1. In industrial problems, such as designing heating plants, convective heat transfer is important because the heat transfer between the hot combustion products and the surfaces in certain types of industrial heating plant is a significant proportion of convective heat transfer. For example, in the firetube of a natural gas-fired shell boiler around 40 % of the heat transferred from the flame will be convective heat transfer. Likewise, in a watertube boiler a large proportion of the heat transfer in the superheater and economiser sections will be via convection. Moreover, some designs of metal reheating furnaces are specifically designed to promote high rates of convective heat transfer, for example, directing a high-velocity jet of combustion products to impringe onto the stock.

2.

$D = 0.1 (m)$

Assumption * $T_1 = 80°c$, $T_2 = 30°C$, $V = 1 (m/s)$

* assume the properties of a cup of coffee as the properties of a cup of water

* do not consider the heat transfer through the surface of the cup.

$Nu = \frac{h_c D}{k} = 0.04\, Re^{0.75} \cdot Pr^{0.33}$ (Film theory, eq (2.1.22)) (5)

$Re = \frac{\rho u D}{\mu} = \frac{985.2 \times 1 \times 0.1}{0.504 \times 10^{-3}} = 195476.2$ $\quad k = 0.649$

$Pr = 3.25$

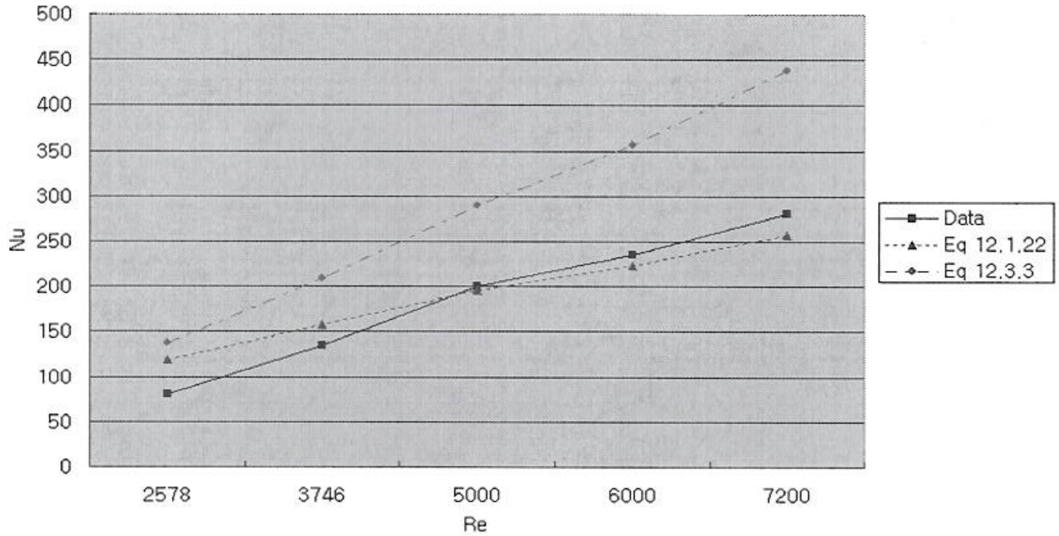
$h_c = \left(\frac{k}{D}\right) \times 0.04\, Re^{0.75} \cdot Pr^{0.33} = \left(\frac{0.649}{0.1}\right) \times 0.04 (195476.2)^{0.75} \times (3.25)^{0.33}$

$= 3560.8 (W/m^2 \cdot k)$

(10)

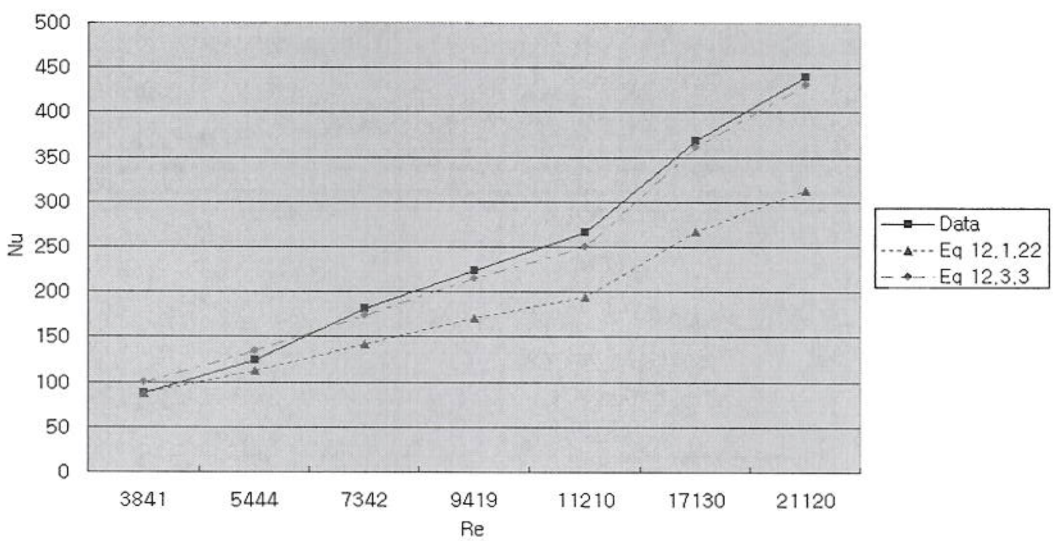
12.1

*Solution I (Pr=590)



The data presented by Friend and Metzner is more approximate to the graph of Eq 12.1.22 than the graph of Eq 12.3.3.

*Solution II (Pr=93)



The data presented by Friend and Metzner is more approximate to the graph of Eq 12.3.3 than the graph of Eq 12.1.22.

12.4 $\quad u_x \frac{\partial \Pi}{\partial x} - \left(\int_0^y \frac{\partial u_x}{\partial x} dy \right) \frac{\partial \Pi}{\partial y} = \frac{\nu}{\Lambda} \frac{\partial^2 \Pi}{\partial y^2}$

$$\eta = \frac{y}{2}\left(\frac{U}{\nu x}\right)^{1/2} \rightarrow \frac{\partial}{\partial y} = \frac{1}{2}\left(\frac{U}{\nu x}\right)^{1/2} \frac{d}{d\eta}$$

$$\rightarrow \frac{\partial}{\partial x} = -\frac{1}{2}\left(\frac{U}{\nu x^3}\right)^{1/2} \frac{d}{d\eta} = -\frac{\eta}{2x}\frac{d}{d\eta}$$

$$\frac{\partial \Pi}{\partial y} = \frac{\partial \eta}{\partial y}\frac{\partial \Pi}{\partial \eta} = \frac{1}{2}\left(\frac{U}{\nu x}\right)^{1/2} \Pi' \;(2) \Rightarrow \frac{\partial^2 \Pi}{\partial y^2} = \frac{1}{4}\frac{U}{\nu x}\Pi''$$

$$\frac{\partial \Pi}{\partial x} = \frac{\partial \eta}{\partial x}\frac{\partial \Pi}{\partial \eta} = -\frac{\eta}{2x}\Pi' \quad (2)$$

$$\int_0^y \frac{\partial u_x}{\partial x} dy = \int_0^\eta U\Pi'\left(-\frac{\eta}{2x}\right)\frac{d\eta}{\partial \eta/\partial y} = \int_0^\eta \frac{-U\eta/2x}{\frac{1}{2}(U/\nu x)^{1/2}} \Pi_u' d\eta$$

$$= -\left(\frac{U\nu}{x}\right)^{1/2}\int_0^\eta \eta\, \Pi_u' d\eta = -\left(\frac{U\nu}{x}\right)^{1/2}\left\{[\eta\cdot\Pi_u]_0^\eta - \int_0^\eta \Pi_u d\eta\right\}$$

$$= -\left(\frac{U\nu}{x}\right)^{1/2}\left\{\eta\cdot\Pi_u(\eta) - \int_0^\eta \Pi_u d\eta\right\}$$

$$u_x \frac{\partial \Pi}{\partial x} - \left(\int_0^y \frac{\partial u_x}{\partial x} dy\right)\frac{\partial \Pi}{\partial y} = \frac{\nu}{\Lambda}\frac{\partial^2 \Pi}{\partial y^2} \quad (3)$$

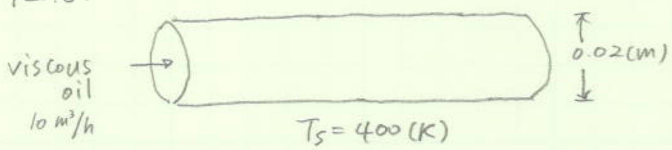
$$\Rightarrow U\Pi_u\left(-\frac{\eta}{2x}\right)\Pi' + \left[\left(\frac{U\nu}{x}\right)^{1/2}\eta\,\Pi_u - \left(\frac{U\nu}{x}\right)^{1/2}\int_0^\eta \Pi_u d\eta\right]\frac{1}{2}\left(\frac{U}{\nu x}\right)^{1/2}\Pi'$$

$$= \frac{\nu}{\Lambda}\frac{U}{4\nu x}\Pi''$$

$$\Rightarrow \Pi_u\cdot\Pi'\cancelto{0}{\left(-\frac{U\eta}{2x} + \frac{U\eta}{2x}\right)} - \left(\frac{\cancel{U}}{\cancel{2x}}\int_0^\eta \Pi_u d\eta\right)\Pi' = \frac{1}{\Lambda}\frac{\cancel{U}}{\cancel{4x}_2}\Pi''$$

$$\Rightarrow \left(-\Lambda\int_0^\eta 2\,\Pi_u d\eta\right)\Pi' = \Pi'' \quad (10)$$

12.8.



viscous oil : $Pr = 200$, $k = 0.15 (W/m \cdot K)$ $\mu = 1 (Pa \cdot s)$ $\rho = 950 (kg/m^3)$

$T_1 = 300(K)$ $T_2 = 350(K)$ $t_{1\to2} = ?$

$$Re = \frac{4W}{\pi \cdot D \cdot \mu} = \frac{4 \times 950 \times 10 \times 1/3600}{\pi \times 0.02 \times 1} = 168 \leftarrow \text{laminar flow.}$$

$$\theta_{cm} = \frac{T_2 - T_s}{T_1 - T_s} = \frac{350 - 400}{300 - 400} = 0.5$$ (5)

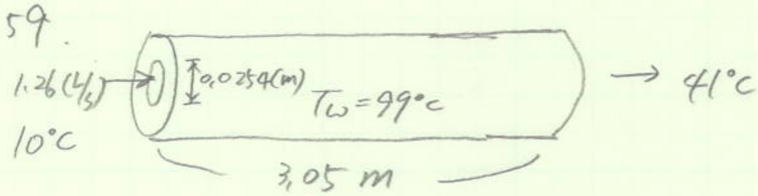
From Fig. P.12.8

$$\theta_{cm} = 0.5 \Rightarrow z^* = \frac{\alpha z}{UR^2} = \frac{4z/D}{Pr \cdot Re_D} = 0.15$$

$$4z = 0.15 \cdot D \cdot Pr \cdot Re_D \Rightarrow \underline{z = 25.2(m)}$$ 10.

12.13.

12.59.



$$Re = \frac{4w}{\pi D \mu} = \frac{4 \times 1000 \times 1.26 \times 0.01}{\pi \times 0.0254 \times 1.0 \times 10^{-3}} = 63160 \rightsquigarrow \text{turbulent. flow}$$

assume $T_{avg} = 25(°C) \Rightarrow P_r \simeq 6$ (From Fig 12.3.3)

$$\frac{\overline{Nu}}{Re \cdot Pr} = 0.023\, Re^{-0.2} \cdot Pr^{-0.6} \Rightarrow \overline{Nu} = 0.023(Re)^{0.8} \cdot (P_r)^{0.4}$$

$$\simeq 326.1$$ (5)

* Colburn Analogy

friction faction : $f \simeq 0.08 \cdot Re^{-1/4} = 0.005$

$$Nu = Re \cdot P_r^{1/3} \cdot \frac{f}{2}$$

$$= 63160 \cdot (6)^{1/3} \cdot \frac{1}{2}(0.005) \simeq 287$$ (5) 10

12.60.

$$Nu_D(Z^*) = 1.076 \left(\frac{Z/D}{Pr \cdot Re_D}\right)^{-1/3} \quad \text{for} \quad \frac{Z/D}{Pr \cdot Re_D} < 0.01$$

$$\overline{Nu_D} = \frac{1}{L}\int_0^L 1.076 \left(\frac{4D}{Pr \cdot Re_D}\right)^{-1/3}$$ (5)

$$= \frac{1}{L} \times 1.076 \times \frac{1}{-\frac{1}{3}+1} \times \frac{L^{\frac{2}{3}}/D^{-\frac{1}{3}}}{(Pr \cdot Re_D)^{-\frac{1}{3}}}$$

$$= 1.614 \left[\frac{L/D}{Pr/Re_D}\right]^{-1/3}$$ 10.