



BSI Standards Publication

Flanges and their joints — Design rules for gasketed circular flange connections

Part 1: Calculation

National foreword

This British Standard is the UK implementation of EN 1591-1:2024. It supersedes BS EN 1591-1:2013, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/15, Flanges.

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Date	Text affected

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Brides et leurs assemblages - Règles de calcul des
assemblages à brides circulaires avec joint - Partie 1:
Méthode de calcul

Flansche und ihre Verbindungen - Regeln für die
Auslegung von Flanschverbindungen mit runden
Flanschen und Dichtung - Teil 1: Berechnungsmethode

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European foreword

This document (EN 1591-1:2024) has been prepared by Technical Committee CEN/TC 74 “Flanges and their joints”, the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by April 2025, and conflicting national standards shall be withdrawn at the latest by April 2025.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1591-1:2013.

The major changes in comparison with the previous edition include:

- Removal of the possibility to handle gasket creep/relaxation behaviour through additional deflection. In this new revision, the gasket creep/relaxation behaviour is only treated using the P_{QR} factor;
- Correction of the lever arms considered for integral flange and collar load ratio calculation (127), (135);
- Introduction of a reduced maximum allowable value of load ratio for large integral flange and collar (128) and for large loose flanges (149);
- Possibility to check a bolted flange connection for a specified assembly bolt force value, previously treated in the body of the document is now defined in a new informative annex (Annex F);
- Update of the Flange/gasket friction factors in Annex E;
- Update of the Annex ZA in accordance with the Directive 2014/68/EU on Pressure Equipment.

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

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

EN 1591 consists of several parts:

- EN 1591-1, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 1: Calculation*;
- CEN/TR 1591-2, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 2: Gasket parameters*;
- CEN/TS 1591-3, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 3: Calculation method for metal to metal contact type flanged joint*;
- EN 1591-4, *Flanges and their joints — Part 4: Qualification of personnel competency in the assembly of the bolted connections of critical service pressurized systems*;
- CEN/TR 1591-5, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 5: Calculation method for full face gasketed joints*.

The calculation method satisfies both leak tightness and strength criteria. The behaviour of the complete flanges-bolts-gasket system is considered. Parameters taken into account include not only basic ones such as:

- fluid pressure;
- material strength values of flanges, bolts and gaskets;
- gasket compression factors;
- nominal bolt load;

but also:

- possible scatter due to bolting up procedure;
- changes in gasket forces due to compliance of all components of the joint;
- influence of connected shell or pipe;
- effect of external axial and lateral forces and torsion and bending moments;
- effect of temperature difference between bolts and all clamped components of the flange connection.

The use of this calculation method is particularly useful for joints where the bolt load is monitored when bolting up. The greater the precision of this, the more benefit can be gained from application of the calculation method.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

1 Scope

This document defines a calculation method for bolted, gasketed, circular flange joints. Its purpose is to ensure structural integrity and control of leak tightness. It uses gasket parameters based on definitions and test methods specified in EN 13555:2021.

The calculation method is not applicable to joints with a metallic contact out of the sealing face or to joints whose rigidity varies appreciably across gasket width. For gaskets in incompressible materials, which permit large deformations, the results given by the calculation method can be excessively conservative (i.e. required bolting load too high, allowable pressure of the fluid too low, required flange thickness too large, etc.).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 13555:2021, *Flanges and their joints — Gasket parameters and test procedures relevant to the design rules for gasketed circular flange connections*

3 Terms and definitions, subscripts, special marks and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions, subscripts, special marks and symbols apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

For standard flange types, as shown in EN 1092 or EN 1759, the relevant figures are the following:

Type 01	Figure 10
Type 02	Figure 12 (with collar type 35, 36 and 37)
Type 05	Figure 11
Type 11	Figure 6
Type 12	Figure 13
Type 13	Figure 14
Type 21	Figures 6 to 9

NOTE Figure 1 to Figure 14 illustrate the notation corresponding to the geometric parameters. They only show principles and are not intended to be practical designs. They do not illustrate all possible flange types for which the calculation method is valid. For further details see 5.2.

3.1.1 flanges

3.1.1.1 integral flange

flange attached to the shell either by welding (e.g. neck weld, see Figure 6 to Figure 9, or slip on welded or weld-on, see Figure 10 and Figure 13) or cast onto the envelope (integrally cast flanges, type 21)

3.1.1.2 blank or blind flange

flat closure (see Figure 11)

3.1.1.3 loose flange

separate flange ring abutting a collar (see Figure 12)

3.1.1.4 hub

axial extension of flange ring, usually connecting flange ring to shell (see Figure 6 and Figure 7)

3.1.1.5 collar or stub

abutment for a loose flange (see Figure 12)

3.1.2 loading

3.1.2.1 external loads

forces and/or moments applied to the joint by attached equipment, e.g. weight and thermal expansion of pipes

3.1.3 load conditions

3.1.3.1 load condition

state with set of applied simultaneous loads; designated by I

3.1.3.2 assembly condition

load condition due to initial tightening of bolts (bolting up), designated by $I = 0$

3.1.3.3 subsequent condition

load condition subsequent to assembly condition, e.g. test condition, operating condition, conditions arising during start-up and shut-down; designated by $I = 1, 2, 3 \dots$

3.1.4 compliances

3.1.4.1 compliance

inverse stiffness (axial), symbol Y , [mm/N]

3.1.4.2

flexibility modulus:

inverse stiffness modulus, excluding elastic constants of material:

- axial: symbol X , [1/mm]
- rotational: symbol Z , [1/mm³]

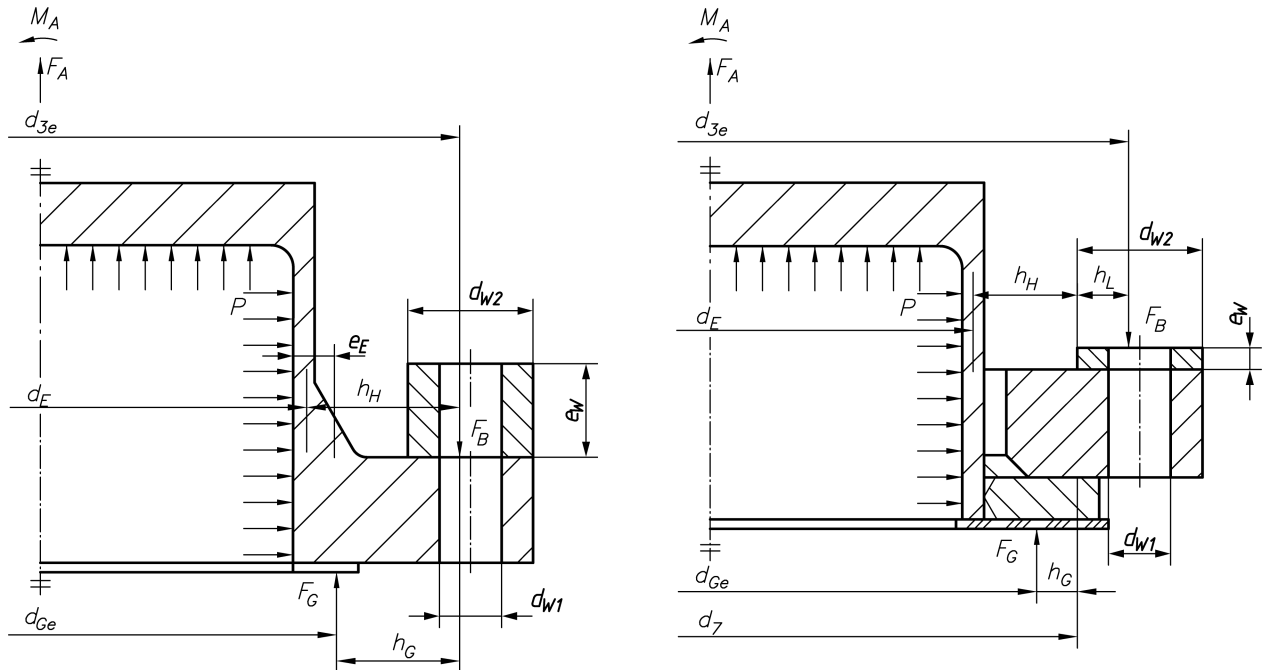


Figure 1 — Loads and lever arms

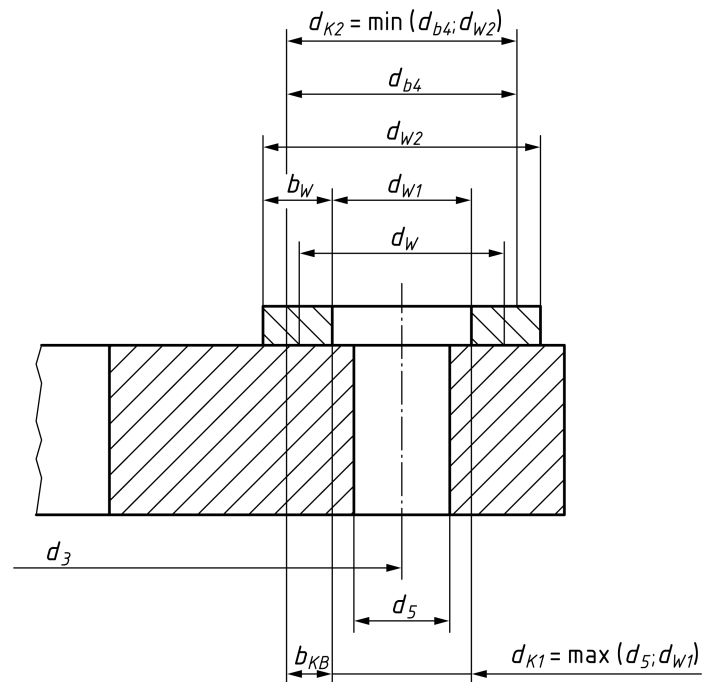


Figure 2 — Washer or spacer

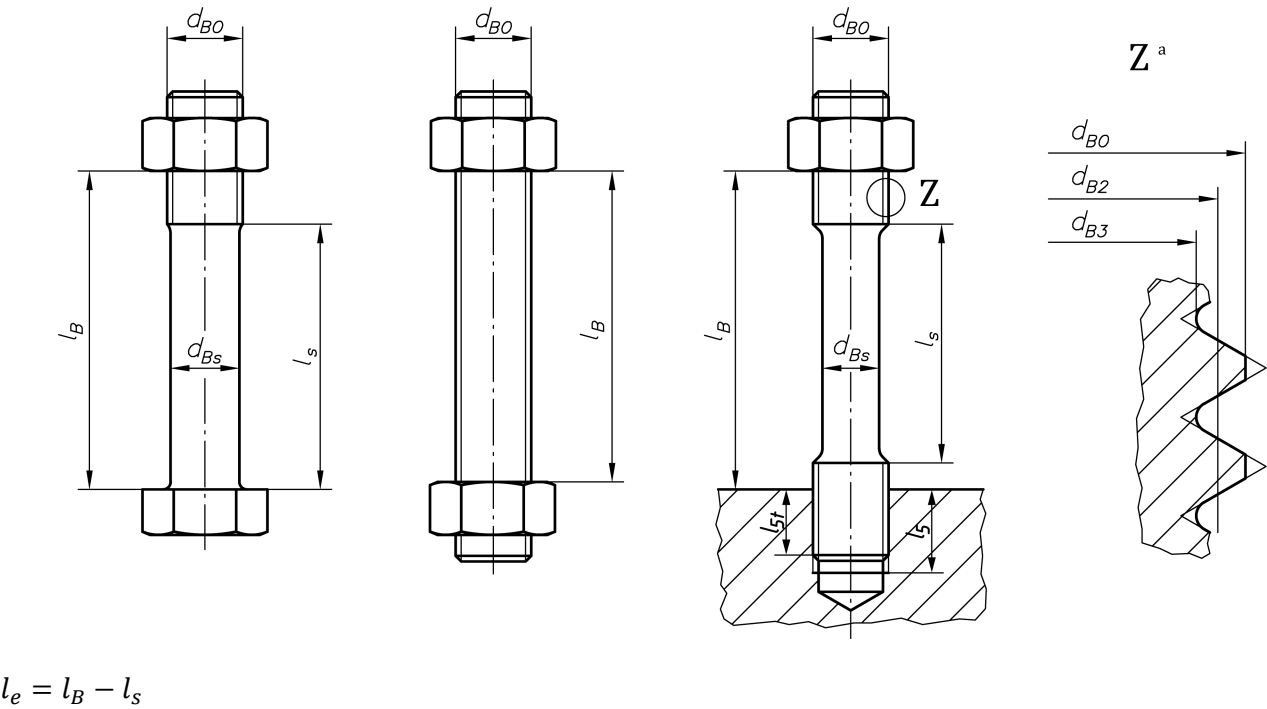
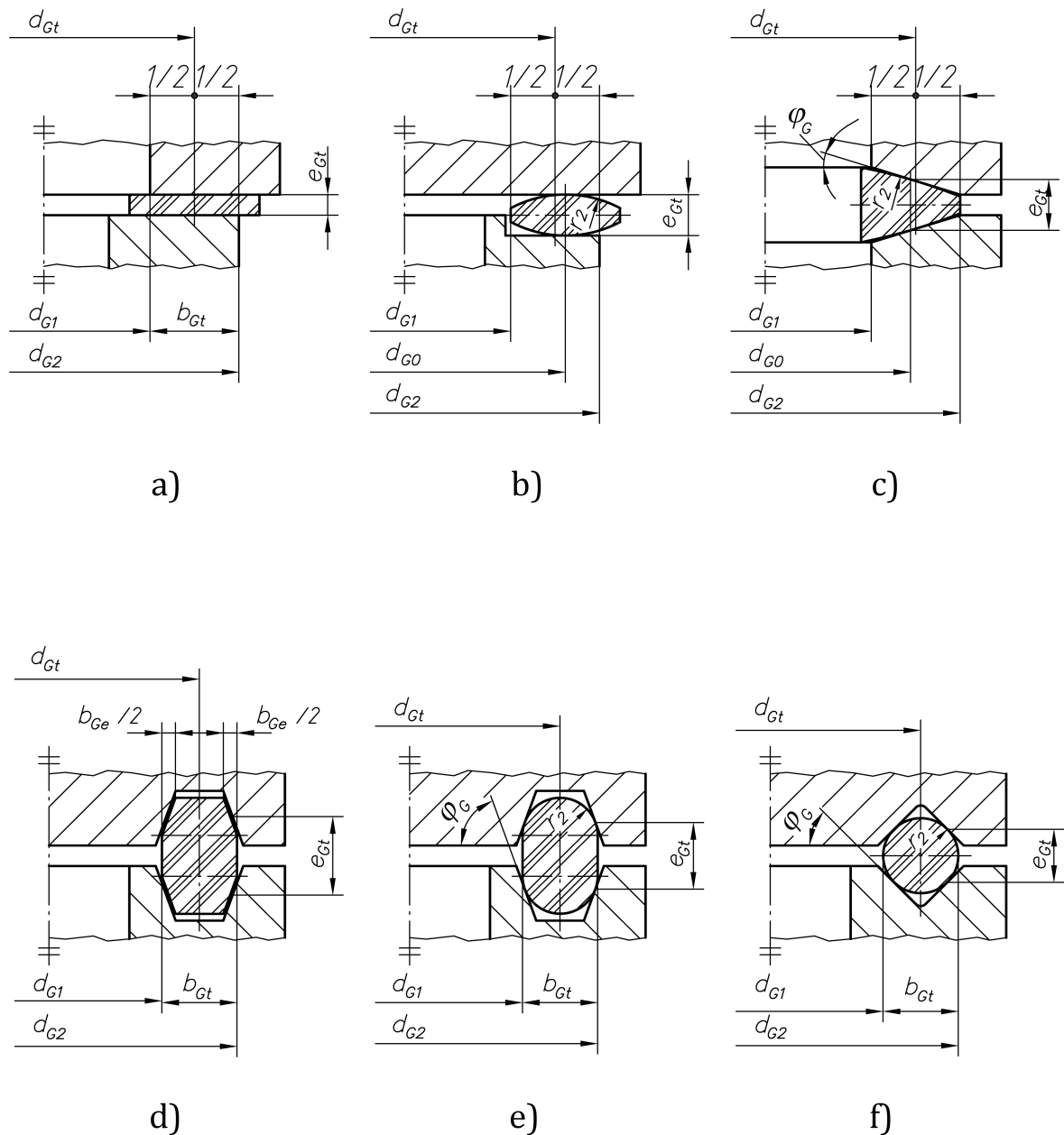


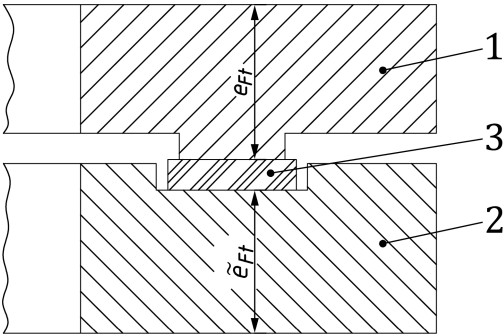
Figure 3 — Bolts



Key

- a) Flat gaskets, of low hardness, composite or pure metallic, materials
- b) and c) Metal gaskets with curved surfaces, simple contact
- d) Metal octagonal section gaskets
- e) and f) Metal oval or circular section gaskets, double contact

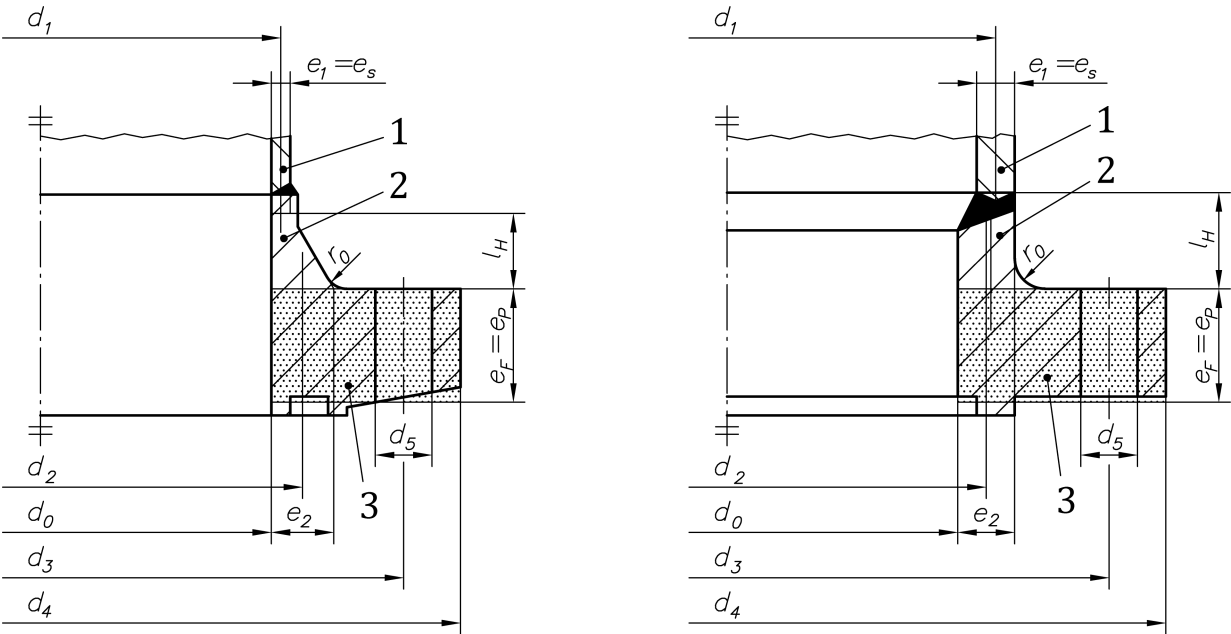
Figure 4 — Gaskets



Key

- 1 male flange (tongue)
- 2 female flange (groove)
- 3 gasket

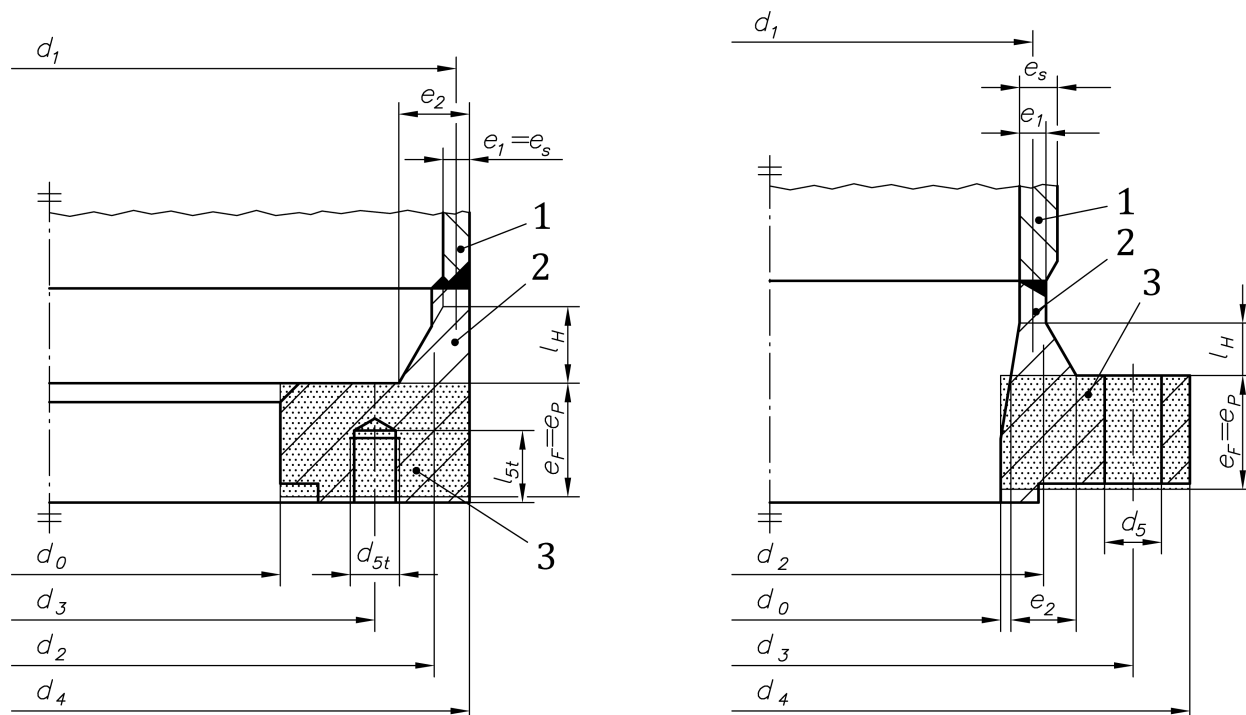
Figure 5 — Details for tongue and groove facing



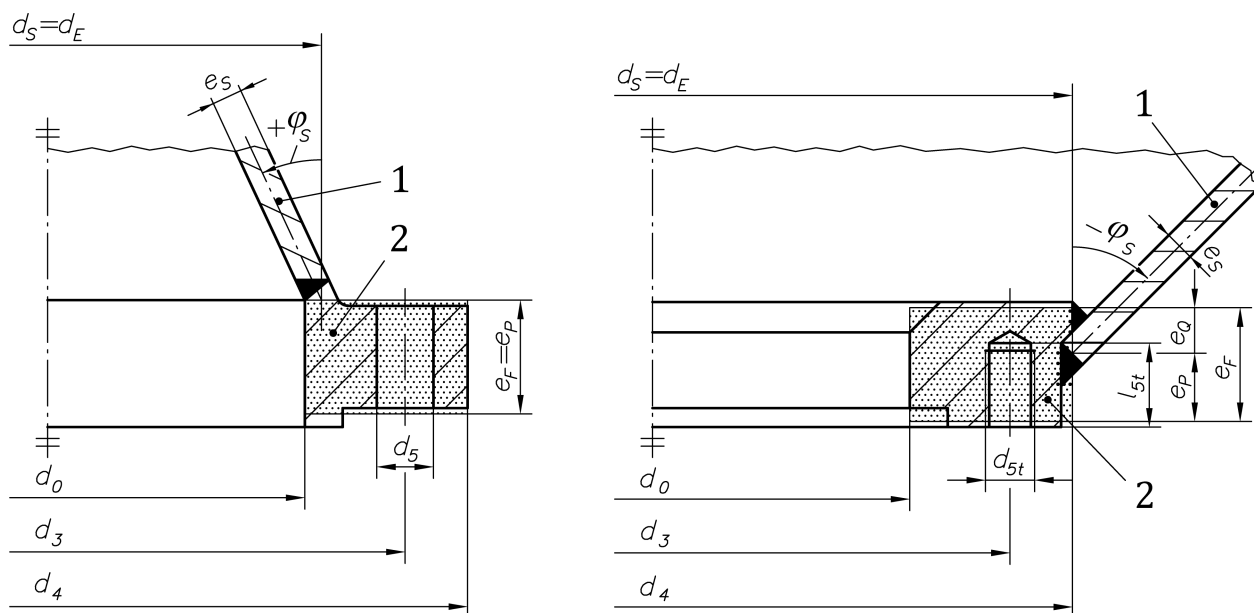
Key

- 1 shell
- 2 hub
- 3 ring

Figure 6 — Weld-neck flanges with cylindrical shells (example 1)

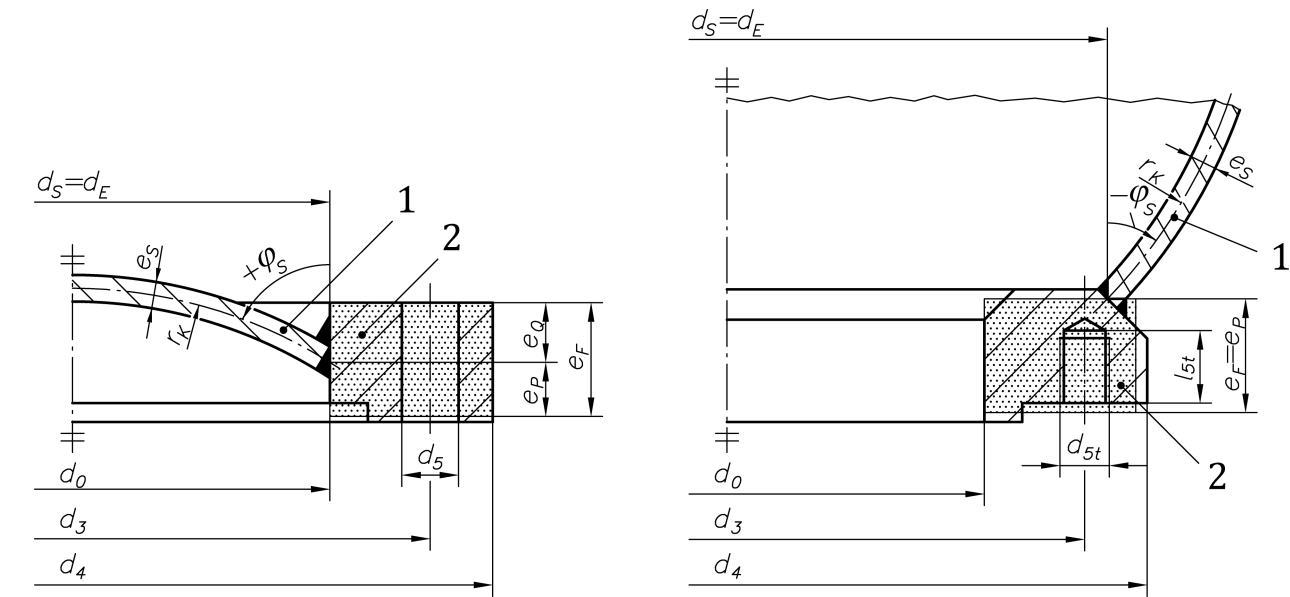
**Key**

- 1 shell
- 2 hub
- 3 ring

Figure 7 — Weld-neck flanges with cylindrical shells (example 2)**Key**

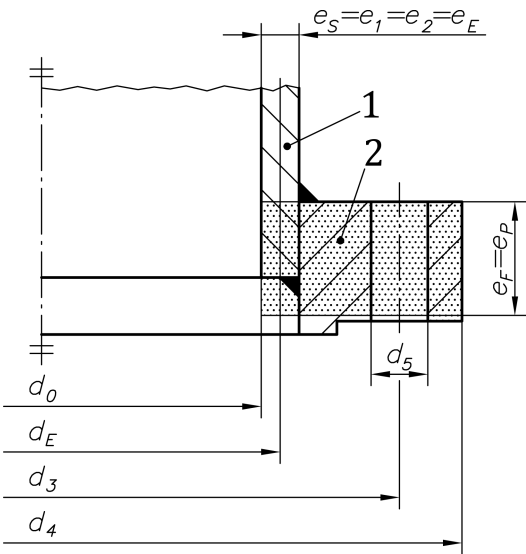
- 1 shell
- 2 ring

Figure 8 — Flanges welded to conical shells



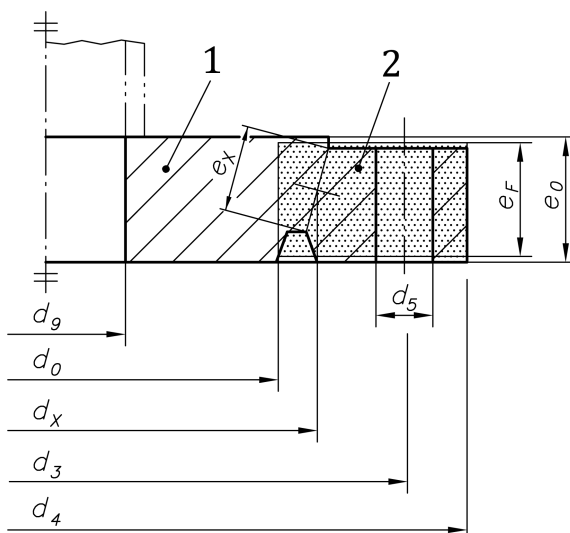
- Key**
- 1 shell
 - 2 ring

Figure 9 — Flanges welded to spherical shells

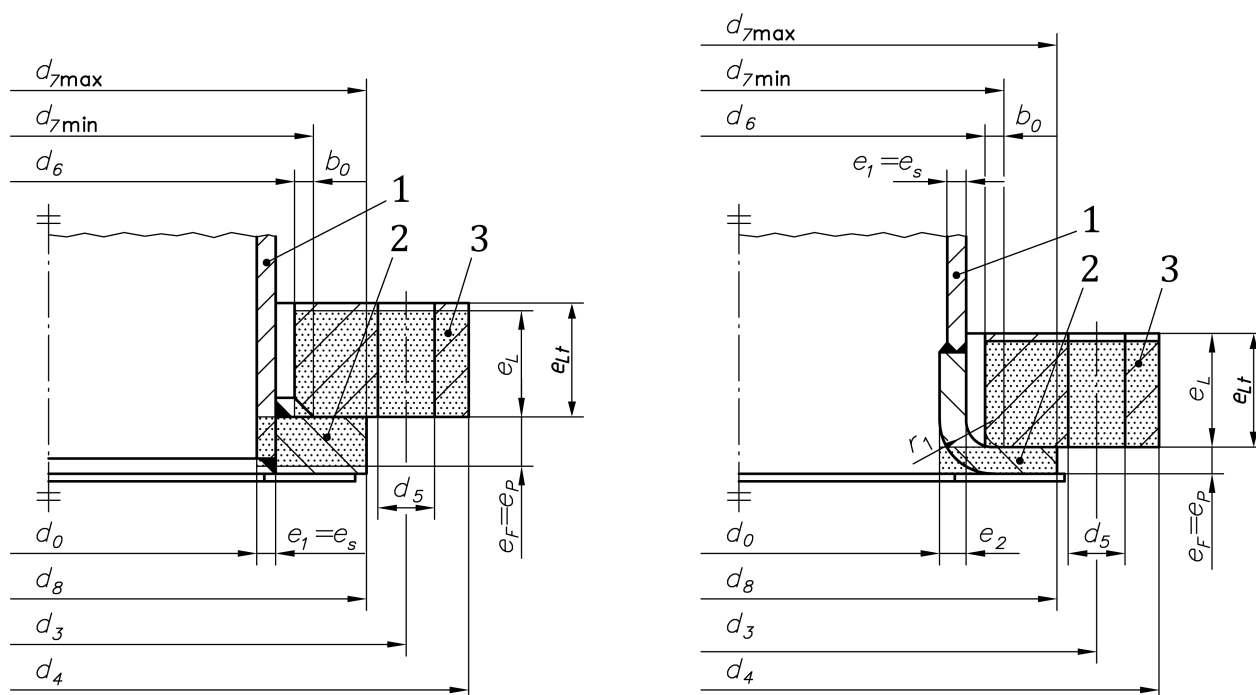


- Key**
- 1 shell
 - 2 ring

Figure 10 — Weld-on plate flange

**Key**

- 1 plate
- 2 ring

Figure 11 — Blank flange**Key**

- 1 shell
- 2 collar
- 3 loose flange

Figure 12 — Collar or stub with loose flanges

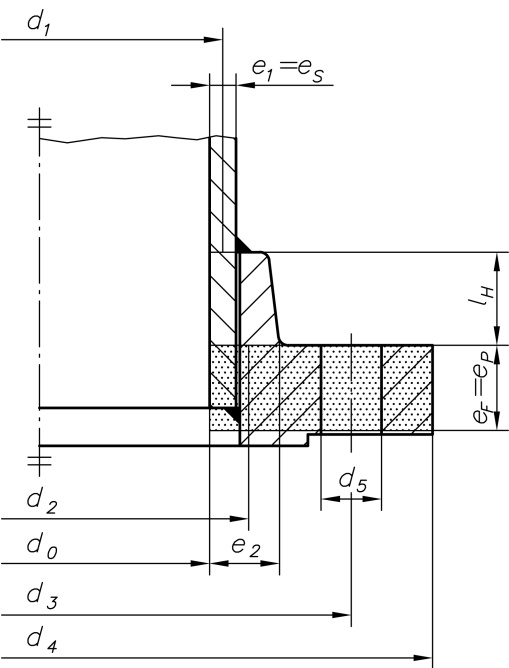


Figure 13 — Hubbed slip-on welded flange

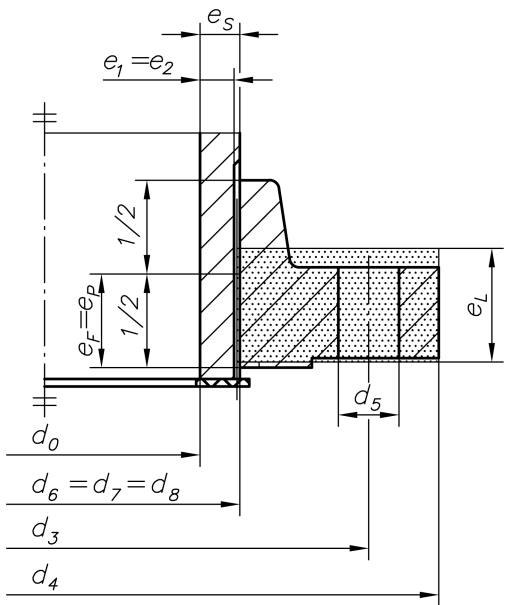


Figure 14 — Hubbed threaded flange

3.2 Subscripts and special marks

3.2.1 Subscripts

A	Additional (F_A , M_A)
B	Bolt
D	Equivalent cylinder (tapered hub + connected shell) for load limit calculation
E	Equivalent cylinder (tapered hub + connected shell) for flexibility calculation
F	Flange
G	Gasket
H	Hub
I	Load condition identifier (taking values 0, 1, 2 ...)
L	Loose flange, Lateral (F_{Li})
M	Moment
N	Nut
P	Fluid pressure
Q	Net axial force due to pressure
R	Net axial force due to external force
S	Shell, Shear
T	Shell, modified
TG	Torsion (M_{TG})
X	Flange weakest cross section
W	Washer or extension sleeve
Δ	Symbol for change or difference
av	average
c	calculated
e	effective
i	Interim value
max	maximum

min	minimum
nom	nominal
opt	optimal
req	required
<i>s</i>	non-threaded part of bolt
<i>specified</i>	refers to the case of calculation performed for a given (specified) assembly bolt force (Annex F)
<i>t</i>	theoretical, torque, thread
0	assembly condition ($I = 0$, see subscript <i>I</i>)

3.2.2 Special marks

~	Accent placed above symbols of flange parameters that refers to the second flange of the joint, possibly different from the first
---	---

3.3 Symbols

Where units are applicable, they are shown in brackets. Where units are not applicable, no indication is given.

A_B	Effective total cross-section area of all bolts [mm ²], Formulae (39), (52), (121), (B.3)
A_F, A_L	Gross radial cross-section area (including bolt holes) of flange ring, loose flange [mm ²], Formulae (8), (11) and (14)
A_{Ge}, A_{Gt}	Gasket area, effective, theoretical [mm ²], Formulae (51), (54), (126)
A_Q	Effective area for the axial fluid-pressure force [mm ²], Formula (88)
E_B, E_F, E_L, E_W	Modulus of elasticity of the part designated by the subscript, at the temperature of the part [MPa] Formulae (60), (63), (97) to (100), (C.1), (C.2)
E_G	Modulus of elasticity of the gasket for unloading/reloading at the considered temperature, considering the gasket surface pressure in assembly Q_{G0} [MPa] Formulae (56), (64), (65), (67), (68), (72), (73), (98)
F_A	Additional external axial force [N], tensile force > 0, compressive force < 0, see Figure 1, Formulae (90) and (94)
F_B	Bolt force (sum of all bolts) [N] Formulae (106), (109) to (117), (120), (121), (144), (146), (148), (B.4), (B.5), (B.9), (C.2) to (C.4), (C.9), (C.10)
F_G	Gasket force [N] Formulae (52), (55), (63), (73), (105) to (108), (116) to (120), (126), (127), (135), (C.1), (C.5) to (C.8)

F_{GA}	Minimum gasket force in assembly condition [N] that guarantees, the required gasket force for all subsequent conditions, Formulae (103), (104)
F_L	Force resulting from the additional radial forces [N], Formulae (91) and (102)
F_Q	Axial fluid-pressure force [N], Formulae (89), (102), (103), (104), (118), (119), (120), (127), (135), (144), (151), (C.1), (C.7) to (C.10)
F_R	Force resulting from the additional external loads [N], Formulae (94), (102), (103), (104), (106), (116), (117), (118), (119), (120), (127), (135), (144), (151), (C.1), (C.5) to (C.10)
F_X, F_Y, F_Z	Additional forces along X, Y and Z-axis at gasket interface [N], Formulae (90) and (91)
I	Load condition identifier, for assembly condition $I = 0$, for subsequent conditions $I = 1, 2, 3, \dots$
I_B	Plastic torsion modulus of bolt shanks $\left\{ I_B = \frac{\pi}{12} \times \min(d_{Be}; d_{Bs})^3 \right\}$ [mm ³], Formula (121)
M_A	Resulting external bending moment [N × mm], Figure 1, Formulae (92) and (102)
$M_{t,nom}$	Nominal bolt assembly torque [N × mm], Formulae (B.4) and (B.5)
M_{tB}	Twisting moment [N × mm] applied to bolt shanks as a result of application of the nominal bolt assembly force $F_{B0,nom}$ Formulae (121) and (B.9)
M_{TG}	Additional external torsion moment due to friction, Formula (93) and (102)
N_R	Number of re-assemblies and re-tightenings during service life of joint, Formulae (117), (F.2)
P	Pressure of the fluid [MPa], internal pressure > 0, external pressure < 0 (1 bar = 0,1 MPa), Formula (89)

NOTE P in this standard is equivalent to the maximum allowable pressure PS according to the PED.

P_{QR}	Creep relaxation factor which is the ratio of the residual and the original gasket surface pressure at load conditions [-] Formulae (103), (104), (118), (119), (C.7), (C.8). (see EN 13555:2021 for more details)
Q_{G0}	Gasket surface pressure in assembly condition [MPa] Formula (55)
Q_A	Gasket surface pressure at assembly prior to the unloading which is necessary for the validity of the corresponding $Q_{Smin(L),I}$ in all subsequent conditions [MPa], Formula (101). The lowest acceptable value for Q_A is $Q_{min(L)}$ from EN 13555:2021.
$Q_{0,min}$	Gasket surface pressure required at assembly prior to the unloading when no specific leak rate is requested [MPa], replacement of Q_A in Formula (101), Annex G

$Q_{\min(L)}$	Minimum level of gasket surface pressure required for tightness class L at assembly (on the effective gasket area) from EN 13555:2021 test results [MPa] (see 6.4.2 NOTE 1)
$Q_{\text{Smin}(L)}$	Minimum level of gasket surface pressure required for tightness class L in service conditions (after off-loading) (on the effective gasket area) from EN 13555:2021 test results [MPa], Formula (102)
Q_{Smax}	Maximum allowable gasket surface pressure that can be safely imposed upon the gasket at the considered temperature without damage [MPa], Formulae (63), (67), (68), (72), (73), (126) and (151)
T_B, T_F, T_G, T_L, T_W	Temperature (average) of the part designated by the subscript [°C] or [K], Formula (95)
T_0	Temperature of joint at assembly [°C] or [K] (usually + 20 °C), Formula (95)
W_F, W_L, W_X	Resistance of the part and/or cross-section designated by the subscript [$\text{N} \times \text{mm}$], Formulae (127), (129), (144) to (148), (150)
X_B, X_G, X_W	Axial flexibility modulus of bolts, gasket, washer [$1/\text{mm}$], Formulae (40), (41), (47), (48), (61), (97), (98)
Y_B, Y_G, Y_Q, Y_R	Axial compliance of the bolted joint, related to F_B, F_G, F_Q, F_R [mm/N], Formulae (97), (98), (99), (100), (103), (104), (118), (119), (C.7), (C.8)
Z_F, Z_L	Rotational flexibility modulus of flange, loose flange [mm^{-3}], Formulae (32), (36), (33), (37), (38), (60), (63), (97) to (100)
b_0	Width of chamfer (or radius) of a loose flange such that: $d_{7\min} = d_6 + 2 \times b_0$ [mm], Figure 12, Formula (83)
b_F, b_L	Effective width of flange, loose flange [mm], Formulae (5), (6), (9), (12), (23), (32), (38), (129), (139), (145), (150), see 4.2 d) 1)
b_{Gi}, b_{Ge}, b_{Gt}	Gasket width (radial), interim, effective, theoretical [mm], Formulae (49), (51), (53), (54), (61) to (63), (66), (67), (68), (70), (72) and (73)
b_{KB}	Contact widths bolt side [mm], Formulae (46) to (48), Figure 2
b_W	Width of a washer [mm], Formulae (42), (47), (48), Figure 2
C_A, C_B, C_F, C_M, C_S	Correction factors [-], Formulae (26), (121) to (125), (133), (134)
d_0	Inside diameter of flange ring [mm] and outside diameter of central part of blank flange (with thickness e_0), in no case greater than inside diameter of gasket [mm], Figures 6 to 14, Formulae (7) to (9), (22), (128), (145)
d_1	Average diameter of hub, thin end [mm], Figures 6, 7, 13
d_2	Average diameter of hub, thick end [mm], Figures 6, 7, 13
d_3, d_{3e}	Bolt circle diameter, real, effective [mm], Figures 6 to 14, Formulae (4), (146)

d_4	Outside diameter of flange [mm], Figures 6 to 14, Formulae (7), (8), (128), (147), (149)
d_5, d_{5b}, d_{5e}	Diameter of bolt hole, pierced, blind, effective [mm], Figures 6 to 14, Formulae (2), (3), (147)
d_6	Inside diameter of loose flange [mm], Formulae (83), (149), Figures 12, 14
$d_7, d_{70}, d_{7\min}, d_{7\max}$	Diameter of position of reaction between loose flange and stub or collar, initial, minimal, maximal [mm], Figure 1, Figure 12, Formulae (59), (82) to (87) and (151)
d_8	Outside diameter of collar [mm], Formulae (9), (10), (84), Figures 12 and 14
d_9	Diameter of a central hole in a blank flange [mm], Formula (34), Figure 11
d_{B0}, d_{Be}, d_{Bs}	Diameter of bolt: nominal diameter, effective diameter, shank diameter [mm], Formulae (39), (40), Figure 3, Table A.1
d_{B2}, d_{B3}	Basic pitch diameter, basic minor diameter of thread [mm], see Figure 3, Table A.1, Formula (B.9)
d_{B4}	Maximum possible outside contact diameter between bolt head or nut and flange or washer [mm], Formula (45), Figure 2
d_{Ge}, d_{Gt}	Diameter of gasket, effective, theoretical [mm], Figure 4, Formula (51), (54), (57) to (59), (63), (66), (69), (71), (74), (75), (77), (78), (79), (85), (88), (102)
d_{K1}, d_{K2}	Extreme contact diameters (inside, outside) [mm], Formulae (44) and (45), Figure 2, 5.3.4.2 NOTE 2
d_{G0}, d_{G1}, d_{G2}	Real, theoretical inside, theoretical outside contact diameters [mm], Formulae (49), (50), (66), (69), (151), Figure 4
d_E, d_F, d_L, d_S, d_X	Average diameter of part or section designated by the subscript [mm], Formulae (6), (7), (10), (13), (20), (22), (24), (27), (32), (34), (35), (36), (38), (75), (77), (78), (80), (86), (129), (131), (132), (139), (146), (147), (151), Figures 1, 8, 9, 10, 11
d_{w1}, d_w, d_{w2}	Inside, Mean, Outside diameter of washer [mm], Formulae (42) to (45), Figure 1, 2
e_0	Wall thickness of central plate of blank flange within diameter d_0 [mm], Formulae (36) and (145), Figure 11
e_1	Lowest wall thickness at thin end of hub or of connected shell [mm], Formulae (15) to (18), Figures 6, 7, 10, 12, 13, 14
e_2	Wall thickness at thick end of hub [mm], Formulae (17) and (18), Figures 6, 7, 10, 12, 13, 14

e_D, e_E	Wall thickness of equivalent cylinder for load limit calculations, for flexibility calculations [mm], Formulae (15), (16), (18), (19), (21), (24), (27), (129), (131), (132), (139)
e_F, e_L	Effective axial thickness of flange, loose flange [mm], Formulae (8), (11), (14), (24), (25), (27), (28), (32), (36), (38), (95), (96), (129), (139), (140), (145), (147), (150), (151), 4.2) 1), Figures 6 to 14
e_{Fb}	Thickness of flange ring at diameter d_3 (bolt position) [mm], Formula (3)
e_{Ft}, e_{Lt}	Thickness of (integral or loose) flange ring at diameter d_{Ge} (gasket force position), relevant for thermal expansion [mm], Formulae (95) and (96), Figure 5 and Figure 12
$e_G(Q_{G0})$	Compressed gasket thickness under contact pressure Q_{G0} [mm], Formulae (61), (63), (95), (96), (104), (119), can be obtained from the tests according to EN 13555:2021
$e_{G(A)}$	Compressed thickness of gasket after all subsequent conditions (including plastic deformation) [mm], Formulae (104), (119) and Annex H
e_{Gt}	Theoretical uncompressed thickness of gasket [mm], Figure 4
e_N	Nut thickness, Formula (125)
e_P, e_Q	Part of flange thickness with (e_P), without (e_Q) radial pressure loading [mm], such that $e_P + e_Q = e_F$, Formulae (25) and (139), Figures 6 to 10 and 12 to 14,
e_S	Thickness of connected shell [mm], Formula (19), 4.2 d) 2), Figures 6 to 10, 12 to 14
e_W	Washer thickness [mm], Formulae (47) and (48), Figure 1
e_X	Flange thickness at weak section [mm], Formula (147), Figure 11
$f_B, f_E, f_F, f_L, f_N, f_S$	Nominal design stress [MPa] of the part designated by the subscript, at design temperature [°C] or [K], as defined and used in pressure vessel codes (see Formulae (121), (125), (129) to (132), (139), (145), (147), (150) and (151))
h_G, h_H, h_L	Lever arms [mm], Figure 1, Formulae (57), (58), (63), (79) to (81) and (85) to (87), (97) to (100), (127), (135), (144), (151), (C.1), (C.2)
h_P, h_Q, h_R, h_S, h_T	Lever arm corrections [mm], Formulae (27) to (29), (35), (75), (77), (78), (99), (100), (127), (135), (C.1)
j_M, j_S	Sign number for moment, shear force (+1 or 1), Formulae (135) and (136)
k_Q, k_R, k_M, k_S	Correction factors, Formulae (30), (31), (77), (129), (137) to (139), Table 2
l_S, l_{St}	Total, effective screws engagement length in threaded hole, Formulae (3) (125), Figures 3, 7, 8 and 9
l_B, l_s	Bolt axial dimensions [mm], Figure 3, Formulae (95), (96) and (40)