P-III ① [illegible]

DISTILLATION

Separation of two or more components of a mixture by distillation when the materials concerned have a definite vapour pressure, has been one of the most widely used processes. Separations which are easy can be accomplished by simple distillation while more difficult separations are made b fractionation which is a processes of multipl distillation for effecting the separation of two or more volatile components. Distillation is usually a batch process and may be carried out in a pipe still or a cylindrical vessel. Multiple distillation is carried out i a fractionating column, when continuous interchange between liquid from a condens and vapour from a still or reboiler lea o the concentration of the lower boiling onstituents of a mixture at the top of olumn. The aim of the column design bring about intimate contact between pour and liquid, while at the same me keeping both stream flowing even opposite direction.

STRESSES IN COLUMN SHELL

[illegible] vertical vessel, [illegible] designed as a tall vertical vessel or are [illegible] a self supporting structure [illegible] situation where any other [illegible] interference caused by any other [illegible] a self appropriate to design it as [illegible] supporting structure, [illegible] column may stresses in the shell of [illegible] be assessed as follows.

(a) circumferential and axial stresses due to Internal pressure or vacuum inside the vessel

(b) compressive stresses resulting from dead Load such as the weight of the vessel and its' contents, the weight of insulation, and attached equipment

(c) stresses resulting from bending moment caused by wind loads acting on the vessel and its attachments.

(d) stresses due to eccentricity as a result of Irregular Load distribution

(e) Stresses due to seismic (earthquake) forces.

The above stresses may be combined to establish the final controlling stress. The stresses due to pressure act both in the circumferential and axial direction of the shell.

It is possible to combine all [illegible] stresses on the basis of linear [illegible]. However, the stresses in the axial direction are not the same over the entire height of the shell and the resultant stresses in the shell are therefore likely to increase towards the bottom of the shell.

In analysing the stresses at various heights of the shell, calculations are made beginning at the top of the column. The selection and thickness of the top head is based on the internal pressure or vacuum. The minium shell thickness in the upper portion of the column is usually determined by the circumferential stress resulting from internal pressure or vacuum. The shell plate thickness at the top of the column can be specified by taking into consideration the corrosion allowance. The thickness for lower portions of the column is determined by taking into consideration all the other stresses.

DETERMINATION OF SHELL THICKNESS (at different Heights)

[illegible]

In determining the stresses at various heights of the shell, calculations are made beginning at the top of the column. The necessary shell thickness of the top head is based on the internal pressure or vacuum. The minimum shell thickness in the upper portion of the column is usually determined by the circumferential stress resulting from internal pressure or vacuum. The shell plate thickness at the top of the column can be specified by taking into consideration the corrosion allowance. The thickness required for lower portions of the column is determined by taking into consideration all the other stresses.

DETERMINATION OF SHELL THICKNESS (at different heights)

The usual criterion of shell thickness is maximum tensile stress which should not exceed the allowable tensile stre which should not exceeds the allowable tensile stress in the material of the shell. The maximum thickness is at the top of the shell and is determined only on the basis of circumferential stress

$$t_s = \frac{p D_i}{2fJ - p} + c$$

t_s → shell thickness

p → design pressure

D_i → Internal diameter of shell

f → allowable stress

J → Joint efficiency.

c → corrosion allowance

This thickness may be satisfactory up to a certain distance from the top of the shell. In case of vacuum or low pressure the thickness ts will be much less. A minimum value for Thickness may be assumed in such cases [illegible] to maintain [illegible]uction.

In order to evaluate the distance x it is necessary to determine the combined maximum stress. The [illegible] stresses at the distance x in the

[illegible]

[illegible]

$$[illegible] = \frac{[illegible]}{[illegible]}$$

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

$$[illegible] = \frac{[illegible]}{[illegible]}$$

$$= \frac{[illegible]}{[illegible]}$$

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

$$= \frac{[illegible]}{[illegible]}$$

axial direction [illegible] [illegible]

AXIAL STRESS DUE TO INTERNAL

$$f_{ap} = \frac{PD}{4(t_s - c)}$$

which is the same [illegible]

- due to column height

STRESS DUE TO DEAD LOADS

④ Compressive stress due to weight of the shell up to distance 'X'

$$f_{ds} = \frac{\text{weight of the shell}}{\text{cross - section of shell}}$$

$$= \frac{\pi/4\,(D_o^2 - D_i^2)\,\rho_s(X)}{\pi/4\,(D_o^2 - D_i^2)}$$

where

Do and Di are Internal and external diame

of shell

$\rho_s \Rightarrow$ density of shell material

Dm = mean diameter of the shell

$$= \frac{\text{weight of the ~~Shell~~ Insulation per unit height}\times}{\pi D_m (t_s - c)}$$

When [illegible]
tensile stress [illegible]
shell. The maximum [illegible]
the top of the shell [illegible]
only on the basis of [illegible]

$$t_s = \frac{P D_i}{2fJ - P} + C$$

t_s → shell thickness

P → design pressure

D_i → internal diameter of shell

f → allowable stress

J → joint efficiency

C → corrosion allowance

This thickness may be satisfactory up to a certain distance from the top of the shell in case of vacuum or low pressure the thickness t_s will be much less. A minimum value of thickness may be assumed in such cases [redacted]uction.

In order to evaluate the distance 'x' it is necessary to determine the combined maximum stress. The [illegible] stresses at the distance 'x' in the shell.

axial direction are given in the following

AXIAL STRESS DUE TO PRESSURE

$$f_{ap} = \frac{PD}{4(t_s - c)}$$

This is the same throughout over the column height

STRESSES DUE TO DEAD LOADS

ⓐ Compressive stress due to weight of shell up to distance 'x'

$$f_{ds} = \frac{\text{weight of the shell}}{\text{cross-section of shell}}$$

$$= \frac{\pi/4 (D_o^2 - D_i^2) \rho_s (x)}{\pi/4 (D_o^2 - D_i^2)}$$

where

Do and Di are Internal and external diameter of shell

$\rho_s \Rightarrow$ density of shell material

Dm = mean diameter of the shell

$$= \frac{\text{weight of the shell Insulation per unit height } x}{\pi D_m (t_s - c)}$$

(b) Compressive stress due to [illegible] insulation at height x

$$f_{d(ins)} = \frac{\pi D_{ins} t_{ins} \rho_{ins} x}{\pi D_m (t_s - c)}$$

$$= \frac{\text{weight of insulation per unit height } (x)}{\pi D_m (t_s - c)}$$

D_{ins}, t_{ins} and ρ_{ins} are the diameter, thickness and density of insulation respectively

D_m = mean diameter of shell

$D_{ins} \simeq D_m$ for large diameter columns

(c) Compressive stress due to liquid in the column up to a height 'x'

$$f_{d(liq)} = \frac{\Sigma \text{ liquid weight per unit height } x}{\pi D_m (t_s - c)}$$

(d) Compressive stress due to attachment such as Internals top head, platforms and ladders up to a height of x

$$f_{d(att)} = \frac{\Sigma \text{ weight of attachment per unit height } x}{\pi D_m (t_s - c)}$$

total compressive dead weight stress

$$f_{dx} = f_{ds} + f_{d(ins)} + f_{d(liq)} + f_{d(att)}$$

Stresses due to wind load at a distance 'x'

$$f_{wx} = \frac{M_w}{Z}$$

when Z – modulus of section for the area of shell

$$= \frac{\pi}{4} D_o^2 (t_s - c)$$

M_w is the bending moment due to wind load at a distance x

The column is considered as a Uniformaly loaded cantilever beam

The stress will be compressive on the down wind side and velocity, for calculations [illegible] of 125 kg per square meter on a flat surface may taken as a satisfactory. For round vessel a shape factor of 0.7 may be used. The projected area of either uninsulated or insulated tower may be taken for operation of wind load

$$M_w = \frac{\text{wind load} \times \text{distance}}{2}$$

To allow a maximum deflection in mm of (5 x overall heights of column in meter) for vertical column. A vibration analysis shall be made on column with 30 meters overall height and above and height to diameter ratio ranging from 15 to 30. The total deflection at the top of the column is calculated as an algebraic sum by following equation

$$\delta = \sum_{1}^{n} \left\{ \left[\frac{WL^3}{8EI} + \frac{(\Sigma W)L^3}{3EI} + \frac{(\Sigma M)L^3}{2EI} \right] + \sum_{1}^{1} \left[\frac{WL^2}{6EI} + \frac{(\Sigma W)L^2}{2EI} + \frac{(\Sigma M)L}{EI} \right] (L_{1+1}) \right\}$$

when

δ → deflection

n → number of sections from top in which the column is suitable divided.

W → wind load on the section

ΣW → concentrated load on the section (due to moment of the section above)

I → moment of interia of the cross section

E → modulus of elasticity

[illegible]

[illegible] to [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

COLUMN INTERNAL DETAILS

Various components known as internals, located inside a distillation column are designed to create an intimate contact between the vapour and liquid while at the same time keeping these streams flowing evenly in opposite directions. According to the mode of contact between vapor and liquid, columns can be classified as equilibrium stage columns and differential stage column. The interfacial mass transfer between phases takes place in stages on a series of plates or trays or in the spacing of either. In differential columns, the mass transfer between phases take place gradually throughout the entire height of column

- [illegible]
  [illegible]
- [illegible] column

[illegible] tray spacing [illegible] for the conventional tray columns is [illegible] for columns with [illegible] internal diameter at a [illegible] spacings of [illegible] are preferred for easier tray [illegible]. When the required column diameter is less than 750 mm conventional tray installation becomes impossible and a cartridge assembly is necessary. These are expensive and difficult to maintain. In particular if corrosion of fouling is expected (for 600 mm diameter), a differential column (packed column) is preferable.

Equillibrium stage column

Depending on the method of the method of contact and the flow of vapour and liquid, the contacting equipment may be classified as follows

Plates without down comers

These are generally flat circular plates of a diameter slightly smaller than the internal diameter of column. They are provided with a large number of holes or slots through which the liquid and vapour pass

The turbogrid is a flat plate with the long rectangular slots. The grid can also be formed by closely spaced parallel bars located in one circular plane, instead of single flat plate.

PLATES WITH DOWN COMERS

These are circular Flat plates or trays with provision of passages known as down comers for the downward flow of the liquid. The down-comer area for each plate will be generally limited to 10% of the total area of the plate.

ⓐ Downcomers [illegible]

The function of the down comer is to provide a passage for the down ward flow of the liquid from a top tray to a lower tray. A projection of a corresponding shape, provided on the downcomer acts as an exit weir. A radial flow is created by downcomers placed at the centre and around the circumference of alternate trays. Multiple down comer trays are also designed.

b) Contacting devices

i) Bubble caps :→ The area of the plate or tray, between the inlet and exit

Wells is provided with a large number of holes over which cylindrical risers, chimneys are placed. Caps in the form of inverted cups located over the risers.

(ii) Valves

These permit effective mixing of liquid and vapor over a wide range loading

(iii) Sieve plates

There is no separate contacting device in these types of plates. Instead of large number of holes distributed uniformaly over the plate act as passages for vapours but at the same time the liquid is prevented from draining through the holes

(c) Distribution baffles.

The spacing by 2.5cm, the gaps are closed by redistribution baffles. The clearance between these baffles and the caps should be equal to the cap spacing.

FEED SYSTEMS

Feed nozzles are sized for a flow velocity of 1meter per second. Liquid feed to the column is above the top tray and at inter-mediate position A pipe is located above the top tray, and just opposite the inlet weir, feeds the top tray, A baffles is provided opposite the feed pipe to create , [illegible] be a [illegible] trays [illegible] in [illegible] normally placed below the bottom tray [illegible] is designed to [illegible] the spacing of [illegible] bottom [illegible] to clean.

DRAIN OFFS [illegible] the draining of [illegible] the column is ensured by [illegible] from the bottom of the column [illegible] or by a drain pan [illegible] use as a [illegible] it should be located as to [illegible] prevent [illegible] vapour against the [illegible]

MANHOLES AND HANDHOLES

Trays should be inspected for corrosion, fouling and damage a few weeks after start up and at six monthly intervals thereafter, trays should be removable from above and below. Manholes are necessary at intervals for the column. Usually each manhole serves 15-20 trays. The manhole size is usually 450 mm minimum diameter or 300 x 400 mm opening. It is to provide a large hand hole at the bottom of each bed. Each manhole must have a platform for access.

DIFFERENTIAL COLUMN

PACKED COLUMNS :- Instead of using plates of trays, this column is packed with suitable packing material. The liquid flows downward over the surface of the packing in the form of thin films, while the vapour rises. The liquid is introduced at the top of packing by means of a distributing plate and the vapour is introduced beneath a grid which supports the packing. Packed columns are particularly useful in the field of vacuum distillation. In corrosion problems packing are most suitable.

LIQUID DISTRIBUTORS :-

Various methods are adopted for distribution of the liquid to effect proper wetting of the packing. Pipe arrangement, flat perforated plates, or weir type distributor are commonly used. For column diameters less than 60 cm a single pipe nozzle,

LIQUID REDISTRIBUTION AND WALL WIPERS

Despite its efficient distribution on the top plate, the liquid has tendency to drift towards the wall as it moves downwards. After a certain vertical height of liquid travel, liquid concentration falls considerably in the inner cross section

It is therefore necessary to direct the liquid towards the centre after it has travelled a certain distance. Redistributors and wall wipers are provided to bring the liquid back to the centre from the wall.

SUPPORT PLATES

These plates are located at the bottom of the column and support the packings. Conventional type of support pla are perforated plate.

HOLD - DOWN PLATES

A hold- down plat on top of a packed section serves an important purpose by resting directly on of the packing restraining the bed. Th free area of the plate is decided between as large a value of the area possible and a value small enough prevent the packing passing through plate.