UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2007/2008

April 2008

IEK 103 – Unit Operations I
[Operasi Unit I]

Duration: 3 hours
[Masa: 3 jam]

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

Answer FIVE questions. All questions can be answered either in Bahasa Malaysia OR English.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS muka surat yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab LIMA soalan. Semua soalan boleh dijawab dalam Bahasa Malaysia ATAU Bahasa Inggeris.]

1. (a) *A horizontal piping consists of an upstream section of diameter 5.0 cm and 25 m long. The end of this pipe is suddenly expanded to a larger pipe of diameter 8.0 cm and 30 m long. The water volumetric flow rate at 15.3°C is 0.0085 m^3/s. At 15.3°C, the density and the viscosity of water are 999.3 kg/m^3 and 1.130 cP, respectively. Calculate*

   (i) *the mass flow rate in both sections, in kg/s;*

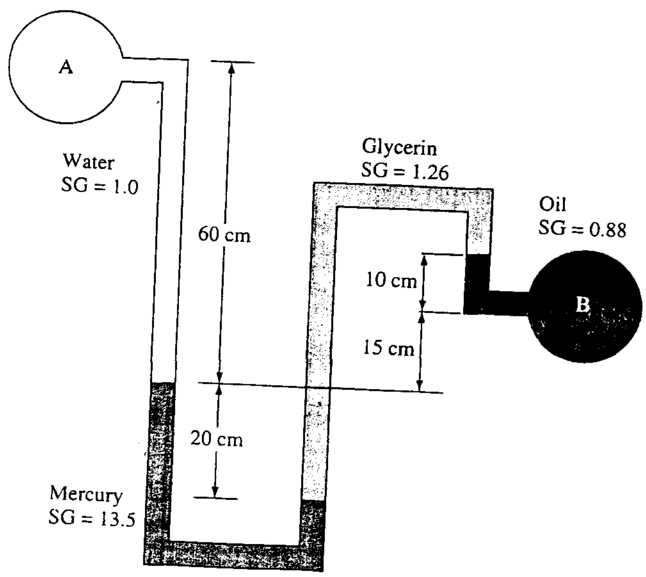
   (ii) *the linear velocity in both sections, in m/s;*

   (iii) *the mass velocity in both sections.*

   (50 marks)

   (b) *The pressure difference between a water (A) pipe and an oil (B) pipe is measured by a double-fluid manometer as shown. For the given fluid heights and specific gravities, calculate the pressure difference $\Delta p = p_B - p_A$ in N/m^2. The density of water is 999.5 kg/m^3.*

   (50 marks)



2. *The lift force F_L of the wing of an airplane is found to vary with fluid speed V, the chord length L_c, the fluid density ρ, the fluid viscosity μ, and the acoustic velocity a. The dimensions of these variables are :*

$[F_L] = \bar{M}\bar{L}/\bar{t}^2$ $[V] = \bar{L}/\bar{t}$ $[L_c] = \bar{L}$ $[\rho] = \bar{M}/\bar{L}^3$

$[\mu] = \bar{M}/\bar{L}\bar{t}$ $[a] = \bar{L}/\bar{t}$

Using Buckingham Theorem, obtain the relation among the variables.

(100 marks)

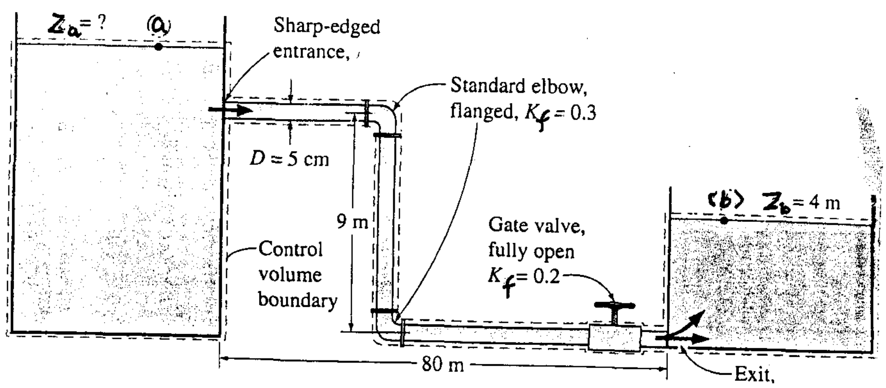
3. *Water at 15°C (ρ = 999 kg/m³ and μ = 1.138 x 10^{-3} kg/m.s) flows through a horizontal steel pipe of diameter 5 cm a at a flow rate of 0.34 m³/min. For a pipe section of 61 m long, determine*

   (a) *the total friction losses;*
   (b) *the pressure drop across the pipe;*
   (c) *power required.*

(100 marks)

4. *Water at 10°C flows from a large reservoir to a small tank through a 5-cm diameter cast iron pipe as shown. The flow rate of water is 6 L/s. Determine the elevation Z_a.*

(100 marks)



5. *The flow rate of methanol at 20°C (ρ = 788.4 kg/m^3 and μ = 5.857 x 10^{-4} kg/m.s) through a 4-cm-diameter pipe is to be measured with a 3-cm-diameter orifice meter. A vertical manometer using mercury (ρ = 13,600 kg/m^3) as the manometer liquid is installed across the orifice meter to measure the pressure difference. The arms of the manometer are filled with methanol. If the manometer reading is 11 cm, determine the volumetric flow rate and the linear velocity of methanol through the pipe. For Re_o > 30,000, C_o = 0.61.*

(100 marks)

6. *A cylindrical tank of diameter 2.4 m is filled with a liquid to the depth of 3.5 m and is equipped with a 6-bladed turbine impeller of diameter 1.0 m. The density of the liquid is 980 kg/m^3 and the liquid viscosity 20 cP. The impeller rotates at 200 rpm. Determine the power delivered by the impeller and the power per unit liquid volume, in kW/m^3, if the system is*

   (a) baffled;
   (b) unbaffled.

(100 marks)

1. (a) Suatu sistem paip mendatar mengandungi satu bahagian hulu yang mempunyai diameter 5.0 cm dan panjang 25 m. Hujung paip ini diperbesarkan secara mendadak ke satu paip yang lebih besar yang mempunyai diameter 8.0 cm dan panjang 30 m. Air pada 15.3°C mengalir di dalam sistem paip ini pada kadar 0.0085 m^3/s. Pada 15.3°C, ketumpatan dan kelikatan air ialah 999.3 kg/m^3 dan 1.130 cP masing-masing. Hitungkan

   (i) kadar aliran jisim di dalam kedua-dua bahagian paip, dalam kg/s;

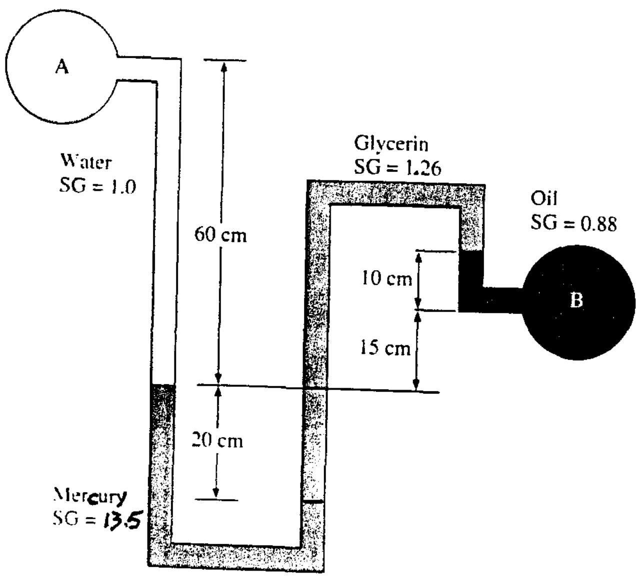
   (ii) halaju linear di dalam kedua-dua bahagian, dalam m/s;

   (iii) halaju jisim di dalam kedua-dua bahagian.

(50 markah)

(b) Perbezaan tekanan di antara paip air (A) dan paip minyak (B) diukur melalui satu manometer dwibendalir seperti ditunjukkan. Dari ketinggian bendalir dan graviti spesifik yang diberikan, hitungkan perbezaan tekanan $\Delta p = p_B - p_A$ dalam unit N/m^2. Ketumpatan air ialah 999.5 kg/m^3.

(50 markah)



2. Daya angkat sayap F_L bagi suatu kapal terbang didapati bersandar kepada halaju bendalir V, panjang perentas L_c, ketumpatan bendalir ρ, kelikatan bendalir μ, dan halaju bunyi a. Dimensi-dimensi pembolehubah adalah seperti berikut:

$[F_L] = \bar{M}\bar{L}/\bar{t}^2$ $\quad [V] = \bar{L}/\bar{t}$ $\quad [L_c] = \bar{L}$ $\quad [\rho] = \bar{M}/\bar{L}^3$

$[\mu] = \bar{M}/\bar{L}\bar{t}$ $\quad [a] = \bar{L}/\bar{t}$

Dengan menggunakan Teorem Buckingham, terbitkan hubungan di antara pembolehubah-pembolehubah di atas.

(100 markah)

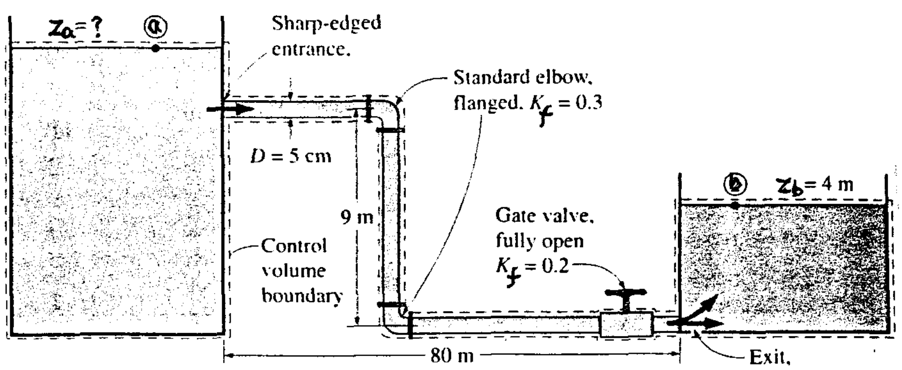
3. Air pada 15°C ($\rho = 999$ kg/m^3 dan $\mu = 1.138 \times 10^{-3}$ kg/m.s) mengalir di dalam satu paip keluli mendatar yang mempunyai diameter 5-cm pada kadar 0.34 m^3/min. Untuk satu bahagian paip sepanjang 61 m, tentukan

(a) jumlah kerugian geseran;
(b) kejatuhan tekanan menyeberangi paip;
(c) kuasa pam yang dikehendaki.

(100 markah)

4. Air pada 10°C mengalir dari satu takungan besar ke satu tangki kecil menerusi satu paip besi tuangan yang berdiameter 5-cm seperti ditunjukkan. Kadar aliran air ialah 6 L/s. Tentukan ketinggian z_a.

(100 markah)



5. Kadar aliran volumetrik bagi metanol pada 20°C (ρ = 788.4 kg/m^3 dan μ = 5.857 x 10^{-4} kg/m.s) menerusi satu paip yang mempunyai diameter 4-cm dapat diukurkan dengan suatu meter orifis yang berdiameter 3-cm. Satu manometer tegak yang menggunakan merkuri (ρ = 13,600 kg/m^3) sebagai cecair manometer dipasangkan menyeberangi meter orifis tersebut untuk menyukat perbezaan tekanan. Lengan-lengan di atas merkuri diisikan dengan metanol. Jika bacaan manometer itu ialah 11 cm, tentukan kadar aliran volumetrik dan halaju linear untuk aliran metanol menerusi paip. Jika $Re_o > 30{,}000$, $C_o = 0.61$.

(100 markah)

6. Suatu tangki berbentuk silinder yang mempunyai diameter 2.4 m diisikan dengan satu cecair sedalam 3.5 m dan dipasangkan dengan impeler turbin 6-bilah yang berdiameter 1.0 m. Ketumpatan cecair ialah 980 kg/m^3 dan kelikatan cecair ialah 20 cP. Impeler tersebut memutar pada 200 rpm. Tentukan kuasa disampaikan oleh impeler tersebut dan kuasa seunit isipadu, dalam unit kW/m^3, sekiranya sistem tersebut

   (a) bersesekat;
   (b) tanpa sesekat.

(100 markah)

...8/-

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-lb_f	1545.3
		Hp-h	7.8045×10^{-4}
		kWh	5.8198×10^{-4}

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-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-°C	1*
Btu/ft^2-h	W/m^2	3.1546
Btu/ft^2-h-°F	W/m^2-°C	5.6783
	kcal/m^2-h-K	4.882
Btu-ft/ft^2-h-°F	W-m/m^2-°C	1.73073
	kcal/m-h-K	1.488

(Continued)

To convert from	To	Multiply by†
cal_{IT}	Btu	3.9683×10^{-3}
	ft-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-lb_f	Btu	1.2851×10^{-3}
	cal_{IT}	0.32383
	J	1.35582
ft-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-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-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)

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.

...11/-

Table Physical properties of water

Temperature (°C)	Density ($kg\ m^{-3}$)	Saturation vapour pressure ($N\ m^{-2} \times 10^{-3}$)	Dynamic viscosity ($N\ s\ m^{-2} \times 10^{3}$)	Surface tension ($N\ m^{-1} \times 10^{3}$)
0	999.87	0.6107	1.787	75.64
5	999.99	0.8721	1.519	74.92
10	999.73	1.2277	1.307	74.22
15	999.13	1.7049	1.139	73.49
20	998.23	2.3378	1.002	72.75
25	997.07	3.1676	0.890	71.97
30	995.68	4.2433	0.798	71.18
35	994.06	5.6237	0.719	70.37
40	992.25	7.3774	0.653	69.56
45	990.24	9.5848	0.596	68.74
50	988.07	12.3380	0.547	67.91
55	985.73	15.7450	0.504	67.05
60	983.24	19.9240	0.467	66.18
65	980.59	25.0130	0.434	65.29
70	977.81	31.1660	0.404	64.40
75	974.89	38.5530	0.378	63.50
80	971.83	47.3640	0.355	62.60
85	968.65	57.8080	0.334	61.68
90	965.34	70.1120	0.315	60.76
95	961.92	84.5280	0.298	59.84
100	958.38	101.3250	0.282	58.90

Source: *CRC Handbook of Chemistry and Physics*, 67th edn (1987).

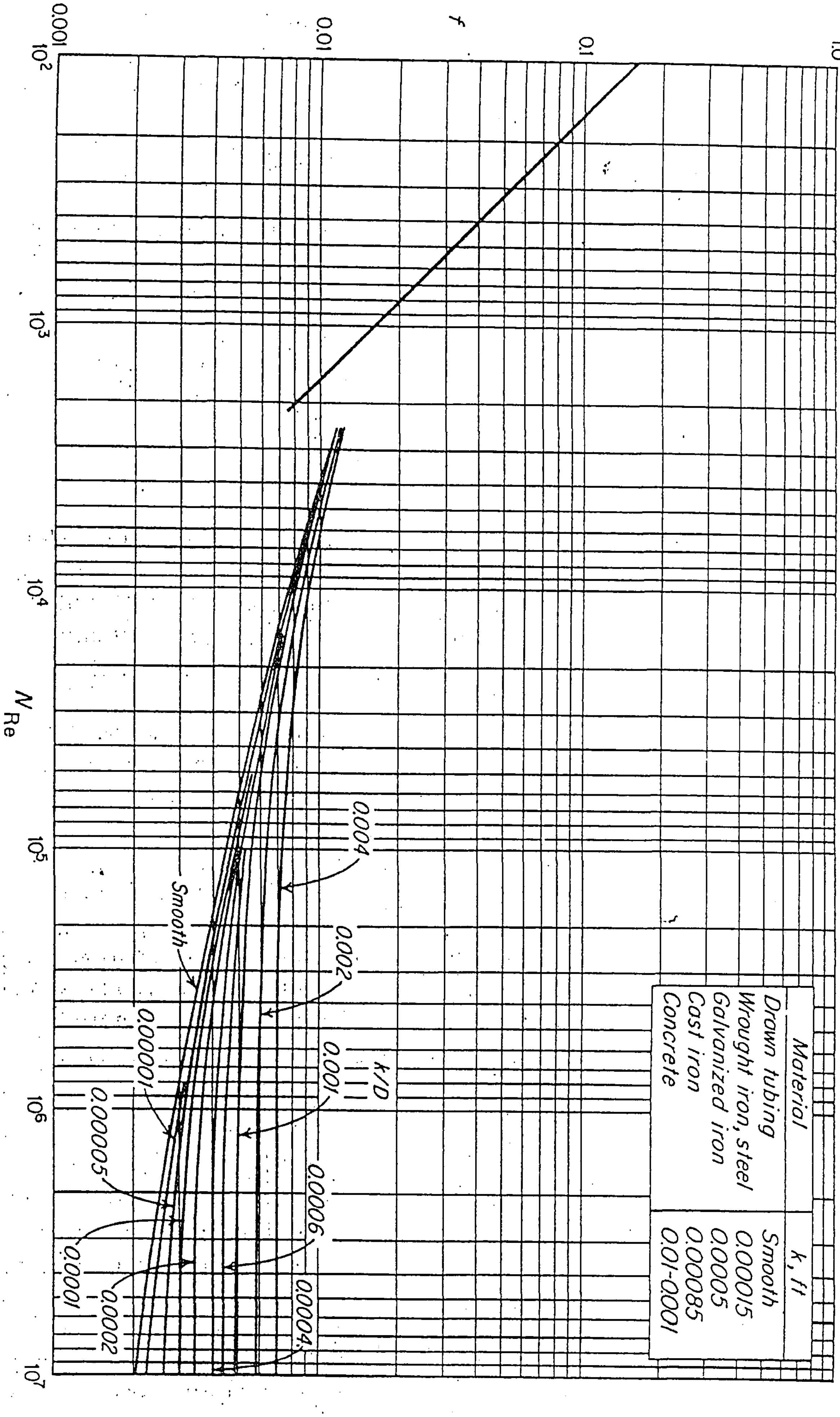


FIGURE
Friction-factor chart.

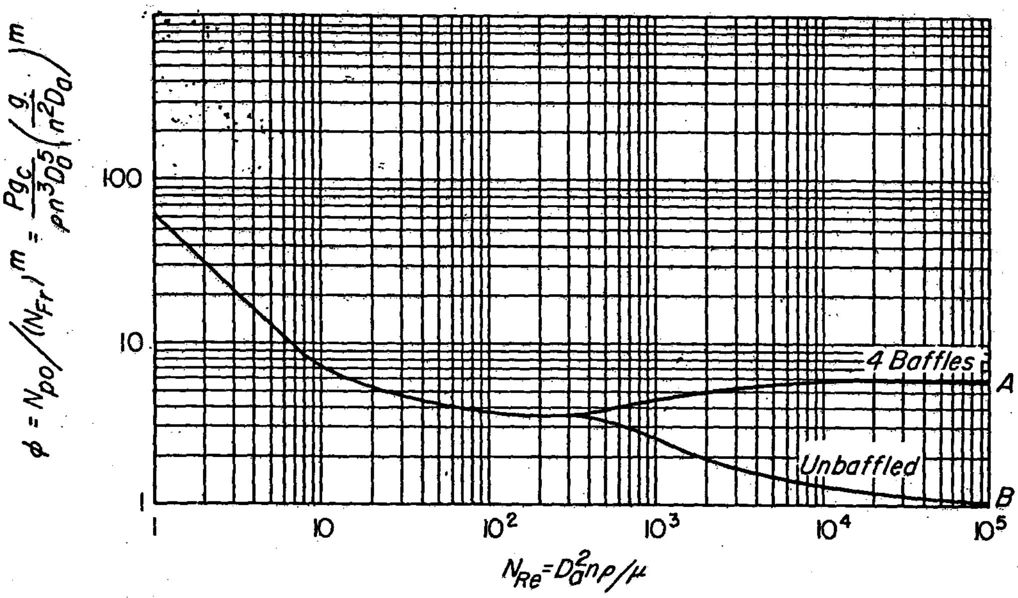


Figure 9-14 Power function ϕ vs. N_{Re} for six-blade turbine.

$S_1 = D_t/D_a$, $S_2 = E/D_a$

$S_3 = L/D_a$, $S_4 = W/D_a$

$S_5 = J/D_t$, $S_6 = H/D_t$

$$m = (a - \log N_{Re})/b$$

Table 9-1 Constants a and b

Fig.	*Line*	*a*	*b*
9-14	*B*	1.0	40.0
9-15	*B*	1.7	18.0
9-15	*C*	0	18.0
9-15	*D*	2.3	18.0

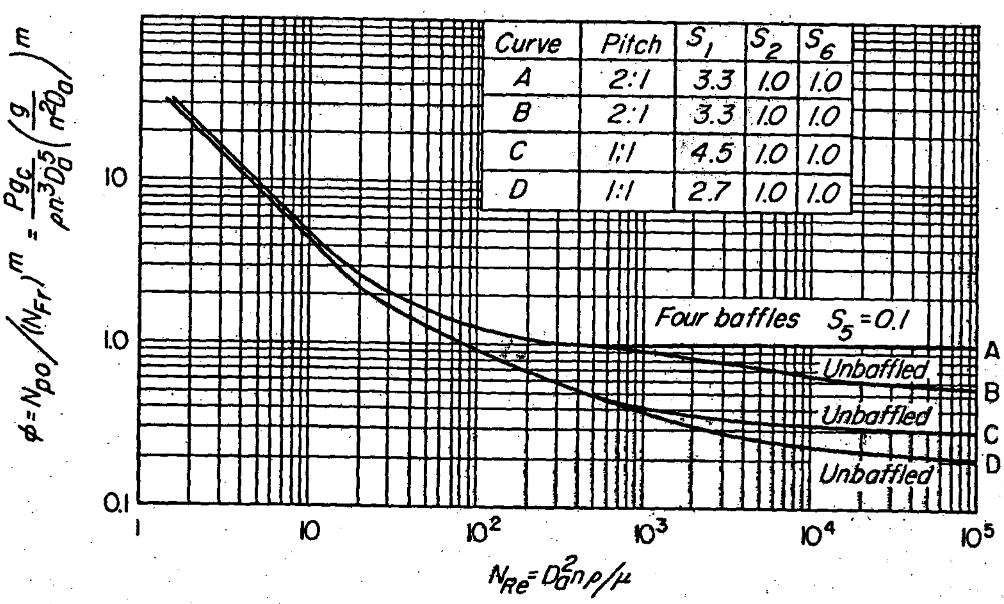


Figure 9-15 Power function ϕ vs. N_{Re} for three-bladed propellers.

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