

Fig. 4 Schematic Device for Cooling Moist Air

Example 4: Moist air, saturated at 35 F, enters a heating coil at a rate of 20,000 cfm. Air leaves the coil at 100 F. Find the required rate of heat addition in Btu per hr.

Solution: Fig. 3 schematically shows the solution. State 1 is located on the saturation curve at 35 F. Thus, $h_1 = 13.01$ Btu/lb dry air, $W_1 = 0.00428$ lb water/lb dry air, and $v_1 = 12.55$ cu ft/lb dry air. State 2 may be located at the intersection of $t = 100$ F and $W_1 = W_2 = 0.00428$ lb water/lb dry air. Thus, $h_2 = 28.77$ Btu/lb dry air. The mass flow of dry air is

$$m_a = \frac{(20,000)(60)}{12.55} = 95,620 \text{ lb dry air/hr.}$$

From Equation 25

$$q_p = (95,620)(28.77 - 13.01) = 1,507,000 \text{ Btu/hr.}$$

Cooling of Moist Air

If moist air is cooled to a temperature below its initial dew point, separation of moisture will occur. Fig. 4 shows a schematic cooling coil where it is assumed that moist air is uniformly processed. Although water may be separated at various temperatures, ranging from the initial dew point to the final saturation temperature, it is assumed that the condensed water is cooled to the final air temperature t_2 before it drains from the system.

For the system of Fig. 4, the steady-flow energy and material balance equations are

$$m_a h_1 = m_a h_2 + m_w h_{w2} + m_a h_{w2}$$

$$m_a W_1 = m_a W_2 + m_w$$

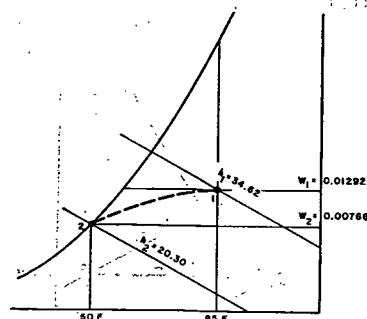


Fig. 5 Schematic Solution for Example 5

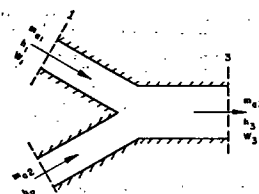


Fig. 6 Adiabatic Mixing of Two Streams of Moist Air

Thus

$$m_a = m_1(W_1 - W_2) \quad (26)$$

$$q_p = m_a [(h_1 - h_2) - (W_1 - W_2)h_{w2}] \quad (27)$$

Example 6: Moist air at 85 F dry-bulb temperature and 50 percent relative humidity enters a cooling coil at a rate of 10,000 cfm. The air is processed to a final condition of saturation at 50 F. Find the tons of refrigeration required.

Solution: Fig. 5 shows the schematic solution. State 1 is located at the intersection of $t = 85$ F and $\phi = 50$ percent. Thus, $h_1 = 34.62$ Btu/lb dry air, $W_1 = 0.01292$ lb water/lb dry air, and $v_1 = 14.01$ cu ft/lb dry air. State 2 is located on the saturation curve at 50 F. Thus, $h_2 = 20.30$ Btu/lb dry air and $W_2 = 0.00766$ lb water/lb dry air. From Table 1, $h_{w2} = 18.11$ Btu/lb water. The mass flow of dry air is

$$m_a = \frac{10,000}{14.01} = 713.8 \text{ lb dry air/min}$$

From Equation 27

$$q_p = (713.8)[(34.62 - 20.30) - (0.01292 - 0.00766)(18.11)] = 10,150 \text{ Btu/min}$$

Since one ton of refrigeration equals a heat withdrawal rate of 200 Btu/min, the required refrigerating capacity is 50.75 tons.

Adiabatic Mixing of Two Streams of Moist Air

A common process involved in air-conditioning systems is the adiabatic mixing of two streams of moist air. Fig. 6 schematically

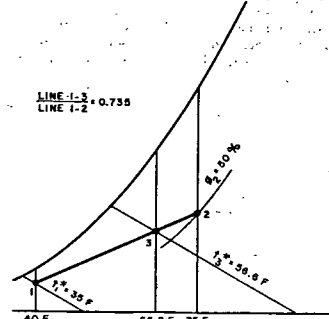


Fig. 7 Schematic Solution for Example 6

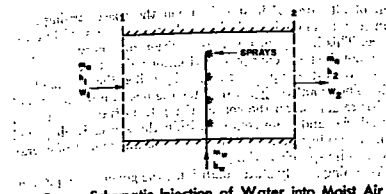


Fig. 8 Schematic Injection of Water into Moist Air

shows the problem. If the mixing is adiabatic, it must be governed by the three equations

$$m_a h_1 + m_w h_w = m_a h_2$$

$$m_a + m_w = m_a$$

$$m_a W_1 + m_w W_w = m_a W_2$$

Elimination of m_w gives

$$\frac{h_2 - h_1}{h_w - h_1} = \frac{W_2 - W_1}{W_w - W_1} = \frac{m_w}{m_a} \quad (28)$$

according to which: on the ASHRAE chart the state-point of the resulting mixture lies on the straight line connecting the state-points of the two streams being mixed and divides the line into two segments which are in the same ratio as are the masses of dry air in the two streams.

Example 7: A stream of 5000 cfm of outdoor air at 40 F dry-bulb temperature and 35 F thermodynamic wet-bulb temperature is adiabatically mixed with 15,000 cfm of recirculated air at 75 F dry-bulb temperature and 50 percent relative humidity. Find the dry-bulb temperature and thermodynamic wet-bulb temperature of the resulting mixture.

Solution: Fig. 7 shows the schematic solution. States 1 and 2 may be located on the ASHRAE chart. Thus, $v_1 = 12.65$ cu ft/lb dry air, and $v_2 = 13.68$ cu ft/lb dry air. Thus,

$$m_a = \frac{5000}{12.65} = 395 \text{ lb dry air/min}$$

$$m_a = \frac{15,000}{13.68} = 1096 \text{ lb dry air/min}$$

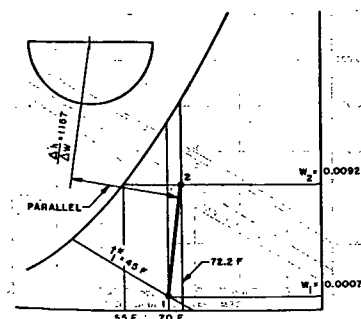


Fig. 9 Schematic Solution for Example 7

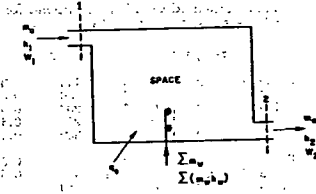


Fig. 10 Schematic Problem of Air Conditioning a Space

According to Equation 28

$$\text{Line 3-2} \quad \frac{m_a}{m_w} = \frac{\text{Line 1-3}}{\text{Line 1-2}} = \frac{1096}{1491} = 0.735$$

$$\text{Line 1-3} \quad \frac{m_a}{m_w} = \frac{\text{Line 1-2}}{\text{Line 1-3}} = \frac{1491}{1096} = 1.35$$

Thus, the length of line segment 1-3 is 0.735 times the length of the entire line 1-2. Through use of a ruler, State 3 may be located, and the values $t_3 = 65.9$ F and $t_{w3} = 56.6$ F found.

Adiabatic Mixing of Moist Air with Injected Water

A frequent air-conditioning process is the injection of steam or liquid water into a moist-air stream in order to raise the humidity ratio of the moist air. Fig. 8 schematically shows the problem. If the mixing is adiabatic, the following equations apply

$$m_a h_1 + m_w h_w = m_a h_2$$

$$m_a W_1 + m_w W_w = m_a W_2$$

Thus

$$\frac{h_2 - h_1}{h_w - h_1} = \frac{W_2 - W_1}{W_w - W_1} = \frac{m_w}{m_a} \quad (29)$$

according to which: on the ASHRAE chart the final state-point of the moist air must lie on a straight line whose direction is fixed by the specific enthalpy of the injected water and which is drawn through the initial state-point of the moist air.

Example 7: Moist air at 70 F dry-bulb temperature and 45 F thermodynamic wet-bulb temperature is to be processed to a final dew-point temperature of 55 F by adiabatic injection of saturated steam at 230 F. The rate of dry air flow is 200 lb per min. Find

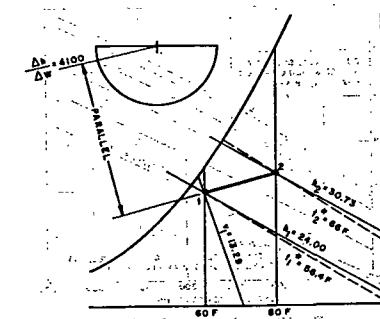


Fig. 11 Schematic Solution for Example 8