UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1993/94

April 1994

EKC 121 - Aliran Bendalir Kejuruteraan Kimia

Masa : [3 jam]

Sila pastikan bahawa kertas peperiksaan ini mengandungi **LIMA** soalan dan **EMPAT** mukasurat serta **DUA PULUH** helaian Lampiran yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab **EMPAT** soalan : **DUA** dari Bahagian A dan **DUA** dari Bahagian B.

Semua soalan mesti dijawab dalam Bahasa Malaysia.

Sumbangan markah setiap soalan adalah **100 markah.**

BAHAGIAN A(JAWAB DUA SOALAN SAHAJA)

SOALAN 1

Satu pam yang mempunyai keefisienan (efficiency) sebanyak 80 peratus digunakan untuk menghantar 30 gallon/min. air dari satu takungan ke sebuah kilang kimia sebatu jauhnya. Paip 3 in skedul 40 digunakan untuk menghantar air tersebut dan kerja rugi disebabkan geseran paip (the lost work due to pipe friction) ialah 200 ft-lbf/lb. Di dalam kilang tersebut, bendalir tersebut mengalir menerusi sebuah reaktor untuk menyejukkan bahan-bahan kimia yang bertindakbalas dan 800,000 Btu/hr haba dipindahkan sebelum air itu didiscaskan. Paras kilang tersebut ialah 873 kaki di atas paras laut dan paras takungan tersebut ialah 928 kaki di atas paras laut. Berapakah kuasa kuda minimum (minimum horse power) yang diperlukan oleh pam tersebut. Andaikan suhu air tersebut ialah 60°F. (1 batu = 5280 kaki).

SOALAN 2

Gas asli yang kandungan utamanya terdiri dari metana (methane) disalurkan melalui satu paip keluli yang bergaris pusat 20 in ID. Setiap stesyen pam yang digunakan menambah sebanyak 100 lbf/in^2 tekanan ke atas aliran tersebut. Tekanan didapati turun ke 25 lbf/in^2 ditempat masuk stesyen pam yang berikutnya yang jaraknya ialah 50 batu dari stesyen pam yang pertama. Berapakah kadar aliran volumetrik gas tersebut (gas flow rate) dalam ft^3/hr. yang disukat pada suhu 60°F dan tekanan 30 in Hg.

SOALAN 3

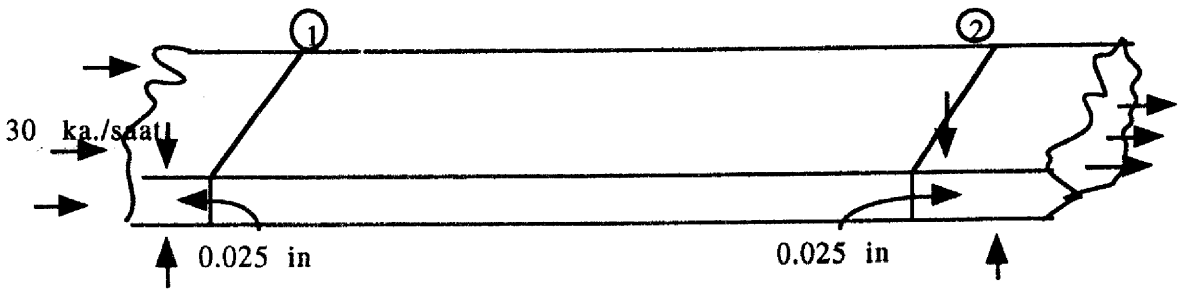
Butiran urea dibuat secara menyembur urea yang boleh dipejalkan ke dalam udara sejuk dari atas suatu menara dan membiarkan urea tersebut menjadi pepejal semasa ia jatuh di dalam menara tersebut. Butiran urea (berbentuk sfera) bergarispusat 6 mm hendak dihasilkan. Ketinggian menara tersebut ialah 25 m dan suhu udara ialah 20°C. Ketumpatan urea ialah 1330 kg/m^3.

(a) Berapakah halaju terminal (terminal velocity) butiran-butiran urea tersebut.

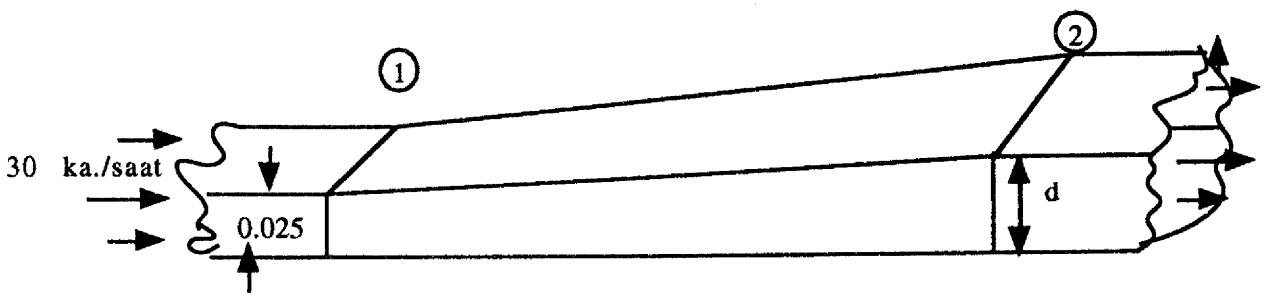
(b) Bolehkah butiran-butiran urea tersebut mencapai 99% daripada halaju terminal sebelum mereka mencecah lantai menara tersebut? Tunjukkan dengan menggunakan pengiraan.

BAHAGIAN B

SOALAN NO. 1 (JAWAB KEDUA-DUA SOALAN)



a) Air mengalir dengan halaju linear sebanyak 30 ka./saat di dalam salur mendatar seperti yang ditunjukkan di atas. Terdapat kejatuhan tekanan sebanyak 1 psi (1 lbf/in^2) di antara tempat masuk (1) dan keluar (2) disebabkan kerugian geseran. Satu salur baru yang mempunyai lebar dan panjang yang sama hendak dibina seperti yang ditunjukkan di bawah untuk mengelakkan kejatuhan tekanan di antara tempat (1) dan (2). Tentukan dimensi d dengan membuat andaian kerugian geseran di dalam salur tersebut sama seperti sebelum ini.

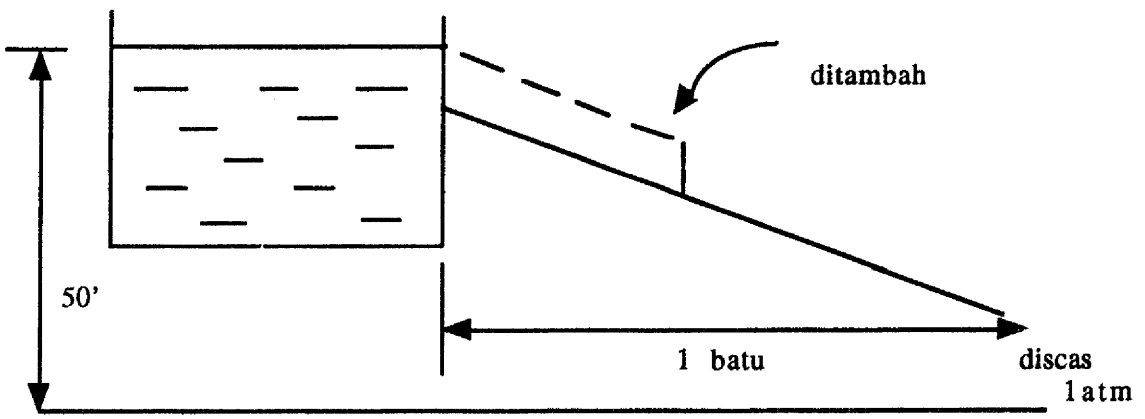


b) Sebaliknya jika kerugian geseran berubah tetapi koefisien kerugian (loss coefficient) K dalam formula

$$hL = \frac{\Delta P_f}{\rho} = K\frac{\bar{u}^2}{2}$$

tidak berubah dan $\bar{u}$ ialah halaju purata aritmatik (arithmatic average) untuk aliran di (1) dan (2). Berapakah nilai d yang diperlukan?

SOALAN NO. 2



Paip bergarispusat 3 in digunakan untuk mengalirkan air dari satu takungan ke satu kampung yang jauhnya 1 batu. Aras permukaan air di dalam takungan ialah 50 kaki di atas aras kampung yang hendak disalurkan. Jika air disalurkan menggunakan daya graviti, berapakah kadar aliran volumetrik (volumetric flow rate) air dalam gallon/min yang boleh dicapai?

Penghantaran air akan digandakan dengan meletakkan sebatang paip yang sama di sebelah paip yang sedia ada. Pada permulaan cuma pada 1/2 batu yang pertama sahaja, paip yang kedua akan disambungkan kepada paip yang sedia ada seperti yang ditunjukkan. Berapa peratuskah pertambahan kadar aliran air yang boleh dicapai?

Abaikan semua kerugian kecuali kerugian yang disebabkan oleh paip dan gunakan nilai $f = t_w/ru^2 = 0.0028$ di dalam semua pengiraan.

ooOoo

LAMPIRAN

$$\rho = \frac{PM}{RT}$$

$$\frac{Pa}{\rho} + \frac{gZa}{g_c} + \frac{\alpha a \overline{V}a^2}{2g_c} + \eta Wp = \frac{Pb}{\rho} + \frac{gZb}{g_c} + \frac{\alpha b Vb^2}{2g_c} + hf$$

$$\frac{U}{U\max} = 1 - \left(\frac{r}{rw}\right)^2$$

$$\overline{V} = \frac{\Delta P s g_c D^2}{32 \Delta L \mu}$$

$$f_F = \frac{16}{N_{Re}}$$

$$f_D = \frac{64}{Re}$$

$$r_H = \frac{S}{L_p}$$

$$hf = \left(4f_F \frac{L}{D} + Kc + Ke + kf\right)\frac{\overline{V}^2}{2g_c}$$

$$Ke = \left(1 - \frac{Sa}{Sb}\right)^2$$

$$Kc = 0.4\left(1 - \frac{Sb}{Sa}\right)$$

$$\frac{M}{2RT}\left[Pa^2 - Pb^2\right] - \frac{G^2}{g_c} \ln \frac{\rho_a}{\rho_b} = \frac{G^2 f \Delta L}{2 g_c r_H}$$

$$C_D = \frac{24}{N_{Re,p}} \quad \text{Stoke's Law}$$

$$N_{Re,p} = \frac{GoDp}{\mu}$$

$$\frac{\Delta P}{L} = \frac{150 \overline{V}_o \mu (1-\varepsilon)^2}{g_c \phi_s{}^2 D_p{}^2 \varepsilon^3} + \frac{1.75 \rho \overline{V}^2 (1-\varepsilon)}{g_c \phi_s D_p \varepsilon} \quad \text{Ergun eqn.}$$

$$Ut = \sqrt{\frac{2g(\rho_p - \rho)m}{A_p \rho_p C_D \rho}}$$

$$C_D = \frac{24}{N_{Re,p}}$$

} at low N_{Re}

$$A_p = \frac{1}{4}\Pi_p^{\,2}$$

$$m = \frac{1}{6}\Pi D_p^{\,3}\rho_p \text{ for sphere}$$

$$Ut = \frac{gD_p^{\,2}(\rho_p - \rho)}{18\mu} \text{ Stoke Law for sphere}$$

$$Ut = 1.75\sqrt{\frac{gD_p(\rho_p - \rho)}{\rho}}$$

$$C_D = 0.44$$

for $1000 < N_{Re,p} < 200{,}000$

$$N_{Re} = \frac{D_p Utp}{\mu}$$

$$K = D_p\left[\frac{g\rho(\rho_p - \rho)}{\mu^2}\right]^{1/3}$$

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VALUES OF GAS CONSTANT

Temperature	Mass	Energy	R
Kelvins	kg mol	J	8314.47
		cal_{IT}	1.9859×10^{3}
		cal	1.9873×10^{3}
		m^3-atm	82.056×10^{-3}
	g mol	cm^3-atm	82.056
Degrees Rankine	lb mol	Btu	1.9858
		$ft\text{-}lb_f$	1545.3
		Hp-h	7.8045×10^{-4}
		kWh	5.8198×10^{-4}

EKC 121

CONVERSION FACTORS AND CONSTANTS OF NATURE

To convert from	To	Multiply by†
acre	ft^2	43,560•
	m^2	4046.85
atm	N/m^2	$1.01325• \times 10^5$
	$lb_f/in.^2$	14.696
Avogadro number	particles/g mol	6.022169×10^{23}
barrel (petroleum)	ft^3	5.6146
	gal (U.S.)	42•
	m^3	0.15899
bar	N/m^2	$1• \times 10^5$
	$lb_f/in.^2$	14.504
Boltzmann constant	J/K	1.380622×10^{-23}
Btu	cal_{IT}	251.996
	$ft\text{-}lb_f$	778.17
	J	1055.06
	kWh	2.9307×10^{-4}
Btu/lb	cal_{IT}/g	0.55556
Btu/lb-°F	$cal_{IT}/g\text{-}°C$	1•
Btu/ft^2-h	W/m^2	3.1546
Btu/ft^2-h-°F	$W/m^2\text{-}°C$	5.6783
	$kcal/m^2\text{-}h\text{-}K$	4.882
Btu-ft/ft^2-h-°F	W-m/m^2-°C	1.73073
	kcal/m-h-K	1.488

(Continued)

EKC 121

CONVERSION FACTORS AND CONSTANTS OF NATURE

To convert from	To	Multiply by†
cal_{IT}	Btu	3.9683×10^{-3}
	$ft\text{-}lb_f$	3.0873
	J	4.1868*
cal	J	4.184*
cm	in.	0.39370
	ft	0.0328084
cm^3	ft^3	3.531467×10^{-5}
	gal (U.S)	2.64172×10^{-4}
cP (centipoise)	kg/m-s	$1* \times 10^{-3}$
	lb/ft-h	2.4191
	lb/ft-s	6.7197×10^{-4}
cSt (centistoke)	m^2/s	$1* \times 10^{-6}$
faraday	C/g mol	9.648670×10^4
ft	m	0.3048*
$ft\text{-}lb_f$	Btu	1.2851×10^{-3}
	cal_{IT}	0.32383
	J	1.35582
$ft\text{-}lb_f/s$	Btu/h	4.6262
	hp	1.81818×10^{-3}
ft^2/h	m^2/s	2.581×10^{-5}
	cm^2/s	0.2581
ft^3	cm^3	2.8316839×10^4
	gal (U.S.)	7.48052
	L	28.31684
ft^3-atm	Btu	2.71948
	cal_{IT}	685.29
	J	2.8692×10^3
ft^3/s	gal (U.S)/min	448.83
gal (U.S.)	ft^3	0.13368
	$in.^3$	231*
gravitational constant	$N\text{-}m^2/kg^2$	6.673×10^{-11}
gravity acceleration, standard	m/s^2	9.80665*
h	min	60*
	s	3600*
hp	Btu/h	2544.43
	kW	0.74624
hp/1000 gal	kW/m^3	0.197
in.	cm	2.54*
$in.^3$	cm^3	16.3871
J	erg	$1* \times 10^7$
	$ft\text{-}lb_f$	0.73756
kg	lb	2.20462
kWh	Btu	3412.1
L	m^3	$1* \times 10^{-3}$
lb	kg	0.45359237*
lb/ft^3	kg/m^3	16.018
	g/cm^3	0.016018
$lb_f/in.^2$	N/m^2	6.89473×10^3
lb mol/ft^2-h	kg mol/m^2-s	1.3562×10^{-3}
	g mol/cm^2-s	1.3562×10^{-4}
light, speed of	m/s	2.997925×10^8

(Continued)

EKC 121

CONVERSION FACTORS AND CONSTANTS OF NATURE

To convert from	To	Multiply by†
m	ft	3.280840
	in.	39.3701
m^3	ft^3	35.3147
	gal (U.S.)	264.17
N	dyn	$1* \times 10^5$
	lb_f	0.22481
N/m^2	$lb_f/in.^2$	1.4498×10^{-4}
Planck constant	J-s	6.626196×10^{-34}
proof (U.S.)	percent alcohol by volume	0.5
ton (long)	kg	1016
	lb	2240*
ton (short)	lb	2000*
ton (metric)	kg	1000*
	lb	2204.6
yd	ft	3*
	m	0.9144*

† Values that end in an asterisk are exact, by definition.

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DIMENSIONS, CAPACITIES, AND WEIGHTS OF STANDARD STEEL PIPE†

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	Cross-sectional area of metal, in.²	Inside sectional area, ft²	Circumference, ft or surface, ft²/ft of length		Capacity at 1 ft/s velocity		Pipe weight lb/ft
							Outside	Inside	U.S. gal/min	Water, lb/h	
⅛	0.405	40	0.068	0.269	0.072	0.00040	0.106	0.0705	0.179	89.5	0.24
		80	0.095	0.215	0.093	0.00025	0.106	0.0563	0.113	56.5	0.31
¼	0.540	40	0.088	0.364	0.125	0.00072	0.141	0.095	0.323	161.5	0.42
		80	0.119	0.302	0.157	0.00050	0.141	0.079	0.224	112.0	0.54
⅜	0.675	40	0.091	0.493	0.167	0.00133	0.177	0.129	0.596	298.0	0.57
		80	0.126	0.423	0.217	0.00098	0.177	0.111	0.440	220.0	0.74
½	0.840	40	0.109	0.622	0.250	0.00211	0.220	0.163	0.945	472.0	0.85
		80	0.147	0.546	0.320	0.00163	0.220	0.143	0.730	365.0	1.09
¾	1.050	40	0.113	0.824	0.333	0.00371	0.275	0.216	1.665	832.5	1.13
		80	0.154	0.742	0.433	0.00300	0.275	0.194	1.345	672.5	1.47
1	1.315	40	0.133	1.049	0.494	0.00600	0.344	0.275	2.690	1,345	1.68
		80	0.179	0.957	0.639	0.00499	0.344	0.250	2.240	1,120	2.17
1¼	1.660	40	0.140	1.380	0.668	0.01040	0.435	0.361	4.57	2,285	2.27
		80	0.191	1.278	0.881	0.00891	0.435	0.335	3.99	1,995	3.00
1½	1.900	40	0.145	1.610	0.800	0.01414	0.497	0.421	6.34	3,170	2.72
		80	0.200	1.500	1.069	0.01225	0.497	0.393	5.49	2,745	3.63

(Continued)

EKC 121

DIMENSIONS, CAPACITIES, AND WEIGHTS OF STANDARD STEEL PIPE

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	Cross-sectional area of metal, in.^{2}	Inside sectional area, ft^2	Circumference, ft or surface, ft^2/ft of length		Capacity at 1 ft/s velocity		Pipe weight lb/ft
							Outside	Inside	U.S. gal/min	Water, lb/h	
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.541	10.45	5,225	3.65
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600	5.02
2½	2.875	40	0.203	2.469	1.704	0.03322	0.753	0.647	14.92	7,460	5.79
		80	0.276	2.323	2.254	0.02942	0.753	0.608	13.20	6,600	7.66
3	3.500	40	0.216	3.068	2.228	0.05130	0.916	0.803	23.00	11,500	7.58
		80	0.300	2.900	3.016	0.04587	0.916	0.759	20.55	10,275	10.25
3½	4.000	40	0.226	3.548	2.680	0.06870	1.047	0.929	30.80	15,400	9.11
		80	0.318	3.364	3.678	0.06170	1.047	0.881	27.70	13,850	12.51
4	4.500	40	0.237	4.026	3.17	0.08840	1.178	1.054	39.6	19,800	10.79
		80	0.337	3.826	4.41	0.07986	1.178	1.002	35.8	17,900	14.98
5	5.563	40	0.258	5.047	4.30	0.1390	1.456	1.321	62.3	31,150	14.62
		80	0.375	4.813	6.11	0.1263	1.456	1.260	57.7	28,850	20.78
6	6.625	40	0.280	6.065	5.58	0.2006	1.734	1.588	90.0	45,000	18.97
		80	0.432	5.761	8.40	0.1810	1.734	1.508	81.1	40,550	28.57
8	8.625	40	0.322	7.981	8.396	0.3474	2.258	2.089	155.7	77,850	28.55
		80	0.500	7.625	12.76	0.3171	2.258	1.996	142.3	71,150	43.39
10	10.75	40	0.365	10.020	11.91	0.5475	2.814	2.620	246.0	123,000	40.48
		80	0.594	9.562	18.95	0.4987	2.814	2.503	223.4	111,700	64.40
12	12.75	40	0.406	11.938	15.74	0.7773	3.338	3.13	349.0	174,500	53.56
		80	0.688	11.374	26.07	0.7056	3.338	2.98	316.7	158,350	88.57

† Based on ANSI B36.10-1959 by permission of ASME.

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VISCOSITIES OF GASES†

No.	Gas	X	Y	No.	Gas	X	Y
1	Acetic acid	7.7	14.3	29	Freon-113	11.3	14.0
2	Acetone	8.9	13.0	30	Helium	10.9	20.5
3	Acetylene	9.8	14.9	31	Hexane	8.6	11.8
4	Air	11.0	20.0	32	Hydrogen	11.2	12.4
5	Ammonia	8.4	16.0	33	$3H_2 + N_2$	11.2	17.2
6	Argon	10.5	22.4	34	Hydrogen bromide	8.8	20.9
7	Benzene	8.5	13.2	35	Hydrogen chloride	8.8	18.7
8	Bromine	8.9	19.2	36	Hydrogen cyanide	9.8	14.9
9	Butene	9.2	13.7	37	Hydrogen iodide	9.0	21.3
10	Butylene	8.9	13.0	38	Hydrogen sulfide	8.6	18.0
11	Carbon dioxide	9.5	18.7	39	Iodine	9.0	18.4
12	Carbon disulfide	8.0	16.0	40	Mercury	5.3	22.9
13	Carbon monoxide	11.0	20.0	41	Methane	9.9	15.5
14	Chlorine	9.0	18.4	42	Methyl alcohol	8.5	15.6
15	Chloroform	8.9	15.7	43	Nitric oxide	10.9	20.5
16	Cyanogen	9.2	15.2	44	Nitrogen	10.6	20.0
17	Cyclohexane	9.2	12.0	45	Nitrosyl chloride	8.0	17.6
18	Ethane	9.1	14.5	46	Nitrous oxide	8.8	19.0
19	Ethyl acetate	8.5	13.2	47	Oxygen	11.0	21.3
20	Ethyl alcohol	9.2	14.2	48	Pentane	7.0	12.8
21	Ethyl chloride	8.5	15.6	49	Propane	9.7	12.9
22	Ethyl ether	8.9	13.0	50	Propyl alcohol	8.4	13.4
23	Ethylene	9.5	15.1	51	Propylene	9.0	13.8
24	Fluorine	7.3	23.8	52	Sulfur dioxide	9.6	17.0
25	Freon-11	10.6	15.1	53	Toluene	8.6	12.4
26	Freon-12	11.1	16.0	54	2,3,3-Trimethylbutane	9.5	10.5
27	Freon-21	10.8	15.3	55	Water	8.0	16.0
28	Freon-22	10.1	17.0	56	Xenon	9.3	23.0

Coordinates for use with figure on next page.

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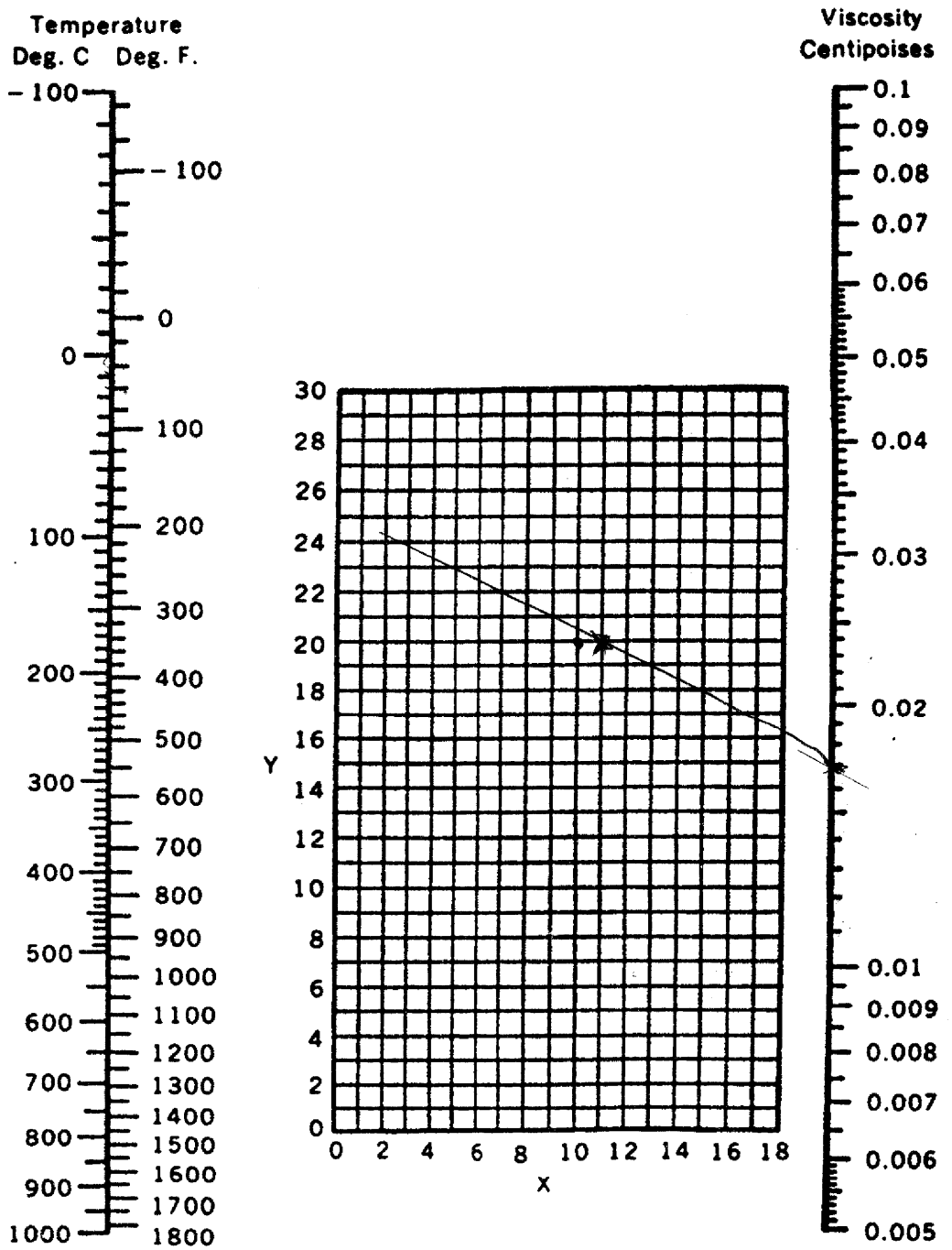
VISCOSITIES OF GASES



Viscosities of gases and vapors at 1 atm; for coordinates, see table on previous page.

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VISCOSITIES OF LIQUIDS†

No.	Liquid	X	Y	No.	Liquid	X	Y
1	Acetaldehyde	15.2	4.8	22	Butyl acetate	12.3	11.0
2	Acetic acid, 100%	12.1	14.2	23	Butyl alcohol	8.6	17.2
3	Acetic acid, 70%	9.5	17.0	24	Butyric acid	12.1	15.3
4	Acetic anhydride	12.7	12.8	25	Carbon dioxide	11.6	0.3
5	Acetone, 100%	14.5	7.2	26	Carbon disulfide	16.1	7.5
6	Acetone, 35%	7.9	15.0	27	Carbon tetrachloride	12.7	13.1
7	Allyl acohol	10.2	14.3	28	Chlorobenzene	12.3	12.4
8	Ammonia, 100%	12.6	2.0	29	Chloroform	14.4	10.2
9	Ammonia, 26%	10.1	13.9	30	Chlorosulfonic acid	11.2	18.1
10	Amyl acetate	11.8	12.5	31	*o*-Chlorotoluene	13.0	13.3
11	Amyl alcohol	7.5	18.4	32	*m*-Chlorotoluene	13.3	12.5
12	Aniline	8.1	18.7	33	*p*-Chlorotoluene	13.3	12.5
13	Anisole	12.3	13.5	34	*m*-Cresol	2.5	20.8
14	Arsenic trichloride	13.9	14.5	35	Cyclohexanol	2.9	24.3
15	Benzene	12.5	10.9	36	Dibromoethane	12.7	15.8
16	Bimethyl oxalate	12.3	15.8	37	Dichloroethane	13.2	12.2
17	Biphenyl	12.0	18.3	38	Dichloromethane	14.6	8.9
18	Brine, $CaCl_2$, 25%	6.6	15.9	39	Diethyl oxalate	11.0	16.4
19	Brine, NaCl, 25%	10.2	16.6	40	Dipropyl oxalate	10.3	17.7
20	Bromine	14.2	13.2	41	Ethyl acetate	13.7	9.1
21	Bromotoluene	20.0	15.9	42	Ethyl alcohol, 100 %	10.5	13.8

(Continued)

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VISCOSITIES OF LIQUIDS

No.	Liquid	X	Y	No.	Liquid	X	Y
43	Ethyl alcohol, 95%	9.8	14.3	77	Nitric acid, 60%	10.8	17.0
44	Ethyl alcohol, 40%	6.5	16.6	78	Nitrobenzene	10.6	16.2
45	Ethyl benzene	13.2	11.5	79	Nitrotoluene	11.0	17.0
46	Ethyl bromide	14.5	8.1	80	Octane	13.7	10.0
47	Ethyl chloride	14.8	6.0	81	Octyl alcohol	6.6	21.1
48	Ethyl ether	14.5	5.3	82	Pentachloroethane	10.9	17.3
49	Ethyl formate	14.2	8.4	83	Pentane	14.9	5.2
50	Ethyl iodide	14.7	10.3	84	Phenol	6.9	20.8
51	Ethylene glycol	6.0	23.6	85	Phosphorus tribromide	13.8	16.7
52	Formic acid	10.7	15.8	86	Phosphorus trichloride	16.2	10.9
53	Freon-11	14.4	9.0	87	Propionic acid	12.8	13.8
54	Freon-12	16.8	5.6	88	Propyl alcohol	9.1	16.5
55	Freon-21	15.7	7.5	89	Propyl bromide	14.5	9.6
56	Freon-22	17.2	4.7	90	Propyl chloride	14.4	7.5
57	Freon-113	12.5	11.4	91	Propyl iodide	14.1	11.6
58	Glycerol, 100%	2.0	30.0	92	Sodium	16.4	13.9
59	Glycerol, 50%	6.9	19.6	93	Sodium hydroxide, 50%	3.2	25.8
60	Heptane	14.1	8.4	94	Stannic chloride	13.5	12.8
61	Hexane	14.7	7.0	95	Sulfur dioxide	15.2	7.1
62	Hydrochloric acid, 31.5%	13.0	16.6	96	Sulfuric acid, 110%	7.2	27.4
63	Isobutyl alcohol	7.1	18.0	97	Sulfuric acid, 98%	7.0	24.8
64	Isobutyric acid	12.2	14.4	98	Sulfuric acid, 60%	10.2	21.3
65	Isopropyl alcohol	8.2	16.0	99	Sulfuryl chloride	15.2	12.4
66	Kerosene	10.2	16.9	100	Tetrachloroethane	11.9	15.7
67	Linseed oil, raw	7.5	27.2	101	Tetrachloroethylene	14.2	12.7
68	Mercury	18.4	16.4	102	Titanium tetrachloride	14.4	12.3
69	Methanol, 100%	12.4	10.5	103	Toluene	13.7	10.4
70	Methanol, 90%	12.3	11.8	104	Trichloroethylene	14.8	10.5
71	Methanol, 40%	7.8	15.5	105	Turpentine	11.5	14.9
72	Methyl acetate	14.2	8.2	106	Vinyl acetate	14.0	8.8
73	Methyl chloride	15.0	3.8	107	Water	10.2	13.0
74	Methyl ethyl ketone	13.9	8.6	108	*o*-Xylene	13.5	12.1
75	Naphthalene	7.9	18.1	109	*m*-Xylene	13.9	10.6
76	Nitric acid, 95%	12.8	13.8	110	*p*-Xylene	13.9	10.9

Coordinates for use with figure on p. 1096.

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PROPERTIES OF LIQUID WATER

Temperature T, °F	Viscosity† μ', cP	Thermal conductivity‡ k, Btu/ft-h-°F	Density§ ρ, lb/ft^3	$\psi_f = \left(\frac{k^3\rho^2 g}{\mu^2}\right)^{1/3}$
32	1.794	0.320	62.42	1,410
40	1.546	0.326	62.43	1,590
50	1.310	0.333	62.42	1,810
60	1.129	0.340	62.37	2,050
70	0.982	0.346	62.30	2,290
80	0.862	0.352	62.22	2,530
90	0.764	0.358	62.11	2,780
100	0.682	0.362	62.00	3,020
120	0.559	0.371	61.71	3,530
140	0.470	0.378	61.38	4,030
160	0.401	0.384	61.00	4,530
180	0.347	0.388	60.58	5,020
200	0.305	0.392	60.13	5,500
220	0.270	0.394	59.63	5,960
240	0.242	0.396	59.10	6,420
260	0.218	0.396	58.53	6,830
280	0.199	0.396	57.94	7,210
300	0.185	0.396	57.31	7,510

† From *International Critical Tables*, vol. 5, McGraw-Hill Book Company, New York, 1929, p. 10.
‡ From E. Schmidt and W. Sellschopp, *Forsch. Geb. Ingenieurw.*, 3:277 (1932).
§ Calculated from J. H. Keenan and F. G. Keyes, *Thermodynamic Properties of Steam*, John Wiley & Sons., Inc., New York, 1937.

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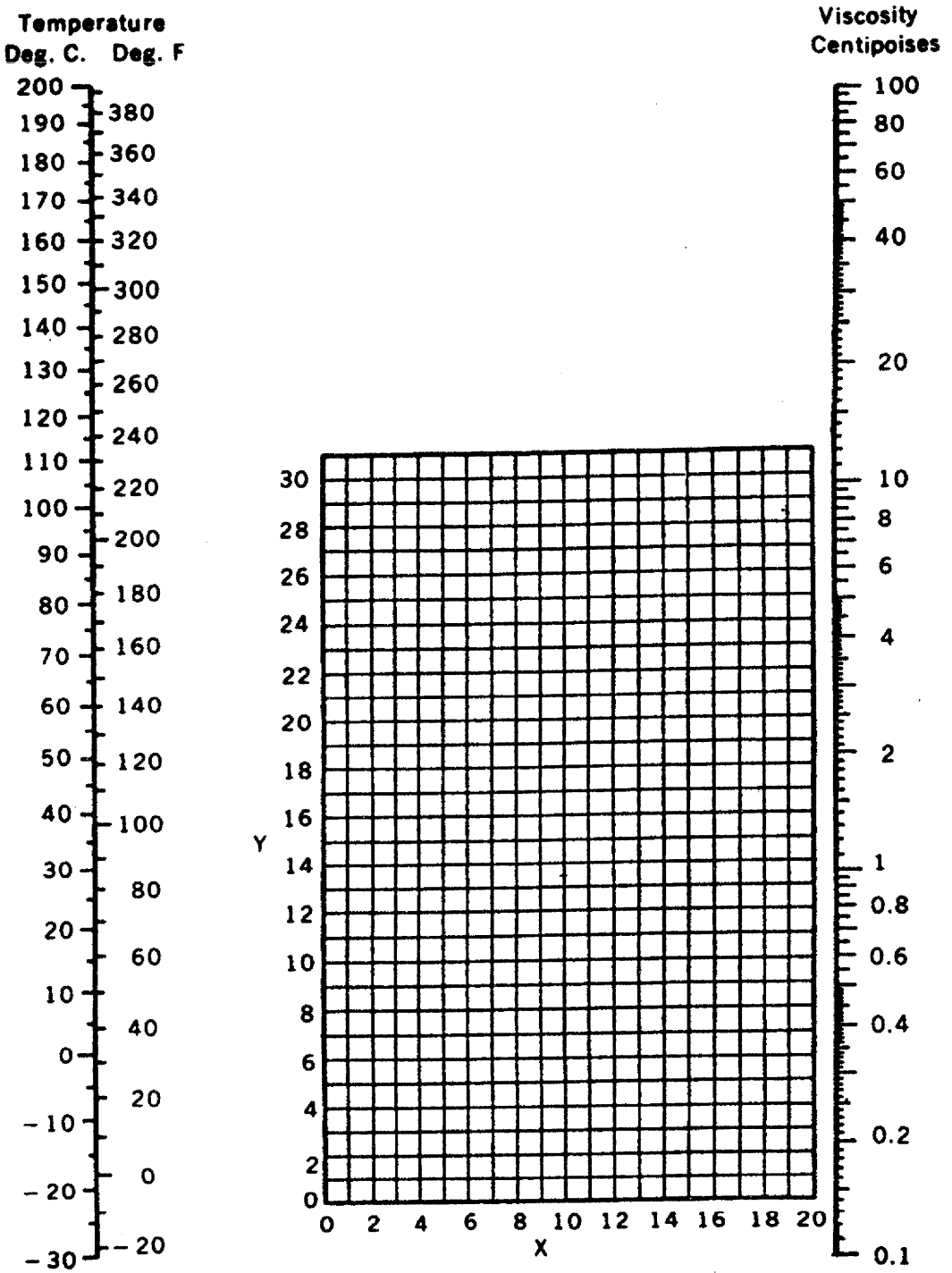
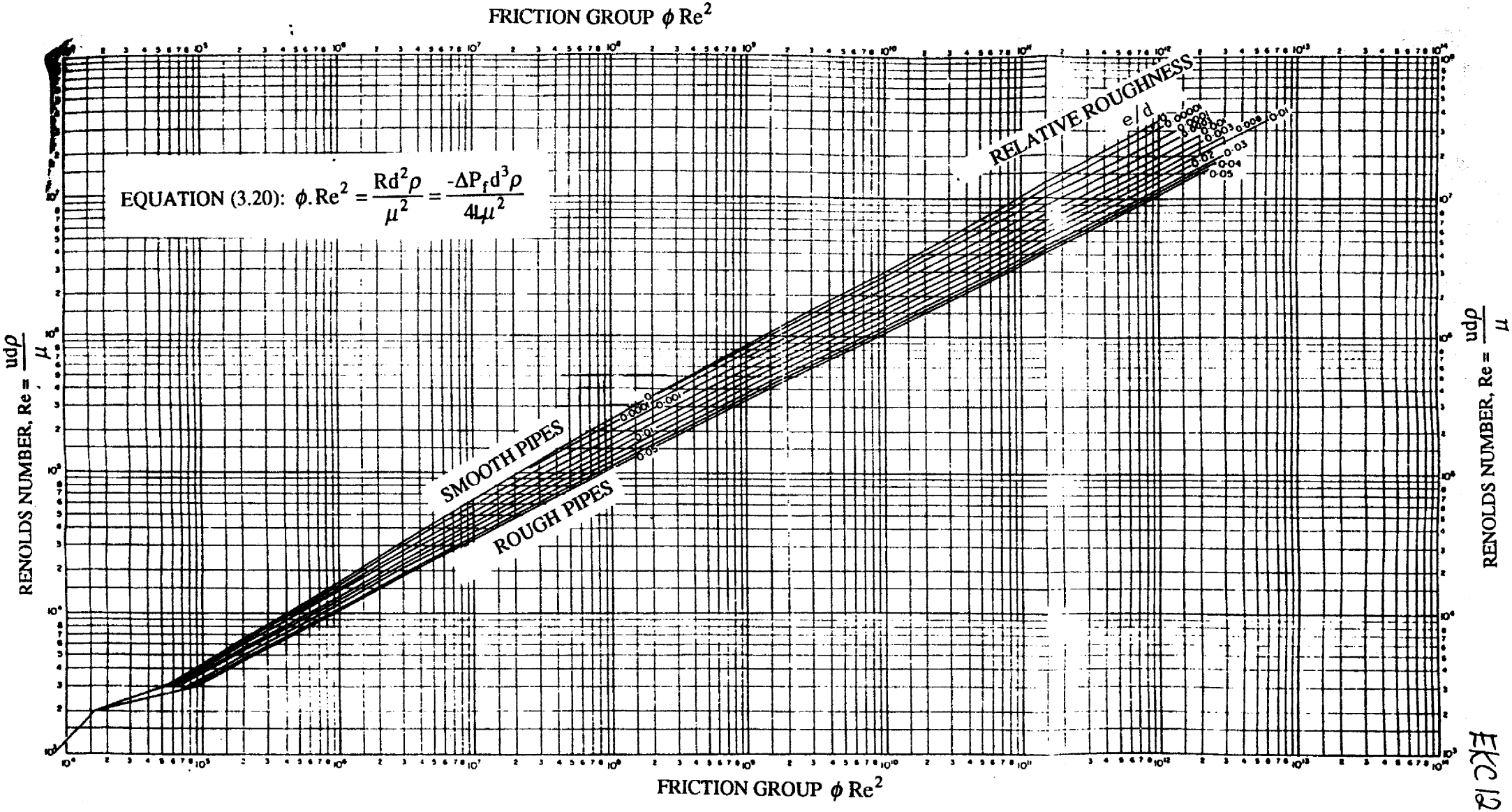
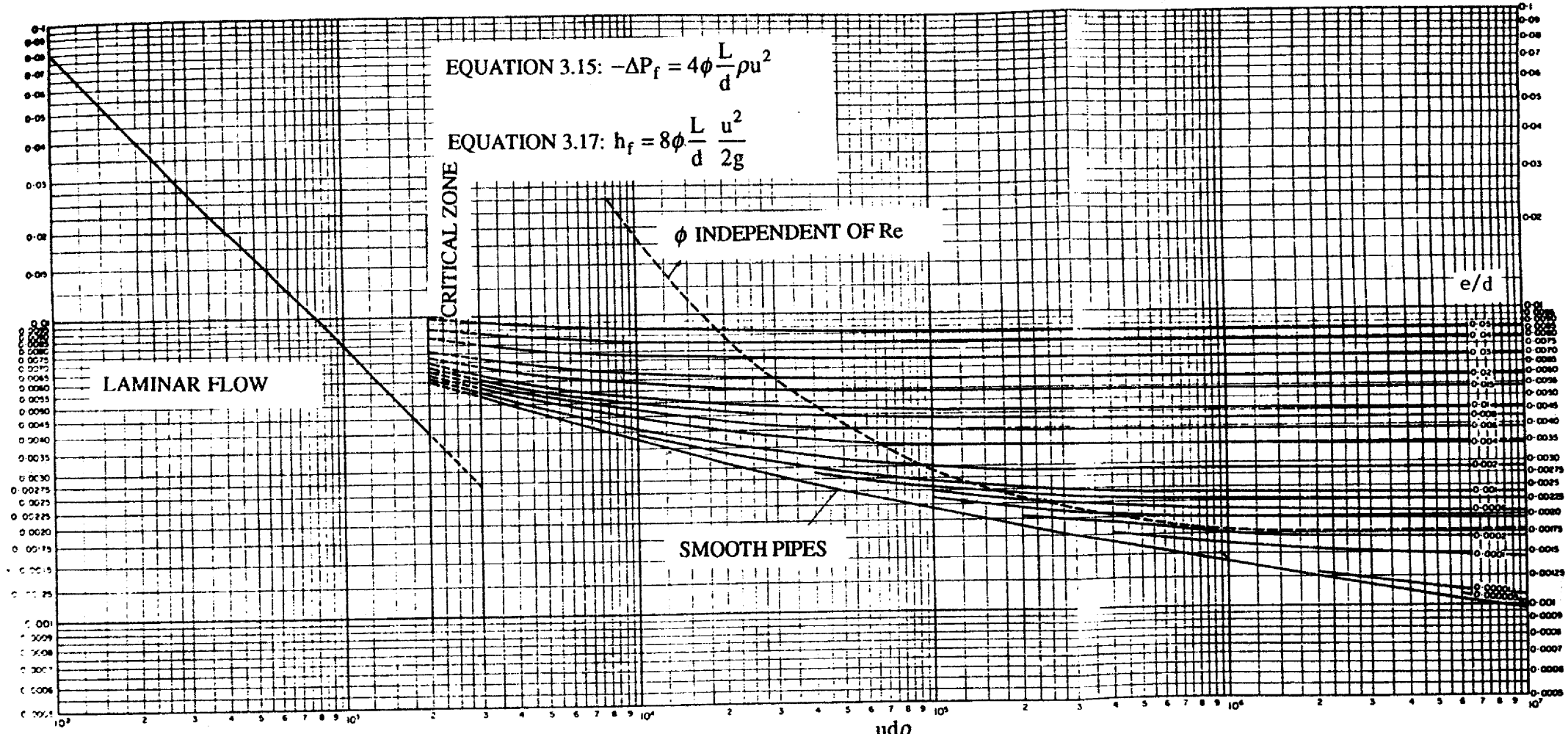
VISCOSITIES OF LIQUIDS



Viscosities of liquids at 1 atm. For coordinates, see table on previous page.



Pipe friction chart $\phi\,\mathrm{Re}^2$ versus Re for various values of e/d



Pipe friction chart ϕ versus Re

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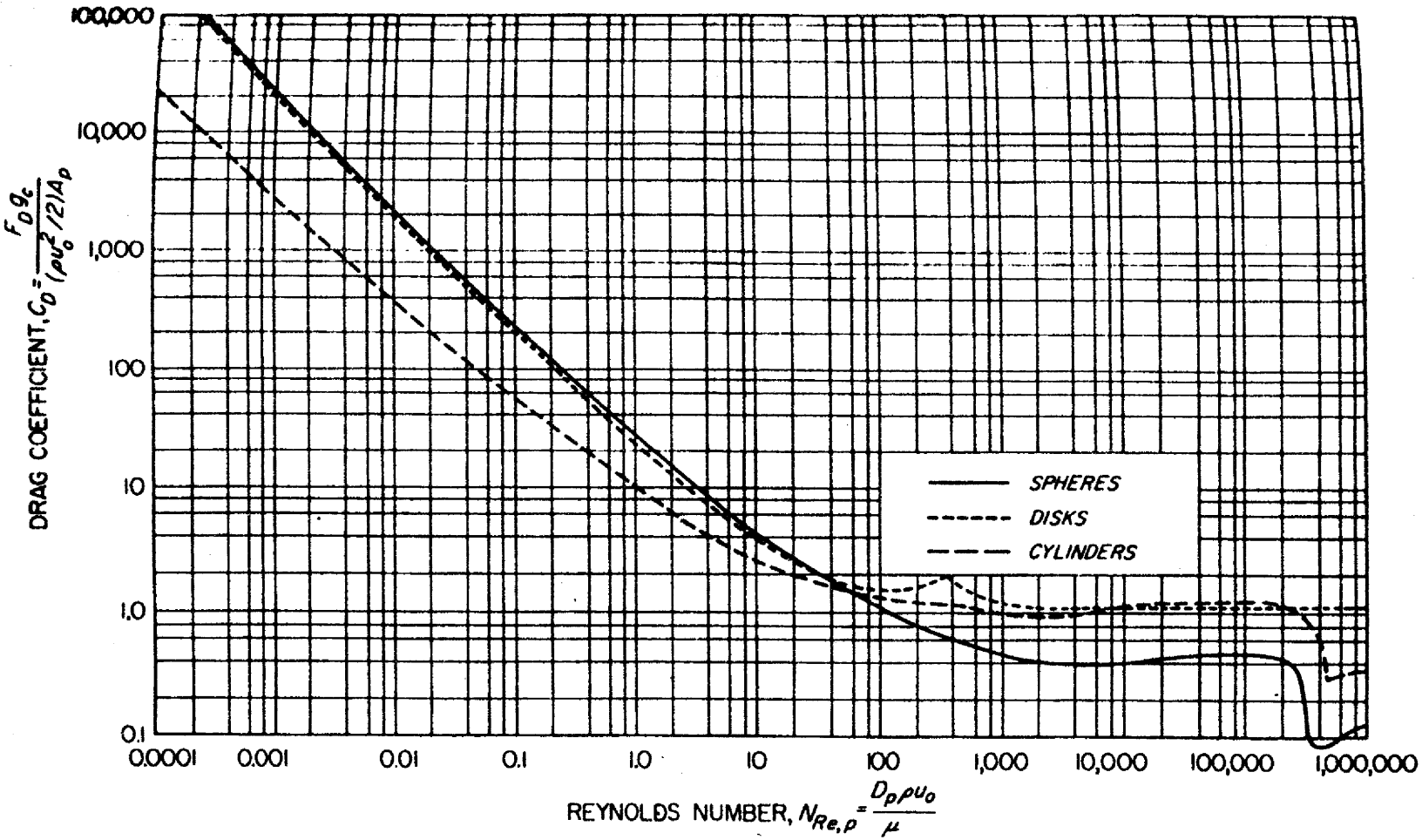

Drag coefficients for spheres. disks, and cylinder.

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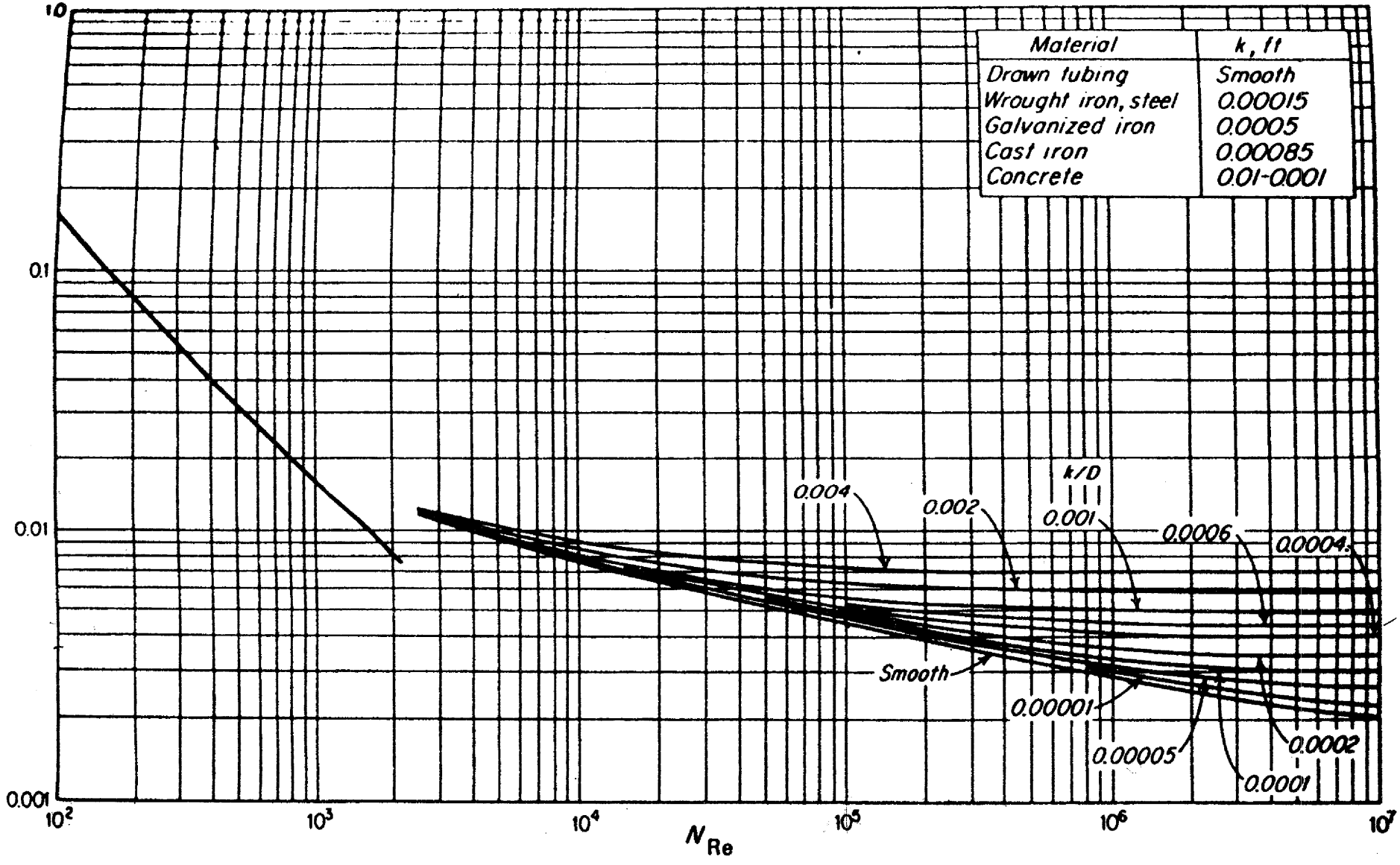

Friction-factor chart

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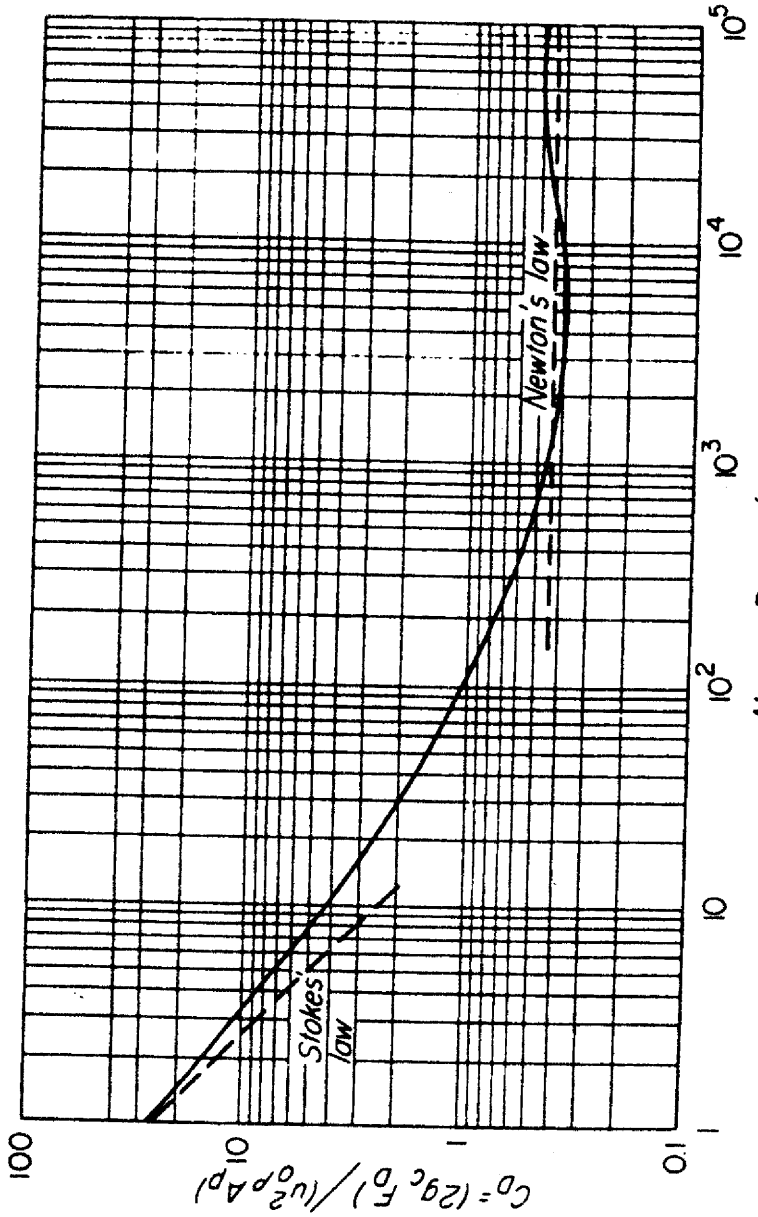

Drag coefficients for spheres

Loss coefficients for standard threaded pipe fittings†

Fitting	K_f
Globe valve, wide open	10.0
Angle valve, wide open	5.0
Gate valve	
Wide open	0.2
Half open	5.6
Return bend	2.2
Tee	1.8
Elbow	
90°	0.9
45°	0.4

† From J. K. Vennard, in V. L. Streeter (ed.), *Handbook of Fluid Dynamics.* McGraw-Hill Book Company, New York, 1961, p. 3–23.