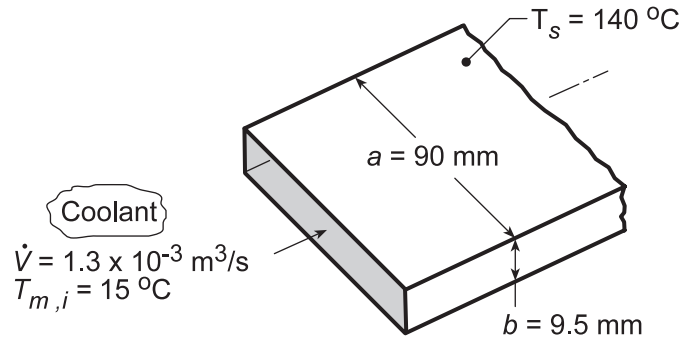## PROBLEM 8.89

KNOWN: Coolant flowing through a rectangular channel (gallery) within the body of a mold.

FIND: Convection coefficient when the coolant is process water or ethylene glycol.

SCHEMATIC:

ASSUMPTIONS: (1) Gallery can be approximated as a rectangular channel with a uniform surface temperature, (2) Fully developed flow conditions.

PROPERTIES: *Table A.6*, Water ($\overline{T}_m$ = (140 + 15)°C/2 = 350 K): ρ = 974 kg/m³, μ = 365 × 10⁻⁶ N·s/m², $\nu = \mu/\rho$ = 3.749 × 10⁻⁷ m²/s, k = 0.668 W/m·K, Pr = 2.29; *Table A.5*, Ethylene glycol ($\overline{T}_m$ = 350 K): ρ = 1079 kg/m³, ν = 3.17 × 10⁻⁶ m²/s, k = 0.261 W/m·K, Pr = 34.6.

ANALYSIS: The characteristic length of the channel, the hydraulic diameter, Eq. 8.66, is $D_h = 4A_c/P$ where A_c is the cross-sectional flow area and P is the wetted perimeter. For our channel,

$$D_h = \frac{4(a \times b)}{2(a+b)} = \frac{4 \times 0.090\,\text{m} \times 0.0095\,\text{m}}{2(0.090 + 0.0095)\,\text{m}} = 0.0172\,\text{m}$$

For the *water* coolant, from the continuity equation, find the Reynolds number to characterize the flow

$$u_m = \frac{\dot{V}}{A_c} = \frac{1.3 \times 10^{-3}\,\text{m}^3/\text{s}}{0.090\,\text{m} \times 0.0095\,\text{m}} = 1.52\,\text{m/s}$$

$$Re_{Dh} = \frac{u_m D_h}{\nu} = \frac{1.52\,\text{m/s} \times 0.0172\,\text{m}}{3.749 \times 10^{-7}\,\text{m}^2/\text{s}} = 69,736$$

Since the flow is turbulent, and assuming fully developed conditions, use the Dittus-Boelter correlation, Eq. 8.60, to estimate the convection coefficient,

$$Nu_{Dh} = \frac{hD_h}{k} = 0.023\,Re_{Dh}^{0.8}\,Pr^{0.4} = 0.023(69,736)^{0.8}(2.29)^{0.4} = 240$$

$$h_w = \frac{0.668\,\text{W/m} \cdot \text{K}}{0.0172\,\text{m}} \times 240 = 9326\,\text{W/m}^2 \cdot \text{K} \qquad <$$

Repeating the calculations using properties for the *ethylene glycol* coolant, find

$$Re_{Dh} = 8,247 \qquad Nu_{Dh} = 128 \qquad h_{eg} = 1957\,\text{W/m}^2 \cdot \text{K} \qquad <$$

Continued...

COMMENTS: (1) The convection coefficient for the *water* coolant is more than 4 times greater than that with the *ethylene glycol* coolant. The corrosion protection afforded by the latter coolant greatly compromises the thermal performance of the gallery. In such situations, it is useful to explore a compromise between corrosion protection and thermal performance by using an aqueous solution of ethylene glycol (50%-50%, for example).

(2) Recognize that for the ethylene glycol coolant calculation the Reynolds number is slightly below the lower limit of applicability of the Dittus-Boelter correlation, and the Gnielinski correlation would be more accurate.