the appropriate limits of relative humidity. Only average permeabilities (or permeances) are measurable directly in practical tests. However, if several average permeabilities at different relative humidities are known, and can be plotted as for the wet-cup and dry-cup tests shown in Fig. 3, it is possible to construct, by trial and error, a spot permeability curve which will satisfy the condition that the average height of the curve between the appropriate limits for each test must equal the value found in each test. Separate curves are required for each temperature so that a large number of permeance cup tests would be required to cover a range of conditions of both temperature and humidity.

Experience to date shows that the effect of temperature is quite moderate and, for some purposes, differences in temperature at which tests are run

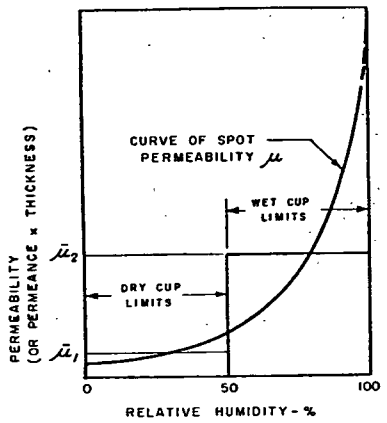

FIG. 3. RELATION BETWEEN DRY AND WET CUP TESTS AND THE SPOT PERMEABILITY FOR A MATERIAL SUCH AS WOOD

may be ignored. Corrections for temperature have been made with some success by the use of an equation based on activation energy[5] which states:

$$\mu = \mu_0 e^{-\frac{E}{RT}} \qquad (8)$$

where, in appropriate units,

μ_0 = permeability at $T = \infty$
R = gas constant
E = activation energy
e = Naperian base of logarithms = 2.718
T = absolute temperature.

Through the use of this equation, spot permeability curves for a variety of temperatures can be constructed from a curve for one temperature, provided only that two tests at different temperatures can be run, from which E, the activation energy, can be evaluated. In this way it becomes possible to describe the permeability of a material reasonably completely from the results of as few as five single tests at carefully selected conditions.

No method has yet been found, other than by direct testing for a particular set of conditions, of predicting the effective permeabilities for conditions of temperature gradient along with a humidity (or vapor pressure) gradient from data obtained under other conditions, even though this is the general situation in practice. A very considerable amount of information is available on the permeances and permeabilities of various materials, but these are frequently obtained at different conditions so that the results cannot be compared directly, nor do they often give a coverage of a range of conditions to permit construction of basic curves of spot permeability or permeance.

Since dry-cup and wet-cup tests are much easier to carry out than tests at intermediate humidities, many of the data available have been obtained in this way. In the absence of data obtained from tests duplicating the conditions of temperature and relative humidity in service the permeance of a piece of material may be judged adequately for many purposes if it is tested by both dry and wet methods. It is obvious that any statement of permeance of a specimen should include the conditions of test.

Method of test E96–53T of the *American Society for Testing Materials* describes procedures for testing for water vapor transmission of materials in sheet form under five different test conditions. These include the dry-cup and wet-cup methods, based on 50 percent relative humidity outside the cup, at either 73.4 or 90 F, and a fifth condition at an elevated temperature of 100 F. with relative humidities of 0 and 90 percent on either side of the sheet. Standard T448m-49 of the *Technical Association of the Pulp and Paper Industry* covers the determination of water vapor transmission of paper and paperboard, and calls for the dry-cup method at 73.4 F., based on 50 percent relative humidity outside the cup.

Unfortunately, there is no general agreement as yet to report results as coefficients of permeance, or of permeability where appropriate, as adopted in this chapter, or to use the same basic units. Test data are frequently reported in terms of weight transmitted per (unit area) (unit time). Such data may be called *water vapor transmission data* or WVT data and values are either high or low depending on the difference of vapor pressure chosen for the test. When this difference is known, WVT data can be converted to permeance, care being taken if conversion of the basic units (weight, area and time) is also required. The following formula applies:

$$\text{Permeance} = \frac{\text{WVT rating}}{\Delta p} \qquad (9)$$

where,

WVT rating = weight of vapor transmitted, grains per (sq ft) (hour).
Δp = vapor pressure difference in the test, in inches of mercury.
Permeance is expressed in perms.

Table 2 presents the conversion factors applicable to the commonly used units and test methods. Table 1 presents some data on typical building materials showing, in each case, the source and method and, where applicable, the thickness tested.

Water-proofed building papers are listed in *Federal Specifications* UU-P-147. May 24, 1948, according to water vapor resistance required as: