CH2407 Process Equipment Design II

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Design of Distillation Column

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Steps Involved

1. Specify the degree of separation required: set product specifications.

2. Select the operating conditions: batch or continuous; operating pressure.

3. Select the type of contacting device: plates or packing.

4. Determine the stage and reflux requirements: the number of equilibrium stages.

5. Size the column: diameter, number of real stages.

6. Design the column internals: plates, distributors, packing supports.

7. Mechanical design: vessel and internal fittings.

Reflux Considerations

- Reflux ratio (R):

$$R = \frac{\text{flow returned as reflux}}{\text{flow of top product taken off}}$$

- The number of stages required for achieving a given separation depends on R

- Total reflux - all the condensate is returned to the column as reflux. No feed, and no product taken out.
  - Though not a practical operating condition, it is a useful guide to get the likely number of stages that will be needed


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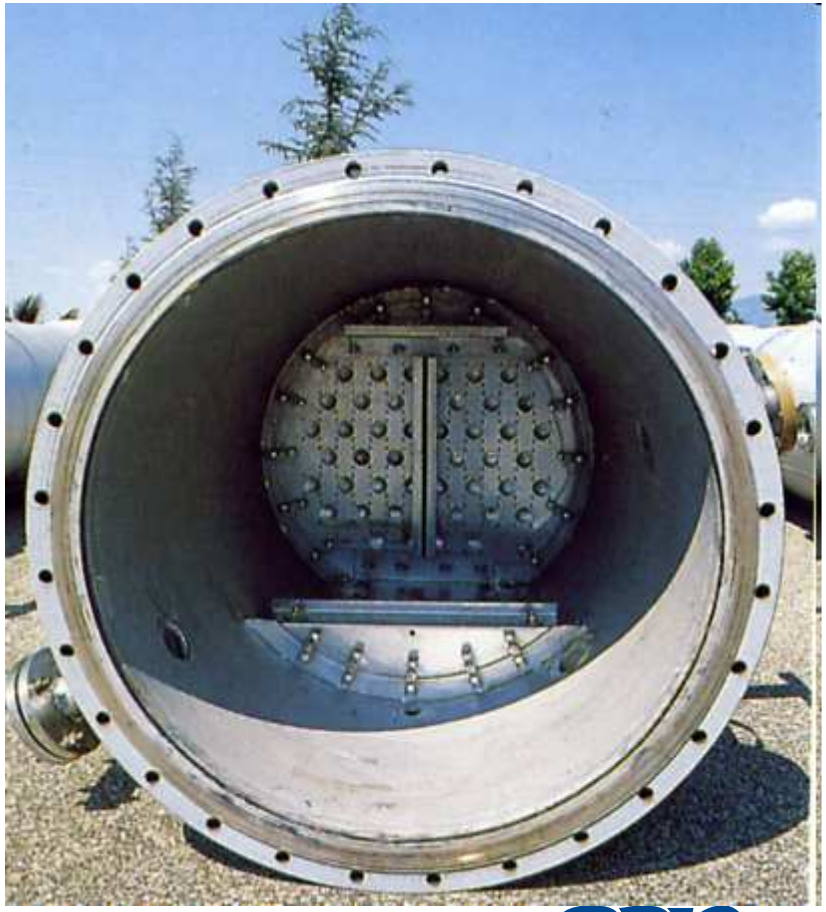
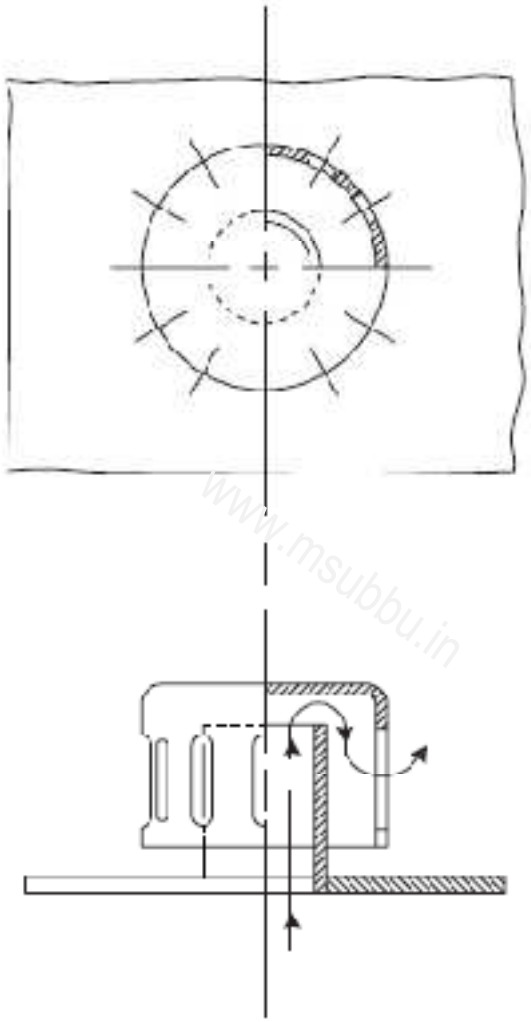


Bubble-cap Tray



Bubble cap

Bubble-cap in Operation

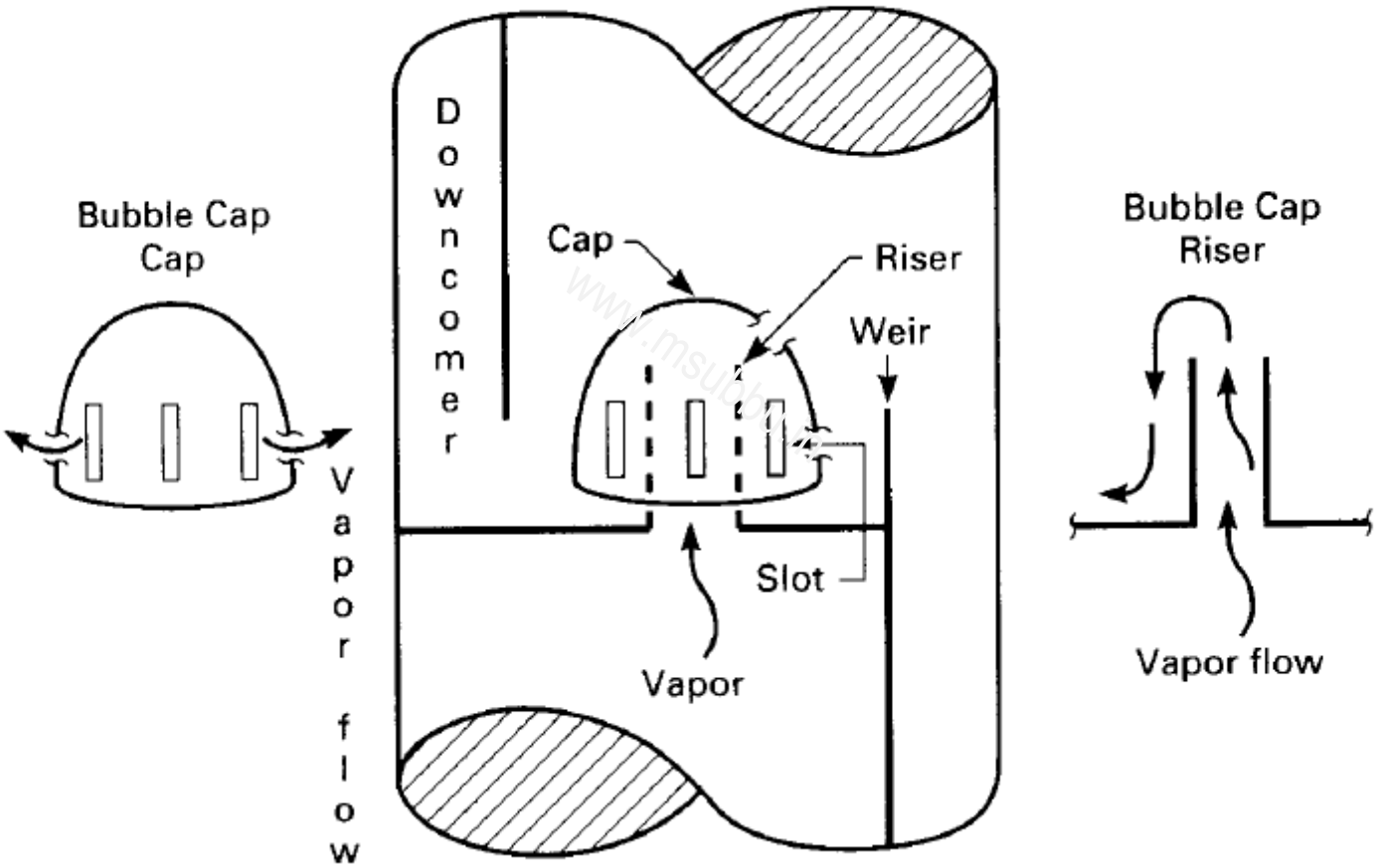
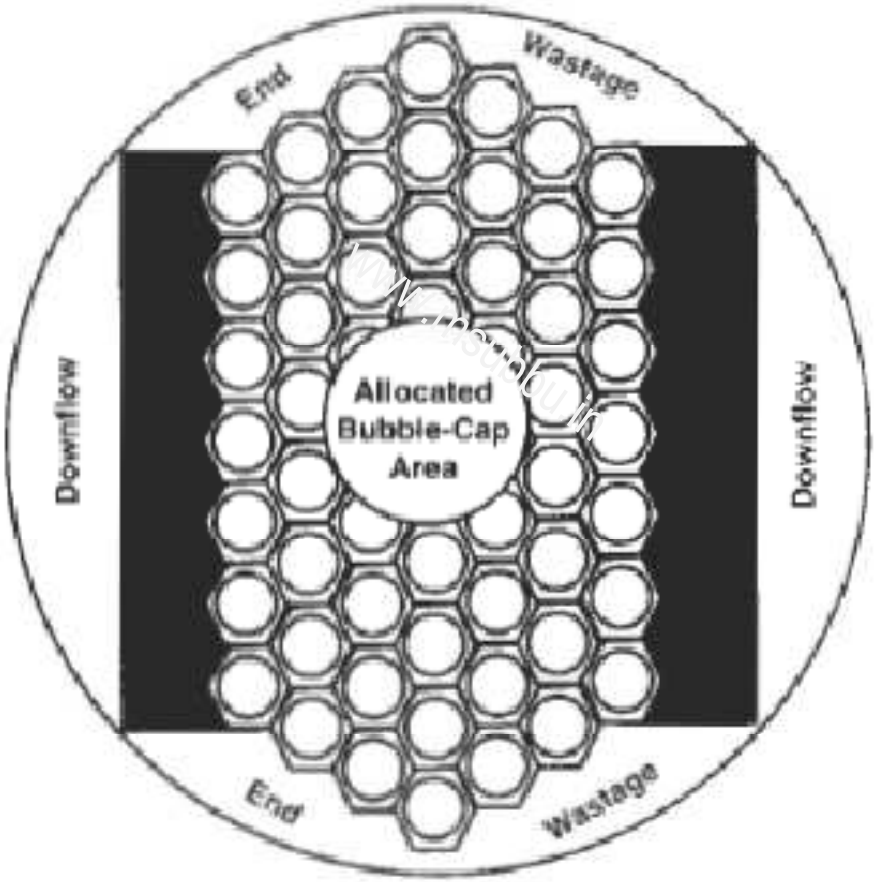


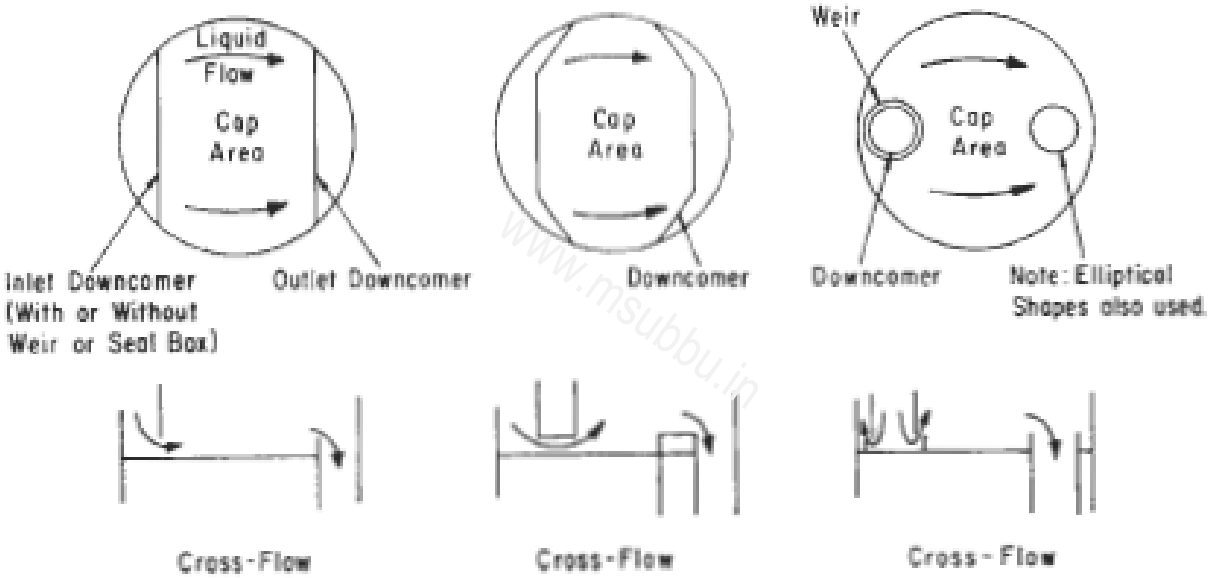
Plate Spacing

- Ranges from 0.15 – 1 m
- For columns above 1 m dia, plate spacing of 0.3 – 0.6 m is normally used; 0.5 m can be taken as the initial estimate
- A larger spacing will be needed between certain plates to accommodate feed and side-streams arrangements, and for man-ways

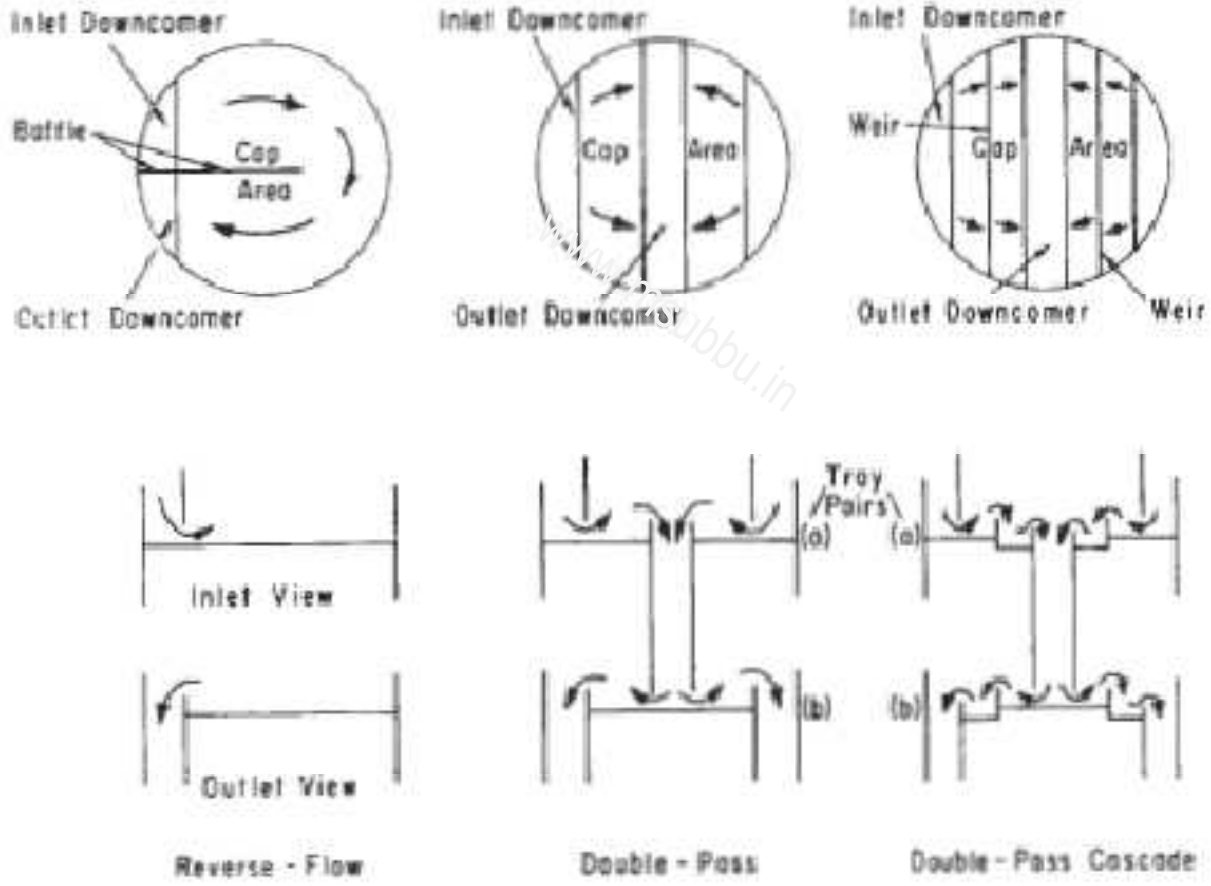
Tray Area


End
Wastage
Downflow
Allocated
Bubble-Cap
Area
Downflow
End
Wastage

Tray types by liquid paths



Tray types by liquid paths (contd.)



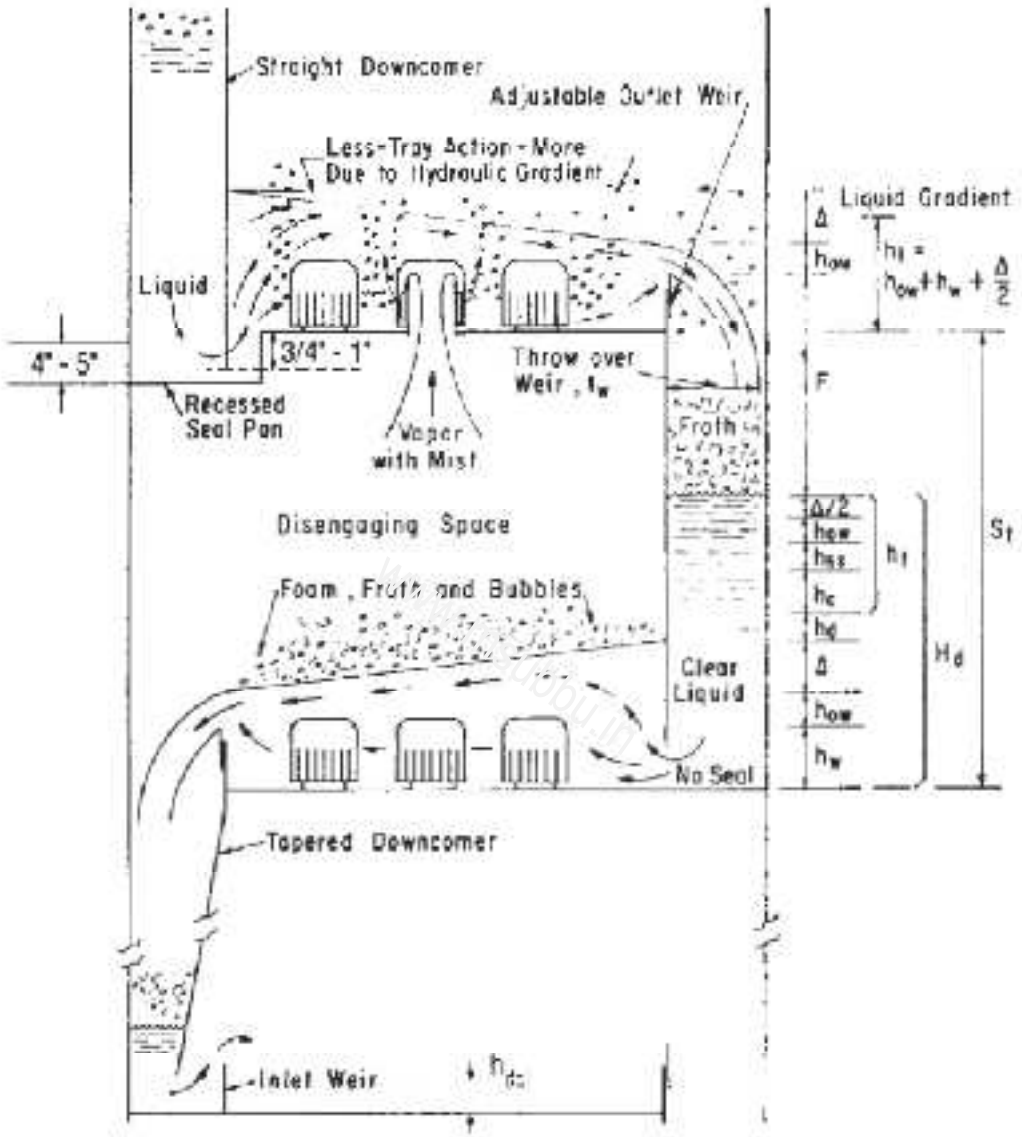
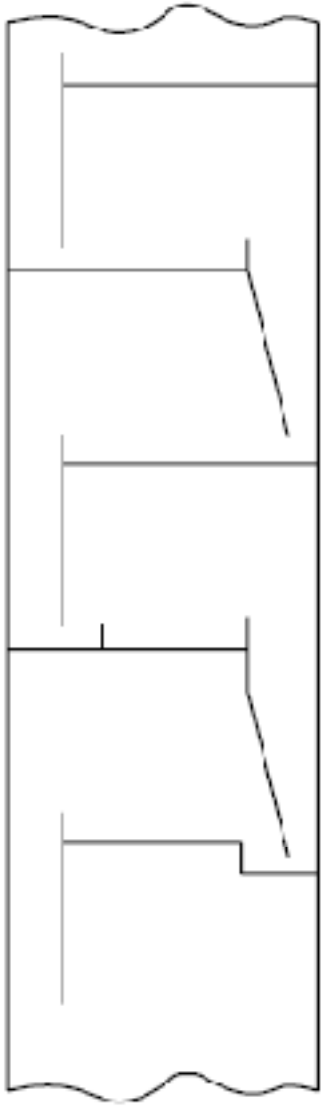


Figure 8-63. Bubble cap tray schematic—dynamic operation.

Downcomer - designs



(a) Vertical apron

(b) Inclined apron

(c) Inlet weir

(d) Recessed well

Column Diameter

- The principal factor which decides is vapor flow rate
- The vapour velocity must be below that which would cause excessive liquid entrainment or a high-pressure drop
- Maximum allowable superficial vapor velocity based on liquid entrainment and pressure drop consideration: (Souders and Brown equation)

Souders and Brown equation

$$\hat{u}_v = (-0.171 l_t^2 + 0.27 l_t - 0.047) \left[\frac{(\rho_L - \rho_v)}{\rho_v} \right]^{1/2}$$

where $\hat{u}_v$ = maximum allowable vapour velocity, based on the gross (total) column cross-sectional area, m/s,

l_t = plate spacing, m, (range 0.5–1.5).

The column diameter, D_c, can then be calculated:

$$D_c = \sqrt{\frac{4\hat{V}_w}{\pi \rho_v \hat{u}_v}}$$

where $\hat{V}_w$ is the maximum vapour rate, kg/s.

The Souders-Brown [67] empirically correlated maximum allowable mass velocity is represented in Figure 8-82 for "C" Factor determination, and in Figure 8-83 for solution of the relation:

$$W = C\,[\rho_v\,(\rho_L - \rho_v)]^{1/2} \qquad (8\text{-}219)$$

where W = maximum allowable mass velocity through column using bubble cap trays, lb/ft^2 cross-section) (hour)

C = factor from Figure 8-82 related to entrainment

ρ_v = vapor density, lbs/ft^3

ρ_L = liquid density, lbs/ft^3

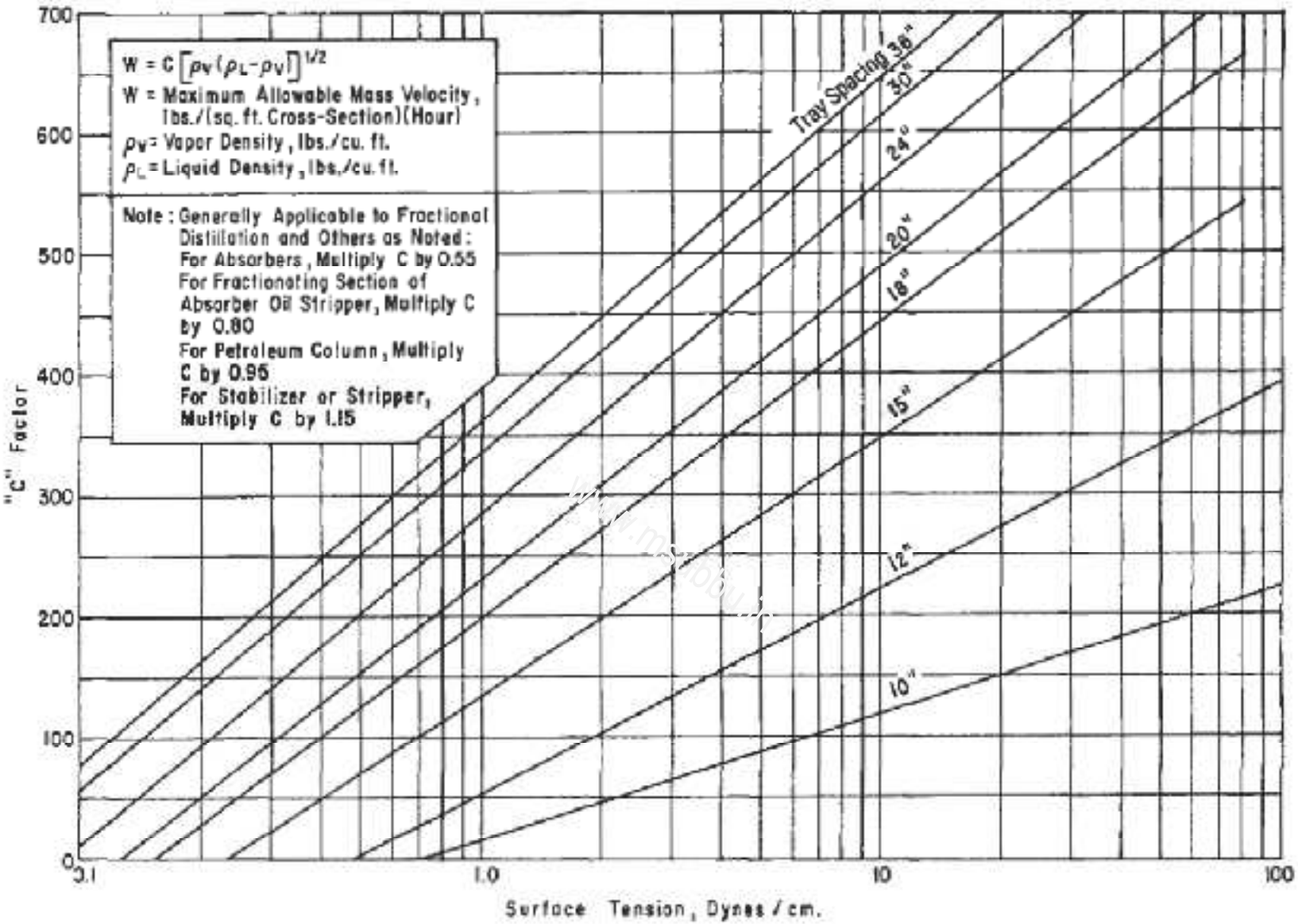


Figure 8-82. "C" factors for column diameter using bubble cap trays. Adapted by permission, The American Chemical Society, Souders, M., Jr., and Brown, G. G. *Ind. and Eng. Chem.* V. 26 (1934), p. 98, all rights reserved.

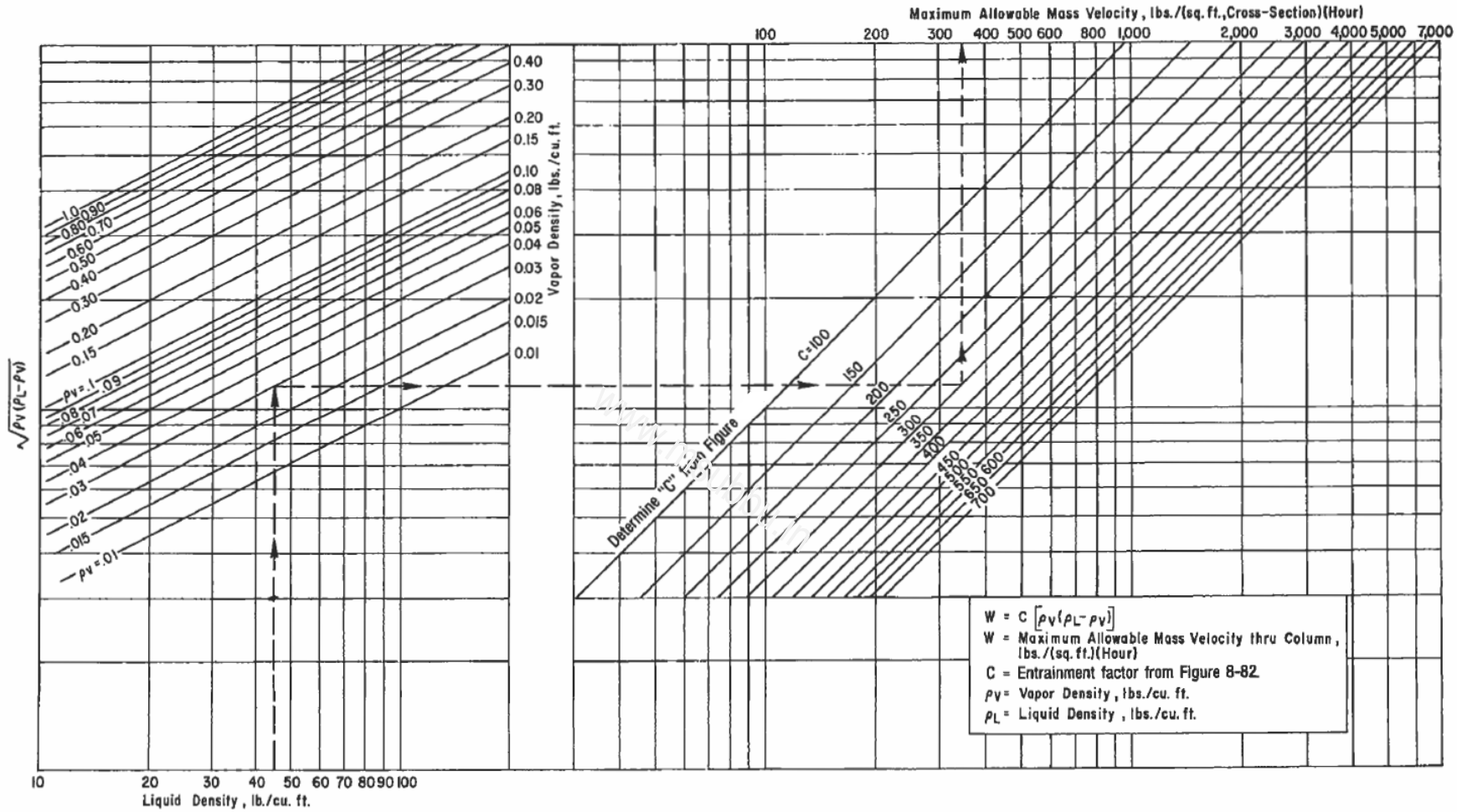


Figure 8-83. Allowable mass velocity for fractionation, absorption, and stripping columns.