UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2005/2006

April/Mei 2006

IEK 103 – Operasi Unit I
[Unit Operations I]

Masa: 3 jam
[Duration: 3 hours]

Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS (13) mukasurat yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan. Semua soalan boleh dijawab dalam Bahasa Malaysia ATAU Bahasa Inggeris.

[Please check that the examination paper consists of THIRTEEN (13) pages of printed material before you begin this examination.]

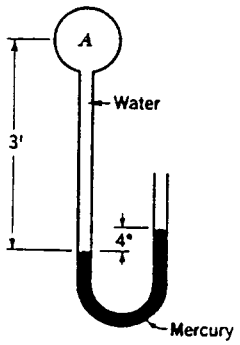
[Answer **FIVE (5)** questions. All questions can be answered either in Bahasa Malaysia OR English.]

1. (a) Kejatuhan tekanan bagi aliran di dalam satu paip adalah berhubung kait dengan pembolehubah-pembolehubah seperti panjang paip L, diameter paip D, halaju linear bendalir $\bar{V}$, kelikatan μ, ketumpatan ρ, kekasaran k, dan faktor pertukaran Newton g_c. Dengan menggunakan teorem Buckingham, carikan perhubungan di antara pembolehubah-pembolehubah tersebut. Dimensi-dimensi untuk pembolehubah-pembolehubah tersebut adalah seperti berikut:

$[\Delta p] = \bar{F}/\bar{L}^2$ $[L] = \bar{L}$ $[D] = \bar{L}$ $[\bar{V}] = \bar{L}/\bar{t}$

$[\mu] = \bar{M}/\bar{L}\bar{t}$ $[\rho] = \bar{M}/\bar{L}^3$ $[k] = \bar{L}$ $[g_c] = \bar{M}\bar{L}/\bar{F}\bar{t}^2$

(50 markah)



(b) Di dalam Rajah yang ditunjukkan, bacaan manometer itu ialah 4 in. Tekanan atmosfera ialah 14.7 psia. Ketumpatan merkuri ialah 848.2 lb/ft^3; ketumpatan air ialah 62.37 lb/ft^3.

(i) Apakah tekanan mutlak di A?

(ii) Jika tekanan mutlak di A digandakan, apakah bacaan manometer akan menjadi?

(50 markah)

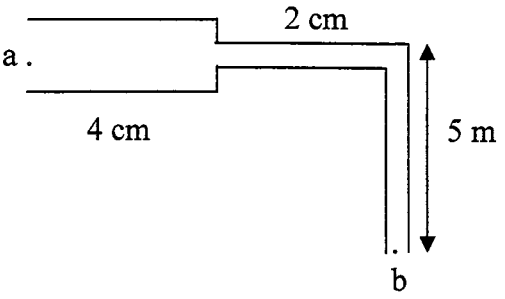
2. (a) Satu cecair yang mempunyai ketumpatan 1200 kg/m^3 dan kelikatan 1.3 cP mengalirdi dalam sistem yang ditunjukkan. Kadar aliran menerusi garispaip ialah 0.005 m^3/s. Jika jumlah kerugian geseran dari a ke b ialah 25 J/kg, hitungkan

(i) kadar aliran jisim;

(ii) halaju linear V_a dan V_b;

(iii) halaju jisim G_a dan G_b;

(iv) kejatuhan tekanan $p_a - p_b$.



(50 markah)

...3/-

(b) Satu cecair yang mempunyai ketumpatan 1005 kg/m^3 dan kelikatan 0.982 cP dipamkan pada kadar malar 0.003 m^3/s dari satu takungan terletak di lantai ke suatu tangki penyimpan terbuka. Titik discas garispaip ialah 7.5 m ke atas lantai, dan jumlah kerugian geseran di dalam 55-mm paip dari takungan ke titik discas paip ialah 3.5 J/kg. Jika pam tersebut hanya boleh memberikan 0.15 kW, apakah paras cecair di dalam takungan akan menjadi?

(50 markah)

3. (a) Satu larutan asid asetik yang mempunyai ketumpatan1060 kg/m^3 dan kelikatan 2.5 mN.s/m^2 mengalir menerusi satu paip mendatar diameternya 75 mm dan panjangnya 70 m. Jika kekasaran permukaan paip ialah 6 x 10^{-5} m, apakah kejatuhan tekanan untuk sistem paip ini?

(50 markah)

(b) Pelet urea diameternya 6 mm akan dibuat di dalam suatu menara tingginya 25 m yang mengandungi udara pada 20°C dan 1 atm dengan menyembur urea lebur dari bahagian atas ke dalam udara sejuk. Ketumpatan urea ialah 1,330 kg/m^3. Ketumpatan dan kelikatan udara pada 20°C dan 1 atm ialah 1.224 kg/m^3 dan 1.73 x 10^{-5} kg/m.s masing-masing. Apakah halaju terminal pelet-pelet tersebut akan menjadi?

$$du/dt = g(\rho_p - \rho)/\rho_p - C_D u^2 \rho A_p/2m$$
$$m = \pi D^3_p \rho_p/6, \qquad A_p = \pi D^2_p/4, \qquad C_D = 24/N_{Re,p}$$
$$N_{Re,p} = D_p u \rho/\mu$$

(50 markah)

4. Satu meter orifis dipasangkan di dalam satu 100-mm garispaip untuk menyukat aliran air. Kadar aliran maksimum dijangka 50 m^3/h pada 15°C.Manometer yang digunakan untuk menyukat tekanan pembeza diisikan dengan merkuri yang berketumpatan 13,586.4 kg/m^3, dan air mengisikan lengan ke atas merkuri. Ketumpatan air pada 15°C ialah 999.0 kg/m^3. (i) Jika bacaan maksimum manometer ialah 1.25 m, apakah diameter orifis akan menjadi? (ii) Jika kerugian tekanan pembeza ialah 81%, apakah kuasa yang dikehendaki untuk mengoperasikan meter tersebut pada penuh beban?

(100 markah)

5. Satu cecair yang mempunyai ketumpatan 70 lb/ft^3 dan kelikatan 1.22 cP dipamkan dari satu takungan ke suatu bukit menerusi satu paip keluli diameternya 5.5 in pada halaju purata 12.5 ft/s. Titik discas paip ialah 3,500 ft ke atas paras cecair di dalam takungan. Panjang garispaip ialah 4,750 ft. Jika keefisienan keseluruhan bagi pam tersebut ialah 65% dan kos tenaga elektrik ialah RM0.05 per kilowatt-jam, apakah kos tenaga untuk mempamkan cecair ini sehari?

(100 markah)

6. Satu turbin 6-bilah dipasangkan di tengah suatu tangki bersesekat yang berdiameter 2 m. Diameter turbin ialah 0.67 m dan ia terletak 0.67 m ke atas dasar tangki. Lebarnya bilah turbin ialah 134 mm. Tangki tersebut diisikan sedalam 2 m dengan satu larutan akeus 50% NaOH pada 65°C. Kelikatan dan ketumpatan larutan pada suhu tersebut ialah 12 cP dan 1,500 kg/m^3 masing-masing. Impeler turbin itu memputar pada 90 rpm. (i) Apakah kuasa akan dikehendaki? (ii) Jika larutan NaOH itu digantikan dengan suatu lateks getah yang mempunyai kelikatan dan ketumpatan 100 kg/m.s dan 1,120 kg/m^3 masing-masing, apakah pula kuasa yang akan dikehendaki?

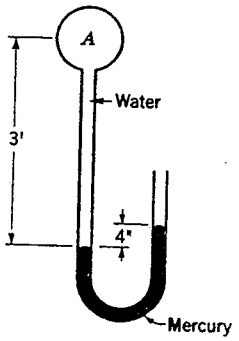
(100 markah)

1. (a) The pressure drop for flow in a pipeline is related to variables such as pipe length L, pipe diameter D, fluid linear velocity $\overline{V}$, viscosity μ, density ρ, pipe roughness k, and Newton conversion factor g_c. By using Buckingham's theorem, find the correlation among the variables. The dimensions of the variables are given below:

$[\Delta p] = \overline{F}/\overline{L}^2$ $\quad [L] = \overline{L}$ $\quad [D] = \overline{L}$ $\quad [V] = \overline{L}/\overline{t}$

$[\mu] = \overline{M}/\overline{L}\overline{t}$ $\quad [\rho] = \overline{M}/\overline{L}^3$ $\quad [k] = \overline{L}$ $\quad [g_c] = \overline{M}\overline{L}/\overline{F}\overline{t}^2$

(50 marks)



(b) In the Figure shown, there is a 4-in manometer reading. Atmospheric pressure is 14.7 psia. The density of mercury is 848.2 lb/ft^3; the density of water is 62.37 lb/ft^3.

(i) What is the absolute pressure at A?

(ii) If the absolute pressure at A is doubled, what then would the manometer reading be?

(50 marks)

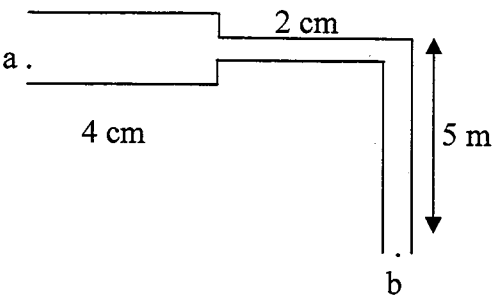
2. (a) A liquid of density 1200 kg/m^3 and viscosity 1.3 cP is flowing in the system shown. The flow rate through the pipeline is 0.005 m^3/s. If the overall friction loss form a to b is 25 J/kg, calculate

(i) the mass flow rate;

(ii) the linear velocities V_a and V_b;

(iii) the mass velocities G_a and G_b;

(iv) the pressure drop $p_a - p_b$.



(50 marks)

...6/-

(b) A liquid of density 1005 kg/m^3 and viscosity 0.982 cP is pumped at a constant flow rate of 0.003 m^3/s from a large reservoir resting on the floor to the open top of a storage tank. The point of discharge of the pipeline is 7.5 m above the floor, and the total friction losses in the 55-mm pipe from the reservoir to the pipe discharge amount to 3.5 J/kg. If the pump can only deliver 0.15 kW, what would the liquid level in the reservoir be?

(50 marks)

3. (a) An acetic acid solution of density 1060 kg/m^3 and viscosity 2.5 mN.s/m^2 flows through a 75 mm diameter horizontal pipe 70 m long. If the roughness of the pipe surface is 6×10^{-5} m, what is the pressure drop in the pipe?

(50 marks)

(b) Urea pellets 6 mm in diameter are to be made in a tower 25 m high containing air at 20°C and 1 atm by spraying drops of molten urea into cold air from the top of the tower. The density of urea is 1,330 kg/m^3. The density and viscosity of the air at 20°C and 1 atm are 1.224 kg/m^3 and 1.73×10^{-5} kg/m.s, respectively. What would be the terminal velocity of the pellets?

$$du/dt = g(\rho_p - \rho)/\rho_p - C_D u^2 \rho A_p/2m$$
$$m = \pi D^3{}_p \rho_p/6, \qquad A_p = \pi D^2{}_p/4, \qquad C_D = 24/N_{Re,p}$$
$$N_{Re,p} = D_p u \rho/\mu$$

(50 marks)

4. An orifice meter is installed in a 100-mm line to measure the flow of water. The maximum flow rate is expected to be 50 m^3/h at 15°C. The manometer used to measure the differential pressure is to be filled with mercury of density 13,586.4 kg/m^3, and water is to fill the leads above the mercury. The density of water at 15°C can be taken as 999.0 kg/m^3. (i) If the maximum manometer reading is 1.25 m, what will be the diameter of the orifice? (ii) If the permanent loss in pressure is 81 % of the differential, what will be the power to operate the meter at full load?

(100 marks)

5. A liquid of density 70 lb/ft^3 and viscosity 1.22 cP is pumped from a reservoir to the top of a mountain through a 5.5 in steel pipe at an average velocity of 12.5 ft/s. The pipe discharges into the atmosphere at a level 3,500 ft above the level in the reservoir. The pipeline itself is 4,750 ft long. If the overall efficiency of the pump is 65% and the electrical energy cost is RM0.05 per kilowatt hour, what is the energy cost for pumping this liquid per day?

(100 marks)

6. A six-bladed turbine is installed centrally in a vertical baffled tank 2 m in diameter. The turbine is 0.67 m in diameter and is positioned 0.67 m above the bottom of the tank. The turbine blades are 134 mm wide. The tank is filled to a depth of 2 m with an aqueous solution of 50% NaOH at 65°C, which has a viscosity of 12 cP and a density of 1,500 kg/m^3. The turbine impeller turns at 90 rpm. (i) What power will be required? (ii) If the NaOH solution is to be replaced by a rubber latex compound having a viscosity of 100 kg/m.s and a density of 1120 kg/m^3, what power will be required?

(100 marks)

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}

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	$W\text{-}m/m^2\text{-}°C$	1.73073
	kcal/m-h-K	1.488

(Continued)

...9/-

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	$N\text{-}m^2/kg^2$	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-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)

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.

...12/-

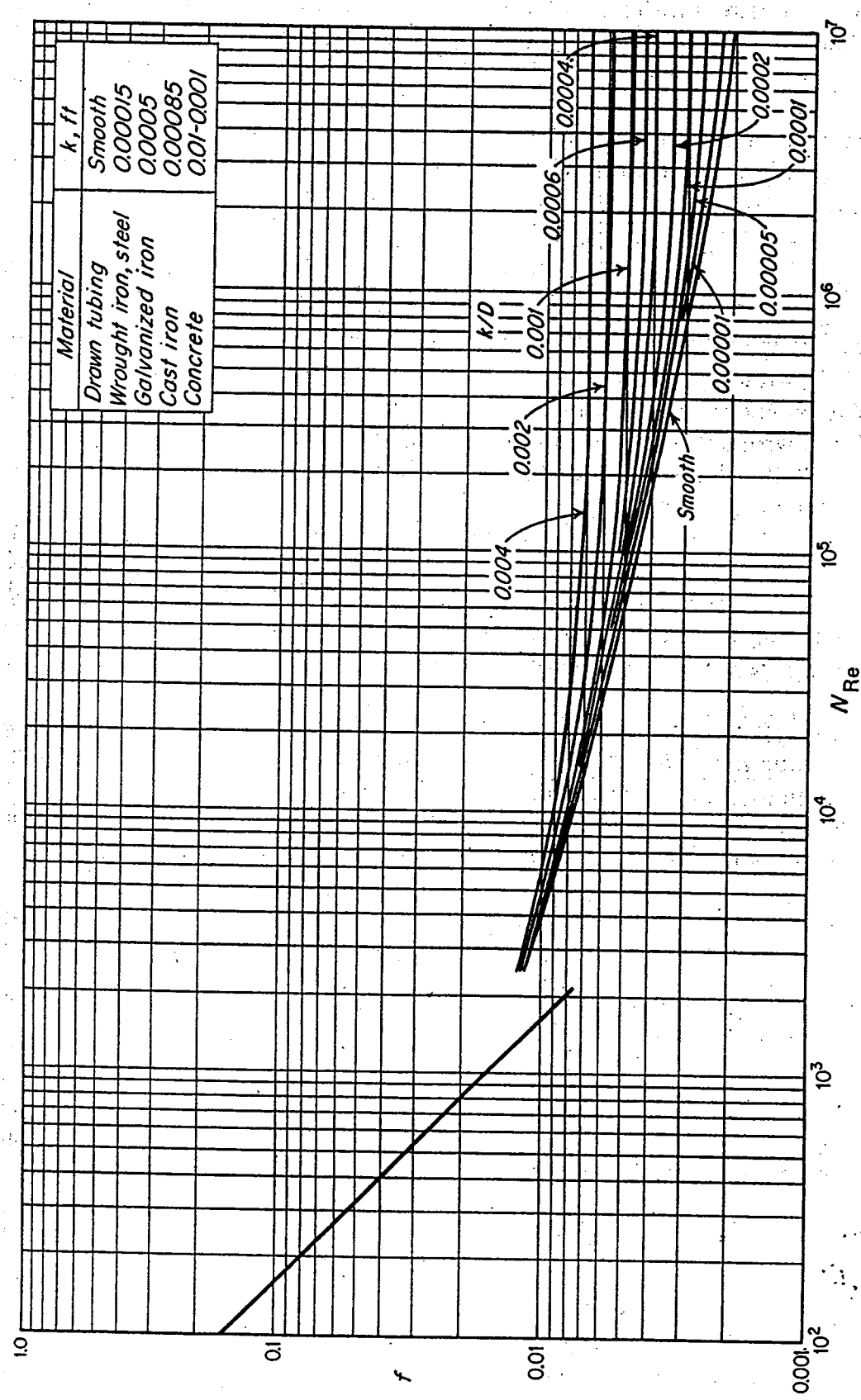


FIGURE
Friction-factor chart.

...13/-

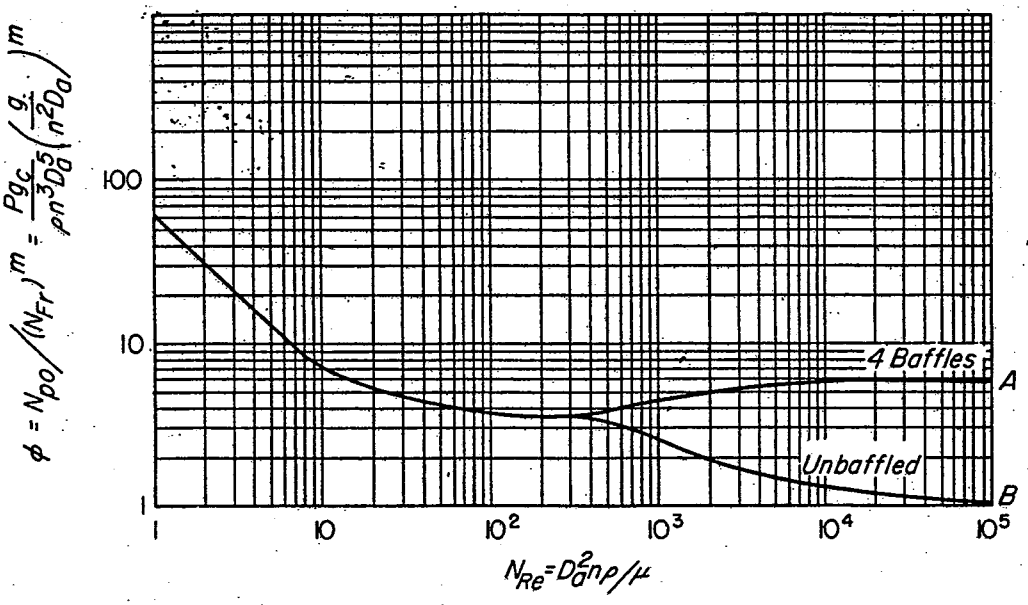


Figure 9-14 *Power function ϕ vs. N_{Re} for six-blade turbine.*

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

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

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

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

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

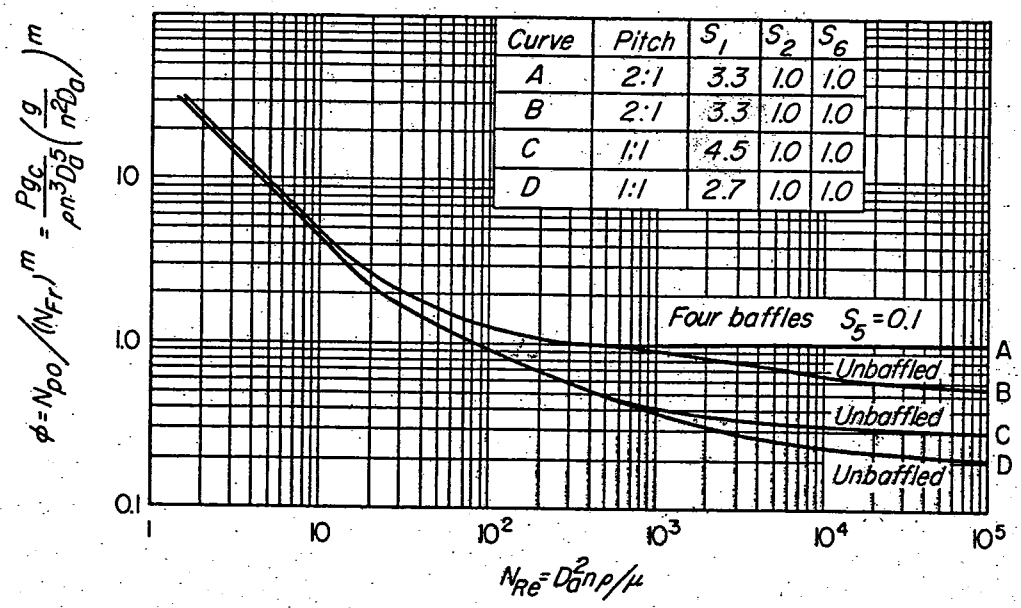


Figure 9-15 *Power function ϕ vs. N_{Re} for three-bladed propellers.*