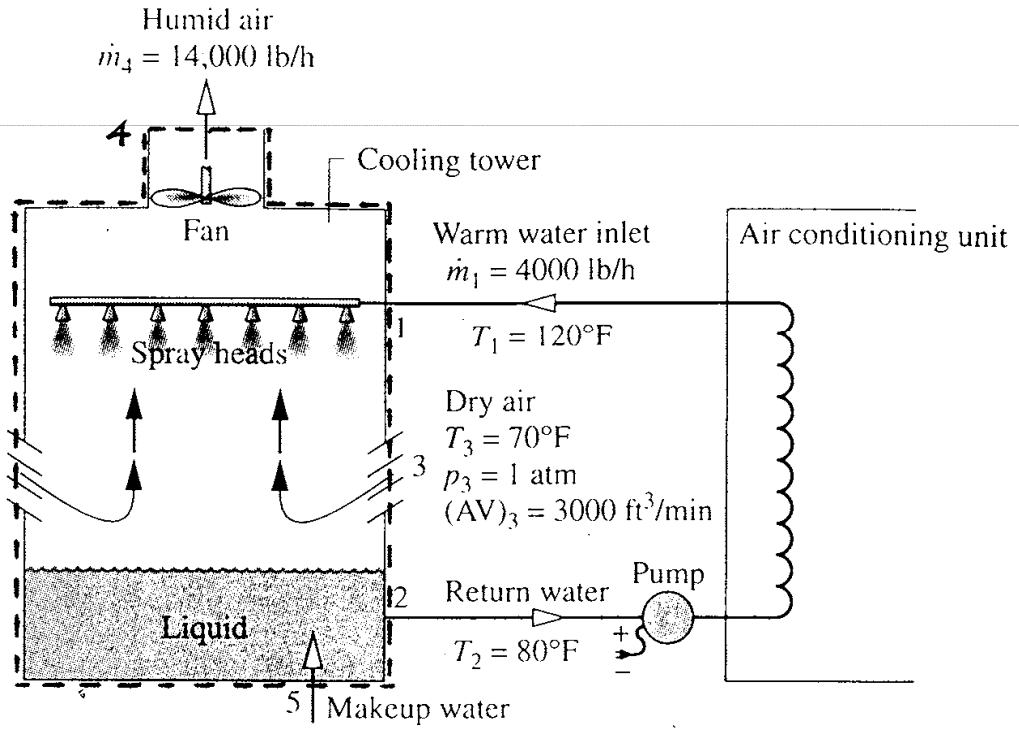
SET Problem
Session 4

Problem Statement

- A cooling tower operates at **steady state**. Warm water from an air conditioning unit enters at **120 degree Fahrenheit** with a **mass flow rate of 4000 lb/h**. Dry air enters the tower at **70 degree Fahrenheit, 1 atm with a volumetric flow rate of 3000 cubic** feet per minute. Because of evaporation within the tower, humid air exits at the top of the tower with a **mass flow rate of 14,000 lb/h.** Cooled liquid water is collected at the bottom of the tower for return to the air conditioning unit together with makeup water. Determine the mass flow rate of the **makeup water,in lb/h**.

Figure:


Humid air
$\dot{m}_4$ = 14,000 lb/h
4
Cooling tower
Fan
Warm water inlet
$\dot{m}_1$ = 4000 lb/h
Air conditioning unit
1
T_1 = 120°F
Spray heads
Dry air
T_3 = 70°F
3
p_3 = 1 atm
$(AV)_3$ = 3000 ft^3/min
Pump
2
Return water
Liquid
T_2 = 80°F
+
−
5
Makeup water

Solution:

- Mass balance :
- $\dot{m}_{out} = \dot{m}_1 - \dot{m}_2 + \dot{m}_3 - \dot{m}_4 + \dot{m}_5$
- $-\dot{m}_1 + \dot{m}_2 - \dot{m}_3 + \dot{m}_4 = \dot{m}_5$
- Or, $-\dot{m}_3 + \dot{m}_4 = \dot{m}_5$, since $\dot{m}_1 = \dot{m}_2$
- To calculate $\dot{m}_3 = \frac{AV}{v}$, where A is the area of cross section, V is velocity and v is specific volume.

Solution:

- $\frac{RT}{P} = v,\ \dot{m}_3 = \frac{AV}{v}$ or $\dot{m}_3 = \frac{AVP}{RT}$
- $\frac{14.696*3000*28.97*144*60}{1545*529}$=13480 lb/h
- Eventually, 14000-13480=520 lb/h

- *Conversions 1 atm in english units 14.969 lb/in^2, Temperature in Rankine Scale T(R)= T(F)+459.67*