Packed Bed Absorber Design Guidelines

(Reference: S.B.Thakore and B.I.Bhatt, Introduction to Process Engineering and Design, Tata McGraw Hill Publishing Company Ltd., New Delhi, 2007)

Process design of packed tower absorbers involve two major steps:
(i) determination of tower diameter, and
(ii) determination of height of packing

(i) Tower Diameter:
For packed bed absorber, tower diameter is determined based on flooding velocity. Actual velocity of gas through the packed tower is kept about 60 to 70% of flooding velocity. Recommended range of pressure drop for this type of absorber is 15 to 50 mm water column per m of packing height depending on the application.

At the time of flooding, one of two conditions may occur:
(i) Liquid phase may occupy the entire cross section of tower. Continuous phase of liquid body rises in the column. The change in pressure drop is very high with only a slight change in gas rate.
(ii) Phase inversion occurs as gas bubbles through the liquid. Pressure drop rises rapidly as phase inversion occurs.

To find the tower diameter, at first the following factor is determined.

$$F_{LV} = \frac{L_w^*}{V_w^*}\sqrt{\frac{\rho_v}{\rho_L}}$$

Where,
L_w^* = mass velocity of liquid, kg/(m^2.s)
V_w^* = mass velocity of gas, kg/(m^2.s)
ρ_v = density of gas, kg/m^3
ρ_L = density of liquid, kg/m^3

Using the generalized pressure drop correlation, available in the form of figure as given below, the factor K_4 is estimated (for a given pressure drop).

$$K_4 = \frac{13.1 (V_w^*)^2 F_p \left(\frac{\mu_L}{\rho_L}\right)^{0.1}}{\rho_v(\rho_L - \rho_v)} \longrightarrow \quad (1)$$

where V_w^* = gas mass flow-rate per unit column cross-sectional area, kg/m^{2}s
F_p = packing factor, characteristic of the size and type of packing,
μ_L = liquid viscosity, Ns/m^2
ρ_L, ρ_v = liquid and vapour densities, kg/m^3

From Eqn.(1), V_w^* is calculated.

Gas flow rate / gas mass velocity gives the required cross sectional area of column. Diameter is then estimated from the cross sectional area.

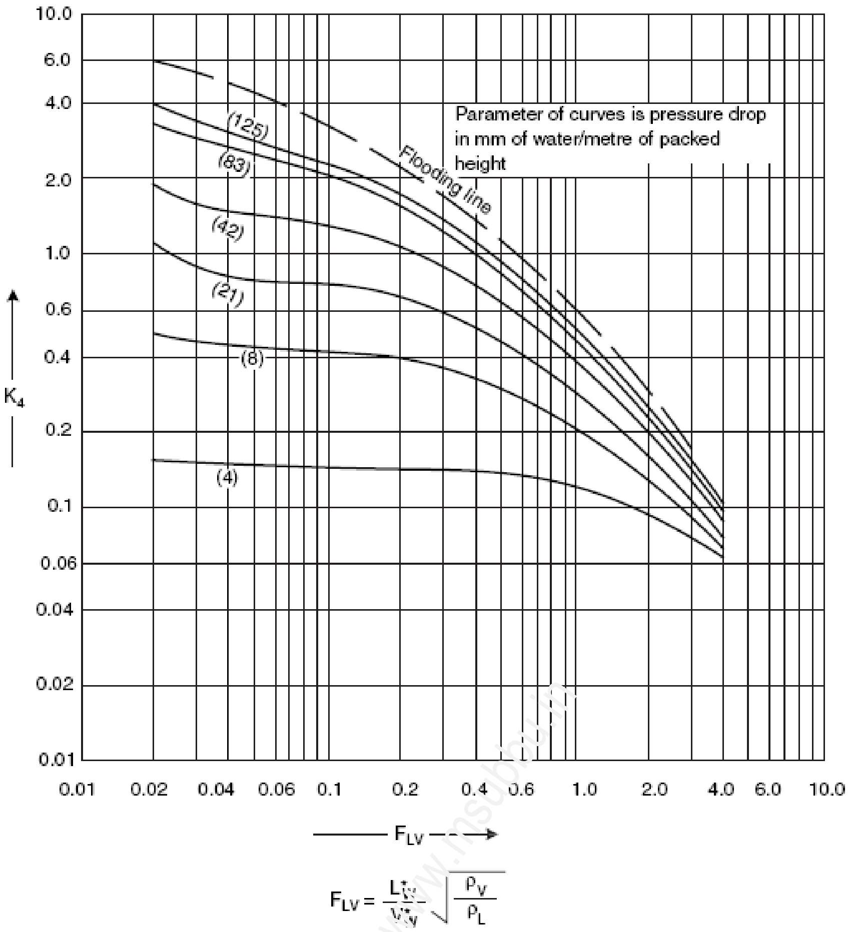

Figure 11.44. Generalised pressure drop correlation, adapted from a figure by the Norton Co. with permission

(Source: Coulson & Richardson, Chemical Engineering Vol.6, Ed.4)

(ii) Tower Height

Height of packing required for the given absorption duty is determined by using one of the following equations.

$$Z = H_{tOG} \cdot N_{tOG}$$
$$Z = H_{tOL} \cdot N_{tOL}$$

If overall resistance to mass transfer is controlled by the gas film, then the first equation is used to find the packing height *Z* for the desired absorption duty.

N_{tOG} can be obtained from following relation.

$$N_{tOG} = \int_{y_2}^{y_1} \frac{dy}{y - y_e}$$

In the special case, if equilibrium curve and operating line, both can be assumed as straight lines, N_{tOG} can be calculated by equation:

$$N_{\mathrm{tOG}} = \frac{\ln\left[\frac{y_1 - mx_2}{y_2 - mx_2}\left(1 - \frac{1}{A}\right) + \frac{1}{A}\right]}{1 - 1/A}$$

Determination of H_{OG} or H_{OL}:

Many different correlations are available to find out the height of transfer unit or to find out the mass transfer coefficients. But, these correlations are not as reliable as the same for finding the heat transfer coefficients. Hence, it is suggested to find out the height of transfer unit or mass transfer coefficient by using the correlation which is derived for the same or a similar system. But, if the correlation for the same or a similar system is not available, then, use more than one generalized correlations for finding the height of transfer units (H_{OG} or H_{OL}) and the maximum value obtained from the different correlations is considered for finding the height of packing.

Height of overall gas phase transfer unit HOG and height of overall liquid phase transfer unit HOL are related with HG and HL by the following equations.

$$H_{tOG} = H_{tG} + \frac{mG}{L} H_{tL}$$

$$H_{tOL} = H_{tG} + \frac{L}{mG} H_{tG}$$

Selection of internals of a packed tower:

Internals of packed tower are packings, packing support, liquid distributor, liquid redistributors, mist eliminator, hold-down plate, etc.

Packings: Packings can be devided into two broad classes – random packings, and regular packings.

Random packings: Various types of random packings are used with packed towers. Most commonly used are Pall rings, Berl saddles, Intalox saddles, Rasching rings, Tellerettes, Hy-Pac, etc.

Regular packings: Grids, structed packings, stacked rings, etc. are of these type. Grids are used for high gas rates as they offer very low pressure drop. Structured packings are widely used in chemical process industries. They are made from corrugated sheets with some perforations or wire mesh. They provide high surface area with high void fraction. HETP of structured packing is generally less than 0.5 m.

Liquid distributors: Uniform initial distribution of liquid at the top of packed bed is essential for the efficient mass transfer operation. For small packed columns (having diameter less than 0.3 m) single point distributor like one spray nozzle is adequate. For large diameter columns, multipoint distributors like perforated pipe distributor, through type distributor, orifice distributor, etc. are used.

Liquid redistributors: After traveling a certain distance in a packed tower, considerable fraction of liquid is migrated to the column wall and flows down in the vicinity of column wall while the gas rises upwards through the central portion. This phenomena is called channeling. Liquid redistributors collects the liquid that has migrated to the column wall and redistributes it evenly over the next bed of the packing.