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

\[ S_H = \frac{fM_o}{Lg_1^2B} \]  \hspace{1cm} (8)

Radial flange stress

\[ S_R = \frac{(1.33te + 1)M_o}{Lt^2B} \]  \hspace{1cm} (9)

Tangential flange stress

\[ S_T = \frac{YM_o}{t^2B} - ZS_R \]  \hspace{1cm} (10)

(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)]:

\[ S_T = \frac{YM_o}{t^2B} \]
\[ S_R = 0 \]
\[ S_H = 0 \]  \hspace{1cm} (11)

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, 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\( S_n \) 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\( S_n \) 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 \( S_f \) and \( (S_H + S_T)/2 \) not greater than \( S_f \).

(b) For hub flanges attached as shown in Figure 2-4, sketches (2), (2a), (3), (3a), (4), (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), (4), (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.
Figure 2-4
Types of Flanges

(1) Screwed Flange With Hub

Full penetration weld, single or double. The full penetration weld may be through the lap \( t_l \) or through the wall \( t_w \).

To be taken at midpoint of contact between flange and lap independent of gasket location. (Optional hub is shown by dotted line.)

(2a) Screwed Flange [Note (2)]

See Note (1)

\[ \text{max.} = c + \frac{1}{4} \text{ in. (6 mm)} \]

(3) [Note (2)]

See Note (1)

\[ \text{max.} = c + \frac{1}{4} \text{ in. (6 mm)} \]

(3a) [Note (2)]

min. = 0.7c

\[ 1/2t \text{ (max.)} \]

(4) [Note (2)]

min. = 0.7c

\[ 1/2t \text{ (max.)} \]

(4a) [Note (2)]

min. = 0.7c

Loose-Type Flanges [Notes (3) and (4)]
Figure 2-4
Types of Flanges (Cont’d)

Integral-Type Flanges [Notes (3) and (4)]

Where hub slope adjacent to flange exceeds 1:3, use sketches (6a) or (6b)

0.25\(g_o\) but not less than 1/4 in. (6 mm), the minimum for either leg. This weld may be machined to a corner radius as permitted in sketch (5), in which case \(g_1 = g_o\).
Optional-Type Flanges [Notes (5), (6), and (7)]

(Optional-Type Flanges [Notes (5), (6), and (7)])

NOTES:
(1) For hub tapers 6 deg or less, use $g_0 = g_1$.
(2) Loading and dimensions for sketches (2a), (3), (3a), (4), (4a), (4b), and (4c) not shown are the same as for sketch (2).
(3) Fillet radius $r$ to be at least 0.25 $g_1$ but not less than $\frac{5}{16}$ in. (5 mm).
(4) Facing thicknesses or groove depths greater than $\frac{5}{16}$ in. (1.5 mm) shall be in excess of the required minimum flange thickness, $t$; those equal to or less than $\frac{5}{16}$ in. (1.5 mm) may be included in the overall flange thickness.
(5) Optional-type flanges may be calculated as either loose or integral type. See 2-4.
2-5 BOLT LOADS

(a) General Requirements

(1) In the design of a bolted flange connection, calculations shall be made for each of the two design conditions of operating and gasket seating, and the more severe shall control.

(2) In the design of flange pairs used to contain a tubesheet of a heat exchanger or any similar design where the flanges and/or gaskets may not be the same, loads must be determined for the most severe condition of operating and/or gasket seating loads applied to each side at the same time. This most severe condition may be gasket seating on one flange with operating on the other, gasket seating on each flange at the same time, or operating on each flange at the same time. Although no specific rules are given for the design of the flange pairs, after the loads for the most severe conditions are determined, calculations shall be made for each flange following the rules of Mandatory Appendix 2.

(3) Recommended minimum gasket contact widths for sheet and composite gaskets are provided in Table 2-4.

(b) Design Conditions

(1) Operating Conditions. The conditions required to resist the hydrostatic end force of the design pressure tending to part the joint, and to maintain on the gasket or joint-contact surface sufficient compression to assure a tight joint, all at the design temperature. The minimum load is a function of the design pressure, the gasket material, and the effective gasket or contact area to be kept tight under pressure, per eq. (c)(1) below, and determines one of the two requirements for the amount of the bolting $A_{m1}$. This load is also used for the design of the flange, per eq. (d)(3) below.

(2) Gasket Seating. The conditions existing when the gasket or joint-contact surface is seated by applying an initial load with the bolts when assembling the joint, at atmospheric temperature and pressure. The minimum initial load considered to be adequate for proper seating is a function of the gasket material, and the effective gasket or contact area to be seated, per eq. (c)(2)(2) below, and determines the other of the two requirements for the amount of bolting $A_{m2}$. For the design of the flange, this load is modified per eq. (e)(4) below to take account of the operating conditions, when these govern the amount of bolting required $A_m$, as well as the amount of bolting actually provided $A_b$.

(c) Required Bolt Loads. The flange bolt loads used in calculating the required cross-sectional area of bolts shall be determined as follows.

(1) The required bolt load for the operating conditions $W_{m1}$ shall be sufficient to resist the hydrostatic end force $H$ exerted by the maximum allowable working pressure on the area bounded by the diameter of gasket reaction, and, in addition, to maintain on the gasket or joint-contact surface a compression load $H_p$ which experience has shown to be sufficient to ensure a tight joint. (This compression load is expressed as a multiple $m$ of the internal pressure. Its value is a function of the gasket material and construction.)

NOTE: Tables 2-5.1 and 2-5.2 give a list of many commonly used gasket materials and contact facings, with suggested values of $m$, $b$, and $y$ that have proved satisfactory in actual service. These values are suggested only and are not mandatory.

The required bolt load for the operating conditions $W_{m1}$ is determined in accordance with eq. (1).

$$W_{m1} = H + H_p = 0.785G^2P + (2b \times 3.14GmP)^{1/2}$$

(2) Before a tight joint can be obtained, it is necessary to seat the gasket or joint-contact surface properly by applying a minimum initial load (under atmospheric temperature conditions without the presence of internal pressure), which is a function of the gasket material and