UNIVERSITI SAINS MALAYSIA

First Semester Examination
2016/2017 Academic Session

December 2016 / January 2017

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 SEVEN pages of printed material and SEVEN pages of Appendix before you begin the examination.

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

Instructions: Answer **ALL** (5) questions.

*[**Arahan:** Jawab **SEMUA** (5) 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 ALL questions.

1. [a] [i] With aids of a diagram, describe briefly an experiment to determine type of flow in a pipe.

[5 marks]

[ii] Sulphuric acid (viscosity 0.025 Ns/m^2, density 1840 kg/m^3) is pumped at a rate of 700 kg/m^3 from the ground floor to an elevation of 2 m height through a tube of 25-mm-ID. Determine the type of flow in the tube.

[5 marks]

[b] A group of second year, Chemical Engineering students are conducting an experiment to investigate the pressure drop (ΔP) in a pipe for a fluid flowing from station *A* to station *B*. They found that the pressure drop between the stations are influenced by:

[i] Diameter of the pipe, d
[ii] Length of the pipe, l
[iii] Velocity of the fluid, u
[iv] Density of the fluid, ρ
[v] Viscosity of the fluid, μ

Perform a dimensional analysis to formulate the relationship among those parameters.

[10 marks]

2. Figure Q.2 shows a closed tank containing compressed air and oil. A *U*-tube manometer is connected to the tank. Calculate the pressure reading (in psi) shown by the pressure gauge at the top of the tank.

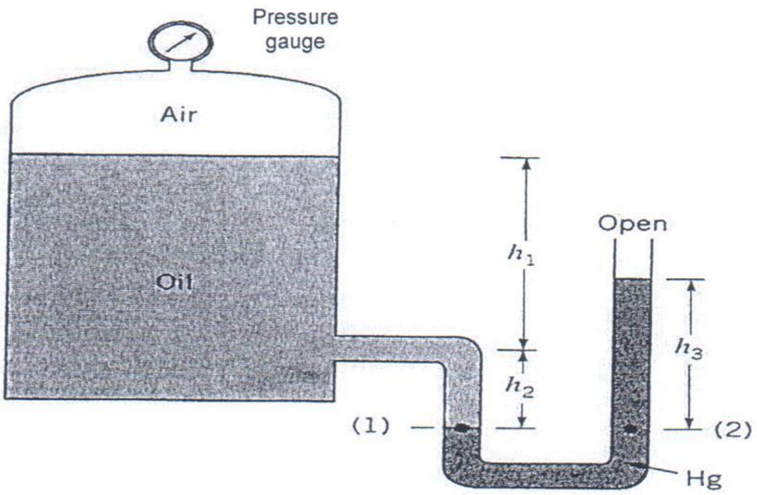


Figure Q.2.

Given data:

Specific gravity of oil = 0.90
Specific gravity of mercury = 13.6
h_1 = 36 inches
h_2 = 6 inches
h_3 = 9 inches

[10 marks]

Jawab SEMUA soalan.

1. [a] [i] *Dengan berbantukan sebuah gambarajah, huraikan secara ringkas suatu ujikaji untuk menentukan jenis pengaliran dalam sesebuah paip.*

[5 markah]

[ii] *Asid sulfurik (kelikatan 0.025 Ns/m^2, ketumpatan 1840 kg/m^3) dipam pada kadar aliran 700 kg/m^3 dari aras bawah ke ketinggian 2 m melalui satu tiub 25-mm-ID. Tentukan jenis pengaliran dalam tiub tersebut.*

[5 markah]

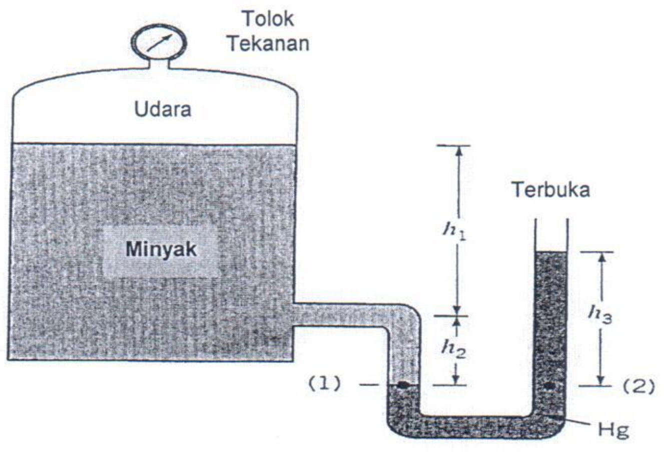
[b] *Sekumpulan pelajar tahun dua, Kejuruteraan Kimia menjalankan suatu ujikaji untuk menyiasat susutan tekanan (ΔP) bagi bendalir yang mengalir dalam suatu paip dari stesen A ke stesen B. Mereka mendapati bahawa susutan tekanan antara stesen tersebut dipengaruhi oleh:*

[i] *Garispusat paip,* d
[ii] *Panjang paip,* l
[iii] *Kelajuan bendalir,* u
[iv] *Ketumpatan bendalir,* ρ
[v] *Kelikatan bendalir,* μ

Lakukan analisis dimensi untuk memformulasikan hubung-kait antara parameter-parameter tersebut.

[10 markah]

2. *Rajah S.2 menunjukkan suatu tangki tertutup yang mengandungi udara dan minyak yang mampat. Suatu manometer tiub-U disambungkan kepada tangki tersebut. Kirakan bacaan tekanan (dalam psi) yang ditunjukkan oleh tolok tekanan di atas tangki tersebut.*



Rajah S.2.

Diberi data:

Graviti tentu minyak = 0.90
Graviti tentu merkuri = 13.6
h_1 = *36 inci*
h_2 = *6 inci*
h_3 = *9 inci*

[10 markah]

3. Figure Q.3 shows that water at 20°C is being pumped from a storage tank on the ground floor to an elevated tank. The volumetric flowrate is 5×10^{-3} m^3/s. All the piping used are the 4-in. Schedule 40 steel pipe. The pump has an efficiency of 70%.

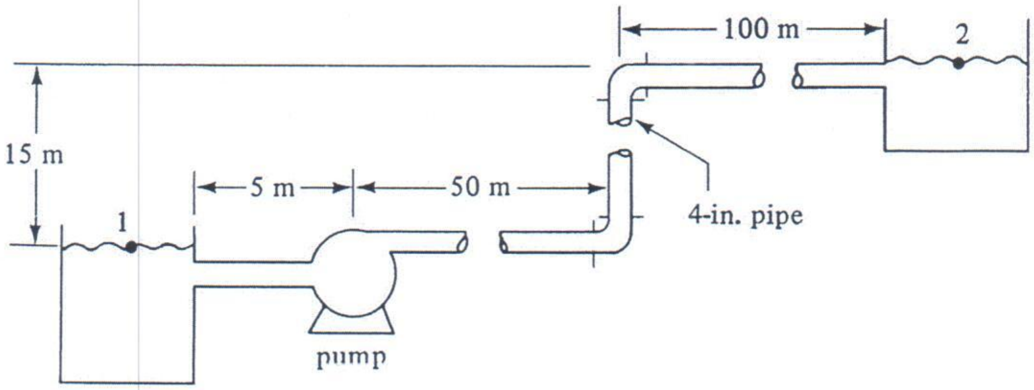


Figure Q.3

[a] Calculate the total friction loss.

[10 marks]

[b] Calculate the power needed in kW for the pump.

[6 marks]

[c] If the electricity cost is 33.32 cent per kWh, calculate the cost per day (24 h).

[4 marks]

4. [a] Air at 101.3 kPa and 25°C is flowing in a wind tunnel at a velocity of 10 m/s. A long cylinder having a diameter of 90 mm is placed in the tunnel and the axis of the cylinder is held perpendicular to the air flow. What is the force on the cylinder per meter length given that density of air = 1.187 kg/m^3 and viscosity of air = 1.845×10^{-5} Pa.s?

[8 marks]

[b] Air is used to fluidize a bed of spherical particles at 25°C and 202.65 kPa abs pressure. The bed diameter is 0.60 m and contains 350 kg of solids. If the void fraction at minimum fluidizing conditions is 0.43, calculate the followings:

[i] Minimum height of the fluidized bed

[4 marks]

[ii] Pressure drop at minimum fluidizing conditions

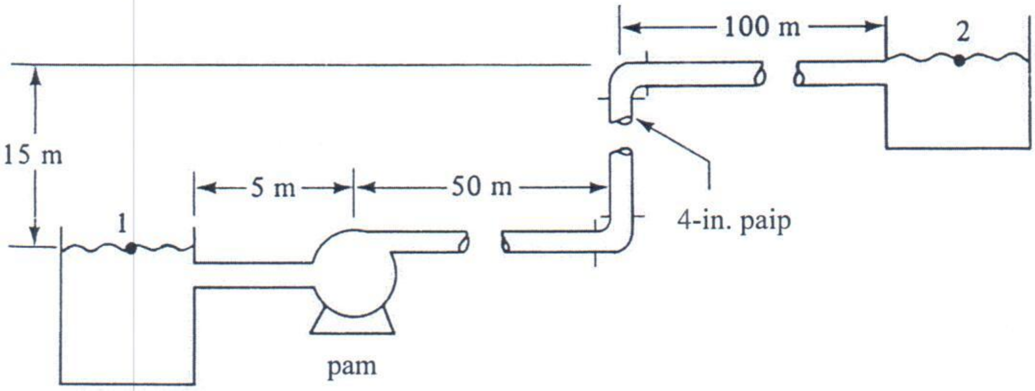
[4 marks]

[iii] Minimum velocity for fluidization

[9 marks]

Data:
$\Phi_s = 0.86$
Diameter of particles = 0.10 mm
Density of particles = 1200 kg/m^3
Density of air = 2.374 kg/m^3
Viscosity of air = 1.845×10^{-5} Pa.s

3. *Rajah S.3 menunjukkan air pada 20°C sedang dipam dari satu tangki penyimpanan yang terletak di aras bawah ke satu tangki yang berada di suatu ketinggian. Kadar aliran isipadu adalah 5 × 10^{-3} m^3/s. Kesemua paip yang digunakan adalah paip keluli 4-in. Schedule 40. Pam tersebut mempunyai kecekapan 70%.*



Rajah S.3

[a] *Kirakan kehilangan keseluruhan geseran.*

[10 markah]

[b] *Kirakan kuasa yang diperlukan oleh pam dalam kW.*

[6 markah]

[c] *Sekiranya kos elektik adalah 33.32 sen bagi setiap kWj, kirakan kos bagi satu hari (24j).*

[4 markah]

4. [a] *Udara pada 101.3 kPa dan 25°C mengalir di dalam terowong angin pada kelajuan 10 m/s. Suatu silinder yang panjang berdiameter 90 mm diletakkan di dalam terowong dan paksi silinder tersebut diletakkan secara serenjang kepada aliran udara. Apakah daya ke atas silinder bagi setiap meter panjang untuk ketumpatan udara = 1.187 kg/m^3 dan kelikatan udara = 1.845 × 10^{-5} Pa.s?*

[8 markah]

[b] *Udara digunakan untuk membendalir suatu lapisan zarah-zarah sfera pada 25°C dan 202.65 kPa tekanan mutlak. Diameter lapisan ialah 0.60 m dan ia mengandungi 350 kg pepejal. Sekiranya pecahan lompang pada keadaan perbendaliran minimum ialah 0.43, kirakan yang berikut:*

[i] *Ketinggian minimum lapisan terbendalir* [4 markah]

[ii] *Susutan tekanan pada keadaan perbendaliran minimum* [4 markah]

[iii] *Kelajuan minimum perbendaliran* [9 markah]

Data:
$\Phi_s = 0.86$
Diameter zarah = 0.10 mm
Ketumpatan zarah = 1200 kg/m^3
Ketumpatan udara = 2.374 kg/m^3
Kelikatan udara = 1.845 x 10^{-5} Pa.s

5. [a] A horizontal venturi meter having a throat diameter of 20 mm is set in a 75-mm-ID pipeline. Water at 15°C is flowing through the line. A manometer containing mercury under water measures the pressure differential over the instrument. The manometer reading is 500 mm.

[i] What is the flow rate in m^3/s?

[ii] If 12% of the differential is permanently lost, what is the power consumption (in kW) of the meter?

<u>Given:</u>

$C_\upsilon = 0.98$

Density of water at 15°C = 999 kg/m^3

$SG_{mercury} = 13.6$

[10 marks]

[b] It is desired to agitate a liquid having a viscosity of 1.5×10^{-3} Pa.s and a density of 969 kg/m^3 in a tank having a diameter of 0.91 m. The agitator is a six-blade open turbine with the diameter of 0.305 m operating at 180 rpm. The tank has four vertical baffles, each with a width J of 0.076 m and $W = 0.0381$ m.

[i] Calculate the required power (in kW) of the agitator.

[7 marks]

[ii] If a different solution with a viscosity of 3.0 Pa.s is used while other conditions remain the same, calculate the required power (in kW). Comment on your answer.

[8 marks]

5. [a] *Satu meter venturi mengufuk dengan diameter kerongkong 20 mm telah dipasang di dalam saluran paip 75-mm-ID. Air pada suhu 15 °C mengalir melalui saluran ini. Suatu manometer mengandungi merkuri di bawah air digunakan untuk menyukat perbezaan tekanan dalam alat. Bacaan manometer ialah 500 mm.*

[i] *Apakah kadar halaju dalam m^3/s?*

[ii] *Sekiranya 12% daripada perbezaan tekanan hilang selamanya, apakah penggunaan kuasa (dalam kW) bagi meter tersebut?*

Diberi:

$C_\upsilon = 0.98$

Ketumpatan air pada 15 °C = 999 kg/m^3

Graviti $tentu_{merkuri} = 13.6$

[10 markah]

[b] *Cecair berkelikatan 1.5×10^{-3} Pa.s dan berketumpatan 969 kg/m^3 perlu diaduk di dalam sebuah tangki berdiameter 0.91 m. Pengaduk ialah turbin terbuka berbilah enam dengan diameter 0.305 m dan beroperasi pada 180 rpm. Tangki tersebut mempunyai empat pengadang tegak, setiap pengadang dengan kelebaran J ialah 0.076 m dan kelebaran pengaduk W ialah 0.0381 m.*

[i] *Kirakan kuasa yang diperlukan oleh pengaduk (dalam kW).*

[7 markah]

[ii] *Jika larutan lain berkelikatan 3.0 Pa.s digunakan manakala keadaan-keadaan lain kekal, kirakan kuasa yang diperlukan (dalam kW). Ulaskan jawapan anda.*

[8 markah]

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Appendix

Table 1: Dimensions of Standard Steel Pipe

Dimensions of Standard Steel Pipe

Nominal Pipe Size (in.)	*Outside Diameter*		*Schedule Number*	*Wall Thickness*		*Inside Diameter*		*Inside Cross-Sectional Area*	
	in.	*mm*		*in.*	*mm*	*in.*	*mm*	*ft^2*	*$m^2 \times 10^4$*
$\frac{1}{8}$	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
				0.300	7.62	2.900	73.66	0.04587	42.61
$3\frac{1}{2}$	4.000	101.6	40	0.226	5.74	3.548	90.12	0.06870	63.79
			80	0.318	8.08	3.364	85.45	0.06170	57.35
4	4.500	114.3	40	0.237	6.02	4.026	102.3	0.08840	82.19
			80	0.337	8.56	3.826	97.18	0.07986	74.17
5	5.563	141.3	40	0.258	6.55	5.047	128.2	0.1390	129.1
			80	0.375	9.53	4.813	122.3	0.1263	117.5
6	6.625	168.3	40	0.280	7.11	6.065	154.1	0.2006	186.5
			80	0.432	10.97	5.761	146.3	0.1810	168.1
8	8.625	219.1	40	0.322	8.18	7.981	202.7	0.3474	322.7
			80	0.500	12.70	7.625	193.7	0.3171	294.7

Table 2: Loss Coefficient for Standard Threaded Pipe Fittings

Friction Loss for Turbulent Flow Through Valves and Fittings

Type of Fitting or Valve	*Frictional Loss, Number of Velocity Heads, K_f*	*Frictional Loss, Equivalent Length of Straight Pipe in Pipe Diameters, L_e/D*
Elbow, 45°	0.35	17
Elbow, 90°	0.75	35
Tee	1	50
Return bend	1.5	75
Coupling	0.04	2
Union	0.04	2
Gate valve		
Wide open	0.17	9
Half open	4.5	225
Globe valve		
Wide open	6.0	300
Half open	9.5	475
Angle valve, wide open	2.0	100
Check valve		
Ball	70.0	3500
Swing	2.0	100
Water meter, disk	7.0	350

Source: R. H. Perry and C. H. Chilton, *Chemical Engineers' Handbook*, 5th ed. New York: McGraw-Hill Book Company, 1973. With permission.

Table 3: Density of Liquid Water

Density of Liquid Water

Temperature		*Density*		*Temperature*		*Density*	
K	*°C*	*g/cm^3*	*kg/m^3*	*K*	*°C*	*g/cm^3*	*kg/m^3*
273.15	0	0.99987	999.87	323.15	50	0.98807	988.07
277.15	4	1.00000	1000.00	333.15	60	0.98324	983.24
283.15	10	0.99973	999.73	343.15	70	0.97781	977.81
293.15	20	0.99823	998.23	353.15	80	0.97183	971.83
298.15	25	0.99708	997.08	363.15	90	0.96534	965.34
303.15	30	0.99568	995.68	373.15	100	0.95838	958.38
313.15	40	0.99225	992.25				

Source: R. H. Perry and C. H. Chilton, *Chemical Engineers' Handbook*, 5th ed. New York: McGraw-Hill Book Company, 1973. With permission.

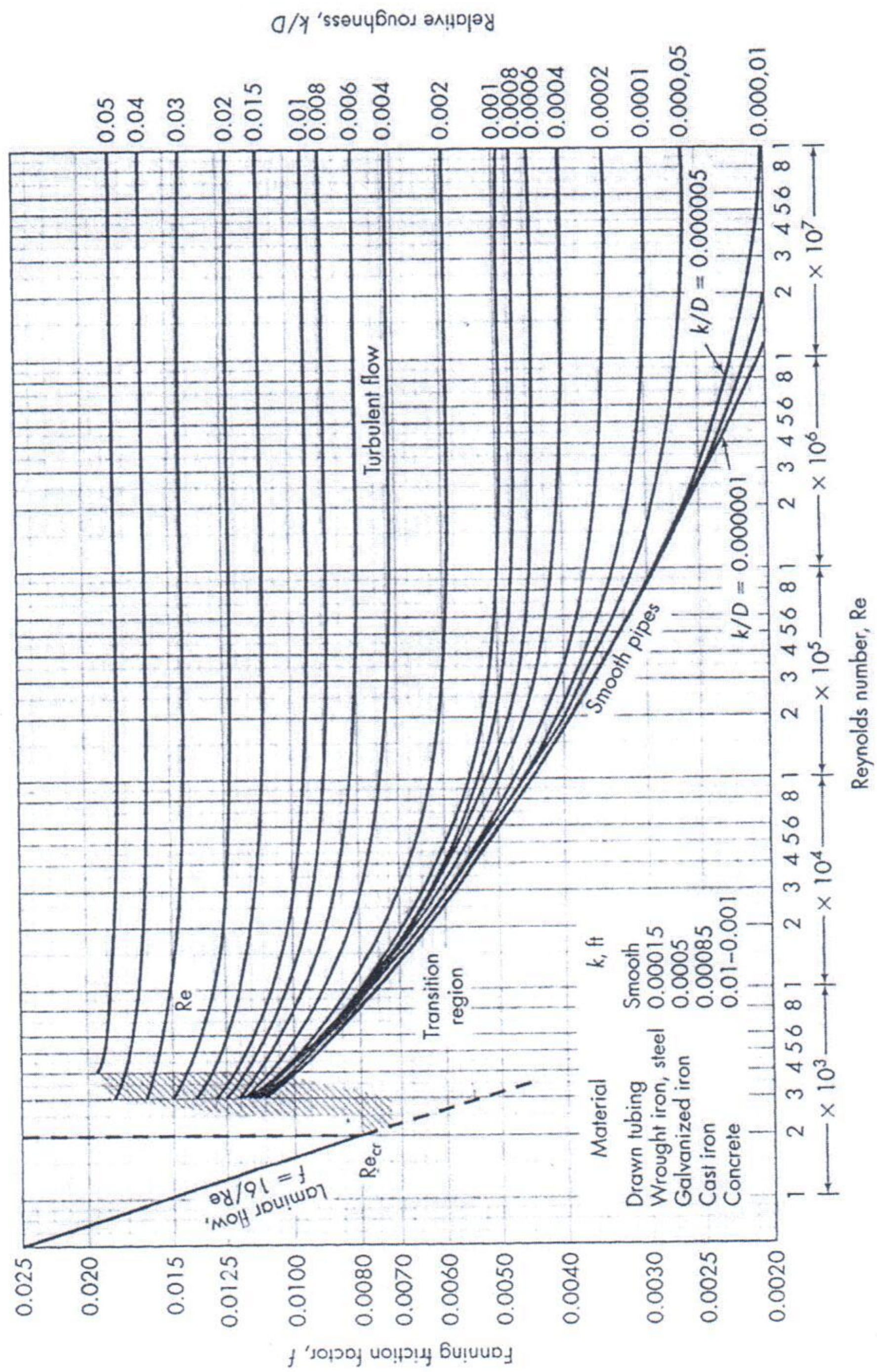
Table 4: Viscosity of Liquid Water

Viscosity of Liquid Water

Temperature K	Temperature °C	Viscosity [(Pa · s) 10^3, (kg/m · s) 10^3, or cp]	Temperature K	Temperature °C	Viscosity [(Pa · s) 10^3, (kg/m · s) 10^3, or cp]
273.15	0	1.7921	323.15	50	0.5494
275.15	2	1.6728	325.15	52	0.5315
277.15	4	1.5674	327.15	54	0.5146
279.15	6	1.4728	329.15	56	0.4985
281.15	8	1.3860	331.15	58	0.4832
283.15	10	1.3077	333.15	60	0.4688
285.15	12	1.2363	335.15	62	0.4550
287.15	14	1.1709	337.15	64	0.4418
289.15	16	1.1111	339.15	66	0.4293
291.15	18	1.0559	341.15	68	0.4174
293.15	20	1.0050	343.15	70	0.4061
293.35	20.2	1.0000	345.15	72	0.3952
295.15	22	0.9579	347.15	74	0.3849
297.15	24	0.9142	349.15	76	0.3750
298.15	25	0.8937	351.15	78	0.3655
299.15	26	0.8737	353.15	80	0.3565
301.15	28	0.8360	355.15	82	0.3478
303.15	30	0.8007	357.15	84	0.3395
305.15	32	0.7679	359.15	86	0.3315
307.15	34	0.7371	361.15	88	0.3239
309.15	36	0.7085	363.15	90	0.3165
311.15	38	0.6814	365.15	92	0.3095
313.15	40	0.6560	367.15	94	0.3027
315.15	42	0.6321	369.15	96	0.2962
317.15	44	0.6097	371.15	98	0.2899
319.15	46	0.5883	373.15	100	0.2838
321.15	48	0.5683			

Source: Bingham, *Fluidity and Plasticity*. New York: McGraw-Hill Book Company, 1922. With permission.

Figure 1: Friction Factor Chart vs Reynold Number



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 = 14.696 psia = 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
Thermal Conductivity*	**Gas Constant***
1 cal/(s.cm.^oC) = 242 Btu/(h.ft.^oR) 1 Btu/(h.ft.^oR) = 1.7307 W/(m.K)	R = 82.057 atm.cm^3/(gmol.K) = 62.361 mm Hg.L/(gmol.K) = 1.134 atm.ft^3/(lbmol.K) = 0.083144 bar.L/(gmol.K) = 10.73 psi. ft^3/(lbmol. ^oR) = 555.0 mm Hg.ft^3/(lbmol. ^oR)

- 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_f.ft/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)

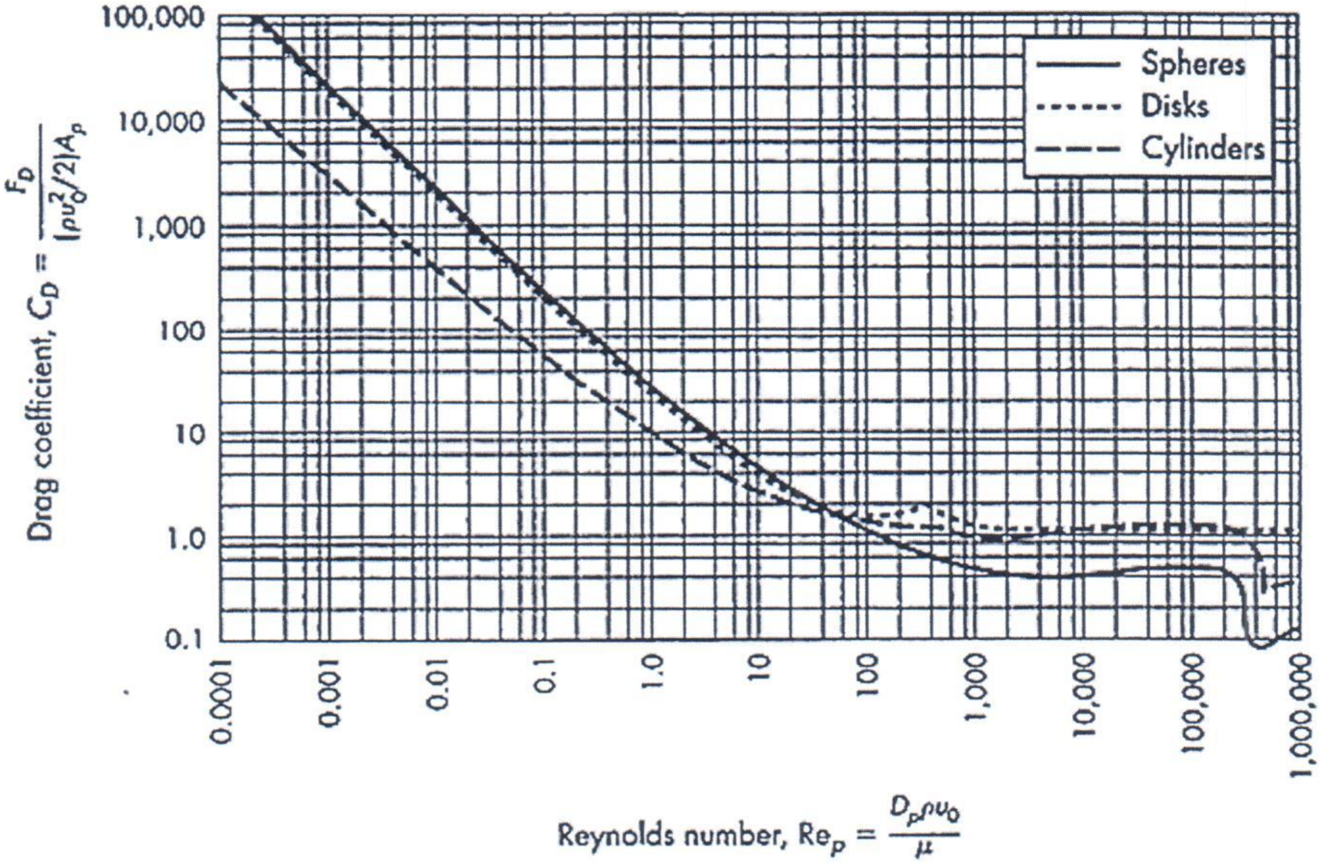


Figure 2

$$\frac{L_1}{L_{mf}} = \frac{(1-\varepsilon_{mf})}{(1-\varepsilon_1)} \qquad \Delta P_{mf} = L_{mf}\,(1-\varepsilon_{mf})(\rho_s-\rho_f)g$$

$$0 = \frac{1.75\,(N_{\mathrm{Re},mf})^2}{\phi_S \varepsilon_{mf}^3} + \frac{150\,(1-\varepsilon_{mf})(N_{\mathrm{Re},mf})}{\phi_S^2 \varepsilon_{mf}^3} - \frac{D_P^3 \rho_f (\rho_P - \rho_f) g}{\mu_f^2}$$

$$q = V_b S_b = \frac{C_v S_b}{\sqrt{1-\beta^4}}\sqrt{\frac{2(p_a-p_b)}{\rho}} \qquad p_a - p_b = gR_m\,(\rho_A - \rho_B)$$

$$N_p = \frac{P}{\rho N^3 D_a^5} \qquad N'_{\mathrm{Re}} = \frac{D_a^2 N \rho}{\mu} \qquad F_d = \frac{C_d A_p V_o^2 \rho_f}{2}$$

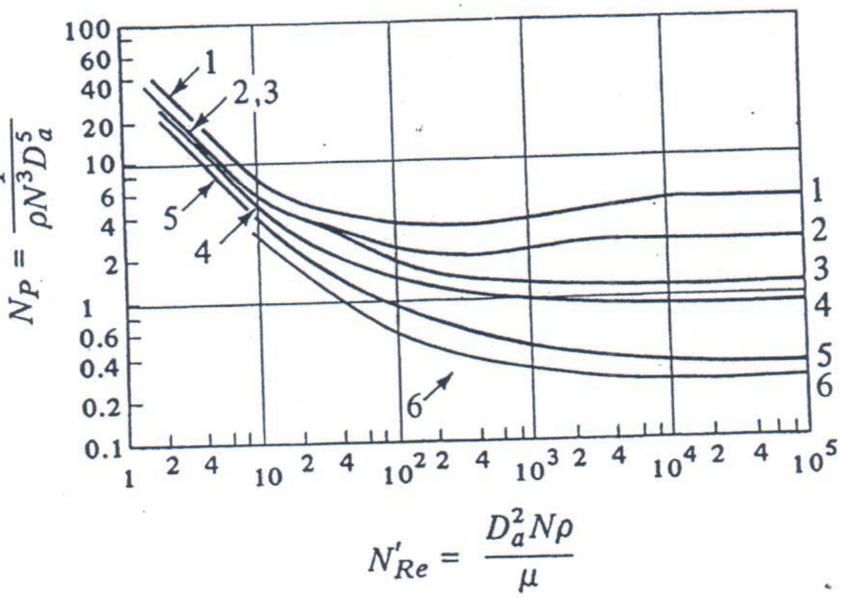


Figure 3. *Power correlations for various impellers and baffles (see Fig. 3.4-3c for dimension D_a, D_t, J, and W).*

Curve 1. *Flat six-blade turbine with disk (like Fig. 3.4-3 but six blades); $D_a/W = 5$; four baffles each $D_t/J = 12$.*

Curve 2. *Flat six-blade open turbine (like Fig. 3.4-2c); $D_a/W = 8$; four baffles each $D_t/J = 12$.*

Curve 3. *Six-blade open turbine (pitched-blade) but blades at 45° (like Fig. 3.4-2d); $D_a/W = 8$; four baffles each $D_t/J = 12$.*

Curve 4. *Propeller (like Fig. 3.4-1); pitch = $2D_a$; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.*

Curve 5. *Propeller; pitch = D_a; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.*

Curve 6. *High-efficiency impeller (like Fig. 3-4-4a); four baffles each $D_t/J = 12$.*