Laboratory Manual

Process Equipment Design-II

List of Practical

Expt No.	Name of Practical
1-2	Drawing of sketches for various parts of equipments as per the list provided with lab manual
3	P and ID and PFD
4 & 5	Design calculations for pressure vessel design [Pressure vessel and Bracket support]
6	Drawing of pressure vessel in sheet/using AUTOCAD.
7 & 8	Design calculations for storage vessel design [Plate thickness and Roof]
9	Drawing of storage vessel in sheet/using AUTOCAD.
10 & 11	Design calculations for tall vertical vessel design [Plate thickness and Skirt support]
12	Drawing of tall vertical vessel in sheet/using AUTOCAD.

Drawing of various sketches:

Draw sketches and prepare tables as per the given list from book of Joshi and Mahajani, 3rd Edition.

Figure No.	Title of Figure
	Basics
Fig. 4.22-24	Group I
Table 4.6	Group I
	Chapter 5
Table 5.1, 5.2	Group II
Fig. 5.3-31	Group II
	Chapter 6
Fig. 6.1-5	Group III
Fig. 6.11-13	Group III
	Chapter 7
Fig. 7.1-16	Group III
	Chapter 8
Fig. 8.1 -15	
	Chapter 11
Fig. 11.1	Group IV
Fig. 11.9 -10	Group IV
Fig. 11.14 -17	Group IV
Fig. 11.19 -24	Group IV
	Chapter 13
Fig. 13.1-18	Group V
	Chapter 14
Fig. 14.1-9, 14.11	Group I
Table 14.1	Group I
Appndix G	Codes and Standards - Group I

Sheet-1 Pressure Vessel Design

Design the pressure vessel with an appropriate support on the basis of the following data.

Data:

Shell:

Internal diameter (approx)	Use data given in table below
Internal pressure	
Permissible stress at 150 ^oC	130 N/mm^2
Material - Stainless steel	0.5 Cr, 18 Ni, 11 Mo

Flanges

Permissible stress (up to 250 ^oC)	95 N/mm^2
Gasket	Asbestos
Material - Carbon steel (IS-2002)	Grade

Bolts

Permissible stress (up to 50 ^oC)	58.7 N/mm^2
Permissible stress (up to 250 ^oC)	54.5 N/mm^2
Material	Hot rolled carbon steel

Nozzle - Welded to head

Internal diameter	150 mm
Thickness	3 mm
Material	Same as shell

Head

(a) Torishperical Head (Flanged and Standard dished)

Crown radius	1200 mm
Knuckle radius	6% of vessel dia.
Total depth of head	257 mm
S_f	40 mm

Determine the thickness and blank diameter of the plate required to fabricate the head

(b) Flanged and dished head

External diameter	1200 mm
Crown radius	1200 mm
Knuckle radius	72 mm
M.O.C.	Same as shell

(c) Elliptical Head

Ratio of major to minor axis	2:1

(d) Hemispherical Head

Poisson's ratio (μ)	0.3
Modulus of elasticity (E)	$1.85*10^{11}$ N/m^2

(e) Butt-welded flat Head

Stress concentration factor(C)	0.45

Support

Bracket or Lug Support

Diameter of vessel	1200 mm
Height of vessel	2000 mm
Clearance of vessel bottom of foundation	1 m
Weight of vessel with contents	40 kN
Wind pressure	1285 N/m^2
Number of brackets	4
Dia. of anchor bolt circle	1.65 m
Height of bracket from foundation	22.5 m
Permissible stresses for structural steel	
Tension	140 N/mm^2
Compression	123.3 N/mm^2
Bending	157.5 N/mm^2
Permissible bearing pressure for concrete	3.5 N/mm^2

Design Data:

Roll No. (As per sequence in muster in each batch)	Internal diameter (mm)	Internal Max. Operating Pressure, Absolute,	Jacket Pressure, (gauge), kg/cm^2
1	1200	4 bar	10
2		11 bar	20
3		16 bar	5
4		21 bar	10
5		36 bar	No jacket
6	800	21 bar	20
7		15 bar	2
8		9 bar	10
9		5 bar	No jacket
10		10 bar	25
11		27 bar	No jacket
12		100 mm hg	5
13		300 mm hg	10
14	1500	27 bar	5
15		0 mm hg	5
16		5 bar	No jacket
17		15 bar	15
18		25 bar	No jacket

Draw similar figures with proper scale according to your design calculations in A1 drawing sheets.

Fig. Nos.: Use the drawing sheet for “Reaction Vessel” available at the end of book of Joshi and Mahajani. **(3rd Edition, M V Joshi and V V Mahajani)**

Vessel data sheet (PROCEED)	Equipment No. (Tag)	
	Descript. (Func.)	
	Sheet No.	

Operating Data

				1
				2
No. REQUIRED		CAPACITY		3
SPECIFIC GRAVITY OF CONTENTS		COMPUTED (yes or no)		4
	SHELL	JACKET FULL/HALF COIL	INTERNAL COIL	5
CONTENTS				6
DIAMETER				7
LENGTH				8
DESIGN CODE				9
MAX. WORKING PRESSURE				10
DESIGN PRESSURE				11
MAX. WORKING TEMP				12
DESIGN TEMP				13
TEST PRESSURE (HYDROSTATIC)				14
TEST PRESSURE (AIR)				15
MATERIALS				16
JOINT FACTOR				17
CORROSION ALLOWANCE				18
THICKNESS				19

END TYPE		THICKNESS		JOINT FACTOR			20
END TYPE		THICKNESS		JOINT FACTOR			21
TYPE OF SUPPORT		THICKNESS		MATERIAL			22
WIND LOAD DESIGN		RADIOGRAPHY %		STRESS RELIEF			23
INTERNAL BOLTS MATERIAL		TYPE		NUTS			24
EXTERNAL BOLTS MATERIAL		TYPE		NUTS			25
INSULATION (SEP. ORDER)		INSULATION FITTING ATTACHMENT BY					26
GASKET MATERIAL		INSPECTION BY					27
PAINTING							28
WEIGHT		EMPTY					29
FULL OF LIQUID		OPERATING					30
INTERNALS and EXTERNALS		DATE OF ENQUIRY		DATE OF ORDER			31
ORDER No.		DRG. No.					32
MANUFACTURER							33

REMARKS AND NOTES:- UNLESS OTHERWISE STATED ALL FLANGE BOLT HOLES TO BE	34
OFF-CENTRE OF VESSEL CENTRE LINES N/S and E/W (NOT RADIALLY)	35
	37
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A										41
B										42
C										43
D										44
E										45
F										46
G										47
H										48
H										49
K										50
K										51
M										52
N										53
P										54
REF	No.	DUTY	NOM BORE	PIPE WALL	TYPE	CLASS	MATERIAL	BRANCH	REMARKS	55
BRANCH			mm/Ins	THICKNESS	RANGE SPEC			COMPEN'N		56
										57

Prepared				3				6				58
Checked				2				5				59
Approved				1				4				60
	Date	Engineering	Process	REV	By	Appr.	Date	REV	By	Appr.	Date	61

Service	Company	Address	62
Equipment No.			63
Project No.			64

Data Sheet for Pressure Vessel Design

Customer . . . . Order No. . . . .

Vessel name . . . . Equipment No . . . .

Description . . . .

Drawing/sketch No . . . .

Design Code . . . .

Design pressure . . . . kN/m^2 Design temperature . . . . °C.

Design liquid level . . . . m

Contents . . . . Density . . . . kg/m^3

Service connections . . . .

Hydraulic test pressure . . . . kN/m^2

Vessel classification . . . .

Joint efficiencies: Shell . . . . Heads . . . .

Materials of construction: Shell . . . .

Heads . . . .

Nozzles . . . .

Flanges . . . .

Corrosion alowances: shell . . . . mm Heads . . . . mm

Nozzles . . . . mm

Notes/comments

Prepared by . . . . Checked by . . . .

Date . . . . Date . . . .

DESIGN OF PRESSURE VESSEL

Design of Shell:

- Thickness of shell

  t_h = (P * Di) / (2*f*J-P)

  Where, P = internal design pressure

  Di= internal diameter

  . f = permisible stress

  J = Joint efficiency

- Check for thickness under combined loading

  1) Stress in circumferential direction. Also called hoop stress,

     f_t = (P*(Di+t)) / (2*t)   [TENSILE]

  2) Stress in the longitudinal or axial direction,

     - due to internal pressure

       f_1 = (P*Di) / (4*t)   [TENSILE]

     - due to weight of vessel and contents

       f_2 = W / (Π* t *(Di+ t))   [COMPRESSIVE]

     - Due to wind or piping in the case of vertical vessels or due to weight of vessel in case of horizontal vessel

       f_3 = M / (Π* Di^2*t)

       Where, M =Bending moment due to wind load

       = p_{lw}* (H/2)   (If H<20m)

       where, p_{lw} = k*P1*h1*Do

       H = height of the vessel

       h1 = height of vessel up to 20m

       Do = OD of the vessel

       k = coefficient depending upon shape factor=0.7(for cylindrical)

       P1 = 0.05 V_w^2 = wind pressure

       V_w = velocity of wind

     Total stress in the longitudinal or axial direction

     f_a = $f_1 + f_2 + f_3$

  3) Stress due to piping or wind

     f_s = (2*T) / (Π*t*Di*(Di+t))

     where ,T = torque about the vessel axis

     Combining the above stresses on the basis of shear strain energy theory criterion, the equivalent stress is

     $$f_R = [\ (\ f_t^2 - f_t * f_a + f_a^2 + 3f_s^2)]^{1/2}$$

     For satisfactory design

f_R (tensile) < = f_t(permissible),

<u>Design of Head</u>

1. *TORISPHERICAL HEAD*

- Thickness subjected to internal pressure

  $t_h = (P*R_c*W) / (2*f*J)$

  where, P = internal design pressure
  R_c = crown radius
  W = stress intensification factor
  $= \frac{1}{4}[3 + \sqrt{(Rc/ r_i)}]$
  r_i = knuckle radius (internal)

- Thickness subjected to external pressure (torispherical, elliptical, hemispherical head)

  $t_h = 4.4 * Rc * \sqrt{3(1-\mu^2)} * \sqrt{(P/2E)}$

  where, E = modulus of elasticity
  μ = Poissons ratio
  P_o = external pressure(internal pr. = 1.67 * external pr.)

- For Torispherical (standard dished) and ellipsoidal dished head
  The external height, h_o of a dished head (excluding straight flange),

  $h_o = R_{co} - \{(R_{co} - D_o/2) * (R_{co} + D_o/2 - 2 r_o)\}^{1/2}$

  where, R_{co} = outside crown radius
  r_o = outside knucke radius

  Blank Diameter of head,

  $= D_o + D_o /42 + 2*S_f + 2/3* r_i$ {where $t_h < 25.4$ mm)
  OR $= D_o + D_o /24 + 2*S_f + 2/3* r_i$ {where $t_h > 25.4$ mm}
  where S_f = height of straight flange

2. *FLANGED AND SHALLOW DISHED HEAD*

Thickness subjected to internal pressure

$t_h = (P*Rc*W) / (2*f*J)$

3. *ELLIPTICAL HEAD*

Thickness subjected to internal pressure

$t_h = (P*D*W) / (2*f*J)$

where, D =major axis of ellipse
k = Major axis/minor axis [common value is 2,should not greater then 2.6]
μ = Poissons ratio
W = stress concentration factor = $(2 + k^2)/ 6$

4. *HEMISPHERICAL HEAD*

Thickness subjected to internal pressure

$t_h = (PD) / (4*f*J)$

5. BUTTWELDED FLAT HEAD

Thickness of head

$t_h = C*D*\sqrt{P/f}$

where, C= stress concentration factor

D = diameter of plate which is actually under operating pressure

6. CONICAL HEAD

Thickness of head

$t_h = PD/(2fJ\cos\propto)$

The circumferential stress in this type of formed head, f

$= PD/(2t\cos\propto)$

DESIGN OF FLANGE

Flange – the shell and top head are connected by flange joint

1. Gasket Design & Selection

- $d_o / d_i = \sqrt{(y-P*m) / (y - P*(m+1))} = X$

Where,

y = gasket seating stress

m=Gasket factor

P= internal design pressure

d_i= ID of gasket , d_o = min OD of gasket = X d_i

d_i >= 10 mm larger than B (ID of flange)

[for ring and slip flange, ID of flange = OD of shell]

d_i = Do + 5 to 20

[For weld flange, ID of flange = ID of shell]

- ***Width of gasket***

Actual gasket width in contact

$N = (d_o - d_i) / 2$

So,

$d_o = d_i + (2*N)$

Basic gasket seating width [b_o]

Type of flange facing	Basic gasket seating width, b_o	Effective gasket seating width, b
Plain face	N/2	B = b_o, when b_o <=6.3 mm
Raised face	N/2	B = 2.5$\sqrt{b_o}$, when b_o>6.3mm
Male and female	N/2	
Tongue & groove	(N+W)/4, W- width of tongue	
Ring type	W/8, W – width of ring gasket	

- Diameter of gasket at location of gasket load reaction [G]

$G = (d_o+d_i)/2$ when b <= 6.3mm
$G = d_o - 2b$ when b >6.3mm

2. Bolt design

- Determination of bolt load under bolting up condition,

$$W_{m2} = \Pi * b * G * y$$

- Determination of bolt load under internal pressure

$$W_{m1} = H + H_p$$

Where , H = load due to design pressure P, acting on an area $\pi\, G^2 * P$
$= \pi/4 * G^2 * P$
H_p = load to achieve adequate compression of the gasket under operating condition = $\pi * (2b) * m * G * P$

- Determination of minimum bolt area theoretically required, A_m

The bolt loads either W_{m1} OR W_{m2} will create a tensile stress in the cross section of the bolt.

$$A_{m1} = W_{m1} / f_a$$
$$A_{m2} = W_{m2} / f_b$$

Where ,
A_{m1} ,A_{m2} = Cross section of the bolt under operating and bolting-up conditions respectively
f_a , f_b = Permissible stress for bolting material under design & atmospheric temp

- Number of Bolts, n = [A_{m1} or A_{m2} (greater of two)] / Root area of bolt(if table is given), otherwise
n = G/ (b_o * 2.5) , n should be in multiple of 4.

Depending upon the value of n, choose the bolt size

- Diameter of bolt = { greater value of (A_{m1} or A_{m2}) * 4 / (n * π)}$^{1/2}$

- If table is provided, then from the value of n, find bolt spacing (B_s) and bolt-circle-diameter(C) and root area. Bolt circle diameter can be calculated by two ways, and the larger value of B should be considered.

$$B = n B_s / \pi \quad \text{or}$$
$$B = d_o + 2 * \text{Dia. of bolt} + 12 \text{ mm}$$

Calculation of flange outside diameter A = B + bolt diameter

- Determination of actual bolt area, A_b

$$A_b = n * \text{Root area of bolt}$$

- To prevent damage to the gasket during bolting up condition, following condition should be satisfied

$$A_b * f_b /(\pi G N) < 2*y$$

3. Flange Thickness

$$t_f = G* \sqrt{(P/(K*f))} + C$$

where, $K = 1/ \{ 0.3+ (1.5*Wm*h_g)/(H*G)\}$
G = Diameter of gasket load reaction
P =design pressure
f = permissible stress
B = bolt circle diameter
C = corrosion allowance
Wm= total bolt load (greater of Wm1& Wm2)
h_G =radial distance from gasket load reaction to bolt circle
= (B-G)/2
H=Total hydrostatic end force $=\pi/4* G^2*P$

<u>Nozzle Reinforcement Design</u>

- **Minimum Nozzle thickness**

$$t_n = (P*Di) / (2*f*J - P)$$

Actual thickness of the nozzle is to be used in further calculation.

- **Condition for Reinforcement**

If the size of nozzle (Diameter of Nozzle) < 5cm, the reinforcement is not required,
For diameter > 5cm, reinforcement is required.

- **Reinforcement for nozzle**

Area to area method of compensation

The maximum horizontal distance for compensation AB = 2*d

The maximum vertical distance for compensation AD = $6t_s$ OR $(3.5t_s+2.5t_n)$

Whichever is smaller.

Where t_s greater value (shell thickness or head thickness)
If the compensation is only provided by nozzle then

$$H_1 = H_2 = 2.5\ t_s$$

If the compensation is to be provided by a combination of nozzle and a compensation ring, then

$$H_1 = 2.5\ t_n$$

The area for which compensation is required is given by

$$A = d * t_s$$

Area available for compensation

a) The portion of the shell or head as excess thickness
$$A_s = d*(t_s - t_s' - C)$$
b) The portion of the nozzle external to the vessel
$$A_o = 2H_1\ (t_n - t_s' - C)$$
c) The portion of the nozzle inside the vessel, if nozzle does not project inside the vessel, $H_2 = 0$
$$A_1 = 2H_2\ (\ t_n - 2C)$$

Now calculate , $As+Ao+A_1$

So area of compensation required is equal to,

$$A = (As+Ao+A_1)$$

Where ,
d = inner diameter of nozzle
t_s = actual thickness of shell or head
t_s'= theoretical minimum thickness of shell or head
t_n = actual thickness of nozzle
t_n' = theoretical minimum thickness of nozzle
C = Corrosion allowance

Design of Support

- **Bracket or Lug support**

For vessels of diameter Do Brackets used are

If $Do > 0.6m$	2 Brackets
$0.6 < Do <= 3m$	4 Brackets
$3 < Do <= 5m$	6 Brackets
$Do > 5m$	8 Brackets

Maximum compressive load act on the bracket support

$P = \{4*pw\,[H-F]\} / n*Db + \sum W/n$

Where,

H = height of vessel above foundation

pw = total force due to wind load acting on vessel

$= k*p_1*h1*Do$

Sheet-2 Design of Storage Tank

Design a storage tank having volume of the tank equivalent to last three digit of roll number multiply with 100, i.e. Roll No. 08BCH001 is having volume of 100 m3, and Roll No. 08BCH156 is having total volume of 15600 m3. Choose proper roof and design it.

Data:

Shell Design :

Plate size used = 2.16 m width X 7.32 m length
Std. Plate thickness available = 5, 6, 8, 10, 12, 14, 16, 18, 20, 24,26,28
Density of fluid = 900 kg/m^3
Permissible stress for the plate = 1260 kg/cm^2
Density of plate material = 7700 kg/m^3
Use Butt welded joints.
Joint efficiency = 0.85

Bottom Design :

Plate size used = 2.5 m width X 5 m length
Use bottom plate thickness, for inside of the tank = 6 mm
Use bottom plate thickness, near shell plate and bottom plate joint = 8 mm
Use Lap welded joints.
Joint efficiency = 0.85

Roof Design :

Plate size used = 1.37 m width X (as per your requirement, i.e. spacing between two polygon or polygon and shell) m length
Std. Plate thickness available = 5, 6, 8
Permissible stress for the plate = 1260 kg/cm^2
Density of plate material = 7700 kg/m^3

Draw similar figures with proper scale according to your design calculations in A1 drawing sheets.

Fig. Nos.: 3.13, 3.15, 3.21, 4.4, 4.5, 4.12, 4.13 (From book of Brownell and Young)

Design of Storage Tank

Shell Design :

Calculation of shell plate thickness ,

th = [(pD)/(2fj)] + C

Where th = Thickness of the shell plate, mm

p = Hydrostatic Pressure on the plate, N/mm^2

$p = \rho(H - 0.30)g \times 10^{-6}$

Where ρ = Density of fluid filled in the tank, kg/m^3

H = Height of the tank, m

g = gravitational constant, m/sec^2

D = Diameter of the tank, mm

f = Maximum permissible stress for the shell plates, N/mm^2

j = Welding joint efficiency

C = Corrosion allowance, mm

Wind girder, $Z = 0.059D^2H$

Where, Z = Section Modulus, cm^3

D = Diameter of tank, m^3

H = Height of Tank, m

Select the proper section based on the above section modulus from Book by Brownell and Young, Appendix-

Bottom Design :

Plate size used = 5.0 m width X 2.5 m length
If diameter of the tank is greater than 12 meter use annular ring plates at bottom of the tank.
Annular ring plate should extend beyond the shell outside diameter by 65 mm on both the sides.
Annular ring plate size used = 5.0 m width X 2.5 m length
Use Lap welded joints.
Over lap between two bottom plates inside the tank = 5 X thickness of the bottom plate
Over lap between sketch plate and annular plate = 65 mm
Joint efficiency = 0.85

Roof Design :

Roof Curb Angle,

Area of roof curb angle, Ac = A - As - Ar

Where Ac = Area of roof curb angle, mm^2

As = Area of shell plates effective = $1.5ts(Rts)^{1/2}$

Ar = Area of roof plates effective = $0.75tr(R_1tr)^{1/2}$

tr = Thickness of roof plate, mm

ts = Thickness of shell plate, mm

R = Radius of tank, mm

R_1= Radius of curvature of roof, mm

OR

Use std. Minimum roof curb angle data given in the book, i.e for D>36 meter,
Size of roof curb angle = 100 mm x 100 mm x 10 mm

Structured Supported Roof :

Design of steps :

1. Choose the min. thickness of the roof plates.
2. Assume the slope of the roof if it is not provided.
3. Determine the no. of polygons required for construction of roof considering the maximum length of rafter is in the range of 6.0 m to 8.0 m and that of the girder is in the range of 7.1 m to 9.1 m.
4. Determine the no. of girders required per polygon based on the choosen length of the girder from the following eq.

$$L = 2R\sin(360/2N)$$

Where, L = Length of girder, m
R = Radius of the tank, m
N = No. of sides of polygon

Based on this N value find the actual length of girder.

5. Calculate the maximum rafter spacing

$$l_{max} = t(2f/P)^{1/2}$$

Where, l_{max} = Maximum rafter spacing, m
f = Permissible stress, N/mm^2
P = Total load on the roof, N/mm^2

Maximum rafter spacing on roof curb angle = 1.91m

6. Minimum no. of rafters required between the outermost polygon and shell,

$$n_{min} = (2\pi R)/l$$

Where, R = radius of tank, m

Actual no. of rafters should be the multiple of the no. of the sides of the polygon. Based on the actual no. of rafters recalculate the actual rafter spacing on the girders of the referred polygon,

$$l = (NL)/n$$

Where, n = Actual no. of rafters on the girders of respective polygon

7. Minimum no. of rafters required between the outermost polygon and the inner polygon,

$$n_{min} = (NL)/l_{max}$$

Repeat the same procedure to find the actual no. of rafters and rafter spacing.

8. Repeat for the step 7 to find the no. of rafter and rafter spacing on the inner polygon and center column.

9. Selection of rafter is based on eq.

$Z = M_{max}/f$

Where, M_{max} = Maximum bending movement based on the total load on the rafter, N.mm

$M_{max} = (WY^2)/8$

Where, W = Total load on the rafter, kg/mm

Y = Distance between the shell plate and outermost polygon or distance between the two polygons, mm.

f = Permissible stress, N/mm^2

Z = Section modulus, mm^3

Total rafter load = Roof load + Rafter load

Initially neglect the weight of rafter,

Total Girder load = (Total load on roof), N.mm

Base on this section modulus find the std. Section available to meet the required value from Appendix G, item 1 of Book by Brownell and Young. In the selection of the rafter initially load due to weight of the rafter is unknown so first calculate Z only based on the roof load and after selecting proper section for rafter repeat the calculation for Z and check. If calculated Z value is small than that of the std. Value for the given section then selected rafter is correct otherwise repeat the calculation.

10. Repeat the calculation for other spacing inside the tank, i.e. between two polygon or between innermost polygon and central column.

11. Selection of girder is based on equation,

$Z = M_{max}/f$

Where, M_{max} = Maximum bending movement based on the total load on the girder, N.mm

$M_{max} = (WL^2)/8$

Where, W = Total load on the girder, kg/mm

L = Length of girder, mm.

f = Permissible stress, N/mm^2

Z = Section modulus, mm^3

Total Girder load = Roof load + Rafter load + Load due to weight of girder

Initially neglect the weight of girder,

Total Girder load = (Total load on one rafter) x (Total no. of rafters per one girder), N.mm

Base on this section modulus find the std. Section available to meet the required value from Appendix G, item 1 of Book by Brownell and Young. In the selection of the girder initially load due to weight of the rafter is unknown so first calculate Z only based on total rafter load and after selecting proper section for rafter repeat the calculation for Z and check. If calculated Z value is small than that of the std. Value for the given section then selected girder is correct otherwise repeat the calculation.

12. Repeat the calculation for other girder of other polygon.

13. Selection of column size,

$$(L'/r) \le 180,$$

where, L' = Length of the column, m
= Height of tank + (slop of the roof)([D/2]-R)
where, D = Diameter of the tank, m
R = Radius of circle which circumscribe the polygon, m
r = Radius of gyration, m

take (L'/r) = 180,

Find the value of r based on this value select such std. column which has next higher radius of gyration from the Appendix G, item No. 9 of Book by Brownell and Young.

Allowable compressive stress for the column may be calculated,

$$f' = f/[1 + (\{L'\}^2/18000r^2)]$$

where, f' = Allowable compressive stress for the column, N/mm^2
f = Permissible stress for the given material, N/mm^2

Actual induced stress for the column = P/a

Where, P = Total Load on the column, N
= [(Load on the girder)(Length of the girder) + [(Load due t
to weight of the of column)(Length of the column)]
a = Cross section area of column, mm^2

For satisfactory design Actual stress (P/a) should be less than the allowable stress (f').

Sheet-3 Design of Tall Vertical Vessel

Design a column with an appropriate support on the basis of the following data.

Data:

Shell:		
	Internal diameter (approx)	Use data provided in table below according to sequence of batch muster
	Working pressure	
	Working temperature	
	Base Chamber Height	2.74 m
	Top Chamber Height	1.05 m
	Material - Carbon Steel (Sp. Gr. 7.7)	
	Permissible Tensile stress	95 N/mm^2
	Insulation thickness	100 mm
	Density of Insulation	7700 M/m^2
Head		
	Elliptical Head Design - Welded to shell	
	Ratio of major to minor axis	2.0
	M.O.C.	Carbon steel
	Permissible tensile stress	95 N/mm^2
Support		
	Skirt Support Design	
	Height	4.9 m
	M.O.C.	Carbon steel
Trays		
	Sieve Tray Design	
	Number of Trays	20
	Spacing between the trays	0.686 m
	Hole diameter	5 mm
	Number of Holes	21100 (Tray No. 1 to 7) 24850 (Tray No. 8 to 34) 29400 (Tray No. 35 to 50)
	Thickness of the plate	2 mm
	Downcomer	
	Centre - Rectangular	Size 30 × 262 cm
	Side – Chord type	Size 30 × 170 cm
	Clearance from tray surface	50 cm
	Weir height	25 mm
	Height above tray	25 mm
	Effective length	
	Centre to side - Distributing	262 cm
	Overflow	170 cm
	Side to centre - distributing	170 cm
	Overflow	262 cm
	M.O.C. - for trays, downcomers and weirs	Stainless steel

<u>Supports for Trays</u>

Purlins - Channels are angles	
Live load - (liquid+ liquid downcomer impact)	2100 N/m^2
M.O.C.	Carbon steel
Permissible tensile stress	127.5 N/mm^2
Weight of Attachment, .i.e Pipes, ladder, platform, etc	1400 N/m^2
Weight of liquid and tray, etc.	920 N/m^2
Weight of Column (approx)	20 000 000 N/m^2
Wind Pressure	1300 N/m^2

Design Data: for Tall Vertical vessel

Roll No. (As per sequence in muster in each batch)	**Internal diameter (mm)**	**Internal Max. Operating Pressure, gauge (or Absolute),** N/mm^2	**Internal Max. Temperature, °C**
1	3000	1.60	180
2		2.5	200
3		1.5	125
4		1.1	150
5		0.0005	50
6	1000	1.70	250
7		3.5	150
8		2.8	200
9		1.1	101
10		0.000005	55
11		1.70	250
12		3.5	125
13		2.8	100
14	1500	1.1	55
15		0.000005	60
16		4.8	**100**
17		2.1	55
18		0.00000001	60

Draw similar figures with proper scale according to your design calculations in A1 drawing sheets.

Fig. Nos.: Fig. 11.1,5,11.10(a),11.11(a),11.15,11.28,11.29, Fig. 13.7(a), 13.11, 13.12, 13.13 **(3rd Edition, M V Joshi and V V Mahajani)**

DESIGN OF TALL VERTICAL VESSEL

- Thickness of the top of the shell end (determined on the basis of circumferential stress)

t = [(p * Di) / (2*f*J – p)] + c

where p = internal design stress
J = joint efficiency
Di = internal diameter
f= circumferential stress
c = corrosion allowance

- This thickness may be satisfactory up to certain distance from the top of the shell.
  Let X = distance from the top up to which we can keep thickness = t

- **The individual stresses at distance X in axial direction are**

1. **Axial stress due to pressure**
   f_{ap} = (p*Di*) / (4*(t-c))
   this is same throughout the column height.

2. **Stresses due to dead loads.**
   a) Compressive stress due to weight of shell up to a distance X

   f_{ds} = Wt. of shell/cross section of shell
   = [(∏/4)*(Do^2 –Di^2) * ρs * X] / (∏*Dm*(t – c))

   Where,
   Do,Di = internal and external diameter of shell
   ρs = Density of shell material
   Dm = mean diameter of shell

   b) Compressive stress due to wt of insulation at height ‘X’

   $f_{d(ins)}$ = (∏*Dins*tins* ρins) /(∏ *Dm*(t – c))

   Where,
   Dins,tins, ρins = diameter, thickness, & density of insulation

   c) Compressive load due to liquid in column and trays up to a height X

   $f_{d(liq+tray)}$ = ∑(wt of (liq.+tray) per unit height(X))/ (∏*Dm*(t-c))

   ∑(wt of (liq.+tray) per unit height(X) = (no of tray up to ht X) * (Wt of one tray +liquid on that tray)*((∏/4)*Di^2)
   No of trays up to height X = [(X – top disengaging space)/tray spacing] + 1

d) Compressive stress due to attachment such as internals, top head, platforms and ladders up to a height of X

$f_{d(att)}$ = (∑wt of attachment per unit height (X)) / (∏*Dm* (t-c))

TOTAL COMPRESSIVE DEAD WEIGHT STRESS

fdx = fds + fd(ins) + fd(liq+tray)+ fd(att)

3. Stresses due to wind load at distance X

Wind pressure

Up to 20m height: 40-100 kgf / cm^2

>20m : 100-200 kgf/cm^2

wind load = 0.7 * pw * Do * X

where,

pw = wind pressure

Bending Moment created by wind force at X from top

Mwx = (wind load * distance) / 2

= (0.7*pw*Do*X^2) / 2

stresses induced by wind load

fwx = Mwx /Z

= ((0.7*pw*Do*X^2)/2)/ ((∏/4)*Do^2*(t-c))

where, Z = modulus of section

= (∏/4)Do^2(t-c)

The stresses will be compressive on downwind side and tensile on the upwind side

4. Stresses due to eccentricity of loads (tensile or compressive according to the position of load)

fe = w_e *e / ((∏/4)*Do^2*(t-c))

where,

w_e = summation of eccentric loads

e= eccentricity

5. Stresses due to seismic loads

fsx = Msx/ ((∏/4)*Do^2*(t-c))

where,

Msx = (CWX^2 /3)* [(3H –X)/H^2]

Where

C = seismic coefficient

W = total wt of column

H = Height of column

A. DETERMINATION OF HEIGHT X

Maximum axial tensile stresses

ftmax = fap –fdx + fwx + fex + fsx (For internal pressure)

ftmax = fwx + fex + fsx – fdx – fap (For external pressure)

Now ftmax <= J*ft(allow)
Where, J = joint efficiency
fwx –fdx +(-) fap + fex + fsx = J*ft(allow)

so,

$$J*f(allow) = [1.4*pw*X^2] / [\prod*Do*(t - c)] + (-) (p*Di*) / (4*(ts-c)) - fdx + fex + fsx$$

This is of the form
$aX^2 + bX + c = 0$
so its solution is $X = (-b + - \sqrt{b^2 - 4ac}) / 2a$

Maximum actual compressive stress
fcmax = fdx - fap + fwx + fex + fsx (For internal pressure)
fcmax = fdx + fap + fwx + fex + fsx (For external pressure)

where , fcmax <= J*fc(allow)

$$fc(allow) = (1/12)*(E/\sqrt{3*(1-\mu^2)}) * [(t - c) / (Do/2)]$$

fdx + (-)fap + fwx + fex + fs = J*fc(allow)

This is of the form
$aX^2 + bX + c = 0$
so its solution is $X = (-b + - \sqrt{b^2 - 4ac}) / 2a$

final value of X is lesser of the two