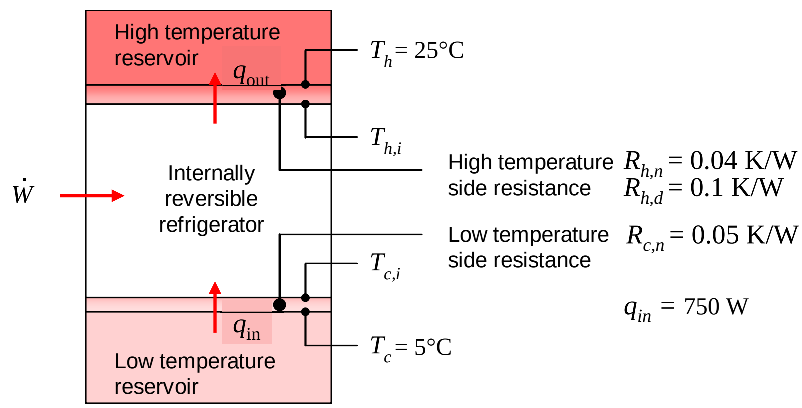
PROBLEM 1.39

KNOWN: Hot and cold reservoir temperatures of an internally reversible refrigerator. Thermal resistances between refrigerator and hot and cold reservoirs under clean and dusty conditions. Desired cooling rate.

FIND: Modified Coefficient of Performance and power input of refrigerator under clean and dusty conditions.

SCHEMATIC:



ASSUMPTIONS: (1) Refrigerator is internally reversible, (2) Steady-state operation, (3) Cold side thermal resistance does not degrade over time.

ANALYSIS: According to Problem 1.38, the modified Coefficient of Performance and power input are given by

$$\mathrm{COP}_m = \frac{T_c - q_{in} R_{tot}}{T_h - T_c + q_{in} R_{tot}} \tag{1}$$

$$\dot{W} = q_{in} \frac{T_h - T_c + q_{in} R_{tot}}{T_c - q_{in} R_{tot}} \tag{2}$$

Under new, clean conditions, with $R_{tot,n} = R_{h,n} + R_{c,n} = 0.09$ K/W, we find

$$\mathrm{COP}_{m,n} = \frac{278\text{ K} - 750\text{ W} \times 0.09\text{ K/W}}{298\text{ K} - 278\text{ K} + 750\text{ W} \times 0.09\text{ K/W}} = 2.41$$ <

$$\dot{W}_n = 750\text{ W} \frac{298\text{ K} - 278\text{ K} + 750\text{ W} \times 0.09\text{ K/W}}{278\text{ K} - 750\text{ W} \times 0.09\text{ K/W}} = 312\text{ W}$$ <

Under dusty, conditions, with $R_{tot,d} = R_{h,d} + R_{c,n} = 0.15$ K/W, we find

$$\mathrm{COP}_{m,d} = \frac{278\text{ K} - 750\text{ W} \times 0.15\text{ K/W}}{298\text{ K} - 278\text{ K} + 750\text{ W} \times 0.15\text{ K/W}} = 1.25$$ <

Continued...

$$\dot{W}_d = 750\text{ W}\frac{298\text{ K} - 278\text{ K} + 750\text{ W} \times 0.15\text{ K/W}}{278\text{ K} - 750\text{ W} \times 0.15\text{ K/W}} = 600\text{ W} \quad <$$

COMMENTS: (1) The cooling rates and power input values are time-averaged quantities. Since the refrigerator does not run constantly, the instantaneous power requirements would be higher than calculated. (2) In practice, when the condenser coils become dusty the power input does not adjust to maintain the cooling rate. Rather, the refrigerator's *duty cycle* would increase. (3) The ideal Carnot Coefficient of Performance is $COP_C = T_c/(T_h - T_c) = 14$ and the corresponding power input is 54 W. (4) This refrigerator's energy efficiency is poor. Less power would be consumed by more thoroughly insulating the refrigerator, and designing the refrigerator to minimize heat gain upon opening its door, in order to reduce the cooling rate, q_{in}.