

PROBLEM 6.30

KNOWN: Form of the Nusselt number correlation for forced convection and fluid properties.

FIND: Expression for figure of merit F_F and values for air, water and a dielectric liquid.

PROPERTIES: Prescribed. Air: $k = 0.026 \text{ W/m}\cdot\text{K}$, $\nu = 1.6 \times 10^{-5} \text{ m}^2/\text{s}$, $\text{Pr} = 0.71$. Water: $k = 0.600 \text{ W/m}\cdot\text{K}$, $\nu = 10^{-6} \text{ m}^2/\text{s}$, $\text{Pr} = 5.0$. Dielectric liquid: $k = 0.064 \text{ W/m}\cdot\text{K}$, $\nu = 10^{-6} \text{ m}^2/\text{s}$, $\text{Pr} = 25$

ANALYSIS: With $\text{Nu}_L \sim \text{Re}_L^m \text{Pr}^n$, the convection coefficient may be expressed as

$$h \sim \frac{k}{L} \left(\frac{VL}{\nu} \right)^m \text{Pr}^n \sim \frac{V^m}{L^{1-m}} \left(\frac{k \text{Pr}^n}{\nu^m} \right)$$

The figure of merit is therefore

$$F_F = \frac{k \text{Pr}^n}{\nu^m} \quad <$$

and for the three fluids, with $m = 0.80$ and $n = 0.33$,

$$F_F \left(\text{W} \cdot \text{s}^{0.8} / \text{m}^{2.6} \cdot \text{K} \right) \quad \begin{array}{ccc} \text{Air} & \text{Water} & \text{Dielectric} \\ \hline 167 & 64,400 & 11,700 \end{array} \quad <$$

Water is clearly the superior heat transfer fluid, while air is the least effective.

COMMENTS: The figure of merit indicates that heat transfer is enhanced by fluids of large k , large Pr and small ν .