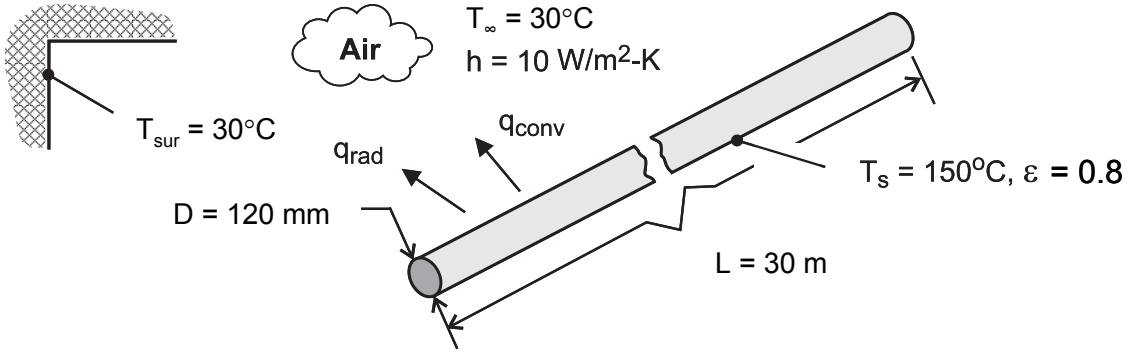
PROBLEM 1.28

KNOWN: Length, diameter, surface temperature and emissivity of steam line. Temperature and convection coefficient associated with ambient air. Efficiency and fuel cost for gas fired furnace.

FIND: (a) Rate of heat loss, (b) Annual cost of heat loss.

SCHEMATIC:



ASSUMPTIONS: (1) Steam line operates continuously throughout year, (2) Net radiation transfer is between small surface (steam line) and large enclosure (plant walls).

ANALYSIS: (a) From Eqs. (1.3a) and (1.7), the heat loss is

$$q = q_{conv} + q_{rad} = A\left[h\left(T_s - T_\infty\right) + \varepsilon\sigma\left(T_s^4 - T_{sur}^4\right)\right]$$

where $A = \pi DL = \pi\left(0.12\text{m} \times 30\text{m}\right) = 11.3\ \text{m}^2$.

Hence,

$$q = 11.3\text{m}^2\left[10\ \text{W/m}^2\cdot\text{K}\left(150-30\right)\text{K} + 0.8\times 5.67\times 10^{-8}\text{W/m}^2\cdot\text{K}^4\left(423^4 - 303^4\right)\text{K}^4\right]$$

$$q = 11.3\ \text{m}^2\left(1200 + 1070\right)\text{W/m}^2 = 25{,}650\ \text{W} \quad <$$

(b) The annual energy loss is

$$E = qt = 25{,}650\ \text{W} \times 3600\ \text{s/h} \times 24\text{h/d} \times 365\ \text{d/y} = 8.09\times 10^{11}\ \text{J}$$

With a furnace energy consumption of $E_f = E/\eta_f = 8.99\times 10^{11}\ \text{J}$, the annual cost of the loss is

$$C = C_g E_f = 0.02\ \$/\text{MJ} \times 8.99\times 10^5\text{MJ} = \$17{,}980 \quad <$$

COMMENTS: The heat loss and related costs are unacceptable and should be reduced by insulating the steam line.