UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2005/2006

April/Mei 2006

IEK 205 – Teknologi Kawalan Pencemaran Udara

Masa: 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi LIMA BELAS mukasurat yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab **EMPAT** soalan. Semua soalan mesti dijawab dalam Bahasa Malaysia.

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

(20 markah)

(b) **Terbitkan** suatu persamaan untuk kecekapan pemendak graviti (*gravity settlers*) bagi aliran laminar (blok) kemudian **jelaskan dengan ringkas** apa yang perlu dibuat untuk meningkatkan kecekapan sesebuah pemendak graviti.

(20 markah)

(c) **Terbitkan persamaan kecekapan siklon** kemudian **tunjukkan** bagaimana kamu boleh mengira **garis pusat potongan,** d_{cut} (*cut diameter*).

(20 markah)

(d) Suatu siklon beroperasi pada keadaan garis pusat potongan, d_{cut} = 12 μ. Terdapat cadangan siklon yang rekabentuknya sama tetapi dimensinya separuh dari siklon sekarang. Jika kadar aliran isipadu, beban partikel dan taburan saiz partikel dikekalkan maka **kira nilai d_{cut} yang baru.**

(20 markah)

(e) Tulis nota ringkas mengenai ESP (Electrostatic Precipitator)

(20 markah)

2. (a) Beri gambaran kewujudan pencemar udara utama seperti CO, NOx, SOx, Pb, O_3 dan bahan partikulat (abu dan HC yang tak terbakar) melalui suatu contoh proses pembakaran yang mudah.

(60 markah)

(b) Suatu *High Volume Sampler* untuk PM10 dijalankan selama 24 jam pada halaju purata 15 L/min. Berat awal kertas turas ialah 0.1500 g dan berat akhir selepas dikeringkan ialah 0.1505 g. Apakah nilai purata PM10 di udara.

(20 markah)

(c) Kira kepekatan SO_2 di sebuah kawasan berhampiran sebuah kilang dalam unit **ppm** jika bacaan kepekatan SO_2 ialah 390 μg/m^3 pada suhu 25 °C dan tekanan 1 atm.

(20 markah)

Maklumat Tambahan

Berat Molekul SO_2 = 64, Berat Atom S = 32, O = 16, C = 12

Untuk menukar antara unit ppm dengan mg/m^3 guna persamaan berikut:

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

3. (a) Bermula dengan mengira jumlah jisim habuk yang terpindah ke satu titisan air yang jatuh semasa hujan, dalam persekitaran yang kepekatan habuk ialah c kg/m^3 maka **terbitkan suatu persamaan reka bentuk untuk satu *scrubber* aliran silang (*crossflow scrubber*)** yang menerangkan faktor-faktor yang mempengaruhi **ln p**.

p ialah ketembusan ($p = C/C_o$)
C = kepekatan partikel keluar dari *scrubber*
C_o = kepekatan partikel masuk ke *scrubber*

(50 markah)

(b) Keberkesanan *scrubber* ialah 90 peratus bagi partikel saiz 3 μ untuk titisan air bergaris pusat 400 μ. Katakan suatu muncung sembur air diubahsuai supaya titisan air menjadi 200 μ sementara kadar aliran air tidak diubah maka **kira keberkesanan** baru *scrubber* itu.

Diberi $N_s = \rho D^2 V / (18\ \mu D_b)$

N_s = nombor pemisahan
ρ = ketumpatan partikel (2000 kg/m^3)
D = diameter partikel
V = halaju tamatan titisan air (*terminal velocity*)
μ = kelikatan udara (1.8×10^{-5} kg/ms)
D_b = diameter titisan air (*diameter of barrier*)

(Lihat **Lampiran 1 dan 2** untuk maklumat tambahan)

(50 markah)

4. (a) Satu unit 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. Ammonia yang dibenarkan terlepas ialah 10 % daripada yang masuk ke dalam sistem. Cecair pelarut yang digunakan ialah air tulen. Kira tinggi dan diameter menara jika diberi maklumat berikut:

Kadar aliran gas	= 6000 lb/h
Kepekatan masuk ammonia	= 2.0 mol %
Padatan	= 1 in cecincin Raschig (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 sisa M_G dan air M_L masing-masing ialah 29 dan 18

Diberi:

$Z = N_{OG}.H_{OG}$ (Z, tinggi menara)

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

y_1 dan y_2 masing-masing ialah komposisi ammonia menurut pecahan mol dalam gas masuk dan gas keluar

$\lambda = mG_m/L_m$

dan masing-masing ialah kadar aliran molar gas dan cecair

$D_T = 1.13\ S^{0.5}$

D_T = diameter menara

S = luas keratan rentas menara

Sila rujuk **Lampiran 3 dan 4** untuk maklumat yang berkaitan.

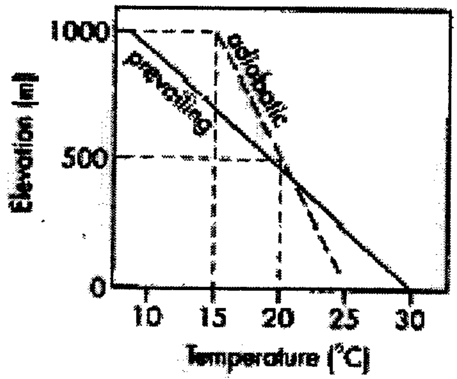
(50 markah)

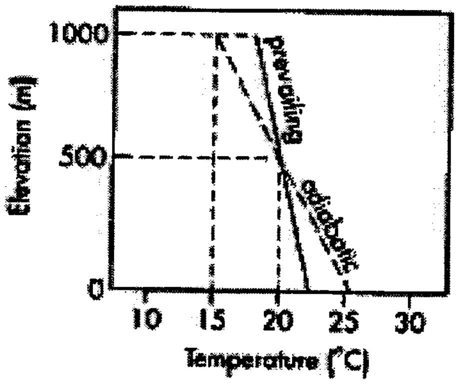
(b) Jelaskan mengenai perawatan gas sisa melalui sama ada kaedah **Penjerapan** atau **Pembakaran.**

(50 markah)

5. (a) Untuk RAJAH 5A dan 5B berikut, apakah yang akan berlaku terhadap asap yang dilepaskan melalui cerobong, tinggi 500 m. Asap keluar dari cerobong pada suhu 20 °C. Beri penjelasan anda melalui pengiraan dan lakaran yang sesuai.

RAJAH 5A. Keadaan sekitaran superadiabatik





RAJAH 5B. Keadaan sekitaran Subadiabatik

(30 markah)

(b) Tulis nota ringkas mengenai perkara berikut:

(i) Songsangan sinaran
(ii) Ketinggian pencampuran
(iii) Ppm
(iv) Garis pusat aerodinamik

(40 markah)

(c) Terdapat cerobong setinggi 150 m di sebuah kilang. Kenaikan plum ialah 75 m. Kilang ini mengeluarkan SO_2 pada kadar 1000 g/s. Anggarkan kepekatan aras bumi SO_2 daripada punca ini pada jarak 3 km bawah angin (downwind) apabila kelajuan angin ialah 3 m/s dan kelas kestabilan atmosfera ialah C.

Diberi :

Persamaan kepekatan plum yang mempunyai imej-cermin:

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

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

Maklumat tambahan terdapat di dalam **Lampiran 5, 6 dan 7.**

(30 markah)

LAMPIRAN /

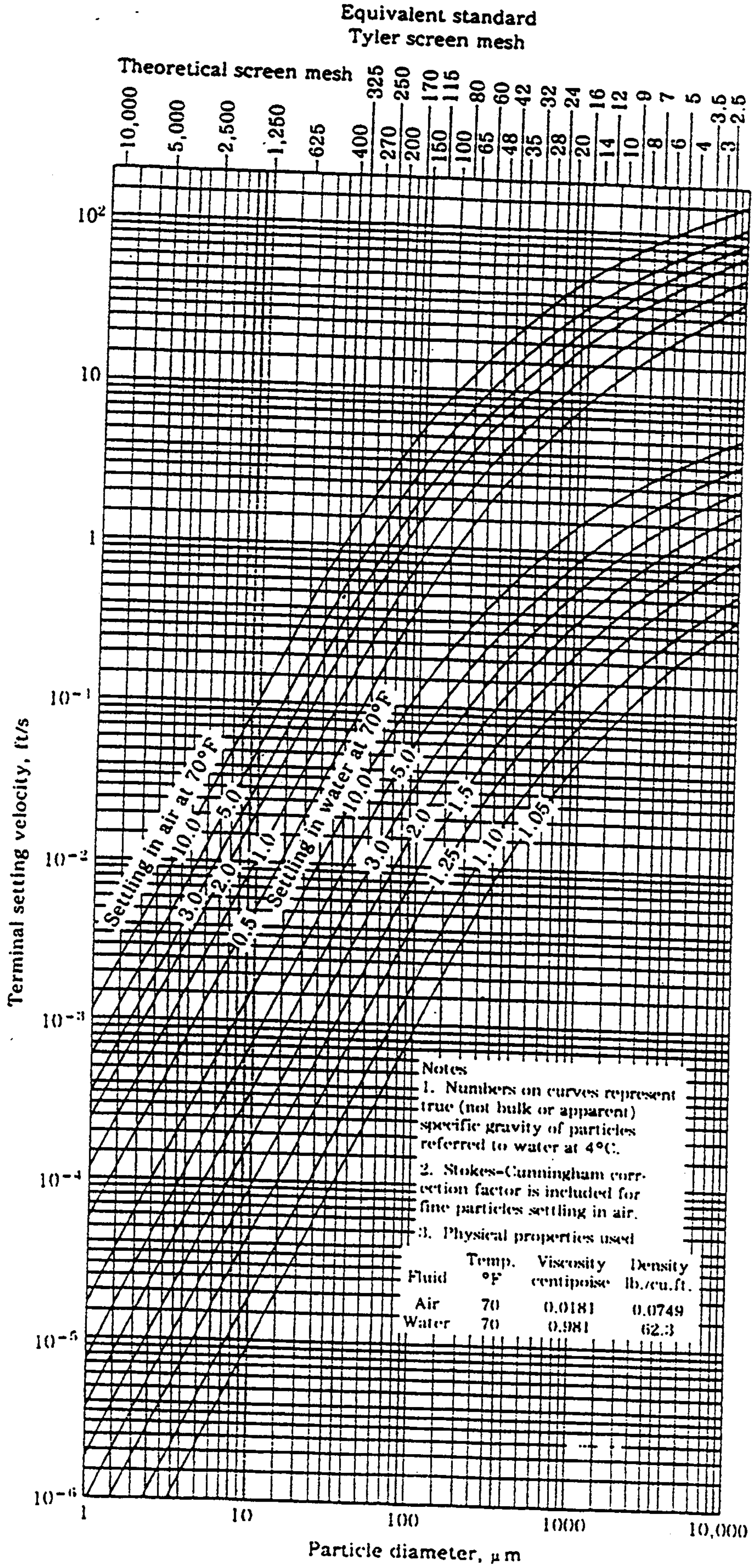


FIGURE 8.7

Terminal settling velocities of spherical particles of different densities settling in air and water at 70°F under the influence of gravity. (From C. E. Lapple, et al., *Fluid and Particle Mechanics,* University of Delaware, Newark, 1951, p. 292.) (Observe that the scale is 1, 1.5, 2, 2.5, 3, 3.5, 4, 5....)

LAMPIRAN 2:

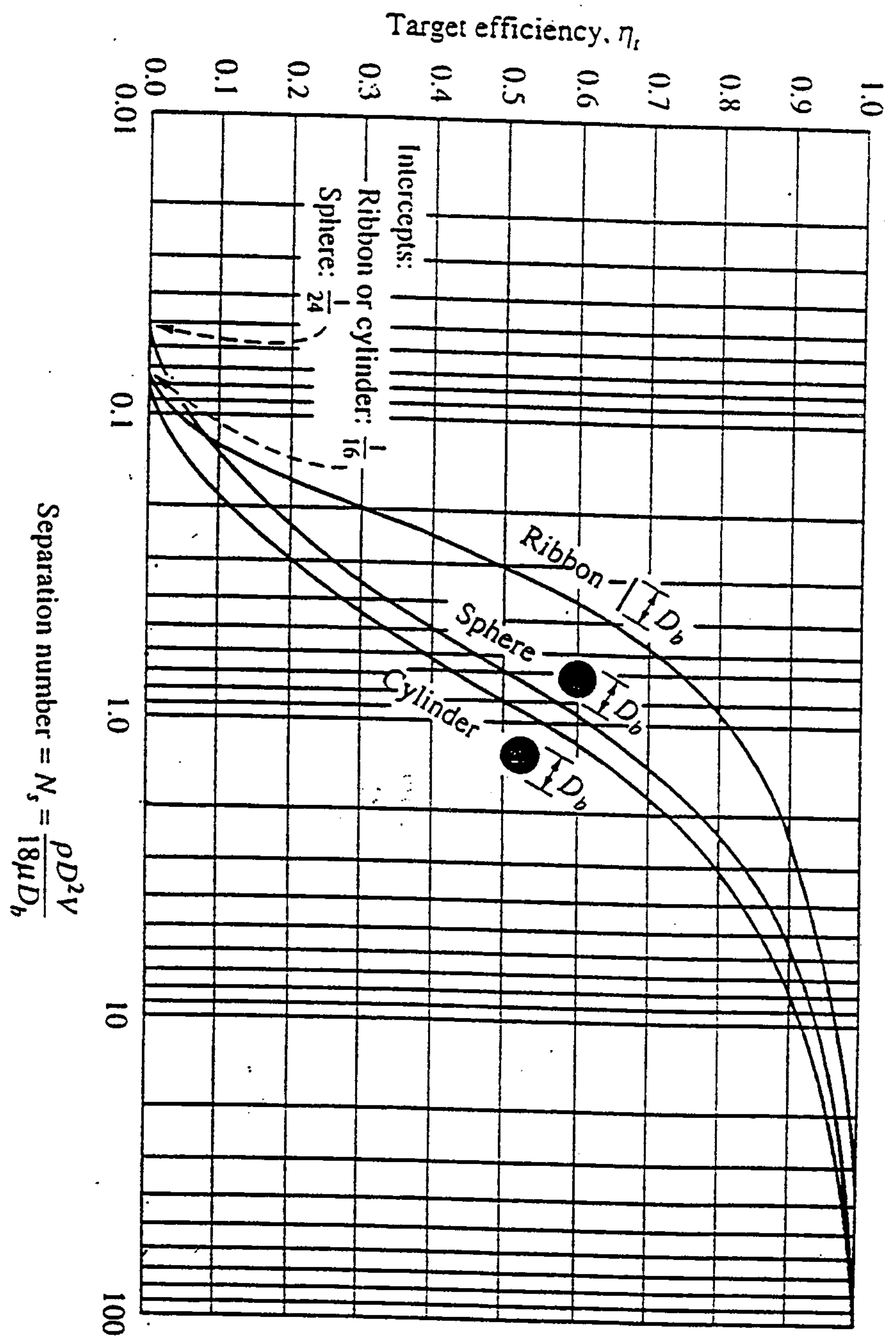


FIGURE 9.18
Target efficiency as a function of separation number, for cylinders, ribbons, and spheres. (From Ref. 18.)

LAMPIRAN 3

TABLE 2. Packing Factors—Dumped Packing

Packing Type	Material	Nominal Packing Size (inches)										
		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	$\frac{1}{32}$" metal	700	390	300	170	185	115					
Raschig rings	$\frac{1}{16}$" 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	

LAMPIRAN 4

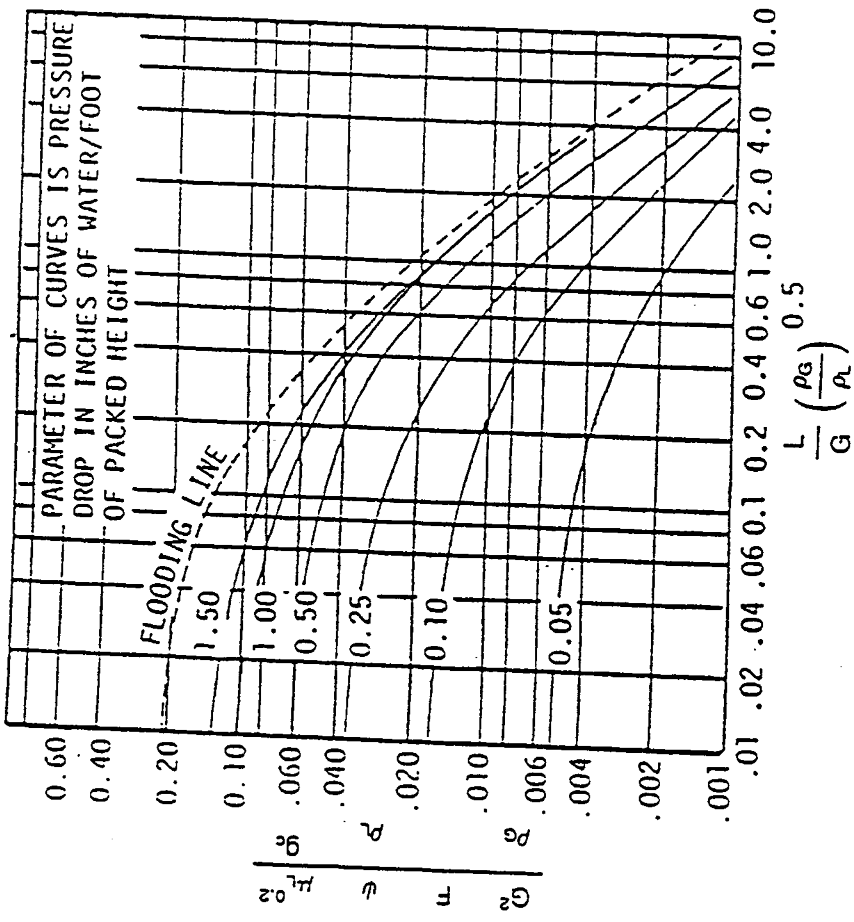


FIGURE 7. Generalized Pressure Drop Correlation to Estimate Column Diameter (G = gas flow rate, lb/sec ft^2; L = liquid flow rate, lb/sec ft^2; F = packing factor; Ψ = ratio, density of water/density of liquid; μ_L = liquid viscosity, cP$_a$; ρ_G = gas density, lb/ft^3; ρ_L = liquid density, lb/ft^3;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

LAMPIRAN 5

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).

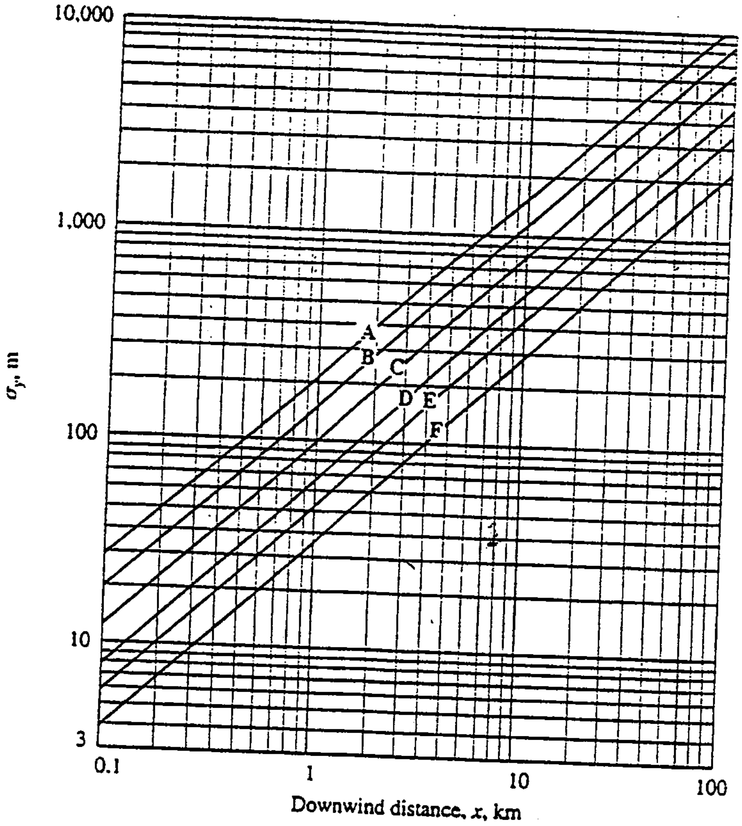


FIGURE 6.7
Horizontal dispersion coefficient σ_y as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [7].)

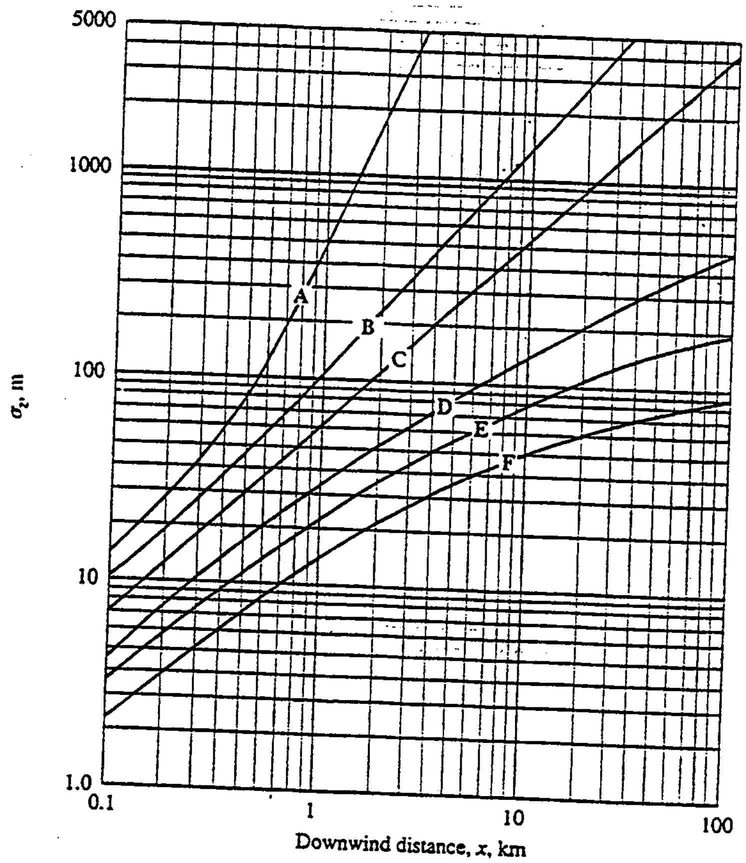


FIGURE 6.8
Vertical dispersion coefficient σ_z as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [7].)

LAMPIRAN 7

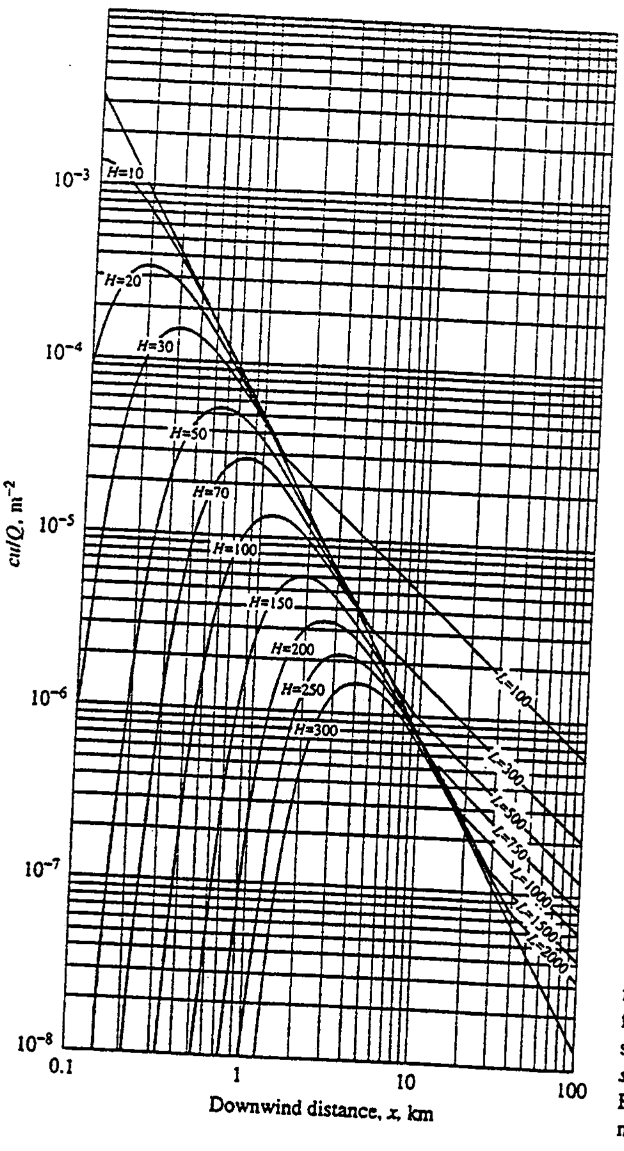


FIGURE 6.9
Ground-level cu/Q, directly under the plume centerline, as a function of downwind distance from the source and effective stack height, H, in meters, *for C stability only.* (From Turner [7].) Here L is the atmospheric mixing height, also in meters.

LAMPIRAN 8

CONVERSION FACTORS*

Length:

$$1 \text{ ft} = 0.3048 \text{ m} = 12 \text{ in.} = \text{mile}/5280 = \text{nautical mile}/6076$$
$$= \text{km}/3281$$

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

Mass:

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

$$1 \text{ kg} = 2.2046 \text{ lbm} = 1000 \text{ g} = (\text{metric ton or tonne or Mg})/1000$$

Force:

$$1 \text{ lbf} = 4.4482 \text{ N} = 32.2 \text{ lbm} \cdot \text{ft/s}^2 = 32.2 \text{ poundal} = 0.4536 \text{ kgf}$$

$$1 \text{ N} = \text{kg} \cdot \text{m/s}^2 = 10^5 \text{ dyne} = \text{kgf}/9.81 = 0.2248 \text{ lbf}$$

Volume:

$$1 \text{ ft}^3 = 0.02831 \text{ m}^3 = 28.31 \text{ liters} = 7.48 \text{ U.S. gallons}$$
$$= 6.23 \text{ Imperial gallons} = \text{acre-ft}/43\,560$$

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

$$1 \text{ m}^3 = 1000 \text{ liters} = 35.29 \text{ ft}^3$$

Energy:

$$1 \text{ Btu} = 1055 \text{ J} = 1.055 \text{ kw} \cdot \text{s} = 2.93 \times 10^{-4} \text{ kwh} = 252 \text{ cal}$$
$$= 777.97 \text{ ft} \cdot \text{lbf} = 3.93 \times 10^{-4} \text{ hp} \cdot \text{h}$$

$$1 \text{ J} = \text{N} \cdot \text{m} = \text{W} \cdot \text{s} = \text{volt} \cdot \text{coulomb} = 9.48 \times 10^{-4} \text{ Btu}$$
$$= 0.239 \text{ cal} = 10^7 \text{ erg} = 6.24 \times 10^{18} \text{ electron volts}$$

*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 9

Power:

$$1\ hp = 550\ ft \cdot lbf/s = 33\ 000\ ft \cdot lbf/min = 2545\ Btu/h = 0.746\ kW$$
$$1\ W = J/s = N \cdot m/s = volt \cdot ampere = 1.34 \times 10^{-3}\ hp = 0.239\ cal/s = 9.49 \times 10^{-4}\ Btu/s$$

Pressure:

$$1\ atm = 101.3\ kPa = 1.013\ bar = 14.696\ lbf/in.^2 = 33.89\ ft\ of\ water = 29.92\ inches\ of\ mercury = 1.033\ kgf/cm^2 = 10.33\ m\ of\ water = 760\ mm\ of\ mercury = 760\ torr$$
$$1\ psi = atm/14.696 = 6.89\ kPa = 0.0689\ bar = 27.7\ in.\ H_2O = 51.7\ torr$$
$$1\ Pa = N/m^2 = kg/m \cdot s^2 = 10^{-5}\ bar = 1.450 \times 10^{-4}\ lbf/in.^2 = 0.0075\ torr = 0.0040\ in.\ H_2O$$
$$1\ bar = 10^5\ Pa = 0.987\ atm = 14.5\ psia$$

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:

$$1\ cp = 0.01\ poise = 0.01\ g/cm \cdot s = 0.001\ kg/m \cdot s = 0.001\ Pa \cdot s = 6.72 \times 10^{-4}\ lbm/ft \cdot s = 2.42\ lbm/ft \cdot h = 2.09 \times 10^{-5}\ lbf \cdot s/ft^2 = 0.01\ dyne \cdot s/cm^2$$

Kinematic viscosity:

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

Temperature:

$$K = °C + 273.15 = °R/1.8 \approx °C + 273 \qquad °C = (°F - 32)/1.8$$
$$°R = °F + 459.67 = 1.8\ K \approx °F + 460 \qquad °F = 1.8°C + 32$$

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) $\mu g/m^3$

Common Units and Values for Problems and Examples:

See inside back cover.

- oooOooo -