Air-Conditioning & Refrigeration

BSc

Lecture 6

Course weekly Outline &

Ch.1 (Introduction to Air conditioning & Refrigeration)

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Example:

In a check on an air-conditioning system, a room was maintained at 22 ^oC DBT and 53% RH, by air supply at 1.6 m^3/s with 10 ^oC DBT and 9 ^oC WBT. The barometric pressure was 920 mbar.

Find: a) sensible heat gain b) latent heat gain c) total heat gain

Solution:

From Table A-2 at $t_w = 9\ ^oC$, $P_{wss} = 1.15$ kPa

$P_s = 1.15 – 92 \times 6.66 \times 10^{-4} (10 – 9) = 1.0887$ kPa

$P_a = 92 – 1.0887 = 90.91$ kPa

$m_a = (P_a V_a)/(R_a T_a) = (90.91 \times 1.6)/(0.287 \times 295) = 1.718$ kg/s

$h_{a1} = 1.007 \times 22 – 0.026 = 22.128$ kJ/kg

$h_{a2} = 1.007 \times 10 – 0.026 = 10.044$ kJ/kg

$Q_s = m_a(h_{a1} – h_{a2}) = 1.718(22.128 – 10.044) = 20.7$ kW

Also, from Table A-2 at $t_d = 22\ ^oC$ $P_{dss} = 2.645$ kPa

$\Phi = P_s/P_{dss} \rightarrow P_s = 0.53 \times 2.645 = 1.4$ kPa

$g_1 = 0.622(1.4)/(92 – 1.4) = 0.00961\ kg/kg_{d.a}$

Example:

$g_2 = 0.622(1.0887)/(92 - 1.0887) = 0.00745\ kg/kg_{d.a}$

$h_{s1} = 2501 + 1.84 \times 22 = 2541.48\ kJ/kg$

$h_{s2} = 2501 + 1.84 \times 10 = 2519.4\ kJ/kg$

$Q_L = m_a(g_1 . h_{s1} - g_2 . h_{s2}) = 1.718(0.00961 \times 2541.48 - 0.00745 \times 2519.4)$

$= 9.714\ kW$

$Q_{Tot} = Q_s + Q_L = 20.7 + 9.714 = 30.414\ kW$

Adiabatic saturation and thermodynamic wet bulb temperature

Adiabatic saturation temperature is defined as that temperature at which water, by evaporating into air, can bring the air to saturation at the same temperature adiabatically. An adiabatic saturator is a device using which one can measure theoretically the adiabatic saturation temperature of air.

As shown in Fig.2.1 an adiabatic saturator is a device in which air flows through an infinitely long duct containing water. As the air comes in contact wit water in the duct, there will be heat and mass transfer between water and air. If the duct is infinitely long, then at the exit, there would exist perfect equilibrium betweer air and water at steady state. Air at the exit would be fully saturated and its temperature is equal to that of water temperature. The device is adiabatic as the walls of the chamber are thermally insulated. In order to continue the process, make up water has to be provided to compensate for the amount of water evaporated intc the air. The temperature of the make-up water is controlled so that it is the same as that in the duct.

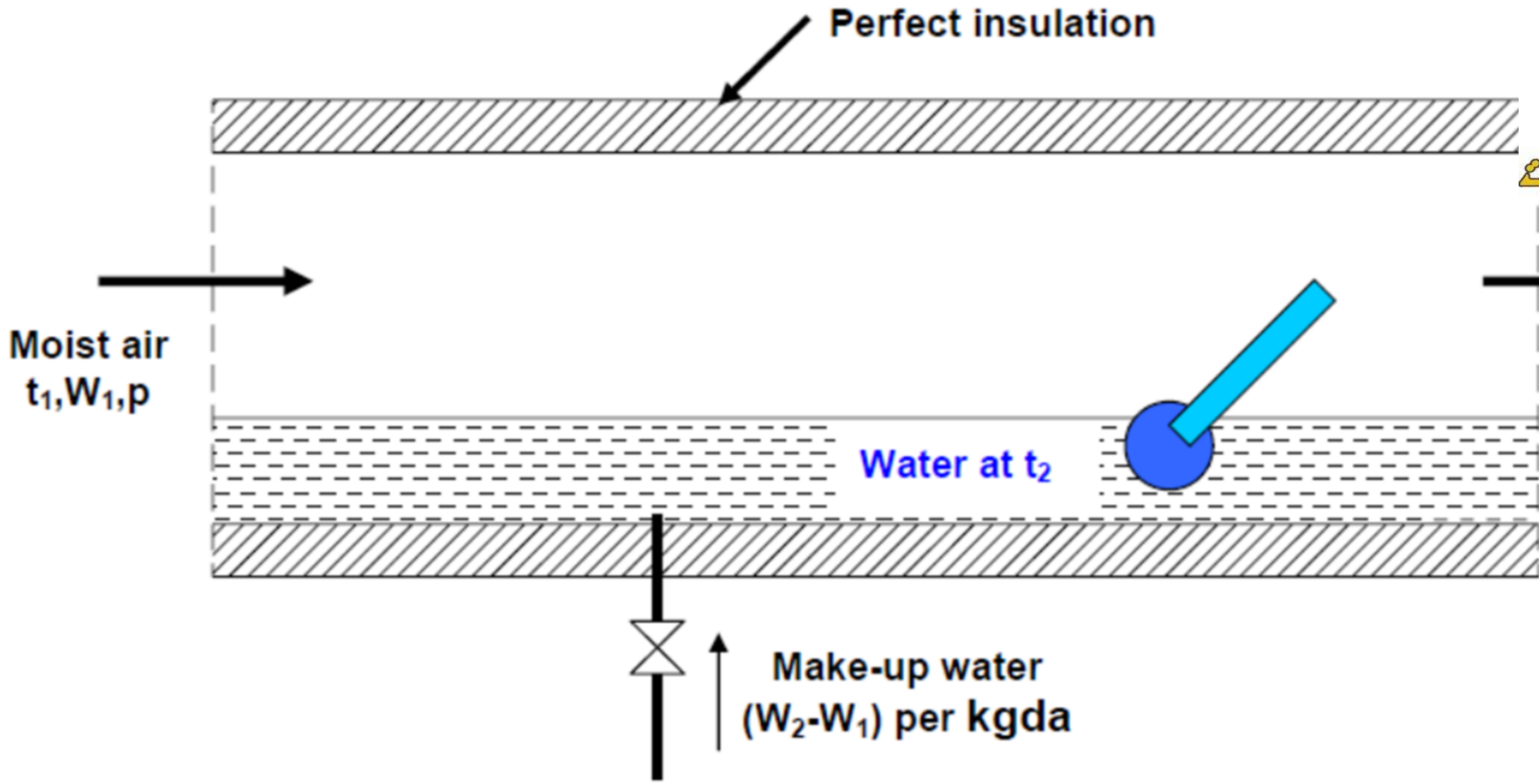

Fig.2.1 The process of adiabatic saturation of air

After the adiabatic saturator has achieved a steady-state condition, the temperature indicated by the thermometer immersed in the water is the *thermodynamic wet-bulb temperature*. The thermodynamic wet bulb temperature will be less than the entering air DBT but greater than the dew point temperature.

Certain combinations of air conditions will result in a given sump temperature, and this can be defined by writing the energy balance equation for the adiabatic saturator. Based on a unit mass flow rate of dry air, this is given by:

$$h_1 = h_2 - (W_2 - W_1)h_f$$

where h_f is the enthalpy of saturated liquid at the sump or thermodynamic wet-bulb temperature, h_1 and h_2 are the enthalpies of air at the inlet and exit of the adiabatic saturator, and W_1 and W_2 are the humidity ratio of air at the inlet and exit of the adiabatic saturator, respectively.

It is to be observed that the thermodynamic wet-bulb temperature is a thermodynamic property, and is independent of the path taken by air. Assuming the humid specific heat to be constant, from the enthalpy balance, the thermodynamic wet-bulb temperature can be written as:

$$t_2 = t_1 - \frac{h_{fg,2}}{c_{pm}}(w_2 - w_1)$$

where $h_{fg,2}$ is the latent heat of vaporization at the saturated condition 2. Thus measuring the dry bulb (t_1) and wet bulb temperature (t_2) one can find the inlet humidity ratio (W_1) from the above expression as the outlet saturated humidity ratio (W_2) and latent heat heat of vaporizations are functions of t_2 alone (at fixed barometric pressure).

2. Use the following equations to calculate the required variables:

$Q_s = 1.22\, V_s (T_r - T_s)$, this can be used to find V_s . or $Q_s = m_a\, c_p\, (T_r - T_s)$

$Q_{coil} = 1.2\, V_s (h_m - h_s)$, if there is mixing

$Q_{coil} = 1.2\, V_s (h_o - h_s)$, for all outside air

$Q_{coil} = 1.2\, V_s (h_r - h_s)$, for all return air

$m_{vap} = m_s\, \Delta g$ and the condition as in Q_{coil}

$Q_{water} = m_{water}\, c_p\, \Delta T_{water}$ where $c_p = 4.2$ kJ/kg. K

$c_p = 1.005$ kJ/kg. K

$V_s = V_{supply} = m_a / \rho$

$Q_L = m_a \Delta g\, h_{fg}$

Examples:

1- An air conditioned space is maintained at DBT= 24 ^{o}C and RH=50%. The outside condition is DBT=38 ^{o}C with WBT= 27 ^{o}C. The space has a sensible heat gain of 24 kW and latent heat gain of 6 kW. Use all outside air system and find: - a) the supply condition of the air if the relative humidity at the supply point is taken to be 90%. b) volume flow rate of supplied air. c) the total cooling load of the cooling coil. d) the chilled water volume flow rate if its temperature rise is 5.6 ^{o}C.

(Answer: Ts= 12.2 ^{o}C, h_s = 32.6 kJ/kg, Q_{coil} =95.6 kW, 4. 06e^{-3} m^3/s)

2- The sensible heat gain of a given space is 50 kW and its latent load is 15 kW. The inside design condition is 26 ^{o}C with 50% relative humidity. The space is air conditioned using all return air system. Find by assuming 90% saturation for the supply air. a) the supply conditioned of the air b) volume flow rate of supplied air c) cooling coil load.

(Answers: T_s= 14.5 c h_s=38.2 kJ/kg, v_s= 3.56 m^3/s, Q_{coil} =60.5 kW)

3- An air conditioned space with inside design condition of DBT=25.5 ^oC, WBT=18 ^oC has a sensible heat gain of 17.5 kW and a latent heat gain of 12.3 kW. The space required an outside air of o.35 m^3/s at DBT= 32.5 ^oC, RH= 50%.

Find:- a) the state of the supplied air and its mass flow rate, b) cooling coil load, c) plot the process on the psychrometric chart and calculate the BPF.

(Answers: Ts= 11.5 ^oC, h_s= 29.5 kJ/kg, m_s = 0.813 kg/s, Q_{coil}= 24.8 kW, BPF=0.25)

Example:

An air conditioned space is need to be maintained at DBT =24 ^oC, RH= 50%. The sensible heat loss of the space is 66 kW and its latent is 16.5 kW. The space required 28.3 m^3/min fresh air. The outside design condition is DBT= 7 ^oC, RH= 80%.

Find:- a) Plot the air conditioning process on the chart. b) The mass flow rate of the supplied air given that Ts= 49 ^oC, c) The heating coil load d) The humidifier heating load, e) The amount of steam required by the humidifier.

(Answers m_s= 2.77 kg/s, Q_{coil}=78.0 kW, Q_{hum}= 16.9 kW, m_{vap}= 0.00825 kg/s)