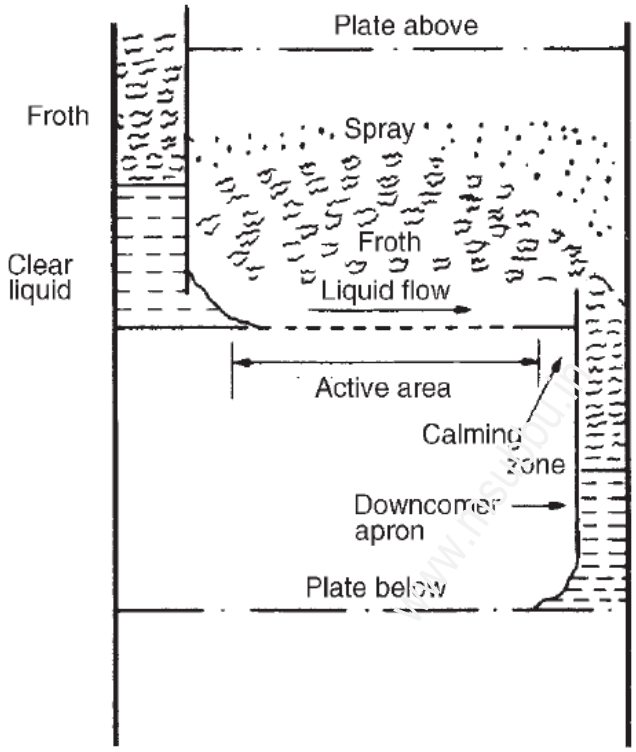
Bubble-cap Distillation Column Design Guidelines

(Reference: R.K.Sinnot, Coulson & Richardson's Chemical Engineering, Volume 6, Edition 4, Butterworth-Heinemann, 2005)

Plate Contactors:

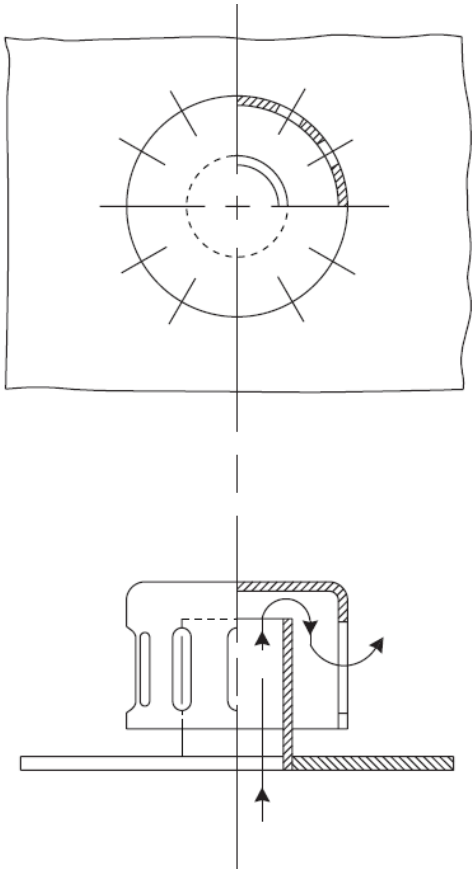
Cross-flow plates are the most common type of plate contactor used in distillation and absorption columns. In a cross-flow plate the liquid flows across the plate and the vapour up through the plate. A typical layout is shown in Figure. The flowing liquid is transferred from plate to plate through vertical channels called "downcomers". A pool of liquid is retained on the plate by an outlet weir.



Three principal types of cross-flow tray are used, classified according to the method used to contact the vapour and liquid: sieve plates, bubble-cap plates, and valve plates.

Bubble-cap plates:

In which the vapour passes up through short pipes, called risers, covered by a cap with a serrated edge, or slots. The bubble-cap plate is the traditional, oldest, type of cross-flow plate, and many different designs have been developed. The most significant feature of the bubble-cap plate is that the use of risers ensures that a level of liquid is maintained on the tray at all vapour flow-rates.



Column Sizing

An estimate of the overall column size can be made once the number of real stages required for the separation is known.

Plate spacing

The overall height of the column will depend on the plate spacing. Plate spacings from 0.15 m (6 in.) to 1 m (36 in.) are normally used. The spacing chosen will depend on the column diameter and operating conditions. Close spacing is used with small-diameter columns, and where head room is restricted; as it will be when a column is installed in a building. For columns above 1 m diameter, plate spacings of 0.3 to 0.6 m will normally be used, and 0.5 m (18 in.) can be taken as an initial estimate. This would be revised, as necessary, when the detailed plate design is made. A larger spacing will be needed between certain plates to accommodate feed and side streams arrangements, and for man-ways.

Column diameter

The principal factor that determines the column diameter is the vapour flow-rate. The vapour velocity must be below that which would cause excessive liquid entrainment or a high-pressure drop. The flooding condition fixes the upper limit of vapour velocity. A high vapour velocity is needed for high plate efficiencies, and the velocity will normally be between 70 to 90 per cent of that which would cause flooding. For design, a value of 80 to 85 per cent of the flooding velocity should be used.

The Souders-Brown empirically correlated maximum allowable velocity is represented in the following figures Fig. 8.82 for ‘C’ factor determination, and Fig. 8.83 for solution of the relation as given below:

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

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

To calculate the column diameter an estimate of the net area A_n is required.

Plate Areas:

The following areas terms are used in the plate design procedure:

A_c = total column cross-sectional area,
A_d = cross-sectional area of downcomer,
A_n = net area available for vapour-liquid disengagement, normally equal to $A_c - A_d$, for a single pass plate,
A_a = active, or bubbling, area, equal to $A_c - 2A_d$ for single-pass plates,

From the chart, maximum mass velocity is estimated. Operating mass velocity is then calculated by multiplying this with the fraction of flooding (about 0.85). Mass flow rate divided by mass velocity gives the required column cross sectional area, from which diameter of the column can be calculated.

Where the vapour and liquid flow-rates, or physical properties, vary significantly throughout the column a plate design should be made for several points up the olumn. For distillation it will usually be sufficient to design for the conditions above and below the feed points.

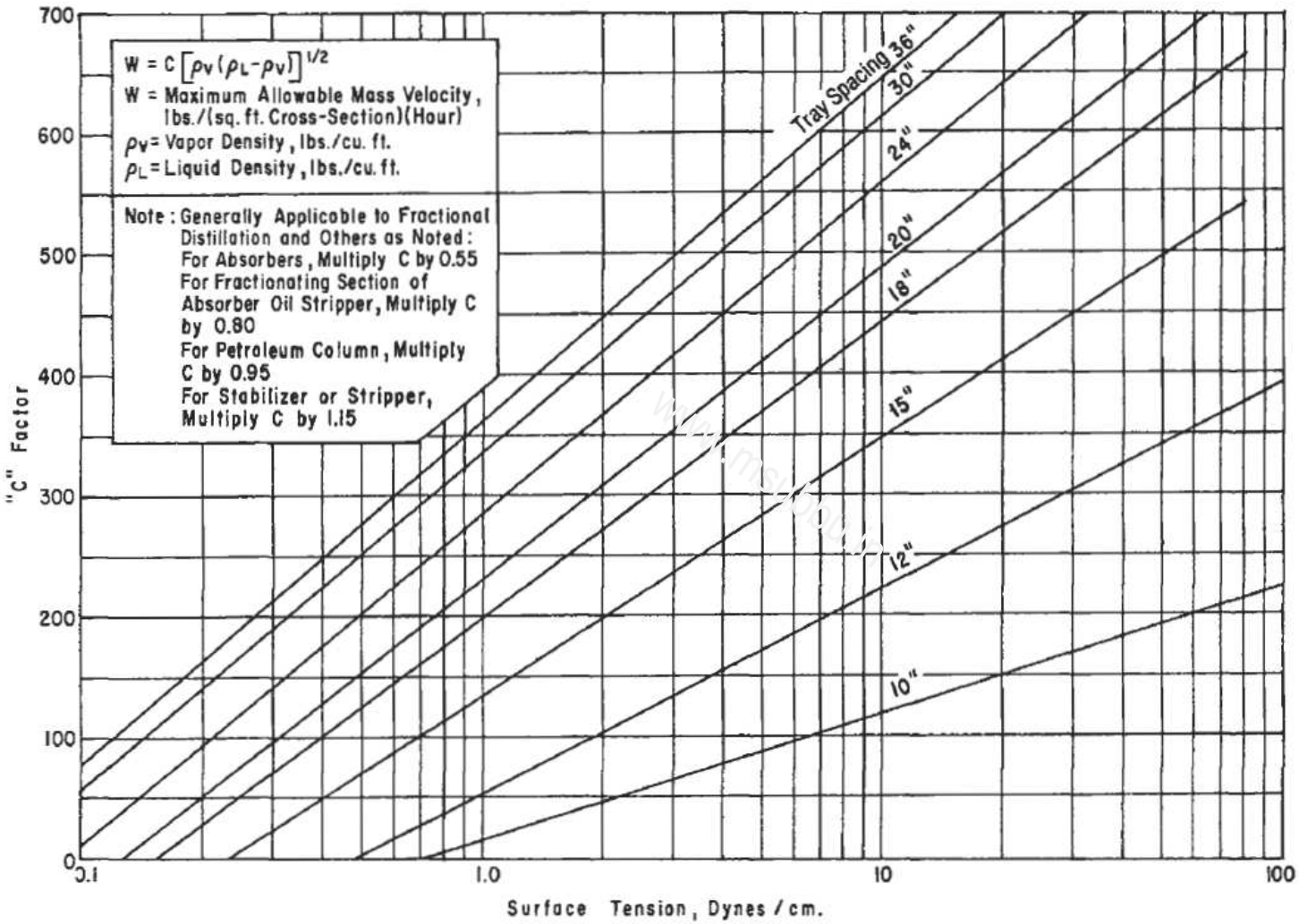


Figure 8-82. "C" factors for column diameter using bubble cap trays. Adapted by permission, The American Chemical Society, Souders, M., Jr., and Brown, G. G. *Ind. and Eng. Chem.* V. 26 (1934), p. 98, all rights reserved.

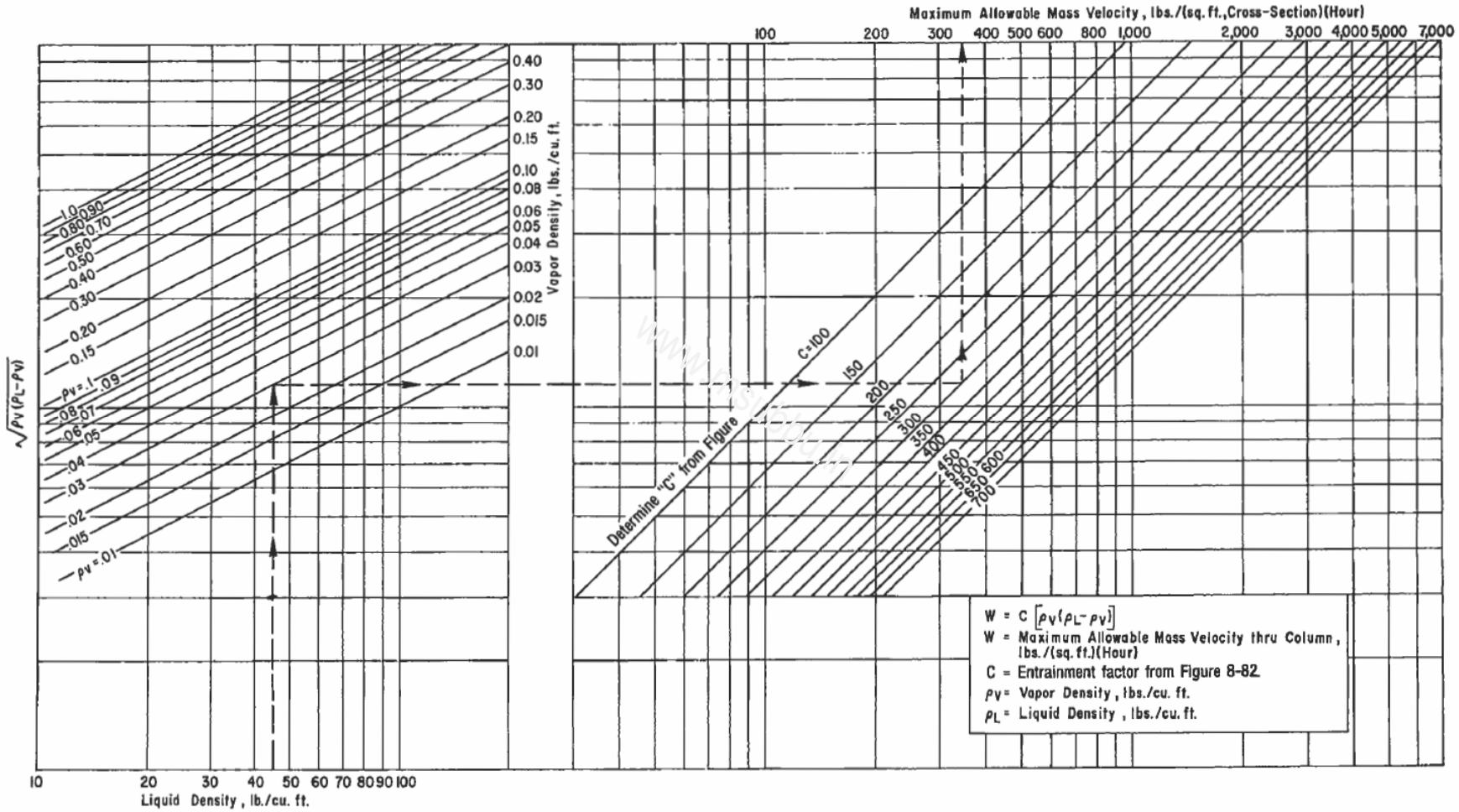


Figure 8-83. Allowable mass velocity for fractionation, absorption, and stripping columns.