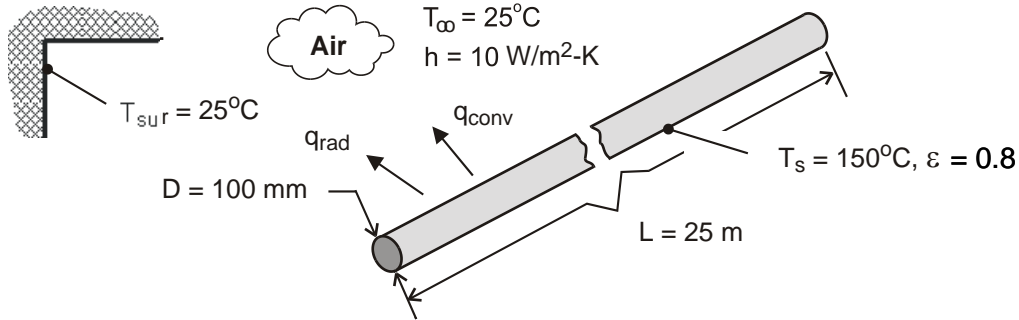


## PROBLEM 1.22

**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

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

where  $A = \pi DL = \pi(0.1\text{m} \times 25\text{m}) = 7.85\text{m}^2$ .

Hence,

$$q = 7.85\text{m}^2 \left[ 10\text{ W/m}^2 \cdot \text{K} (150 - 25)\text{K} + 0.8 \times 5.67 \times 10^{-8}\text{ W/m}^2 \cdot \text{K}^4 (423^4 - 298^4)\text{K}^4 \right]$$

$$q = 7.85\text{m}^2 (1,250 + 1,095)\text{ W/m}^2 = (9813 + 8592)\text{ W} = 18,405\text{ W}$$

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(b) The annual energy loss is

$$E = qt = 18,405\text{ W} \times 3600\text{ s/h} \times 24\text{ h/d} \times 365\text{ d/y} = 5.80 \times 10^{11}\text{ J}$$

With a furnace energy consumption of  $E_f = E/\eta_f = 6.45 \times 10^{11}\text{ J}$ , the annual cost of the loss is

$$C = C_g E_f = 0.02\text{ \$/MJ} \times 6.45 \times 10^5\text{ MJ} = \$12,900$$

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