UNIVERSITI SAINS MALAYSIA

First Semester Examination
2010/2011 Academic Session

November 2010

EKC 212 – Fluids Flow For Chemical Engineering
[Aliran Bendalir Kejuruteraan Kimia]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of SIX pages of printed material and FIVE pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM muka surat yang bercetak dan LIMA muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instructions: Answer **ALL** (4) questions.

*[**Arahan:** Jawab **SEMUA** (4) soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

Answer <u>ALL</u> questions.
Jawab <u>SEMUA</u> soalan.

1. [a] A viscous incompressible fluid is contained between two infinite, horizontal plates as shown in Figure Q.1.[a]. The fluid moves between the plates under the action of a pressure gradient. The upper plate moves with a velocity U while the bottom plate is fixed. A U-tube manometer connected between point 1 and point 2 indicates a differential reading of h.

Bendalir likat tidak termampat terkandung antara dua plat melintang yang tak terbatas seperti yang ditunjukkan pada Gambarajah S.1.[a]. Bendalir bergerak antara plat tersebut di bawah tindakan kecerunan tekanan. Plat atas bergerak dengan kelajuan U sedangkan plat bawah adalah tetap. Sebuah manometer U-tiub disambung antara titik 1 dan titik 2 menunjukkan bacaan perbezaan, h.

[i] Derive an expression for the velocity profile assuming $\frac{dp}{dx}$ is constant.
Terbitkan persamaan untuk corak kelajuan dengan andaian $\frac{dP}{dx}$ adalah malar.

[ii] Calculate the shear stress on the upper plate
Kirakan ricihan luncur pada plat atas

[iii] What distance from the bottom plate does the maximum velocity occur?
Apakah jarak dari plat bawah di mana kelajuan maksima berlaku?

Given, h= 2.5 mm, d=25 mm, U = 6 mm/s, L = 15 cm
Viscous fluid : ρ = 1280 kg/m^3; μ=1.43 kg/m.s
Manometer fluid: ρ = 1600 kg/m^3

Diberi, h= *2.5 mm,* d=*25 mm,* U *= 6 mm/s,* L *= 15 sm*
Bendalir likat : ρ *= 1280 kg/m*^{3}*;* μ*=1.43 kg/m.s*
Bendalir manometer: ρ *= 1600 kg/m*^{3}

[15 marks/markah]

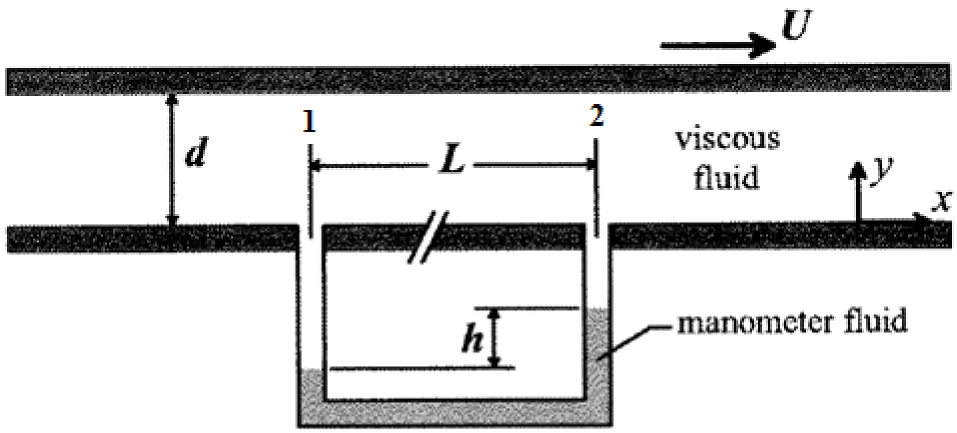

Figure Q.1.[a].
Gambarajah S.1.[a].

[b] The time, *t*, for oil to drain out of a viscosity calibration container depends on the fluid viscosity, μ, and density, ρ, the orifice diameter, *d*, and gravity, *g*. Use dimensional analysis to find the functional dependence of t on the other variables. Express *t* in the simplest form. For two dynamically similar fluid, what will be the percentage of time changes for oil to drain out if the kinematic viscosity is increased 5 times. The orifice diameter is kept constant.

Masa, t*, untuk minyak mengalir keluar dari bekas kalibrasi kelikatan bergantung pada kelikatan bendalir,* μ *dan ketumpatan,* ρ*, diameter orifis,* d*, dan graviti,* g*. Gunakan analisa dimensi untuk mencari pergantungan berfungsi* t *pada pembolehubah lain. Tunjukkan* t *dalam bentuk yang paling mudah. Untuk dua bendalir dinamik yang sama, apakah peratusan perubahan masa untuk minyak mengalir keluar sekiranya kelikatan kinematik meningkat 5 kali. Diameter orifis adalah malar.*

[10 marks/markah]

2. [a] A heat exchanger consists of a closed system with a series of parallel copper tubes connected by 180° elbows as shown in the Figure Q.2.[a]. There are a total of 14 return elbows. The pipe diameter is 2 cm and the total pipe length is 10 m. The head loss coefficient for each return elbow is 2.2. Water with an average temperature of 40 ^{o}C flows through the system with a mean velocity of 10 m/s. Find the power required to operate the pump if the pump is 80% efficient.

Penukar haba yang terdiri daripada sistem tertutup mempunyai serangkaian tiub tembaga selari dihubungkan dengan siku 180^{o} seperti yang ditunjukkan dalam Gambarajah S.2.[a]. Terdapat 14 siku berkembali. Diameter paip adalah 2 sm dan jumlah panjang keseluruhan paip adalah 10 m. Pekali kehilangan turus untuk setiap siku kembali adalah 2.2. Air dengan purata suhu 40 ^{o}C mengalir melalui sistem tersebut dengan kelajuan purata 10 m / s. Kirakan kuasa yang diperlukan untuk menjalankan pam tersebut sekiranya ia beroperasi pada kecekapan sebanyak 80%.

[15 marks/markah]

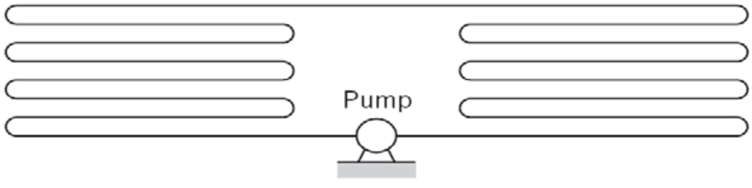

Figure Q.2.[a].
Gambarajah S.2.[a].

[b] Air is allowed to flow from a reservoir with temperature of 21°C and with pressure of 5 MPa (abs) through a tube. It was measured that air mass flow rate is 1 kg/s. At some point on the tube, static pressure was measured to be 3 MPa (abs). Assume that process is isentropic and neglect the velocity at the reservoir, calculate the Mach number, velocity, and the cross section area at that point where the static pressure was measured. Assume that the ratio of specific heat is $K = C_p/C_v = 1.4$.

Udara dibenarkan mengalir dari takungan bersuhu 21 °C dan tekanan mutlak 5 MPa ke dalam tiub. Ia didapati bahawa kadar aliran udara adalah 1 kg / s Pada suatu titik dalam tiub tersebut, tekanan statik diukur sebanyak 3 MPa (mutlak). Anggapkan proses tersebut adalah isentropik dan kelajuan udara dalam takungan boleh diabaikan, kirakan nombor Mach, kelajuan, dan luas keratan rentas pada titik di mana tekanan statik diukur. Anggapkan bahawa nisbah haba tentu adalah $K = C_p / C_v = 1.4$.

[10 marks/markah]

3. [a] Define fluidization and how the minimum fluidization can be occurred?
Takrifkan pembendaliran dan bagaimana pembendaliran minimum boleh terhasil?

[3 marks/markah]

[b] Initially, 2 spherical particles with same position fall into water. The particles have same final terminal velocity. The specifications of the spheres are given in Table Q.3.[b]. What is the distance between them when :

2 zarah sfera yang pada mulanya berada pada kedudukan yang sama, telah jatuh ke dalam air. Zarah-zarah tersebut mempunyai halaju tamatan akhir yang sama. Spesifikasi sfera-sfera tersebut ditunjukkan dalam Jadual S.3.[b]. Apakah jarak antara zarah-zarah tersebut jika :

[i] all the particles achieve terminal velocity of 99%
semua zarah mencapai 99% halaju tamatan

[ii] any particle achieves terminal velocity of 99%.
mana-mana zarah mencapai 99% halaju tamatan.

Assume that Stoke law is valid for this case.
Anggap hukum Stoke dapat digunapakai bagi kes ini.

[14 marks/markah]

Table Q.3.[b].
Jadual S.3.[b].

	Density (kg/m^3) *Ketumpatan (kg/m^3)*	Viscosity (mNs/m^2) *Kelikatan (mNs/m^2)*	Diameter (μm)
Spherical 1 (S1) *Sfera 1 (S1)*	1900	-	42
Spherical 2 (S2) *Sfera 2 (S2)*	3700	-	D_2
Water *Air*	1000	1	-

[c] [i] Estimate the terminal velocity for 0.020 mm-0.044 mm particles of limestone falling in water at 30 ^oC.
Kirakan halaju tamatan untuk zarah batu kapur bersaiz 0.020 mm - 0.044 mm yang jatuh ke dalam air bersuhu 30 ^oC.

[ii] Using limestone particles in [c][i], how much the velocity be in a centrifugal separator where the acceleration is 20 x *g*?
Dengan menggunakan zarah di [c][i], berapakah halaju zarah jika ia berada dalam pemisah empar yang pecutannya 20 x *g?*

Given : ρ_{water} = 995.7 kg/m^3; μ_{water} = 0.801 x 10^{-3} kg/ms.
ρ_s = 2450 kg/m^3

Diberi : ρ_{air} *= 995.7 kg/m^3;* μ_{air} *= 0.801 x 10^{-3} kg/ms;*
ρ_{zarah} *= 2450 kg/m^3*

[8 marks/markah]

4. [a] [i] From continuity equation, show that the fluid pass over the venturi meter can be expressed as:
Bermula daripada persamaan keterusan, tunjukkan bahawa aliran bendalir yang melalui meter venturi boleh diterbitkan sebagai :

$$G = \frac{C_D \rho A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh_v}$$

where,
G = mass flowrate
A_1 = area of throat
A_2 = area of convergence
C_D = discharge coefficient
ρ = fluid density
h_v = pressure drop at convergence

di mana,
G = kadar aliran jisim
A_1 = luas kerongkongan
A_2 = luas penumpuan
C_D = pekali luahan
ρ = ketumpatan bendalir
h_v = kejatuhan tekanan pada penumpuan

[7 marks/markah]

[ii] Give two purposes of suspension of solid particles.
Berikan dua tujuan pengapungan zarah pepejal.

[2 marks/markah]

[iii] Sketch the schematic diagram of (a) axial flow and (b) radial flow.
Lakarkan rajah skematik bagi (a) aliran paksi dan (b) aliran jejarian.

[4 marks/markah]

[b] A propeller with three blades is installed centrally in a vertical tank. The tank is 2.7 m in diameter. The propeller is 0.81 m in diameter and is positioned 0.81 m from the bottom of the tank. The tank is filled to a depth of 2.7 m with a caustic soda solution, which has a viscosity of 1.5 cP and a density of 1498 kg/m^3. The turbine is operated at 3.21 rpm. What power will be required to operate the propeller if:
Sebuah kipas dengan tiga bilah dipasang di tengah-tengah sebuah tangki menegak. Tangki berdiameter 2.7 m serta kipas berdiameter 0.81 m berkedudukan 0.81 m dari dasar tangki. Tangki diisi sedalam 2.7 m dengan larutan soda kaustik, berkelikatan 1.5 cP dan berketumpatan 1498 kg/m^3. Kipas beroperasi pada kadar 3.21 rpm. Berapakah kuasa yang diperlukan oleh kipas ini untuk beroperasi jika:

[i] The tank was baffled.
Tangki ini dibina dengan sesekat.

[ii] The tank was unbaffled.
Tangki ini dibina tanpa sesekat.

[12 marks/markah]

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Appendix

Compressible Flow (isentropic)

$$\frac{T}{T_o} = \frac{1}{1+[(k-1)/2]Ma^2} \qquad \frac{\rho}{\rho_o} = \left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{1/k-1} \qquad \frac{dV}{V} = -\frac{dA}{A}\frac{1}{(1-Ma^2)}$$

$$\frac{P}{P_o} = \left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/k-1} \qquad \frac{A}{A^*} = \frac{1}{Ma}\left\{\frac{1+[(k-1)/2]Ma^2}{1+[(k-1)/2]}\right\}^{(k+1)/[2(k-1)]}$$

Navier-stokes Equation

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)-\frac{\partial P}{\partial x}+\rho g_x$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)-\frac{\partial P}{\partial y}+\rho g_y$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)-\frac{\partial P}{\partial z}+\rho g_z$$

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

$$a_1 = \frac{18\mu}{D_1^2\rho_1}; \quad b_1 = \left(1-\frac{\rho_f}{\rho_1}\right)g$$

$$y = \frac{bt}{a}-\frac{b}{a^2}+\frac{b}{a^2}e^{-at} \; ; \; \dot{y} = \frac{b}{a}\left(1-e^{-at}\right)=u_t\left(1-e^{-at}\right)$$

$u_t = \frac{gD_p^2[\rho_p-\rho_f]}{18\mu_f}$ for Stoke's law

$u_t = 1.75\sqrt{\frac{gD_p(\rho_p-\rho_f)}{\rho_f}}$ for Newton's law

...2/-

For tank : $N_{RE} = \frac{D_a^2 n\rho}{\mu}$

$$P = N_P n^3 D_a^5 \rho$$

$$N_{Fr} = \frac{n^2 D_a}{g}$$

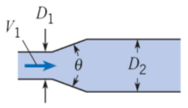
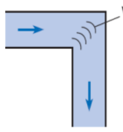
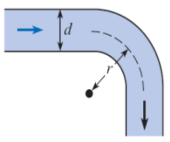
$$m = \frac{1.7 - \log_{10} N_{\mathrm{Re}}}{18}$$

$$N_{P(Corr)} = N_P \text{ X } N_{Fr}^m$$

Pipe Roughness

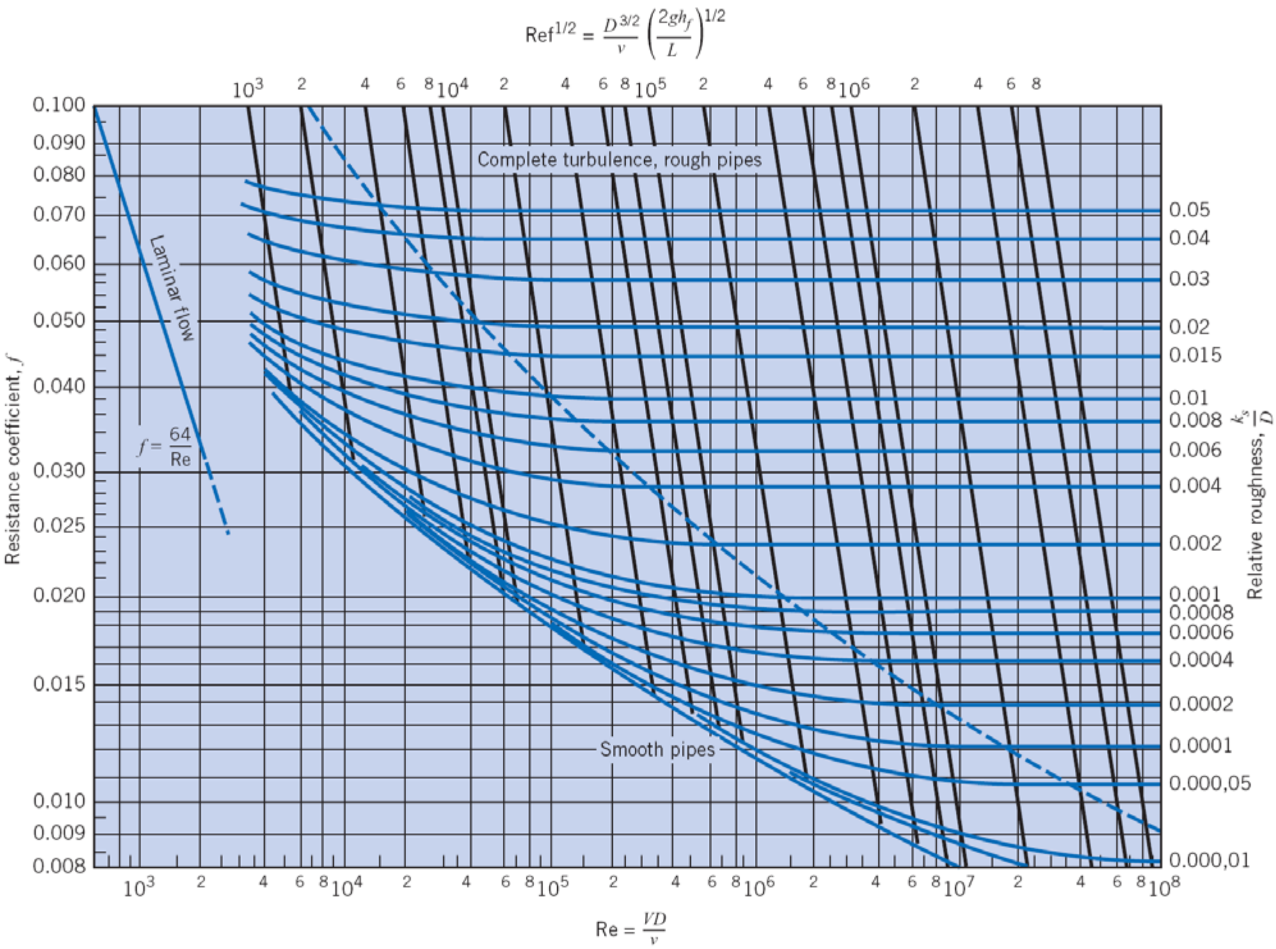
EQUIVALENT SAND GRAIN ROUGHNESS, k_s, FOR VARIOUS PIPE MATERIALS		
Boundary Material	**k_s, millimeters**	**k_s, inches**
Glass, plastic	Smooth	Smooth
Copper or brass tubing	0.0015	6×10^{-5}
Wrought iron, steel	0.046	0.002
Asphalted cast iron	0.12	0.005
Galvanized iron	0.15	0.006
Cast iron	0.26	0.010
Concrete	0.3 to 3.0	0.012–0.12
Riveted steel	0.9–9	0.035–0.35
Rubber pipe (straight)	0.025	0.001

Loss Coefficient for fittings

.3 LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS (CONTINUED)					
Description	**Sketch**	**Additional Data**	**K**		**Source**
Expansion		D_1/D_2	K_E $u = 20°$	K_E $u = 180°$	(17)
		0.0		1.00	
		0.20	0.30	0.87	
		0.40	0.25	0.70	
		0.60	0.15	0.41	
$h_L = K_E V_1^2/2g$		0.80	0.10	0.15	
90° miter bend		Without vanes	$K_b = 1.1$		(23)
		With vanes	$K_b = 0.2$		(23)
90° smooth bend		r/d			(24) and (17)
		1	$K_b = 0.35$		
		2	0.19		
		4	0.16		
		6	0.21		
		8	0.28		
		10	0.32		
Threaded pipe fittings	Globe valve—wide open	$K_v = 10.0$			(23)
	Angle valve—wide open	$K_v = 5.0$			
	Gate valve—wide open	$K_v = 0.2$			
	Gate valve—half open	$K_v = 5.6$			
	Return bend	$K_b = 2.2$			
	Tee				
	straight-through flow	$K_t = 0.4$			
	side-outlet flow	$K_t = 1.8$			
	90° elbow	$K_b = 0.9$			
	45° elbow	$K_b = 0.4$			

†Reprinted by permission of the American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, Georgia, from the 1981 *ASHRAE Handbook—Fundamentals*.

Moody Chart



Physical Properties of Water

Temperature (°C)	Density (kg/m^3)	Specific weight (kN/m^3)	Dynamic viscosity (N.s/m^2)	Kinematic Viscosity (m^2/s)
0	999.9	9.806	1.787E-3	1.787E-6
10	999.7	9.804	1.307E-3	1.307E-6
20	998.2	9.789	1.002E-3	1.004E-6
30	995.7	9.765	7.975E-4	8.009E-7
40	992.2	9.731	6.529E-4	6.580E-7
50	988.1	9.690	5.468E-4	5.534E-7
60	983.2	9.642	4.668E-4	4.745E-7

Physical Properties of Gas

Gas	Density (kg/m^3)	Kinematic Viscosity (m^2/s)	Gas constant (R) J/kg.K	Specific heat ratio, k
Air	1.22	1.46E-5	287	1.40
Carbon dioxide	1.85	7.84E-6	189	1.30
Helium	0.169	1.14E-4	2077	1.66
Hydrogen	0.0851	1.01E-4	4127	1.41
Methane	0.678	1.59e-5	518	1.31
Nitrogen	1.18	1.45E-5	297	1.40
Oxygen	1.35	1.50e-5	260	1.40

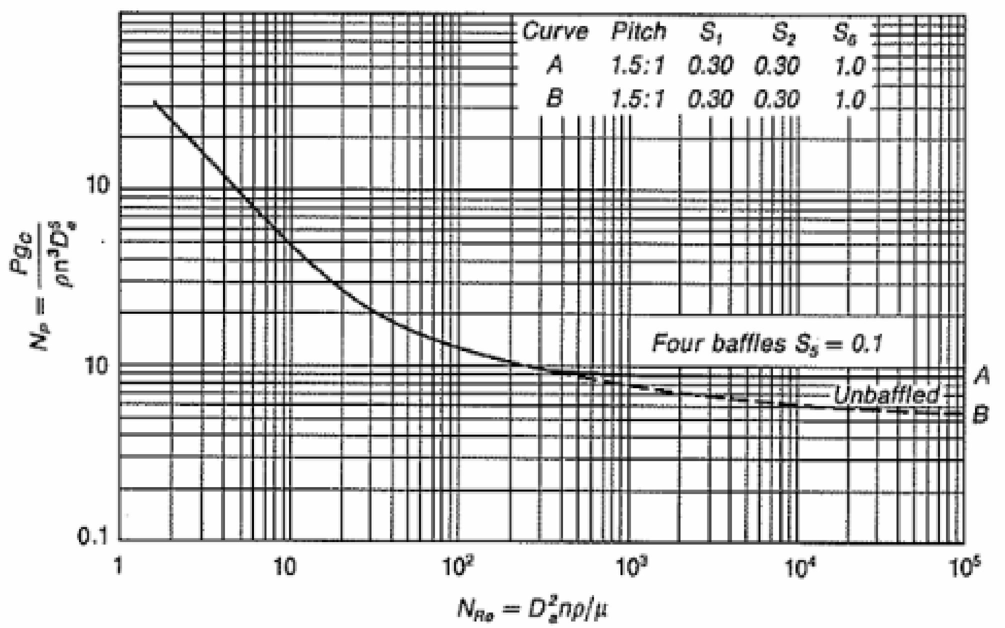


FIGURE 9.13
Power number N_p versus N_{Re} for three-blade propellers. (*After Oldshue.*[35]) With the dashed portion of curve *B*, the value of N_p read from the figure must be multiplied by N_{Fr}^m.