UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 1997/98

September 1997

EKC 365 Kejuruteraan Kawalan Pencemaran Udara

Masa: [3 jam]

ARAHAN KEPADA CALON:

Sila pastikan kertas soalan ini mengandungi **TIGA (3)** mukasurat bercetak dan **SEMBILAN (9)** Lampiran sebelum anda memulakan peperiksaan.

Kertas soalan ini mengandungi **LIMA (5)** soalan.

Jawab hanya **EMPAT (4)** soalan sahaja

Semua soalan **MESTI** dijawab dalam Bahasa Malaysia.

...2/-

1. [a] Senaraikan 7 kategori pencemar udara.

(7 markah)

[b] Terbitkan perhubungan di antara bahagian per juta (ppm) dan mikrogram per meter padu ($\mu g/m^3$) untuk pencemar gas.
Ambil P = 1 atm, T = 25°C dan R = 0.08208 atm.m^2/kg mol.

(9 markah)

[c] Kepekatan ozon boleh mencapai nilai 295 $\mu g/m^3$ dalam masa 1 jam dalam kawasan perbandaran dengan masalah-masalah kabus photokimia. Tentukan dalam peratus tahap yang melebihi NAAQS utama untuk ozon. Keadaannya ialah 25°C dan 1 atm.

(9 markah)

2. [a] Apakah penyonsangan radiasi?

(9 markah)

[b] Plum telah diklasifikasikan kepada 4 kategori berlainan. Bincangkan setiap satu kategori.

(16 markah)

3. [a] Sulfur diosida telah dilepaskan pada kadar 160 g/s dari cerobong bertinggian 60 m. Kelajuan angin pada ketinggian ini ialah 6 m/s dan kelas kestabilan atmosfera ialah D pada hari redup. Tentukan kepekatan gas tersebut pada paras tanah sepanjang garis tengah pada jarak 500 m dari cerobong dalam mikrogram per meter padu.

(12 markah)

[b] Sebuah syarikat mengeluarkan 10 g/jam trimethylamina dari cerobong bertinggian 10 m tanpa sebarang peningkatan plum. Kepekatan yang paling rendah yang manusia biasa boleh membaunya ialah 5×10^{-7} g/m^3. Jika angin bertiup pada kelajuan 2 m/s pada malam yang berawan, apakah jarak maksimum dalam arah angin yang membolehkan seseorang membaunya?

(13 markah)

...3/-

4. [a] Kaedah analisis piawaian yang dibenarkan EPA telah dimajukan untuk pelbagai pencemar. Bincangkan kaedah ujian rujukan (reference test method) untuk setiap pencemar berikut.

[i] Zarah, berdiameter (PM_{10}) 10 micron atau kurang
[ii] Ozon
[iii] Karbon monoksida (CO)
[v] Plumbum

(16 markah)

[b] Apakah kestabilan atmosfera? Bincangkan pelbagai keadaan untuk kestabilan atmosfera.

(9 markah)

5. [a] Arangbatu dibakar pada kadar 1.00 kg per saat. Jika analisa arang batu menunjukkan kandungan sulfur adalah 3.00 peratus, apakah kadar tahunan keluaran sulfur dioksida SO_2?
(Anggapkan 5% sulfur di dalam arangbatu akan kekal sebagai abu arang selepas pembakaran).

(13 markah)

[b] Sisa gas dari satu proses industri mengandungi 3,000 ppm toluena (C_7H_8), 18% O_2, dan 81.7% N_2. Ianya akan dibakar dengan kehadiran metana (CH_4) sebagai bahanapi tambahan. Metana akan dibekalkan pada kadar 3 mol/100 mol gas.

[i] Kirakan peratusan lebihan oksigen.

[ii] Anggapkan pembakaran lengkap, kirakan komposisi di dalam gas serombong.

(12 markah)

-ooo0ooo-

Table National Ambient Air Quality Standards (Primary)

Pollutant	Averaging Time	Standard
SO_2	Annual average	80 µg/m³
	24 h	365 µg/m³
NO_2	Annual average	100 µg/m³
CO	8 h	10 mg/m³
	1h	40 mg/m³
Ozone	1 h	0.12 ppm
Particulate matter (PM_{10})	Annual geometric mean	50 µg/m³
	24 h	150 µg/m³

Source: 40 CFR (Code of Federal Regulations) 50, 1982.

413

TABLE
Federal Standards of Performance for New Stationary Sources (commonly called *new source performance standards* [NSPS])

This list is an excerpt from the 1991 version of 40CFR60. Standards are listed there for 68 industrial categories. New categories are regularly added, and existing ones modified. This excerpt shows the kind of regulations that are contained in that much larger compilation.

1. *Coal-fired power plants* whose construction started after September 18, 1978, may not emit the following to the atmosphere:
   a. Particulate matter more than 0.03 lb/10^6 Btu, or 1% of the ash solids in the fuel, whichever is less.
   b. Sulfur dioxide more than 1.2 lb/10^6 Btu, or more than 30% of the SO_2 that would be formed if all the sulfur in the coal were converted to SO_2, whichever is less.
   c. Nitrogen oxides more than 0.6 lb/10^6 Btu for most coals, or 0.5 lb/10^6 Btu for sub-bituminous coal.
2. Large *incinerators* shall not emit to the atmosphere gas that contains particulates in concentrations greater than 0.08 grain/dry standard cubic foot, corrected to 12% CO_2.
3. *Portland cement plants* shall not emit to the atmosphere the following:
   a. Gases from the kiln containing more than 0.30 lb/ton of kiln feed (dry basis).
   b. Gases from the clinker cooler containing more than 0.10 lb/ton of feed to the kiln (dry basis).
4. *Nitric acid plants* shall not emit gases containing more than 3.0 lb of NO_2 per ton of nitric acid produced.
5. *Sulfuric acid plants* shall not emit gases containing more than 4 lb of SO_2 and/or 0.15 lb of sulfuric acid mist/ton of acid produced (100% basis).

The above regulations also limit the opacity of the plumes from these plants, mostly as a control measure, and have very detailed discriptions of testing and monitoring requirements.

TABLE
Emission factors for bituminous coal combustion without control equipment; emission factor rating, A

Furnace size, 10^6 Btu/h heat input[a]	Particulates[b] lb/ton coal burned	Particulates[b] kg/MT coal burned	Sulfur oxides[c] lb/ton coal burned	Sulfur oxides[c] kg/MT coal burned	Carbon monoxide lb/ton coal burned	Carbon monoxide kg/MT coal burned	Hydrocarbons[d] lb/ton coal burned	Hydrocarbons[d] kg/MT coal burned	Nitrogen oxides lb/ton coal burned	Nitrogen oxides kg/MT coal burned	Aldehydes lb/ton coal burned	Aldehydes kg/MT coal burned
Greater than 100 (utility and large industrial boilers)												
Pulverized												
General	16A	8A	38S	19S	1	0.5	0.3	0.15	18	9	0.005	0.0025
Wet bottom	13A[e]	6.5A	38S	19S	1	0.5	0.3	0.15	30	15	0.005	0.0025
Dry bottom	17A	8.5A	38S	19S	1	0.5	0.3	0.15	18	9	0.005	0.0025
Cyclone	2A	1A	38S	19S	1	0.5	0.3	0.15	55	27.5	0.005	0.0025
10 to 100 (large commercial and general industrial boilers)												
Spreader stoker[f]	13A[e]	6.5A	38S	19S	2	1	1	0.5	15	7.5	0.005	0.0025
Less than 10 (commercial and domestic furnaces)												
Spreader stoker	2A	1A	38S	19S	10	5	3	1.5	6	3	0.005	0.0025
Hand-fired units	20	10	38S	19S	90	45	20	10	3	1.5	0.005	0.0025

Source: Table 1-1 of EPA Emissions Factors [7]. The original gives references to the literature on which the values are based.

[a] 1 Btu/h = 0.252 kcal/h

[b] The letter A on all units other than hand-fired equipment indicates that the weight percentage of ash in the coal should be multiplied by the value given. Example: If the factor is 16 and the ash content is 10 percent, the particulate emissions before the control equipment would be 10 × 16 or 160 lb of particulate per ton of coal (10 × 8 kg, or 80 kg, of particulates per MT of coal).

[c] S = sulfur content, which plays the same role as A for the ash content in the preceding footnote.

[d] Expressed as methane.

[e] Without fly ash reinjection.

TABLE
Some values for fuels derived from wood

Material	Ultimate analysis, weight %, dry basis, typical values						Heating value, Btu/lb[g]		% by weight of U.S. electric generation coal, 1991[a]
	C	H	O	N	S	Ash	Dry basis[h]	Average wet basis, as delivered, U.S., 1991[a]	
Wood[b]	52.3	6.3	40.5	0.1	< 0.1	0.8	9,050		
Peat[c]	57.0	5.5	31.0	1.5	0.2	4.8	9,300		
Lignite (also called *brown coal*)[d]	55.0	4.4	13	1.0	1.7	24.9	9,727	6,372	10.2
Sub-bituminous coal[e]	72.5	6.1	17.2	0.7	0.4	3.1	13,006	8,741	31.2
Bituminous coal[f]	75.8	5.0	7.4	1.5	1.6	8.7	13,600	11,964	58.5
Anthracite coal	82.1	2.3	2.0	0.8	0.6	12.2	13,258		0.1
U.S. average coal for electric generation, 1991[a]					1.30	9.76		10,387	100.0

Notes:

[a] The values for average U.S. coal, average heating value,and % by weight for electric generation are from "Cost and Quality of Fuels for Electric Utility Plants 1991," U.S. Department of Energy Report No. DOE/EIA-0191(91), U.S. Government Printing Office, Washington, DC, 1992.

[b] The wood values are those for Douglas fir; other kinds of wood are similar but not identical. These values are from D. A. Tillman, A. J. Rossi, and W. D. Kitto, *Wood Combustion: Principles, Processes and Economics*, Academic Press, New York, p. 43, 1981.

[c] The peat values are from B. F. Haanel, *Final Report of the Peat Committee*, A. C. Acland, Ottawa, p. 7, 1925.

[d] The lignite values are for a typical Texas lignite, courtesy of the Texas Mining and Reclamation Association.

[e] The sub-bituminous values are for a typical Powder River Basin coal, courtsey of the Western Research Institute.

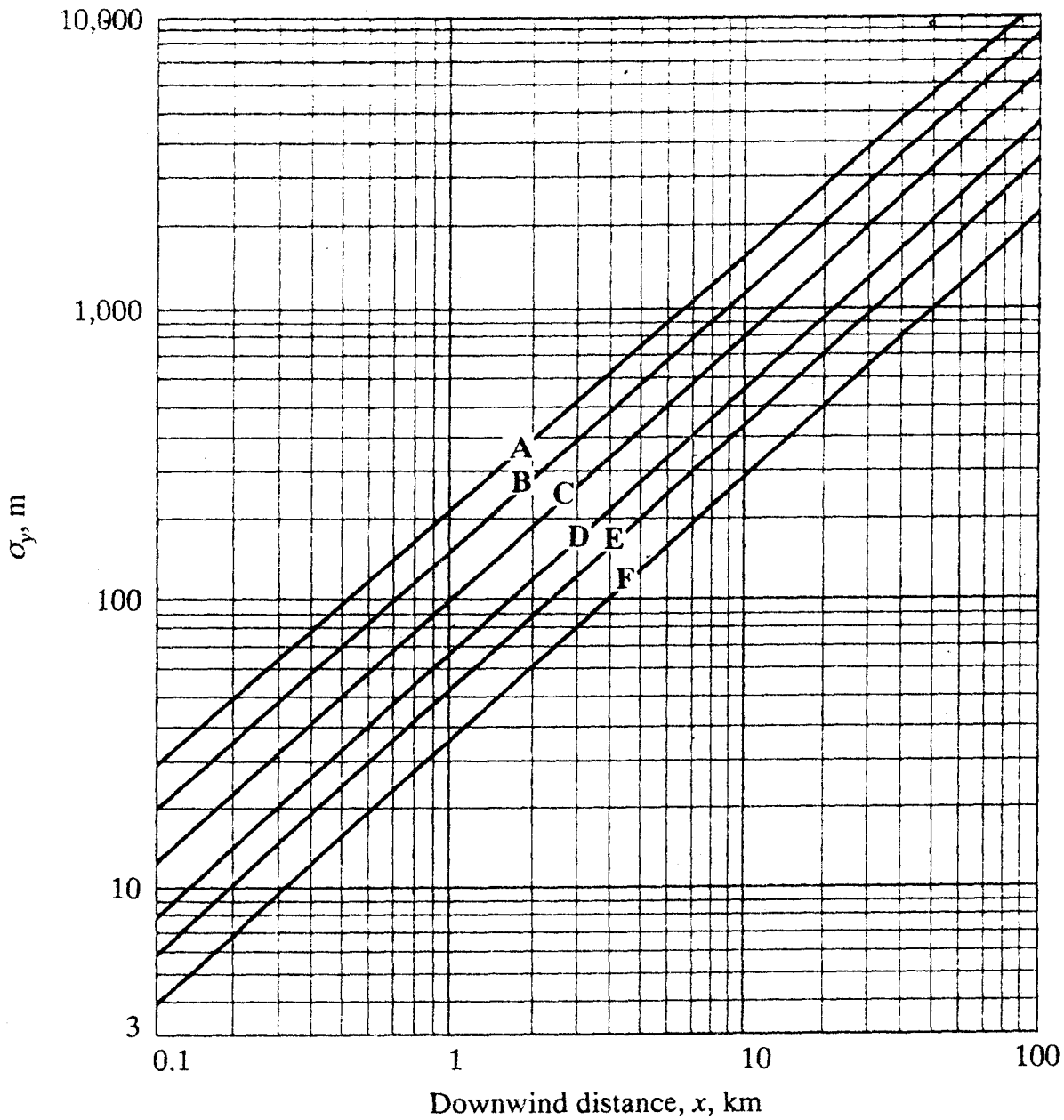
[f] The bituminous value is for a "typical Pittsburgh seam coal." Throughout this book in examples and problems the values for this coal are used, except when it is stated to the contrary.

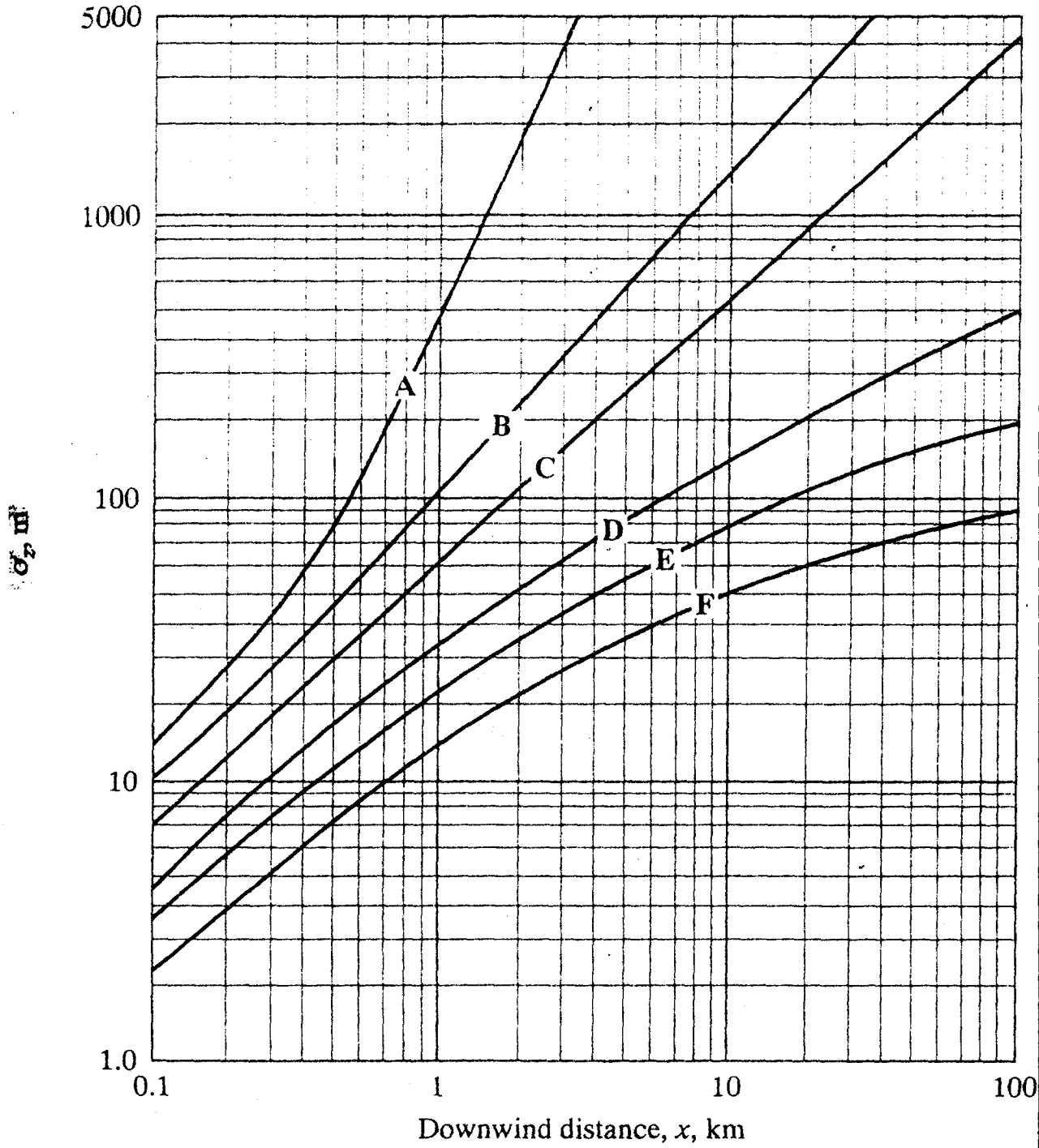
[g] In the United States heating values of coal are generally stated as the higher heating value, as shown here. In Europe they are generally stated as the lower heating value. See the discussion of the difference in Section 10.3.4.1.

[h] The dry basis heating values are computed from the equation

$$\begin{pmatrix}\text{Higher heating}\\ \text{value, Btu/lb}\end{pmatrix} = 14,544C + 62,028\left(H - \frac{O}{8}\right) + 4050S$$

where C, H, O, and S are the weight fractions of carbon, hydrogen, oxygen, and sulfur, respectively. This formula is reported to give values within ± 3% of experimental results.


10,000
1,000
100
10
3
σ_y, m
A
B
C
D
E
F
0.1
1
10
100
Downwind distance, x, km


5000
1000
100
10
1.0
0.1
1
10
100
A
B
C
D
E
F
Downwind distance, x, km

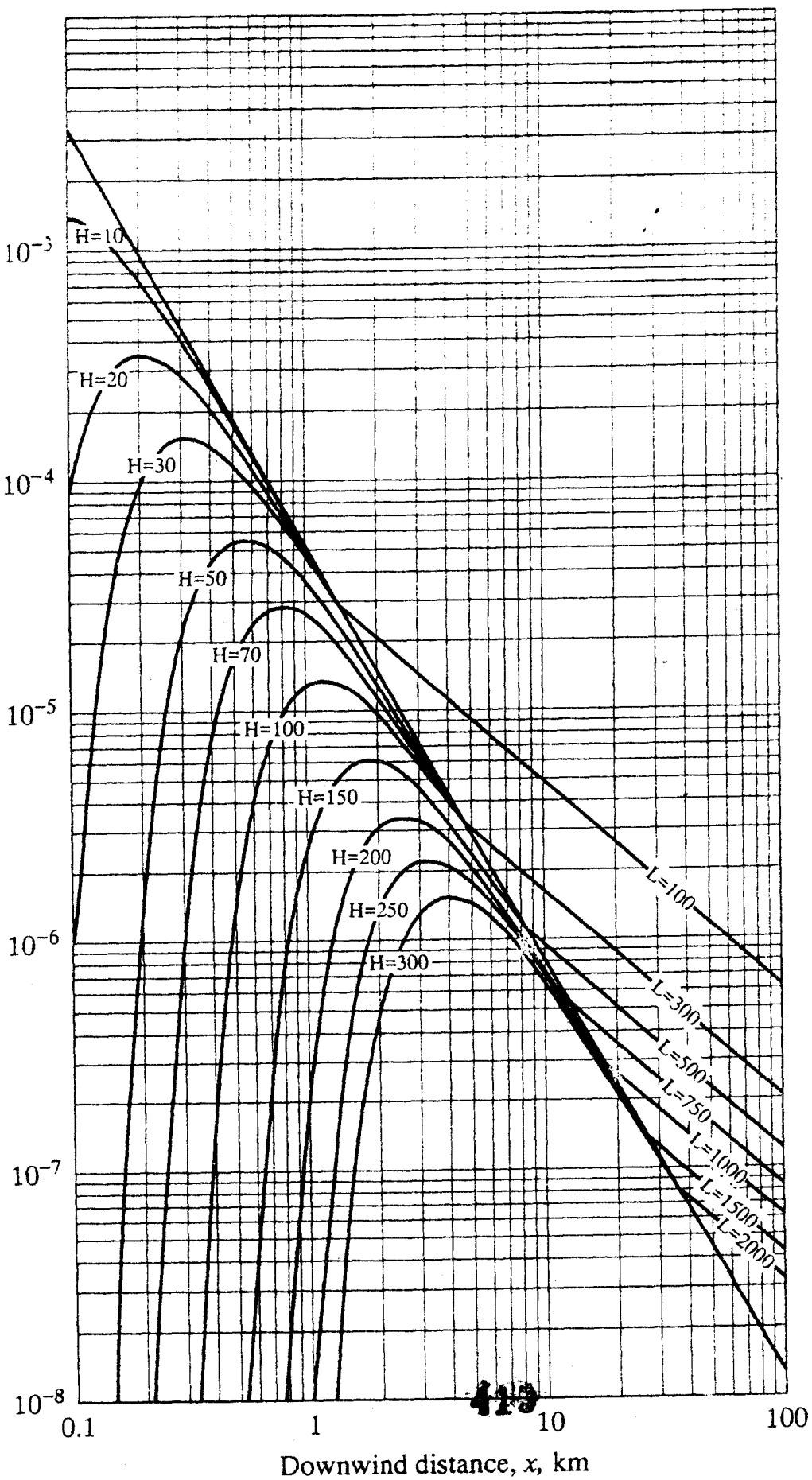

H=10
H=20
H=30
H=50
H=70
H=100
H=150
H=200
H=250
H=300
L=100
L=300
L=500
L=750
L=1000
L=1500
L=2000
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0.1
1
10
100
cu/Q, m^{-2}
Downwind distance, x, km

TABLE
Key to stability categories

Surface wind speed (at 10 m), m/s	Day			Night	
	Incoming solar radiation				
	Strong	Moderate	Slight	Thinly overcast or $\geq \frac{4}{8}$ cloud	Clear or $\leq \frac{3}{8}$ 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

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

LAMPIRAN

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

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

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