Table 6 . . . . Coefficients A, B, C Appearing in Equations 34, 35, 36, Maximum Values of Corrections Defined by Equations 34, 35, 36. Degree of Saturation at Which These Three Maxima Occur, $\bar{\mu}_m$. Maximum Value of Correction Defined by Equation 37, and Degree of Saturation at Which This Maximum Occurs, $\bar{\bar{\mu}}_m$

(Standard Atmospheric Pressure)

t (F)	A (ft³/lb$_a$)	B (Btu/lb$_a$)	C (Btu/F/lb$_a$)	$\bar{v}_{max}$ (ft³/lb$_a$)	$\bar{h}_{max}$ (Btu/lb$_a$)	$\bar{s}_{max}$ (Btu/F/lb$_a$)	$\bar{\mu}_m$	$\bar{\bar{s}}_{max}$ (Btu/F/lb$_a$)	$\bar{\bar{\mu}}_m$
96	0.0018	0.0268	0.00004	0.0004	0.0069	0.00001	0.4925	0.0015	0.3650
112	0.0042	0.0650	0.00009	0.0010	0.0155	0.00002	0.4878	0.0025	0.3632
128	0.0096	0.1439	0.00020	0.0022	0.0332	0.00005	0.4805	0.0040	0.3602
144	0.0215	0.3149	0.00042	0.0047	0.0693	0.00009	0.4691	0.0065	0.3557
160	0.0487	0.6969	0.00091	0.0099	0.1418	0.00019	0.4511	0.0106	0.3485
176	0.1169	1.636	0.00207	0.0207	0.2903	0.00037	0.4213	0.0179	0.3363
192	0.3363	4.608	0.00567	0.0451	0.6180	0.00076	0.3662	0.0333	0.3129

DETERMINATION OF THERMODYNAMIC PROPERTIES OF MOIST AIR FROM TABLE 2 DATA

The Table 2 data are given for either perfectly dry or completely saturated air. Convenient interpolation will yield magnitudes of the volume, enthalpy, or entropy of mixtures between these limits. The basis of this interpolation is the *degree of saturation*, denoted by the symbol μ. (Degree of saturation plays a role closely similar to steam quality in the steam tables.) Interpolation formulas are the following:

$$v = v_a + \mu v_{as} + \bar{v} \tag{31}$$

$$h = h_a + \mu h_{as} + \bar{h} \tag{32}$$

$$s = s_a + \mu s_{as} + \bar{s} + \bar{\bar{s}} \tag{33}$$

$$\bar{v} = \frac{\mu(1-\mu)A}{1 + aW_s\mu} \tag{34}$$

where

a = ratio of apparent molecular weight of dry air (28.966) to the molecular weight of water (18.016) = 1.6078.

$$\bar{h} = \frac{\mu(1-\mu)B}{1 + aW_s\mu} \tag{35}$$

$$\bar{s} = \frac{\mu(1-\mu)C}{1 + aW_s\mu} \tag{36}$$

$$\bar{\bar{s}} = 0.1579\ [(1 + \mu aW_s)\log_{10}(1 + \mu aW_s - \mu aW_s \log_{10}\mu) - \mu(1 + aW_s)\log_{10}(1 + aW_s)] \tag{37}$$

Table 6 gives magnitude of the factors A, B, and C, and also an indication of the maximum magnitudes attained by the various *correction terms* in Equations 34, 35, and 36. If moist air were a mixture of *perfect gases*, the terms $\bar{v}$, $\bar{h}$, and $\bar{s}$ would be zero. The term $\bar{\bar{s}}$ is a *mixing entropy change*, which is the consequence of partial-pressure variations with degree of saturation at fixed system pressure and exists even for perfect gases.

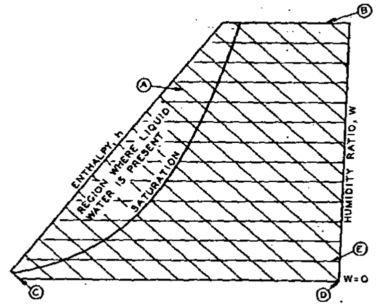
Note particularly that the corrections to direct interpolation based upon degree of saturation are small below about 150 F and usually they may be neglected. This gives quantitative substance to the common approximation that perfect-gas relationships are reasonably valid below roughly 150 F and at pressures near 1 atmosphere.

THE ASHRAE PSYCHROMETRIC CHART

A psychrometric chart is a graphical representation of the thermodynamic properties of moist air. Its distinctive features are selected to be of practical value in the graphical solution of engineering problems.

Two kinds of psychrometric charts are most used today. The first is plotted on rectangular coordinates of dry-bulb temperature and humidity ratio; the second is plotted on oblique-angle coordinates of enthalpy and humidity ratio. While the same problems can be solved with either chart, detailed computational procedures and language differ slightly. The ASHRAE Chart, a copy of which is included with THE GUIDE, is of the second type. This chart is based on the thermodynamic data of Goff and Gratch, as given in Table 2.

Fig. 4 is a skeleton sketch showing the oblique coordinate system of enthalpy and humidity ratio, which provides the framework upon which other curve families are plotted to give important properties. The h, W coordinates were chosen because steady-state energy and mass balances, as introduced in the beginning of this chapter, are expressible and solvable in terms of these two properties only. Restriction of the chart to a constant pressure of 1 standard atmosphere is conventional; actually the chart is usable for pressure variations up to roughly ±1 in. mercury from the standard.



A. Lines of constant h are straight, parallel and inclined at an oblique angle. The angle is chosen for convenience.
B. Top line is the maximum humidity ratio W to be considered.
C. This corner point is the enthalpy of dry air at the minimum dry-bulb temperature to be considered.
D. This corner point is enthalpy of dry air at maximum dry-bulb temperature to be considered.
E. Lines of constant W are straight, parallel, and horizontal.

Fig. 4 . . . . Basic Coordinates of ASHRAE Psychrometric Chart

The h, W oblique coordinates were first used in 1923 by Mollier,[10, 11] who also showed one way to modify the chart for various pressures.

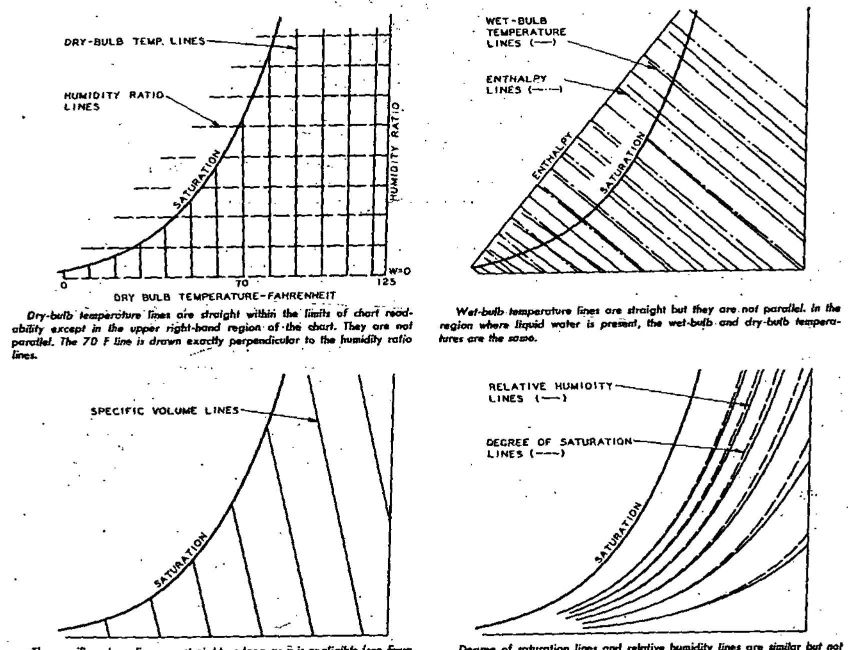
The scale units, coordinate angle, and range of the ASHRAE Chart have been chosen for convenience and reasonable accuracy. The temperature range 0 to 125 F covers the most-used range of air-conditioning problems. Similar charts can be drawn for other temperature ranges. The five additional curve families plotted on the chart are shown schematically in Fig. 5, and these families provide the necessary additional data to solve the usual types of problems.

An abridgment of the ASHRAE PSYCHROMETRIC CHART is shown as Fig. 6. A large chart is inside of the back cover.

The feature to be considered next is the enthalpy-humidity difference ratio, $(h_2 - h_1)/(W_2 - W_1)$, where the subscripts indicate a change from state 1 to state 2 on the chart. It is essential to recognize that mass and energy balances are formulated in terms of *net changes between defined states*; the detailed history or process path of a change is not involved. Graphical analysis of these mass and energy balances is indispensably aided by the use of *loci lines*, which are drawn to contain all possible locations of the two states being considered, state 1 and state 2, according to the particular overall conditions imposed upon the problem. These loci lines are commonly called *condition lines*, and in the ASHRAE Chart the slope of a condition line is given by the ratio $(h_2 - h_1) \div (W_2 - W_1)$. The protractor scale on the chart, used with drafting equipment for drawing parallel lines, permits either the setting of a desired condition-line slope or the numerical evaluation of this slope for different given problem data.

The region above and to the left of the saturation line on the ASHRAE Chart is a two-phase region giving equilibrium states when water is present either in both the liquid and the vapor phase or both the solid and the vapor phase. Humidity ratio here represents *total* water present (both phases) in pounds per pound of dry air. The three curve families in this region are enthalpy, humidity ratio, and temperature; the temperature lines are continuations of the wet-bulb lines, and the wet-bulb and dry-bulb temperatures are identical.

Moist air in the two-phase region always is saturated, and its vapor-phase humidity ratio is that for saturation at the prevailing temperature and pressure. The liquid or solid water present, expressed as pounds of liquid or solid per pound of dry air, is found as the *difference* between the humidity ratio



Dry-bulb temperature lines are straight within the limits of chart readability except in the upper right-hand region of the chart. They are not parallel. The 70 F line is drawn exactly perpendicular to the humidity ratio lines.

Wet-bulb temperature lines are straight but they are not parallel. In the region where liquid water is present, the wet-bulb and dry-bulb temperatures are the same.

The specific volume lines are straight as long as $\bar{v}$ is negligible (see Equation 31).

Degree of saturation lines and relative humidity lines are similar but not identical.

Fig. 5 . . . . Arrangement of Families of Curves on ASHRAE Psychrometric Chart