13. B Heat Transfer in Laminar Tube Flow
One hundred pounds per hour of oil at 100°F are flowing through a 1-inch copper tube, 20 ft long. The inside surface of the tube is maintained at 215°F by condensing steam on the outside surface. Fully developed flow may be considered, constant.

Using the following values:
- \( \text{Pr} = 0.85 \)
- \( \text{Re} = 8.44 \)
- \( \text{Nu} = \text{constant} \)
- \( \text{h}_a = 0.82 \text{ Btu/h}^2 \text{F} \)
- \( \text{h}_w = 0.10 \text{ Btu/h}^2 \text{F} \)
- \( \text{Vin} = \frac{1}{2} \text{ ft/s} \)
- \( \text{Vin} = \frac{1}{2} \text{ ft/s} \)

From empirical data, the Nusselt number (see ex. 9.6-1 solved earlier)

\[
\text{Nu} = \text{constant} \]

From the given data:

\[
\text{Nu} = 0.82 \text{ Btu/h}^2 \text{F} \]

\[
\text{h}_a = 0.10 \text{ Btu/h}^2 \text{F} \]

\[
\text{Vin} = \frac{1}{2} \text{ ft/s} \]

\[
\text{Vin} = \frac{1}{2} \text{ ft/s} \]

\[
100 \text{ lbm/h} \left( \frac{215-100}{0} \right) = (0.10 \text{ Btu/h}^2 \text{F}) \left( \frac{215-100}{0} \right) \left( \frac{2.2 \text{ Btu/lbm} \cdot \text{F}}{1 \text{ lbm/h}} \right) \left( \frac{215-100}{215-70} \right)
\]

\[
49 \left( \frac{215-100}{215-70} \right) = 32.85 \left( \frac{215-100}{215-70} \right)
\]

\[
\text{T}_b = 155 \text{ F}
\]

\[
\text{Q} = 49 \text{ Btu/h} \left( \frac{155-100}{215-70} \right) = \frac{724 \text{ Btu/h}}{	ext{h} \cdot \text{F}}
\]