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Neogrevane (nekurjene) tlačne posode - 3. del: Konstruiranje - Dopolnilo A14

Unfired pressure vessels - Part 3: Design

Unbefeuerte Druckbehälter - Teil 3: Konstruktion

Récipients sous pression non soumis à la flamme - Partie 3 : Conception

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ICS:

23.020.32	Tlačne posode	Pressure vessels

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Unfired pressure vessels - Part 3: Design

Récipients sous pression non soumis à la flamme - Partie 3 : Conception

Unbefeuerte Druckbehälter - Teil 3: Konstruktion

This draft amendment is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 54.

This draft amendment A14, if approved, will modify the European Standard EN 13445-3:2014. If this draft becomes an amendment, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for inclusion of this amendment into the relevant national standard without any alteration.

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European foreword

This document (EN 13445-3:2014/prA14:2019) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of EN 13445-3:2014.

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1 Modification to Clause 9, Openings in shells

Replace the whole Clause 9 with the following one:

"

9 Openings in shells

9.1 Purpose

The design method specified in this clause is applicable to circular, elliptical or obround openings in dished ends or cylindrical, conical or spherical shells under internal or external pressure.

This clause is applicable to openings, nozzles and reinforcing plates in dished ends which are completely located inside the central area limited by a radius equal to 0,4D_e as shown in Figure 9.5-4. For different locations (i.e. nozzles in knuckle regions) the relevant design rules are given in Clause 7.

Design for non-pressure loads is covered by Clause 16.

9.2 Specific definitions

The following definitions apply in addition to those in Clause 3.

9.2.1
ligament check
evaluation of the reinforcement between two adjacent openings

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9.2.2
opening
reinforcing ring or a nozzle, through penetration of the shell which may or may not be fitted with a reinforcing plate

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9.2.2.1
obround opening
opening with an obround shape, given by two semicircles connected by two parallel straight lines

9.2.3
overall check
evaluation of the reinforcement in the cross-section including the walls on each side of each opening and the lengths of adjacent shell

9.2.4
reinforcement
loaded cross-sectional area of metal considered to provide resistance to the pressure at an opening

9.2.5
reinforced opening
opening where the reinforcement includes a contribution from the shell, from a nozzle, a reinforcing plate or a reinforcing ring

9.2.6
reinforcing plate
plate which is fillet welded to the shell and contributes to the reinforcement

9.2.7
reinforcing ring
set-in ring which contributes to the reinforcement

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9.2.8
set-in nozzle
nozzle which passes through the shell and is welded to it on the inside and outside of the shell (see Figure 9.4-8)

9.2.9
set-on nozzle
nozzle which is welded only to the outside of the shell (see Figure 9.4-7)

9.2.10
shell
cylinder, sphere, cone or dished end

9.2.11
shell discontinuity
junction between any two of the following: cylinder, cylinder on a different axis, cone, dished head, spherical end, flange or flat head

9.2.12
small opening
isolated opening which satisfies the condition of Formula (9.5-18)

9.3 Specific symbols and abbreviations

9.3.1 General

The following symbols, subscripts and abbreviations apply in addition to those in Clause 4.

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9.3.2 Subscripts

The following subscripts apply to the symbols listed in 9.3.3.

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a refers to the analysis thickness of a component;

b refers to a nozzle or branch;

c refers to the mean value of a dimension;

e refers to the outside or external dimension;

i refers to the inside or internal dimension;

L refers to a ligament check;

O refers to an overall check;

o refers to a possible maximum or minimum value; among different values;

p refers to a reinforcing plate;

r refers to a reinforcing ring;

s refers to the shell;

w refers to the area of fillet weld which may be taken into account for reinforcement;

φ refers to additional pressure loaded area for an oblique nozzle connection;

1 refers to the first of two adjacent openings;

2 refers to the second of two adjacent openings.

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9.3.3 Symbols

Symbol	Description	Unit
a	Distance taken along the mid-thickness of the shell between the centre of an opening and the external edge of a nozzle or ring; or, if no nozzle or ring is present, a is the distance between the centre of the hole and its bore.	mm
a_1, a_2	Values of a on the ligament side of the opening (Figures 9.6–2 and 9.6–3).	mm
a'_1, a'_2	Values of a on the opposite side of the opening to the ligament (see Figure 9.6–5).	mm
Af	Stress loaded cross-sectional area effective as reinforcement.	mm²
Af_{Ls}	Af of the shell contained along the length L_b (see Figures 9.6–1 to 9.6–4).	mm²
Af_{Os}	Af of the shell contained along the length L_{b1} (see Figures 9.6–5 to 9.6–6).	mm²
Af_w	Cross-sectional area of fillet weld between nozzle (or plate) and shell (see 9.5.2.3.3 and Figures 9.4–4 and 9.5–1).	mm²
Ap	Pressure loaded area.	mm²
Ap_{Ls}	Ap of the shell for the length L_b (see Figures 9.6–1 to 9.6–4).	mm²
Ap_{Os}	Ap of the shell for the length L_{b1} (see Figures 9.6–5 to 9.6–6).	mm²
Ap_φ	Additional pressure loaded area for oblique nozzle connection, function of angle φ (see Figures 9.5–1 to 9.5–3).	mm²
d	Diameter (or maximum width) of an opening in shell without nozzle.	mm
d_{eb}	External diameter of a nozzle fitted in a shell.	mm
d_{ib}	Internal diameter of a nozzle fitted in a shell.	mm
d_{ip}	Internal diameter of a reinforcing plate.	mm
d_{er}	External diameter of a reinforcing ring.	mm
d_{ir}	Internal diameter of a reinforcing ring.	mm
d_{ix}	Internal diameter of extruded opening.	mm
D_c	Mean diameter of a cylindrical shell at the junction with another component.	mm
D_e	External diameter of a cylindrical or spherical shell, the cylindrical part of a torispherical or an elliptical dished end, a conical shell at the centre of an opening.	mm
D_i	Internal diameter of a cylindrical or spherical shell, the cylindrical part of a torispherical or an elliptical dished end, a conical shell at the centre of an opening.	mm
e_1	Minimum required thickness of a cylindrical shell at the junction with another component (see Figures 9.7–6 and 9.7–10).	mm
e_2	Minimum required thickness of a conical shell at the junction with a cylindrical shell (see Figures 9.7–6 and 9.7–10).	mm

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Symbol	Description	Unit
e_b	Effective thickness of nozzle (or mean thickness within the external length l_{bo} or internal length l_{bio}) taken into account for reinforcement calculation.	mm
$e_{a,b}$	Analysis thickness of nozzle (or mean analysis thickness within the length l_b external or internal by the shell).	mm
$e_{a,m}$	Average thickness along the length l_o for reinforcing rings (see Formula (9.5–48)).	mm
$e_{c,s}$	Assumed shell thickness of shell wall (see Formula (9.5–2) for checking of reinforcement of an opening. The thickness may be assumed by designer between the minimum required shell thickness e and the shell analysis thickness $e_{a,s}$. This assumed thickness shall then be used consistently in all requirements. For $e_{c,s}$ the shell analysis thickness may be used always, but sometimes it may be advantageous to use a smaller assumed value to obtain smaller distances from adjacent shell discontinuities.	mm
e_p	Effective thickness of reinforcing plate taken into account for reinforcement calculation.	mm
$e_{a,p}$	Analysis thickness of reinforcing plate.	mm
e_r	Effective thickness of reinforcing ring taken into account for reinforcement calculation.	mm
$e_{a,r}$	Analysis thickness of reinforcing ring.	mm
$e_{a,s}$	Analysis thickness of shell wall or mean analysis thickness within the length l'_s and excluding the thickness of the reinforcing pad if fitted.	mm
e'_s	Length of penetration of nozzle into shell wall for set-in nozzles with partial penetration.	mm
f_b	Nominal design stress of the nozzle material.	MPa
f_p	Nominal design stress of the reinforcing plate material.	MPa
f_s	Nominal design stress of shell material.	MPa
h	Inside height of a dished end, excluding cylindrical skirt.	mm
k	Reduction factor for l_{so} (used for overall check in 9.6.4).	–
l_b	Length of nozzle extending outside the shell.	mm
l'_b	Effective length of nozzle outside the shell for reinforcement.	mm
l_{bi}	Length of nozzle extending inside the shell (i.e.: protruding nozzle).	mm
l'_{bi}	Effective length of nozzle inside the shell for reinforcement.	mm
l_{bo}	Maximum length of nozzle outside the shell for reinforcement.	mm

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Symbol	Description	Unit
l_{cyl}	Length of cylindrical shell given by Formula (9.7–3) and used in the strength assessment of a junction (see Figure 9.7–6) between a cylinder and: — the small end of a conical shell with same axis; — a spherical shell convex towards the cylinder; — a cylindrical shell with convergent axis.	mm
l_{con}	Length of conical shell given by Formula (9.7–7) and used in the strength assessment of a junction between the small end of a cone and a cylindrical shell, (see Figure 9.7–6).	mm
l_n	Distance between the centre line of a shell butt-weld and the centre of an opening near or crossing the butt-weld.	mm
l_o	Maximum length of ring and shell wall in reinforcing rings for reinforcement.	mm
l_p	Width of reinforcing plate.	mm
l_{pi}	Width of reinforcing plate between two adjacent openings (Figure 9.6–5).	mm
l'_p	Effective width of reinforcing plate for reinforcement.	mm
l_r	Width of reinforcing ring.	mm
l'_r	Effective width of reinforcing ring for reinforcement.	mm
l_s	Length of shell, from the edge of an opening or from the external diameter of a nozzle, to a shell discontinuity.	mm
l'_s	Effective length of shell for opening reinforcement.	mm
l_{so}	Maximum length of shell contributing to opening reinforcement, taken on the mean surface of the shell wall.	mm
L_b	Centre-to-centre distance between two openings or nozzles taken on the mean surface of the shell (see Figure 9.6–2).	mm
L_{b1}	Length of cross sectional area of shell including the whole section of two adjacent openings taken on the surface of the shell.	mm
r_{is}	Inside radius of curvature of the shell at the opening centre.	mm
R	Inside radius of a hemispherical end or of the crown of a torispherical end.	mm
w	Distance between an opening and a shell discontinuity (see Figures 9.7–1 to 9.7–11).	mm
w_{min}	Required minimum value for w.	mm
w_p	Minimum value for w which has no influence on l_s from shell discontinuities.	mm
α	Half apex angle of a conical shell.	degrees

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Symbol	Description	Unit
θ	For a nozzle having a longitudinal weld, angle between the plane containing the nozzle axis and the longitudinal weld line, and the plane containing the nozzle axis and the shell generatrix passing through the centre of the opening.	degrees
φ	Obliquity angle in the longitudinal or transversal cross-section, measured between the normal to the wall at the opening centre and the projection of the nozzle axis on the considered cross-section.	degrees
φ_e	Projection of φ in the plane in which L_b lies for ligament check of multiple openings.	radians
Φ	Angle between the centre-to-centre line of two openings or nozzles and the generatrix of a cylindrical or conical shell ($0° \leq \Phi \leq 90°$) (see Figure 9.6–1).	degrees
Ω	— for isolated openings, angle between shell generatrix and axis of major diameter — for adjacent openings, angle between the plane containing the opening centres and the axis of major diameter.	degrees

9.4 General

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9.4.1 Opening

A shell containing an opening shall be adequately reinforced in the area adjacent to the opening. This is to compensate for the reduction of the pressure bearing section. The reinforcement shall be obtained by one of the following methods:

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a) increasing the wall thickness of the shell above that required for an unpierced shell (see Figures 9.4-1 and 9.4-2);

b) using a reinforcing plate (see Figures 9.4-3 and 9.4-4);

c) using a reinforcing ring (see Figures 9.4-5 and 9.4-6);

d) increasing the wall thickness of the nozzle (see Figures 9.4-7 and 9.4-8) above that required for the membrane pressure stress;

e) using a combination of the above (see Figures 9.4-9 to 9.4-13).

9.4.2 Reinforcement

The dimensions of the reinforcement area at an opening shall be assumed and the design shall be verified by the method laid down in the following subclauses.

The method is based on ensuring that the reactive force provided by the material is greater than, or equal to, the load from the pressure. The former is the sum of the product of the average membrane stress in each component and its stress loaded cross-sectional area (see Figures 9.4-1 to 9.4-13). The latter is the sum of the product of the pressure and the pressure loaded cross-sectional areas. If the reinforcement is insufficient, it shall be increased and the calculation repeated.

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Reinforcement and strength may vary around the axis of an opening. Reinforcement shall be shown to be sufficient in all planes.

9.4.3 Design

The design method is applicable when the opening is located at a minimum distance from a shell discontinuity. Rules for determining this minimum distance are given in 9.7.

9.4.4 Elliptical or obround openings

Elliptical or obround openings resulting from a circular nozzle oblique to the shell wall shall be calculated according to 9.5.2.4.5.

For all other elliptical or obround openings the ratio between the major and minor diameter shall not exceed 2.

9.4.4.1 Elliptical or obround openings reinforced by increased shell wall thickness, reinforcing plate or reinforcing ring (see 9.4.1 a), b) or c)):

In cylindrical or conical shells the diameter d of the opening for reinforcing calculations shall be taken:

— along the generatrix of the shell for isolated openings;

— in the plane containing the centres of the openings.

In spherical shells and dished ends the diameter d of the opening shall be taken:

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— along the largest dimension of the bore (major axis) for isolated openings;

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— in the plane containing the centres of the openings.

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9.4.4.2 Openings reinforced by elliptical or obround nozzles normal to the shell wall (see 9.4.1 d)):

In cylindrical or conical shells the diameter d of the opening shall be calculated as follows:

$$d = d_{\min} \cdot (\sin^2 \Omega + \frac{d_{\max}}{d_{\min}} \cdot \frac{(d_{\min} + d_{\max})}{2 \cdot d_{\min}} \cdot \cos^2 \Omega) \qquad (9.4\text{-}1)$$

where

d_{min} and d_{max} are the minor and major diameter of the opening, and

Ω is:

— for isolated openings, the angle between the shell generatrix passing through the centre of the opening and the axis of the major diameter.

— for adjacent openings, and for each of the two openings, the angle between the shortest line lying on the surface of the shell passing through the centres of the two openings, and the line resulting on the shell from the intersection of the plane defined by the nozzle axis and the axis of the major diameter of any nozzle cross section under consideration.

In spherical shells and dished ends the diameter d of the opening shall be calculated as follows:

$$d = d_{\max} \cdot (\frac{d_{\min} + d_{\max}}{2 \cdot d_{\min}}) \qquad (9.4\text{-}2)$$

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where

d_{min} and d_{max} are defined above.

The diameter for the calculation of value l_{bo} in Formula (9.5-75) is defined in 9.5.2.4.4.1.

For nozzles with elliptical or obround cross-section the pressure produces not only membrane stresses, but also bending stresses in the circumferential direction. Thus the attached shell wall on one side and the attached flange or circular pipe on the other side have to support the nozzle if its wall thickness has been determined using only membrane stresses. The nozzle loads the shell and it is possible that the diameter which applies for the elliptical or obround nozzle is larger than the major axis.

9.4.4.3 For elliptical or obround nozzles not normal to the shell wall 9.4.4.2 is not applicable, therefore 9.4.4.1 shall be used without contribution of nozzle wall for reinforcing calculations.

9.4.5 Limitations on diameter

9.4.5.1 Shell reinforced openings

Shell reinforced openings without a nozzle shall satisfy the following condition:

$$\frac{d}{2r_{is}} \leq 0{,}5 \quad (9.4\text{-}3)$$

9.4.5.2 Openings with reinforcing plates

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Where an opening is fitted with a reinforcing plate without the presence of a nozzle, the condition of the Formula (9.4-3) shall be satisfied. Reinforcing plates are normally situated on the external surface of the shell, but they may be situated also on the internal surface or on both surfaces.

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In case of high mean wall temperature for the shell (more than 250 °C) or in the presence of severe temperature gradients through the shell, the use of reinforcing plates shall be avoided; if it is necessary then the material of the reinforcing plate shall be of the same quality of shell material, and special measures and warnings shall be taken to avoid thermal stress concentrations.

9.4.5.3 Openings in dished ends

For openings in hemispherical ends and dished ends, the ratio d / D_e shall not exceed 0,6. Therefore, if the opening is reinforced by a nozzle or a reinforcing ring d_{ib} / D_e and d_{ir} / D_e shall not exceed 0,6.

9.4.5.4 Openings with nozzles

For openings in cylindrical shells reinforced by nozzles the ratio $d_{ib} / (2r_{is})$ shall not exceed 1.0 (see Figures 9.4-14 and 9.4-15).

9.4.6 Effective thickness for nozzles

9.4.6.1 In fatigue applications where fatigue is assessed using Clause 17 and if the opening is a critical area (as defined in 17.2)

The ratio $e_b/e_{a,s}$ shall not exceed the value taken from the graph in Figure 9.4-14 and the value of e_b shall never exceed the value of $e_{a,b}$. Nozzle thickness in excess of that calculated using Figure 9.4-14 shall not be included in the reinforcement calculation.

Furthermore the ratio $e_{a,b}/e_{a,s}$ shall not exceed the value taken from the graph in Figure 9.4-15.

NOTE 1 e_b is the effective thickness of the nozzle, to be used for the verification of the reinforcement; $e_{a,b}$ is the analysis thickness of this nozzle; the ratio $e_b/e_{a,s}$ limits the contribution of the nozzle to the resistance of the opening; the ratio $e_{a,b}/e_{a,s}$ limits the analysis thickness of the nozzle, and thus its manufacturing thickness, in order

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to limit the stresses which can occur due to great thickness differences and to avoid the fatigue problems which can result.

NOTE 2 When fatigue is assessed using Clause 18, no limitation to the thickness ratio is necessary because in that case more accurate stresses are used for fatigue calculations.

9.4.6.2 In creep applications (i.e.: when the calculation temperature is situated in the creep range)

The effective thickness e_b may be taken equal to the analysis thickness $e_{a,b}$ of the nozzle.

However the ratio $e_{a,b}/e_{a,s}$ shall not exceed the value taken from the graph in Figure 9.4-15.

9.4.6.3 In applications without creep and without fatigue assessment using Clause 17 (i.e.: when the calculation temperature is situated out of the creep range and the opening is not a critical area as defined in 17.2)

The effective thickness e_b may be taken equal to the analysis thickness $e_{a,b}$ of the nozzle and no limitations apply to the ratio $e_{a,b/ea,s}$.

9.4.7 Nozzles to shell connections

Nozzles are usually of the following forms: welded (set-in, set-on, protruding nozzles) or extruded or screwed.

For welded nozzles the cross sectional area of the nozzle can always be taken in account for reinforcement of the opening, provided weld dimensions are in accordance with Tables A-6 and A-8 of Annex A of this standard.

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For nozzles extruded from the shell the cross sectional area of the nozzle shall be taken in account for reinforcement provided the requirements of 9.5.2.4.4.2 are applied.

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For screwed nozzles the cross sectional area of the nozzle shall not be taken in account for reinforcement of the opening.

9.4.8 Distance between a nozzle and a shell butt-weld

The distance between the centre line of a shell butt-weld (longitudinal or circumferential) and the centre of an opening shall be either less than d_{ib} / 6 or greater than the value l_n given by:

$$l_n = \min (0,5\, d_{eb} + 2e_{a,s}\, ;\, 0,5\, d_{eb} + 40) \qquad (9.4\text{-}4)$$

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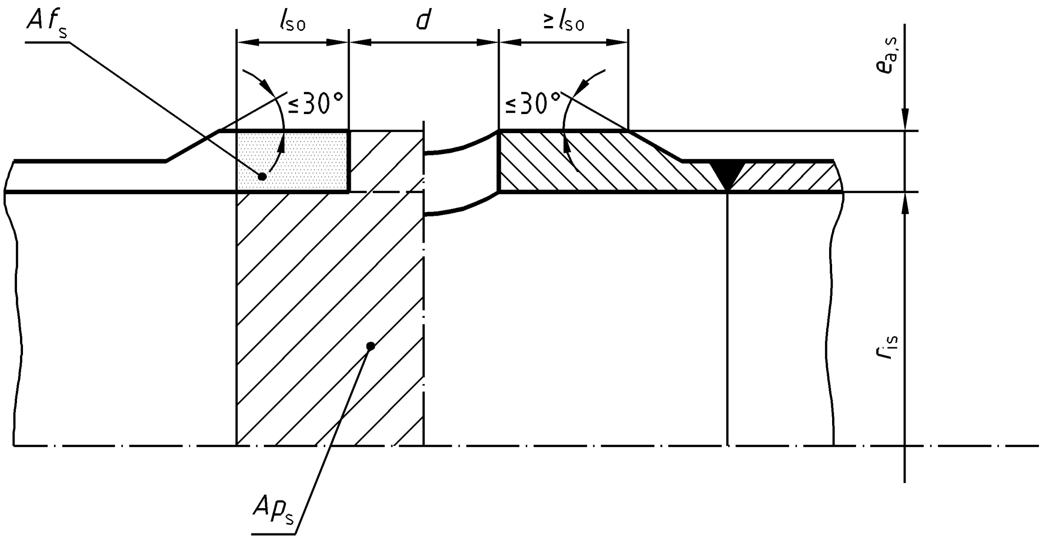

Figure 9.4-1 — Cylindrical shell with isolated opening and increased wall thickness

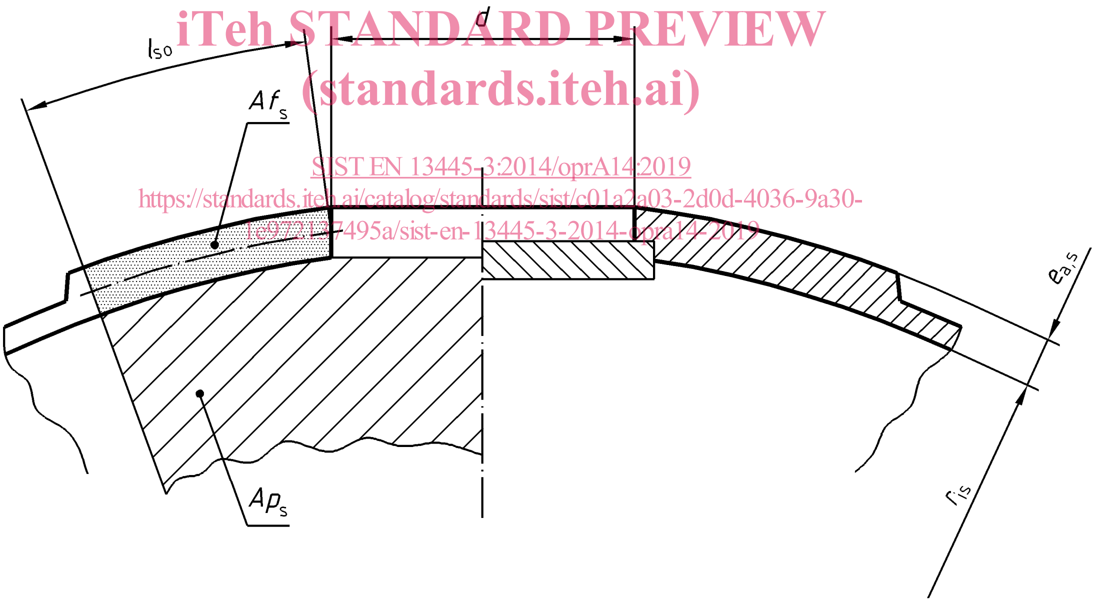

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Figure 9.4-2 — Spherical shell or dished end with isolated opening and increased wall thickness