\[ S_T = \text{allowable design stress for material of flange at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply (see UG-23)} \]

\[ S_H = \text{calculated longitudinal stress in hub} \]

\[ S_n = \text{allowable design stress for material of nozzle neck, vessel or pipe wall, at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply (see UG-23)} \]

\[ S_R = \text{calculated radial stress in flange} \]

\[ S_T = \text{calculated tangential stress in flange} \]

\[ T = \text{factor involving } K \text{ (from Figure 2-7.1)} \]

\[ t = \text{flange thickness} \]

\[ t_n = \text{nominal thickness of shell or nozzle wall to which flange or lap is attached} \]

\[ t_x = \text{two times the thickness } g_0 \text{, when the design is calculated as an integral flange or two times the thickness of shell nozzle wall required for internal pressure, when the design is calculated as a loose flange, but not less than } \frac{1}{4} \text{ in. (6 mm)} \]

\[ U = \text{factor involving } K \text{ (from Figure 2-7.1)} \]

\[ V = \text{factor for integral type flanges (from Figure 2-7.3)} \]

\[ V_L = \text{factor for loose type flanges (from Figure 2-7.5)} \]

\[ W = \text{flange design bolt load, for the operating conditions or gasket seating, as may apply [see 2-5(e)]} \]

\[ w = \text{width used to determine the basic gasket seating width } b_w \text{ based upon the contact width between the flange facing and the gasket (see Table 2-5.2)} \]

\[ W_{m1} = \text{minimum required bolt load for the operating conditions [see 2-5(c)]. For flange pairs used to contain a tubesheet for a floating head or a U-tube type of heat exchangers, or for any other similar design, } W_{m1} \text{ shall be the larger of the values as individually calculated for each flange, and that value shall be used for both flanges.} \]

\[ W_{m2} = \text{minimum required bolt load for gasket seating [see 2-5(c)]. For flange pairs used to contain a tubesheet for a floating head or U-tube type of heat exchanger, or for any other similar design where the flanges or gaskets are not the same, } W_{m2} \text{ shall be the larger of the values calculated for each flange and that value shall be used for both flanges.} \]

\[ Y = \text{factor involving } K \text{ (from Figure 2-7.1)} \]

\[ y = \text{gasket or joint-contact-surface unit seating load, [see Note 1, 2-5(c)]} \]

\[ Z = \text{factor involving } K \text{ (from Figure 2-7.1)} \]

### 2-4 CIRCULAR FLANGE TYPES

(a) For purposes of computation, there are three types:

1. **Loose Type Flanges.** This type covers those designs in which the flange has no direct connection to the nozzle neck, vessel, or pipe wall, and designs where the method of attachment is not considered to give the

\[ = 0.785G^2P \]

\[ h = \text{hub length} \]

\[ H_D = \text{hydrostatic end force on area inside of flange} \]

\[ = 0.785B^2P \]

\[ h_D = \text{radial distance from the bolt circle, to the circle on which } H_D \text{ acts, as prescribed in Table 2-6} \]

\[ H_G = \text{gasket load (difference between flange design bolt load and total hydrostatic end force)} \]

\[ = W - H \]

\[ h_G = \text{radial distance from gasket load reaction to the bolt circle} \]

\[ = \frac{(C - G)}{2} \]

\[ h_o = \text{factor} \]

\[ = \frac{1}{2} \]

\[ H_p = \text{total joint-contact surface compression load} \]

\[ = 2b \times 3.14 \cdot GmP \]

\[ H_T = \text{difference between total hydrostatic end force and the hydrostatic end force on area inside of flange} \]

\[ = H - H_D \]

\[ h_T = \text{radial distance from the bolt circle to the circle on which } H_T \text{ acts as prescribed in Table 2-6} \]

\[ K = \text{ratio of outside diameter of flange to inside diameter of flange} \]

\[ = \frac{A/B}{\pi} \]

\[ L = \text{factor} \]

\[ = \frac{m}{2} \]

\[ m = \text{gasket factor, obtain from Table 2-5.1} \text{ [see Note in 2-5(c)]} \]

\[ M_D = \text{component of moment due to } H_D \]

\[ = \frac{H_Db_w}{2} \]

\[ M_G = \text{component of moment due to } H_G \]

\[ = \frac{H_Gb_w}{2} \]

\[ M_o = \text{total moment acting upon the flange, for the operating conditions or gasket seating as may apply (see 2-6)} \]

\[ M_T = \text{component of moment due to } H_T \]

\[ = \frac{H_Tb_w}{2} \]

\[ N = \text{width used to determine the basic gasket seating with } b_w \text{ based upon the possible contact width of the gasket (see Table 2-5.2)} \]

\[ P = \text{internal design pressure (see UG-21). For flanges subject to external design pressure, see 2-11.} \]

\[ R = \frac{c - b - g_1}{2} \]

\[ R = \text{radial distance from bolt circle to point of intersection of hub and back of flange. For integral and hub flanges,} \]

\[ S_a = \text{allowable bolt stress at atmospheric temperature (see UG-23)} \]

\[ S_b = \text{allowable bolt stress at design temperature (see UG-23)} \]
vessel, or pipe wall extends near to the flange face and may form the gasket contact face, the shearing stress carried by the welds shall not exceed 0.8 $S_n$. The shearing stress shall be calculated on the basis of $W_{m1}$ or $W_{m2}$ as defined in 2-3, whichever is greater. Similar cases where flange parts are subjected to shearing stress shall be governed by the same requirements.

2-9 SPLIT LOOSE FLANGES

Loose flanges split across a diameter and designed under the rules given in this Appendix may be used under the following provisions.

(a) When the flange consists of a single split flange or flange ring, it shall be designed as if it were a solid flange (without splits), using 200% of the total moment $M_o$ as defined in 2-6.

(b) When the flange consists of two split rings each ring shall be designed as if it were a solid flange (without splits), using 75% of the total moment $M_o$ as defined in 2-6. The pair of rings shall be assembled so that the splits in one ring shall be 90 deg from the splits in the other ring.

(c) The splits should preferably be midway between bolt holes.

2-10 NONCIRCULAR SHAPED FLANGES WITH CIRCULAR BORE

The outside diameter $A$ for a noncircular flange with a circular bore shall be taken as the diameter of the largest circle, concentric with the bore, inscribed entirely within the outside edges of the flange. Bolt loads and moments, as well as stresses, are then calculated as for circular flanges, using a bolt circle drawn through the centers of the outermost bolt holes.

2-11 FLANGES SUBJECT TO EXTERNAL PRESSURES

(a) The design of flanges for external pressure only [see UG-99(f)] shall be based on the equations given in 2-7 for internal pressure except that for operating conditions:

$$M_o = h_p(h_D - h_G) + h_r(h_T - h_G)$$  \hspace{1cm} (10)

For gasket seating,

$$M_o = Wh_G$$  \hspace{1cm} (11)
2-7 CALCULATION OF FLANGE STRESSES

The stresses in the flange shall be determined for both the operating conditions and gasket seating condition, whichever controls, in accordance with the following equations:

(a) for integral type flanges [Figure 2-4, sketches (5), (6), (6a), (6b), and (7)], for optional type flanges calculated as integral type [Figure 2-4, sketches (8), (8a), (9), (9a), (10), (10a), and (11)], and for loose type flanges with a hub which is considered [Figure 2-4, sketches (1), (1a), (2), (2a), (3), (3a), (4), (4a), (4b), and (4c)];

Longitudinal hub stress

\[ S_H = \frac{f M_o}{L \sqrt{2} B} \]  

Radial flange stress

\[ S_R = \frac{(1.33 \pi + 1) M_o}{L \sqrt{2} B} \]  

Tangential flange stress

\[ S_T = \frac{Y M_o}{t \sqrt{2} B} - Z S_R \]  

(b) for loose type flanges without hubs and loose type flanges with hubs which the designer chooses to calculate without considering the hub [Figure 2-4, sketches (1), (1a), (2), (2a), (3), (3a), (4), (4a), (4b), and (4c)] and optional type flanges calculated as loose type [Figure 2-4, sketches (8), (8a), (9), (9a), (10), (10a), and (11)]:

\[ S_T = \frac{Y M_o}{t \sqrt{2} B} \]
\[ S_H = 0 \]
\[ S_R = 0 \]

(19) 2-8 ALLOWABLE FLANGE DESIGN STRESSES

(a) The flange stresses calculated by the equations in 2-7 shall not exceed the following values:

(1) longitudinal hub stress \( S_H \) not greater than \( S_F \) for cast iron and, except as otherwise limited by (-a) and (-b) below, not greater than 1.5\( S_F \) for materials other than cast iron:

\[ (-a) \] longitudinal hub stress \( S_H \) not greater than the smaller of 1.5\( S_F \) or 1.5\( S_m \) for optional type flanges designed as integral [Figure 2-4, sketches (8), (8a), (9), (9a), (10), (10a), and (11)], also integral type [Figure 2-4, sketch (7)] where the neck material constitutes the hub of the flange;

\[ (-b) \] longitudinal hub stress \( S_H \) not greater than the smaller of 1.5\( S_F \) or 2.5\( S_m \) for integral type flanges with hub welded to the neck, pipe or vessel wall [Figure 2-4, sketches (6), (6a), and (6b)].

(2) radial flange stress \( S_R \) not greater than \( S_F \);

(3) tangential flange stress \( S_T \) not greater than \( S_F \);

(4) also \( (S_H + S_R)/2 \) not greater than \( S_T \) and \( (S_H + S_T)/2 \) not greater than \( S_T \).

(b) For hub flanges attached as shown in Figure 2-4, sketches (2), (2a), (3a), (4a), (4b), and (4c), the nozzle neck, vessel or pipe wall shall not be considered to have any value as a hub.

(c) In the case of loose type flanges with laps, as shown in Figure 2-4, sketches (1) and (1a), where the gasket is so located that the lap is subjected to shear, the shearing stress shall not exceed 0.8 \( S_n \) for the material of the lap, as defined in 2-3. In the case of welded flanges, shown in Figure 2-4, sketches (3), (3a), (4a), (4b), (4c), (7), (8), (8a), (9), (9a), (10), and (10a) where the nozzle neck, vessel, or pipe wall extends near to the flange face and may form the gasket contact face, the shearing stress carried by the welds shall not exceed 0.8 \( S_n \). The shearing stress shall be calculated on the basis of \( W_{m1} \) or \( W_{m2} \) as defined in 2-3, whichever is greater. Similar cases where flange parts are subjected to shearing stress shall be governed by the same requirements.

2-9 SPLIT LOOSE FLANGES

Loose flanges split across a diameter and designed under the rules given in this Appendix may be used under the following provisions.

(a) When the flange consists of a single split flange or flange ring, it shall be designed as if it were a solid flange (without splits), using 200% of the total moment \( M_o \) as defined in 12-4.

(b) When the flange consists of two split rings each ring shall be designed as if it were a solid flange (without splits), using 75% of the total moment \( M_o \) as defined in 12-4. The pair of rings shall be assembled so that the splits in one ring shall be 90 deg from the splits in the other ring.

(c) The splits should preferably be midway between bolt holes.

(d) It is not a requirement that the flange rigidity rules of 2-14 be applied to split loose flanges.
\[ H_D = \text{hydrostatic end force on area inside of flange} \]
\[ h_D = \text{radial distance from the bolt circle, to the circle on which } H_D \text{ acts} \]
\[ H_G = \text{gasket load for the operating condition} \]
\[ h_G = \text{radial distance from gasket load reaction to the bolt circle} \]
\[ h_o = \text{factor} \]
\[ = \sqrt{\frac{B}{d}} \]
\[ H_p = \text{total joint-contact surface compression load} \]
\[ = 2b \times 3.14 \times G \times m \times P \]
\[ H_T = \text{difference between total hydrostatic end force and the hydrostatic end force on area inside of flange} \]
\[ = H - H_D \]
\[ h_T = \text{radial distance from the bolt circle to the circle on which } H_T \text{ acts as prescribed in Table 2-6} \]
\[ K = \text{ratio of outside diameter of flange to inside diameter of flange} \]
\[ = \frac{A}{B} \]
\[ L = \text{factor} \]
\[ = \frac{\pi + 1}{T} + \frac{t^3}{d} \]
\[ m = \text{gasket factor, obtain from Table 2-5.1} \] (see Note in 2-5(c)(1))
\[ M_D = \text{component of moment due to } H_D \]
\[ M_G = \text{component of moment due to } H_G \]
\[ M_o = \text{total moment acting upon the flange, for the operating conditions or gasket seating as may apply} \] (see 12-4)
\[ M_T = \text{component of moment due to } H_T \]
\[ N = \text{width used to determine the basic gasket seating with } b_o, \text{ based upon the possible contact width of the gasket} \] (see Table 2-5.2)
\[ P = \text{internal design pressure} \] (see UG-21). For flanges subject to external design pressure, see 2-11.
\[ R = \text{radial distance from bolt circle to point of intersection of hub and back of flange. For integral and hub flanges,} \]
\[ = \frac{C-B}{2} - g_1 \]
\[ S_a = \text{allowable bolt stress at atmospheric temperature} \] (see UG-23)
\[ S_b = \text{allowable bolt stress at design temperature} \] (see UG-23)
\[ S_f = \text{allowable design stress for material of flange at design temperature (operating condition) or atmospheric} \]
\[ \text{temperature (gasket seating), as may apply} \] (see UG-23)
\[ S_h = \text{calculated longitudinal stress in hub} \]
\[ S_n = \text{allowable design stress for material of nozzle neck, vessel or pipe wall, at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply} \] (see UG-23)
\[ S_R = \text{calculated radial stress in flange} \]
\[ S_T = \text{calculated tangential stress in flange} \]
\[ T = \text{factor involving } K \] (from Figure 2-7.1)
\[ t = \text{flange thickness} \]
\[ t_n = \text{nominal thickness of shell or nozzle wall to which flange or lap is attached} \]
\[ t_x = \text{two times the thickness } g_0, \text{ when the design is calculated as an integral flange or two times the thickness of shell nozzle wall required for internal pressure, when the design is calculated as a loose flange, but not less than } \frac{1}{4} \text{ in. (6 mm)} \]
\[ U = \text{factor involving } K \] (from Figure 2-7.1)
\[ V = \text{factor for integral type flanges} \] (from Figure 2-7.3)
\[ V_L = \text{factor for loose type flanges} \] (from Figure 2-7.5)
\[ W = \text{flange design bolt load, for the operating conditions or gasket seating, as may apply} \] (see 2-5(e))
\[ w = \text{width used to determine the basic gasket seating width } b_o, \text{ based upon the contact width between the flange facing and the gasket} \] (see Table 2-5.2)
\[ W_{m1} = \text{minimum required bolt load for the operating conditions} \] (see 2-5(c)). For flange pairs used to contain a tubesheet for a floating head or a U-tube type of heat exchangers, or for any other similar design, \( W_{m1} \) shall be the larger of the values as individually calculated for each flange, and that value shall be used for both flanges.
\[ W_{m2} = \text{minimum required bolt load for gasket seating} \] (see 2-5(c)). For flange pairs used to contain a tubesheet for a floating head or U-tube type of heat exchanger, or for any other similar design where the flanges or gaskets are not the same, \( W_{m2} \) shall be the larger of the values calculated for each flange and that value shall be used for both flanges.
\[ Y = \text{factor involving } K \] (from Figure 2-7.1)
\[ y = \text{gasket or joint-contact-surface unit seating load} \] (see Note 1, 2-5(c))
\[ Z = \text{factor involving } K \] (from Figure 2-7.1)

2-4 CIRCULAR FLANGE TYPES

For purposes of computation, there are three types:
(a) Loose Type Flanges. This type covers those designs in which the flange has no direct connection to the nozzle neck, vessel, or pipe wall, and designs where the method of attachment is not considered to give the mechanical strength equivalent of integral attachment. See Figure 2-4, sketches (1), (1a), (2), (2a), (3), (3a), (4), (4a), (4b), and (4c) for typical loose type flanges and the location of the loads and moments. Welds and other details of