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JAPANESE INDUSTRIAL STANDARD

**Basis for calculation of
pipe flanges**

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Basis for calculation of pipe flanges

B 2205-1991

1. Scope

This Japanese Industrial Standard specifies the basis for stress calculation of bolt-fastening pipe flanges using a ring gasket (hereafter referred to as "flange").

Furthermore, the basis for calculation of flat-face flange using a full-face gasket is shown in Informative reference 1, and that of metal face contact flange, in Informative reference 2.

- Remarks 1. The basis for calculation specified in this Standard is used to calculate and to evaluate the stress generated in the flange at each stage, by assuming the two independent imaginary stages at the time of gasket clamping and under the operating condition (pressurized state, hereinafter similar to this). Therefore, the load to be used for calculation herein shall be the load which actuate to the flange when bolts are fastened and inner pressure or outer pressure is applied, and the loads as shown in the following are not considered.
- (1) The unnatural forced force which acts when the flange is installed.
 - (2) The outer force transmitted from the connected piping system during service.
 - (3) The thermal stress generated inside the flange during service.
 - (4) The stress generated by heat expansion difference between the flange and the bolt during service.
2. This Standard is not applicable in the case where the flange surfaces contact with each other at the outside of center circle of bolt holes in both cases of clamping time of gasket and of operating condition.
3. In this Standard the units, numerical values and calculation formulae shown in { } are in accordance with the conventional units and indicated for informative reference.

2. Symbols

The symbols used in this Standard shall be as follows:

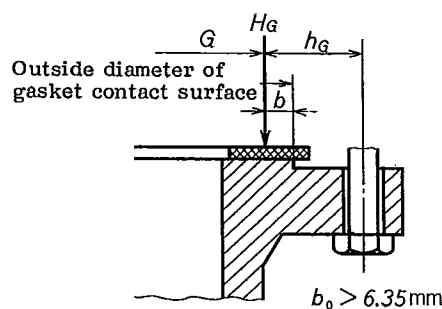
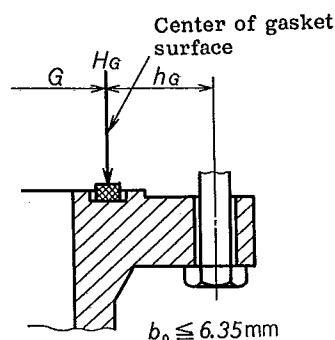
- A : Outside diameter of flange (mm). However, in the case where bolt holes are notched till the outside diameter of the flange, it is the diameter of the inscribed circle of notches.
- A_b : $n \frac{\pi}{4} d_b^2$, total effective sectional area of actually used bolts (mm²)
- A_m : Required total effective sectional area of bolts (mm²), and the larger value out of A_{m1} , and A_{m2}
- A_{m1} : Required total effective sectional area of bolts under operating condition (mm²)
- A_{m2} : Required total effective sectional area of bolts at the time of clamping the bolts (mm²)
- B : Inside diameter of flange (mm). However, in the calculation formula of axial stress σ_H of hub, when B is smaller than $20 g_1$, B_1 may be used instead of B .
- B_1 : $B + g_0$ (mm) (in the case of integral type flange when $f \geq 1$)
- B_1 : $B + g_1$ (mm) (in the case of loose type flange or of integral type flange when $f < 1$. Provided that the minimum value of f is 1.)
- b : Effective gasket seating width (mm), which is as follows:
- where $b_0 \leq 6.35$ mm $b = b_0$
- where $b_0 > 6.35$ mm $b = 2.52 \sqrt{b_0}$
- b_0 : Basic gasket seating width (mm) in accordance with Attached Table 2.
- C : Bolt circle diameter (mm)
- c : Basic dimension (mm) for the minimum weld dimension, t_n or t_1 , whichever is less.
- D_g : Outside diameter of gasket (mm)
- d : Factor, for integral type flange and for optional type flange to be calculated as integral type flange $\frac{U}{V} h_0 g_0^2$, for loose type flange $\frac{U}{V_L} h_0 g_0^2$
- d_b : Minor diameter of threaded portion of bolt or the minimum part of shaft diameter, whichever is less (mm)
- e : Factor, for integral type flange and for optional type flange to be calculated as integral type flange $\frac{F}{h_0}$, for loose type flange as $\frac{F_L}{h_0}$

F : Factor for integral type flange and for optional type flange to be calculated as integral type flange and to be in accordance with Attached Fig. 2 or Attached Table 3.

F_L : Factor for loose type flange to be in accordance with Attached Fig. 3 or Attached Table 3.

f : Hub stress correction factor to be in accordance with Attached Fig. 1 or Attached Table 3 (When $f > 1$, f expresses the ratio of the stress at the part of g_0 in hub thickness to the stress at the part of g_1 in thickness. When $f < 1$, $f = 1$.).

G : Diameter of gasket reaction force circle (mm)



where $b_0 \leq 6.35$ mm G = diameter of central circle of gasket surface

where $b_0 > 6.35$ mm G = (outside diameter of gasket contact surface) - $2b$

However, lap joint type flange is to be as shown in Fig. (a) of 3.2.

g_1 : Thickness of hub at back of flange (mm)

g_0 : Thickness of hub at small end (mm)

H : $\frac{\pi}{4} G^2 P \left\{ \frac{\pi}{400} G^2 P \right\}$, total load applied to flange by internal pressure (N{kgf})

H_D : $\frac{\pi}{4} B^2 P \left\{ \frac{\pi}{400} B^2 P \right\}$, load applied to inside diameter surface of flange by internal pressure (N{kgf})

H_G : $W_0 - H$, gasket load (N{kgf}), i.e., the difference between the bolt load and the total load applied to flange by internal pressure

H_p : $2\pi b G m P \left\{ \frac{2\pi b}{100} G m P \right\}$, compression force (N{kgf}) applied to gasket or joint contact surface so as to maintain sufficient air-tightness

H_T : $H - H_D$, difference between the total load applied to the flange and the load applied to the inside diameter surface of flange by internal pressure (N{kgf})

- h : Hub length (mm), in accordance with Fig. 1 of 3.2.
- h_D : Radial distance from bolt circle to H_D acting point (mm), in accordance with Table 1 of 3.4.
- h_G : Radial distance from bolt circle to H_G acting point (mm), in accordance with Table 1 of 3.4.
- h_T : Radial distance from bolt circle to H_T acting point (mm), in accordance with Table 1 of 3.4.
- h_0 : $\sqrt{B g_0}$ (mm)
- K : Factor, $\frac{A}{B}$
- L : Factor, $\frac{te+1}{T} + \frac{t^3}{d}$
- M : Moment acting on flange (N·mm{kgf·mm}), in accordance with the following:
- (1) Under operation condition $M=M_0$
 - (2) At clamping gasket $M=M_g$
- M_D : $H_D h_D$, moment due to load acting on inside diameter surface of flange according to internal pressure (N·mm{kgf·mm})
- M_G : $H_G h_G$, moment due to gasket load (that is, the moment due to the difference between bolt load of flange and the total load applied to flange by internal pressure) (N·mm{kgf·mm})
- M_T : $H_T h_T$, moment due to the difference between the total load applied to flange according to the internal pressure and the load applied to inside diameter surface of flange (N·mm {kgf·mm})
- M_g : Moment acting on flange at clamping the gasket (N·mm{kgf·mm})
- M_0 : Total moment acting on the flange under the operating condition (N·mm{kgf·mm})
- m : Gasket factor, in accordance with Attached Table 1
- N : Width of gasket contact surface (mm), in accordance with Attached Table 2.
- n : Number of bolts
- P : Internal pressure (MPa{kgf/cm²})
- P_e : External pressure (MPa{kgf/cm²})
- R : $\frac{C-B}{2} - g_1$, radial distance from bolt circle to the intersecting point of hub and back of flange (mm)

- r : Rounding of corner (mm), not less than $0.25 g_1$, provided that it is 4.5 mm or more.
- T : Factor determined by the value of $K\left(=\frac{A}{B}\right)$, in accordance with Attached Fig. 4.
- t : Flange thickness (mm), not including the height of gasket seating surface and depth of gasket groove.
- t_n : Thickness of connecting tube (mm)
- t_1 : In the case of calculating as the integral type flange, $2 g_0$, and of calculating as loose type flange, twice (mm) the thickness required for calculation of connecting tube relative to internal pressure, provided not less than 6.35 mm.
- U : Factor determined by the value of $K\left(=\frac{A}{B}\right)$, and in accordance with Attached Fig. 4.
- V : Factor for integral type flange and for optional type flange to be calculated as the integral type flange, in accordance with Attached Fig. 5 or Attached Table 3.
- V_L : Factor for loose type flange, in accordance with Attached Fig. 6 or Attached Table 3.
- W_0 : Bolt load under the operating condition (N{kgf})
- W_g : Bolt load at clamping the gasket (N{kgf})
- W_{m1} : Minimum bolt load required under the operating condition (N{kgf})
- W_{m2} : Minimum bolt load required for clamping the gasket (N{kgf})
- Y : Factor determined by the value of $K\left(=\frac{A}{B}\right)$, in accordance with Attached Fig. 4.
- y : Minimum design clamping pressure (N/mm²{kgf/mm²}) of gasket or joint contact surface, in accordance with Attached Table 1.
- Z : Factor determined by the value of $K\left(=\frac{A}{B}\right)$, in accordance with Attached Fig. 4.
- σ_H : Axial stress of hub (N/mm²{kgf/mm²})
- σ_R : Radial stress of flange (N/mm²{kgf/mm²})
- σ_T : Circumferential stress of flange (N/mm²{kgf/mm²})
- σ_a : Permissible tensile stress of bolt material at ordinary temperature (N/mm²{kgf/mm²})
- σ_b : Permissible tensile stress of bolt material at operating temperature (N/mm²{kgf/mm²})

σ_f : Permissible tensile stress of flange material at operating temperature ($\text{N/mm}^2\{\text{kgf/mm}^2\}$)

Further, relative to the gasket fastening time, the permissible tensile stress at ordinary temperature ($\text{N/mm}^2\{\text{kgf/mm}^2\}$)

σ_n : Permissible tensile stress of the material of tube or tubular part at operating temperature ($\text{N/mm}^2\{\text{kgf/mm}^2\}$)

Furthermore, for gasket clamping time, the permissible tensile stress at ordinary temperature ($\text{N/mm}^2\{\text{kgf/mm}^2\}$)

3. Calculation for flange

3.1 Calculation for flange The calculation shall generally be in accordance with 3.2 to 3.5. However, the flange receiving external pressure, split flange, and non circular flange with circular holes shall be in accordance with 4., 5., and 6.

3.2 Classification of flanges The classification of flanges herein shall be as follows:

(1) Loose type flange

(a) Lap joint type flanges [Figs. 1 (a), (b)] The flange to be used in combination with stub end.

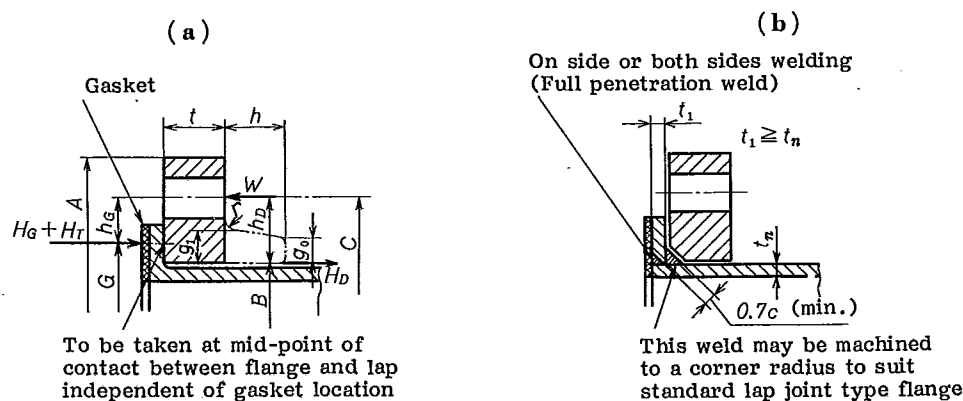
(b) Slip-on type flanges [Figs. 1 (c), (d), (e)] The flange which is screwed in or inserted into a tube and attached by welding as shown in Figs. 1 (d), (e).

(2) Integral type flanges [Figs. 1 (f), (g), (h), (i), (j)] The flange casted or forged integrally with tube or the flange so welded by complete joint penetration that the flange and the tube become integral as shown in Figs. 1 (g) to (j).

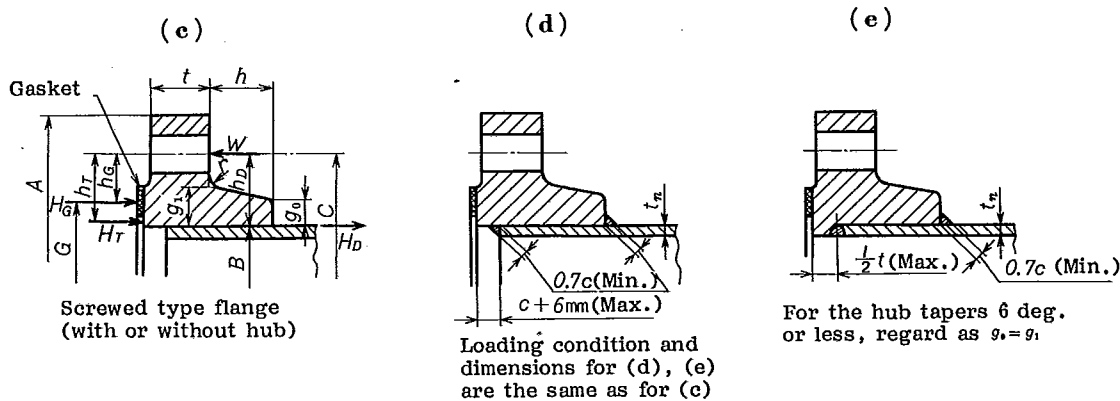
(3) Optional type flanges [Figs. 1 (k), (l), (m), (n), (o)] The flange attached to the tube by welding as shown in Figs. 1 (k) to (o). This flange must be calculated as the integral type flange. However, in the case where all values of the following numerical values are not exceeded, it may be calculated for simplification as without hub loose type flange.

$$g_0 = 16 \text{ mm}, \frac{B}{g_0} = 300, P = 2 \text{ MPa} (20 \text{ kgf/cm}^2), \text{ operating temperature} = 370^\circ\text{C}$$

Fig. 1. Types of flanges

(1) Loose type flanges
(Lap joint type flanges)

(Slip-on type flanges)



(2) Integral type flange

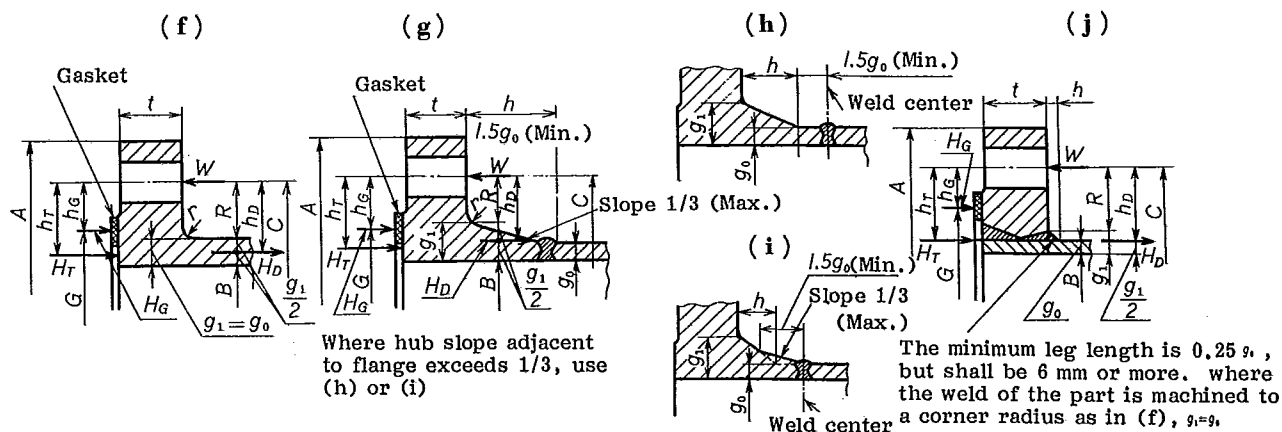
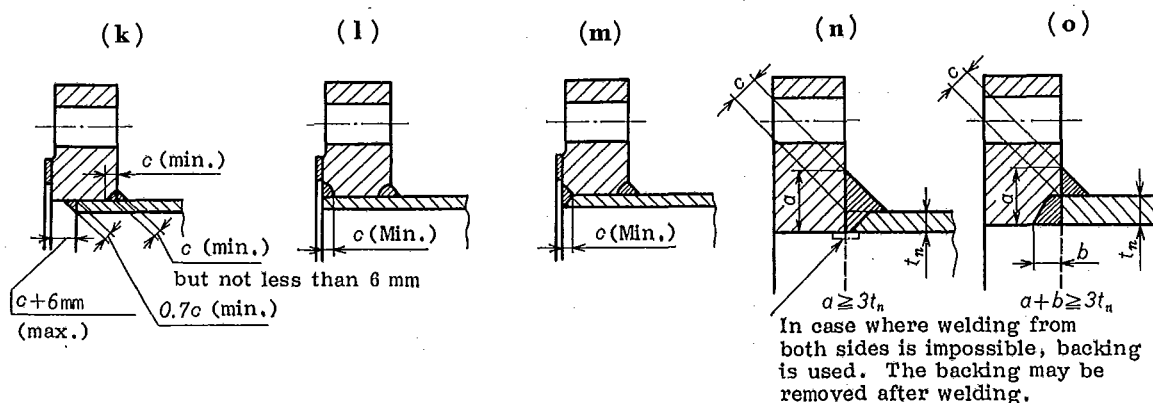


Fig. 1 (Continued)

(3) Optional type flange



3.3 Bolt loads The bolt loads shall be as follows:

- (1) Bolt loads required for calculation The bolt loads to be used for calculation of total effective sectional area required for bolt are to be as follows:

- (a) Bolt load required under operating condition

$$W_{m1} = H + H_p = \frac{\pi}{4} G^2 P + 2\pi b G_m P = \frac{\pi G P}{4} (G + 8bm)$$

$$\left\{ W_{m1} = H + H_p = \frac{\pi}{400} G^2 P + \frac{2\pi b}{100} G_m P = \frac{\pi G P}{400} (G + 8bm) \right\}$$

- (b) Bolt load required at clamping gasket

$$W_{m2} = \pi b G y$$

- (c) Bolt load required where self-seal gasket is used In this case, the bolt load may be in accordance with the following formula, excepting the special shape in which the axial load for clamping can not be neglected.

$$W_{m1} = H = \frac{\pi}{4} D_o^2 P \left\{ W_{m1} = H = \frac{\pi}{400} D_o^2 P \right\}$$

$$W_{m2} = 0$$

- (2) Total effective sectional area required for bolt and that for actual bolt The total effective sectional area A_m required for bolt relative to both of operating condition and gasket clamping time are to be the value out of the values according to the following two formulae, whichever the larger.

$$A_{m1} = \frac{W_{m1}}{\sigma_b}$$

$$A_{m2} = \frac{W_{m2}}{\sigma_a}$$

The total effective sectional area of bolt to be used actually A_b must be so determined that it is always larger than the total effective sectional area required for bolt A_m .

- (3) Bolt load to be used for calculation of flange The bolt load to be used for calculation of flange is to be as follows:

- (a) Bolt load under the operating condition

$$W_0 = W_{m1}$$

- (b) Bolt load at the time of clamping the gasket

$$W_g = \frac{A_m + A_b}{2} \sigma_a$$

Remarks: In the case where the safety against over clamping is required excessively or where the flange is required to resist against the effective total bolt load $A_b \times \sigma_a$, the flange may be calculated on the basis of bolt load at clamping the gasket.

3.4 Moments acting on flange The moments acting on flange shall be as follows:

- (1) Total moments acting on flange under operating condition The total moments acting on a flange under the operating condition is to be as follows:

$$M_0 = M_D + M_G + M_T$$

- (2) Moment arm to flange load under operating condition The moment arm relative to flange load under the operating condition is to be in accordance with Table 1.

Table 1. Moment arm to flange load under operating condition

Type of flange	h_D	h_G	h_T
Lap joint type flange	$\frac{C-B}{2}$	$\frac{C-G}{2}$	$\frac{C-G}{2}$
Integral type flange and optional type flange to be calculated as the integral type flange	$R+0.5g_1$	$\frac{C-G}{2}$	$\frac{R+g_1+h_G}{2}$
Slip-on type flange and optional type flange to be calculated as the loose type flange	$\frac{C-B}{2}$	$\frac{C-G}{2}$	$\frac{h_D+h_G}{2}$

- (3) Moment acting on flange at clamping gasket The moment acting on flange at the time of clamping the gasket is to be as follows:

$$M_g = W_g \frac{C-G}{2}$$

3.5 Stress of flange The stress of flange shall be as follows:

- (1) Stresses of loose type flanges without hub and to be calculated with neglecting hub, and of optional type flange to be calculated as loose type flange without hub The stresses under the operating condition and at the time of clamping the gasket are calculated according to the following formulae:

Axial stress of hub $\sigma_H=0$

Radial stress of flange $\sigma_R=0$

Circumferential stress of flange $\sigma_T = \frac{YM}{t^2 B}$

- (2) Stresses of integral type flange, optional type flange to be calculated as integral type flange and loose type flange to be calculated taking into consideration the hub The stresses under the operating condition and at the time of clamping gasket are calculated according to the following formulae, taking into assumption dimensions of each part of flange.

Axial stress of hub $\sigma_H = \frac{fM}{Lg_1^2 B}$

Radial stress of flange $\sigma_R = \frac{(1.33te+1)M}{Lt^2 B}$

Circumferential stress of flange $\sigma_T = \frac{YM}{t^2 B} - Z\sigma_R$

3.6 Permissible values on calculated stresses of flanges

3.6.1 Calculated stresses of flanges The calculated stresses of flanges shall not exceed the permissible values shown in the following:

- (1) Permissible value of axial stress σ_H of hub
 $= \sigma_f$ (grey cast iron flange)
 $= 1.5 \sigma_f$ [flange of material other than grey cast iron. However, the flanges corresponding to following (a) or (b) are to be in accordance with (a) or (b).]
 - (a) In the cases of integral type flange having a part of tube as hub as shown in (j) of Fig. 1 and of the optional flange to be calculated as the integral type flange, it shall be $1.5 \sigma_f$ or $1.5 \sigma_n$, whichever is less.
 - (b) In the case of integral type flange, the hub of which is welded with the tube as shown in (g), (h) and (i) of Fig. 1, either $1.5 \sigma_f$ or $2.5 \sigma_n$, whichever is less.
- (2) Permissible value on radial stress σ_R of the flange $= \sigma_f$
- (3) Permissible value on circumferential stress σ_T of flange $= \sigma_f$
- (4) Permissible value of $\frac{\sigma_H + \sigma_R}{2} = \sigma_f$
- (5) Permissible value of $\frac{\sigma_H + \sigma_T}{2} = \sigma_f$

3.6.2 In the case of calculating the slip-on type flange with hub as shown in (c), (d) and (e) of Fig. 1, the pipe connected with this shall not be added as the hub.

3.6.3 In the case of the lap-joint type flange as shown in (a) and (b) of Fig. 1, where the gasket is so mounted that the lap (or stub end) receives shearing force, it shall not exceed 0.8 times the permissible tensile stress of lap material.

3.6.4 In the case where the pipe is welded with the flange adjacent to bearing surface of gasket as shown in (d), (e), (j), (k), (l) and (m) of Fig. 1, the shearing stress of weld shall not exceed 0.8 times the permissible tensile stress (σ_n) of the pipe material. These shearing stresses shall be calculated by using W_{m1} and W_{m2} of 3.3 (1).

4. Flanges receiving external pressure

As to the flange receiving external pressure, excepting the following conditions, the specifications to the flange receiving the internal pressure shall be applied, as appropriate.

- (1) Moment acting on flange under operating condition The moment acting on flange under the operating condition is as follows:

$$M_0 = H_D(h_D - h_G) + H_T(h_T - h_G)$$

- (2) Moment acting on flange at clamping gasket The moment acting on the flange at the time of clamping gasket is as follows:

$$M_g = W h_G$$

where,

$$W = \frac{A_{m2} + A_b}{2} \sigma_a$$

$$H_D = \frac{\pi}{4} B^2 P_e \left\{ H_D = \frac{\pi}{400} B^2 P_e \right\}$$

$$H_T = H - H_D$$

$$H = \frac{\pi}{4} G^2 P_e \left\{ H = \frac{\pi}{400} G^2 P_e \right\}$$

5. Split flange

To the split flange of lap joint type, the specifications of 3.4 and 3.5 shall be applied in accordance with the following conditions, as appropriate.

- (1) The moment M acting on the flange shall be calculated as the loose type flange without split by using the value twice the value obtained in 3.4.
- (2) In the case of double split flange, each flange shall be calculated as the loose type flange without split by using the value 0.75 times the moment M acting on the whole flange.
- (3) The split of the split flange must be arranged at the intermediate of bolt holes. In the case of double split flange, it shall be so assembled that splits of each flange are at right angles with each other.

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6. Noncircular flange having circular holes

As to the noncircular flange having circular holes, the specifications of 3.2 to 3.6 shall be applied, as appropriate, after assuming as follows.

- (1) The diameter of a circle which is concentric with the circular hole and inscribes the outside edge of the flange is taken as the outside diameter A (mm) of the flange.
- (2) The diameter of circle passing through the center of bolts at the outermost side is taken as the diameter C (mm) of bolt circle.

Attached Table 1. Gasket materials and contact surface

Gasket material	Gasket factor $m(^1)$	Minimum design clamping pressure p (N/mm ² {kgf/mm ² })	Shape of gasket	Shape of seating face (See Attached Table 2)	Basic width of gasket of seating (See Attached Table 2)
Self-sealing gasket (O rings, metal, rubber and other gasket types considered as self-sealing)	0	0	—	—	—
Cloth or rubber seat containing a not large amount of asbestos	0.50 1.00	0 1.37 {0.14}		1a, 1b, 1c, 1d, 4, 5 II	
Spring hardness (JIS A) less than 75					
Spring hardness (JIS A) 75 min.					
Thickness 3.2 mm	2.00	10.98 {1.12}			
Thickness 1.6 mm	2.75	25.50 {2.60}			
Thickness 0.8 mm	3.50	44.82 {4.57}			
Rubber seat with cotton cloth insertion	1.25	2.75 {0.28}			
Rubber seat with asbestos cloth insertion (with gold wire insertion or without)	2.25 2.50 2.75	15.20 {1.55} 20.01 {2.04} 25.50 {2.60}			
3-ply					
2-ply					
1-ply					
Vegetable fibre	1.75	7.55 {0.77}			

Attached Table 1 (Continued)

Gasket material		Gasket factor $m^{(1)}$	Minimum design clamping pressure p (N/mm ² {kgf/mm ² })	Shape of gasket	Shape of seating face (See Attached Table 2)	Basic width of gasket seating (See Attached Table 2)
Spiral wound gasket (asbestos filled)	Carbon steel	2.50	68.89 {7.03}		1a, 1b	II
	Stainless steel or Monel	3.00				
	Soft aluminium	2.50	20.01 {2.04}			
	Soft copper or brass	2.75	25.50 {2.60}			
	Soft steel or iron	3.00	30.99 {3.16}			
Monel or 4 to 6 % Cr steel	3.25	37.95 {3.87}				
	Stainless steel	3.50	44.82 {4.57}			
Corrugated metal gasket	Soft aluminium	2.75	25.50 {2.60}		1a, 1b, 1c, 1d	
	Soft copper or brass	3.00	30.99 {3.16}			
	Soft steel or iron	3.25	37.95 {3.87}			
	Monel or 4 to 6 % Cr steel	3.50	44.82 {4.57}			
	Stainless steel	3.75	52.37 {5.34}			
Flat metal jacketed type gasket (asbestos plate inserted)	Soft aluminium	3.25	37.95 {3.87}		1a, 1b, 1c*, 1d*, 2*(²)	
	Soft copper or brass	3.50	44.82 {4.57}			
	Soft steel or iron	3.75	52.37 {5.34}			
	Monel	3.50	55.11 {5.62}			
	4 to 6 % Cr steel	3.75	62.08 {6.33}			
	Stainless steel	3.75	62.08 {6.33}			