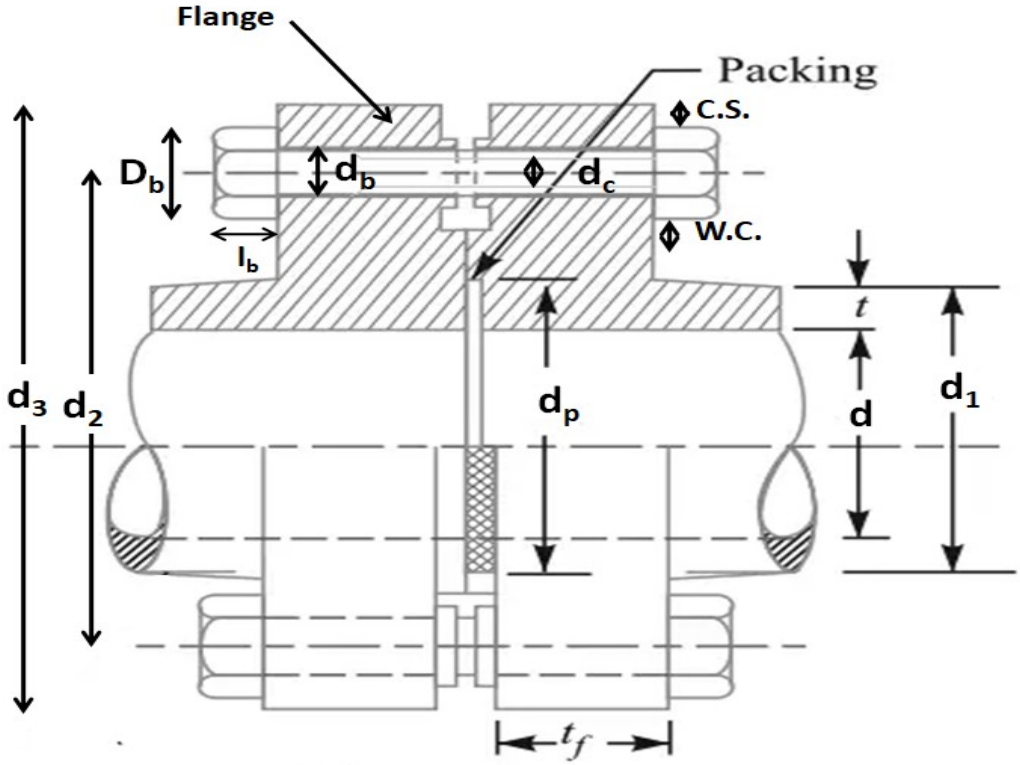
Standard size of Rod/Shaft/Tube/Bolts/Pipe

Range of Size	Increment steps
0-10	1mm
10-24	2mm
24-45	3 mm
45-100	5 mm
>100	10 mm

Flanged Pipe Joint

Design 5: Design a pipe joint for joining two pipes of bore diameter, d = 50/55/60/70 mm subjected to an internal fluid pressure (p) of 12/14/16/18/20 MPa. The allowable tensile stress in the pipe material (σ_{tp}) is not to exceed 50 MPa and in the bolts (σ_{tb}) not to exceed 70 MPa.



Nomenclature & Empirical relations:

d = Internal or Bore Diameter of pipe
t = thickness of pipe
$\mathbf{d_1}$= outside diameter of pipe
$\mathbf{d_2}$= pitch circle diameter passing through centre of bolts
$\mathbf{d_3}$= outside diameter of flanges
$\mathbf{d_b}$ = Nominal diameter of bolt = $1.2d_c$ or $d_c/0.84$
$\mathbf{d_c}$= Core diameter of bolt
$\mathbf{D_b}$ = diameter of bolt head
$\mathbf{l_b}$ = Length of bolt head = $0.85d_b$
$\mathbf{t_f}$ = thickness of flange
$\mathbf{d_p}$ = Packing diameter
W.C. = Working clearance of 10-15 mm
C.S. = Clear space of 10-15 mm

Design Steps:

1. Calculate the bore diameter **'d'** of pipe from the discharge **'Q'** and velocity of fluid flow **'v'** through pipe using:

$$Q = \frac{\pi}{4} d^2 v$$

$$\Longrightarrow d = \sqrt{\frac{4Q}{\pi v}}$$

$$if\ not\ given$$

2. By Lame's equation (considering pipe as thick cylinder)

$$t = \left[\sqrt{\frac{\sigma_{tp} + p}{\sigma_{tp} - p}} - 1\right]\frac{d}{2}$$

3. Outer diameter of pipe, $d_1 = [(d + 2t) \times 1.1]$
   Factor **'1.1'** is considered to account for corrosion, rusting of ferrous pipe over a long period of time and for threading allowance.
4. Assuming a radial width of packing of w = 10-12 mm
   therefore, diameter of packing, $d_p = d+2w$
   In order to keep separating force small, the packing diameter d_p should be kept as small as possible so there is restriction on outer diameter of packing and it is not kept equal to the outside diameter of flange.
5. **<u>Separating force (F_S):</u>**
   In order to make a leak proof joint, the pressure on the packing should be equal to or greater than the inside fluid pressure (p). Assuming the pressure on packing is created by the tightening of bolts, therefore separating force is given by:

$$F_S = p\left(\frac{\pi}{4} d^2\right) + p\frac{\pi}{4}\left(d_p^2 - d^2\right)$$

$$F_S = p\frac{\pi}{4} d_p^2$$

6. **<u>Holding force (F_H):</u>**

$$F_H = n.\sigma_{tb}\frac{\pi}{4} d_c^2$$

where, n is no. of bolts

Equating $F_H = F_S$

$$n.\sigma_{tb}\frac{\pi}{4} d_c^2 = p\frac{\pi}{4} d_p^2$$

7. **<u>Case I:</u>** Let **n=2 (Oval/ Elliptical Flange)**, get d_c from above equation
   d_b = Nominal diameter of bolt = $1.2d_c$
   Take standard size as M10, M12, M14, bolts etc.
   Diameter of bolt head, $D_b = 2d_b$

Check that D_b<d by atleast 4-5 mm.

Else take **n=4 (Circular/ Square Flange)**, and reiterate step no. 7 and check D_b<d

Else take n=6,8 and so on

8. Pitch circle diameter passing through centre of bolts,

$$d_2 = d_1 + 2W.C. + 2\frac{d_b}{2}$$

$$d_2 = d_1 + 2W.C. + d_b$$

9. Outside diameter of flanges,

$$d_3 = d_2 + 2\frac{D_b}{2} + 2C.S.$$

$$d_3 = d_2 + D_b + 2C.S.$$

10. **Calculating thickness of flanges, t_f**

When the bolts are tightened, flanges will be subjected to bending about the tangent to the outer diameter of pipe.

Arm 'a' = distance of bolt center from the tangent

b = Length of tangent

Bending moment = $\frac{F_S}{n} \times a$

Resistance in bending of flange = $\sigma_{tp} \frac{bt_f^2}{6}$

On equating above two equations, t_f is determined.

Values of 'a' and 'b' will be determined on the basis of the type of flange as follows:

a) Oval/ Elliptical Flange (n=2):

Oval flange is made of circular arcs and straight lines. The circular profile is drawn at the tip of minor axis, with radius

R_2 = Outer radius of pipe + W.C.

Arcs at major tip have a radius

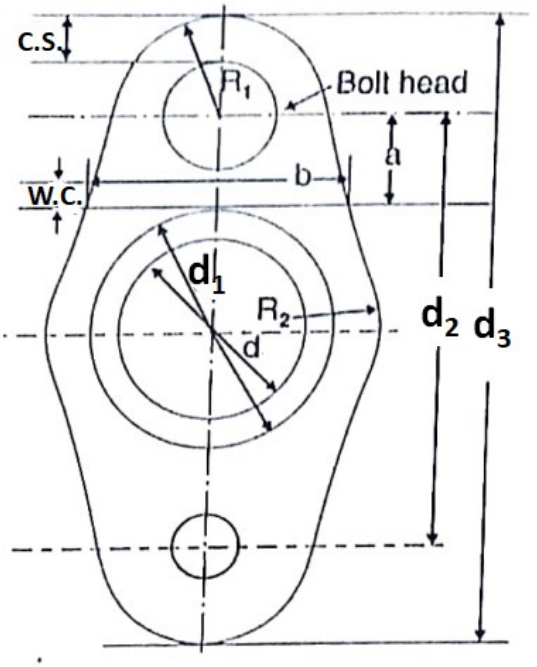
R_1 = bolt diameter + C.S.

and arcs having centre as centre of bolt.

The arcs are joined by drawing tangents to complete the oval shape. Therefore,

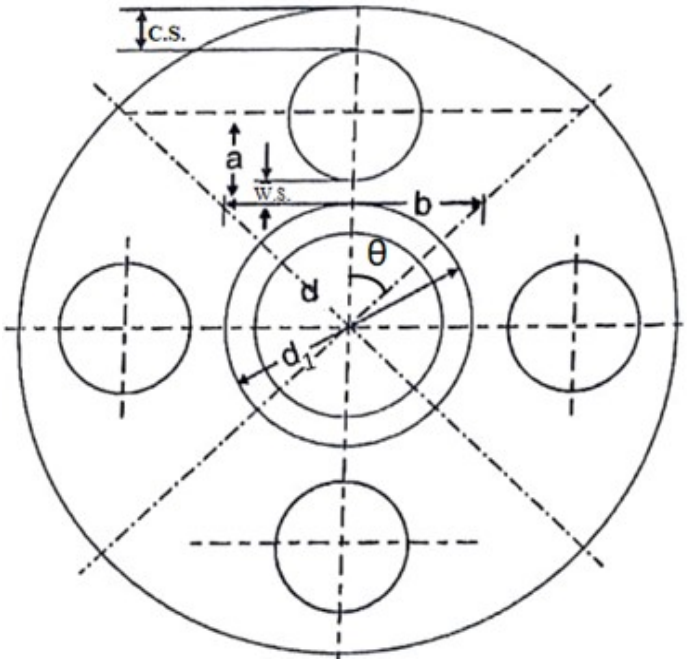
$$\boldsymbol{a = \frac{d_2}{2} - \frac{d_1}{2}}$$

and **'b'** needs to be measured from the drawing as it is not an exact ellipse.



b) <u>Circular Flange (n=4,6,8…):</u>

Take angle bisector between two bolts as shown.



Half angle,

$$\theta = \frac{360°}{2n} = \frac{180°}{n}$$

$$\tan\theta = \frac{b/2}{d_1/2} = \frac{b}{d_1}$$

$$\boldsymbol{b = d_1 \tan\theta}$$

While distance,

$$\boldsymbol{a = \frac{d_2}{2} - \frac{d_1}{2}}$$

VIVA QUESTIONS

1. What purpose is served by a packing in a pipe joint?
2. It is not desirable to have a packing diameter of very large size. Why? Explain