TECH TIP # 19

HEATING, AIRCONDITIONING & REFRIGERATION DISTRIBUTORS INTERNATIONAL

One of a series of dealer contractor technical advisories prepared by HARDI wholesalers as a customer service.

HOW TO FIGURE THE DENSITY OF THE AIR

A significant number of the computations executed in air conditioning work involve the use of the air density factor, or its reciprocal --- specific columns. It enables the dealer-contractor to convert from cubic feet (cu ft) to pounds (lb) per minute, hour, etc. or vice versa. It also enables him to make corrections to charts and tabular data for “other than standard conditions.”

The density value most frequently assigned air is 0.075 lb/cu ft or 13.34 cu ft/lb. But this value is of course valid only for what is termed standard air -- 29.921 in. mercury (Hg) barometric pressure, approximately 70º F dry bulb temperature and dry air (0% relative humidity).

To be technically exact, for any other set of conditions a new air density value should be used. An equation to calculate the density of air for any set of conditions can be derived from the basic gas equation --- Pv = RT.

where:
P = the pressure exerted by the gas
V = the specific volume (1/v equals density)
R = universal gas constant
T = absolute temperature of gas (460º plus F)

The density of air would be:

$$1/v_a = d_a = \frac{P_a}{R_a T}$$

where subscript (a) refers to dry air.

The density of water vapor (as an invisible gas) would be:

$$1/v_w = d_w = \frac{P_w}{R_w T}$$

where subscript (w) refers to water vapor.

The density or total weight per cu ft of the mixture of the two gases would be the sum of the above:

$$D_m = \frac{P_a + P_w}{R_a T + R_w T}$$

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Now that all known factors are substituted, adjusted, re-arranged, etc., we can arrive at the following practical formula:

$$Dm = \frac{1.326\,[B\text{-}0.38\,(RH)P_s]}{t + 460}$$

where B is the barometric pressure, in inches *Hg* (sum of $P_a + P_w$); P_s is the vapor pressure exerted with 100 percent *RH*, in inches *Hg* (values of P_s can be found in many texts -- Table 1 is a partial listing); *RH* is the relative humidity expressed as a decimal; and *t* is the dry bulb temperature.

Consider this example: find the density of air at 100º F, for a barometric pressure of 28.85 in *Hg* -- first for dry air (0% *RH*) and then for 60% *RH.*

For dry air, the term $0.38(RH)P_s$ is equal to zero, so:

$$d_m = \frac{1.326 \times 28.85}{100 + 460} \quad \text{or } d_m = 0.0683 \text{ lb/ cu ft}$$

For the case of 60% *RH* air, from Table 1 (page 3) at 100º F, P_s is equal to 1.933 in *Hg* (solid type).

Hence:

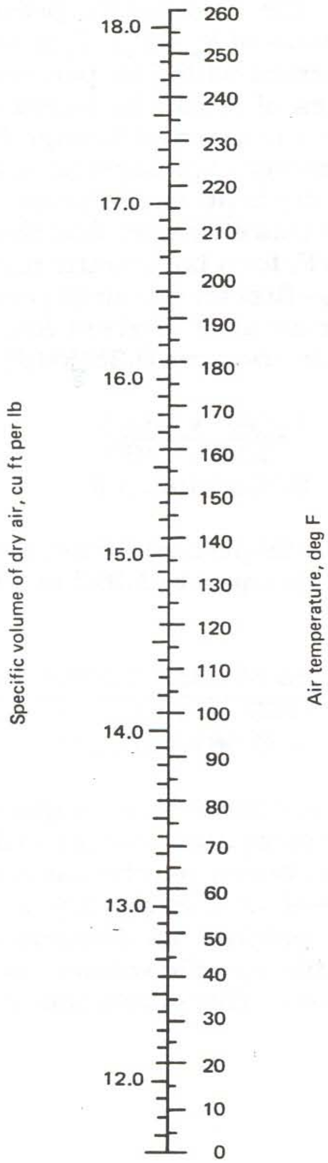
$$d_m = \frac{1.326\,[28.85 - 0.38\,(.60)1.933]}{100 + 460} \quad \text{or } d_m = 0.0673 \text{ lb cu ft}$$

The specific volume of an air-vapor moisture is frequently computed on a per lb of *dry* air basis (e.g. standard psychrometric chart). The reciprocal of the density of the 60 percent *RH* mixture as computed above would yield the specific volume on a per lb of mixture basis. This distinction should be noted.

Many times it is sufficient to assume dry air conditions exist---especially for heating-only problem solutions. In those instances the nomograph in Figure 1 can be used to find specific volume of air for air temperatures between 0 and 260º F.

Figure 1. NOMOGRAPH yields specific volume (reciprocal of air density) of dry air for dry bulb temperatures from zero to 260º F assuming standard barometric pressure.

TABLE 1 -- VALUES of saturated (water) vapor pressure (Ps) in air temperatures from 40 to 155º F. Use and density equation presented in text on opposite page.



Vapor pressure for saturated (Ps) air	
Air temperature:	in. Hg
40	.248
45	.300
50	.362
55	.436
60	.522
65	.622
70	.739
75	.875
80	1.032
85	1.214
90	1.422
95	1.661
100	**1.933**
105	2.244
110	2.597
115	2.996
120	3.447
125	3.956
130	4.527
135	5.168
140	5.884
145	6.683
150	7.572
155	8.561