UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2008/2009

November 2008

EKC 212 – Fluid 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 THREE pages of Appendix before you begin the examination.

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

Instructions: Answer **SIX** (6) questions. Answer **ALL** (3) questions from Section A. Answer **THREE** (3) questions from Section B.

*[**Arahan**: Jawab **ENAM** (6) soalan. Jawab **SEMUA** (3) soalan dari Bahagian A. Jawab **TIGA** (3) soalan dari Bahagian B.]*

You may answer the question either in Bahasa Malaysia or in English.

[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

Section A : Answer ALL questions.
Bahagian A : Jawab SEMUA soalan.

1. [a] The dimension of the manometer can sometimes give a significant effect to the pressure measurement. In Figure Q.1. [a] below, containers (a) and (b) are cylindrical in shape and conditions are such that $p_a = p_b$. Derive a formula for the pressure difference $p_a - p_b$ when the brine-oil interface on the right rises a distance $\Delta h < h$, for $d << D$. Let the densities of brine and cooking oil be ρ_{brine} kg/m^3 and ρ_{oil} kg/m^3 respectively.

Dimensi suatu manometer kadang-kadang memberi kesan yang bererti kepada pengukuran tekanan. Dalam Gambarajah S.1. [a] di bawah, bekas-bekas (a) dan (b) berbentuk silinder dan berkeadaan; $p_a = p_b$. Terbitkan formula bagi perbezaan tekanan, $p_a - p_b$, apabila antara fasa air garam-minyak masak pada sebelah kanan meningkat pada jarak $\Delta h < h$, bagi $d << D$. Biarkan ketumpatan air garam dan minyak masing-masing sebagai $\rho_{air\ garam}$ kg/m^3 dan ρ_{minyak} kg/m^3.

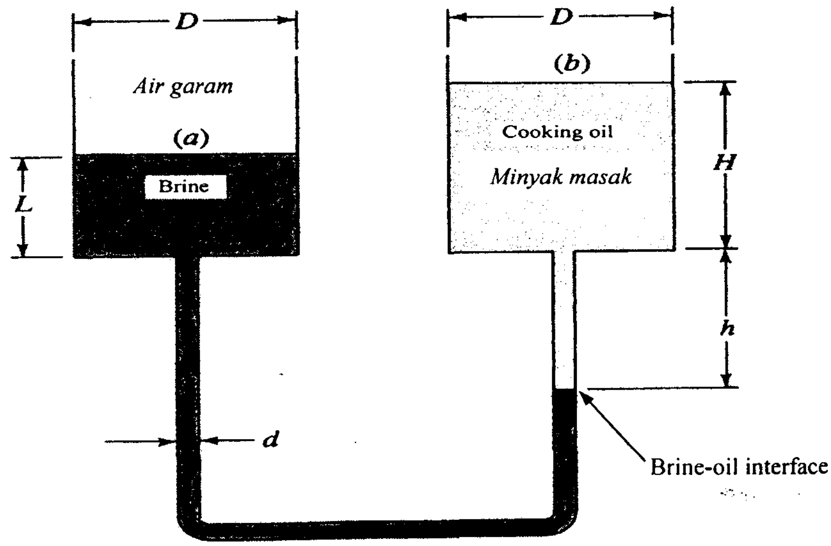

Figure Q.1. [a]
Gambarajah S.1.[a]

[8 marks/markah]

[b] Consider a sphere moving through a viscous fluid completely submerged. The resistance to motion R, depends upon the diameter D, the velocity v, the density ρ and the dynamic viscosity μ. Show that a function relating all the variables is given by;

$$Ne = f(Re)$$

Pertimbangkan sebuah sfera yang tenggelam dan bergerak melalui cecair likat. Rintangan terhadap pergerakan, R bergantung kepada diameter D, halaju v, ketumpatan, ρ dan kelikatab dinamik, μ. Tunjukkan bahawa fungsi yang menghubungkan kesemua pembolehubah di atas diberikan sebagai

$$Ne = f(Re)$$

where *Ne* and *Re* are the Newton and Reynolds numbers respectively.
di mana Ne dan Re adalah masing-masing nombor Newton dan Reynolds.

[7 marks/markah]

2. [a] What is pump cavitation? What is its cause?

Apakah peronggaan pam? Apakah punca terjadinya peronggaan tersebut?

[3 marks/markah]

[b] Sketch the schematic diagram of (i) orifice meter, (ii) venturi meter and (iii) pitot tube.

Lakarkan gambarajah skema untuk (i) meter orifis, (ii) meter venturi dan (iii) tiub pitot.

[3 marks/markah]

[c] Show that from continuity equation, the fluid flow through the orifice meter (pressure drop is measured by U manometer) can be expressed as:

Bermula daripada persamaan keterusan, tunjukkan bahawa bendalir melalui meter orifis (kejatuhan tekanan diukur menggunakan manometer U) boleh diungkapkan sebagai:

$$G = C_D A_2 \rho \sqrt{2gh_v}$$

where, *di mana,*

G = mass flowrate
kadar aliran jisim

A_2 = cross sectional area of orifice meter
luas permukaan meter orifis

C_D = discharge coefficient
pekali luahan

ρ = fluid density
ketumpatan bendalir

h_v = pressure drop
kejatuhan tekanan

[9 marks/markah]

3. [a] A storage cylindrical tank is 25 ft in diameter and 60 ft height. It contains an equal volume of water and oil. The tank is full and open to atmosphere. Calculate

Sebuah tangki silinder simpanan dengan diameter 25 kaki dan tinggi 60 kaki mengandungi isipadu air dan minyak yang sama. Tangki tersebut adalah penuh dan terbuka kepada atmosfera. Kirakan:

[i] The specific weight of the oil.
Berat tentu minyak.

[ii] The gauge pressure at the oil-water interface.
Tekanan tolok di antara fasa minyak-air.

[iii] The gauge pressure and pressure force at the bottom of the tank.
Tekanan tolok dan daya tekanan di dasar tangki.

Given : Specific gravity of oil = 0.89
Diberi : Graviti tentu minyak = 0.89

[10 marks/markah]

Section B : Answer any THREE question
Bahagian B : Jawab mana-mana TIGA soalan.

4. [a] Give 2 purposes of agitation of liquid and 2 methods on preventing vortex.

Berikan 2 tujuan pengadukan cecair dan 2 kaedah untuk menghalang vorteks.

[4 marks/markah]

[b] Sketch 3 types of mixing flows.

Lakarkan 3 jenis aliran bercampur.

[6 marks/markah]

[c] A flat-blade turbine with three blades is installed centrally in a vertical tank. The tank is 2.4 m in diameter, the turbine is 0.35 m in diameter and is positioned at 0.65 m from the bottom of the tank. The turbine blades are 70 mm wide. The tank is filled to a depth of 1.9 m with a solution of 50% caustic soda at 65.6°C, which has a viscosity of 12 cP and a density of 1498 kg/m^3. The turbine is operated at 45 rpm. Calculate the power required to operate the mixer if:-

Sebuah turbin berbilah rata dengan 3 bilah dipasang ditengah-tengah sebuah tangki tegak. Tangki ini berdiameter 2.4 m. Turbin berdiameter 0.35 m berkedudukan 0.65 m dari dasar tangki. Lebar bilah turbin ialah 70 mm. Tangki diisi dengan kedalaman 1.9 m larutan 50% soda kaustik yang bersuhu 65.6°C, berkelikatan 12 cP dan berketumpatan 1498 kg/m^3. Turbin beroperasi pada 45 rpm. Kirakan kuasa yang diperlukan oleh pengacau untuk beroperasi jika:

[i] The tank is baffled
tangki bersesekat

[5 marks/markah]

[ii] The tank is unbaffled.
Tangki tanpa sesekat

[5 marks/markah]

5. [a] Give 3 applications of fluidized beds.

Berikan 3 aplikasi lapisan terbendalir.

[3 marks/markah]

[b] For a particle of mass, m and density ρ_p, moving through a fluid of density ρ_f under an action of gravitational force g, show that the terminal velocity v_t of the particle is given by;

Bagi suatu zarah dengan jisim, m dan berketumpatan, ρ_p bergerak melalui cecair yang berketumpatan ρ_f di bawah tindakan daya graviti, g, tunjukkan bahawa halaju terminal, v_t bagi zarah tersebut diberi oleh;

$$v_t = \sqrt{\frac{2gm(\rho_p - \rho_f)}{A_p C_D \rho_p \rho_f}}$$

[10 marks/markah]

[c] Water is flowing at a velocity of 0.02 m/s in a pipe of 0.25 m in diameter. In the pipe, there is an orifice with a hole diameter of 0.15 m. What is the measured pressure drop across the orifice?

Air mengalir dengan kelajuan 0.02 m/s di dalam sebatang paip berdiameter 0.25 m. Di dalam paip ini terdapat sebuah meter orifis dengan diameter lubang 0.15 m. Berapakah kejatuhan tekanan yang terhasil di sepanjang orifis?

Given:
Diberi:

$$\Delta P = \frac{\rho u_2^2}{2C_D^2}(1-\beta^4)$$

$\mu_{water} = 1x10^{-3}$ kg/ms
$\mu_{air} = 1x10^{-3}$ *kg/ms*

$\rho_{water} = 1000$ kg/m^3
$\rho_{air} = 1000$ *kg/m*^{3}

[7 marks/markah]

6. [a] Using the steady flow energy equation, in conjunction with the relation;

Dengan menggunakan persamaan kuasa aliran mantap yang berpandukan kepada perkaitan;

$$\frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$

which applies to the isentropic changes in a perfect gas, show that the ratio of the stagnation pressure to static pressure is related to the Mach number, Ma of a gas flow by the equation;

yang digunakan kepada pertukaran isentropik pada gas unggul, tunjukkan bahawa nisbah tekanan genangan kepada tekanan statik dikaitkan kepada nombor Mach, Ma bagi suatu aliran gas melalui persamaan;

$$\frac{p_o}{p} = \left[1 + \left(\frac{\gamma-1}{2}\right)Ma^2\right]^{\frac{\gamma}{\gamma-1}}$$

[8 marks/markah]

[b] A pitot-static tube inserted in a flow of argon gives a total pressure reading of 158 kN/m^2 absolute and a static pressure of 104 kN/m^2 absolute. The temperature of the gas is 20 °C. Determine the speed of the gas flow, and the error which could occur in this determination if the gas was assumed to be incompressible with a density equal to that in the undisturbed stream. Instrumental errors are to be ignored. For argon (Ar), R = 208.2 J/kg.K, ratio of specific heat, $\gamma = 1.68$.

Suatu tiub statik-pitot yang dipasang kepada aliran argon memberikan bacaan 158 kN/m^2 *mutlak dan tekanan statik 104 kN/m*^{2} *mutlak. Suhu gas tersebut adalah 20 °C. Tentukan halaju aliran gas dan ralat yang diperolehi hasil daripada pengiraan tersebut jika gas itu dianggap sebagai ketidakbolehmampatan dengan ketumpatan yang bersamaan dengan aliran tidak terganggu. Ralat alatan boleh diabaikan. Bagi gas Argon (Ar), R = 208.2 J/kg.K, nisbah haba tentu,* $\gamma = 1.68$.

[12 marks/markah]

7. Figure Q.7 shows a pump pumping a fluid at a rate of 0.2 ft^3/s from an open tank having a large cross-sectional area. The discharge flow goes to an open overhead tank as shown in the figure. If the friction loss in the piping system are 20 $ft.lb_f/lb_m$ and the efficiency of the pump is 70%, calculate

Gambarajah S.7 menunjukkan sebuah pam yang mengepam suatu bendalir pada kadar 0.2 kaki^3/s dari sebuah tangki terbuka dengan luas keratan rentas yang besar. Aliran luahan ke sebuah tangki atas yang terbuka adalah seperti yang ditunjukkan dalam gambarajah. Jika kehilangan geseran dalam sistem perpaipan ialah 20 kaki.lb_f/lb_m dan kecekapan pam ialah 70%, kirakan

[i] What pressure must the pump develop
Tekanan yang perlu dijana oleh pam

[ii] What is the horse power of the pump.
Kuasa kuda pam

Density of the fluid = 1.15 g/cm^3
Ketumpatan bendalir = 1.15 g/cm^3

Given: Pipe A = 3 in Schedule 40 steel pipe
Diberi: Paip A – Paip keluli 3 inci Jadual 40

Pipe B = 2 in Schedule 80 steel pipe
Paip B = Paip keluli 2 inci Jadual 80

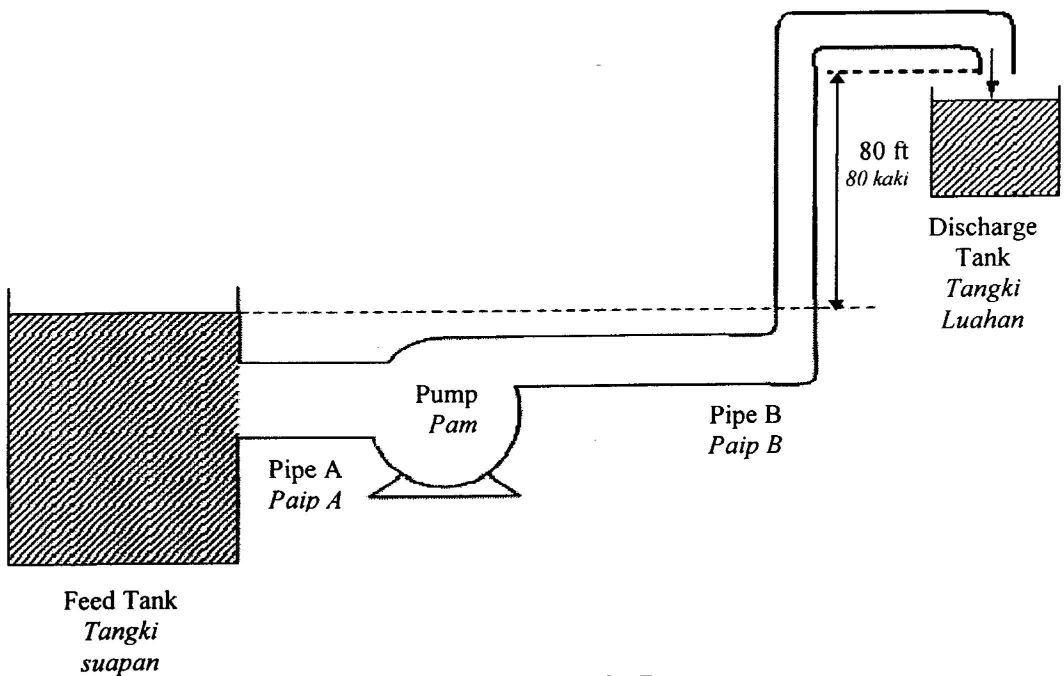

Figure Q. 7.
Gambarajah S. 7.

[20 marks/markah]

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Appendix
Lampiran

Common Engineering Conversion Factors

Length	Volume
1 ft = 12 in = 0.3048 m, 1 yard = 3 ft 1 mi = 5280 ft = 1609.344 m 1 nautical mile (nmi) = 6076 ft	1 ft^3 = 0.028317 m^3 = 7.481 gal. 1 bbl = 42 U.S. gal 1 U.S. gal = 231 in^3 = 3.7853 L = 4qt = 0.833 Imp.gal. 1 L = 0.001 m^3 = 0.035315 ft^3 = 0.2642 U.S. gal
Mass	**Density**
1 slug = 32.174 lb_m = 14.594 kg 1 lb_m = 0.4536 kg = 7000 grains	1 slug/ft^3 = 515.38 kg/m^3 , 1 g/cm^3 = 1000 kg/m^3 1 lb_m/ft^3 = 16.0185 kg/m^3 , 1 lb_m/in^3 = 27.68 g/cm^3
Acceleration & Area	**Velocity**
1 ft/s^2 = 0.3048 m/s^2 1 ft^2 = 0.092903 m^2	1 ft/s = 0.3048 m/s , 1 knot = 1 min/h = 1.6878 ft/s 1 min/h = 1.4666666 ft/s (fps) = 0.44704 m/s
Mass Flow & Mass Flux	**Volume Flow**
1 slug/s = 14.594 kg/s. 1 lb_m/s = 0.4536 kg/s 1 kg/m^2s = 0.2046 lb_m/ft^2s = 0.00636 slug/ft^2s	1 gal/min = 0.00228 ft^3/s = 0.06309 L/s 1 million gal/day = 1.5472 ft^3/s = 0.04381 m^3/s
Pressure	**Force and Surface Tension**
1 lb_f/ft^3 = 47.88 Pa, 1 torr = 1 mm Hg 1 psi = 144 psf, 1 bar = 10^5 Pa 1 atm = 2116.2 psf = 14696 psi = 101,325 Pa = 29.9 in.Hg = 33.9 ft H_2O	1 lb_f = 4.448222 N = 16 oz, 1 dyne = 1 g cm/s^2 = 10^{-5}N 1 kg_f = 2.2046 lb_f = 9.80665 N 1 U.S. (short) ton = 2000 lb_f , 1 N = 0.2248 lb_f 1 N/m = 0.0685 lb_f/ft
Power	**Energy and Specific Energy**
1 hp = 550 (ft lb_f)/s = 745.7 W 1 (ft lb_f)/s = 1.3558 W 1 Watt = 3.4123 Btu/h = 0.00134 hp	1 ft lb_f = 1.35582 J, 1 hp·h = 2544.5 Btu 1 Btu = 252 cal = 1055.056 J = 778.17 ft lb_f 1 cal = 4.1855 J, 1 ft.lb_f/lb_m = 2.9890 J/kg
Specific Weight	**Heat Flux**
1 lb_f/ft^3 = 157.09 N/m^3	1 W/m^2 = 0.3171 Btu/(h ft^2)
Viscosity	**Kinematic Viscosity**
1 slug/(ft s) = 47.88 kg/(m s) = 478.8 poise (p) 1 p=1 g/(cm s) 0.1 kg/(m s) = 0.002088 slug/(ft s)	1 ft^2/h = 2.506 .10^{-5} m^2/s, 1 ft^2/s = 0.092903 m^2/s 1 stoke (st) = 1 cm^2/s = 0.0001 m^2/s = 0.001076 ft^2/s

Temperature Scale Readings

^oF = (9/5)^oC + 32	^oC = (5/9) (^oF – 32)	^oR = ^oF + 459.69	^oK = ^oC + 273.16

Specific Heat or Gas Constant*	Thermal Conductivity*
1 (ft lb_f)/(slug ^oR) = 0.16723 (N m) (kg K) 1 Btu/(lb ^oR) = 4186.8 J/(kg K)	1 cal/(s cm ^oC) = 242 Btu/(h ft ^oR) 1 Btu/(h ft ^oR) = 1.7307 W/(m K)

- Note that the intervals in absolute (Kelvin) and ^oC are equal. Also, 1 ^oR = 1 ^oF.

Latent heat: 1 J/kg = 4.2995 × 10^{-4} Btu/lb_m = 10.76 lb_fft/slug = 0.3345 lb_f – ft/lb_m, 1 Btu/lb_m = 2325.9 J/kg
Heat transfer coefficient: 1 Btu/(h ft^2 ^oF) = 5.6782 W/(m^2 ^oC).
Heat generation rate: 1 W/m^3 = 0.09665 Btu/(h ft^3)
Heat transfer per unit length: 1 W/m = 1.0403 Btu/(h ft)
Mass transfer coefficient: 1 m/s = 11.811 ft/h, 1 lb_{mol}/(h ft^2) = 0.013562 kgmol/(s m^2)

Dimensions of Standard Steel Pipe

Nominal Pipe Size (in.)	Outside Diameter in.	Outside Diameter mm	Schedule Number	Wall Thickness in.	Wall Thickness mm	Inside Diameter in.	Inside Diameter mm	Inside Cross-Sectional Area ft^2	Inside Cross-Sectional Area $m^2 \times 10^4$
$\frac{1}{8}$	0.405	10.29	40	0.068	1.73	0.269	6.83	0.00040	0.3664
			80	0.095	2.41	0.215	5.46	0.00025	0.2341
$\frac{1}{4}$	0.540	13.72	40	0.088	2.24	0.364	9.25	0.00072	0.6720
			80	0.119	3.02	0.302	7.67	0.00050	0.4620
$\frac{3}{8}$	0.675	17.15	40	0.091	2.31	0.493	12.52	0.00133	1.231
			80	0.126	3.20	0.423	10.74	0.00098	0.9059
$\frac{1}{2}$	0.840	21.34	40	0.109	2.77	0.622	15.80	0.00211	1.961
			80	0.147	3.73	0.546	13.87	0.00163	1.511
$\frac{3}{4}$	1.050	26.67	40	0.113	2.87	0.824	20.93	0.00371	3.441
			80	0.154	3.91	0.742	18.85	0.00300	2.791
1	1.315	33.40	40	0.133	3.38	1.049	26.64	0.00600	5.574
			80	0.179	4.45	0.957	24.31	0.00499	4.641
$1\frac{1}{4}$	1.660	42.16	40	0.140	3.56	1.380	35.05	0.01040	9.648
			80	0.191	4.85	1.278	32.46	0.00891	8.275
$1\frac{1}{2}$	1.900	48.26	40	0.145	3.68	1.610	40.89	0.01414	13.13
			80	0.200	5.08	1.500	38.10	0.01225	11.40
2	2.375	60.33	40	0.154	3.91	2.067	52.50	0.02330	21.65
			80	0.218	5.54	1.939	49.25	0.02050	19.05
$2\frac{1}{2}$	2.875	73.03	40	0.203	5.16	2.469	62.71	0.03322	30.89
			80	0.276	7.01	2.323	59.00	0.02942	27.30
3	3.500	88.90	40	0.216	5.49	3.068	77.92	0.05130	47.69

$$H = W_p\eta = \frac{P_{b'}}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_{b'}\overline{V}_b^2}{2g_c} + h_f - \frac{P_{a'}}{\rho}$$

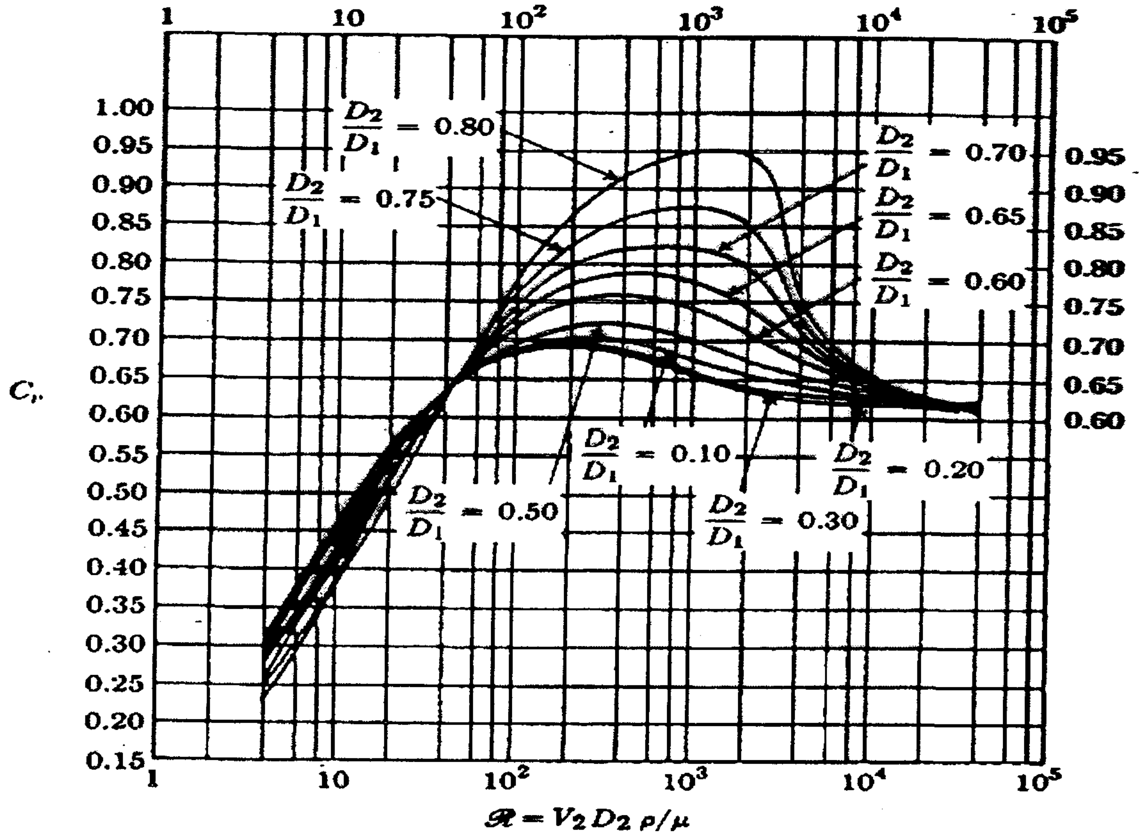
$$P_B = \frac{m\Delta H}{\eta} = \frac{P_f}{\eta}$$

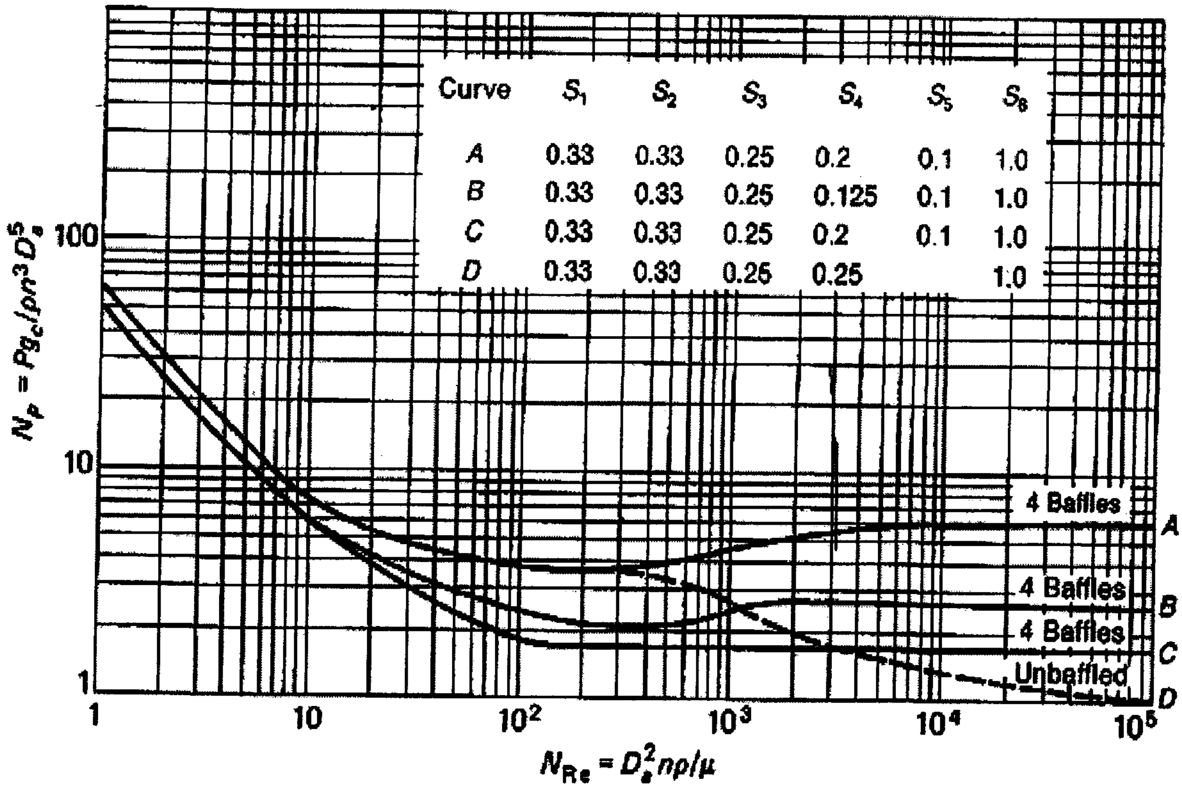
$$NPSH = \frac{g_c}{g}\left(\frac{p_i - p_v}{\rho} - h_{fs}\right) - Z_a$$

$$P = \frac{N_P n^3 D_a^5 \rho}{g_c}$$

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

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





Power number N_P versus N_{Re} for six-blade turbines. With the dashed portion of curve D, the value of N_P read from the figure must be multiplied by N_{Fr}^m