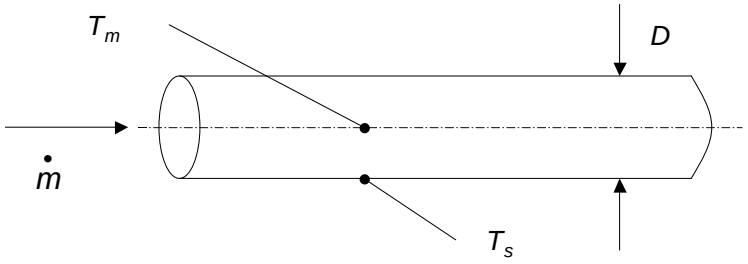
PROBLEM 8.39

KNOWN: Fully-developed conditions for laminar or turbulent flow characterized by a fixed mass flow rate. Constant surface temperature conditions with $T_s < T_m$.

FIND: Determine whether a small or large diameter tube will be more effective in minimizing heat loss from the flowing fluid.

SCHEMATIC:



ASSUMPTIONS: (1) Fully-developed, (2) Constant properties, (3) Negligible viscous dissipation.

ANALYSIS: The heat loss rate per unit tube length is

$$q' = \pi D h (T_s - T_m) \quad \text{where} \quad h = Nu_D k / D$$

Combining the preceding equations yields

$$q' = \pi Nu_D k (T_s - T_m) \tag{1}$$

Laminar Conditions

For laminar conditions, $Nu_D = 3.66$. Substituting this expression into Eq. (1) yields

$$q' = 3.66 \pi k (T_s - T_m)$$

and the heat loss rate is independent of the tube diameter. <

Turbulent Conditions

For turbulent flow, we may substitute the Dittus-Boelter correlation, $Nu_D = 0.023 Re_D^{4/5} Pr^{0.3}$ with $Re_D = \left(4\dot{m} / \pi D \mu\right)$ into Eq. (1) to find

$$q' = \pi (0.023) \left(\frac{4\dot{m}}{\pi \mu} \right)^{4/5} D^{-4/5} Pr^{0.3} k (T_s - T_m)$$

Hence, to minimize the heat loss, a large diameter tube is preferred. <

COMMENTS: The large diameter tube will result in reduced heat loss, but will be more expensive relative to a small diameter tube. If the cool surface temperature is induced by heat losses to the environment, a more effective approach to minimize heat loss would be to insulate the exterior of the tube.