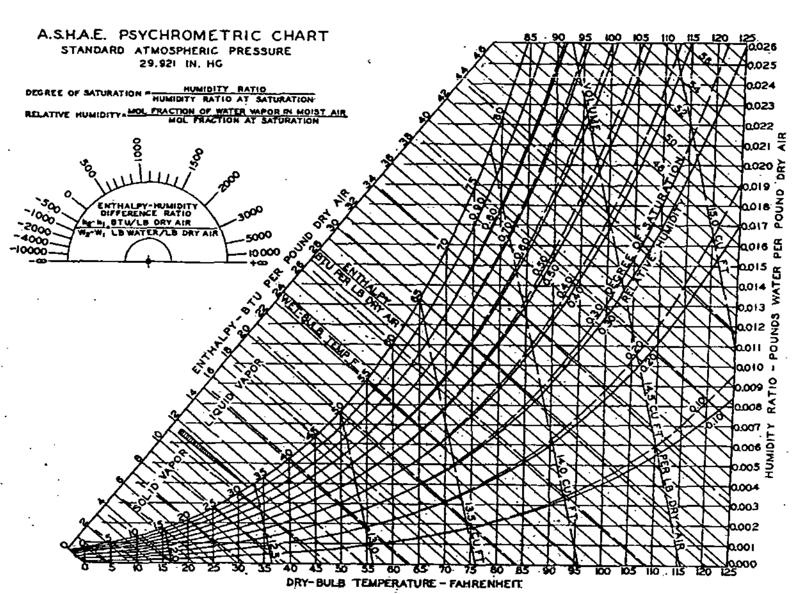

Fig. 5 . . . . Abridgment of ASHAE Psychrometric Chart

point at which the break in the isotherm through the point in question occurs, is the weight of water per pound of dry air in the vapor phase. Consequently, the difference between the two ordinates is the weight of condensed moisture per pound of dry air in the vapor phase.

The shaded solid-liquid-vapor region at 32 F is an isothermal three-phase zone, and separates the liquid-vapor zone from the solid-vapor zone. The temperature is 32 F throughout the shaded area.

It is possible to obtain two values for the wet-bulb temperature when this temperature is below 32 F. If the bulb of a thermometer is dipped into water at a temperature slightly above 32 F and held in a stream of air whose wet-bulb temperature is below 32 F, the temperature indicated by the thermometer will drop rapidly until a minimum is reached below 32 F. This will be accomplished without the formation of ice on the bulb of the thermometer. After reaching this minimum temperature, the reading will jump back to 32 F and remain there until the water on the bulb is frozen, after which it will slowly drop again until equilibrium is reached. The final temperature may be higher or lower than the first minimum reading, or it may be the same depending on the amount of moisture present in the mixture. In the absence of reliable data on the wet-bulb temperature over subcooled water, the chart, below 32 F, has been drawn for the equilibrium condition, that is, the values plotted on the ASHAE chart are for the condition where the minimum temperature is reached with ice on the bulb of the thermometer.

USE OF TABLE 2 AND THE ASHAE PSYCHROMETRIC CHART

The use of Table 2 and the ASHAE Psychrometric Chart in analyzing typical air-conditioning problems is best explained by means of illustrative examples. In each of the following it is to be understood that the processes in question take place at a constant pressure of 29.921 in. Hg, i.e., standard atmospheric pressure.

Example 1: Determine the enthalpy of moist air at 80 F dry-bulb temperature and 0.40 degree of saturation.

Solution a: From the data of Table 2, at 80 F, $h_a = 19.221$ Btu per lb of dry air and $h_{as} = 24.47$ Btu per lb of dry air. Then h at the specified conditions is $19.221 + 0.40(24.47) = 29.01$ Btu per lb of dry air.

Solution b: From the ASHAE Chart. Follow the 80 F dry-bulb line upward until it intersects the 0.40 degree of saturation line. From this intersection, follow the line of constant enthalpy to the enthalpy scale and read 29.00 Btu per lb of dry air.

Example 2: Determine the thermodynamic wet-bulb temperature of moist air at the conditions of *Example 1*.

Solution a: From the data of Table 2. Applying Equation 8, $h_1 = 29.01$ Btu per lb of dry air (*Example 1*). As a first approximation this is h_s^* the enthalpy at saturation at the thermodynamic wet-bulb temperature which is, therefore, approximately 63.5 F. W^* at 63.5 F is 12.57×10^{-3} lb of water vapor per lb of dry air, and W_1 is $0.02233 \times 0.40 = 0.00893$ lb of water vapor per lb of dry air. The specific enthalpy of liquid water at 63.5 F is 31.58 Btu per lb of water. As a second approximation, $h^* = 29.01 + (0.01257 - 0.00893)(31.58) = 29.12$ Btu per lb of dry air. Interpolation in Table 2 gives as the final answer $t^* = 63.64$ F.

Solution b: From the ASHAE Chart. At the intersection of the 80 F dry-bulb temperature line and the 0.40 degree of saturation line, read the thermodynamic wet-bulb temperature.

Heating of Moist Air at Constant Pressure Without Addition of Moisture

Example 3: Air initially at 20 F, 0.80 degree of saturation, is heated to 120 F. Find the quantity of heat required to process 20,000 cfm of heated air.

The process is diagrammatically illustrated in Fig. 6. The energy equation for the process is

$$G h_1 + {}_1q_2 = G h_2$$

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

Solution a: From the data of Table 2. The initial humidity ratio, which is the same as the final humidity ratio, is $0.80(0.002152) = 0.001722$ lb of water vapor per lb of dry air; the initial enthalpy is $4.804 + 0.80(2.302) = 6.646$ Btu per lb of dry air; the final degree of saturation is $0.001722/0.08149 = 0.02113$; the final enthalpy is $28.841 + 0.02113(90.70) = 30.757$ Btu per lb of dry air; the final volume is $14.611 + 0.02113(1.905) = 14.651$ cu ft per lb of dry air. Since 20,000 cfm of heated air are to be processed, the total quantity of heat required is

$$ {}_1q_2 = (20{,}000/14.651) \times 24.111 = 32{,}914 \text{ Btu per min.}$$

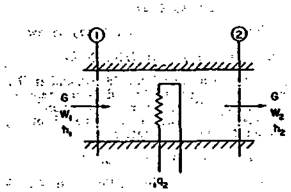

Fig. 6 . . . . Illustration of Process of *Example 3*

Solution b: From the ASHAE Chart. The process is represented by the horizontal line 1–2, Fig. 7. The initial enthalpy, at 20 F dry-bulb temperature and 0.80 degree of saturation, is 6.65 Btu per lb of dry air. Since the final humidity ratio is the same as the initial humidity ratio, the ratio $(h_2 - h_1)/(W_2 - W_1) = \infty$. The horizontal line 1–2, Fig. 7, then represents the condition line for the process, and the final state of the moist air must lie on this line. The final state is located at the point at which the 120 F dry-bulb temperature line crosses the condition line, and is labeled Point 2 on the figure. At this condition the final enthalpy is 30.8 Btu per lb of dry air and the final specific volume is 14.65 cu ft per lb of dry air. Substituting these values in the energy equation,

$$ {}_1q_2 = (20{,}000/14.65) \times (30.8 - 6.65) = 32{,}950 \text{ Btu per min.}$$

Cooling of Moist Air at Constant Pressure with Condensation of Water

Referring to Fig. 8, moist air cooled from State 1 passes through successive states along the line, $W = W_1 =$ constant, until the saturation line is intersected. The temperature at this point of intersection is by definition the dew-point temperature for State 1.

Further cooling through successive equilibrium states is accompanied by condensation. The succession of states for the total system, moist air, and liquid water, is represented by a continuation of the $W = W_1$ line into the liquid-vapor region. (Temperatures below 32 F would involve the solid-vapor region.) Consider that the final temperature is t_3. The final enthalpy is then h_3; the liquid water formed is $(W_1 - W_3)$,

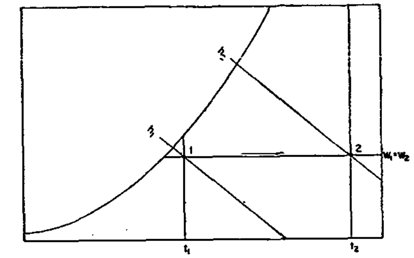

Fig. 7 . . . . Solution of *Example 3* on ASHAE Psychrometric Chart

where Point 3 is at the intersection of the isotherm through 2 and the saturation curve; the final humidity ratio of the moist air is W_3; and this final moist air has dew-point, wet-bulb, and dry-bulb temperatures all equal to t_3.

Example 4: How much heat must be removed from 20,000 cfm of air at 95 F dry-bulb temperature and 0.50 degree of saturation to cool the air to 70 F, saturated?

Solution a: From the data of Table 2. The initial humidity ratio is $0.50(0.03673) = 0.01837$ lb of water vapor per lb of dry air; the initial enthalpy is $22.827 + 0.50(40.49) = 43.072$ Btu per lb of dry air; the humidity ratio at saturation at the final temperature is 0.01582 lb of water vapor per lb of dry air; the quantity of liquid formed is $0.01837 - 0.01582 = 0.00255$ lb of water vapor per lb of dry air; h_{w3} at 70 F is 38.11 Btu per lb of water; the initial specific volume is $13.980 + 0.50(0.822) = 14.391$ cu ft per lb of dry air.

Fig. 9 illustrates the process diagrammatically. The energy equation for the process is

$$G h_1 = G h_3 + G(W_1 - W_3)h_{w3} + {}_1q_3$$

$$ {}_1q_3 = G[h_1 - h_3 - (W_1 - W_3)h_{w3}]$$

$$= \frac{20{,}000}{14.391} \times (43.072 - 34.09 - 0.00255 \times 38.07)$$

$$= 12{,}350 \text{ Btu per min.}$$

Solution b: From the ASHAE Chart. Two methods may be used to solve the problem by use of the psychrometric chart. The simpler is to use the region to the left of the saturation line (Fig. 8). From Point 1 draw a horizontal line on the chart

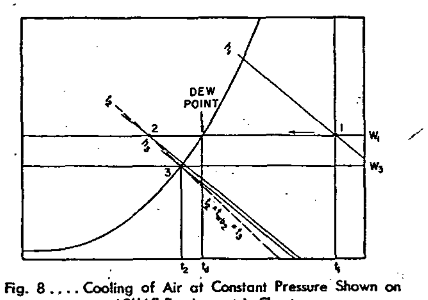

Fig. 8 . . . . Cooling of Air at Constant Pressure Shown on ASHAE Psychrometric Chart