UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2003/2004

Februari/Mac 2004

IEK 205/3 – TEKNOLOGI KAWALAN PENCEMARAN UDARA

Masa: 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi **EMPAT BELAS (14)** mukasurat yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab EMPAT dari lima soalan. Semua soalan mesti dijawab dalam Bahasa Malaysia.

1. (a) Tulis nota ringkas mengenai perkara berikut.

    i. Kadar susut adiabatik *(adiabatic lapse rate)*
    ii. Keadaan atmosfera superadiabatik
    iii. Keadaan atmosfera songsangan
    iv. Model serakan plum
    v. Kenaikan plum

(60 markah)

(b) Had harian SO_2 pada suatu tempat yang dibenarkan oleh sebuah jabatan alam sekitar ialah 360 $\mu g/m^3$ pada suhu 25°C dan tekanan 1 atm. Nyatakan had itu dalam sebutan ppm.

Maklumat Tambahan:

(BM) Berat Molekul SO_2 = 64
Berat atom S = 32
O = 16
C = 12

$$mg/m^3 = \frac{ppm \times (BM)}{22.414} \times \frac{273.15K}{T\ (K)} \times \frac{P(atm)}{1\ atm}$$

(20 markah)

(c) Suatu alat ukur PM10 dijalankan selama 24 jam pada halaju purata 17L/min. Berat awal kertas turas ialah 0.1400g dan berat akhir selepas dikeringkan pada kelembapan yang sama seperti kertas turas baru ialah 0.1405g. Apakah nilai purata PM10 di udara?

(20 markah)

2. (a) Terbitkan persamaan untuk halaju tamatan suatu partikel, diameter d, yang mendak dalam udara menurut hukum Stoke.

(25 markah)

(b) Terbitkan suatu persamaan untuk kecekapan pemendak graviti *(gravity settlers)* bagi aliran tidak bercampur.

(25 markah)

(c) Suatu *crossflow scrubber* memerangkap 80 peratus partikel yang melaluinya. Katakan kadar aliran gas perlu dijadikan dua kali aliran asal dan jika faktor-faktor pemprosesan lain ditetapkan, maka apakah keberkesanan *scrubber* pada kadar baru ini?

Diberi untuk alat ini.

$$\ln p = -1.5.\frac{\eta t}{D_D}.\frac{Q_L}{Q_G}.\Delta z$$

p ialah ketembusan $\left(p = \frac{C}{C_O}\right)$

C_O ialah kepekatan masuk partikel
C ialah kepekatan keluar partikel
D_D ialah diameter titisan air
Q_L ialah kadar aliran isipadu cecair
Q_G ialah kadar aliran isipadu gas

(25 markah)

(d) ESP *(Electrostatic Precipitator)* di Kilang Simen Langkawi dapat memerangkap 95% partikel dalam aliran gas sisa. Perundangan baru memerlukan 99% partikel diperangkap. Sekiranya sebelum perundangan baru dikuatkuasa, kilang tersebut beroperasi dengan menggunakan 10 unit ESP yang serupa maka kira berapa unit lagi yang diperlukan untuk kecekapan ESP yang baru.

Diberi $\eta = 1 - \exp\left(-\frac{\omega A}{Q}\right)$

$p = 1 - \eta$

(25 markah)

3. (a) Anggarkan kepekatan karbon monoksida ke bawah angin *(downwind)* sebuah bandar. Bandar itu boleh dianggap sebagai tiga bahagian selari terletak secara merentas tepat laluan angin. Untuk ketiga-tiga bahagian halaju angin ialah 3 m/s. Ciri-ciri setiap bahagian ialah seperti berikut.

Nama Bahagian	**Panjang, km**	**Kadar Emisi $g/s.km^2$**	**Tinggi Pencampuran H, m**
Atas Angin	5	100	400
Bandar	2	500	500
Bawah Angin	5	100	400

Andaikan model kotak tetap pada setiap bahagian. Kepekatan latar, b, pada angin yang mendatang ialah 1 g/m^3.

(40 markah)

(b) Sebuah kilang mempunyai cerobong 200m tinggi dan kenaikan plum 75m. Kilang ini mengeluarkan SO_2 pada kadar 1000 g/s. Anggarkan kepekatan aras bumi SO_2 daripada punca ini pada jarak 5 km bawah angin *(downwind)* apabila kelajuan angin ialah 3 m/s dan kelas kestabilan atmosfera ialah C.

(30 markah)

(c) Dikatakan kepekatan yang dikira di lokasi dalam soalan bahagian (b) tadi adalah dua kali ganda yang dibenarkan. Pihak kilang mencadangkan memasang cerobong yang lebih tinggi.

Kira tinggi cerobong supaya kepekatan di lokasi tersebut akan hanya tinggal separuh dari kes tadi. Katakan kenaikan plum masih sama.

(30 markah)

Untuk soalan 3(b) dan 3(c), maklumat berikut boleh membantu anda.

Persamaan kepekatan plum yang mempunyai imej-cermin:

$$c = \frac{Q}{2\pi u\sigma_y\sigma_z}\exp-0.5\left(\frac{y}{\sigma_y}\right)^2\left[\exp-0.5\left(\frac{z-H}{\sigma_z}\right)^2+\exp-0.5\left(\frac{z+H}{\sigma_z}\right)^2\right]$$

$$\frac{cu}{Q} = \frac{1}{\pi\sigma y\sigma z}\exp-0.5\left(\frac{H}{\sigma_z}\right)^2 \quad \text{for } z = 0,\ y = 0$$

Lihat juga **Lampiran 3, Lampiran 4 dan Lampiran 5.**

4. Bincang mengenai faktor-faktor yang perlu diambil kira dalam menentukan lokasi kilang dari sudut kawalan pencemaran udara dan juga meteorologi.

(100 markah)

5. (a) Satu turus padatan (packed tower) digunakan untuk menyerap ammonia dari suatu aliran gas sisa. Unit itu beroperasi pada 70% halaju banjir jisim gas sisa. Kadar aliran cecair sebenar ialah 30% lebih daripada takat minimum. Amonia yang dibenarkan terlepas ialah 10% daripada yang masuk ke dalam sistem. Cecair pelarut yang digunakan ialah air tulen. Kira <u>tinggi</u> dan <u>diameter</u> menara jika diberi maklumat berikut:

Kadar aliran gas	= 6000 lb/h
Kepekatan masuk ammonia	= 2.0 mol%
Padatan	= 1 in cecincin Rashig (ceramics)
H_{OG}	= 2.55 ft
Pemalar Henry, m	= 1.25
Ketumpatan gas	= 0.075 lb/ft^3
Ketumpatan air	= 62.4 lb/ft^3
Kelikatan air	= 1.8 cP

Berat molekul gas $_{MG}$ dan air M_L masing-masing ialah 29 dan 18.

Sila rujuk **<u>lampiran 6 dan 7</u>** untuk maklumat lanjut.

(50 markah)

Diberi:

$Z = N_{OG} \, . \, H_{OG}$

$$N_{OG} = \frac{1}{1-\lambda} \ln\left[(1-\lambda)\frac{y_1}{y_2} + \lambda\right]$$

$\lambda = mG_m/L_m$

G_m, L_m masing-masing kadar aliran molar gas dan cecair
$D_T = 1.13\ S^{0.5}$
D_T garis pusat turus
S luas keratan rentas turus

5. (b) Sila namakan 2 (dua) sahaja kaedah kawalan pencemaran emisi gas dan kemudian jelaskan mengenai kedua-dua kaedah tersebut.

(50 markah)

LAMPIRAN 1

CONVERSION FACTORS*

Length:

1 ft = 0.3048 m = 12 in. = mile/5280 = nautical mile/6076
= km/3281

1 m = 3.281 ft = 39.37 in. = km/1000 = 100 cm = 1000 mm
= 10^6 microns = 10^6 μm = 10^9 nm = 10^{10} Å

Mass:

1 lbm = 0.45359 kg = short ton/2000 = long ton/2240 = 16 oz (av.)
= 14.58 oz (troy) = metric ton (tonne)/2204.63 = 7000 grains
= slug/32.2

1 kg = 2.2046 lbm = 1000 g = (metric ton or tonne or Mg)/1000

Force:

1 lbf = 4.4482 N = 32.2 lbm · ft/s^2 = 32.2 poundal = 0.4536 kgf

1 N = kg · m/s^2 = 10^5 dyne = kgf/9.81 = 0.2248 lbf

Volume:

1 ft^3 = 0.02831 m^3 = 28.31 liters = 7.48 U.S. gallons
= 6.23 Imperial gallons = acre-ft/43 560

1 U.S. gallon = 231 in.^{3} = barrel (petroleum)/42 = 4 U.S. quarts
= 8 U.S. pints = 3.785 liters = 0.003785 m^3

1 m^3 = 1000 liters = 35.29 ft^3

Energy:

1 Btu = 1055 J = 1.055 kw · s = 2.93 × 10^{-4} kwh = 252 cal
= 777.97 ft · lbf = 3.93 × 10^{-4} hp · h

1 J = N · m = W · s = volt · coulomb = 9.48 × 10^{-4} Btu
= 0.239 cal = 10^7 erg = 6.24 × 10^{18} electron volts

---

*These values are mostly rounded. There are several definitions for some of these quantities, e.g., the Btu and the calorie; these definitions differ from each other by up to 0.2 percent. For the most accurate values see the *ASTM Metric Practice Guide*, ASTM Pub. E 380-93, Philadelphia, 1993.

LAMPIRAN 2

Power:

$$1\ \mathbf{hp} = 550\ \text{ft}\cdot\text{lbf/s} = 33\ 000\ \text{ft}\cdot\text{lbf/min} = 2545\ \text{Btu/h} = 0.746\ \text{kW}$$

$$1\ \mathbf{W} = \text{J/s} = \text{N}\cdot\text{m/s} = \text{volt}\cdot\text{ampere} = 1.34\times10^{-3}\ \text{hp} = 0.239\ \text{cal/s} = 9.49\times10^{-4}\ \text{Btu/s}$$

Pressure:

$$1\ \mathbf{atm} = 101.3\ \text{kPa} = 1.013\ \text{bar} = 14.696\ \text{lbf/in.}^2 = 33.89\ \text{ft of water} = 29.92\ \text{inches of mercury} = 1.033\ \text{kgf/cm}^2 = 10.33\ \text{m of water} = 760\ \text{mm of mercury} = 760\ \text{torr}$$

$$1\ \mathbf{psi} = \text{atm}/14.696 = 6.89\ \text{kPa} = 0.0689\ \text{bar} = 27.7\ \text{in. } H_2O = 51.7\ \text{torr}$$

$$1\ \mathbf{Pa} = \text{N/m}^2 = \text{kg/m}\cdot\text{s}^2 = 10^{-5}\ \text{bar} = 1.450\times10^{-4}\ \text{lbf/in.}^2 = 0.0075\ \text{torr} = 0.0040\ \text{in. } H_2O$$

$$1\ \mathbf{bar} = 10^5\ \text{Pa} = 0.987\ \text{atm} = 14.5\ \text{psia}$$

Psia, psig:

Psia means pounds per square inch, absolute. Psig means pounds per square inch, gauge, i.e., above or below the local atmospheric pressure.

Viscosity:

$$1\ \mathbf{cp} = 0.01\ \text{poise} = 0.01\ \text{g/cm}\cdot\text{s} = 0.001\ \text{kg/m}\cdot\text{s} = 0.001\ \text{Pa}\cdot\text{s} = 6.72\times10^{-4}\ \text{lbm/ft}\cdot\text{s} = 2.42\ \text{lbm/ft}\cdot\text{h} = 2.09\times10^{-5}\ \text{lbf}\cdot\text{s/ft}^2 = 0.01\ \text{dyne}\cdot\text{s/cm}^2$$

Kinematic viscosity:

$$1\ \mathbf{cs} = 0.01\ \text{stoke} = 0.01\ \text{cm}^2\text{/s} = 10^{-6}\ \text{m}^2\text{/s} = 1\ \text{cp/(g/cm}^3) = 1.08\times10^{-5}\ \text{ft}^2\text{/s} = \text{cp/(62.4 lbm/ft}^3)$$

Temperature:

$$\text{K} = {}^\circ\text{C} + 273.15 = {}^\circ\text{R}/1.8 \approx {}^\circ\text{C} + 273 \qquad {}^\circ\text{C} = ({}^\circ\text{F} - 32)/1.8$$

$${}^\circ\text{R} = {}^\circ\text{F} + 459.67 = 1.8\ \text{K} \approx {}^\circ\text{F} + 460 \qquad {}^\circ\text{F} = 1.8{}^\circ\text{C} + 32$$

Concentration (ppm):

In the air pollution literature and in this book, ppm applied to a gas always means parts per million by volume or by mol. These are identical for an ideal gas, and practically identical for most gases of air pollution interest at 1 atm pressure. Ppm applied to a liquid or solid means parts per million by mass.

For perfect gases at 1 atm and 25°C, 1 ppm = (40.87 · molecular weight) μg/m^3

Common Units and Values for Problems and Examples:

See inside back cover.

LAMPIRAN 3

Table 7.7 Wind Profile Exponent p, for Rough Terrain[a]

Stability Class	Description	Exponent p
A	Very unstable	0.15
B	Moderately unstable	0.15
C	Slightly unstable	0.20
D	Neutral	0.25
E	Slightly stable	0.40
F	Stable	0.60

[a] For smooth terrain, multiply p by 0.6; see Table 7.8 for further descriptions of the stability classifications used here (Peterson, 1978).

Table 7.8 Atmospheric Stability Classifications

Surface wind speed[a] (m/s)	Day solar insolation			Night cloudiness[e]	
	Strong[b]	Moderate[c]	Slight[d]	Cloudy ($\geq$ 4/8)	Clear ($\leq$ 3/8)
<2	A	A–B[f]	B	E	F
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	D
>6	C	D	D	D	D

[a]Surface wind speed is measured at 10 m above the ground.
[b]Corresponds to a clear summer day with sun higher than 60° above the horizon.
[c]Corresponds to a summer day wth a few broken clouds, or a clear day with sun 35–60° above the horizon.
[d]Corresponds to a fall afternoon, or a cloudy summer day, or clear summer day with the sun 15–35° above the horizon.
[e]Cloudiness is defined as the fraction of sky covered by clouds.
[f]For A–B, B–C, or C–D conditions, average the values obtained for each.
Note: A, Very unstable; B, moderately unstable; C, slightly unstable; D, neutral; E, slightly stable; F, stable. Regardless of windspeed, class D should be assumed for overcast conditions, day or night.
Source: Turner (1970).

...11/-

LAMPIRAN 4

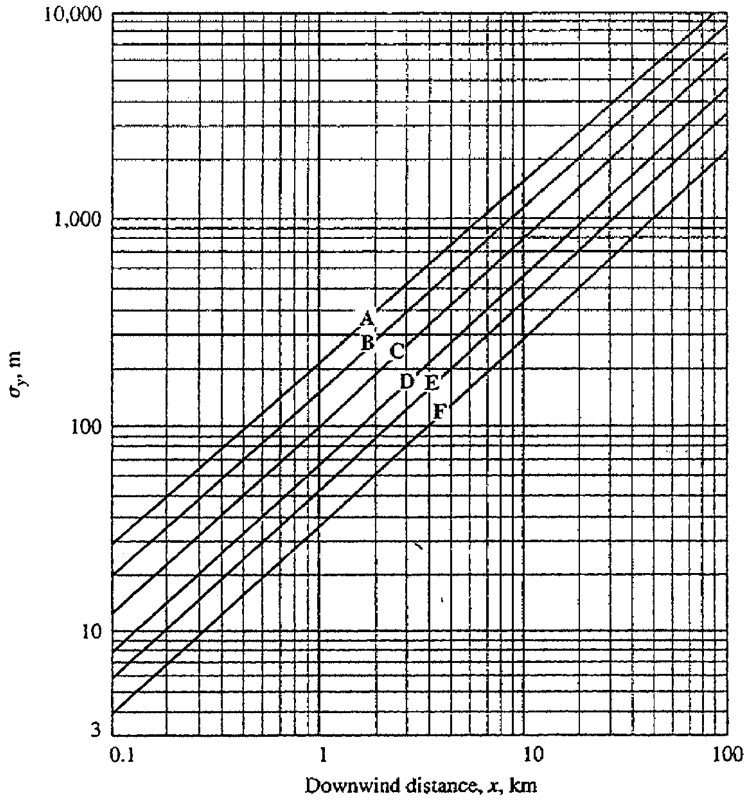

FIGURE 6.7
Horizontal dispersion coefficient σ_y as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [7].)

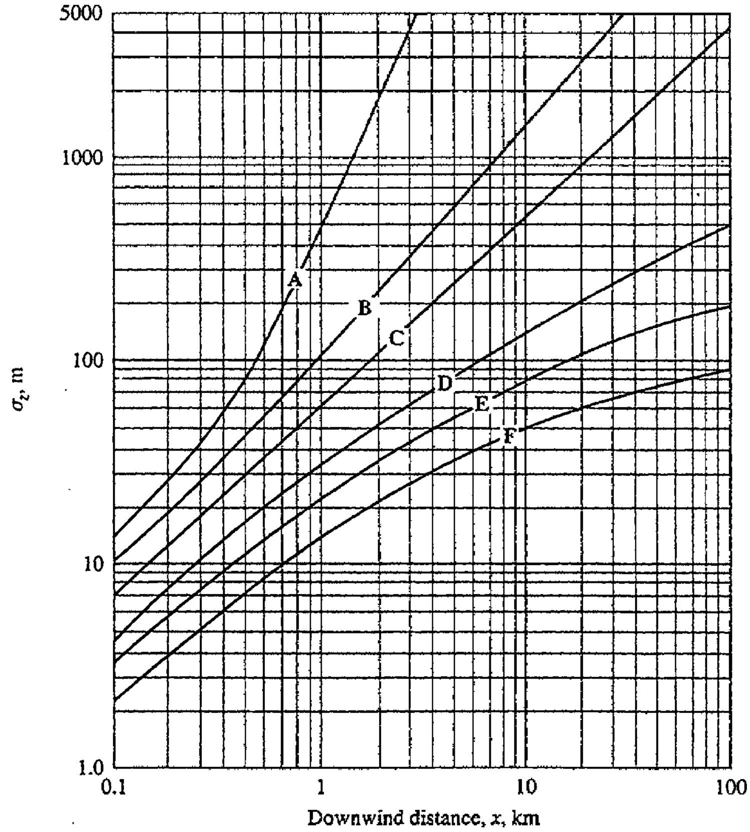

FIGURE 6.8
Vertical dispersion coefficient σ_z as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [7].)

LAMPIRAN 5

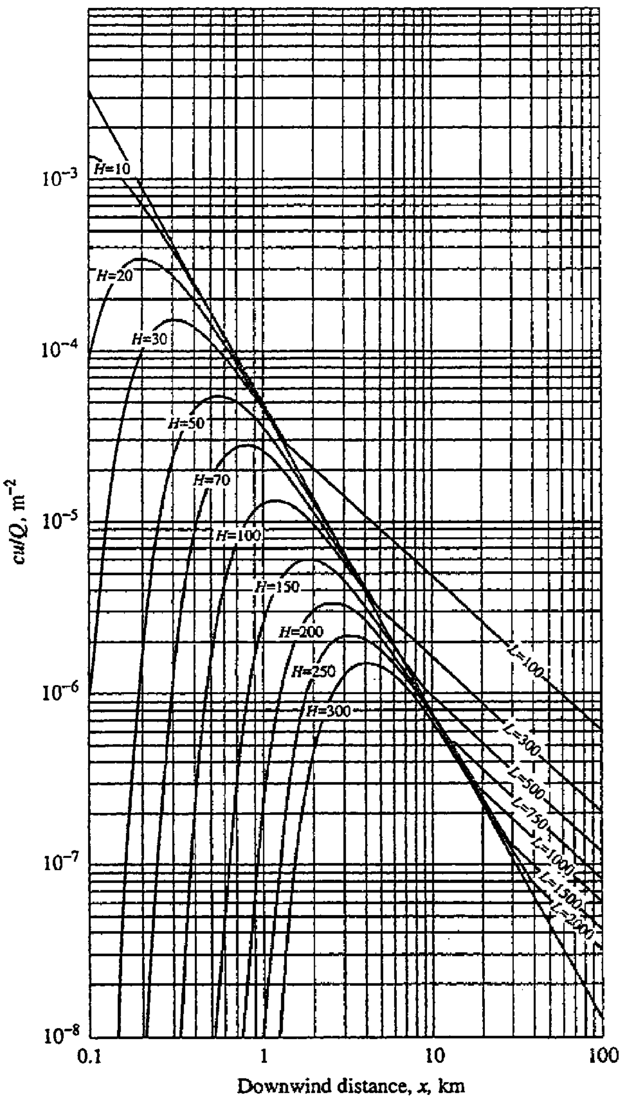

FIGURE 6.9
Ground-level cu/Q, directly under the plume centerline, as a function of downwind distance from the source and effective stack height, H, in meters, *for C stability only.* (From Turner [7].) Here L is the atmospheric mixing height, also in meters.

TABLE 2. Packing Factors—Dumped Packing

		Nominal Packing Size (inches)										
Packing Type	Material	¼	⅜	½	⅝	¾	1	1¼	1½	2	3	3½
Hy-Pak™	Metal						43			18	15	
Super Intalox® saddles	Ceramic						60			30		
Super Intalox saddles	Plastic						33			21	16	
Pall rings	Plastic				97		52		40	25		16
Pall rings	Metal				70		48		28	20		16
Intalox® saddles	Ceramic	725	330	200		145	98		52	40	36	
Raschig rings	Ceramic	1600	1000	640	380	255	160	95	65	65		
Raschig rings	1/32" metal	700	390	300	170	185	115					
Raschig rings	1/16" metal			410	290	230	137	110	83	57	32	
Berl saddles	Ceramic	900		240		170	110		65	45		
Tri-packs	Plastic						28			15		14
Tri-packs	Metal									18	14	

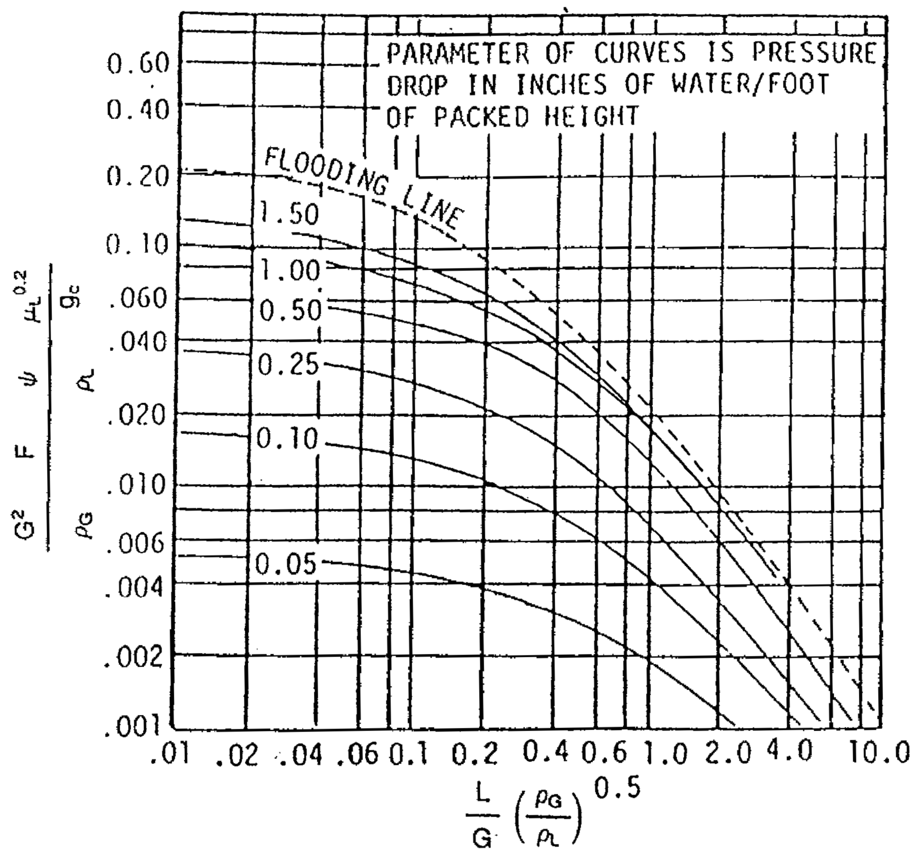

FIGURE 7. Generalized Pressure Drop Correlation to Estimate Column Diameter (G = gas flow rate, lb/sec ft^2; L = liquid flow rate, lb/sec ft^2; F = packing factor; Ψ = ratio, density of water/density of liquid; μ_L = liquid viscosity, cP_a; ρ_G = gas density, lb/ft^3; ρ_L = liquid density, lb/ft^3; g_c = 32.2).

- oooOOOooo -