Tutorial on Flange Qualification using CAEPIPE

This document explains the procedure on performing Flange Qualification using CAEPIPE.

General

Flange joints are essential components in all pressurized systems; they are also one of the most complex. Many factors are involved in determining the successful design and operation of a bolted flange joint service, namely, the interaction between the bolting, flange, and gasket as well as important non-linear variables such as friction and gasket properties. The Pressure Vessel and Piping Codes were developed with safety in mind; they provide a method for sizing the flange and bolts to be structurally adequate for the specified design conditions.

The Flange Qualification module implemented in CAEPIPE addresses the design rules contained in the ASME Section VIII, Division 1, Appendix 2 on bolted flange connections with gaskets.

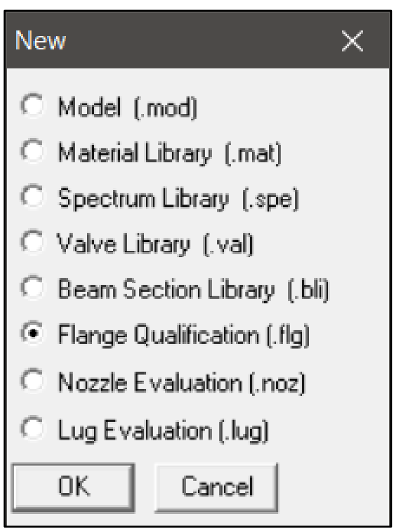
These design rules will help you to obtain better insight into a flange joint's tendency to leak, beyond the insight gathered from CAEPIPE's results as per NC3658.1 of ASME Section III Class 2, 1992 or later editions under Results > Flange Report. You can examine the flange and bolt stresses arising from the bolt tightening loads required for a leakage-free joint.

Tutorial

Step 1:

Flange Qualification module calculates flange and bolt stresses which are separate from a piping model (.mod) file. This module can be accessed/created through Main Frame > File > Open/New command.

When you first create a new flange qualification file, it comes populated with default values for a sample flange.



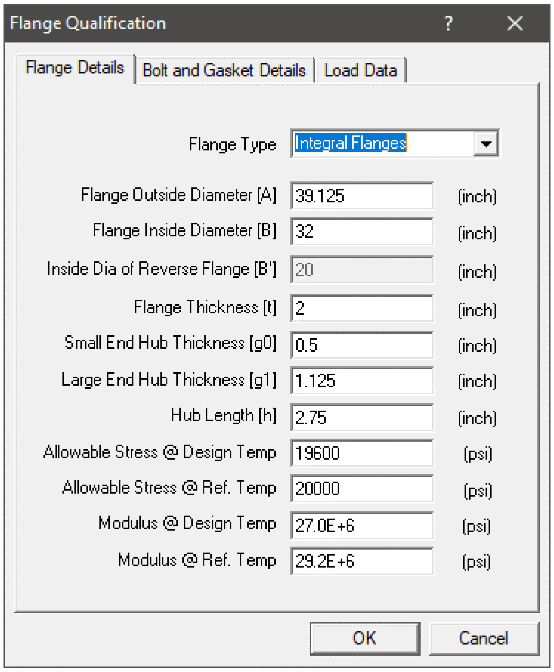
As this module accepts axial load and bending moment at a flange as input among many others, you will need to first create in CAEPIPE your piping model that includes flanges (which you need to validate) and generate a Flange Report. Such a report will contain the information you can now use in the Flange Qualification module to calculate flange and bolt stresses.

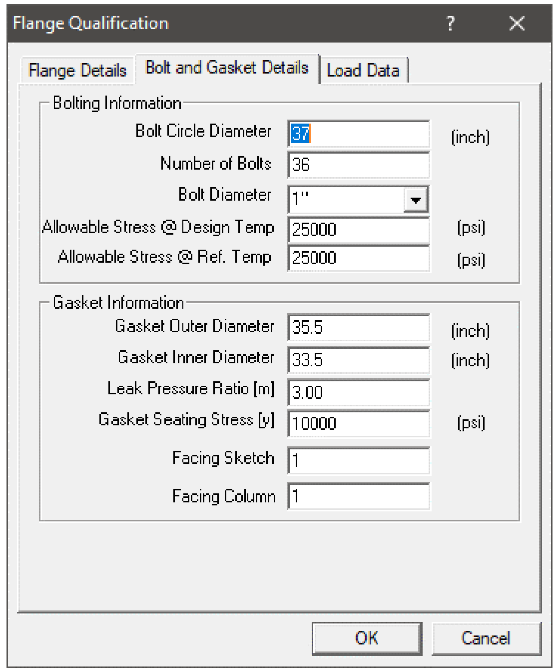
Step 2:

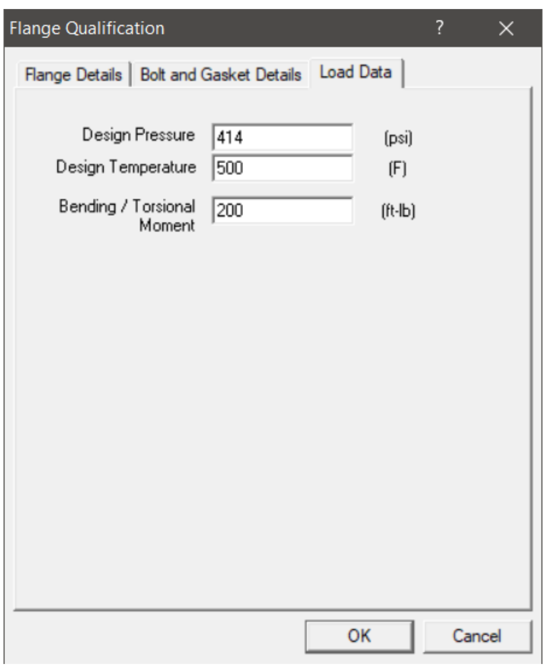
Double-clicking anywhere in the window shown (or select the option Edit menu > Edit (Ctrl+E)) opens a dialog with input fields (already populated with default values) which you can now edit. You will need to enter all of your flange data in this dialog. Legends of the different parameters you see here are explained in detail towards the end of this document.

Step 3:

Required flange input information is organized into three Property tabs – Flange Details, Bolt and Gasket Details, and Load Data, the last of which accepts data from a piping model's Flange Report.

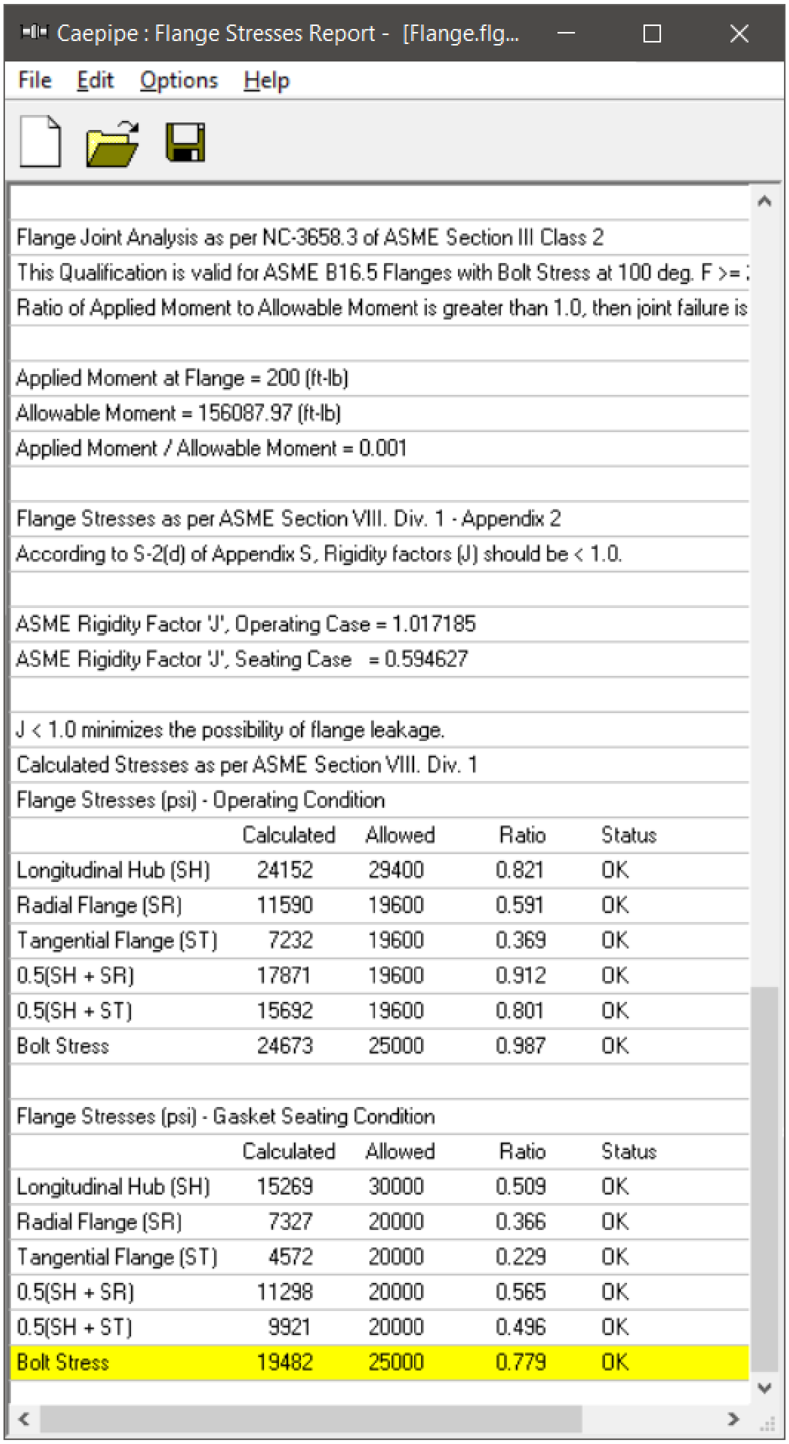






Step 4:

Once all the data values are input, save the model (Flange Qualification filenames will have a .flg extension). Now, select File menu > Analyze to calculate flange stresses, which will be shown right below the input information.



Flange Joint Analysis as per NC-3658.3 of ASME Section III Class 2
This Qualification is valid for ASME B16.5 Flanges with Bolt Stress at 100 deg. F >=
Ratio of Applied Moment to Allowable Moment is greater than 1.0, then joint failure is

Applied Moment at Flange = 200 (ft-lb)
Allowable Moment = 156087.97 (ft-lb)
Applied Moment / Allowable Moment = 0.001

Flange Stresses as per ASME Section VIII. Div. 1 - Appendix 2
According to S-2(d) of Appendix S, Rigidity factors (J) should be < 1.0.

ASME Rigidity Factor 'J', Operating Case = 1.017185
ASME Rigidity Factor 'J', Seating Case = 0.594627

J < 1.0 minimizes the possibility of flange leakage.
Calculated Stresses as per ASME Section VIII. Div. 1
Flange Stresses (psi) - Operating Condition

	Calculated	Allowed	Ratio	Status
Longitudinal Hub (SH)	24152	29400	0.821	OK
Radial Flange (SR)	11590	19600	0.591	OK
Tangential Flange (ST)	7232	19600	0.369	OK
0.5(SH + SR)	17871	19600	0.912	OK
0.5(SH + ST)	15692	19600	0.801	OK
Bolt Stress	24673	25000	0.987	OK

Flange Stresses (psi) - Gasket Seating Condition

	Calculated	Allowed	Ratio	Status
Longitudinal Hub (SH)	15269	30000	0.509	OK
Radial Flange (SR)	7327	20000	0.366	OK
Tangential Flange (ST)	4572	20000	0.229	OK
0.5(SH + SR)	11298	20000	0.565	OK
0.5(SH + ST)	9921	20000	0.496	OK
Bolt Stress	19482	25000	0.779	OK

There are three main sections in the results shown:

1. Flange Allowable Moment as per NC3658.3 of ASME Section III Class 2,
2. Flange Stresses for Operating Case as per Appendix 2 of ASME Section VIII Division 1, and
3. Flange Stresses for Gasket Seating Case as per Appendix 2 of ASME Section VIII Division 1.

Step 5:

You can print a Flange Report by using the Print command. You can also preview the report by clicking the Preview button on the print dialog.

Caepipe Page 1

Flange Stress Calculation as per ASME Section VIII. Div. 1 - Appendix 2

Flange Details:
Flange Type : Integral Flanges
Flange Outside Diameter [A] = 39.125 (inch)
Flange Inside Diameter [B] = 32 (inch)
Inside Diameter of Reverse Flange [B'] = 20 (inch)
Flange Thickness [t] = 2 (inch)
Small End Hub Thickness [g0] = 0.5 (inch)
Large End Hub Thickness [g1] = 1.125 (inch)
Hub Length [h] = 2.75 (inch)
Allowable Stress @ Design Temp [sf] = 19600 (psi)
Allowable Stress @ Ref. Temp [sfa] = 20000 (psi)
Modulus @ Design Temp [E] = 27.0E+6 (psi)
Modulus @ Ref. Temp [Ea] = 29.2E+6 (psi)

Bolting Information:
Bolt Circle Diameter = 37 (inch)
Number of Bolts = 36
Bolt Diameter = 1 (inch)
Allowable Stress @ Ref. Temp [sa] = 25000 (psi)
Allowable Stress @ Design Temp [sb] = 25000 (psi)

Gasket Information:
Gasket Outside Diameter = 35.5 (inch)
Gasket Inner Diameter = 33.5 (inch)
Leak Pressure Ratio [m] = 3.00
Gasket Seating Stress [y] = 10000 (psi)
Facing Sketch = 1
Facing Column = 1

Load Data:
Design Pressure = 414 (psi)
Design Temperature = 500 (F)
Bending / Torsional Moment = 200 (ft-lb)

Flange Joint Analysis as per NC-3658.3 of ASME Section III Class 2

This Qualification is valid for ASME B16.5 Flanges with Bolt Stress at 100 deg. F >= 20000 psi (138 MPa)
Ratio of Applied Moment to Allowable Moment is greater than 1.0, then joint failure is predicted

Applied Moment at Flange = 200 (ft-lb)
Allowable Moment = 156087.97 (ft-lb)
Applied Moment / Allowable Moment = 0.001

Flange Stresses as per ASME Section VIII. Div. 1 - Appendix 2

According to S-2(d) of Appendix S, Rigidity factors (J) should be < 1.0.

ASME Rigidity Factor 'J', Operating Case = 1.017185
ASME Rigidity Factor 'J', Seating Case = 0.594627

J < 1.0 minimizes the possibility of flange leakage.

Calculated Stresses as per ASME Section VIII. Div. 1

Flange Stresses (psi) - Operating Condition

	Calculated	Allowed	Ratio	Status
Longitudinal Hub (SH)	24152	29400	0.821	OK
Radial Flange (SR)	11590	19600	0.591	OK
Tangential Flange (ST)	7232	19600	0.369	OK
0.5(SH + SR)	17871	19600	0.912	OK

Version 10.40 Flange.flg Jun 24,2021

0.5(SH + ST)	15692	19600	0.801	OK
Bolt Stress	24673	25000	0.987	OK

Flange Stresses (psi) - Gasket Seating Condition

	Calculated	Allowed	Ratio	Status
Longitudinal Hub (SH)	15269	30000	0.509	OK
Radial Flange (SR)	7327	20000	0.366	OK
Tangential Flange (ST)	4572	20000	0.229	OK
0.5(SH + SR)	11298	20000	0.565	OK
0.5(SH + ST)	9921	20000	0.496	OK
Bolt Stress	19482	25000	0.779	OK

Flange Qualification as per ASME Section VIII, Division 1, Appendix 2 (2013)

Notations

The symbols described below are used in the formulas for the design of flanges

A = outside diameter of flange

A_b = cross-sectional area of the bolts using the root diameter of the thread

A_m = total required cross-sectional area of bolts taken as greater of A_{m1} and A_{m2}

A_{m1} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for the operating conditions

$$= \frac{W_{m1}}{S_b}$$

A_{m2} = total cross-sectional area of bolts at root of thread or section of least diameter under stress

$$= \frac{W_{m2}}{S_a}$$

B = inside diameter of flange

B' = inside diameter of reverse flange

b = effective gasket or joint-contact-surface seating width

b_0 = basic gasket seating width (from Table 2-5.2)

C = bolt-circle diameter

c = basic dimension used for the minimum sizing of welds

e = factor $= \frac{F}{h_o}$

d = factor $= \frac{U}{V} h_o g_0^2$ for integral type flanges

d = factor $= \frac{U}{V_L} h_o g_0^2$ for loose type flanges

e = factor $= \frac{F}{h_o}$ for integral type flanges

c = factor $= \frac{F_L}{h_o}$ for loose type flanges

F = factor for integral type flanges (from Fig. 2-7.2)

F_L = factor for loose type flanges (from Fig. 2-7.4)

f = hub stress correction for integral flanges from Fig. 2-7.6 (when greater than one, this is the ratio of the stress in the small end of hub to the stress in the large end), (for values below limit of figure, use f = 1.)

G = diameter at location of gasket load reaction

$g0$ = thickness of hub at small end

$g1$ = thickness of hub at back of flange

H = total hydrostatic end force = $0.785G^2P$

H_D = hydrostatic end force on area inside of flange $= 0.785B^2P$

H_G = gasket load (difference between flange design bolt load and total hydrostatic end force) = W – H

H_P = total joint-contact surface compression load = 2b x 3.14 G_mP

H_T = difference between total hydrostatic end force and the hydrostatic end force on area inside of flange = $H - H_D$

h = hub length

h_D = radial distance from the bolt circle, to the circle on which HD acts, as prescribed in Table 2-6

h_G = radial distance from gasket load reaction to the bolt circle = $\frac{C-G}{2}$

h_O = factor = $\sqrt{B_{g0}}$

h_T = distance from the bolt circle, to the circle on which H_T acts, as prescribed in Table 2-6

K = ratio of outside diameter of flange to inside diameter of flange = A / B

L = factor = $\frac{(t_e+1)}{T} + \frac{t^3}{d}$

M_D = component of moment due to $H_D = H_D h_D$

M_G = component of moment due to $H_G = H_G h_G$

M_T = component of moment due to $H_T = H_T h_T$

M_O = total moment acting upon the flange for the operating conditions or gasket seating as may apply

M_O = $W \frac{(C-G)}{2}$ for gasket seating condition

M_O = $H_D h_D + H_G h_G + H_T h_T$ for operating condition

N = width used to determine the basic gasket seating with b_0, based upon the possible contact width of the gasket (see Table 2-5.2)

P = internal design pressure

R = radial distance from bolt circle to point of intersection of hub and back of flange. For integral and hub flanges, R = (C-B / 2) – g1

S_a = allowable bolt stress at reference temperature

S_b = allowable bolt stress at design temperature

S_f = allowable stress for material of flange at design temperature (operating condition)

S_H = calculated longitudinal stress in hub

S_R = calculated radial stress in flange

S_T = calculated tangential stress in flange

T = factor involving K (from Fig. 2-7.1)

t = flange thickness

U = factor involving K (from Fig. 2-7.1)

V = factor for integral type flanges (from Fig. 2-7.3)

V_L = factor for loose type flanges (from Fig. 2-7.5)

W = flange design bolt load, for the operating condition or gasket seating

= W_{m1} for operating condition

= $\frac{(A_m+A_b)S_a}{2}$ for gasket seating condition

W_{m1} = minimum required bolt load for the operating conditions

W_{m1} = minimum required bolt load for gasket seating

w = width used to determine the basic gasket seating width b_0, based upon the contact width between the flange and the gasket (see Table 2-5.2)

Y = factor involving K (from Fig. 2-7.1)

y = gasket or joint-contact-surface unit seating load

Z = factor involving K (from Fig. 2-7.1)

Calculation of Flange Stresses

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

(1) Integral type flanges

Longitudinal hub stress $S_H = \frac{fM_O}{Lg_1^2B} < 1.5S_f$

Radial flange stress $S_R = \frac{(1.33te+1)M_O}{Lt^2B} < S_f$

Tangential flange stress $S_T = \frac{YM_O}{t^2B} - ZS_R < S_f$

Combined stress

$\frac{S_H+S_R}{2} < S_f$ and

$\frac{S_H + S_T}{2} < S_f$

(2) Loose type flanges with hubs

Longitudinal hub stress $S_H = \frac{fM_O}{Lg_1^2B} < 1.5S_f$

Radial flange stress $S_R = \frac{(1.33te+1)M_O}{Lt^2B} < S_f$

Tangential flange stress $S_T = \frac{YM_O}{t^2B} - ZS_R < S_f$

Combined stress

$\frac{S_H+S_R}{2} < S_f$ and

$\frac{S_H + S_T}{2} < S_f$

where,

L = factor $= \frac{(te+1)}{T} + \frac{t^3}{d}$

d = factor $= \frac{U}{V_L} h_o g_0^2$ for integral type flanges

e = factor $= \frac{F_L}{h_o}$

V_L = factor for loose type flanges (from Fig. 2-7.5)

F_L = factor for loose type flanges (from Fig. 2-7.4)

(3) Loose type flanges without hubs

Longitudinal hub stress $S_H = 0$
Radial flange stress $S_R = 0$
Tangential flange stress $S_T = \frac{YM_O}{t^2B} < S_f$

Combined stress

$\frac{S_H+S_R}{2} < S_f$ and

$$\frac{S_H + S_T}{2} < S_f$$

where,

L = factor = $\frac{(te+1)}{T} + \frac{t^3}{d}$

d = factor = $\frac{U}{V_L} h_0 g_0^2$

e = factor = $\frac{F_L}{h_o}$

V_L = factor for loose type flanges (from Fig. 2-7.5)
F_L = factor for loose type flanges (from Fig. 2-7.4)

(4) Optional type flanges (calculated as loose flanges without hubs)

Longitudinal hub stress $S_H = 0$
Radial flange stress $S_R = 0$
Tangential flange stress $S_T = \frac{YM_O}{t^2B} < S_f$

Combined stress

$\frac{S_H+S_R}{2} < S_f$ and

$$\frac{S_H + S_T}{2} < S_f$$

where,

L = factor = $\frac{(te+1)}{T} + \frac{t^3}{d}$

d = factor = $\frac{U}{V_L} h_0 g_0^2$

e = factor = $\frac{F_L}{h_o}$

V_L = factor for loose type flanges (from Fig. 2-7.5)
F_L = factor for loose type flanges (from Fig. 2-7.4)

(5) <u>Reverse type flanges</u>

Longitudinal hub stress $S_H = \frac{fM_O}{L_r g_1^2 B'} < 1.5S_f$

Radial flange stress $S_R = \frac{(1.33te_r+1)M_O}{L_r t^2 B'} < S_f$

Tangential flange stress $S_r = \frac{YM_O}{t^2 B} - ZS_R \frac{0.67te_r+1}{1.33te_r+1} < S_f$

Combined stress

$\frac{S_H+S_R}{2} < S_f$ and
$\frac{S_H + S_T}{2} < S_f$

where,

L_r = factor = $\frac{(te_r+1)}{T} + \frac{t^3}{d_r}$
d_r = factor = $\frac{U_r}{V} h_o g_0^2$
e_r = factor = $\frac{F}{h_o}$
h_o = factor = $\sqrt{Ag_0}$
α_r = $\frac{1+0.668\frac{(K+1)}{Y}}{K^2}$
T_r = $\frac{Z+0.3}{Z-0.3}\alpha_r T$
U_r = $\alpha_Y U$
Y_r = $\alpha_Y Y$

TABLE 2-5.1
GASKET MATERIALS AND CONTACT FACINGS[1]
Gasket Factors *m* for Operating Conditions and Minimum Design Seating Stress *y*

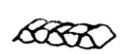
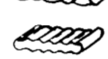
Gasket Material	Gasket Factor *m*	Min. Design Seating Stress *y*, psi (MPa)	Sketches	Facing Sketch and Column in Table 2-5.2
Self-energizing types (0 rings, metallic, elastomer, other gasket types considered as self-sealing)	0	0 (0)	. . .	. . .
Elastomers without fabric or high percent of asbestos fiber:				
Below 75A Shore Durometer	0.50	0 (0)		(1a),(1b),(1c),(1d), (4),(5); Column II
75A or higher Shore Durometer	1.00	200 (1.4)		
Asbestos with suitable binder for operating conditions:				
$\frac{1}{8}$ in. (3.2 mm) thick	2.00	1,600 (11)		(1a),(1b),(1c),(1d), (4),(5); Column II
$\frac{1}{16}$ in. (1.6 mm) thick	2.75	3,700 (26)		
$\frac{1}{32}$ in. (0.8 mm) thick	3.50	6,500 (45)		
Elastomers with cotton fabric insertion	1.25	400 (2.8)		(1a),(1b),(1c),(1d), (4),(5); Column II
Elastomers with asbestos fabric insertion (with or without wire reinforcement):				
3-ply	2.25	2,200 (15)		(1a),(1b),(1c),(1d), (4),(5); Column II
2-ply	2.50	2,900 (20)		
1-ply	2.75	3,700 (26)		
Vegetable fiber	1.75	1,100 (7.6)		(1a),(1b),(1c),(1d), (4)(5); Column II
Spiral-wound metal, asbestos filled:				
Carbon	2.50	10,000 (69)		(1a),(1b); Column II
Stainless, Monel, and nickel-base alloys	3.00	10,000 (69)		
Corrugated metal, asbestos inserted, or corrugated metal, jacketed asbestos filled:				
Soft aluminum	2.50	2,900 (20)	 	(1a),(1b); Column II
Soft copper or brass	2.75	3,700 (26)		
Iron or soft steel	3.00	4,500 (31)		
Monel or 4%–6% chrome	3.25	5,500 (38)		
Stainless steels and nickel-base alloys	3.50	6,500 (45)		

TABLE 2-5.2
EFFECTIVE GASKET WIDTH[2]

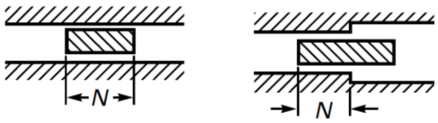
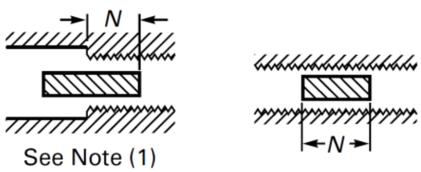
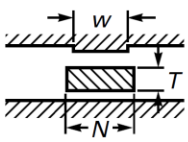
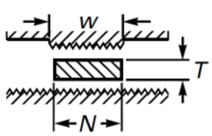
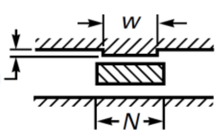
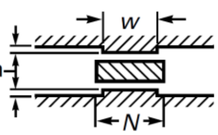
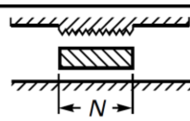
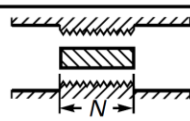
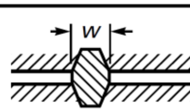
Facing Sketch (Exaggerated)	Basic Gasket Seating Width b_o Column I	Basic Gasket Seating Width b_o Column II
(1a) 	$\frac{N}{2}$	$\frac{N}{2}$
(1b)  See Note (1)		
(1c)  $w \le N$	$\frac{w+T}{2}$; $\left(\frac{w+N}{4}\text{ max}\right)$	$\frac{w+T}{2}$; $\left(\frac{w+N}{4}\text{ max}\right)$
(1d)  See Note (1) $w \le N$		
(2) $^1/_{64}$ in. (0.4 mm) nubbin  $w \le N/2$	$\frac{w+N}{4}$	$\frac{w+3N}{8}$
(3) $^1/_{64}$ in. (0.4 mm) nubbin  $w \le N/2$	$\frac{N}{4}$	$\frac{3N}{8}$
(4)  See Note (1)	$\frac{3N}{8}$	$\frac{7N}{16}$
(5)  See Note (1)	$\frac{N}{4}$	$\frac{3N}{8}$
(6) 	$\frac{w}{8}$	. . .

TABLE 2-6
MOMENT ARMS FOR FLANGE LOADS UNDER OPERATING CONDITIONS

	h_D	h_T	h_G
Integral type flanges [see Fig. 2–4 sketches (5), (6), (6a), (6b), and (7)]; and optional type flanges calculated as integral type [see Fig. 2-4 sketches (8), (8a), (9), (9a), (10), (10a), and (11)]	$R + 0.5g_1$	$\frac{R + g_1 + h_G}{2}$	$\frac{C - G}{2}$
Loose type, except lap-joint flanges [see Fig. 2-4 sketches (2), (2a), (3), (3a), (4), and (4a)]; and optional type flanges calculated as loose type [see Fig. 2-4 sketches (8), (8a), (9), (9a), (10), (10a), and (11)]	$\frac{C - B}{2}$	$\frac{h_D + h_G}{2}$	$\frac{C - G}{2}$
Lap-type flanges [see Fig. 2-4 sketches (1) and (1a)]	$\frac{C - B}{2}$	$\frac{C - G}{2}$	$\frac{C - G}{2}$

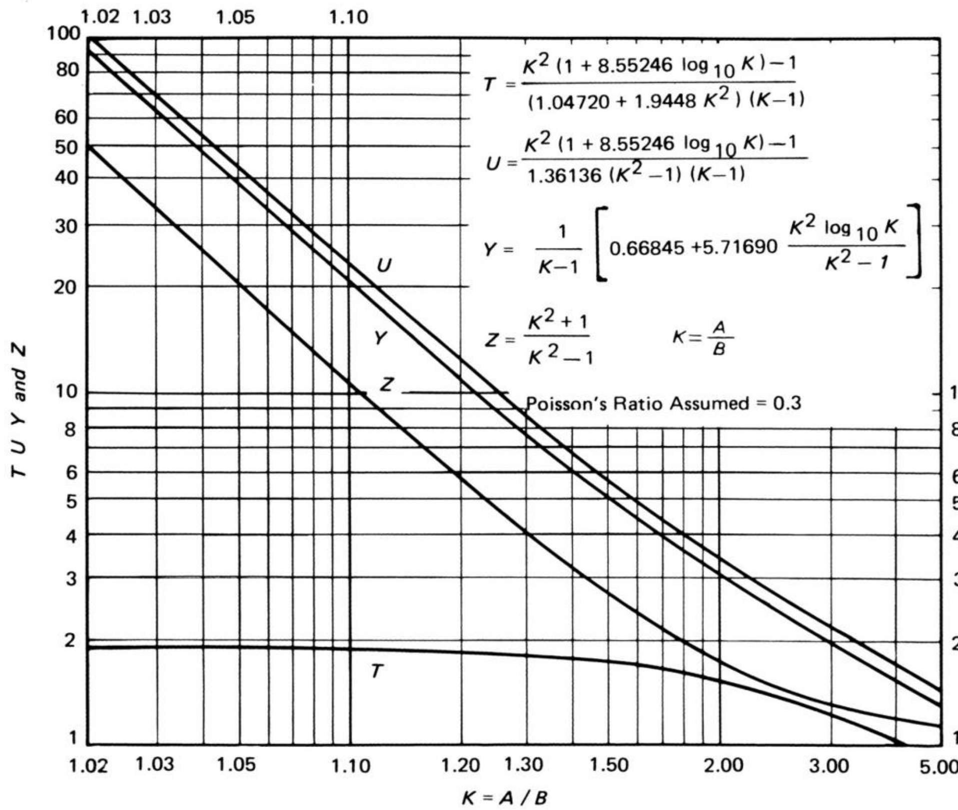


FIG. 2-7.1 VALUES OF *T, U, Y,* AND *Z*
(Terms Involving K)

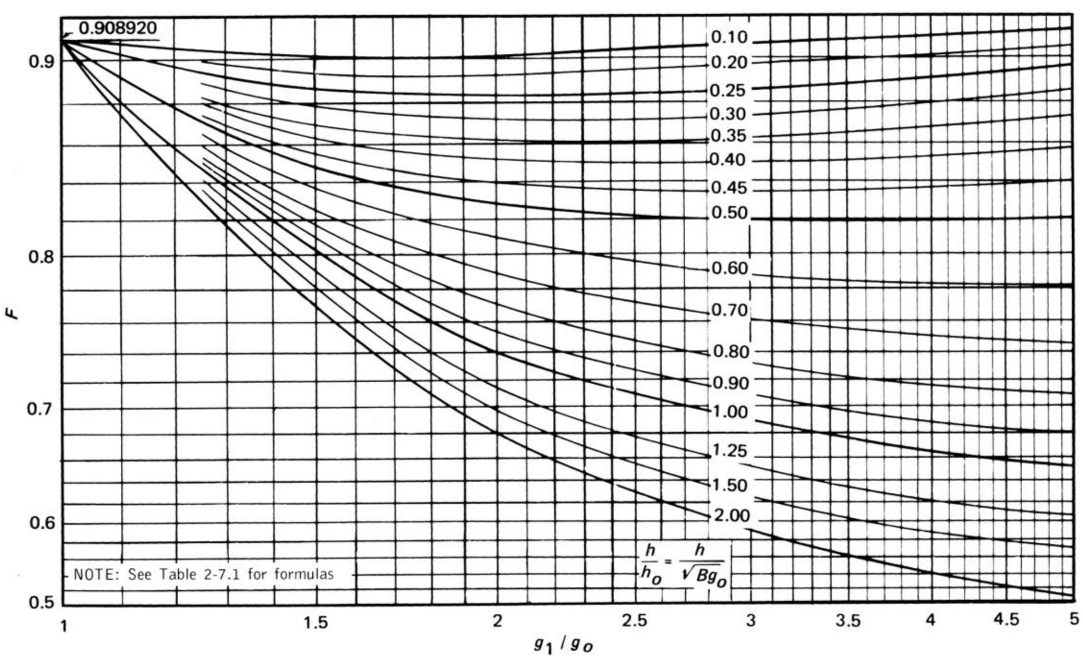


FIG. 2-7.2 VALUES OF *F*
(Integral Flange Factors)

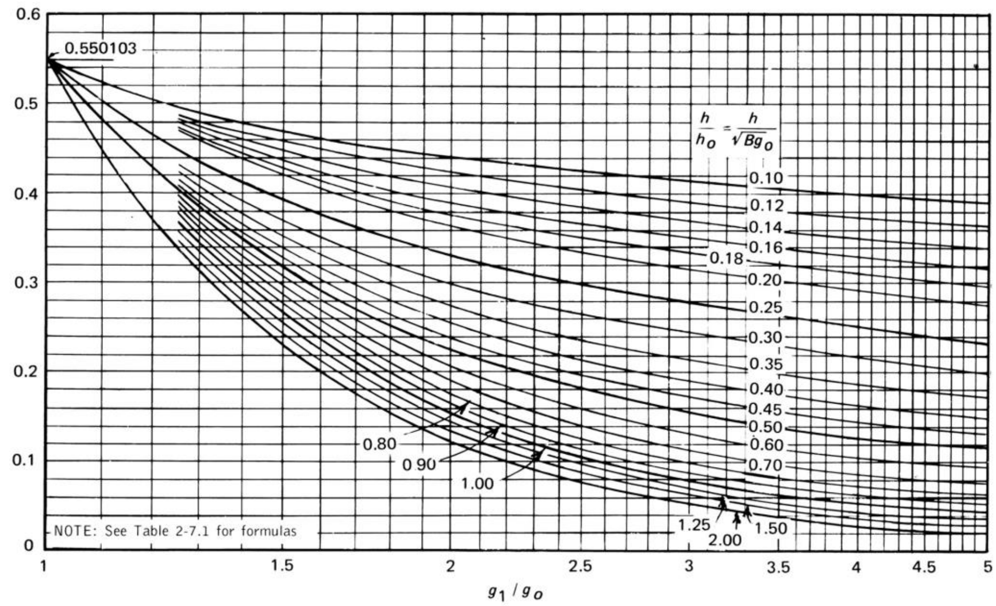


FIG. 2-7.3 VALUES OF *V*
(Integral Flange Factors)

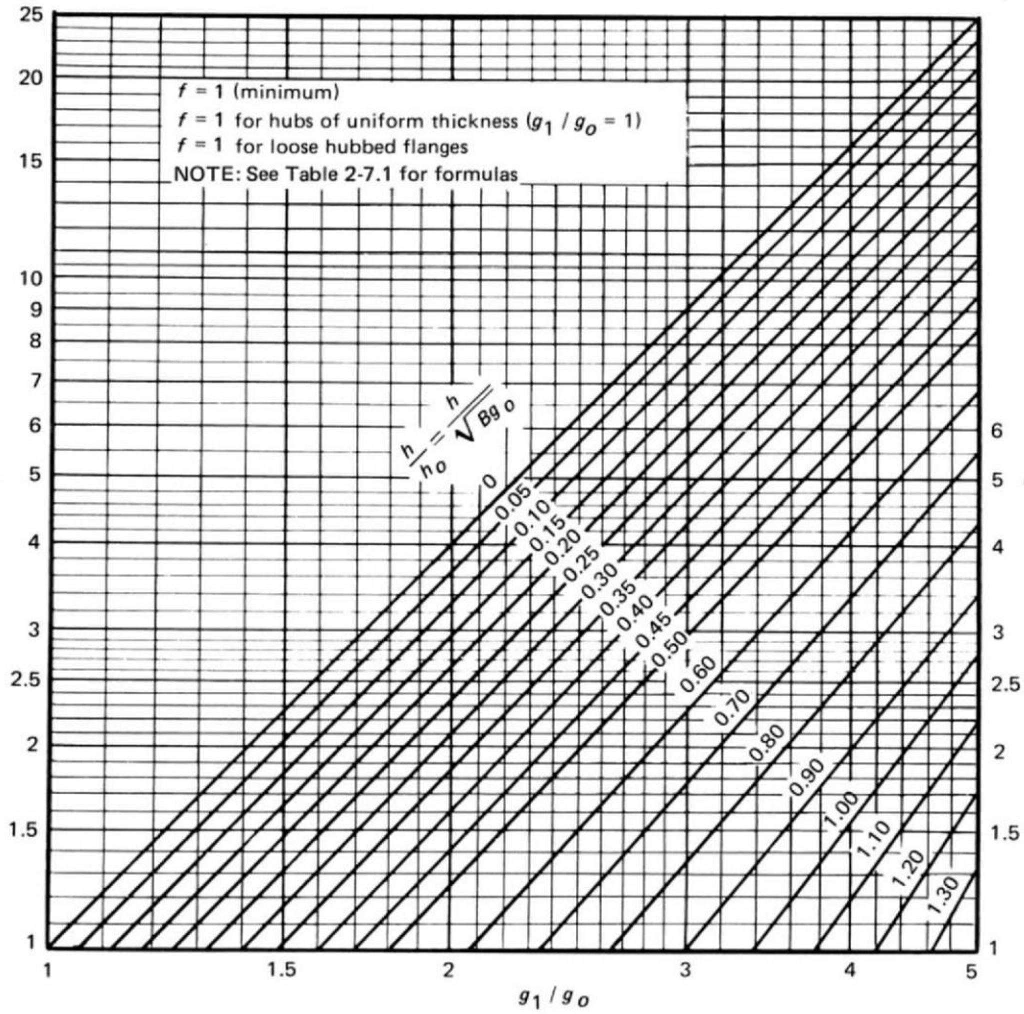


FIG. 2-7.6 VALUES OF f
(Hub Stress Correction Factor)

Problem 1:

(Example from "Taylor Forge & Pipe Works, 1961")

Flange Details:

Flange Type : Loose Flanges with Hubs
Flange Outside Diameter [A] = 40.375 (inch)
Flange Inside Diameter [B] = 33.25 (inch)
Inside Diameter of Reverse Flange [B'] = 20 (inch)
Flange Thickness [t] = 2.125 (inch)
Small End Hub Thickness [g0] = 0.875 (inch)
Large End Hub Thickness [g1] = 1.125 (inch)
Hub Length [h] = 2.5 (inch)
Allowable Stress @ Design Temp [sf] = 17500 (psi)
Allowable Stress @ Ref. Temp [sfa] = 17500 (psi)
Modulus @ Design Temp [E] = 2.7E+7 (psi)
Modulus @ Ref. Temp [Ea] = 2.92E+7 (psi)

Bolting Information:

Bolt Circle Diameter = 38.25 (inch)
Number of Bolts = 44
Bolt Diameter = 1 (inch)
Allowable Stress @ Ref. Temp [sa] = 20000 (psi)
Allowable Stress @ Design Temp [sb] = 20000 (psi)

Gasket Information:

Gasket Outside Diameter = 35.75 (inch)
Gasket Inner Diameter = 34.25 (inch)
Leak Pressure Ratio [m] = 2.75
Gasket Seating Stress [y] = 3700 (psi)
Facing Sketch = 1
Facing Column = 1

Load Data:

Design Pressure = 400 (psi)
Design Temperature = 500 (F)
Bending Moment = 200 (ft-lb)

Comparison of Results:

Flange Stresses	**Text Book Results (psi)**	**CAEPIPE (psi)**	**CAESAR II (psi)**
Operating condition			
Longitudinal Hub (SH)	20800	21153	21214
Radial Flange (SR)	11100	11110	11155
Tangential Flange (ST)	13800	13826	13797
0.5(SH + SR)	15950	16132	16185
0.5(SH + ST)	17300	17489	17506
Gasket Seating Condition			
Longitudinal Hub (SH)	14400	14623	15095
Radial Flange (SR)	7660	7681	7938
Tangential Flange (ST)	9500	9558	9818
0.5(SH + SR)	11030	11152	11517
0.5(SH + ST)	11950	12091	12457

Problem 2:

(Example 10.5 on page 209 Chapter 10 on "CASTI Guidebook to ASME Section VIII Div.1 – Pressure Vessels – Third Edition")

Flange Details:

Flange Type : Reverse Flanges
Flange Outside Diameter [A] = 49 (inch)
Flange Inside Diameter [B] = 48.25 (inch)
Inside Diameter of Reverse Flange [B'] = 20.25 (inch)
Flange Thickness [t] = 5.25 (inch)
Small End Hub Thickness [g0] = 0.375 (inch)
Large End Hub Thickness [g1] = 1.375 (inch)
Hub Length [h] = 6 (inch)
Allowable Stress @ Design Temp [sf] = 12000 (psi)
Allowable Stress @ Ref. Temp [sfa] = 20000 (psi)
Modulus @ Design Temp [E] = 2.7E+7 (psi)
Modulus @ Ref. Temp [Ea] = 2.92E+7 (psi)

Bolting Information:

Bolt Circle Diameter = 44 (inch)
Number of Bolts = 32
Bolt Diameter = 1.25 (inch)
Allowable Stress @ Ref. Temp [sa] = 25000 (psi)
Allowable Stress @ Design Temp [sb] = 21000 (psi)

Gasket Information:

Gasket Outside Diameter = 24 (inch)
Gasket Inner Diameter = 22 (inch)
Leak Pressure Ratio [m] = 2.50
Gasket Seating Stress [y] = 10000 (psi)

Facing Sketch = 1
Facing Column = 1

Load Data:

Design Pressure = 150 (psi)
Design Temperature = 800 (F)
Bending Moment = 200 (ft-lb)

Comparison of Results:

Flange Stresses	Text Book Results (psi)	CAEPIPE (psi)	CAESAR II (psi)
Operating condition			
Longitudinal Hub (SH)	2060	2257	2055
Radial Flange (SR)	280	307	280
Tangential Flange (ST)	1340	1314	1336
0.5(SH + SR)	1170	1282	1168
0.5(SH + ST)	1700	1785	1695
Gasket Seating Condition			
Longitudinal Hub (SH)	9220	10082	9220
Radial Flange (SR)	1260	1372	1257
Tangential Flange (ST)	6000	7004	5997
0.5(SH + SR)	5240	5727	5239
0.5(SH + ST)	7610	8543	8703

Problem 3:

(Example from KEDKEP CONSULTING, INC. dated May 27, 2008)

Flange Details:

Flange Type : Loose Flanges without Hubs / Optional Flanges
Flange Outside Diameter [A] = 38.4 (inch)
Flange Inside Diameter [B] = 32 (inch)
Inside Diameter of Reverse Flange [B'] = 32 (inch)
Flange Thickness [t] = 4 (inch)
Small End Hub Thickness [g0] = 0.001 (inch)
Large End Hub Thickness [g1] = 0.001 (inch)
Hub Length [h] = 0.001 (inch)
Allowable Stress @ Design Temp [sf] = 20000 (psi)
Allowable Stress @ Ref. Temp [sfa] = 20000 (psi)
Modulus @ Design Temp [E] = 2.7E+7 (psi)
Modulus @ Ref. Temp [Ea] = 2.92E+7 (psi)

Bolting Information:

Bolt Circle Diameter = 36 (inch)
Number of Bolts = 28
Bolt Diameter = 1 (inch)

Allowable Stress @ Ref. Temp [sa] = 25000 (psi)
Allowable Stress @ Design Temp [sb] = 25000 (psi)

Gasket Information:

Gasket Outside Diameter = 32.75 (inch)
Gasket Inner Diameter = 32 (inch)
Leak Pressure Ratio [m] = 0.50
Gasket Seating Stress [y] = 0 (psi)
Facing Sketch = 2
Facing Column = 2

Load Data:

Design Pressure = 300 (psi)
Design Temperature = 295 (F)
Bending Moment = 200 (ft-lb)

Comparison of Results:

Flange Stresses	**Text Book Results (psi)**	**CAEPIPE (psi)**	**CAESAR II (psi)**
Operating Condition			
Longitudinal Hub (SH)	0	0	3
Radial Flange (SR)	0	0	0
Tangential Flange (ST)	10577	10569	10618
0.5(SH + SR)	0	0	1.5
0.5(SH + ST)	0	0	5310.5
Bolt Stress	16378	16371	16445
Gasket Seating Condition			
Longitudinal Hub (SH)	0	0	3
Radial Flange (SR)	0	0	0
Tangential Flange (ST)	12147	11987	12166
0.5(SH + SR)	0	0	1.5
0.5(SH + ST)	0	0	6085
Bolt Stress	0	0	124