Problem: 10-61

Given:	Cool water from 100 $^\circ F$ to 75 $^\circ F$ at a flow rate of 200,000 lbm/hr using air at 60 $^\circ F$ at a relative humidity of 50%. The exit temperature of the air is 90 $^\circ F$
Find:	The air-flow rate and the makeup water required.
Assumptions:	steady state $\Delta ke + \Delta pe$ is negligible adiabatic

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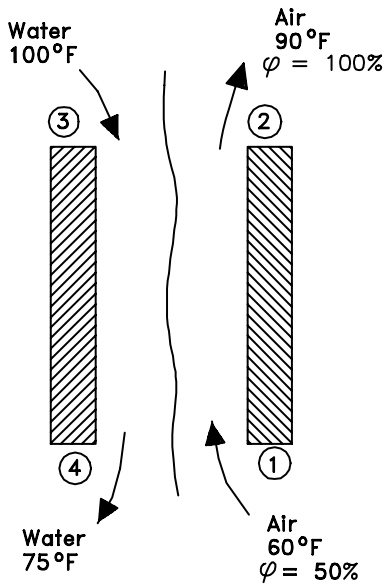

Energy Balance

$$\dot{m}_{a_1} h_{a_1} + \dot{m}_{W_1} h_{W_1} + \dot{m}_{W_3} h_{W_3} = \dot{m}_{a_2} h_{a_2} + \dot{m}_{W_2} h_{W_2} + \dot{m}_{W_4} h_{W_4}$$

or

$$\dot{m}_{a_1} h^*_{a_1} + \dot{m}_{W_3} h_{W_3} = \dot{m}_{a_2} h^*_{a_2} + \dot{m}_{W_4} h_{W_4}$$

Assume makeup is negligible compared to $\dot{m}W_3$ the $\dot{m}W_3 \approx \dot{m}W_4$. Also $\dot{m}_{a_1} = \dot{m}_{a_2}$. Then

$$\dot{m}_a = \dot{m}_{W_3} \frac{(h_3 - h_4)}{(h^*_2 - h^*_1)}$$

For water at state #3 (100 $^\circ F$, 1 atm), and state #4 (SF, 1 atm). From Table B.1a - State #3 and #4 are subcooled state

i.e.

at 100 $^\circ F$ pressure greater than 0.9503 $psia$
at 75 $^\circ F$ pressure greater than 0.4300 $psia$

Finding enthalpies, h_1, h_4, h_2^*, h_1^*. From Table B.1a

$$h_3(100^\circ F, 1\ atm) \approx h_f(100^\circ F, 0.9503\ psia) = 68.0\ Btu/lbm$$
$$h_4(75^\circ F, 1\ atm) \approx h_f(75^\circ F, 0.4300\ psia) = 43.1\ Btu/lbm$$

From Psych. chart, Fig. B.13a

$$h_2^*(90^\circ F, \phi = 100\%) \approx 55.5\ Btu/lbm$$
$$h_1^*(60^\circ F, \phi = 50\%) \approx 20.5\ Btu/lbm$$

Therefore

$$\dot{m}_a = 200{,}000\ lbm/hr \left[\frac{68 - 43.1}{55.5 - 20.5}\right] = \boxed{142{,}286\ lbm/hr}$$

Find makeup water. Makeup water is required since some water is lost due to evaporation.

$$\text{Makeup water} = \dot{m}_{w_3} = \dot{m}_{w_4} = m_a(\gamma_2 - \gamma_1)$$

From Psych. chart $\gamma \approx 0.03$ and $\gamma \approx 0.005$. (Note: converted from grams to lbm H_2O)
Therefore

$$\begin{aligned} \text{makeup} &= 142286\ lbm/hr\ [0.03 - 0.005] \\ &= \boxed{3557\ lbm/hr} \end{aligned}$$