WATER VAPOR PERMEANCE OF ROOFING AND CONSTRUCTION MATERIALS

By William A. Kirn, RRC

Introduction

The fundamental expectation of any roofing system is that it keep the interior of the building, including the occupants, equipment, and other assets, dry. As a first approximation, a building owner or facility manager might only look at the ceiling tiles on the top floor of a building. If they are dry, the roof must be functioning properly. A slightly more sophisticated approach would be to inspect the underside of the roof deck looking for moisture to ensure that the building is watertight. However, roofing professionals fully understand that this oversimplification of water intrusion into the building envelope is fraught with a fundamental problem.

If one dissects any roofing composite, it is comprised of individual, discreet components that together have (hopefully) the necessary water resistance to maintain a dry building interior. In the laboratory evaluating roofing materials, water resistance is actually studied as the amount of water that travels through a roofing material, vis à vis the amount that is prevented from moving through. This idea captures the fundamental property of water vapor permeance or permeability.

What is Permeance? What is Permeability?

Permeance is defined in ASTM D-1079 as the rate of moisture vapor per unit area at a steady state through a membrane or assembly, expressed in ng/Pa.s.m^2 (grain/ft^2.hr.in.Hg). It is defined in terms of weight of water per hour moving through a one square meter (foot) membrane at a given saturation vapor pressure. (More about saturation vapor pressure later.) Simply stated, it is the rate that water vapor moves through a roofing or construction material given a specific set of test conditions.

There are numerous ASTM methods for determining permeance. Typical ones used in roofing are ASTM E-96 and ASTM D-1653. The ASTM E-96 method is specifically designed for single ply sheet materials such as EPDM, PVC, TPO, and other membranes. This method differs from D-1653 as the latter is designed for measuring the permeance of coatings. The method describes specific

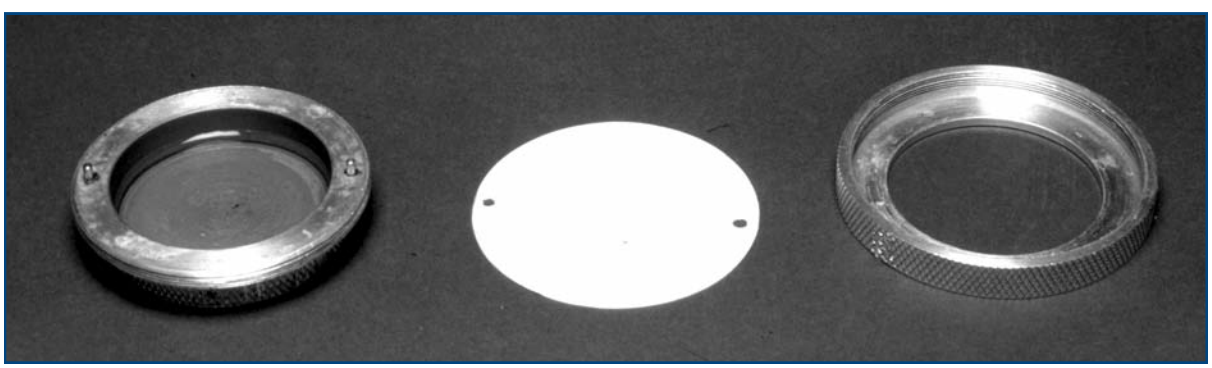

Figure 1: Typically, the membrane is affixed to the top of a cup and becomes the lid. Pictured is one type of cup used for these tests. Here a white, single-ply membrane is being tested in the assembly. The cup contains either water or desiccant (a granular material that "captures" water vapor in the air). The cup is then placed in a constant temperature and humidity environment.

techniques for preparing and casting the coating into a sheet that can be tested. Beyond this point, both methods are similar.

Typically, the membrane is affixed to the top of a cup and becomes the lid. *Figure 1* shows one type of cup used for these tests. Here, a white, single-ply membrane is being tested in the assembly. The cup contains either water or desiccant (a granular material that "captures" water vapor in the air). The cup is then placed in a constant temperature and humidity environment. The environment has a significantly different humidity than the inside of the cup.

Typical testing would have water in the cup and the surrounding environment having 50% relative humidity. This method is exemplified by ASTM E-96 Procedures B and BW. It can easily be seen that the vapor drive is from inside the cup (100% relative humidity) to the outside environment (50%). The method gets more complicated as the cup can be placed with the roofing membrane as the lid, so that the "head space" (the air inside the cup between the top of the water and the bottom of the membrane) has a relative humidity of 100%, but only water vapor is in contact with the roofing membrane. However, the test can also be run with the cup inverted (ASTM E-96BW) where liquid water is in contact with the membrane.

Figure 2 shows a different type of cup placed in the inverted position on a wire grid to allow air to pass freely underneath the membrane. After several hours to achieve equilibrium, the cup is weighed, and a plot of cup weight versus time is generated.

Figure 2 shows a different type cup placed in the inverted position on a wire grid to allow air to pass freely underneath the membrane. Each test will give slightly different results for the same material. After several hours to achieve equilibrium, the cup is weighed and a plot of cup weight versus time is generated. The slope of that curve is defined as "moisture (water) vapor transmission." Note that when this datum is presented in a manufacturer's product data sheet or laboratory report, it does not provide specific information about the test conditions. That is, the temperature of the test has a dramatic effect on the permeance of a roofing material, usually with higher permeance observed at higher temperature.

Cup Up or Cup Down?

Typically, roofing professionals are interested in keeping the building contents dry. Thus, their primary interest would be in a test in which liquid water is in contact with the roofing material, ASTM E-96BW. However, when considering the drying rate of a wet roof or the ability of an elastomeric coating to allow internal moisture vapor to escape from a roofing assembly or wall cavity, the test where water vapor is in contact with the membrane seems most suitable.

It Gets More Complex

The fundamentals of this test are relatively simple. However, to accurately report the data, some additional math is required and, unfortunately, the results can be confusing. The generated "raw data" must be normalized for a set of standard conditions based on the "vapor drive" of water at the specific test temperature. This is where the "saturation vapor pressure of water" factor is used and why the resulting unit of measure is comprised of the rate of water moving through a defined area of the membrane, grains/hour x ft^2 in Hg. ("in Hg" is inches of Mercury. These data are easily obtained from a chemical handbook.) However, when the term "perm" is used, it implies permeance of that material at its "as supplied" film thickness. However, if metric equivalents are used, the units of measure are grams/24 hours x m^2 x mm Hg. It is important that when comparing products, the specific test method, beyond ASTM E-96 (there are actually six variants of this test), the units of measure and the film thickness of the membrane be specified. The conversion relationship from English perm to metric perm is:

1 Perm (US) = 0.66gm/24hr x m^2 x mm Hg

Permeance versus Permeability

Often the terms "permeance" and "permeability" are used interchangeably. However, this is incorrect. Permeance does not normalize for the thickness of the membrane. Thus, it would be expected that the permeance of 60-mil thick EPDM is lower than its 45 mil analog. The term "permeability" normalizes the value for a specific thickness. For metric perms, it is normalized to one centimeter thickness. For English units, it is one inch thickness. Caution should be exercised by the user of this data, as it is easily possible to see permeability values of 0.1 Perms, even though the "as used thickness" (20 mils) may be considerably higher, 5.0.

Permeance of Typical Construction Materials

Listed below are measured permeance values for several typical roofing and construction materials:

Product	Method	Value, Metric Perms
#15 Asphalt Roofing Felt	E-96 BW	37.7 Perms
#30 Asphalt Roofing Felt	E-96 BW	22.2 Perms
Acrylic Coating (20 mil film, unweathered)	D-1653 BW	45.5 Perms
0.045 mil EPDM	E-96 BW	0.43 Perms
Commercial Underlayment ("Peel and Stick")	E-96 BW	0.05 Perms

Table 1: Permeance of Different Construction Materials

Does Permeance Change with Time?

Values reported in product technical data sheets are usually for new, unaged, unweathered materials. However, as these materials weather, their permeance may change slightly. At this point we wish to ignore such catastrophic effects as splitting, cracking, or the development of pinholes that were not visible when the material was installed. Studies conducted by Rohm and Haas have shown very little change in permeance of roofing materials after several thousand hours of accelerated weathering. One noteworthy exception is water-based coatings, such as asphaltic and non-asphaltic roof coatings, elastomeric wall coatings, or even latex house paints or acrylic latex caulks. Some background is required here. In order for these materials to be stable in the can or caulk tube, they contain very small quantities of dispersants, emulsifiers, and water miscible stabilizers and additives. These materials are inherently water sensitive and contribute to increased water permeance. However, after drying and brief exposure to water in the form of heavy dew or rain, these water-sensitive materials "leach out" of the membrane and the permeance actually drops significantly, often by an order of magnitude or more.

Breather Versus Non-Breather

Anyone familiar with GoreTex® fabric used to make ski apparel or camping equipment knows that the value of this material is its ability to "breathe" or allow moisture vapor (body perspiration) to move through the fabric, while still blocking out "bulk water" in the form of rain or snow. Roofing and construction materials can also be categorized in a similar fashion, with typical threshold for non-breather at less than 0.5 Perms. Vapor retarders in the form of prefabricated sheets or specialty coatings (butyl chemistries are excellent vapor retarders) are often used in refrigeration and cold rooms where reverse vapor drive occurs.

Permeance, Ponding Water, and Adhesion

When evaluating roof coating performance, the term "ponding water resistance" is often used to describe coatings that adhere well in "ponded" situations,—i.e., where water stands on the roof for extended periods of time. Ignoring the NRCA recommendation that roofs be free of ponding water within 48 hours of precipitation, permeance is often considered as a measure of "ponding water resistance." Unfortunately, permeance is merely a material science property and does not necessarily correlate to the real product requirement, wet adhesion. Thus, regarding ponding water resistance, the question should be reframed to determine the wet adhesion of the coating to the roofing substrate. Obviously, the wet adhesion will vary based on the substrate. When evaluating multiple alternative roofing materials that must adhere under ponded water condition, the wet adhesion to that specific substrate becomes most important.

Conclusion

While the concept of permeance seems rather simple, the actual data can be confusing. However, if properly educated to ask the correct questions, the roofing professional can glean valuable information about specific roofing materials. This information can then aid in the proper roof design and selection of materials that can ensure a long service life and complete satisfaction of the building owner. ■

Suggested Readings and Bibliography:

1. "Terminology Update" *ASTM Standardization News*, May 1988.
2. "Water Vapor Permeability Measurements of Common Building Materials," *ASHRAE Transactions*, 1992 Vol. 98.
3. "Water Vapor Sorption Measurements of Common Building Materials," *ASHRAE Transactions*, 1992 Vol. 98.

About the Author

Bill Kirn

Bill Kirn has been employed by Rohm and Haas Company since 1973 and is currently a Market Manager for Roof Coatings in the North American Coating Business Team. Prior to moving into marketing, he spent 22 years in research, developing improved acrylic products for a wide range of construction applications. He holds four U.S. patents for a wide range of chemical applications. Bill is an RRC and on the faculty of RIEI. He is Secretary of the Polymeric Materials Subcommittee of ASTM D-08 (Roofing and Waterproofing) and a member of E-06 (Building Performance). Kirn currently chairs the Technical Committee of the Cool Roof Rating Council and is a member of CSI and the Roof Coating Manufacturers Association. He holds a bachelor's degree in Chemistry from Temple University, a masters in Organic Chemistry from St. Joseph's University, and an MBA from Temple University.