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Industrijski ventili - Trdnost ohiġja - 2. del: Metoda za izraẹ un ohiġij jeklenih ventilov

Industrial valves - Shell design strength - Part 2: Calculation method for steel valve shells

Industriearmaturen - Gehäusefestigkeit - Teil 2: Berechnungsverfahren für drucktragende Gehäuse von Armaturen aus Stahl

Robinetterie industrielle - Résistance mécanique des enveloppes - Partie 2: Méthode de calcul relative aux enveloppes d'appareils de robinetterie en acier

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This document (EN 12516-2:2004) has been prepared by Technical Committee CEN/TC 69 "Industrial valves", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2005, and conflicting national standards shall be withdrawn at the latest by January 2005.

This document has been prepared under a mandate 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 this document.

EN 12516*, Industrial valves – Shell design strength,* consists of four parts:

— *Part 1: Tabulation method for steel valve shells*

— *Part 2: Calculation method for steel valve shells*

— *Part 3: Experimental method*

— *Part 4: Calculation method for valve shells in metallic materials other than steel*

The annexes A, B and C are informative.

This document includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

EN 12516, *Industrial valves — Shell design strength*, is in four parts. Parts 1 and 2 specify methods for determining the thickness of steel valve shells by tabulation or calculation methods respectively. Part 3 establishes an experimental method for assessing the strength of valve shells in steel, cast iron and copper alloy by applying an elevated hydrostatic pressure at ambient temperature. Part 4 specifies methods for calculating the thickness for valve shells in metallic materials other than steel.

The calculation method, Part 2 is similar in approach to DIN 3840 where the designer calculates the wall thickness for each point on the pressure temperature curve using the allowable stress at temperature for the material he has chosen (see Bibliography, reference [1]). The allowable stress is calculated from the material properties using safety factors that are defined in Part 2. The equations in Part 2 consider the valve as a pressure vessel and ensure that there is no excessive deformation or plastic instability.

The tabulation method, Part 1 is similar in approach to ASME B16.34 in that the designer can look up the required minimum wall thickness of the valve body from a table (see Bibliography, reference [2]). The internal diameter of the straight pipe, into which the valve is to be mounted, gives the reference dimension from which the tabulated wall thicknesses of the body are calculated.

The tabulated thicknesses in Part 1 are the minimum thickness in the crotch region and are calculated using an allowable stress equal to 118 N/mm^2 and a calculation pressure, p_c, in N/mm^2. The values of the calculation pressure, p_c, and the equation used for calculating the thickness are given in Part 1.

Part 1 specifies Standard and Special pressure temperature ratings for valve bodies having the tabulated thickness. These tabulated pressure temperature ratings are applicable to a group of materials and are calculated using a selected stress, which is determined from the material properties representative of the group, using safety factors defined in Part 1.

Each tabulated pressure temperature rating is given a reference pressure designation to identify it. The B (Body) pressure designation is used to differentiate it from the PN pressure designation that is used for flanges because the rules for determining the pressure temperature ratings for B and PN designations are different.

In the case where a valve body designed to Part 1 is having PN designated flanged ends, the designer considers the requirements laid down in Part 1 to ensure that the valve body is not weaker than the flange.

Maximum allowable pressures for Special ratings are higher than those for Standard ratings as additional non-destructive examination of the body used for Special rating allows the use of lower safety factors in calculating the allowable pressure.

A merit of the calculation method is that it allows the most efficient design for a specific application using the allowable stresses for the actual material selected for the application.

A merit of the tabulation method, which has a fixed set of shell dimensions irrespective of the material of the shell, is that it is possible to have common patterns and forging dies. The allowable pressure temperature rating for each material varies proportionally to the selected stresses of the material group to which the material belongs.

The two methods are based on different assumptions, and as a consequence the detail of the analysis is different (see Bibliography, reference [7]). Both methods offer a safe and proven method of designing pressure-bearing components for valve shells.

1 Scope

This part of EN 12516 specifies the method for the strength calculation of the shell with respect to internal pressure of the valve.

2 Normative references

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

EN 19, *Industrial valves — Marking of metallic valves.*

EN 1092-1, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated — Part 1: Steel flanges.*

EN 1515-1, *Flanges and their joints — Bolting — Part 1: Selection of bolting.*

EN 1591-1, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 1: Calculation method.*

EN 13445-3, *Unfired pressure vessels — Part 3: Design.*

3 Symbols and units

The following symbols are used:

Table 1 — Symbols characteristics and units

Symbol	Characteristic	Unit
A	elongation after rupture	%
B_n	calculation coefficient for oval cross-sections	—
E	modulus of elasticity	MPa or N/mm^2
e	thickness	mm
f	nominal design stress	MPa or N/mm^2
f_d	maximum value of the nominal design stress for normal operating load cases	MPa or N/mm^2
$f_{d/t}$	nominal design stress for design conditions at temperature t °C	MPa or N/mm^2
f_{exp}	nominal design stress for exceptional conditions	MPa or N/mm^2
k_c	welding factor	—
p	pressure	MPa or N/mm^2
p_c	calculation pressure	MPa or N/mm^2
p_d	design pressure	MPa or N/mm^2
PS	maximum allowable pressure	MPa or N/mm^2
R_e	yield strength	MPa or N/mm^2
$R_{eH/t}$	upper yield strength at temperature t °C	MPa or N/mm^2

Table 1 — (*concluded*)

Symbol	Characteristic	Unit
R_m	tensile strength	MPa or N/mm^2
$R_{m/t}$	tensile strength at temperature t °C	MPa or N/mm^2
$R_{m/T/t}$	creep rupture strength for T hours at temperature t °C	MPa or N/mm^2
$R_{p0,2}$	0,2 % - proof strength	MPa or N/mm^2
$R_{p0,2/t}$	0,2 % - proof strength at temperature t °C	MPa or N/mm^2
$R_{p1,0}$	1,0 % - proof strength	MPa or N/mm^2
$R_{p1,0/t}$	1,0 % - proof strength at temperature t °C	MPa or N/mm^2
$R_{p1,0/T/t}$	1,0 % - creep proof strength for T hours at temperature t °C	MPa or N/mm^2
SF	safety factor	—
T	time	h
t	temperature	°C
t_c	calculation temperature	°C
t_d	design temperature	°C
α	linear expansion factor	K^{-1}
β	cone calculation coefficient	—
ε	strain	%
μ	Poisson's ratio	—

4 General conditions for strength calculation

Equations 1 and 2 apply to mainly static internal pressure stressing. The extent to which these equations can also be applied to pulsating internal pressure stressing is described in clause 12.

The total wall thickness is found by adding the following allowances:

$$e_0 = e_{c0} + c_1 + c_2 \tag{1}$$

$$e_1 = e_{c1} + c_1 + c_2 \tag{2}$$

where

e_{c0}, e_{c1} are the calculated wall thicknesses in accordance with the rules given in this standard at different locations on the valve shell (see Figures 1, 2, 5 and 8 to 20);

c_1 is a manufacturer tolerance allowance;

c_2 is a corrosion allowance.

The values of the corrosion allowance are:

c_2 = 1 mm for ferritic and ferritic-martensitic steels;

c_2 = 0 mm for all other steels.

When checking the wall thickness of existing pressure retaining shells these allowances shall be subtracted from the actual wall thickness.

5 Design pressure

All reasonably foreseeable conditions shall be taken into account, which occur during operation and standby.

Therefore the design pressure p_d shall be not less than the maximum allowable pressure PS.

6 Nominal design stresses for pressure parts other than bolts

6.1 General

The nominal design stresses (allowable stresses) for steels with a minimum elongation after rupture of ≥ 14 % and a minimum impact energy measured on a Charpy-V-notch impact test specimen of ≥ 27 J should be calculated in accordance with Table 2.

Table 2 — Nominal design stresses (allowable stresses)

Material	Design conditions	Creep conditions
Steel as defined in 6.2	$f = \min (R_{p0,2/t} / 1,5 ; R_{m/20} / 2,4)$	$f = R_{m/100\,000/t} / 1,5$
Austenitic steel and cast steel as defined in 6.2	$f = \min (R_{p1,0/t} / 1,5 ; R_{m/20} / 2,4)$	$f = R_{m/100\,000/t} / 1,5$
Austenitic steel as defined in 6.3 with rupture elongation ≥ 30 %	$f = R_{p1,0/t} / 1,5$	$f = R_{m/100\,000/t} / 1,5$
Austenitic steel as defined in 6.4 with rupture elongation ≥ 35 %	$f = \max [R_{p1,0/t} / 1,5;$ $\min (R_{p1,0/t} / 1,2; R_{m/t} / 3,0)]$	$f = R_{m/100\,000/t} / 1,5$
Cast steel as defined in 6.5	$f = \min (R_{p0,2/t} / 1,9; R_{m/20} / 3,0)$	$f = R_{m/100\,000/t} / 1,9$
Weld-on ends on cast steel as defined in 6.5	$f = \min (R_{p0,2/t} / 1,5; R_{m/20} / 2,4)$ [a]	$f = R_{m/100\,000/t} / 1,5$

[a] The transition zone situated immediately outside the effective length l_0 or l_1 may be calculated with this higher nominal design strength if the length of the transition zone ≥ 3 × e_v , however = 50 mm min. and the angle of the transition ≤ 30°.

However, materials with lower elongation values and/ore lower values for a Charpy-V-notch impact test may also be applied, provided that appropriate measures are taken to compensate for these lower values and the specific requirements are verifiable.

6.2 Steels and cast steels other than defined in 6.3, 6.4 or 6.5

The maximum value of the nominal design stress for normal operating load cases f_d shall not exceed the smaller of the following two values:

— the yield strength $R_{eH/t}$ or 0,2 % proof strength $R_{p0,2/t}$ at calculation temperature, as given in the material standard, divided by the safety factor SF = 1,5. For austenitic steels and cast steels with a rupture elongation less than 30 % and with a relationship at 20 °C between proof and tensile strength less than or equal 0,5 the 1,0 % proof strength $R_{p1,0/t}$ can by used, divided by the safety factor SF = 1,5;

— the minimum tensile strength R_m at 20 °C as given in the material standard, divided by the safety factor SF = 2,4.

6.3 Austenitic steel and austenitic cast steel with a minimum rupture elongation not less than 30 %

The maximum value of the nominal design stress for normal operating load cases f_d shall not exceed the 1,0 % proof strength $R_{p1,0/t}$ at calculation temperature, as given in the material standard, divided by the safety factor SF = 1,5.

NOTE The nominal design stresses of this clause are in accordance with the Pressure Equipment Directive 97/23/EC Annex 1, Clause 7. The term "nominal design stress" means the "permissible general membrane stress" in the context of this Directive.

6.4 Austenitic steel and austenitic cast steel with a minimum rupture elongation not less than 35 %

The maximum value of the nominal design stress for normal operating load cases f_d shall not exceed the greater of the following two values:

— the 1,0 % proof strength $R_{p1,0/t}$ at calculation temperature, as given in the material standard, divided by the safety factor SF = 1,5;

— the smaller of the two values:

  — the 1,0 % proof strength $R_{p1,0/t}$ at calculation temperature, as given in the material standard, divided by the safety factor SF = 1,2;
  — the minimum tensile strength $R_{m/t}$ at calculation temperature divided by the safety factor SF = 3,0.

6.5 Non-alloy and low-alloy cast steel

The maximum value of the nominal design stress for normal operating load cases f_d shall not exceed the smaller of the following two values:

— the yield strength $R_{eH/t}$ or 0,2 % proof strength $R_{p0,2/t}$ at calculation temperature, as given in the material standard, divided by the safety factor SF = 1,9;

— the minimum tensile strength R_m at 20 °C as given in the material standard, divided by the safety factor SF = 3,0.

6.6 Creep conditions

The maximum value of the nominal design stress for normal operating load cases shall not exceed the average creep rupture strength at calculation temperature $R_{m/T/t}$ divided by the safety factor SF = 1,5 for the T = 100 000 hours value.

The nominal design stress calculated in 6.2 to 6.5 has to be compared with the nominal design stress calculated in this clause and the lower value shall be used.

For cast steel defined in 6.5 the safety factor SF = 1,9 for the T = 100 000 hours value.

For limited operating times and in certain justified cases, creep rupture strength values for shorter times may be used for calculations but not less than T = 10 000 hours.

7 Calculation methods for the wall thickness of valve bodies

7.1 General

Valve bodies are considered to be hollow bodies penetrating each other with different angles i.e. basic bodies with branches.

Basic bodies and branches can be tubes, balls or conical hollow parts with cylindrical, spherical, elliptical or rectangular cross-sections.

In special cases the body consists only of a basic body.

The basic body-part is the part of the body with the larger diameter or cross-section, with the symbol d_0. For the branches, the symbols are for example, d_1, d_2.

It follows that:

$d_0 \geq d_1$; $b_2 \geq d_1$, see Figure 8

7.2 Valve bodies

7.2.1 General

The wall thickness of a valve body composed of different geometric hollow components cannot be calculated directly. The calculation needs two steps:

— the calculation of the wall thickness of the basic body and the branches outside of the intersection — or crotch area, see 7.2.2;

— the calculation of the wall thickness in the crotch area, see 7.2.3.

A check of the wall thickness of the crotch area is necessary by considering the equilibrium of forces, see 7.2.3.

7.2.2 Wall thickness of bodies and branches outside crotch area

7.2.2.1 General

Outside the intersection or crotch area, means that the calculated hollow body is without openings or cutaways in this zone (e.g. a smooth tube).

The welding factor k_c in the following equations is a calculation factor dependent on the level of destructive and non-destructive testing to which the weld or series of welds is subject.

The values of the welding factor k_c shall be:

1,0 for equipment subject to destructive and non-destructive tests, which confirm that the whole series of joints show no significant defects;

0,85 for equipment of which 10% of the welds are subject to random non-destructive testing and all welds are subject to 100% visual inspection;

0,7 for equipment not subject to non-destructive testing other than 100% visual inspection of all the welds;

1,0 for no welds.

All the calculated wall thicknesses are wall thicknesses excluding allowances.

d_i = inner diameter or radius;

d_o = outer diameter or radius.

7.2.2.2 Cylindrical bodies or branches

$d_o / d_i \leq 1{,}7$

$$e_c = \frac{d_i \times p}{(2 \times f - p) \times k_c} \quad (3)$$

or

$$e_c = \frac{d_o \times p}{(2 \times f - p) \times k_c + 2 \times p} \quad (4)$$

7.2.2.3 Both equations are equivalent when $d_i = d_o - 2 \times e_c$

7.2.2.4 Spherical bodies or branches

$d_o / d_i \leq 1{,}2$

$$e_c = \frac{r_i \times p}{(2 \times f - p) \times k_c} \quad (5)$$

or

$$e_c = \frac{r_o \times p}{(2 \times f - p) \times k_c + p} \quad (6)$$

$1{,}2 < d_o / d_i \leq 1{,}5$

$$e_c = r_i \times \left[\sqrt{1 + \frac{2 \times p}{(2 \times f - p) \times k_c}} - 1\right] \quad (7)$$

or

$$e_c = r_o \times \frac{\sqrt{1 + \frac{2 \times p}{(2 \times f - p) \times k_c}} - 1}{\sqrt{1 + \frac{2 \times p}{(2 \times f - p) \times k_c}}} \quad (8)$$

Both equations are equivalent when $r_i = r_o - e_c$

7.2.2.5 Conical bodies or branches

$e_c / d_o > 0{,}005$

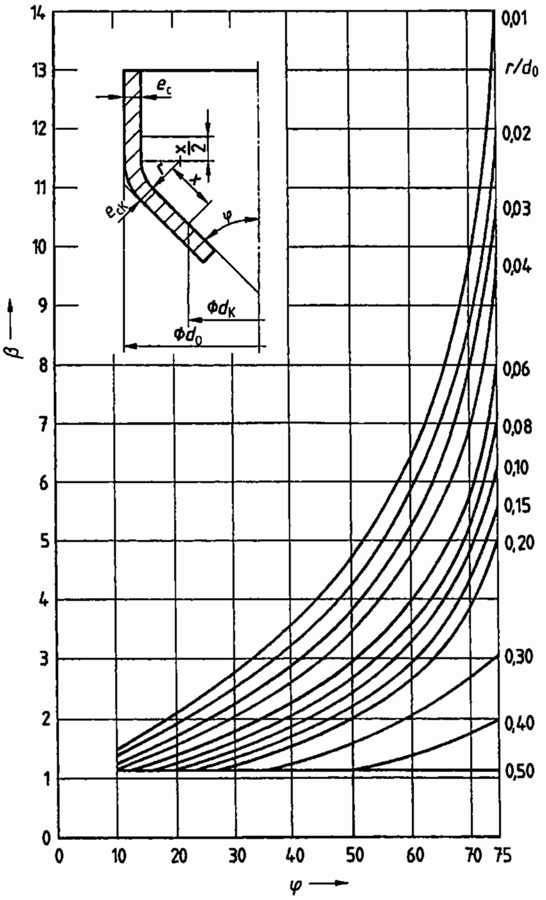


Figure 1 — Cone calculation coefficient

$$e_c = \frac{p \times d_K}{2 \times f \times k_c - p} \times \frac{1}{\cos(\varphi)} \tag{9}$$

Wall thickness in the knuckle or in a corner weld:

$$e_{cK} = \frac{d_o \times p \times \beta}{4 \times f \times k_c} \tag{10}$$

e_{cK} is also required in the zone x and $\frac{x}{2}$

$$x = \sqrt{d_o \times e_c} \tag{11}$$

k_c is now a factor for a weld situated in the knuckle or in the influence zone of the knuckle running in meridian direction.

In cases of corner welds which are admissible for angles $\varphi \leq 30°$, $e_{cK} \leq 20$ mm and double joint weld, β shall be read off Figure 1 by taking for the ratio $r / d_o = 0{,}01$.

For corner welds, diameter d_K is equal to the inside diameter of the wide end.

In case of flat cones with a knuckle and $\varphi > 70°$:

$$e_c = 0{,}3 \times (d_o - r) \times \frac{\varphi}{90} \times \sqrt{\frac{p}{f \times k_c}} \quad (12)$$

Table 3 — Cone calculation coefficient

Angle φ	β for the ratio r / d_o												cos φ
	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50	
10	1,4	1,3	1,2	1,2	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	0,985
20	2,0	1,8	1,7	1,6	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1	0,940
30	2,7	2,4	2,2	2,0	1,8	1,7	1,6	1,4	1,3	1,1	1,1	1,1	0,866
45	4,1	3,7	3,3	3,0	2,6	2,4	2,2	1,9	1,8	1,4	1,1	1,1	0,707
60	6,4	5,7	5,1	4,7	4,0	3,5	3,2	2,8	2,5	2,0	1,4	1,1	0,500
75	13,6	11,7	10,7	9,5	7,7	7,0	6,3	5,4	4,8	3,1	2,0	1,1	0,259

If two conical shells with different taper angles are joined together, the angle φ arising between the conical portion with the more pronounced taper and that with the less pronounced taper shall be determined for the determination of β.

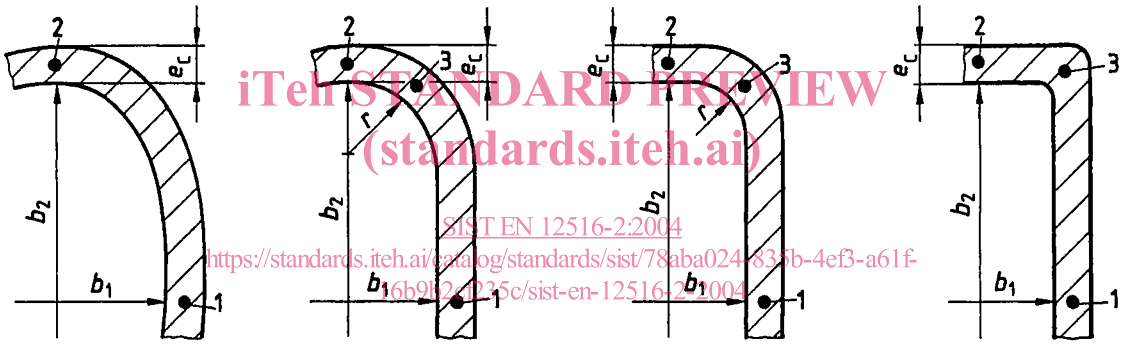
7.2.2.6 Bodies or branches with oval or rectangular cross-sections

7.2.2.6.1 General

The following calculation rules apply to oval or rectangular valve bodies with a wall thickness/diameter ratio $e_c / b_2 \leq 0{,}15$ and a ratio $b_1 / b_2 \geq 0{,}4$.

For ratios $e_c / b_2 \leq 0{,}06$, these rules are applicable for $b_1 / b_2 \geq 0{,}25$ (see Bibliography, reference [3]).

7.2.2.6.2 In the case of oval shaped cross-sections (see Figure 2a)) and of rectangular shapes with or without radiusing of the corners (see Figures 2b) to 2d)), the additional bending stresses, which arise in the walls or in the corners, shall be taken into consideration.



a) oval-shaped

b) rectangular radiused on one side

c) rectangular, with radiused corner

d) rectangular, corner not radiused

Figure 2 — Cross-sections

The theoretical minimum wall thickness of such bodies under internal pressure stressing can be calculated by means of the equation below, without any allowance for edge effects:

$$e_{c0} = \frac{p \times b_2}{2f} \times \sqrt{B_0^2 + \frac{4f}{p} \times B_n} \qquad (13)$$

7.2.2.6.3 The calculation shall be carried out in respect of locations 1 and 2 (designated in Figure 2a for oval-shaped cross-sections), and in respect of locations 1 and 3 (designated in Figures 2b to 2d for rectangular cross-sections), because the bending moments, which have a predominant influence on the strength behaviour, exhibit their maximum values at the above locations. In exceptional cases (e.g. a low b_1 / b_2 ratio) a check calculation for location 2 may also be necessary for square cross-sections.

7.2.2.6.4 The calculation coefficient B_0, which is a function of the normal forces, shall be:

$B_0 = b_1 / b_2$ for location 1

$B_0 = 1$ for location 2

For location 3, B_0 can be obtained from Figure 3 as a function of the sides ratio b_1 / b_2 and of the corner radii ratio r / b_2, or it can be calculated in accordance with equation (14):

$$B_0 = \left[1 - \frac{2r}{b_2}(1 - \sin\varphi_k)\right]\sin\varphi_k + \left[\frac{b_1}{b_2} - \frac{2r}{b_2}(1 - \cos\varphi_k)\right]\cos\varphi_k \qquad (14)$$

with $$\tan\varphi_k = \frac{1 - 2r / b_2}{\frac{b_1}{b_2} - \frac{2r}{b_2}} \qquad (15)$$

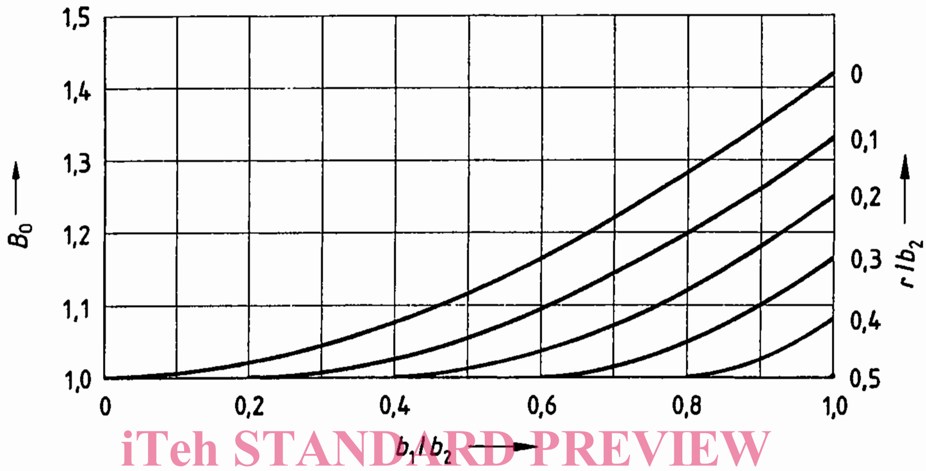


Figure 3 — Calculation coefficient B_0 for location 3