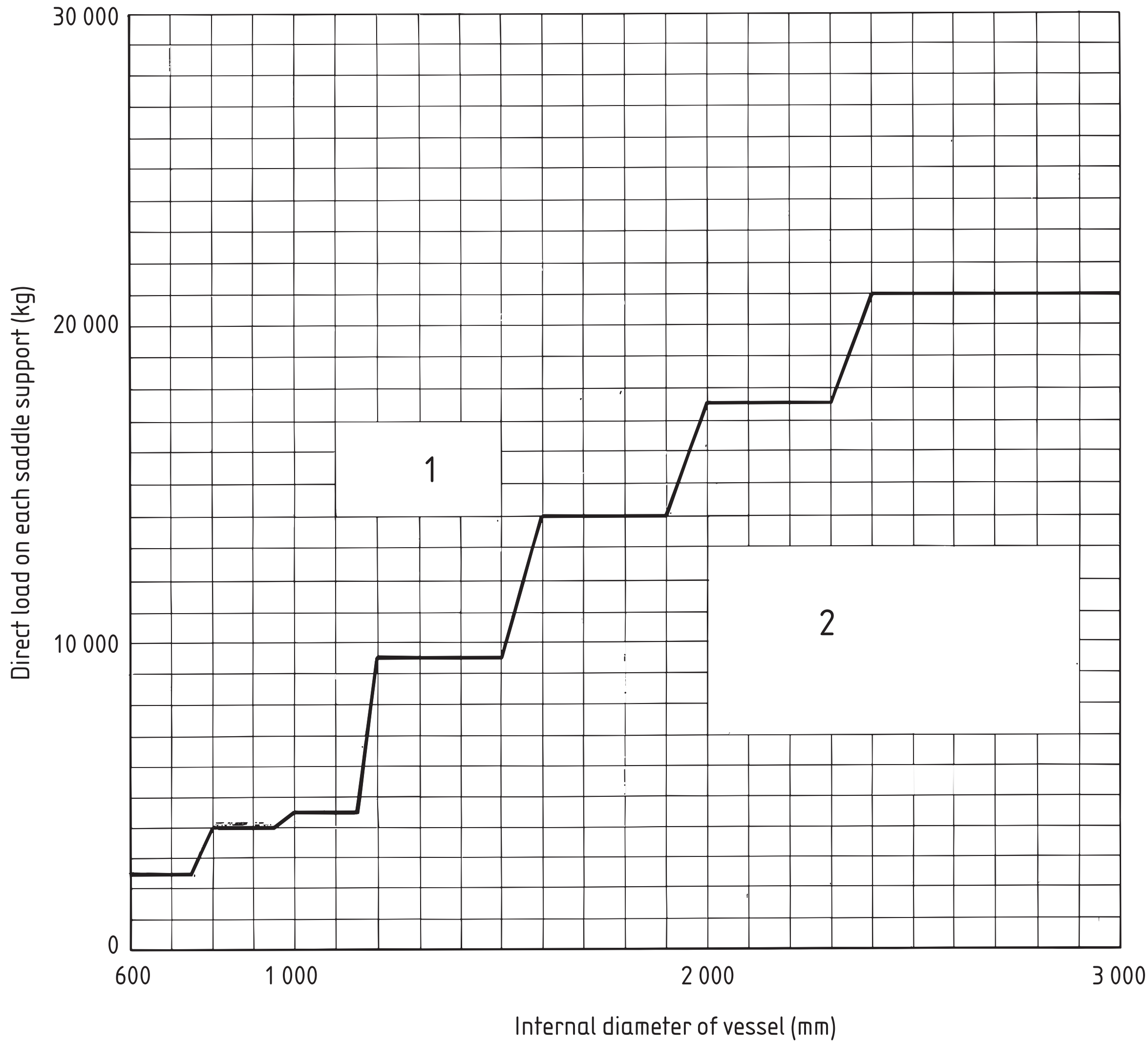
b_1 is the effective width of the saddle support (see Figure 1 and Figure 2);

D_i is the inside diameter of the vessel.

NOTE 5 The shell cylinder is stiffened by the vessel ends.

NOTE 6 Permissible locations are shown in Figure 6.

NOTE 7 This information for locating the supports takes into account the requirements of item 4) and also the need for adequate distance between the weld connecting the saddle plate to the vessel and the weld connecting the shell cylinder to the domed end.

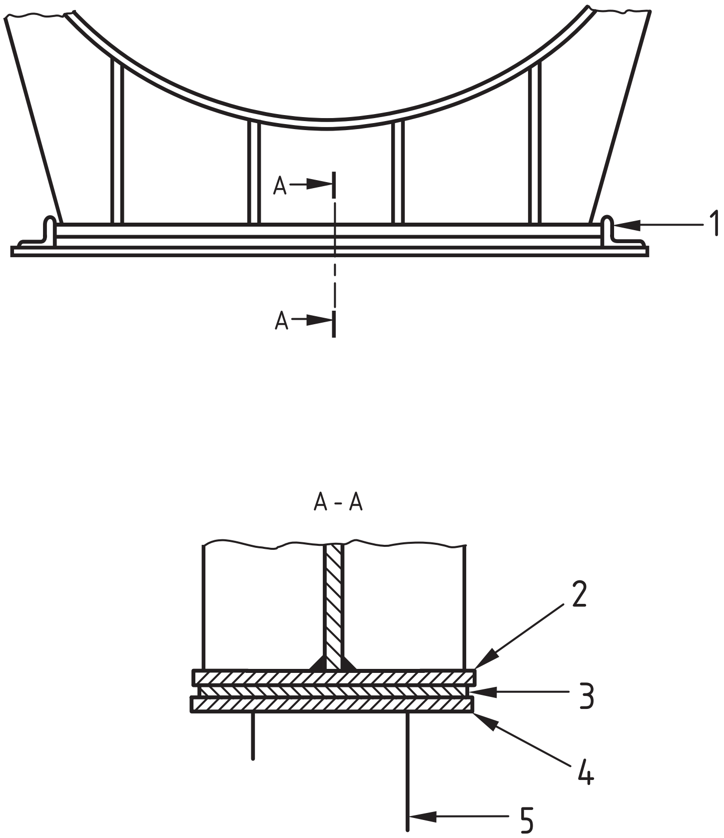


Key

1 Above line use low friction materials.

2 Below line steel-on-steel may be used providing that the load is less than $0.1W_v$ and the horizontal force on the foundations or supporting steelwork is acceptable (see **6.1**).

Figure 3 — Selection chart for type of sliding support required



Key

1 Guide angles to prevent lateral movement.

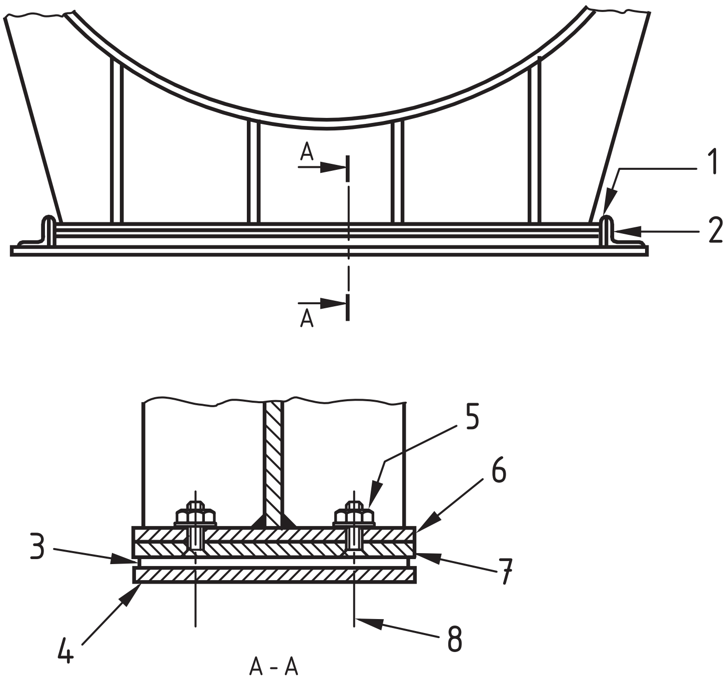
2 Saddle support base plate.

3 Rubbing plate.

4 Foundation plate.

5 Foundation plate holding down bolts.

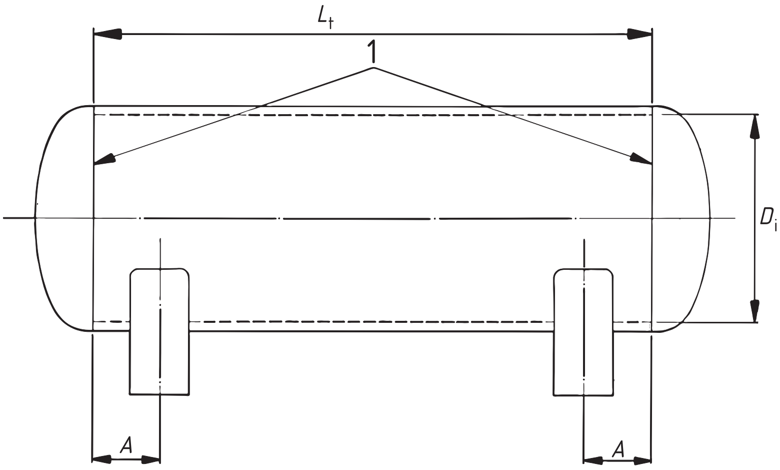
Figure 4 — Typical design of steel-on-steel type of sliding support



Key

1 Optional low friction material facing on edge of base plate or on guide angle.
2 Guide angles to prevent lateral movement.
3 Low friction material bearing pad (smaller than the backing plate) fixed to the foundation plate.
4 Foundation plate.
5 Countersunk head bolts.
6 Saddle support base plate.
7 Backing plate bolted to base plate.
8 Foundation plate holding down nuts.

Figure 5 — Typical design of sliding support with low friction materials



NOTE The minimum vessel length L_t which will permit this location for the supports is 1 000 mm.

For vessels of diameter of 800 mm to 3 000 mm dimension A shall be as follows:

All dimensions are in millimetres

Internal diameter of vessel	Dimension A	
	Min.	**Max.**
800 to 950	200	$\frac{D_i}{4}$
1 000 to 1 400	250	
1 500	260	
1 600 to 2 300	300	
2 400 to 3 000	400	

For vessels of internal diameter of 600 mm to 750 mm A = $L_t/5$

Key

1 Tangent lines.

Figure 6 — Location of supports relative to domed ends

Table 2 — Coefficient *K* for calculating permissible load (W_v) per saddle support

Vessel internal diameter mm	L_t/D_i[a]	t[a]							
		6	8	10	12.5	15	20	25	30
600 to 750	1.25	30	61	101	167	247	*247*	*247*	*247*
	2.5	19	40	68	112	167	*167*	*167*	*167*
	3	23	47	80	132	197	*197*	*197*	*197*
	4	30	62	104	151	185	*185*	*185*	*185*
	5	30	62	94	122	149	*149*	*149*	*149*
800 to 950	1.25	37	75	126	207	306	*306*	*306*	*306*
	2.5	68	135	217	280	344	*344*	*344*	*344*
	3	79	156	217	280	344	*344*	*344*	*344*
	4	99	166	217	280	344	*344*	*344*	*344*
	5	99	166	217	280	344	*344*	*344*	*344*
1 000 and 1 050	1.25	45	77	130	213	316	578	*578*	*578*
	2.5	83	142	235	350	430	589	*589*	*589*
	3	96	165	271	350	430	589	*589*	*589*
	4	121	207	271	350	430	589	*589*	*589*
	5	121	207	271	350	430	589	*589*	*589*
1 100 and 1 150	1.25	45	77	130	213	316	578	*578*	*578*
	2.5	83	142	235	379	473	648	*648*	*648*
	3	96	165	271	385	473	648	*648*	*648*
	4	121	207	298	385	473	648	*648*	*648*
	5	121	207	298	385	473	648	*648*	*648*
1 200 to 1 500	1.25	45	77	130	213	315	577	*577*	*577*
	2.5	82	142	234	378	516	707	*707*	*707*
	3	96	165	270	420	516	707	*707*	*707*
	4	121	206	325	420	516	707	*707*	*707*
	5	121	206	325	420	516	707	*707*	*707*

NOTE 1 Supports for vessels where the coefficients are shown in italics do not satisfy the condition in PD 5500:2003, **G.3.3.2.7**, that b_1 should be at least equal to $\sqrt{30D}$. The coefficients shown are conservative values repeated horizontally from those calculated for thinner vessels which do satisfy the rule $b_1 \geq \sqrt{30D}$.

NOTE 2 Values of coefficient *K* may be linearly interpolated between adjacent values of L_t/D_i.

NOTE 3 Where coefficients are to the left of the heavy line, this indicates the vessels designed to a maximum stress of 70 N/mm^2 might be overstressed if filled with water even without superimposed loads. Where coefficients are to the left of the double line, this indicates that vessels designed to a maximum stress of 130 N/mm^2 might be overstressed if filled with water even without superimposed loads.

[a] The symbols used have the following meanings:
- t is the vessel shell thickness in the uncorroded condition (in mm);
- L_t is the length of cylindrical portion of vessel between tangent lines of domed ends (in mm);
- D is the mean diameter of vessel;
- D_i is the inside diameter of vessel (in mm).

Table 2 — Coefficient *K* for calculating permissible load (W_v) per saddle support *(continued)*

Vessel internal diameter mm	L_t/D_i[a]	t[a]							
		6	8	10	12.5	15	20	25	30
1 600	1.25	45	79	132	217	322	590	933	*933*
	2.5	85	146	242	393	575	943	1 198	*1 198*
	3	99	171	282	454	661	943	1 198	*1 198*
	4	126	216	353	561	688	943	1 198	*1 198*
	5	126	216	353	561	688	943	1 198	*1 198*
1 700 to 1 900	1.25	45	79	132	217	322	590	933	*933*
	2.5	85	146	242	395	575	1 002	1 237	*1 237*
	3	99	171	282	454	661	1 002	1 237	*1 237*
	4	126	216	353	563	731	1 002	1 237	*1 237*
	5	126	216	353	563	731	1 002	1 237	*1 237*
2 000 to 2 200	1.25	45	79	132	217	322	590	934	*934*
	2.5	85	146	243	393	576	1 034	1 497	*1 497*
	3	100	171	282	454	662	1 179	1 497	*1 497*
	4	127	216	353	564	816	1 179	1 497	*1 497*
	5	117	216	353	564	816	1 179	1 497	*1 497*
2 300 and 2 400	1.25	45	79	132	217	322	590	934	*934*
	2.5	85	146	243	393	576	1 034	1 611	*1 611*
	3	100	171	282	454	662	1 181	1 722	*1 722*
	4	127	216	353	564	816	1 355	1 722	*1 722*
	5	110	216	353	564	816	1 355	1 722	*1 722*
2 500 and 2 600	1.25	46	94	135	222	329	604	955	1 383
	2.5	87	176	251	407	598	1 075	1 676	2 270
	3	103	205	293	473	692	1 236	1 871	2 270
	4	132	260	370	593	861	1 473	1 871	2 270
	5	102	260	370	593	861	1 473	1 871	2 270
2 700 to 3 600	1.25	46	94	135	222	329	604	955	1 383
	2.5	87	176	251	407	598	1 075	1 676	2 397
	3	103	205	293	473	692	1 236	1 971	2 451
	4	112	260	370	593	861	1 520	2 021	2 451
	5	83	253	370	593	861	1 520	2 021	2 451

NOTE 1 Supports for vessels where the coefficients are shown in italics do not satisfy the condition in PD 5500:2003, **G.3.3.2.7**, that b_1 should be at least equal to $\sqrt{30D}$. The coefficients shown are conservative values repeated horizontally from those calculated for thinner vessels which do satisfy the rule $b_1 \geq \sqrt{30D}$.

NOTE 2 Values of coefficient *K* may be linearly interpolated between adjacent values of L_t/D_i.

NOTE 3 Where coefficients are to the left of the heavy line, this indicates the vessels designed to a maximum stress of 70 N/mm^2 might be overstressed if filled with water even without superimposed loads. Where coefficients are to the left of the double line, this indicates that vessels designed to a maximum stress of 130 N/mm^2 might be overstressed if filled with water even without superimposed loads.

[a] The symbols used have the following meanings:
- t is the vessel shell thickness in the uncorroded condition (in mm);
- L_t is the length of cylindrical portion of vessel between tangent lines of domed ends (in mm);
- D is the mean diameter of vessel;
- D_i is the inside diameter of vessel (in mm).

Annex A (informative) Derivation of maximum permissible loads

A.1 Derivation of W_s (see Figure 1 and Figure 2)

A.1.1 The maximum permissible loads for the support parts have been determined in accordance with BS 449-2, taking into account the combined effect of the vessel load, the wind load and a resistance to movement of the sliding support consistent with Clause **6** and Figure 3.

A.1.2 The permissible design stresses have been taken as those appropriate for material in accordance with grades 1.0044 or 1.0143 of BS EN 10025 at ambient temperature.

A.2 Derivation of coefficient, *K* (see Table 2)

Coefficients are based on calculations in accordance with PD 5500:2003, **G.3.3**, for shells not stiffened by rings at the saddles. The coefficients are based on the minimum load allowed by each of the following stress considerations.

a) Tensile longitudinal bending stresses at mid span and at the saddles, in conjunction with the maximum permitted stress due to internal pressure.

b) Compressive longitudinal bending stresses at mid span and at the saddles, in conjunction with full vacuum.

c) Tangential shearing stresses.

d) Tensile circumferential stresses at the horn of the saddle, taking $\theta = 120°$. These calculations only include the thickness of the saddle plate when the width of the saddle plate is equal to or greater than $b_1 + 10t$.

e) Tensile circumferential stresses at the edge of the saddle plate taking $\theta = 132°$.

NOTE Calculation of the compressive circumferential stress at the lowest point of the cross section has been omitted. Experimental studies have shown this consideration to be unnecessary when the saddle is welded to the shell.

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PD 6497:1982, *Stresses in horizontal cylindrical pressure vessels supported on twin saddles: a derivation of the basic equations and constants used in* ***G.3.3*** *of BS 5500:1982.*

Related reference documents

The following related reference documents were presented at an Institute of Mechanical Engineers conference on 28 May 1981. They are reproduced in *The Journal of Strain Analysis for Engineering Design*, 17, No. 3, July 1982.

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Duthie G., White, G.C. and Tooth, A.S. An analysis for cylindrical vessels under local loading — application to saddle supported vessel problems, 157.

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Stanley, P. and Mabelson, A.R. A three-dimensional photoelastic study of the stresses in horizontal, saddle-supported, liquid-filled storage vessels, 177.

Tooth, A.S. and Jones, N. Plastic collapse loads of cylindrical pressure vessels supported by rigid saddles, 187.

Questions and discussion contributions, 199.

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