TEST – MEN310 (Heat Transfer)

January 31, 2000

1. Water at T_1 = 24 °C is to be heated to T_2 = 74 °C by passing it through a tube bundle in staggered tube arrangement. Tubes have an outside diameter D = 2.5 cm and are maintained at a uniform surface temperature T_w = 100 °C. The longitudinal and the transverse pitches for the staggered arrangement are 1.5D and 2D respectively. The velocity of water just before entering the tube bundle is u_∞ = 0.3 m/s. Determine the average heat transfer coefficient and the number of rows in the direction of flow needed to achieve the above temperature rise of water.

2. A thin vertical panel L = 3 m high and w = 1.5 m wide is thermally insulated on one side and exposed to a solar radiation flux of 1250 W/m^2 on the other side. The exposed surface has the following absorption properties for solar radiation

$$\alpha_\lambda = 0.1 \quad \text{for} \quad 0.0 \le \lambda < 2.4\ \mu m$$
$$\alpha_\lambda = 0.2 \quad \text{for} \quad 2.4 \le \lambda < 5.0\ \mu m$$
$$\alpha_\lambda = 0.8 \quad \text{for} \quad 5.0 \le \lambda < 10.0\ \mu m$$
$$\alpha_\lambda = 0.1 \quad \text{for} \quad 10.0 \le \lambda < \infty\ \mu m$$

Assuming that the energy absorbed by the plate is dissipated into the surroundings quiescent air at atmospheric pressure and T = 300 K, determine the surface temperature of the panel.

3. Two parallel plates are at temperature T_1 and T_2 and have emissivities $\varepsilon_1 = 0.8$ and $\varepsilon_2 = 0.5$. A radiation shield having the same emissivity ε on both sides is placed between the plates. Calculate the emissivity of the shield in order to reduce the radiation exchange between the two plates to one tenth of that without the shield.

Points: 1 (35%), 2 (40%) and 3 (25%).

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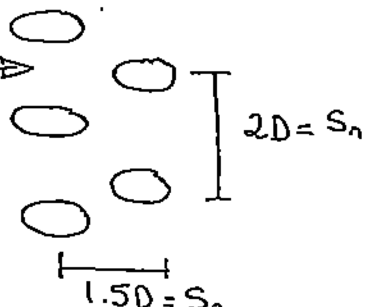
staggered arrangement

Water $\longrightarrow$



1) $T_{\infty_1} = 24°C$

$T_{\infty_2} = 74°C$

$D = 2.5\,cm = 0.025\,m.$

$T_w = 100°C$

$u_\infty = 0.3\,m/sec$

$\frac{S_n}{D} = 2$

$\frac{S_p}{D} = 1.5$

$\rightarrow C = 0.502$, $n = 0.568$

$T_{\infty\,ave} = \frac{24+74}{2} = 49°C$

$h = ?\ ;\ t = ?$

$$T_f = \left(T_w + \frac{T_{\infty_1} + T_{\infty_2}}{2}\right)\frac{1}{2} = 74.5°C \rightarrow 347.5\,K$$

$2\{[(S_n/2)^2 + S_p^2]^{1/2} - d\} = 1.6d > S_n - d = d$

So we use $\rightarrow u_{max} = 0.3\left[\frac{2D}{2D-D}\right] = 0.6$

not $\rightarrow u_{max} = \frac{0.3[d]}{[d^2 + (1.5d)^2]^{1/2} - d} = 0.3737\,m/sec$

$\hookrightarrow \rho = 975.105036\ Kg/m^3$

$c_p = 4.189 \times 10^3\ J/Kg\,°C$

$\mu = 3.83339\ Kg/m.sec \times 10^{-4}$

$k = 0.666827\ W/m\,°C$

$P_r = 2.4082$

$$Re_{d_{max}} = \frac{\rho u_{max} \cdot d}{\mu} = 3.815 \times 10^4$$

$h = 7182.847125\ W/m^2°C$

eq. 6.17 $\rightarrow$ $h = \frac{k_f}{d} \cdot 0.502(Re)^{0.568} \times P_r^{1/3} \rightarrow$ ~~h = 5830.396 W/m²°C~~

for 1 row, that's why we don't include N (the number of tubes ⊥ to flow)

$$q = hA\left(T_w - \frac{T_{\infty_1} + T_{\infty_2}}{2}\right) = \dot{m} c_p (T_{\infty_2} - T_{\infty_1})$$ locally at the entrance

$$h \times L \times t \times \pi \times d\left(T_w - \frac{T_{\infty_1} + T_{\infty_2}}{2}\right) = \underbrace{\rho_\infty u_\infty L \cdot 2 \cdot D}_{\text{area at the entrance}}\, c_p (T_{\infty_2} - T_{\infty_1});$$

$\rho_{\infty\,avg} = 98..$, $c_{p\,avg} = 4..$

$\rightarrow\ ht = 772742.6382 \rightarrow$

$t = 107.581 \rightarrow$ Use $108 = t$

N tubes

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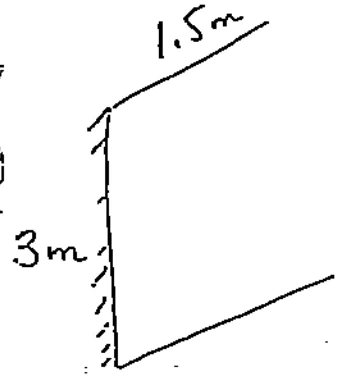
2)



$q = 1250\ W/m^2$

find α as in pb. 8.6 (Sol... at $T_{SUN} = 6000K$.

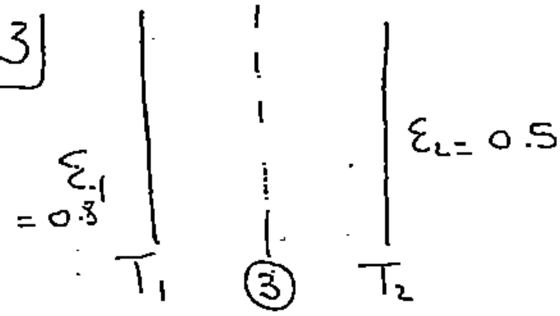
$\Rightarrow \alpha =$

$\hookrightarrow \boxed{\alpha q = hA(T_w - T_\infty)}$

known known known

Assume a T_w; find h → then find T_∞ according to Itera...

3)



$q_{shield} = \frac{1}{10} q_{without}$

$$\rightarrow \frac{\sigma(T_1^4 - T_2^4)}{\Sigma R} = \frac{1}{10} \frac{\sigma(T_1^4 - T_2^4)}{\Sigma R}$$

$$\rightarrow \Sigma R)_{shield} = 10\ \Sigma R)_{without}$$

$$\rightarrow \frac{1-\varepsilon_1}{\varepsilon_1} + 2(1) + 2\left(\frac{1-\varepsilon_3}{\varepsilon_3}\right) + \frac{1-\varepsilon_2}{\varepsilon_2} = 10\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right)$$

$$\rightarrow \varepsilon_3 = \frac{8}{85} = \boxed{0.0941 = \varepsilon_3}$$