UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Tambahan

Sidang 1988/89

Jun 1989

**EBB 218 Proses-proses Pengangkutan**

Masa : [3 jam]

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**ARAHAN KEPADA CALON**

1. Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH muka surat bercetak sebelum anda memulakan peperiksaan ini.

2. Jawab LIMA soalan sahaja.

3. Jawapan untuk setiap soalan MESTI dimulakan pada muka surat yang berasingan.

4. Semua jawapan MESTILAH dijawab di dalam Bahasa Malaysia.

5. Kertas soalan ini mengandungi ENAM soalan.

...2/-

1. a) Bagi aliran laminar di antara dua plat selari jarak z, tunjukkan bahawa kadar alir Q boleh diungkapkan sebagai berikut dengan menggunakan persamaan Navier Stoke. Lihat lampiran 1.

$$Q = \frac{-1}{\eta} \frac{dp}{d\ell} \frac{z^3}{12} + \frac{z}{2} \left( U + V \right)$$

$\eta$ adalah kelikatan dinamik bendalir, $\frac{dp}{d\ell}$ adalah kecerunan tekanan diarah alir, U adalah halaju plat atas dan V adalah halaju plat bawah.

(60 markah)

b) Ketumpatan bendalir adalah 1260 $kg/m^3$ dan kelikatan 0.9 $Ns/m^2$ mengalir di antara dua plat selari jarak 2 cm. Jika kadar alir adalah 0.5 litre/saat per lebar, kirakan susutan tekanan per unit panjang jika kedua-dua plat pegun. Tentukan halaju purata. Tunjukkan bahawa halaju purata adalah $\frac{2}{3}$ halaju maksimum.

(40 markah)

2. a) Tunjukkan formula Darcy boleh diungkapkan seperti berikut berdasarkan persamaan pergerakan.

$$h_f = \frac{4fv^2L}{2dg}$$

(30 markah)

b) Minyak, graviti tentu 0.9 dan kelikatan kinematik 0.00001 $m^2/s$ mengalir pada 2 $m^3/s$ melalui paip panjang 500 m dan garispusat 200 mm. Relatif kekasaran bagi paip besi tuang adalah 0.0013.

a) Tentukan kehilangan turus akibat geseran

b) Susutan tekanan jika paip condong $10^o$ dari mendatar.

(70 markah)

...3/-

3. a) Berdasarkan aliran haba ke dalam unsur kecil, buktikan bahawa persamaan Poisson keselanjaran aliran haba bagai sistem koordinat segi empat adalah seperti berikut.

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q''}{k} = 0$$

$q'' \equiv$ Penjanaan haba dalaman

$k \equiv$ Pekali keberkondukan (30 markah)

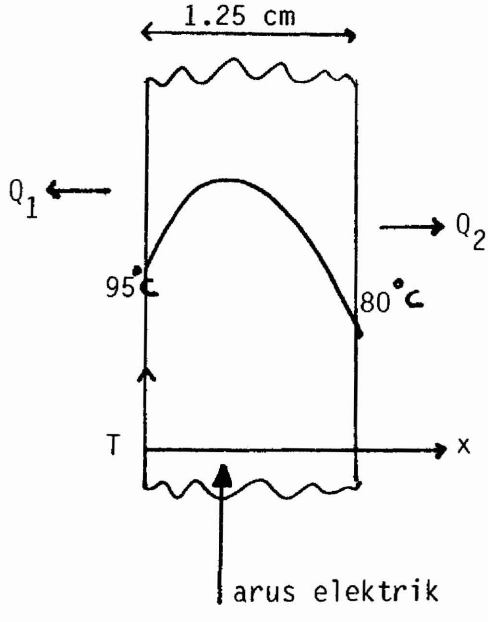
b) Timbangkan pengaliran satu dimensi dengan penjanaan haba melalui plat keluli. Tebal plat adalah 1.25 cm, lebarnya 10 cm dan panjangnya tak terhingga.

Arus elektrik mengalir sepanjang plat keluli dan menjanakan haba 88780 kW/m². Suhu permukaan plat adalah 80°C dan 95°C. Lihat Rajah 1. Pekali keberkondukan adalah 54 W/mK.

i) Dapatkan persamaan taburan suhu

ii) Tentukan nilai suhu maksimum dan kedudukannya.

iii) Kadar alir per unit panjang $Q_1$ dan $Q_2$ (kW/m) daripada permukaan plat




(70 markah)

4. a) Dengan menggunakan teorem $\pi$ Buckingham, tunjukkan bahawa bagi permindahan haba olakan bebas

$$Nu = f(Gr, Pr)$$

$Nu \equiv$ No Nusselt $\dfrac{hd}{k}$

$Gr \equiv$ No Grashof $\dfrac{\beta g \rho^2 d^3 \Delta T}{\eta^2}$

$Pr \equiv$ No Pranatl $\dfrac{\eta C}{k}$

$h$ $\equiv$ pekali permindahan haba

$d$ $\equiv$ garispusat tiub

$k$ $\equiv$ pekali keberkondukan bendalir

$\rho$ $\equiv$ ketumpatan bendalir

$\eta$ $\equiv$ kelikatan bendalir

$C$ $\equiv$ muatan haba

$\beta$ $\equiv$ pekali pengembangan

$T$ $\equiv$ suhu

$g$ $\equiv$ pecutan graviti

(40 markah)

...5/-

b) Sebatang silinder mendatar mempunyai garispusat 8 cm dan terdedah kepada udara pegun pada suhu 400 K dan tekanan 1 atmosfera. Suhu permukaan silinder adalah 500 K. Tentukan kehilangan haba per unit panjang silinder.

Data bagi sifat udara boleh ditentukan daripada lampiran 2.

(60 markah)

5. a) Secara ringkas terangkan mekanisme resapan berikut;

i) Resapan kekosongan

ii) Resapan gelang

iii) Resapan kecelahan

iv) Resapan celahan (30 markah)

b) Sekeping keluli karbon setebal 1 mm mempunyai 0.2% berat karbon. Proses penyahkarbonan mengkehendaki 0.1% berat karbon di bahagian satu pertiga daripada permukaan.

Berikan tiga kombinasi masa rawatan dan suhu rawatan bagi proses ini dengan mengunakan jeda suhu yang berpatutan.

Malar resapan untuk karbon di dalam keluli adalah seperti berikut:

$A = 2 \times 10^{-5}\ m^2/s$

$Q = 145$ kJ/mol

$R = 8.31$ J/K mol

Berat atom karbon = 12.0

Berat atom besi = 55.8

Persamaan untuk sistem resapan tidak tak terhingga adalah

$$C_x = \frac{4Co}{\pi} \sum_{j=o}^{\infty} \frac{1}{2j+1} \operatorname{Sin} (2j+1) \frac{\pi x}{\Delta x} \exp\left[-\left(\frac{(2j+1)\pi}{\Delta x}\right)^2 Dt\right]$$

(70 markah)



...6/-

6. a) Dengan menggunakan teorem $\pi$ Buckingham buktikan bahawa bagi pengangkutan jisim dengan olakan paksa

$$Sh = f\ (Re,\ Sc)$$

$Sh$ = No sherwood $\frac{kx}{D}$

$Re = \frac{\rho \upsilon x}{\eta}$

$Sc = \eta/\rho D$

$k$ = pekali permindahan jisim

$D$ = pekali resapan

$x$ = jarak

$\rho$ = ketumpatan bendalir

$\upsilon$ = halaju

$\eta$ = kelikatan bendalir (40 markah)

b) Bagi lapisan sempadan laminar

$$Sh = 0.332\ Re_x^{1/2}\ Sc^{1/3}$$

dan bagi lapisan sempadan gelora

$$Sh = 0.0292\ Re_x^{4/5}\ Sc^{1/3}$$

Peralihan dariapda laminar ke gelora berlaku apabila $Re_t = 3 \times 10^5$

Bagi $Sc = 1.2$, $Re = 1 \times 10^6$, panjang plat 2 meter dan pekali resapan $D = 1.3 \times 10^{-5}\ m^2/s$, tentukan pekali permindahan jisim purata.

(60 markah)

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TABLE 3.4-2

THE EQUATION OF MOTION IN RECTANGULAR COORDINATES $(x, y, z)$

In terms of $\tau$:

*x-component* $$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} - \left(\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z}\right) + \rho g_x \quad (A)$$

*y-component* $$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} - \left(\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z}\right) + \rho g_y \quad (B)$$

*z-component* $$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} - \left(\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right) + \rho g_z \quad (C)$$

In terms of velocity gradients for a Newtonian fluid with constant $\rho$ and $\mu$:

*x-component* $$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2}\right) + \rho g_x \quad (D)$$

*y-component* $$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} + \mu\left(\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2}\right) + \rho g_y \quad (E)$$

*z-component* $$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right) + \rho g_z \quad (F)$$

LAMPIRAN 1(b)



TABLE 3.4-3

THE EQUATION OF MOTION IN CYLINDRICAL COORDINATES $(r, \theta, z)$

In terms of $\boldsymbol{\tau}$:

*r-component*[a]
$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} - \frac{v_\theta^2}{r} + v_z\frac{\partial v_r}{\partial z}\right) = -\frac{\partial p}{\partial r} - \left(\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rr}) + \frac{1}{r}\frac{\partial \tau_{r\theta}}{\partial \theta} - \frac{\tau_{\theta\theta}}{r} + \frac{\partial \tau_{rz}}{\partial z}\right) + \rho g_r \quad (A)$$

*θ-component*[b]
$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r v_\theta}{r} + v_z\frac{\partial v_\theta}{\partial z}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} - \left(\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\tau_{r\theta}) + \frac{1}{r}\frac{\partial \tau_{\theta\theta}}{\partial \theta} + \frac{\partial \tau_{\theta z}}{\partial z}\right) + \rho g_\theta \quad (B)$$

*z-component*
$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} - \left(\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rz}) + \frac{1}{r}\frac{\partial \tau_{\theta z}}{\partial \theta} + \frac{\partial \tau_{zz}}{\partial z}\right) + \rho g_z \quad (C)$$

In terms of velocity gradients for a Newtonian fluid with constant $\rho$ and $\mu$:

*r-component*[a]
$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} - \frac{v_\theta^2}{r} + v_z\frac{\partial v_r}{\partial z}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_r)\right) + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta} + \frac{\partial^2 v_r}{\partial z^2}\right] + \rho g_r \quad (D)$$

*θ-component*[b]
$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r v_\theta}{r} + v_z\frac{\partial v_\theta}{\partial z}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_\theta)\right) + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta} + \frac{\partial^2 v_\theta}{\partial z^2}\right] + \rho g_\theta \quad (E)$$

*z-component*
$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z \quad (F)$$

**TABLE B-3**
**PROPERTIES OF AIR AT ATMOSPHERIC PRESSURE**

The values of $\mu$, $k$, $c_p$, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures.

| $T$, K | $\rho$, kg/m³ | $c_p$, kJ/kg·°C | $\mu$, kg/m·s × $10^5$ | $\nu$, m²/s × $10^6$ | $k$, W/m·°C | $\alpha$, m²/s × $10^4$ | Pr |
|---|---|---|---|---|---|---|---|
| 100 | 3.6010 | 1.0266 | 0.6924 | 1.923 | 0.009 246 | 0.025 01 | 0.770 |
| 150 | 2.3675 | 1.0099 | 1.0283 | 4.343 | 0.013 735 | 0.057 45 | 0.753 |
| 200 | 1.7684 | 1.0061 | 1.3289 | 7.490 | 0.01809 | 0.101 65 | 0.739 |
| 250 | 1.4128 | 1.0053 | 1.5990 | 11.31 | 0.02227 | 0.156 75 | 0.722 |
| 300 | 1.1774 | 1.0057 | 1.8462 | 15.69 | 0.02624 | 0.221 60 | 0.708 |
| 350 | 0.9980 | 1.0090 | 2.075 | 20.76 | 0.03003 | 0.2983 | 0.697 |
| 400 | 0.8826 | 1.0140 | 2.286 | 25.90 | 0.03365 | 0.3760 | 0.689 |
| 450 | 0.7833 | 1.0207 | 2.484 | 31.71 | 0.03707 | 0.4222 | 0.683 |
| 500 | 0.7048 | 1.0295 | 2.671 | 37.90 | 0.04038 | 0.5564 | 0.680 |
| 550 | 0.6423 | 1.0392 | 2.848 | 44.34 | 0.04360 | 0.6532 | 0.680 |
| 600 | 0.5879 | 1.0551 | 3.018 | 51.34 | 0.04659 | 0.7512 | 0.680 |
| 650 | 0.5430 | 1.0635 | 3.177 | 58.51 | 0.04953 | 0.8578 | 0.682 |
| 700 | 0.5030 | 1.0752 | 3.332 | 66.25 | 0.05230 | 0.9672 | 0.684 |
| 750 | 0.4709 | 1.0856 | 3.481 | 73.91 | 0.05509 | 1.0774 | 0.686 |
| 800 | 0.4405 | 1.0978 | 3.625 | 82.29 | 0.05779 | 1.1951 | 0.689 |
| 850 | 0.4149 | 1.1095 | 3.765 | 90.75 | 0.06028 | 1.3097 | 0.692 |
| 900 | 0.3925 | 1.1212 | 3.899 | 99.3 | 0.06279 | 1.4271 | 0.696 |
| 950 | 0.3716 | 1.1321 | 4.023 | 108.2 | 0.06525 | 1.5510 | 0.699 |
| 1000 | 0.3524 | 1.1417 | 4.152 | 117.8 | 0.06752 | 1.6779 | 0.702 |
| 1100 | 0.3204 | 1.160 | 4.44 | 138.6 | 0.0732 | 1.969 | 0.704 |
| 1200 | 0.2947 | 1.179 | 4.69 | 159.1 | 0.0782 | 2.251 | 0.707 |
| 1300 | 0.2707 | 1.197 | 4.93 | 182.1 | 0.0837 | 2.583 | 0.705 |
| 1400 | 0.2515 | 1.214 | 5.17 | 205.5 | 0.0891 | 2.920 | 0.705 |
| 1500 | 0.2355 | 1.230 | 5.40 | 229.1 | 0.0946 | 3.262 | 0.705 |
| 1600 | 0.2211 | 1.248 | 5.63 | 254.5 | 0.100 | 3.609 | 0.705 |
| 1700 | 0.2082 | 1.267 | 5.85 | 280.5 | 0.105 | 3.977 | 0.705 |
| 1800 | 0.1970 | 1.287 | 6.07 | 308.1 | 0.111 | 4.379 | 0.704 |
| 1900 | 0.1858 | 1.309 | 6.29 | 338.5 | 0.117 | 4.811 | 0.704 |
| 2000 | 0.1762 | 1.338 | 6.50 | 369.0 | 0.124 | 5.260 | 0.702 |
| 2100 | 0.1682 | 1.372 | 6.72 | 399.6 | 0.131 | 5.715 | 0.700 |
| 2200 | 0.1602 | 1.419 | 6.93 | 432.6 | 0.139 | 6.120 | 0.707 |
| 2300 | 0.1538 | 1.482 | 7.14 | 464.0 | 0.149 | 6.540 | 0.710 |
| 2400 | 0.1458 | 1.574 | 7.35 | 504.0 | 0.161 | 7.020 | 0.718 |
| 2500 | 0.1394 | 1.688 | 7.57 | 543.5 | 0.175 | 7.441 | 0.730 |

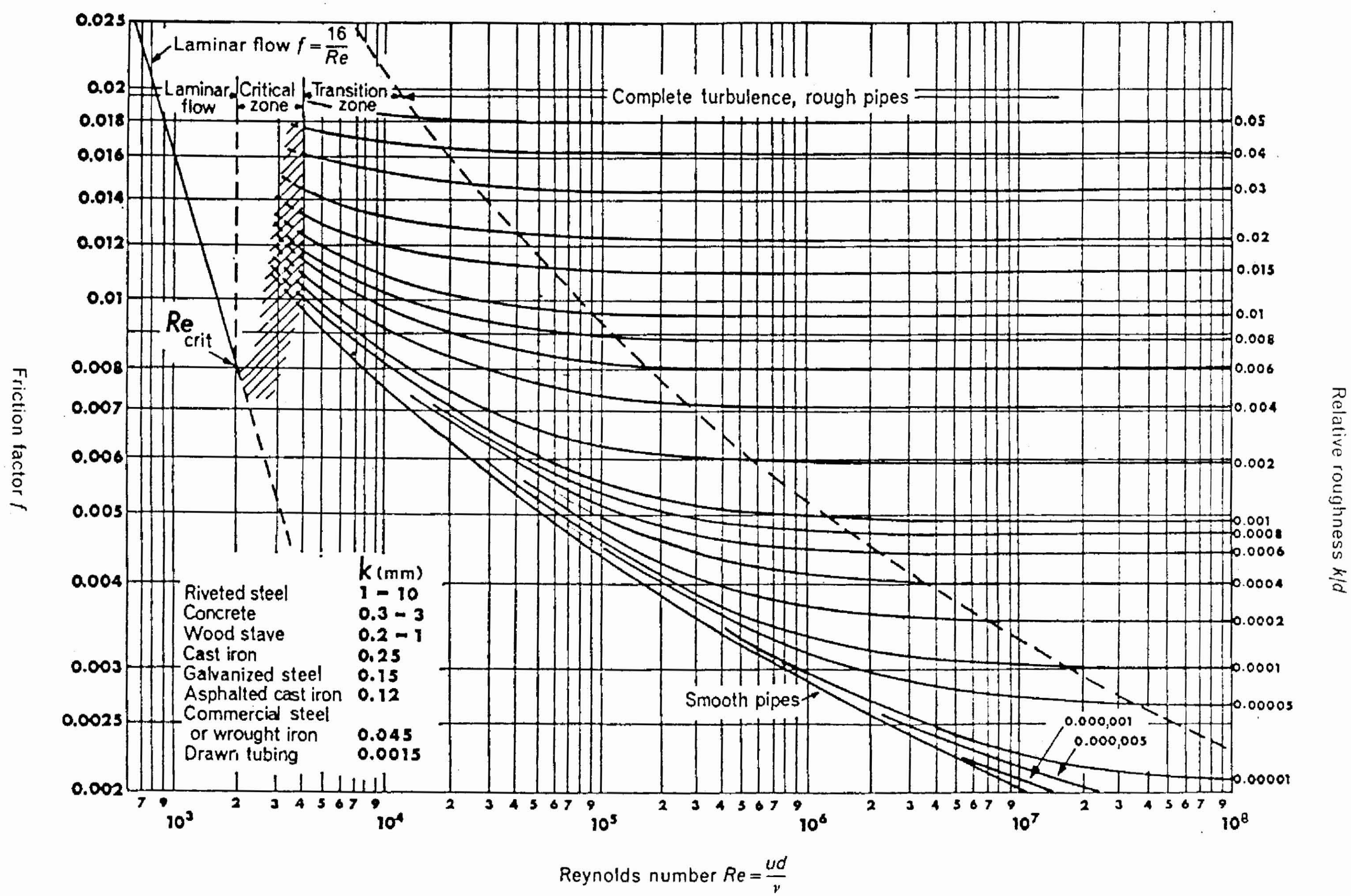
*Source*: From *Natl. Bur. Stand. (U.S.) Circ.* 564, 1955.

**TABLE 11-6**
Convection Heat-Transfer Correlations for Free Convection, Constant Surface Temperature

General relation: $\overline{Nu} = C(GrPr)^m$ with properties evaluated at film temperature

| | GrPr | C | m |
|---|---|---|---|
| Vertical planes and cylinders | | | |
| | $10^4$–$10^9$ | 0.59 | 1/4 |
| | $10^9$–$10^{13}$ | 0.10 | 1/3 |
| Horizontal cylinders | | | |
| | $10^{-10}$–$10^{-2}$ | 0.675 | 0.058 |
| | $10^{-2}$–$10^2$ | 1.02 | 0.148 |
| | $10^2$–$10^4$ | 0.85 | 0.188 |
| | $10^4$–$10^9$ | 0.53 | 1/4 |
| | $10^9$–$10^{12}$ | 0.13 | 1/3 |
| Upper surface of heated plates or lower surface of cooled plates | $2 \times 10^4$–$8 \times 10^6$ | 0.54 | 1/4 |
| Upper surface of heated plates or lower surface of cooled plates | $8 \times 10^6$–$10^{11}$ | 0.15 | 1/3 |
| Lower surface of heated plates or upper surface of cooled plates | $10^5$–$10^{11}$ | 0.58 | 1/5 |

LAMPIRAN 4



Laminar flow $f = \frac{16}{Re}$
Laminar flow
Critical zone
Transition zone
Complete turbulence, rough pipes
$Re_{crit}$
Friction factor $f$
Relative roughness $k/d$
Smooth pipes
k (mm)
Riveted steel 1 – 10
Concrete 0.3 – 3
Wood stave 0.2 – 1
Cast iron 0.25
Galvanized steel 0.15
Asphalted cast iron 0.12
Commercial steel or wrought iron 0.045
Drawn tubing 0.0015
0.025
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.007
0.006
0.005
0.004
0.003
0.0025
0.002
0.05
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0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.000,001
0.000,005
0.00001
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
Reynolds number $Re = \frac{ud}{\nu}$