KMU 346-22
Mass Transfer

Chapter 10.6
Absorption in Plate and Packed Towers

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GAS ABSORPTION

-Definition: It is a process in which a vapor solute A in a gas mixture is absorbed by means of a liquid in which the solute is more or less soluble.

-Gas mixture: Inert gas +the solute A

-The liquid is primarily immiscible in the gas phase.

-Thus, its vaporization into the gas phase is relatively slight.

Equipment for absorption and distillation

1) TRAY (PLATE) TOWERS
    - Sieve tray
    - Valve tray
    - Bubble-cap tray

2)PACKED TOWERS
    - a)Structured packing
    - b)Random packing

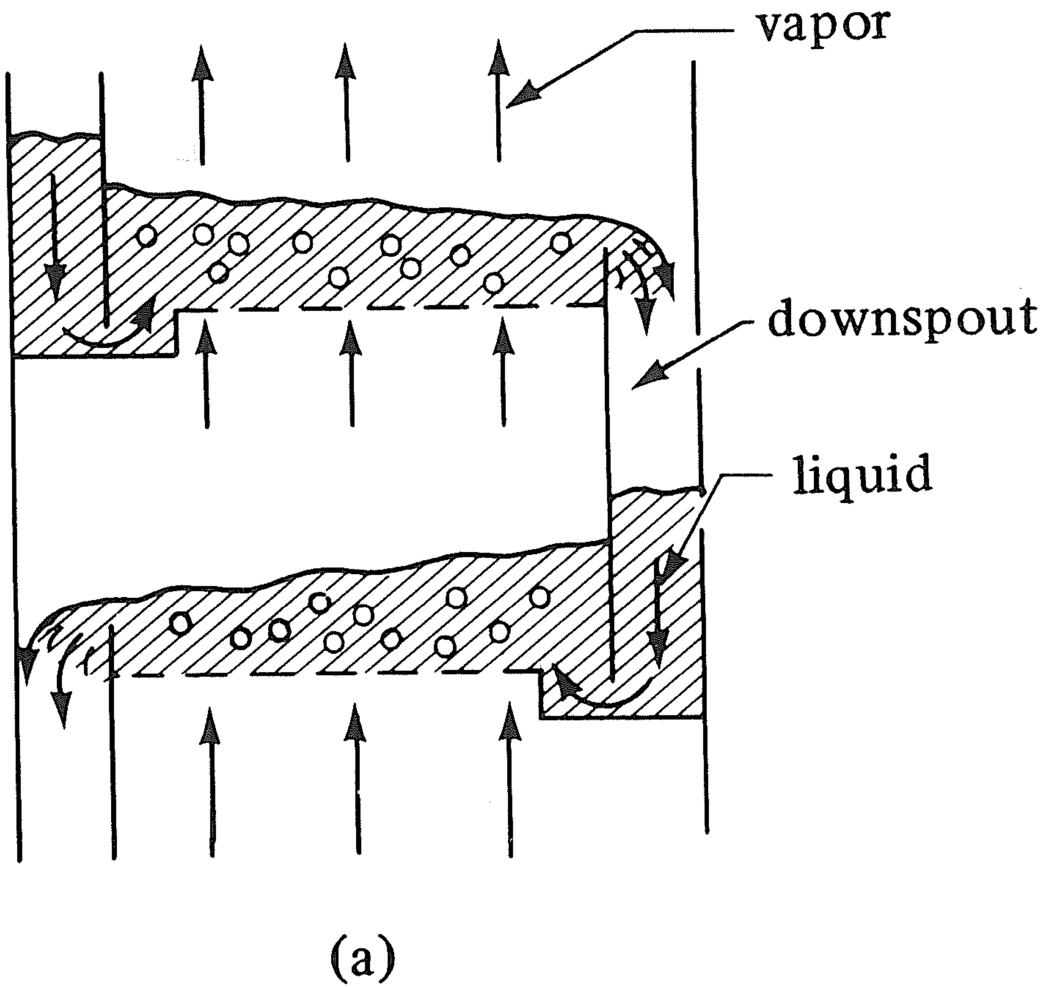

FIGURE 10.6-1. *Tray contacting devices: (a) detail of sieve-tray tower, (b) detail of valve-tray tower.*

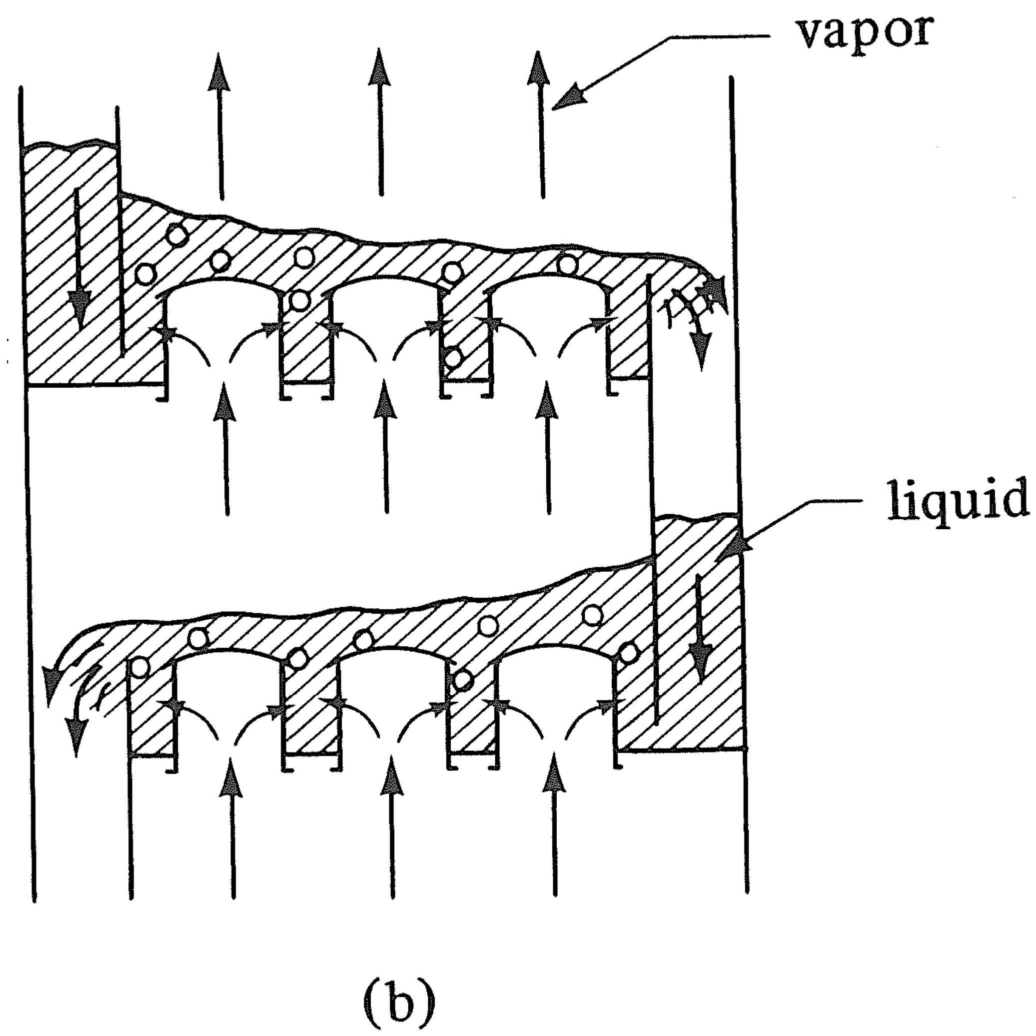

FIGURE 10.6-1. *Tray contacting devices: (a) detail of sieve-tray tower, (b) detail of valve-tray tower.*

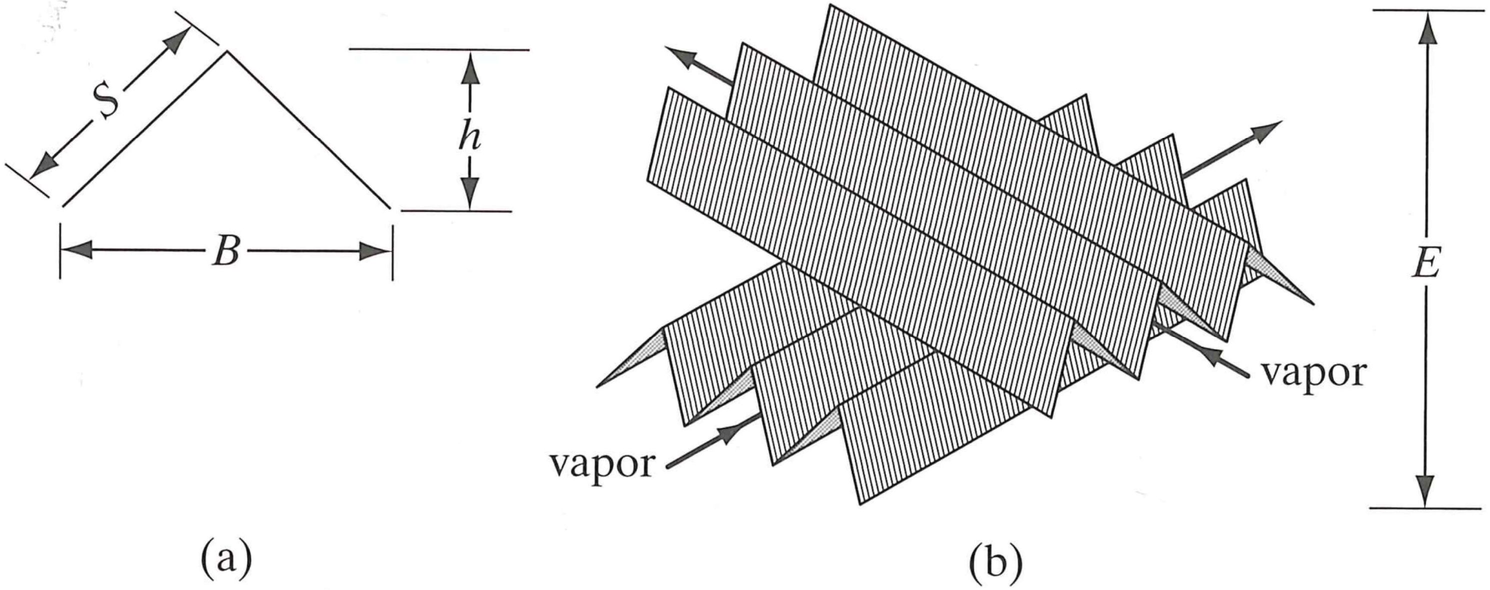

FIGURE 10.6-2. *Typical corrugated structured packing: (a) triangular cross section of flow channel; (b) flow-channel arrangement, with vapor flowing upward, indicated by arrows, and liquid downward. [From J. R. Fair and J. L. Bravo,* Chem. Eng. Progr., ***86,*** *(Jan.), 19 (1990). With permission.]*

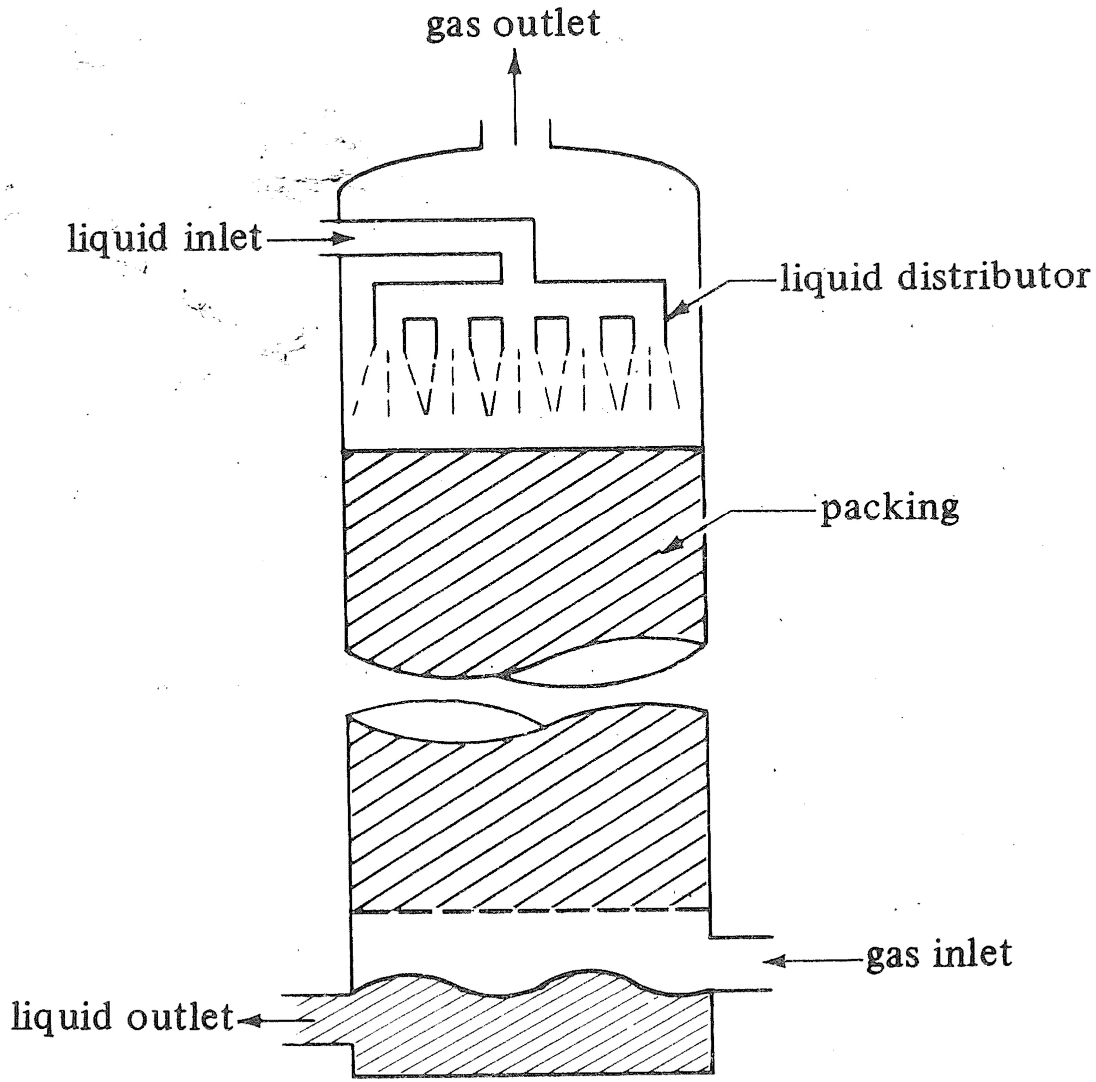

FIGURE 10.6-3. *Packed tower flows and characteristics for absorption.*

PACKED TOWERS

- A large area of intimate contact between the liquid and gas is provided by the packing.

Types of Packing Materials

- Raschig ring
- Berl saddle
- Pall ring
- Intalox metal
- Jaeger Metal Tri-Pack

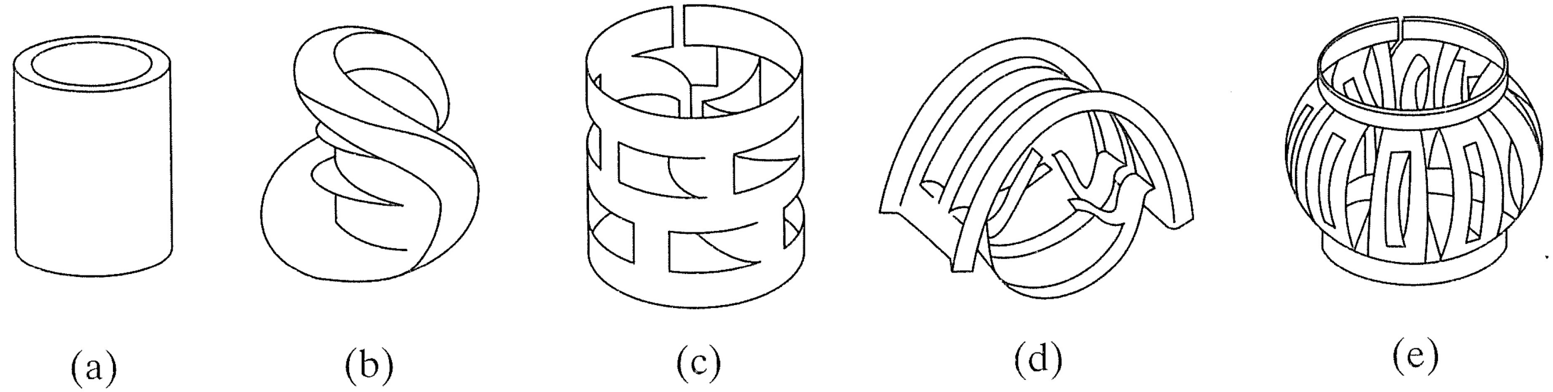

FIGURE 10.6-4. *Typical random or dumped tower packings: (a) Raschig ring; (b) Berl saddle; (c) Pall ring; (d) Intalox metal, IMTP; (e) Jaeger Metal Tri-Pack.*

PACKING MATERIALS

Clay; Porcelain; Metal; Plastic

Void spaces:65-95%

Raschig rings and Berl saddles: 1st generation; oldest types; seldom used now; ceramic

Pall rings: 2nd generation packing; plastic or metal; 100-200 m^2/m^3 ; 90-96% porosity; still used; more efficient

Intalox metal type: 3rd generation packing; combination of Berl saddle and the Pall ring.

Metal Tri-Pack: Pall ring in spherical shape. More efficient than Pall ring. Porosity:0.95-0.98.

TABLE 10.6-1. *Packing Factors for Random and Structured Packing*

Type	*Material*	*Nominal size, in.*	*Void fraction, ε*	*Surface area, a, ft^2/ft^3 (m^2/m^3)*	*Packing factor, F_p, ft^{-1} (m^{-1})*	*Relative mass-transfer coefficient, f_p*
Random Packing						
Raschig Rings	Ceramic	1/2	0.64	111 (364)	580 (1900)	1.52
		1	0.74	58 (190)	179 (587)	1.20
		1 1/2	0.73	37 (121)	95 (312)	1.00
		2	0.74	28 (92)	65 (213)	0.85
Berl Saddles	Ceramic	1/2	0.62	142 (466)	240 (787)	1.58
		1	0.68	76 (249)	110 (361)	1.36
		2		32 (105)	45 (148)	
Pall Rings	Metal	1	0.94	63 (207)	56 (184)	1.61
		1 1/2	0.95	39 (128)	40 (131)	1.34
		2	0.96	31 (102)	27 (89)	1.14
Metal Intalox (IMTP)	Metal	1	0.97	70 (230)	41 (134)	1.78
		2	0.98	30 (98)	18 (59)	1.27
Nor-Pac	Plastic	1	0.92	55 (180)	25 (82)	
		2	0.94	31 (102)	12 (39)	
Hy-Pak	Metal	1	0.96	54 (177)	45 (148)	1.51
		2	0.97	29 (95)	26 (85)	1.07
	Plastic	1	0.92	55 (180)	25 (82)	
		2	0.94	31 (102)	12 (39)	
Structured Packing						
Mellapak 250Y	Metal		0.95	76 (249)	20 (66)	
500Y				152 (499)	34 (112)	
Flexipac 2			0.93	68 (223)	22 (72)	
4			0.98		6 (20)	
Gempak 2A			0.93	67 (220)	16 (52)	
4A			0.91	138 (452)	32 (105)	
Norton Intalox 2T			0.97	65 (213)	17 (56)	1.98
3T			0.97	54 (177)	13 (43)	1.94
Montz B300				91 (299)	33 (108)	
Sulzer CY	Wire Mesh		0.85	213 (700)	70 (230)	
BX			0.90	150 (492)	21 (69)	

Data from Ref. (K1, L2, P2, S4). The relative mass-transfer coefficient, f_p, is discussed in Section 10.8B.

PRESSURE DROP and FLOODING in PACKED TOWERS

- Pressure drop in the gas flow is an important parameter in the design of packed towers.
- Flooding velocity:Upper limit to the rate of gas flow.
- Above this gas velocity the tower can not operate.

- At a gas flow rate called the **loading point,** the gas starts to hinder the liquid downflow, and local accumulations or pools of liquid start to appear in the packing.
- At the **flooding point**, the liquid can no longer flow down through the packing and is blown out with the gas.

1. Pressure drop in random packings. Empirical correlations for various random packings based on experimental data are used to predict the pressure drop in the gas flow. The original correlation by Eckert (K1) correlated the gas and liquid flow rates and properties with pressure drop. The latest version has been replotted by Strigle (K1, S4) and is shown in Fig. 10.6-5. The line for $\Delta P = 2.0$ in. H_2O/ft has been extrapolated. The ordinate (capacity parameter) is $v_G[\rho_G/(\rho_L - \rho_G)]^{0.5} F_p^{0.5} \nu^{0.05}$ and the abscissa (flow parameter) is $(G_L/G_G)(\rho_G/\rho_L)^{0.5}$, where v_G is superficial gas velocity in ft/s, ρ_G is gas density in $\text{lb}_\text{m}/\text{ft}^3$, $v_G = G_G/\rho_G$, ρ_L is liquid density in $\text{lb}_\text{m}/\text{ft}^3$, F_p is a packing factor in ft^{-1}, ν is kinematic viscosity $\mu_L/(\rho_L/62.4)$ in centstokes, μ_L is liquid viscosity in cp, G_L is liquid mass velocity in $\text{lb}_\text{m}/(\text{s} \cdot \text{ft}^2)$, and G_G is gas mass velocity in $\text{lb}_\text{m}/(\text{s} \cdot \text{ft}^2)$. Note that this capacity parameter is not dimensionless and that only these units should be used. This correlation predicts pressure drops to an accuracy of ±11% (L2).

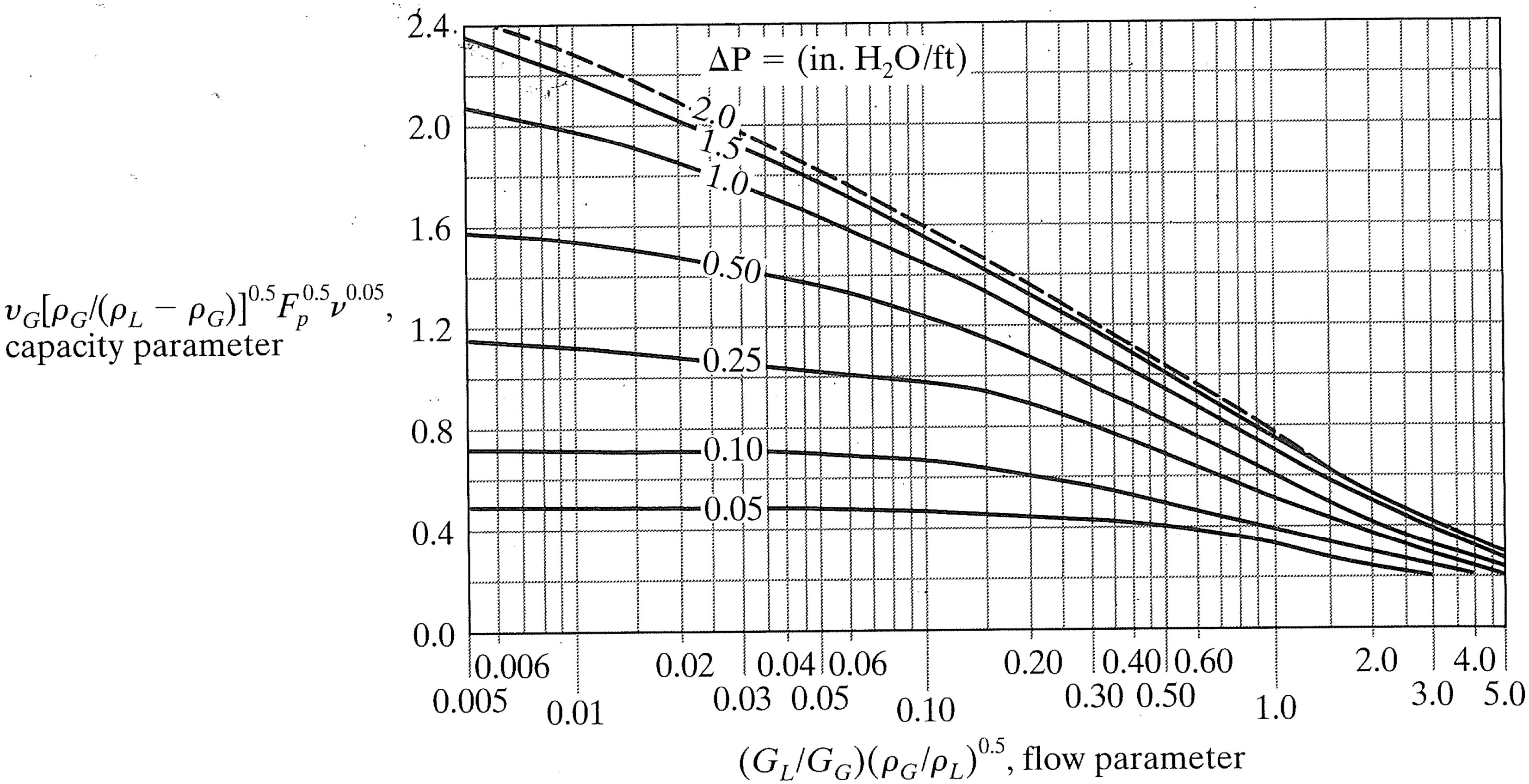

FIGURE 10.6-5. *Pressure-drop correlation for random packings by Strigle. (From R. F. Strigle, Jr.,* Random Packings and Packed Towers, *Houston: Gulf Publishing Company, 1987. With permission from Elsevier Science.)*

2. *Pressure drop in structured packings.* An empirical correlation for structured packings is given in Fig. 10.6-6 by Kister and Gill (K1). They modified the Eckert correlation for random packings to better fit only the structured-packing data. An extrapolated line for $\Delta P = 0.05$ in. H_2O/ft and for $\Delta P = 2.0$ has been added. The packing factors F_p to be used for structured packing are those given in Table 10.6-1 and references (K1, L2, P2). The units on the ordinate and abscissa of Fig. 10.6-6 are the same as those for Fig. 10.6-5.

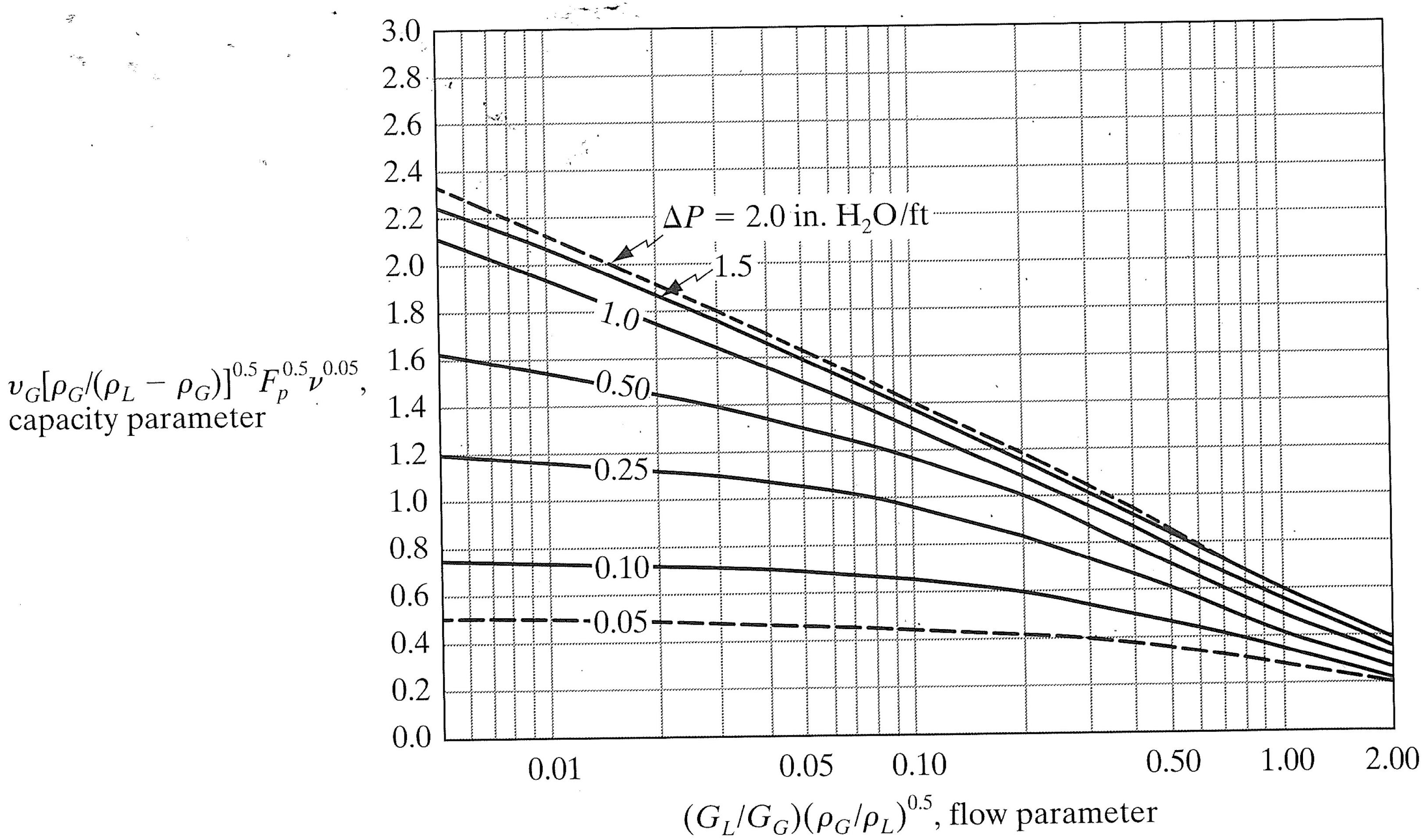

FIGURE 10.6-6. *Pressure-drop correlation for structured packings by Kister and Gill (K2). (From H. Z. Kister,* Distillation Design, *New York: McGraw-Hill Book Company, 1992. With permission.)*

3. Flooding pressure drop in packed and structured packings. It is important for proper design to be able to predict the flooding pressure drop in towers and, hence, the limiting flow rates at flooding. Figures 10.6-5 and 10.6-6 do not predict flooding conditions. Kister and Gill (K2) have developed an empirical equation to predict the limiting pressure drop at flooding. This equation is

$$\Delta P_{flood} = 0.115 F_p^{0.7} \tag{10.6-1}$$

where ΔP_{flood} is in in. H_2O/ft height of packing and F_p is the packing factor in ft^{-1} given in Table 10.6-1 for random or structured packing. To convert from English to SI units, 1.00 in. H_2O/ft height = 83.33 mm H_2O/m height of packing. This can be used for packing factors from 9 up to 60. It predicts all of the data for flooding within ±15% and most for ±10%. At a packing factor of 60 or higher, Eq. (10.6-1) should not be used; instead, the pressure drop at flooding can be taken as 2.00 in. H_2O/ft (166.7 mm H_2O/m).

The following procedure can be used to determine the limiting flow rates and the tower diameter.

1. First, a suitable random packing or structured packing is selected, giving an F_p value.
2. A suitable liquid-to-gas ratio G_L/G_G is selected along with the total gas flow rate.
3. The pressure drop at flooding is calculated using Eq. (10.6-1), or if F_p is 60 or over, the $\Delta P_{flooding}$ is taken as 2.0 in./ft packing height.
4. Then the flow parameter is calculated, and using the pressure drop at flooding and either Fig. 10.6-5 or 10.6-6, the capacity parameter is read off the plot.
5. Using the capacity parameter, the value of G_G is obtained, which is the maximum value at flooding.
6. Using a suitable % of the flooding value of G_G for design, a new G_G and G_L are obtained. The pressure drop can also be obtained from Figure 10.6-5 or 10.6-6.
7. Knowing the total gas flow rate and G_G, the tower cross-sectional area and ID can be calculated.

4. Approximate design factors to use. In using random packing, the radio of tower diameter to packing size should be 10/1 or greater. This is to ensure good liquid and gas distribution. For every 3 m (10 ft) height of packing, a liquid redistribution should be used to prevent channeling of liquid to the sides. Random-packed towers are generally used only for diameters of 1.0 m (3.3 ft) or less. Tray towers less than 0.6 m (2 ft) in diameter are usually not used because of cleaning and access problems.

DESIGN

- In an actual operating tower

  The gas velocity is well below flooding.

  The start of loading in packed towers is usually at about 65-70% of the flooding velocity.

  The optimum economic gas velocity is about ½ or more of the flooding velocity.

For absorption the tower should be designed using about 50-70% of the gas flooding velocity.