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Industrial valves - Shell design strength - Part 1: Tabulation method for steel valve shells

Industriearmaturen - Gehäusefestigkeit - Teil 1: Tabellenverfahren für drucktragende Gehäuse von Armaturen aus Stahl

Robinetterie industrielle - Résistance mécanique des enveloppes - Partie 1: Méthode tabulaire relative aux enveloppes d'appareils de robinetterie en acier

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Contents

Page

Foreword

This document (EN 12516-1:2005) 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of an identical text or by endorsement, at the latest by October 2005, and conflicting national standards shall be withdrawn at the latest by October 2005.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.

For relationship with EU Directive, see informative Annex ZA, which is an integral part of this document.

EN 12516 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.*

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 as a type test by applying an elevated hydrostatic pressure at ambient temperature. Part 4 specifies a method for calculating the thickness for valve shells in metallic material other than steel.

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 dimension of the valve body from a table. The internal diameter of the straight pipe, into which the valve is to be mounted, gives the reference dimension from which the tabulated wall thickness of the body are calculated. It applies only to valve bodies, bonnets and covers with essentially circular cross-section. For valve shells with oval or rectangular shapes and for additional loads, EN 12516-2 should be used (see 8.6).

The calculation method, Part 2 is similar in approach to DIN 3840 where the designer is required to calculate the wall thickness for each point on the pressure temperature curve using the allowable stress at that temperature for the material he has chosen (see [2]). The allowable stress is calculated from the material properties using the 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.

Part 1 specifies standard and special pressure temperature ratings for valve shells with bodies having the tabulated thickness.

The tabulation method gives one thickness for the body for each Body (see 3.1) or Class designation depending only on the inside diameter, D_i, of the body at the point where the thickness is to be determined.

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 designation that is used for flanges because the rules for determining the pressure temperature ratings for the B and PN designations are different.

The thicknesses in Table 10 are calculated using the thin cylinder equation that is also used in Part 2. The allowable stress used in the equation is equal to 118 N/mm^2 and the operating pressure varies for each B and Class designation. The equation uses a calculation pressure, p_c, in N/mm^2 (e.g. 75,86 N/mm^2 for Class 4500; 5,06 N/mm^2 for Class 300 and 3,00 N/mm^2 for B 25). Table 1 gives these values for all the tabulated B and Class designations.

Table 1 — Pressure used to calculate tabulated thickness

Designation	B 2,5	B 6	B 10	B 16	B 20	B 25	B 40	Class 300
Pressure, p_c N/mm^2	0,33	0,78	1,30	2,08	2,60	3,00	4,40	5,06
Designation	B 63	B 100	Class 600	Class 900	Class 1500	Class 2500	Class 4500	—
Pressure, p_c N/mm^2	6,30	10,00	10,11	15,17	25,29	42,14	75,86	—

The equation for calculating the thickness is $e_{min} = \frac{1{,}5\ p_c\ D_i}{(2 \times 118) - (1{,}2\ p_c)} + \text{constant}$ (1)

For the Class designations, except Class 150, the rules for determining the pressure/temperature ratings are the same for both valve shells and flanges. Hence, only one designation is required. The rules for determining Class 150 flange pressure/temperature ratings are different to those for the valve shell and therefore B 20 is used for the designation of the valve shell.

The Special Class pressure temperature rating for Class 4500 is calculated using the equation:

$$\text{allowable pressure at temperature } t = \text{selected Special stress at temperature } t \times \frac{4\,500}{7\,000} \quad (2)$$

The Standard Class pressure temperature rating for Class 4500 is calculated using the equation:

$$\text{allowable pressure at temperature } t = \frac{\text{selected standard stress at temp. } t}{1{,}25} \times \frac{4\,500}{7\,000} \quad (3)$$

NOTE In ASME B16.34, 7 000 times 1,25 is shown as 8750.

This appears to show that allowable pressures for standard rating valves are always 80 % of the equivalent special rating values. However, the rules for determining the selected stress for standard and special ratings are different. Therefore at low temperatures, the difference in allowable pressures is nil or very small and it is only at high temperatures where the full 80 % difference can be seen. The selected stresses are applicable for a group of materials and are determined from the material properties of ASME Section IID (see [3]) The reason for the down rating of standard rating values relative to Special rating is that the standard rating body is not subject to the specified non-destructive examination procedures and acceptance levels.

The thicknesses for all designations are approximately proportional to the Class 4500 thickness in the ratio of the pressures in Table 1. Similarly, the pressure/temperature ratings are proportional to the Class 4500 rating. For B designated ratings the ratio are based on 760 bar being the metric value needed to get equivalence to the value of Class 4500. See Table 2.

Table 2 — Ratio for determining pressure/temperature ratings

Designation	B 2,5	B 6	B 10	B 16	B 20	B 25	B 40	Class 300
Ratio	2,5/760	6/760	10/760	16/760	20/760	25/760	40/760	300/4500
Designation	B 63	B 100	Class 600	Class 900	Class 1500	Class 2500	Class 4500	—
Ratio	63/760	100/760	600/4500	900/4500	1500/4500	2500/4500	4500/4500	—

For each material group, this results in a series of pressure temperature lines.

For flanges a series of pressure temperature lines is also calculated and designated PN 2,5, PN 6, PN 10, PN 16, Class 150, PN 25, PN 40, PN 63 and PN 100. The rules for calculating these flange lines differ from those for the valve shell. Hence, there are points where these two families of lines, i.e. flanges and B designated valve shells, intersect.

The main reasons for the differences are due to the treatment of ceiling values. In PN flanges, a constant ceiling stress of 225 N/mm^2 at room temperature is applied. In B and Class designations, the ASME B16.34 ceiling criteria apply, which are temperature dependent.

In the case where the valve body designed with this part of EN 12516 has PN, designated flanged ends the designer should consider the requirements laid down in 6.6 to ensure that the valve body is not weaker than the flange.

This document tabulates the commonly used ratings. It is possible to design shells to suit particular applications or markets using intermediate ratings. This data can be obtained using linear interpolation of the tabulated data in Part 1.

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 group varies proportional to the selected stresses of the material group to which the material belong, using the simple rules above.

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.

The two methods are based on different assumptions, and as a consequence the detail analysis is different (see [3]). Both methods offer a safe and proven method of designing pressure-bearing components of valve shells.

1 Scope

This document specifies the tabulation method for determining the wall thickness of valve bodies with essentially circular cross-section made in forged, cast or fabricated steel.

For valve shells with oval, rectangular or non-circular shapes, see 8.6.

The range of B or Class designations for which thicknesses are tabulated is:

B 2,5, B 6, B 10, B 16, B 20, B 25, B 40, Class 300, B 63, B 100, Class 600, Class 900, Class 1500, Class 2500, Class 4500.

Standard and special pressure temperature ratings are specified for each material group for the above B and Class designations.

The non-destructive examination procedures and acceptance levels that shall be applied to the valve shell components in order for the valve to be used at Special pressure temperature ratings are defined. Details are also given for the alternative rules for small bore valves of DN 65 and smaller.

This document does not apply to threaded end valves:

— DN 80 or larger;

— or which have pressure ratings greater than Class 2500;

— or which operate at temperatures greater than 540 °C.

Socket welding end valves DN 80 or larger are outside the scope of this document.

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.

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

EN 287-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

EN 444, *Non-destructive testing — General principles for radiographic examination of metallic materials by X- and gamma-rays*

EN 462, *Non-destructive testing — Image quality of radiographs*

EN 571-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

EN 584-1, *Non-destructive testing — Industrial radiographic film — Part 1: Classification of film systems for industrial radiography*

EN 736-1:1995, *Valves — Terminology — Part 1: Definition of types of valves*

EN 736-2:1997, *Valves — Terminology — Part 2: Definition of components of valves*

EN 736-3:1999, *Valves — Terminology — Part 3: Definition of terms*

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

EN 1759-1, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, Class designated — Part 1: Steel flanges, NPS ½ to 24*

EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN 10028-2, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

EN 10028-3, *Flat products made of steels for pressure purposes — Part 3: Weldable fine grain steels, normalized*

EN 10028-4, *Flat products made of steels for pressure purposes — Part 4: Nickel alloy steels with specified low temperature properties*

EN 10028-7, *Flat products made of steels for pressure purposes — Part 7: Stainless steels*

EN 10213-2, *Technical delivery conditions for steel castings for pressure purposes — Part 2: Steel grades for use at room temperature and elevated temperatures*

EN 10213-3, *Technical delivery conditions for steel castings for pressure purposes — Part 3: Steel grades for use at low temperatures*

EN 10213-4, *Technical delivery conditions for steel castings for pressure purposes — Part 4: Austenitic and austenitic-ferritic steel grades*

EN 10222-2, *Steel forgings for pressure purposes — Part 2: Ferritic and martensitic steels with specified elevated temperature properties*

EN 10222-3, *Steel forgings for pressure purposes — Part 3: Nickel steels with specified low temperature properties*

EN 10222-4, *Steel forgings for pressure purposes — Part 4: Weldable fine grain steels with high proof strength*

EN 10222-5, *Steel forgings for pressure purposes — Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels*

EN 10228-1, *Non-destructive testing of steel forgings — Part 1: Magnetic particle inspection*

EN 10228-3:1999, *Non-destructive testing of steel forgings — Part 3: Ultrasonic testing of ferritic or martensitic steel forgings*

EN 12516-2, *Industrial valves — Shell design strength — Part 2: Calculation method for steel valve shells*

EN 12517, *Non-destructive examination of welds - Radiographic examination of welded joints - Acceptance levels*

EN 12627, *Industrial valves — Butt welding ends for steel valves*

EN 12680-1:2003, *Founding — Ultrasonic examination — Part 1: Steel castings for general purposes*

EN ISO 3452, *Non-destructive testing — Penetrant testing*

EN ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles (ISO 9934-1:2001)*

EN ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules (ISO 15607:2003)*

ASTM A 105-03, *Standard Specification for Carbon Steel Forgings for Piping Applications*

ASTM A 106-04a, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*

ASTM A 182-04, *Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*

ASTM A 203-97, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

ASTM A 204-03, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum*

ASTM A 216-93, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service*

ASTM A 217-02, *Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service*

ASTM A 240-04ae1, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

ASTM A 302-93, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel*

ASTM A 312-04a, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

ASTM A 335-03, *Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*

ASTM A 350-04, *Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components*

ASTM A 351-03, *Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts*

ASTM A 352-03, *Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*

ASTM A 358-04, *Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications*

ASTM A 369-02, *Standard Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service*

ASTM A 376-02a, *Standard Specification for Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service*

ASTM A 387-03, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

ASTM A 479-04, *Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels*

ASTM A 515-03, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

ASTM A 516-04, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

ASTM A 537-95, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

ASTM A 672-96, *Standard Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures*

ASTM A 675-03, *Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties*

ASTM A 691-98, *Standard Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures*

ASTM A 696-90a, *Standard Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components*

ASTM A 739-90a, *Standard Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both*

ASTM A 789-04a, *Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service*

ASTM A 790-04a, *Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe*

ASTM E 186-98(2004)e1, *Standard Reference Radiographs for Heavy-Walled (2 to 41/2-in. [51 to 114-mm]) Steel Castings*

ASTM E 280-98(2004)e1, *Standard Reference Radiographs for Heavy-Walled (41/2 to 12-in. [114 to 305-mm]) Steel Castings*

ASTM E 446-96(2002)e1, *Standard reference radiographs for steel castings up to 2in. in thickness.*

ASME B16.34-1996, *Valves - Flanged, Threaded and Welding End*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in EN 736-1:1995, EN 736-2:1997 and EN 736-3:1999 and the following apply.

3.1
B (Body)
alphanumeric designation used for reference purposes related to a combination of mechanical and dimensional characteristics of a valve body. It comprises the letter B followed by a dimensionless number

3.2
Class
(see EN 736-3)

3.3
special
designation associated with B and Class threaded end or welding end valves which indicates that the shell components have been subjected to the specified levels of non destructive examination (NDE) and that the valve can be used for a higher pressure/temperature rating

Table 3 - Symbols and units

Symbol	Characteristic	Unit
A	Minimum diameter of socket	mm
A_σ	Metal area	mm^2
A_f	Fluid area	mm^2
B	Maximum diameter of socket	mm
c	constant	mm
d'	Body neck inside diameter	mm
D'_i	Body neck inside diameter beyond	mm
D''_i	Body neck inside diameter used for wall thickness determination	mm
D_i	Inside diameter of the valve	mm
$D_{i,max}$	Maximum inside diameter of the valve	mm
$D_{i,min}$	Minimum inside diameter of the valve	mm
D_{ni}	Inside diameter at the body end port	mm
e_b	Neck wall thickness	mm
e_{min}	Minimum wall thickness	mm
e_r	Body run wall thickness	mm
J	Diameter of the boss	mm
O	ovality	dimensionless
$p_{ceil/std}$	Ceiling pressure for standard rating	bar
p_c	Calculation pressure	N/mm^2
$p_{ceil/spe}$	Ceiling pressure for special rating	bar
p_{ld}	Limited class rated working pressure	bar
p_r	Pressure rating index	dimensionless
PS	Allowable pressure at temperature	bar
p_{sd}	Special rated working pressure	bar
r	Filet radius at crotch	mm
S	Stress factor	N/mm^2
$S_{sel/spe}$	Selected stress for special rating	N/mm^2
$S_{sel/std}$	Selected stress for standard rating	N/mm^2
T	Length of thread	mm
y	Temperature coefficient	dimensionless
σ_{zul}	Allowable stress	N/mm^2