AD 2000-Merkblatt

ICS 23.020.30

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Design of pressure vessels	Unstayed and stayed flat ends and plates	AD 2000-Merkblatt B 5

The AD 2000-Merkblätter are prepared by the seven associations listed below who together form the "Arbeitsgemeinschaft Druckbehälter" (AD). The structure and the application of the AD 2000 Code and the procedural guidelines are covered by AD 2000-Merkblatt G 1.

The AD 2000-Merkblätter contain safety requirements to be met under normal operating conditions. If above-normal loadings are to be expected during the operation of the pressure vessel, this shall be taken into account by meeting special requirements.

If there are any divergences from the requirements of this AD 2000-Merkblatt, it shall be possible to prove that the standard of safety of this Code has been maintained by other means, e.g. by materials testing, tests, stress analysis, operating experience.

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> *Deutsche Gesetzliche Unfallversicherung (DGUV), Berlin*
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> *Verband der Chemischen Industrie e. V. (VCI), Frankfurt/Main*
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> *VGB PowerTech e. V., Essen*
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The above associations continuously update the AD 2000-Merkblätter in line with technical progress. Please address any proposals for this to the publisher:

Verband der TÜV e. V., Friedrichstraße 136, 10117 Berlin.

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supersedes November 2014 edition; │ = amendments to previous edition

AD 2000-Merkblatt

0   Foreword

The AD 2000 Code can be applied to satisfy the basic safety requirements of the Pressure Equipment Directive, principally for the conformity assessment in accordance with modules "G" and "B + F".

The AD 2000 Code is structured along the lines of a self-contained concept. If other technical rules are used in accordance with the state of the art to solve related problems, it is assumed that the overall concept has been taken into account.

The AD 2000 Code can be used as appropriate for other modules of the Pressure Equipment Directive or for different sectors of the law. Responsibility for testing is as specified in the provisions of the relevant sector of the law.

1   Scope

The design rules hereafter apply to flat ends and plates and tube bundles of heat exchangers as far as their staying effect is concerned. They are based on the Kirchhoff equations for plates taking into consideration the effect of the boundary conditions and multiple openings approximately. In addition, the C-factors also include the effect of a Poisson's ratio of 0,3.

In the case of materials where the Poisson's ratio differs considerably, and in those cases where the dimensions exceed the limits

$$\frac{s_e - c_1 - c_2}{D} \geq \sqrt[4]{0{,}0087\frac{p}{E}}; \; \frac{s}{D} \leq \frac{1}{3}$$

a separate stress and deformation analysis is necessary.

For D, the relevant design diameter shall be substituted. This distinction does not apply to tube plates where mutual bracing is provided by the tubes.

2   General

2.1   This AD 2000-Merkblatt shall only be used in conjunction with AD 2000-Merkblatt B 0.

2.2   When using blind flanges to DIN 2527 and blind covers (flat covers of steel) to DIN 28122 the requirements of this AD 2000-Merkblatt are deemed to be met if non-metallic gaskets (e.g. flat gaskets for flanges with a flat face according to DIN EN 1514-1) are used.

Blind flanges according to DIN EN 1092-1 can be used for pressure vessels and tubing without further calculation if they fulfil all of the following conditions as specified in EN 13445-3, Subclause 11.4.2:

a)   Under normal operating conditions, the design (calculation) pressure does not exceed the rating pressure given in the tables of DIN EN 1092-1 for flange and material under consideration of the calculation temperature.

b)   Under test conditions or exceptional conditions, the design pressure does not exceed 1,5 times the rating pressure given in the same tables, at appropriate temperature.

c)   The gasket is one of those permitted in Table 1 of AD 2000-Merkblatt B 8 for the relevant PN series or Class.

d)   The bolts are of a strength category (see Table 2 in AD 2000-Merkblatt B 8) at least equal to the minimum required by Table 1 of AD 2000-Merkblatt B 8 as a function of the gasket type used in the connection.

e)   The vessel is subjected to loadings of predominantly non-cyclic nature.

f)   The difference between mean temperatures of bolts and flange does not exceed 50 °C in any condition.

g)   In the case of different coefficients of thermal expansion of the bolt and flange materials (e.g. austenitic steel flanges with ferritic steel bolts), the maximum operating temperature is 120 °C. For operating temperatures > 120 °C, the difference between the coefficients of thermal expansion of the bolt and flange materials shall not exceed 10 %.

3   Symbols and units

In addition to AD 2000-Merkblatt B 0 the following applies:

d_1, d_2	design diameters	mm
h	cylindrical part	mm
l_K	effective length	mm
l_w	length over which tube is roller-expanded into tube plate	mm
l_w^*	length of connection between tube and tube plate	mm
p_i, p_u	design pressure within or around the tubes	bar
D_1, D_2, D_3, D_4	design diameter	mm

F_A	axial force	N
F_K	buckling force	N
F_R	tube force	N
s_1	wall thickness at the junction	mm
t	in this context: pitch	mm
λ	slenderness ratio	–
l	auxiliary variable for calculation	mm
f	permitted design stress	N/mm^2
δ	ratio of the required bolt load and the internal pressure	–

4 Weakenings

4.1 Openings in unstayed flat ends and plates

4.1.1 Central openings with diameter d_i can be as shown in Figure 21 for designs as specified in Subclauses 6.1 and 6.2 and as shown in Figure 22 for designs as specified in Subclauses 6.3 and 6.4.

4.1.2 The required wall thickness of the plate with an opening is determined from Equations (2) to (4) where the C- or C_1-factor as specified in Table 1 or Figure 5 is multiplied by the opening factor C_A or C_{A1}.

4.1.3 The values of C_A or C_{A1} shall be taken from curve A or B depending on whether an opening does not have a connector (design A in Figures 21 and 22) or does have a connector (design B in Figures 21 and 22). If the diameter ratio $d_i/d_D \geq 0,8$, the flange design rules as specified in AD 2000-Merkblatt B 8 shall be applied.

4.1.4 Eccentric openings can be considered in the same way as central openings.

4.1.5 For round unstayed plates having an equidirectional additional peripheral moment where the ratio $(s_e - c_1 - c_2)/d_t \geq 0,1$, if there are several cut-outs, the cut-out correction value C_{A1} can be determined as follows:

$$C_{A1} = \sqrt{\frac{A}{A - A_A}} \tag{1}$$

where A is the cross-sectional area of the unpierced plate and A_A is the sum of the cross-sectional areas of the openings in a cross section which represents the maximum weakening effect.

4.1.6 For tube plates, the efficiency factors shall be determined in accordance with Equations (17) and (18).

5 Allowances

Please refer to AD 2000-Merkblatt B 0, Clause 9, but note that, unlike that clause, there is no c_1 allowance for walls thicker than 25 mm.

6 Calculation

6.1 Unstayed circular flat ends and plates with no additional peripheral moment

6.1.1 The required wall thickness s of unstayed circular flat ends or plates with no additional peripheral moment is

$$s = C \cdot D_1 \cdot \sqrt{\frac{p \cdot S}{10\,K}} + c_1 + c_2 \tag{2}$$

with the design factor C and the design diameter D_1 according to Table 1.

In the case of designs a) and b) given in Table 1, the following conditions shall be taken into consideration:

1) The ratio of the design stresses f_{Bord}/f_{Mantel} is to be at least 0,75

$$\Rightarrow \frac{K_{Bord}}{S_{Bord}} \geq 0,75 \cdot \frac{K_{Mantel}}{S_{Mantel}}$$

If this ratio is fallen short of, the sufficient wall thickness of the cylindrical part shall be proven in accordance with AD 2000-Merkblatt B 1 regardless of its height h.

2) In the case of a ratio of $1 > f_{Bord}/f_{Mantel} \geq 0,75$, the sufficient wall thickness of the cylindrical part shall be proven in accordance with AD 2000-Merkblatt B 1, if the height h of the cylindrical part exceeds a value of

$$\frac{f_{Bord}}{f_{Mantel}} \sqrt{D_1 \cdot s_1}$$