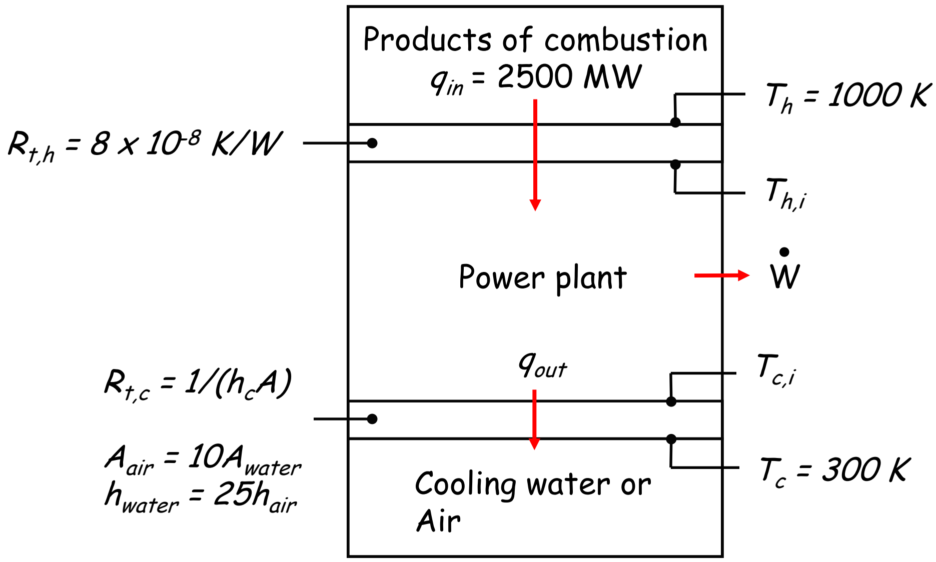
PROBLEM 1.33

KNOWN: Power plant and operating conditions of Example 1.7. Change in cold-side heat transfer surface area and convection heat transfer coefficient.

FIND: Modified efficiency and power output.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) power plant operates as an internally reversible heat engine, (3) clean operating conditions.

ANALYSIS: The cold-side thermal resistance for water cooling (for design conditions) is provided in Example 1.7 and is $R_{t,c} = 2 \times 10^{-8}$ K/W. The cold side thermal resistance is given by $R_{t,c} = 1/(h_c A)$, therefore

$$\frac{R_{t,c,\text{air}}}{R_{t,c,\text{water}}} = \frac{(hA)_{\text{water}}}{(hA)_{\text{air}}} = \left(\frac{h_{\text{water}}}{h_{\text{air}}}\right) \times \left(\frac{A_{\text{water}}}{A_{\text{air}}}\right) = \frac{25}{10} = 2.5$$

Hence, $R_{t,c,\text{air}} = 2.5 \times 2 \times 10^{-8}$ K/W $= 5 \times 10^{-8}$ K/W and $R_{\text{tot,air}} = 8 \times 10^{-8} + 5 \times 10^{-8} = 13 \times 10^{-8}$ K/W.

The modified efficiency for the air-cooled condenser is

$$\eta_m = 1 - \frac{T_c}{T_h - q_{in} R_{\text{tot,air}}} = 1 - \frac{300\text{K}}{1000\text{K} - 2500 \times 10^6\,\text{W} \times 1.3 \times 10^{-7}\,\text{K/W}} = 0.556 \qquad <$$

The power output is

$$\dot{W} = q_{\text{in}} \eta_m = 2500\ \text{MW} \times 0.556 = 1390\ \text{MW} \qquad <$$

Continued …

PROBLEM 1.33 (Cont.)

The air-cooled condenser is both (1) more expensive and (2) leads to a lower plant efficiency and power output relative to the water-cooled condenser of Example 1.7.

COMMENT: The diminished performance and higher cost of the air-cooled condenser, relative to the water-cooled condenser, is typical. This problem illustrates the profound linkage between power generation and water usage, and is referred to as “the water-energy nexus.”