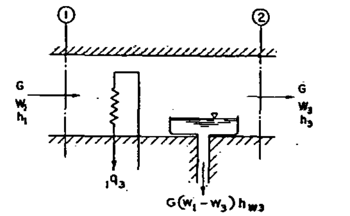

Fig. 9 .... Illustration of Process of *Example 4*

until it intersects the constant temperature line in the liquid-vapor region corresponding to the final temperature 70 F. This is shown as Point 2 on the diagram. Then,

$$_1q_2 = G(h_1 - h_2)$$

The initial enthalpy is 43 Btu per lb of dry air; the initial specific volume is 14.4 cu ft per lb of dry air; and the final enthalpy is 34.2 Btu per lb of dry air. The solution of the problem is

$$_1q_2 = \frac{20{,}000}{14.4} \times (43 - 34.2) = 12{,}200 \text{ Btu per min.}$$

The other method is to use an energy balance,

$$_1q_2 = G[h_1 - h_2 - h_{w2}(W_1 - W_2)]$$

The initial humidity ratio is 0.0183 lb of water vapor per lb of dry air, and the final humidity ratio is 0.0158 lb of water vapor per lb of dry air. Therefore, the heat to be removed is

$$_1q_2 = \frac{20{,}000}{14.4} \times (43 - 34.1 - 0.0025 \times 38.07)$$

$$= 12{,}130 \text{ Btu per min.}$$

Adiabatic Mixing of Two Steady Flow Air Streams at Constant Pressure

The process is diagrammed in Fig. 10. By applying the principles of the *conservation of mass and energy, three equations* may be written:

Mass balance for the dry air,

$$G_1 + G_2 = G_3$$

Energy balance for the process,

$$G_1h_1 + G_2h_2 = G_3h_3$$

Mass balance for the water vapor,

$$G_1W_1 + G_2W_2 = G_3W_3$$

Eliminating G_3 and combining the three equations yields the equation,

$$\frac{h_2 - h_3}{h_3 - h_1} = \frac{W_2 - W_3}{W_3 - W_1} = \frac{G_1}{G_2} \tag{34}$$

Example 5: Outdoor air at 0 F dry-bulb temperature and 0.80 degree of saturation is to be mixed adiabatically with recirculated indoor air at 70 F dry-bulb temperature and 0.20 degree of saturation, in the ratio of one pound of dry air in the former to four in the latter. Find the temperature and degree of saturation in the resulting mixture.

Solution a: From the data of Table 2. The only unknown properties are the humidity ratio W_3 and the enthalpy h_3 of the resulting mixture. These may be determined from Equation 34. Thus,

$$\frac{20.270 - h_3}{h_3 - 0.668} = \frac{0.003164 - W_3}{W_3 - 0.000630} = \frac{1}{4}$$

from which $h_3 = 16.350$ and $W_3 = 0.002657$. The enthalpy of the final mixture may also be expressed by Equation 28:

$$h_3 = h_a + \mu h_{as}$$

Since μ by definition is W_3/W_s, Equation 28 may be rewritten as

$$16.350 = h_a + (0.002657/W_s) \times h_{as}$$

At 56 F the right side of the equation is 16.332, and at 57 F it is 16.582. *Interpolation gives as the final dry-bulb temperature* of the mixture 56.07 F. At this temperature the humidity ratio at saturation is 0.00960 lb of water vapor per lb of dry air. Therefore, the final degree of saturation is

$$\mu = 0.002657/0.00960 = 0.277$$

Solution b: From the ASHAE Chart. Equation 34 indicates that the state point of the resulting mixture lies on a straight *line connecting the state points of the two streams being mixed,* and divides this line into two segments whose respective lengths are inversely proportional to the rates of dry air flow in the corresponding streams. This is illustrated in Fig. 11. Points 1 and 2 are located and connected by a straight line. The state of the final mixture is set so that

$$\frac{G_1}{G_2} = \frac{D_{2-3}}{D_{3-1}} = \frac{1}{4}$$

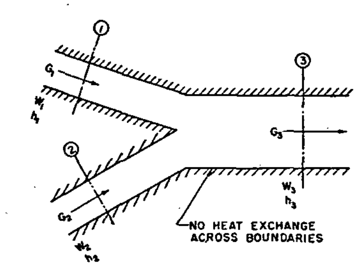

Fig. 10 .... Illustration of Mixing of Two Steady Flow Streams at Constant Pressure

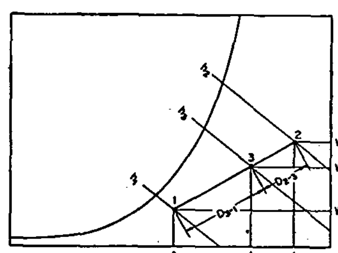

Fig. 11 .... Solution of *Example 5* on ASHAE Psychrometric Chart

Scaling the distances on the chart, the required solution to *Example 5* is 56 F dry-bulb temperature and 0.28 degree of saturation.

Addition of Moisture to an Adiabatic Stream

Consider a stream of moist air flowing adiabatically between two sections, 1 and 2, as in Fig. 12, with moisture addition at the rate $G_1(W_2 - W_1)$ and the moisture having the enthalpy h_w Btu per pound of moisture.

An energy balance yields

$$G_1h_1 + G_1(W_2 - W_1)h_w = G_1h_2 \tag{35}$$

Example 6: Liquid water chilled to 40 F is injected into an air stream initially at 95 F dry-bulb temperature and 80 F *thermodynamic* wet-bulb temperature. At what temperature will saturation be reached? How much water must be evaporated to reach saturation?

Solution a: From the data of Table 2. The solution of Equation 35 for h_2 yields.

$$h_2 = h_1 + (W_2 - W_1)h_w$$

The initial enthalpy of the moist air h_1 must be found from Equation 8,

$$h_1 = h^* - (W^* - W_1)h_w^*$$

$$22.827 + \mu 40.49 = 43.69 - (0.02233 - 0.03673\mu)\,(48.05)$$

from which $\mu = 0.511$.

Hence,

$$h_1 = 22.827 + 0.511(40.49)$$

$$= 43.52 \text{ Btu per lb of dry air.}$$

and

$$W_1 = 0.03673(0.511)$$

$$= 0.01877 \text{ lb per lb of dry air.}$$

The solution of Equation 35 is

$$h_2 = 43.52 + (W_2 - 0.01877)(8.09)$$

By trial and error, this equation will be satisfied at the temperature 79.87 F. At this temperature the humidity ratio W_2 is 0.02223. The weight of water evaporated is therefore $0.02223 - 0.01877 = 0.00346$ lb per lb of dry air.

Solution b: From the ASHAE Chart. Solution of Equation 35 for the ratio $(h_2 - h_1)/(W_2 - W_1)$ yields

$$\frac{h_2 - h_1}{W_2 - W_1} = h_w \tag{36}$$

The slope of the condition line is therefore determined by

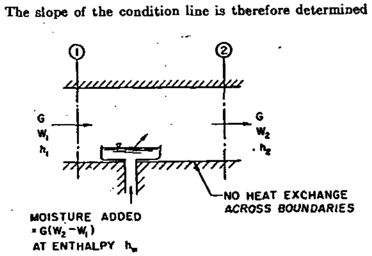

Fig. 12 .... Illustration of Addition of Moisture to an Adiabatic Stream

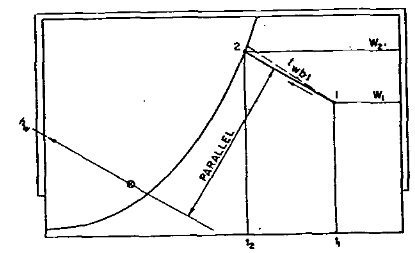

Fig. 13 .... Solution of *Example 6* on ASHAE Psychrometric Chart

the enthalpy of the water which is supplied. This slope is established on the chart by connecting the center of the protractor on the psychrometric chart with the value of h_w on the protractor. Draw a line parallel to this reference line through the initial Point 1 (Fig. 13). The second line is the condition line for the process. Since the conditions of the problem require the final point to lie on the saturation line, the intersection of the condition line with the saturation line gives the desired solution.

Adiabatic Saturation

Adiabatic saturation is the designation given any process in which the state of moist air is changed from some initial unsaturated condition to a saturated one without the addition or removal of heat. According to this definition, the addition of moisture to an adiabatic stream may become an adiabatic saturation process. *Example 6* is an illustration.

A type of adiabatic saturation of further practical interest is the use of continually recirculated spray water in a saturating air washer. Here the spray water will ultimately come to the same temperature as the saturated leaving air; this temperature is, by definition, the thermodynamic wet-bulb temperature. Hence, adiabatic saturation in this manner will have the final state point on the saturation curve, with the same thermodynamic wet-bulb temperature as the original state point.

In a process such as this, the moist air enthalpy changes very slightly. The moisture added and temperature change may be obtained from the psychrometric chart as sketched in Fig. 14.

Example 7: Moist air at 75 F dry-bulb temperature and 0.60 degree of saturation, is saturated adiabatically with recircu-

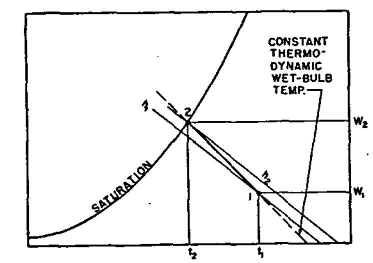

Fig. 14 .... Moisture Added and Temperature Change