TABLE 4. SPECIFIC ENTHALPY OF DRY AIR[a] AT 29.921 IN. HG

Temp F t	Specific Enthalpy Btu per Lb h_a	Specific Heat $[c_p]_0^t$	Temp F t	Specific Enthalpy Btu per Lb h_a	Specific Heat $[c_p]_0^t$	Temp F t	Specific Enthalpy Btu per Lb h_a	Specific Heat $[c_p]_0^t$
−96	−23.035	0.2399	32	7.680	0.2400	160	38.454	0.2403
−64	−15.356	0.2399	64	15.363	0.2400	192	46.172	0.2405
−32	−7.678	0.2399	96	23.053	0.2401	224	53.903	0.2406
0	0.000	0.2400	128	30.749	0.2402	256	61.649	0.2408

[a]Prepared by John A. Goff.

enthalpy of dry air at standard atmospheric pressure (29.921 in. Hg) as computed from Equation 6 are given in Table 4.

Reference Point. It is desired to give some prominence to the choice of reference point. As energy, and therefore enthalpy, is purely relative, any convenient state can be selected at which to assign the value *zero* to specific enthalpy. The state chosen is 0 F, 29.921 in. Hg. Perhaps the only really valid argument for this particular choice is that, for ordinary calculations at, or near, atmospheric pressure, a very simple equation can be used, namely,

$$h_a = 0.24t \tag{7}$$

WATER VAPOR

Saturation Pressure. It is common knowledge that a substance like water can exist in at least three distinct phases, solid (ordinary ice), liquid and vapor; and that under certain conditions two or more phases can *coexist* in stable equilibrium. For example, steam having a quality of 98 per cent is a mixture of two coexisting phases, vapor and liquid, 98 per cent by weight being vapor and 2 per cent by weight, liquid. When two phases can coexist in stable equilibrium, each is said to be *saturated* with respect to the other.

One of the important problems of thermodynamics is to formulate the conditions for *saturation* in mathematical terms. The answer to the problem can be stated quite generally as equality, between the several coexisting phases, of (a) pressure, (b) temperature, (c) each component *chemical potential.*

In the case of a pure substance like water, containing a single component, there is only one component chemical potential; and this becomes identical with a thermodynamic property called *specific free enthalpy* denoted by the letter g (Btu per pound) and defined by the equation:

$$g = h - Ts$$

where

h = specific enthalpy, Btu per pound.
T = absolute temperature, degrees Fahrenheit.
s = specific entropy, Btu per pound per degree Fahrenheit.

To illustrate, *liquid* water at 212 F, 14.696 lb per square inch has a specific free enthalpy of 180.07 − 671.70 × 0.3120 = −25.90 Btu per pound. At the same temperature and pressure, water *vapor* has a specific

free enthalpy of 1150.4 − 671.70 × 1.7566 = −25.90 Btu per pound. The numerical data used in these calculations are to be found in the steam tables[1]. Since the two specific free enthalpies are equal *at the same temperature and the same pressure*, the two phases can coexist in stable equilibrium to form a saturated mixture and are therefore saturated with respect to each other.

But suppose that a different pressure had been assumed, the temperature being 212 F as before; for example, assume a pressure of 14 lb per square inch. The specific free enthalpy of the liquid phase will be practically the same as before, but that of the vapor phase will change from −25.90 to −32.84 Btu per pound, most of this change being due to change of entropy which, in the case of a vapor, depends markedly upon the pressure. Since the specific free enthalpies of the two phases are no longer equal, they cannot coexist in stable equilibrium and neither is saturated. As a matter of fact the vapor is superheated while the liquid is supersaturated.

From this analysis it will be seen that *to a given temperature T there corresponds a definite saturation pressure* p_s. This is also called the *vapor pressure* of the liquid or solid as the case may be. It will also be seen that a working definition of saturation can only be arrived at by application of the fundamental laws of thermodynamics.

Referring specifically to the vapor phase, if the actual pressure is *less* than the saturation pressure corresponding to the actual temperature, the vapor is said to be *superheated*; if it is *greater*, as it may well be under proper circumstances, the vapor is said to be *supersaturated.* Values of the saturation pressure of pure water are given in Table 6[2].

Specific Volume

Accurate values of the specific volume of water vapor at pressures equal or near the saturation pressure (for the given temperature) can be computed from Equation 1 since the second virial coefficient $A(T)$ is known with satisfactory accuracy. Usually, however, the desired information can be read directly from the steam tables. Values for the specific volume of the *saturated* vapor, v_g, are also listed in Table 8.

Specific Enthalpy

The zero-pressure specific enthalpy, as calculated by A. R. Gordon from spectroscopic measurements, has recently been corrected for distortion of the water molecules due to centrifugal forces. Best values at present available are listed in Table 5.

From the numerical values of mean specific heat, it is clear that for ordinary calculations the following simple relation may be used:

$$h_w^\circ = 0.444t + 1061 \tag{8}$$

Reference Point. The reference point for water has been chosen as *saturated liquid at 32 F* in conformity with usual steam table practice. In order to refer the zero-pressure values of specific enthalpy to this

[1]Thermodynamic Properties of Steam, by J. H. Keenan and F. G. Keyes, published by John Wiley & Sons, Inc., 1936, of which Table 8 is an abridgment.

[2]Strictly speaking the values listed in Table 6 are not values of p_s as labeled, but of p_s' (Equation 13b) with the Dalton Factor (DF) taken to be unity.