UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 1995/96

Oktober/November

EKC 365 - Kejuruteraan Kawalan Pencemaran Udara

Masa: [3 jam]

ARAHAN KEPADA CALON:

Sila pastikan kertas peperiksaan ini mengandungi **LAPAN (8)** muka surat dan **ENAM (6)** lampiran bercetak sebelum anda mula menjawab soalan.

Kertas peperiksaan ini mengandungi **ENAM (6)** soalan.

Jawab **EMPAT (4)** soalan: Pilih **DUA (2)** soalan dari Bahagian A dan **DUA (2)** soalan dari Bahagian B.

Semua soalan dari Bahagian A **MESTI** dijawab dalam Bahasa Malaysia. Soalan-soalan dari Bahagian B boleh dijawab dalam Bahasa Inggeris.

Soalan terjemahan Bahasa Inggeris ditaib dalam bentuk tulisan Italic.

Jadual dan rajah-rajah yang diperlukan untuk pengiraan penggosok venturi disertakan.

BAHAGIAN A

1. [a] USEPA telah menetapkan standard mutu udara Ambien untuk 7 jenis pencemaran, namakan 6 daripadanya.
The USEPA has established Ambient Air Quality Standards for 7 pollutants. Name 6 of them.

(3 markah)

[b] Zarah-zarah kecil daripada 10μm diambil kira sebagai bahan-bahan pencemaran yang berbahaya walaupun bahan asas kimianya tidak toksik. Kenapa?
Particulates smaller than 10 μm are considered dangerous pollutants even though their basic chemical makeup is not toxic. Why?

(3 markah)

[c] Sulfur dioksida adalah gas tak berwarna. Bagaimanakah ia menyumbang ke arah pengurangan kebolehlihatan?
Sulfur dioxide is a colorless gas. How does it contribute to reduced visibility.

(3 markah)

[d] Kepekatan karbon monoksida (CO) di dalam asap rokok mencecah aras 400 ppm atau lebih tinggi. Untuk nilai ini, tentukan peratusan isipadu dan kepekatan dalam miligram setiap meter padu (mg/m^3) pada 25°C dan 1 atm.
The concentration of carbon monoxide (CO) in cigarette smoke reaches levels of 400 ppm or higher. For this particular value determine the percent by volume and the concentration in milligrams per cubic meter (mg/m^3) at 25°C and 1 atm.

(8 markah)

[e] Sebuah loji kuasa membakar 150 tan arang batu setiap hari, dan terdapat 18.2 lb gas serombong arang batu setiap paun arang batu. Kandungan sulfur bagi arang batu ialah 2.0 peratus dan berat molekul gas serombong ialah 30.5. Jika semua sulfur di dalam arang batu keluar sebagai SO_2 di dalam gas serombong, apakah kepekatan SO_2 di dalam gas serombong dalam bahagian per juta (ppm)?

A power plant burns 150 tons of coal per day, and there are 18.2 Ib of coal flue gas produced per pound of coal. The sulfur content of the coal is 2.0 percent and the molecular weight of the flue gas is 30.5. If all the sulfur in the coal appears as SO_2 in the flue gas, what is the concentration of SO_2 in the flue gas in parts per million?

(1 tan = 2000 Ib)

(8 markah)

2. Sebuah loji akan dibina bagi mengeluarkan 3.5 tan metrik hidrogen sulfida setiap hari. Salah satu daripada nilai tara rekabentuk ialah kepekatan 1 km angin bawah daripada cerobong mesti tidak melebihi 120 $\mu g/m^3$, agar ambang bau tidak dilampaui. Untuk tujuan anggaran, pada mulanya kenaikan plum diabaikan. Anggarkan ketinggian cerobong, dalam meter, untuk kelajuan angin (a) 4 m/s dan (b) 8 m/s. (Kirakan halaju udara sebenar pada aras ketinggian cerobong menggunakan persamaan sepertimana di lampiran).

A plant is to be constructed which will emit 3.5 metric tons of hydrogen sulfide per day. One of the design criteria is that the concentration 1 km downwind from the stack must not exceed 120 $\mu g/m^3$, so that the odor threshold is not exceeded. For the purpose of estimation the plume rise is neglected initially. Estimate the required stack height, in metres, for wind speeds of (a) 4 m/s and (b) 8 m/s. (Calculate the actual air velocity at the stack height level using the equations given in Appendix).

(25 markah)

3. Satu sampel zarah di dalam satu arus gas mempunyai ciri-ciri berikut:
A particulate sample in a gas stream has the following characteristics:

Saiz zarah µm (*Particle size*),	0	2	3	5	7	10	25	30
Berat bertokok (*Cum. wt.*), %	1	2	10	40	70	92	99.9	100

[a] Tentukan sama ada agihan itu "log-normal"
Determine if the distribution is log-normal,

(8 markah)

[b] Tentukan garispusat min geometri
Determine the geometric mean diameter,

(8 markah)

[c] Menggunakan Rajah 2 sebagai mewakili data kecekapan untuk satu pengumpul, tentukan kecekapan keseluruhan pengumpulan, dalam peratus.
Using figure 2 as representative efficiency data for a collector, determine the overall collection efficiency, in percent.

(9 markah)

BAHAGIAN B

4. [a] Kepekatan maksimum CO yang selalu diukur di dalam sebuah bandar adalah lebih kurang 4000 $\mu g/m^3$. Nilai-nilai ini wujud ketika penyongsangan yang kuat di mana nilai untuk u dan H boleh diambil masing-masing sebagai 1 m/s dan 100m. Kepekatan latar belakang ialah 500 $\mu g/m^3$. Bandar itu boleh dianggarkan sebagai segiempat 10 km (panjang) dan 5 km (lebar). Angin bertiup sepanjang kelebaran bandar.
The maximum CO concentrations normally measured in a city are about 4000 $\mu g/m^3$. These values occur during strong inversions for which the values of u and H may be taken as 1 m/s and 100m respectively. The background concentration is 500 $\mu g/m^3$. The city may be approximated as a 10 km (length) by 5 km (width) rectangle. Wind is blowing along the width of the city.

[i] Anggarkan kadar pengeluaran (g/s) untuk CO
Estimate the emission rate (g/s) for CO

(8 markah)

[ii] Kepekatan maksimum CO yang dibenarkan ialah 2000 $\mu g/m^3$. Anggarkan peratusan pengurangan dalam pengeluaran CO diperlukan untuk mencapai piawai ini.
The maximum allowable CO concentration is 2000 $\mu g/m^3$. Estimate the percentage reduction in CO emission required to achieve this standard.

(7 markah)

[b] Kepekatan C, suatu pencemar sebagai asas bagi model kotak tetap boleh ditakrifkan dengan $C = b + \frac{qL}{uH}$; terbitkan ungkapan setara dengan andaian bahawa kepekatan berbeza disepanjang arah tiupan angin (Petunjuk: ambil unsur kebezaan yang tebalnya dx disepanjang arah tiupan angin dan buat imbangan jisim).

The concentration, C of a pollutant as the basis of fixed box model is defined by $C = b + \frac{qL}{uH}$ *; derive an equivalent expression on the assumption that concentration varies along the wind direction (Hints: take a differential element of thickness dx along the wind direction and make mass balance).*

(10 markah)

5. [a] Maklumat dibawah disediakan untuk satu pelebur tembaga yang besar dan tidak dikawal dengan baik.
Following information are available for a large, poorly controlled copper smelter.

Ketinggian cerobong (*Stack height*) = 150 m
Kadar pengeluaran (*Emission rate*)of SO_2:
- Halaju angin bawah (*Down wind speed*) = 5 m/s
- Garis pusat cerobong (*Stack diameter*) = 3 m
- Kadar aliran isipadu (*Volumetric flow rate*) = 50 m^3/s
- Kepekatan SO_2 (*Conc. of* SO_2) = 5000 ppm (mol/mol)
- Tekanan (*Pressure*) = 1 atm
- Suhu cerobong (*Stack temperature*) = 100°C
- Suhu sekitar (*Surrounding temperature*) = 30°C

Kepekatan $C = \frac{Q}{\pi \sigma_y \sigma_z u} \exp - 0.5 \left(\frac{H}{\sigma_z} \right)^2$ pada aras bumi

Berat molekul (*Mol. wt.*) SO_2 = 64

Pemalar gas (*Gas constant*) (R) = $8.314 \frac{m^3.Pa}{mol.K}$

[i] Tentukan kepekatan SO_2 pada 5 km arah angin bawah untuk hari mendung.
Determine the concentration of SO_2 at 5 km downwind direction for an overcast day

(5 markah)

[ii] Tentukan kepekatan aras bumi maksimum dan lokasi angin bawahnya untuk hari cerah.
Determine the maximum ground level concentration and its down wind location for a very bright day.

Kenaikan plum diberikan oleh:
Plume rise is given by:

$$\Delta h = \frac{V_s D}{u}\left(1.5 + 2.8\text{x}10^{-3} PD \frac{T_s - T_a}{T_s}\right)$$

dimana (*where*) P = tekanan dalam milibar (*pressure in millibars*)

(5 markah)

[b] Anda sedang menyiasat masalah karat di dalam peranti kawalan pencemaran udara untuk sebuah loji kuasa pembakaran arang batu. Analisis arang batu diberikan dibawah:
You are investigating the corrosion problem in the air pollution control device of a coal fired power plant. The analysis of coal is given below:

Komponen (*Component*)	**% berat (*by weight*)**
Lembapan (*Moisture*)	6
Karbon (*Carbon*)	70
Hidrogen (*Hydrogen*)	5
Oksigen (*Oxygen*)	10
Sulfur	1
Abu (*Ash*)	8
Jumlah (Total):	**100**

Andaikan lebihan udara 20% (E = 0.2), penukaran 5% SO_2 kepada H_2SO_4 dan pembakaran udara ialah pada 30°C dan 0.02 kg lembapan/kg udara kering kelembapan mutlak. Hitungkan titik embun asid untuk gas ekzos. Beri ulasan tentang kemungkinan pengaratan peralatan, jika suhu keluar gas ekzos ialah 150°C. Titik embun gas serombong boleh didapati dengan menggunakan:

titik embun (°C) = $27 + 0.3\ ppm_{H_2SO_4}$ Di sini ppm (mol/mol)

Assuming 20% excess air (E = 0.2), 5% conversion of SO_2 to H_2SO_4 and the combustion air is at 30°C and absolute humidity 0.02 kg Moisture/kg dry air. Calculate the acid dew point for the exhaust gas. Comment on the chance of corrosion of equipment, if the exit temperature of the exhaust gas is 150°C. The dew point of the flue gas can be obtained using:

dew point (°C) = $27 + 0.3 ppm_{H_2SO_4}$ *; Here ppm (mol/mol)*

(15 markah)

6. [a] Sebuah penggahar venturi digunakan untuk mengawal pencemaran bahan zarah di dalam sebuah kilang keluli. Data dibawah disediakan:

A venturi scrubber is used to control particulate material pollution in a steel mill. Following data are available

Gas ekzos (*Exhaust gas*)	= 50 m^3/s
Q_L/Q_G	= 10^{-3}
Ketumpatan air (*Water density*)	= 1000 kg/m^3
Ketumpatan zarah (*Particle density*)	= 2000 kg/m^3
Faktor pembetulan (*Cunningham correction factor*) (C)	= 1.2
Luas leher penggahar(*Scrubber throat area*)	= 0.5 m^2
Kecekapan motor dan peniup (*Efficiency of the motor and blower*)	= 0.9
Susutan tekanan (*Pressure drop*)	= $V_G^2 \rho_L \frac{Q_L}{Q_G}$

[i] Tentukan susutan tekanan gas di dalam penggahar menggunakan air sebagai cecair penggahar. Tentukan kos kuasa tahunan untuk sistem ini jika kos elektrik ialah 10 sen/kWh

Determine the gas pressure drop in the scrubber using water as the scrubbing liquid. Determine the annual power cost for this system if the electricity cost 10 cents/kWh.

(10 markah)

[ii] Bolehkah sistem ini mencapai garis pusat potongan aerodinamik di bawah 0.5 μma.

Can this system attain Aerodynamic cut diameter below 0.5 μma

$$[D_{pca} = D\,(\rho_{part}\,C)^{1/2}]$$

(10 markah)

[b] Bincangkan penggunaan kotak tetap dan model plum Gaussian di dalam pencemaran udara.

Discuss the applications of fixed boxed and the Gaussian plume models in air pollution.

(5 markah)

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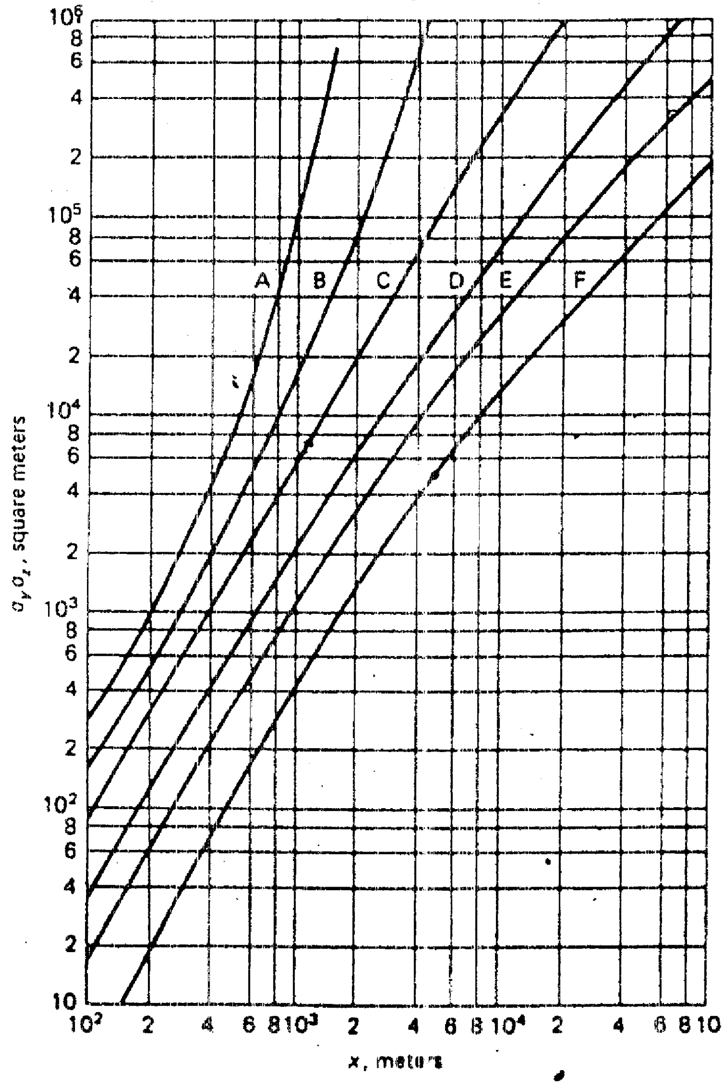

Figure 1 The product, $\sigma_y \sigma_z$, of the dispersion standard deviations as a function of downwind distance. (SOURCE: D. B. Turner. *Workbook of Atmospheric Dispersion Estimates*. Washington, D.C.: HEW, 1969.)

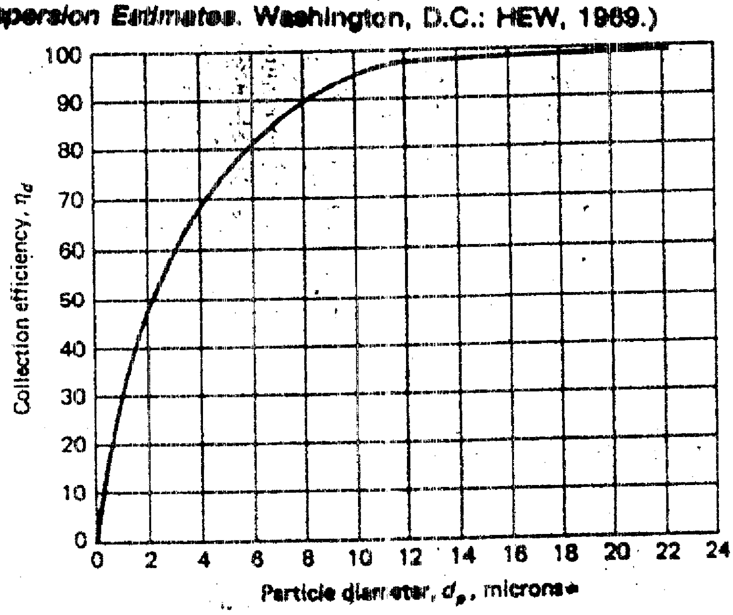

Figure 2 Hypothetical fractional collection efficiency curve as a function of particle diameter.

Table 1 APPROXIMATE VALUES OF σ_y AND σ_z AS A FUNCTION OF DOWNWIND DISTANCE FOR VARIOUS STABILITY CLASSES IN METERS

DISTANCE (km)	STABILITY CLASSES AND σ_y VALUES						STABILITY CLASSES AND σ_z VALUES					
	A	*B*	*C*	*D*	*E*	*F*	*A*	*B*	*C*	*D*	*E*	*F*
0.1	27	19	13	8	6	4	14	11	7	5	4	2
0.2	50	36	23	15	11	8	29	20	14	8	6	4
0.4	94	67	44	29	21	14	72	40	26.	15	11	7
0.7	155	112	74	48	36	24	215	73	43	24	17	11
1.0	215	155	105	68	51	34	455	110	61	32	21	14
2.0	390	295	200	130	96	64	1950	230	115	50	34	22
4.0		550	370	245	180	120		500	220	77	49	31
7.0		880	610	400	300	200		780	360	109	66	39
10.0		1190	840	550	420	275		1350	510	135	79	46
20.0		2150	1540	1000	780	500		2900	950	205	110	60

SOURCE: D. B. Turner, *Workbook of Atmospheric Dispersion Estimates*. Washington, D.C.: HEW, Rev., 1969.

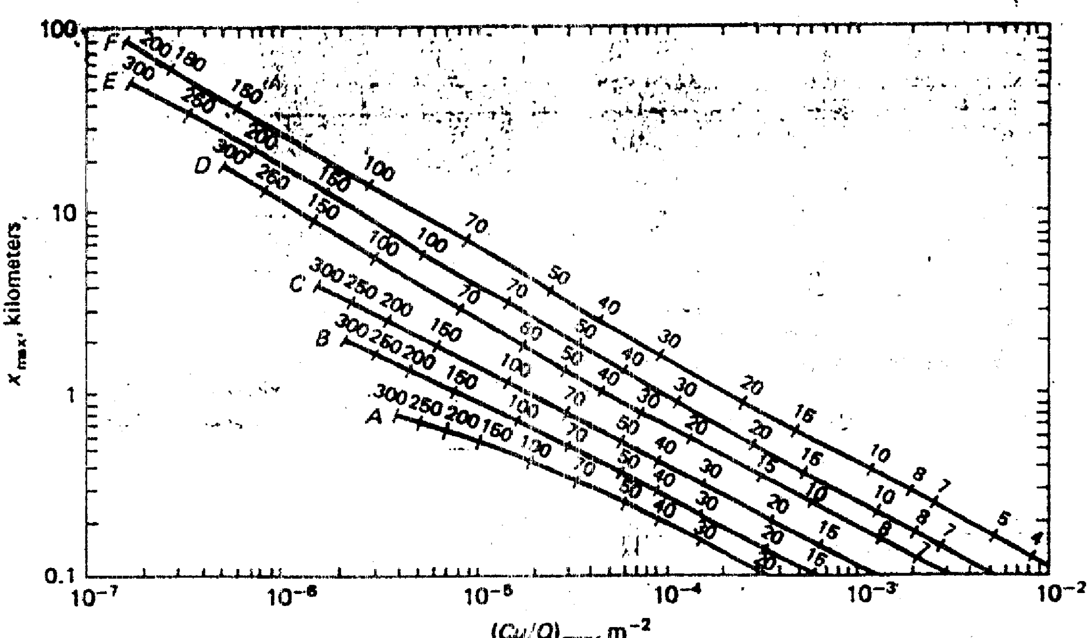

Figure 3 Distance of maximum downwind concentration and maximum downwind Cu/Q value as a function of stability class and effective height in meters. (SOURCE: D. B. Turner. *Workbook of Atmospheric Dispersion Estimates*. Washington, D.C.: HEW, 1969.)

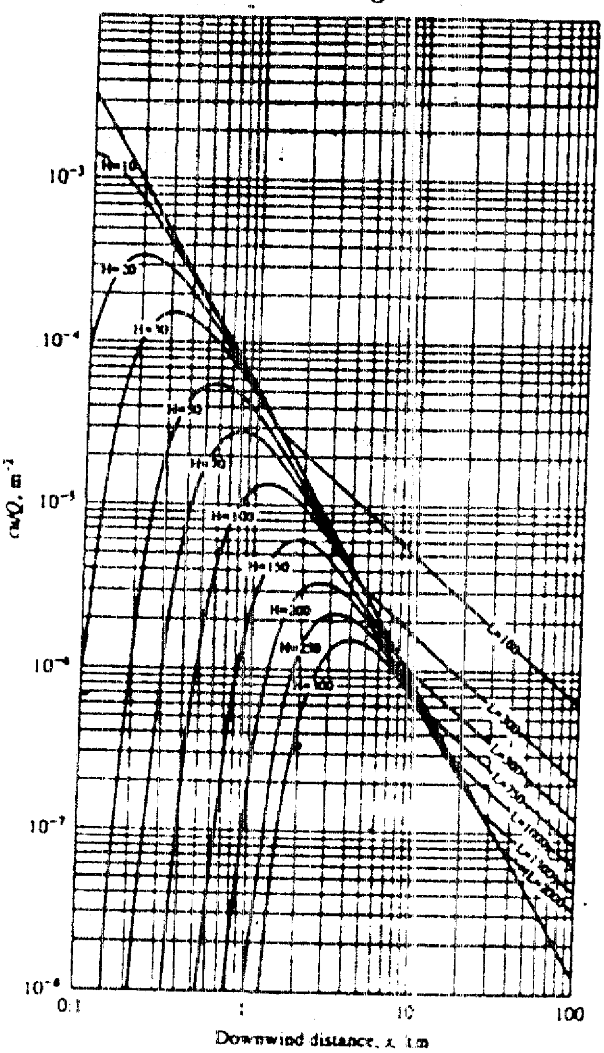

FIGURE 4
Ground-level cu/Q, directly under the plume centerline, as a function of downwind distance from the source and effective stack height H, in meters, *for C stability only*. (From Turner [6].) Here L is the atmospheric mixing height, also in meters.

TABLE 2
Key to stability categories

Surface wind speed (at 10 m), m/s	Day: Incoming solar radiation: Strong	Day: Incoming solar radiation: Moderate	Day: Incoming solar radiation: Slight	Night: Thinly overcast or ≥ 4/8 cloud	Night: Clear or ≤ 3/8 cloud
0–2	A	A–B	B	—	—
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

Source: Ref 6.

Note: The neutral class D should be assumed for overcast conditions during day or night.

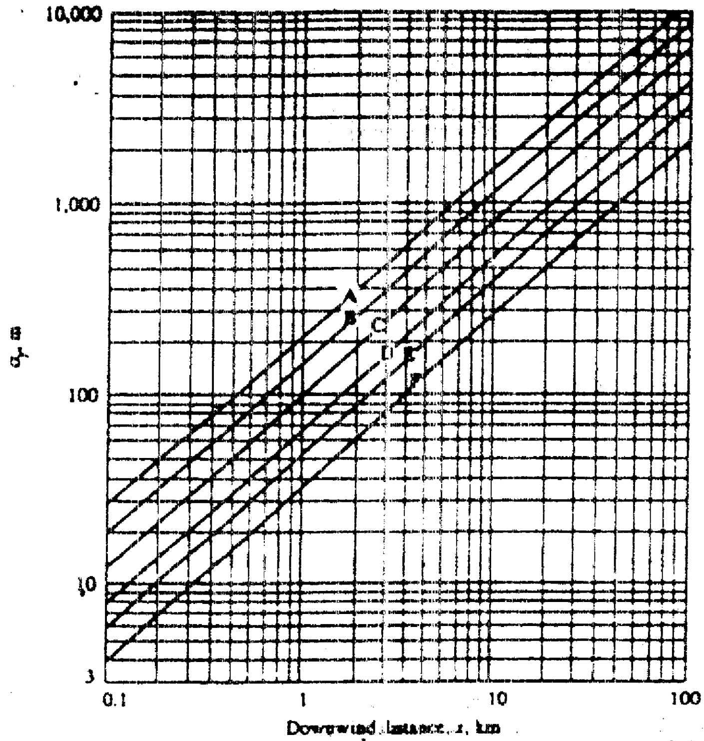

FIGURE 5
Horizontal dispersion coefficient σ_y as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [6].)

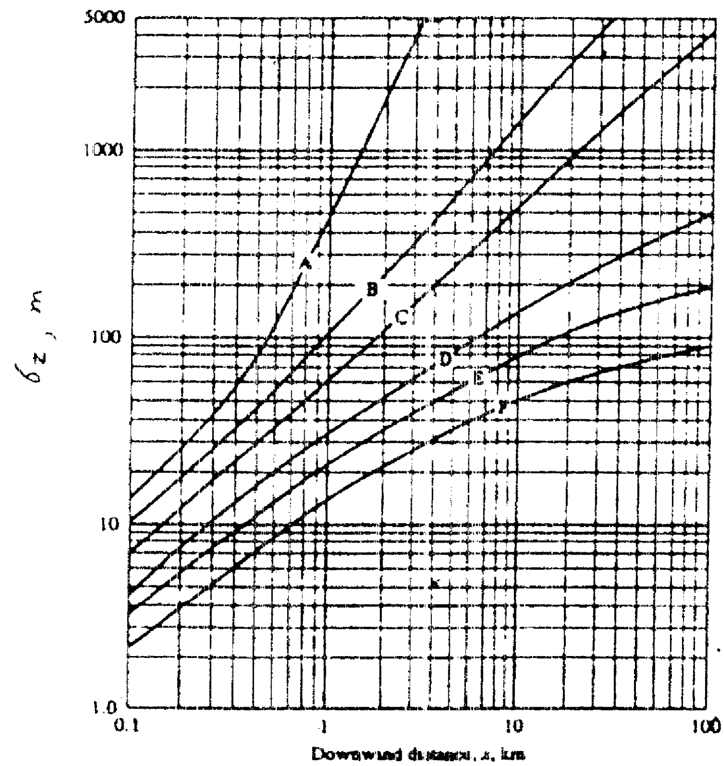

FIGURE 6
Vertical dispersion coefficient σ_z as a function of downwind distance from the source for various stability categories. See Problem 6.16. (From Turner [6].)

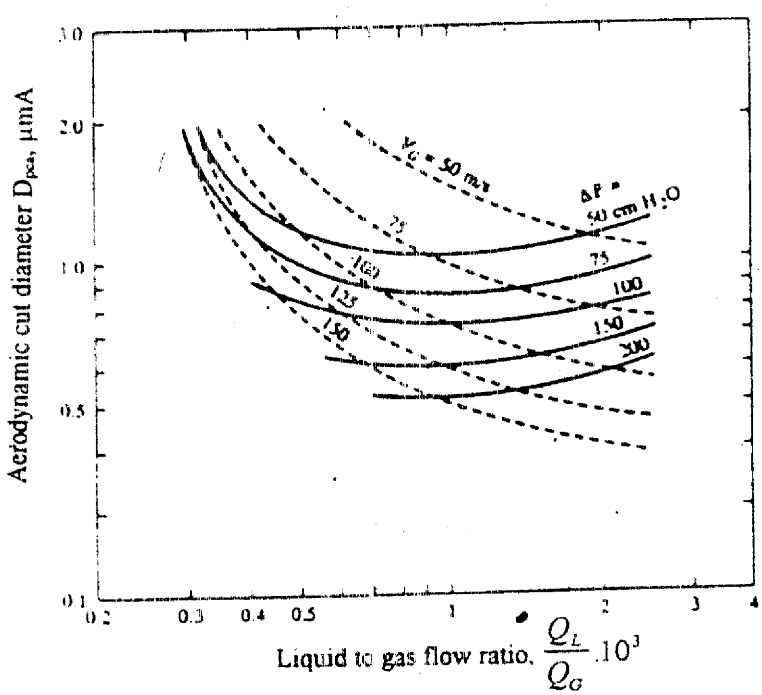

FIGURE 7
Aerodynamic cut diameter and pressure drop predictions for a typical venturi scrubber. V_G is the velocity at the throat. (From Ref. 19.)

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$$\sigma_y \, \sigma_x = \frac{0.117Q}{C_{max} U}$$

$$U = U_1 \left(\frac{Z}{Z_1} \right)^P \qquad P = \frac{n}{2-n} \qquad Z_1 = 1m. \qquad ; n = 0.27$$

Where U is air velocity at the stack height

$$\sigma_z = 0.717H$$

$$C(x,y,) = \frac{Q}{\pi u \sigma_y \sigma_z} \exp\left(\frac{-H^2}{2\sigma_z^{\,2}} \right) \exp\left(\frac{-y^2}{2\sigma_y^{\,2}} \right) \text{ at ground level}$$

$\eta_o = \Sigma(weight\ fraction)(\eta_d)$ where η_d is the collection efficiency for particle diameter, d