UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2007/08

April 2008

IEK 205 – Teknologi Kawalan Pencemaran Udara
[Air Pollution Control Technology]

Masa: 3 jam
[Duration: 3 hours]

Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA PULUH muka surat yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab **EMPAT** soalan. Semua soalan boleh dijawab dalam Bahasa Malaysia ATAU Bahasa Inggeris.

[Please check that the examination paper consists of TWENTY pages of printed material before you begin this examination.

*Answer **FOUR** questions. All questions can be answered either in Bahasa Malaysia OR English]*

(c) Suatu siklon mempunyai garispusat potongan 3 mikron. Ia digunakan untuk persampelan gas sisa yang masuk pada halaju 30 m/s pada salur masuknya.

(i) Apakah maksud garispusat potongan?
(ii) Kira garispusat luar siklon, D_o, jika N = 5 kitaran, $\rho_p = 2000$ kg/m^3, $\mu = 1.8 \times 10^{-5}$ kg/m.s.
(iii) Kira kadar aliran isipadu melalui siklon ini.

(40 markah)

3. (a) Sebuah sistem ESP (Electrostatic Precipitator) di Kilang Simen Langkawi dapat memerangkap 96 % partikel dalam aliran gas sisa. Perundangan baru memerlukan 99% partikel mesti diperangkap. Sekiranya sebelum ini pihak kilang beroperasi dengan menggunakan 10 unit ESP yang serupa, maka kira berapa unit lagi yang diperlukan untuk kecekapan sistem ESP yang baru(η) dengan andaian aliran bercampur.

Diberi $\eta = 1 - \text{eks}(-\eta_b)$; $p = 1 - \eta$ dan $\eta_b = \omega A/Q$

Jelaskan semua simbol di atas.

(40 markah)

(b) Suatu ESP mengumpulkan 96 % partikel yang terdapat di dalam arus keluar. Anda dikehendakki memperbaikki prestasi itu. Terdapat saranan menyejukkan gas masuk dari 650 °F kepada 250 °F, untuk meningkatkan prestasi. Adakah saranan itu boleh diterima, jika kadar aliran jisim malar dan dimensi ESP tidak diubah? Anggap juga halaju hanyutan ω tidak berubah apabila suhu berubah.

Persamaan dalam bahagian 3 (a) boleh digunakan untuk pengiraan anda.

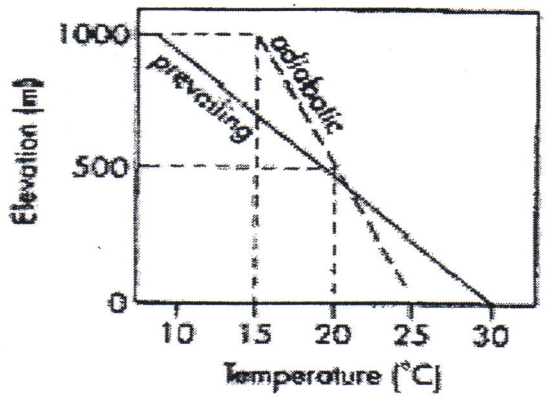
Diberi juga °R = °F + 460 dan PV/T = malar; P, V dan T masing-masing ialah tekanan, isipadu dan suhu gas.

(30 markah)

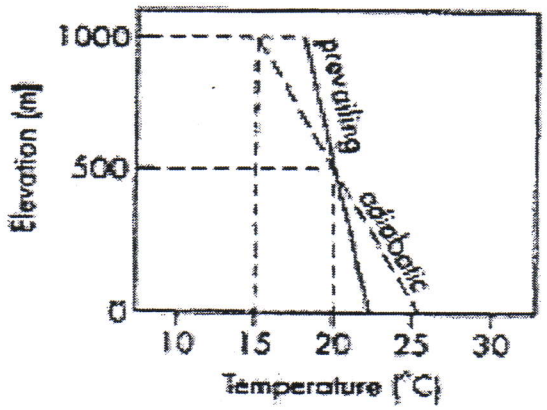
5. (a) Sebuah kilang mempunyai cerobong setinggi 80 m dan kenaikan plum ialah 20 m. Kilang ini mengeluarkan SO_2 pada kadar 500 g/s. Anggarkan kepekatan aras bumi SO_2 daripada cerobong ini pada jarak 2 km bawah angin apabila kelajuan angin ialah 2 m/s dan kelas kestabilan atmosfera Pasquill ialah D.

(30 markah)

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



RAJAH 5A Keadaan sekitaran superadiabatik



RAJAH 5B Keadaan sekitaran subadiabatik

1. *The air pollution control equipment at a factory includes a fabric filter particle collector (known as a baghouse). The baghouse contains 425 cloth bags arranged in parallel, that is 1/425 of the flow goes through each bag. The gas flow rate into and out of the baghouse is 47 m^3/s, and the concentration of particles entering the baghouse is 15 g/m^3. In normal operation the baghouse particulate discharge meets the regulatory limit of 24 mg/m^3. During preventive maintenance replacement of the bags, one bag is mistakenly not replaced, so that only 424 bags are in place.*
Assume the efficiency for each individual bag is the same as the overall efficiency for the baghouse and by using appropriate schematic mass balance diagram, proceed to

   (a) calculate the fraction of particulate matter removed and the efficiency of particulate removal when all the 425 bags are in place and the emissions comply with the regulatory requirements.

   (b) estimate the mass emission rate when one of the bags is missing and recalculate the efficiency of the baghouse.

(100 marks)

2. *(a) Derive the equation for terminal velocity of a particle falling in air under Stoke's condition. Derive also the efficiency equation for a gravity settler. All symbols and assumptions must be stated.*

(30 marks)

   (b) Derive the efficiency equation of a cyclone used to reduce dust in air and discuss how the efficiency of a cyclone can be improved. Show how the cut diameter (d_{cut}) can be determined.
All symbols and assumptions must be stated.

(30 marks)

   (c) A cyclone which has a cut diameter of 3 micron is used for sampling waste gas that enters its inlet pipe at a velocity of 30 m/s.

      (i) What is cut diameter?
      (ii) Calculate the external diameter of the cyclone, D_o, if $N = 5$ cycles, $\rho_p = 2000\ kg/m^3$, $\mu = 1.8 \times 10^{-5}\ kg/m.s$.
      (iii) Calculate the volumetric flow rate through this cyclone.

(40 marks)

...8/-

4. *You wish to treat an airstream containing 0.010 mol fraction toluene at 38 °C and at atmospheric pressure by removing 99% of the toluene before releasing it to the atmosphere. You choose the absorption method to accomplish this and water as the absorbing liquid. Given that the molecular weight of toluene, $M_{toluene}$ = 92 g/mol, and the solubility of toluene in water at 25 °C is 5.2 × 10^{-2} wt %, answer the following questions.*

   (a) *Show that the solubility of toluene in water at 25 °C corresponds to a Henry's constant of about 9800 atm. Assume that this value is constant until 38 °C.*

   (40 marks)

   (b) *Then compute $x_{toluene,\ bottom}$ and from it L/G. Assume that $y^*_{toluene}$ = $0.8y_{toluene}$.*

   (40 marks)

   (c) *Based on your answer in 4 b), give reasons why water is a not a good solvent to use in this case.*

   (20 marks)

   The following equation would be helpful to answer question 4,

$$H_i = \frac{Py_i^*}{x_i}$$

5. (a) *A factory has a smoke stack of 80 m in height. The smoke plume emitted from the stack has a plume height of 20 m. Given that the stack is emitting SO_2 at a flow rate of 500 g/s, calculate the ground-level concentration of SO_2 two kilometers downwind from the stack. Wind speed is 2 m/s and the atmospheric stability corresponds to Pasquill's atmospheric stability class D.*

   (30 marks)

The following equation would be helpful to answer question 5,

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

LAMPIRAN 2:

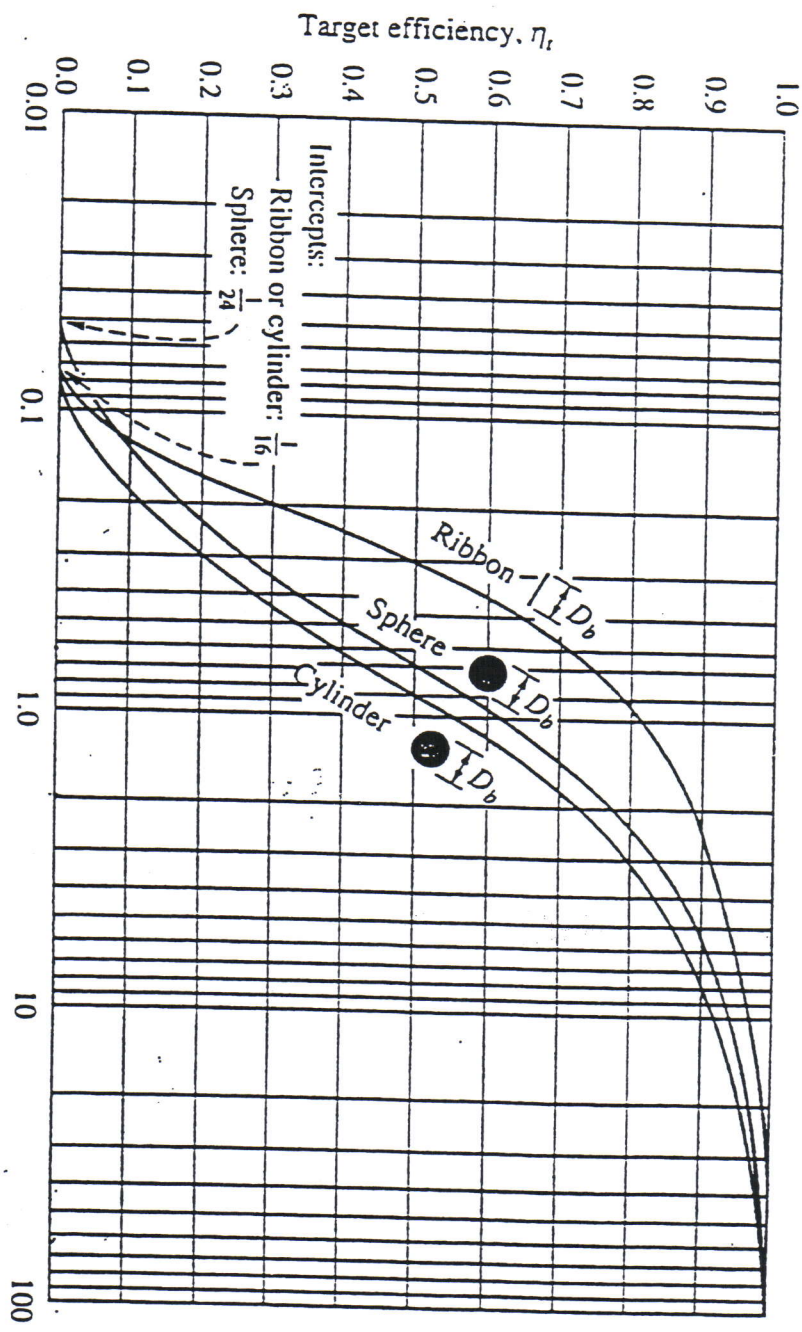


FIGURE 9.18
Target efficiency as a function of separation number, for cylinders, ribbons, and spheres. (From Ref. 18.)

LAMPIRAN 4

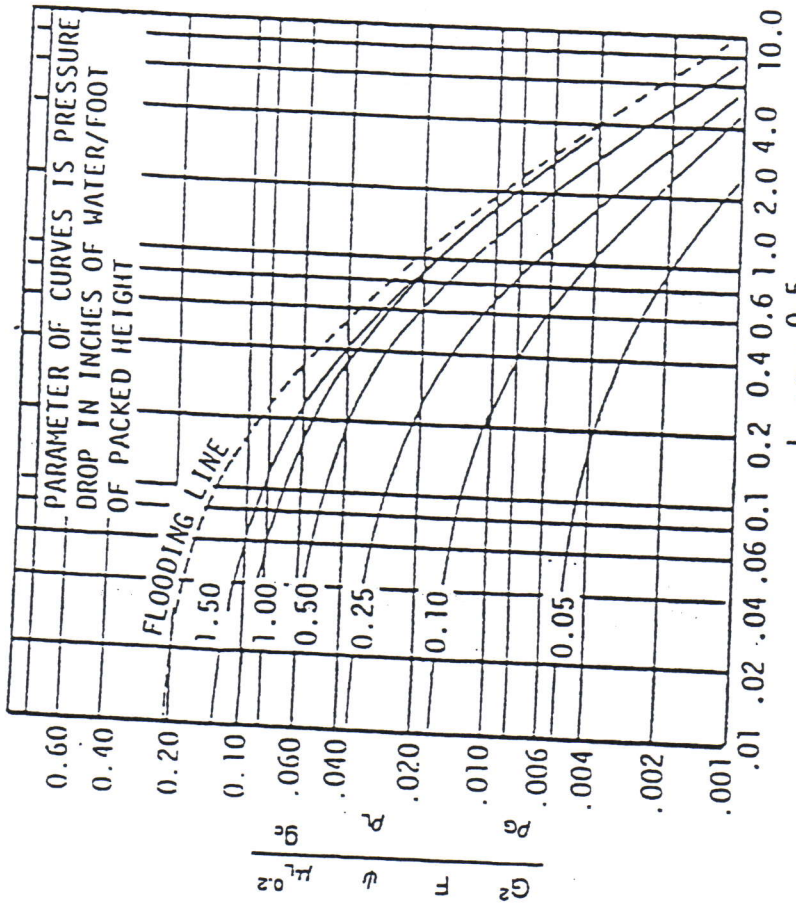


FIGURE 7. Generalized Pressure Drop Correlation to Estimate Column Diameter (G = gas flow rate, lb/sec ft²; L = liquid flow rate, lb/sec ft²; F = packing factor; ψ = ratio, density of water/density of liquid; μ_L = liquid viscosity, cP$_a$; ρ_G = gas density, lb/ft³; ρ_L = liquid density, lb/ft³; g_c = 32.2).

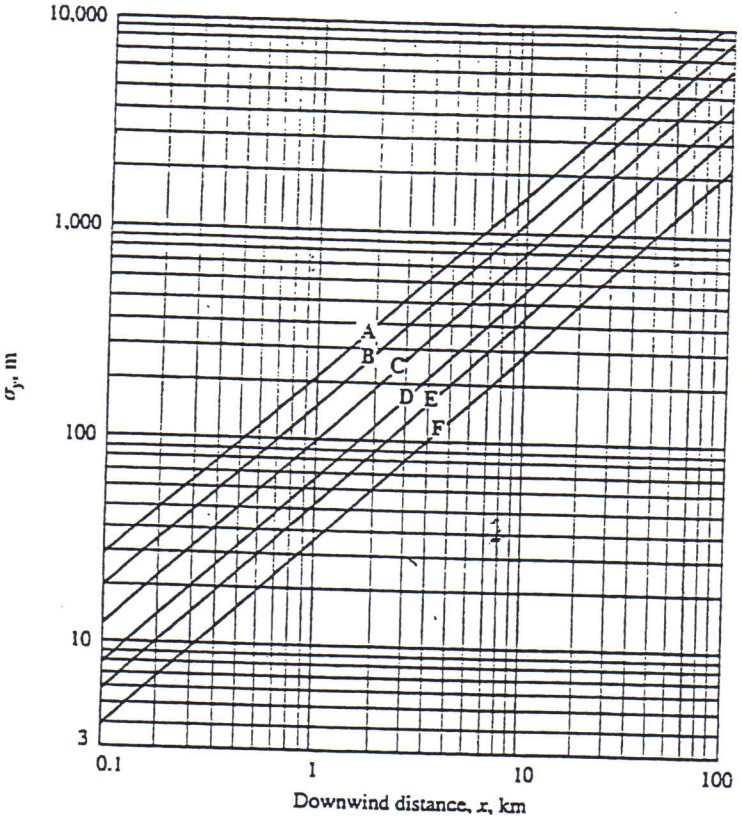


FIGURE 6.7
Horizontal dispersion coefficient σ_y as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [7].)

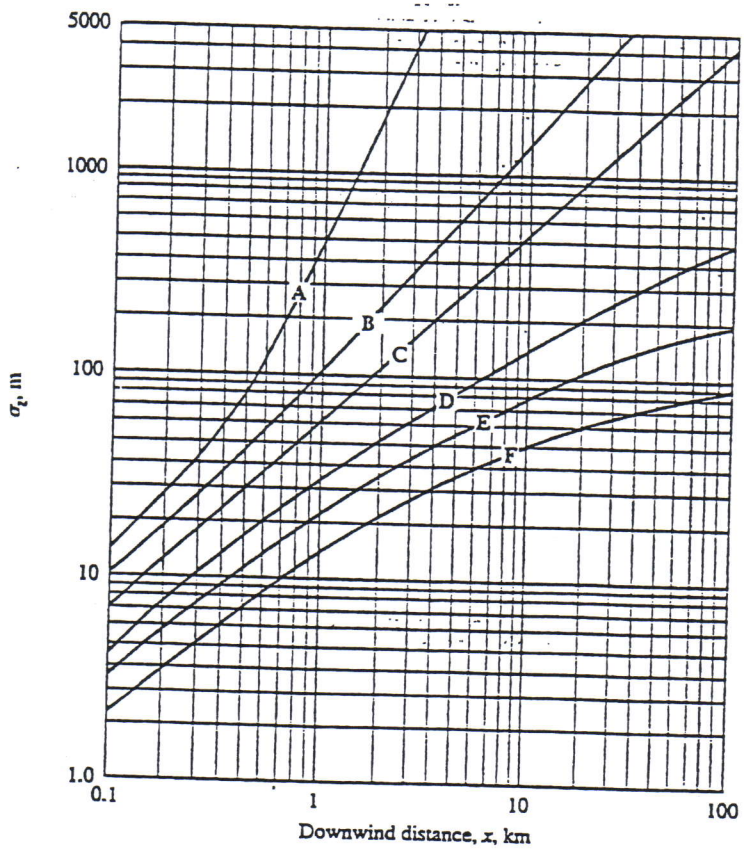


FIGURE 6.8
Vertical dispersion coefficient σ_z as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [7].)

...18/-

LAMPIRAN 8

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.

...20/-