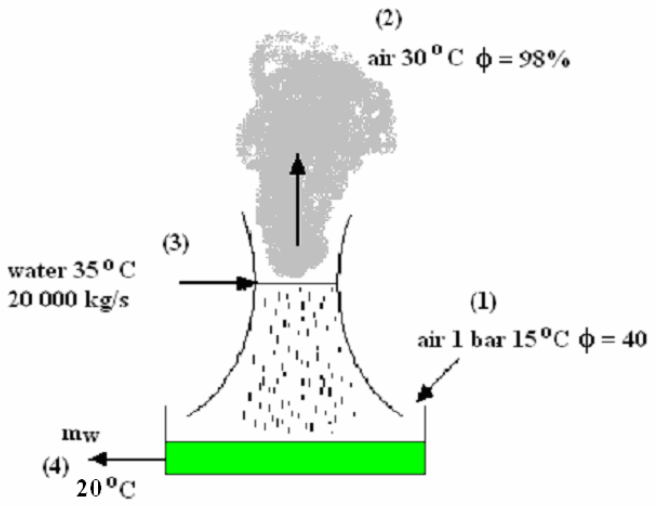
THERMODYNAMICS 201 2003

Q8 The water-flow rate from the condenser of a 500 MW power plant is 20 x 10^3 kg/s. The water is cooled in an array of cooling towers from a temperature of 35°C to 20°C. Atmospheric air at a pressure of 1 bar enters the towers at 15°C with a relative humidity of 40% and exits with a temperature of 30°C at 98% relative humidity.

Determine the make-up water required and the air-flow rate.
Assume that the specific heat capacity at constant pressure for air and steam are 1.005 kJlkgK and 1.86 kJ/kgK respectively and the specific heat capacity for water is 4.187 kJ/kgK.



INLET AIR

p_{g1} = 0.01704 bar at 15°C
ϕ_1 = 0.4 = p_{s1} / p_g
p_{s1} = 0.4 x 0.01704 = 0.006816 bar
hence p_{a1} = 1.0 - 0.006816 = 0.993184 bar

$$\omega_1 = 0.622\frac{0.006816}{0.993184} = 0.004268647$$

m_{s1} = 0.004268647 m_a

OUTLET AIR

ϕ_2 = 0.98
p_{s2} = 0.98p_{g2} =0.98 x 0.0424242 = 0.041575716 bar hence p_{a2} = 0.95842428 bar

$$\omega_2 = 0.622\frac{0.00415757}{0.9584242} = 0.021698$$

m_{s2} = 0.021698 m_a

MASS BALANCE

$m_{w4} = m_{w3} - (m_{s2} - m_{s1}) = 20000 - (0.021698\ m_a - 0.0042686\ m_a) = 20000 - 0.017429\ m_a$

ENERGY BALANCE

$h_{s2} = h_g$ = 2555.7 kJ/kg
h_{s1} = 2530 kJ/kg (from h-s chart)

Balancing energy we get
(20000 x 4.86 x 35) + (m_a x 1.005 x 15) + (0.0042686 x m_a x 2530) =
{(20000 – 0.017429 m_a) x 4.186 x 20} + (0.021698 x 2555.7 m_a) + (m_a x 1.005 x 30)

3402000 + 15.075 m_a + 10.8 m_a = 1674400 - 1.459 m_a + 70.4 m_a + 30.15 m_a

1727600 = 73.216 m_a

m_a = 23596 kg/s

m_{s2} = 512 kg/s

m_{s1} = 100.72 kg/s

Evaporation rate is 411.3 kg/s so this is the required make up water