W = weight of water vapor mixed with each pound of dry air, pounds.
h'_{fg} = latent heat of vaporization at t', Btu per pound.

Since this definition holds for any mixture of dry air and water vapor, the total heat of a mixture with a relative humidity of 100 per cent and at a temperature equal to the wet-bulb temperature (t') is

$$\Sigma' = c_{p_a}(t' - 0) + W_{t'} h'_{fg} \qquad (11)$$

By equating Equation 10 to Equation 11, the equation for the adiabatic saturation process, Equation 9a, follows. This demonstrates that the adiabatic saturation process at constant wet-bulb temperature is also a process of constant total heat. In short, the total heat of a mixture of dry air and water vapor is the same for any two states of the mixture at the same wet-bulb temperature. This fact furnishes a convenient means of finding the total heat of an air-vapor mixture in any state.

Example 5. Find the total heat of an air-vapor mixture having a dry-bulb temperature of 85 F and a wet-bulb temperature of 70 F.

Solution. From Table 5, for saturation at the wet-bulb temperature $W_{t'} = 0.01574$, and from Equation 11,

$$\Sigma' = c_{p_a}(70 - 0) + 0.01574\, h'_{fg} = 16.8 + 17.16 = 33.96$$

By considering the temperatures in Table 5 to be wet-bulb readings, the total heat of any air-vapor mixture may be obtained from the last column in the table.

Enthalpy

This total heat of an air-vapor mixture is not exactly equal to the true heat content or enthalpy of the mixture since the heat content of the liquid is not included in Equation 10. With the meaning of heat content in agreement with present practise in other branches of thermodynamics, the true heat content of a mixture of dry air and water vapor (with 0 F as the datum for dry air, and the saturated liquid at 32 F as the datum for the water vapor) is

$$h = c_{p_a}(t - 0) + W h_s = 0.24\,(t - 0) + W h_s \qquad (12)$$

where

h = the heat content of the mixture, Btu per pound of dry air.
t = the dry-bulb temperature, degrees Fahrenheit.
W = the weight of vapor per pound of dry air, pounds.
h_s = the heat content of the vapor in the mixture, Btu per pound.

The heat content of the water vapor in the mixture may be found in steam charts or tables when the dry-bulb temperature and the partial pressure of the vapor are known. Or, since the heat content of steam at low partial pressures, whether super-heated or saturated, depends only upon temperature, the following empirical equation, derived from Keenan's Steam Tables, may be used:

$$h_s = 1059.2 + 0.45\,t \qquad (13)$$

Substituting this value of h_s in Equation 12, the heat content of the mixture is

$$h = 0.24\,(t - 0) + W\,(1059.2 + 0.45\,t) \qquad (14)$$

An energy equation can be written that applies, in general, to various air-conditioning processes, and this equation can be used to determine the quantity of heat transferred during such processes. In the most general form, this equation may be explained with the aid of Fig. 1 as follows:

The rectangle may represent any apparatus, *e.g.*, a drier, humidifier, dehumidifier, cooling tower, or the like, by proper choice of the direction of the arrows.

In general, a mixture of air and water vapor, such as atmospheric air, enters the apparatus at 1 and leaves at 3. Water is supplied at some temperature, t_2. For the flow of 1 lb of dry air (with accompanying vapor) through the apparatus, provided there is no appreciable change in the elevation or velocity of the fluids and no mechanical energy delivered to or by the apparatus,

$$h_1 + E_h + (W_3 - W_1)\,h_2 = h_3 + R_c$$

or

$$E_h - R_c = h_3 - h_1 - (W_3 - W_1)\,h_2 \qquad (15)$$

where

E_h = the quantity of heat supplied per pound of dry air, Btu.
R_c = the quantity of heat lost externally by heat transfer from the apparatus, Btu per pound of dry air.
W_1 = the weight of water vapor entering, per pound of dry air.
W_3 = the weight of water vapor leaving, per pound of dry air.
h_2 = the heat content of the water supplied at t_2, Btu per pound.
$h_3 - h_1$ = the increase in the heat content of the air-water vapor mixture in passing through the apparatus, Btu per pound of dry air
$= 0.24\,(t_3 - t_1) + W_3\,(1059.2 + 0.45\,t_3) - W_1\,(1059.2 + 0.45 t_1)$

The net quantity of heat added to or removed from air-water vapor mixtures in air conditioning work is frequently *approximated* by taking the differences in total heat at exit and entrance.

For example, in Fig. 1, an *approximate* result is

$$E_h - R_c = \Sigma_3 - \Sigma_1 \qquad (16)$$

where

Σ_3 = the total heat of the air-vapor mixture at exit, Btu per pound of dry air.
Σ_1 = the total heat of the air-vapor mixture at entrance, Btu per pound of dry air.

From the definitions of *total heat* and *heat content*, it may be demonstrated that Equation 16 is exactly equivalent to Equation 15, when, and only when, $t'_3 = t'_1 = t_2$; *i.e.*, when the initial and final wet-bulb temperatures and the temperature of the water supplied are equal. The one process that meets these conditions is adiabatic saturation, and either equation will give a result of zero; for other conditions, Equation 16 is approximate but satisfactory for many calculations.

The following problems illustrate the application of these principles:

Example 6. Heating (data from Example 2). Assuming the water to be supplied at 50 F, the net quantity of heat supplied is, from Equation 15,

$$E_h - R_c = 0.24\,(70 - 0) + 0.000548 \times 0.45\,(70 - 0) + 0.005632\,[1059.2 + 0.45 \times 70 - (50 - 32)] = 22.90 \text{ Btu per pound of dry air.}$$