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Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment[1]

This standard is issued under the fixed designation E2556/E2556M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification is limited to vapor permeable flexible sheet materials which are intended to be mechanically attached and are generally installed behind the cladding system in exterior walls.

1.2 This specification is limited to the evaluation of materials and does not address installed performance. Although the fastening practices (type of fastener, fastening schedule, etc.) may affect the installed function of these materials, they are not included in this specification.

1.3 This specification does not address integration of the water-resistive barrier with other wall elements. The topic is addressed in more detail in Practice E2112 and Guide E2266.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D226/D226M Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing

D779 Test Method for Determining the Water Vapor Resistance of Sheet Materials in Contact with Liquid Water by the Dry Indicator Method

D828 Test Method for Tensile Properties of Paper and Paperboard Using Constant-Rate-of-Elongation Apparatus

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D4869/D4869M Specification for Asphalt-Saturated Organic Felt Underlayment Used in Steep Slope Roofing

D5034 Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)

E96/E96M Test Methods for Water Vapor Transmission of Materials

E631 Terminology of Building Constructions

E1677 Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls

E2112 Practice for Installation of Exterior Windows, Doors and Skylights

E2128 Guide for Evaluating Water Leakage of Building Walls

E2136 Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings—Durability

E2266 Guide for Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion

G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

2.2 *Other Standards:*

AATCC Test Method 127 Water Resistance: Hydrostatic Pressure Test[3]

CGSB CAN2-51.32.M77 Sheathing Membrane, Breather Type[4]

Federal Specification UU-B-790a Federal Specification Building Paper, Vegetable Fiber (Kraft, Waterproofed, Water Repellent and Fire Resistant)[5]

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[1] This specification is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.55 on Performance of Building Enclosures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709-2215, http://www.aatcc.org.

[4] Available from Canadian General Standards Board (CGSB), 11 Laurier St., Phase III, Place du Portage, Gatineau, Quebec K1A 0S5, Canada, http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb.

[5] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

TABLE 1 Requirements for Water Resistive Barriers

Test Requirement	Specimen Type	Test Method	Minimum Performance Requirements	
			Type I	Type II
Dry tensile strength or dry breaking force (choose 1)	(1) as manufactured and (2) aged in accordance with A1.2	Test Method D828 for paper and felt materials, or	3500 N/m [20 lb/in.] minimum (machine and cross direction)	
		Test Method D882 for polymeric materials, or	3500 N/m [20 lb/in.] minimum (machine and cross direction)	
		Test Method D5034 (Grab Method)	178 N [40 lbf] minimum (machine direction) 156 N [35 lbf] minimum (cross direction)	
Water resistance test (choose 1)	(1) as manufactured and (2) aged in accordance with A1.2	Test Method D779, or	10 min minimum	60 min minimum
		Water Resistance Ponding Test (A1.1), or	No water shall penetrate through the membrane in 120 min	not applicable
		AATCC Test Method 127 except that the specimens shall be held at a hydrostatic head of 55 cm [21.6 in.]	not applicable	No leakage is permitted to the underside of any specimen in 5 h
Water vapor transmission test	as received	Test Methods E96/E96M (Dessicant Method)	290 ng/(Pa · s · m^2) (5 perms) minimum	
Pliability test	as received	see A1.3	The material shall not crack when bent over a 1.6 mm [1⁄16-in.] diameter mandrel at a temperature of 0 °C [32 °F]	

TAPPI T-410 Test Method for Grammage of Paper and Paperboard (Weight Per Unit Area)[6]
UBC Standard 14-1 Kraft Waterproof Building Paper[7]
UBC Standard 32-1 Asphalt Saturated Rag Felt[7]
ICC-ES Acceptance Criteria AC38 for Water-Resistive Barriers[8]

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this specification, refer to Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *felt-based barrier, n*—asphalt-saturated organic felts that comply with Specification D226/D226M and are intended for use as water-resistive barriers.

3.2.2 *paper-based barrier, n*—building papers composed predominantly of sulfate pulp fibers that comply with Federal Specification UU-B-790a and that are intended for use as water-resistive barriers.

3.2.3 *polymer-based barrier, n*—plastic sheet materials for use as water-resistive barriers. These materials are generally referred to as a housewrap or building wrap. These materials can be perforated with small holes or may be non-perforated, composed of films or non-woven materials.

3.2.4 *Type I WRB, n*—water-resistive barrier with base-level water resistance (see Table 1).

3.2.5 *Type II WRB, n*—water-resistive barrier with enhanced water resistance (see Table 1).

3.2.6 *Water-Resistive Barrier (WRB), n*—a material that is intended to resist liquid water that has penetrated the cladding system.

NOTE 1—Wall assemblies often include two lines of defense against rain water ingress. The cladding serves as the first line of defense and the water-resistive barrier as the second line of defense

NOTE 2—Water-resistive barriers are sometimes referred to as weather resistant barriers or sheathing membranes.

4. Classification

4.1 This specification covers vapor permeable flexible sheet materials that are classified as Type I and Type II, which are determined by the degree of water resistance. The water-resistive barrier material composition shall determine the specific test method used to measure physical and mechanical properties (see Table 1). Appendix X1 provides explanatory information on the physical and mechanical property test methods.

5. Materials and Manufacture

5.1 Description of the material composition and structure shall be made available upon request.

5.1.1 Descriptions of the materials shall include roll weight and dimensions.

5.1.2 Descriptions of the material composition shall include linear density (basis weight). Basis weight shall be measured using TAPPI T-410.

6. Performance Requirements

6.1 All products seeking compliance with this specification shall conform to the minimum performance requirements listed in Table 1. Sampling and specimen size shall be in accordance with the referenced test methods. If not otherwise specified in the referenced test method, a minimum of five specimens shall be tested and all specimens shall meet the minimum performance requirements.

NOTE 3—The laboratory accelerated-ultraviolet (UV)/condensation exposure procedure specified in A1.2 is not intended to represent a specific

[6] Available from Technological Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Suite 115, Peachtree Corners, GA 30092, http://www.tappi.org.

[7] Uniform Building Code (UBC) information is available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.

[8] Available from the ICC Evaluation Service (ICC-ES), 3060 Saturn Street, Suite 100, Brea, CA 92821, http://www.icc-es.org.

service exposure. It is a method of comparing the stability of materials under consistent laboratory exposure conditions.

7. Other Requirements

7.1 The material shall not adhere to itself to an extent that will cause tearing or other damage on unrolling.

8. Sampling

8.1 The product to be tested for conformance to this specification shall be taken directly from a randomly selected roll which is representative of commercial product.

8.2 The specimens shall be cut from the interior of the sample roll so that no specimen edge is nearer than 75 mm [3 in.] to the original sample edge.

8.3 Unless otherwise stated, all specimens to be tested shall be conditioned for a minimum period of 40 h at 23 ± 2 °C [73.4 ± 4 °F] and 50 ± 5 % relative humidity (RH).

9. Marking and Labeling

9.1 The finished product shall be marked or labeled with product identification.

9.2 Installation instructions shall be provided and shall include as a minimum the maximum weather exposure time allowed before cladding shall be installed, type of mechanical fastener and minimum fastener spacing to attach the WRB to the underlying structure, and lapping and taping requirements. This information shall be recorded and reported in any applicable test report or product rating.

10. Keywords

10.1 building felt; building paper; building wrap; housewrap; sheathing membrane; water-resistive barrier; weather-resistive barrier

ANNEX

(Mandatory Information)

A1. TEST METHODS AND PRACTICES

A1.1 Water Resistance Ponding Test

A1.1.1 *Scope*—This is a test method intended for evaluating the water resistance of a Type I water-resistive barrier.

A1.1.2 *Significance and Use*—This method is for use with water-resistive barriers.

A1.1.3 *Procedure:*

A1.1.3.1 Five specimens will be chosen at random from the material supplied.

A1.1.3.2 A ring shall be constructed with a sample of the membrane fastened between two 200-mm [8-in.] diameter aluminum rings using a rubber-type gasket. The membrane shall be placed between the rings and cupped to permit a depth of 25 mm [1 in.] of water to be exposed to 16 000 mm^2 [25 in.^{2}] of its surface.

A1.1.3.3 Distilled water shall be poured into the cylinder to a depth of 25 mm [1 in.].

A1.1.3.4 The ring shall be raised by 250 mm [9.8 in.] above a sheet of plain kraft paper placed underneath the membrane to aid in monitoring any passage of water.

A1.1.3.5 The membrane shall be maintained at constant conditions of temperature (23 ± 2 °C [73.4 ± 4 °F]) and RH (50 ± 5 %) and be inspected at frequent intervals over a period of 2 h for water passage through the barrier material.

A1.1.4 *Report:*

A1.1.4.1 The report shall include the following:

(1) The material and the side tested.
(2) The material sampling procedure used.
(3) Pass/fail test results for each specimen tested.
(4) Any modification to the method.

A1.1.5 *Precision and Bias*—No information is presented about either the precision or bias of this test method for evaluating water resistance since the test result is nonquantitative.

A1.2 Accelerated Aging (UV Exposure and Cyclic Drying/Wetting)

A1.2.1 *Scope*—This practice is used to condition samples of water-resistive barriers to evaluate degradation of performance due to accelerated aging (UV exposure and dry/wet cycling).

A1.2.2 *Significance and Use*—This practice is not intended to represent a service exposure. It is a method of comparing the stability of materials under consistent laboratory exposure conditions.

A1.2.3 *Procedure:*

A1.2.3.1 Three samples shall be conditioned at 23 ± 2 °C [73 ± 4 °F] and 50 ± 5 % RH for a minimum of 40 h. One sample shall be used for preparing unexposed specimens as a control. Two samples shall be exposed to UV radiation, followed by exposure to drying and wetting cycles in accordance with A1.2.3.2 of this specification.

A1.2.3.2 Two samples shall be exposed to fluorescent UVA-340 lamps in a fluorescent UV condensation apparatus operated in accordance with Practice G154, Cycle 1. The samples shall be exposed for a duration of 2 weeks (336 h). UV radiation exposure shall be directed on the sample surfaces that will be exposed to sunlight in normal applications.

A1.2.3.3 Three specimens shall be cut from each of the samples that have been exposed to UV radiation and subjected to further accelerated aging consisting of 25 cycles of drying and soaking as follows:

(1) Oven drying at 49 °C [120 °F] for 3 h, with all surfaces exposed.

(2) Immersion in room-temperature (23 ± 2 °C [73 ± 4 °F]) water for 3 h, with all surfaces submerged.

(3) After removal from the water, specimens shall be blotted dry, then air-dried for 18 h at a 23.8 ± 2.8 °C [75 ± 5 °F] room temperature, with all surfaces exposed.

A1.3 Pliability

A1.3.1 *Scope*—This is the test method intended for evaluating the pliability of a water-resistive barrier

A1.3.2 *Significance and Use*—This method is for use with water-resistive barriers

A1.3.3 *Procedure:*

A1.3.3.1 Five specimens will be chosen at random from the material supplied.

A1.3.3.2 Each specimen is bent 180 ± 5° over a 1.6 mm [1⁄16 in.] mandrel in 2 ± 1 s.

A1.3.3.3 The specimen and mandrel shall be maintained at constant conditions of temperature (0 ± 2 °C [32 ± 4 °F]) during the test procedure.

A1.3.4 *Report:*

A1.3.4.1 The report shall include the following:

(1) The material tested.

(2) The material sampling procedure used.

(3) Observations of any visual cracking.

(4) Any modification to the method.

A1.3.5 *Precision and Bias*—No information is presented about either the precision or bias of this test method for evaluating pliability since the test result is non-quantitative.

APPENDIXES

(Nonmandatory Information)

X1. EXPLANATORY INFORMATION ON MECHANICAL AND PHYSICAL TEST METHODS

INTRODUCTION

X1.1 There are a number of attributes of WRBs that should be considered in their selection. These include water resistance, water vapor permeance, air resistance, durability[9] compatibility with other materials, cost, installation challenges, and more. There are three different base materials that make up Type I and II water-resistive barriers. These base materials are felt, paper, and polymeric materials. Within North America, each base material has been historically evaluated using test methods that each respective base material industry recognized as most applicable or appropriate for material characterization. These test methods, while providing distinction with a given base material, are not always transferable between base material types. Because the goal of a single set of test methods that can be used to accurately evaluate the comparable critical performance properties of all WRBs is not attainable at this time, this specification is envisioned as a first step towards that goal. Appendix X1 describes additional information about the test methods prescribed in this specification and their specificity to material composition.

TENSILE STRENGTH

X1.2 Although tensile strength does not directly measure field performance of a WRB, it may indicate durability of materials that are subjected to repetitive straining and stressing. The test methods used to test different materials differ primarily in the initial grip separation and the rate of strain of the test. Test Method D828, the test method used for paper and felt-based materials, prescribes an initial grip separation of 180 mm [7 in.], and a separation (strain) rate of 25 mm/min [1 in./min]. Test Method D882, used for polymeric materials, prescribes an initial grip separation, and rate of strain which are dependent on the percent elongation at break of the material.

RESISTANCE TO LIQUID WATER

X1.3 The most fundamental property of a WRB is its resistance to the passage of liquid water, typically originating as precipitation. Test methods commonly used for water resistance were developed by the paper and textile industries for applications in such things as packaging and tarpaulins and bear limited resemblance to the function that WRBs play in building-wall assemblies.

X1.3.1 Test methods and code requirements.

X1.3.1.1 Water resistance of WRBs is commonly measured in the United States by three test methods that are referenced, directly or indirectly, in building codes. The three methods are AATCC Test Method 127 (“hydrostatic pressure test”), some variation of Test Method D779 – Water Resistance of Paper, Paperboard, and Other Sheet Materials by the Dry Indicator Method (“boat test”), or the water resistance ponding test developed by the Canadian Construction Materials Center (CCMC). WRBs evaluated by the CCMC water resistance ponding test are subjected to water for 2 h at a depth of 25 mm [1 in.].[10]

X1.3.1.2 Codes used in the United States typically allow #15 asphalt saturated felt, conforming to Specification D226/D226M, prescriptively or Grade D asphalt treated kraft paper (10 min water resistance) under some variation of Test Method

[9] For more information see Guide E2136.

[10] The CGSB offers a Certification Program for Breather Type Sheathing Membrane based on standard CGSB CAN2-51.32.M77—Sheathing, Membrane, Breather Type. For information, contact the Conformity Assessment Officer at CGSB’s Certification Services - Products and Services.

D779. Specification D226/D226M covers felts both with and without perforations, but only the non-perforated type is referenced in the IBC for use as a WRB. Other materials, including polymeric housewraps, are qualified by testing and reporting under ICC-ES Acceptance Criteria AC38.

X1.3.1.3 Felt and paper-based materials are tested for water resistance within this specification by Test Method D779 "the boat test." This test is performed by measuring the amount of time it takes for water to diffuse through the material and affect an indicator dye when the opposite side is in full contact with water. The 1997 UBC Standard 14-1, Kraft Waterproof Building Paper, is based on Federal Specification UU-B-790a (February 5, 1968). UBC Standard 14-1 does not describe the test protocol but simply states in a footnote "approved test methods shall be used." The "boat test" from UU-B-790a was incorporated into Test Method D779 and is referenced in ICC-ES Acceptance Criteria AC38 as one of the alternate tests applicable to polymer-based water-resistive barriers. This test method is sensitive for both vapor and liquid-transfer through the sample. As stated in Section 4.1 of Test Method D779, "The dry indicator used in this test method is so strongly hygroscopic it will change color in a moderate- to high-humidity atmosphere without contacting liquid water. It will also change in contact with liquid water. This test method, therefore, measures the combined effect of vapor and liquid transmission. For test times up to approximately 30 s, liquid transudation rate is dominant and this test method can be considered to measure this property. As test times exceed 30 s, the influence of vapor-transmission rate increases and this test method cannot be regarded as a valid measure of liquid."

X1.3.1.4 Polymer-based materials are tested for water resistance within this specification by three different tests; AATCC Test Method 127 the "hydrostatic pressure test, the "water resistance ponding test" and Test Method D779.

(1) The "hydrostatic pressure test," "water column test," or, technically, AATCC Test Method 127, is listed in ICC-ES Acceptance Criteria AC38 as an alternate test for polymer-based materials. This test measures the hydrostatic pressure head at which three drops of water can be forced through a material specimen. Manufacturers of these types of membranes use a water column test. This involves sealing a sample of membrane to the base of a hollow column. Water is then poured into the column and the height of water over time is measured until water is observed on the dry side of the membrane. The pressure at penetration is recorded. Alternatively, the test can be run by maintaining a specific pressure of water above a sample and measuring the time for three drops of water to penetrate. ICC-ES Acceptance Criteria AC38 recognizes polymer-based WRBs that withstand a hydrostatic pressure of 55 cm [22 in.] for 5 h as equivalent to having a 60 min rating by Test Method D779. Non-perforated polymeric membranes generally perform better than building papers in this test because of the small pores in the membrane and the better water-saturated strength of the membrane. Other housewrap products, such as perforated polyolefin membranes, usually fall somewhere between sheathing papers and non-perforated polymeric membranes in terms of vapor permeability and resistance to liquid water (**1**).[11] The properties of these products will vary with the size and number of holes that are perforated though the base sheet. Resistance to liquid water of perforated products will usually decrease as the vapor permeance increases.

(2) The water resistance ponding test is described in CCMC Technical Guide for Sheathing, Membrane, Breather-Type, Masterformat Section 07102 (Technical Update July 7, 1993), Section 6.4.5, in which a cylindrical bowl of the sample material is filled with 25 mm [1 in.] of water and observed for 2 h. To pass the test, no seepage can be observed below the sample. The Guide states that it is applicable to Breather-Type Sheathing Membranes, which are "polyethylene-based or polypropylene-based, woven or non-woven."

(3) The Test Method D779 water resistance test is also used to evaluate polymeric water resistive barriers as described in X1.3.1.3."

X1.3.2 *Typical Test Results*—Unexposed material: In a type of test where pressure is not a factor, asphalt-saturated felt typically and significantly outperforms asphalt-saturated kraft paper. With high pressures, asphalt-saturated kraft paper typically slightly outperforms asphalt-saturated felt. This may be because kraft paper has a tighter matrix than felt, thus performing better under pressure. Felt, however, has more asphalt, thus resisting migration of water longer under low pressure. It is well accepted that unperforated polymer WRBs perform well under higher pressure compared to cellulose-based WRBs. However, the pressure at which even the least water-resistant WRB failed a hydrostatic test 6000 Pa [0.87 lbf/in.^{2}] is equivalent to the force of a 320 kph [200 mph] wind (**2**). Most low-rise residential windows are designed to withstand a water-penetration pressure equivalent to a wind speed of 50 to 80 kph [30 to 50 mph]. An 80 kph [50 mph] wind speed is equivalent to approximately 300 Pa [0.04 lbf/in.^{2}]. Relatively high performance of polymeric WRBs under high hydrostatic pressures may be impressive but not necessarily indicative of a property required to fulfill their intended function.

X1.3.3 *Resistance to Liquid Water: Aged Material*—There is no test information in the literature about comparative water resistance of WRBs after prolonged exposure to water, UV light or to wet/dry cycling. Under ICC-ES Acceptance Criteria AC38, weathering by UV light exposure and wet/dry cycling is required of polymeric WRBs if they are tested for water resistance using AATCC Test Method 127, Section 6.4.5 of CCMC 07102 or Test Method D779. Current codes do not require paper or felt based products to be evaluated after UV exposure or accelerated aging. Polymeric WRB manufacturers typically limit exposure of their products prior to cladding.

WATER VAPOR PERMEANCE

X1.4 Conventional wisdom has been that it is important for a WRB to be water-vapor permeable so as to allow drying of water from the wall cavity. Water can exist in a wall cavity

[11] The boldface numbers in parentheses refer to a list of references at the end of this standard.

from any number of sources including initial construction moisture, seasonal condensation of water vapor within a wall assembly, condensation of vapor from air leakage or incidental water leakage as defined in Guide E2128. The optimum level of vapor permeance will, however, be dependent on the wall system, the climate in which it is built, and the interior conditions of the building structure. The appropriate level of permeability for specific climates and wall designs is the subject of current building science research. The vapor permeability requirement in this specification is consistent with Grade D water-resistive barriers and vapor permeable membrane definition in the International Building Code and International Residential Code.[12]

X1.4.1 *Test Methods and Code Requirements:*

X1.4.1.1 In North America, the typical tests for the measurement of permeance and water vapor transmission rate (WVT) are defined in Test Methods E96/E96M. Permeance[13] is the typical measurement of the performance of a WRB for passage of water vapor. In the United States, permeance has been typically expressed in perms. 1 perm = 1 grain/(ft^2•h•in Hg). In SI, permeance is measured in ng/(s•m^2•Pa), and 1 perm is equal to 5.72 x 10-8 g/(s•m^2•Pa).

X1.4.1.2 Permeance is often confused with permeability,[13] which is permeance per unit thickness, or with water vapor transmission rate[14] (WVT), measured in grains/(h•ft^2) and (g/h•m^2), which does not include unit vapor pressure difference.

X1.4.1.3 To add even more confusion, Test Methods E96/E96M includes two basic methods (dessicant method and water method) and two variations include service conditions with one side wetted and service conditions with low humidity on one side and high humidity on the other. In accordance with Test Methods E96/E96M: "Agreement should not be expected between results obtained by different methods."

X1.4.1.4 Although WVT, is not the typical measure of vapor permeance, both ICC-ES Acceptance Criteria AC38 and UBC Standard 14-1 require a minimum average WVT of "35 g/(m^2 • 24h)" measured by Test Methods E96/E96M Desiccant Method. The National Building Code of Canada requires permeance of >170 ng/Pa • s • m^2 (3 perms). Without knowing the vapor pressure difference under which the test was conducted, these permeance and WVT cannot be directly compared.

X1.4.1.5 Because of common misuse of terminology and the fact that competing WRBs are typically tested for either WVT or permeance, and one or the other is reported, performance comparisons are difficult. See Moisture Control in Buildings (**3**) for a detailed discussion of the challenges of defining vapor permeance for WRBs.

X1.4.1.6 In ICC-ES Acceptance Criteria AC38, there is no requirement for permeance; however, there is a requirement for maximum or minimum water vapor transmission, referencing Test Methods E96/E96M, Desiccant Method. Unfortunately, the determination of water vapor transmission is only an intermediate step in the calculation of permeance as required by the "Report" section of Test Methods E96/E96M. Water Vapor Transmission measurements require the addition of the vapor pressure difference under which the measurement was obtained to calculate permeance, which is the accepted measurement of the performance of a WRB membrane for passage of water vapor.

X1.4.1.7 In some cases, the permeance of a WRB varies with RH, temperature, and vapor pressure (**3**). Saturated materials typically perform differently than dry materials. Wet-dry cycling, as required in CGSB CAN2-51.32.M77, also changes the permeance of WRBs. Establishing the hypothetical service condition under which the permeance of a WRB would be most critical is a challenge that has yet to be met.

PLIABILITY

X1.5 Pliability of WRBs is assessed to determine their suitability to be installed and conform to building details without cracking or damage.

ACCELERATED AGING

X1.6 WRBs are tested both in the as-manufactured state and after accelerated aging by exposure to UV radiation, moisture, and elevated temperature followed by repeated cycles of oven drying and immersion in water. This is intended to demonstrate the material's change in performance as a a result of laboratory accelerated weathering conditions.

X1.6.1 ICC-ES Acceptance Criteria AC38 has a specific UV exposure cycle: "Light from UV sun lamps for 210 h (10 h per day for 21 days). Lamps and enclosure shall be adjusted so the specimen temperature is between 57 °C and 60 °C [135 °F and 140 °F]. Sunlamp bulbs shall be General Electric Type H275 RUV (275 W) or equivalent bulbs, providing UV characteristics of 5.0 W/m^2 irradiance at a wavelength of 315 to 400 nm at 1 meter." This UV exposure procedure was replaced in this specification because the lamps specified within ICC-ES Acceptance Criteria AC38 are no longer generally available.

X1.6.2 Accelerated aging is simulated by laboratory accelerated weathering followed by repeated cycles of oven drying and immersion in water. In service there may be other exposures which cause deterioration in the properties of WRBs, including exposure to surfactants, or incompatible construction sealants and caulks. This specification does not include test methods to address these issues as no standard industry tests are currently available.

[12] The International Building Code and the International Residential Code are available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.

[13] Test Methods E96/E96M, quoted from C168 Terminology Relating to Thermal Insulating Materials, defines water vapor permeance as "the time rate of water vapor transmission through unit area of flat material of unit thickness induced by unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions."

[14] Test Methods E96/E96M, quoted from C168 Terminology Relating to Thermal Insulating Materials, defines water vapor transmission rate as "the steady water vapor flow in unit time through unit area of a body, normal to specific parallel surfaces, under specific conditions of temperature and humidity."

X2. SELECTION AND USE OF WATER RESISTIVE BARRIERS

X2.1 A critical component in the long-term performance of a drainage wall is the WRB. Although a number of terms are used to describe this building material, the term "water-resistive barrier" has been selected because it has predominated in U.S. building codes in recent decades. WRBs are typically integrated with flexible flashings at penetrations to provide a positive connection to penetrating wall components, such as doors and windows. Thus, WRB performance is critically important in maintaining the integrity of the window/wall interface. WRBs must also withstand the rigors of exposure to sun, wind, and precipitation prior to installation of cladding, a period that can stretch into months, but no WRB can be expected to survive extended exposure undamaged (see footnote, Table 1). Water from leaks originating at windows and doors often results in damage to the underlying structure only after it damages or ultimately breaches the WRB at some location near the door or window.

X2.2 In a drainage wall cladding is intended to provide a substantial and primary barrier to water originating as precipitation. However, joints, discontinuities, minor damage or extreme weather conditions may result in limited amounts of water penetrating the cladding. That water is provided a means to flow by gravity to the exterior or evaporate before damaging water-sensitive materials. Drainage to the exterior from a WRB is typically facilitated by the use of weep holes, weep screeds or simply freely-draining terminations at the base of walls. A WRB is typically not accessible and therefore is expected, along with associated flashings, to remain functional for the service life of the building cladding system.

X2.3 Although the Exterior Wall Covering chapters of both the 2006 International Building Code (Section 1402.2) and the 2006 International Residential Code (Section R703.2) list asphalt saturated felt prescriptively as an approved WRB, the Gypsum Board and Plaster sections of the International Building Code and International Residential Code require a "water-resistive vapor-permeable barrier with a performance[15] at least equivalent to two layers of Grade D paper" over wood-based sheathing, and the 1998 California Building Code (Section 2506.04) requires a WRB that "shall include two layers of Grade D paper." The origin and theory behind this requirement is described in the 1997 Handbook to the Uniform Building Code: 2506.4 Weather-resistive barriers. The code requires a weather-resistive barrier to be installed behind exterior plaster for the reasons discussed in the previous provisions of Section 1402. Furthermore, the code requires that when the barrier is applied over wood-base sheathing such as plywood, for example, the barrier shall be two layers of Grade D paper. This requirement is based on the observed problems where one layer of a typical Type 15 felt is applied over wood sheathing. The wood sheathing eventually exhibits dry rot because moisture penetrates to the sheathing. Cracking is created in the plaster due to movement of the sheathing caused by alternate expansion and contraction. Field experience has shown that where two layers of building paper are used, penetration of moisture to the sheathing is considerably decreased, as is the cracking of the plaster due to movement of the sheathing caused by wet and dry cycles. The Grade D paper is specified because it has the proper water vapor permeability to prevent entrapment of moisture between the paper and the sheathing." (**4**) The appropriate range of permeance for a WRB under any specific service condition is still very much a subject of debate among experts.

X2.4 *Surfactants and Water-Resistive Barriers*—A surfactant is a substance that reduces the surface tension of a liquid, and there is evidence that surfactants commonly found in some building materials or otherwise in use at construction sites can adversely affect the water resistance of water-resistive barriers. Potential sources of surfactants in construction include stucco admixtures (plasticizers) to aid in pumping or reducing the water-cement ratio, wood extractives, detergents, emulsions, paints, adhesives, and agrichemicals. Wood lignin, the binding material in plants that gives them their strength and rigidity, is used in the manufacture of some water reducing admixtures. Using two layers of water-resistive barrier material is one way of mitigating the potential adverse affects of surfactants that may be in contact with one layer but not the second.

X2.5 *Type I and Type II Water Resistive Barriers* (see Table 1)—The categorizing of water-resistive barriers into higher and lower performance categories follows industry practice primarily related to asphalt treated kraft papers (for paper-based barriers, see 3.2.2) originally rated under now obsolete UU-B-790a. The code minimum for these types of products is still a 10-min Grade D barrier paper. Higher performance 30-min and 60-min products are now commonly used, but Grade D barriers are widely available and are still in use. A Grade D paper-based barrier or other Type I product may be appropriate for use in climates or applications where little exposure to moisture is expected.

X2.6 Despite significant progress by model code organizations, industry groups, standards organizations and the building industry media to provide updated technical information, the selection and application of materials commercially available for water-resistive barriers and flexible flashings remains challenging for much of the design profession and construction industry, particularly as the proliferation and nature of these materials continues to increase and evolve rapidly. Much of the information publicly available is limited to product and marketing literature provided from manufacturers. There is limited published data that compares properties, such as tested water-penetration resistance of common WRB materials, using even the often obsolete test methods accepted in codes and standards. Architects, contractors, and developers often tend to ignore incomplete and conflicting new information, falling back on traditional practices with which they are comfortable or relying on the sometimes questionable

[15] Some building officials interpret "equivalency" as comparable water resistance, while others interpret it as comparable permeance.

claims of vendors. Anecdotal information abounds, but reliable and technical comparisons of alternate materials and methods are inadequate.

X3. HISTORY AND DESCRIPTION OF WATER-RESISTIVE BARRIER MATERIALS

X3.1 Asphalt-Saturated Felt

X3.1.1 There continues to be substantial confusion between two similar waterproofing materials composed of organic materials produced in similar ways and perhaps diverging from a common predecessor. There is a tendency to refer to asphalt-saturated felt and asphalt-saturated kraft paper interchangeably, using such common terms as "building paper," "tarpaper," "felt," etc., although they are two very distinct products.

X3.1.2 The first known use in the United States of organic felt in roofing reportedly occurred in 1844 in Newark, NJ, a seaport, where a method of using pine-tar impregnated paper and wood pitch was copied from ship construction and used for roofing buildings. Papermaking and felting are similar processes and are both old arts involving the working of fibers together by a combination of mechanical means, chemical action, moisture, and heat. What started out as roofing paper developed into "rag" felt and gradually emerged as "organic" felt. These products must be sufficiently "open" to have space between fibers to permit maximum absorption of the waterproofing asphalt. The primary ingredient, cloth rags, became significantly less useful following the introduction of "wash and wear" textiles (**5**).

X3.1.3 Saturation (with asphalt) is achieved in the saturator by passing the sheet rapidly under and over a series of rolls which repeatedly dip the felt into a vat of molten bitumen. Moisture and air are expelled, and bitumen takes their places in the porous felt. The consistency and composition of the bitumen together with the properties of the dry felt affect the rate of saturation. Since saturation is not complete, the resulting felt still can absorb moisture and is vapor permeable. The vapor permeance and water absorption of saturated felt can be greatly reduced by coating it with mineral-stabilized bitumen (**6**).

X3.1.4 Saturated wood-fibre felts can absorb water up to 80 % of their weight when immersed, and this produces expansion up to 2 % parallel to and 1.5 % perpendicular to, the fiber or machine direction of the felt. Also as felts dry there is an accompanying shrinkage, which can be greater than the original expansion. When exposed to water and air, organic fibers are subject to rot and fungal attack, and roots of vegetation may grow into them (**6**).

X3.1.5 Originally, the weight of felts was based on 45 m^2 [480 ft^2], the typical felt ream (**6**). Currently, the weight is based on a roofing "square," or 9 m^2 [100 ft^2]. Klimas reports that "roof ply felt is 27-lb grade (unsaturated)" (**6**). That would be equivalent to 2500 g [5.6 lb] per square, just 18 g [0.04 lb] more than the current requirement of Specification D226/D226M. Specification D226/D226M requires a minimum weight of 2400 g [5.2 lb] for desaturated #15 felt and a weight of the saturant of 2800 g [6.2 lb], for a total of 5200 g [12 lb]. In 1979, the UBC Standard 32-1 required the saturant to not be less than 1.4 times the dry felt weight, so 2400 g [5.2 lb.] dry felt, when saturated, would be 5700 g [12.5 lb] per 9.2 m^2 [100 ft^2]. It is widely claimed that #15 asphalt-saturated felt historically weighed 6800 g [15 lb] and that the pound sign (#) was moved from the right to the left of what was originally the weight, to change "15#" to "#15" or "No. 15" as the weight diminished. We have seen no credible documentation that the original weight of this product was 6800 g [15 lb], but as can be seen from the following building code extracts, the weight has, apparently, diminished over the last 40 years.

X3.1.6 The 1964 Uniform Building Code, Section 1707(a) required "building paper" described therein as "asphalt saturated felt free from holes and breaks and weighing not less than 14 lb/100 ft^2 (680 g/m^2) or approved waterproof paper."

X3.1.7 The 1973 Uniform Building Code, Section 1707(a) referenced two asphalt saturated sheet products: UBC Standard 14-1 for "Kraft waterproof building paper", and UBC Standard 32-1 for "asphalt saturated rag felt." UBC Standard 32-1 required a desaturated felt weight of not less than 5.2 lb per 100 ft^2 [250 g/m^2] for Type 15 felt and a saturated weight of not less than 1.4 times the weight of the unsaturated moisture free felt, resulting in a finish weight not less than 12.48 lb per 100 ft^2 [600 g/m^2].

X3.1.8 The 1997 Uniform Building Code and the 1998 California Building Code (based on the 1997 UBC) continued to reference UBC Standard 14-1 for kraft waterproof building paper but dropped the reference to UBC Standard 32-1 for asphalt-saturated rag felt, although the material is still included in 1402(a) as an allowable water-resistive barrier. The 2003 International Building Code (1404.2) describes "A minimum of one layer of No. 15 asphalt felt, complying with Specification D226/D226M for Type 1 [commonly called No. 15] felt…"

X3.1.9 The last (1999) BOCA National Building Code stated: "1405.3.6 Water-resistive barrier: A minimum of one layer of No. 15 asphalt felt complying with Specification D226/D226M as listed in Chapter 35, for Type I felt…" (**7**).

X3.1.10 A relatively new standard for asphalt saturated organic felt is Specification D4869/D4869M. Unlike Specification D226/D226M, this specification includes a water resistance test ("liquid water transmission test") that involves a 4-h exposure to a shower without any evidence of wetness on the underside.

X3.1.11 Products conforming to both Specifications D226/D226M and D4869/D4869M, as well as products that conform to neither, are commercially available.

X3.2 Asphalt-Saturated Kraft Paper

X3.2.1 The term kraft paper is broadly used to describe all types of sulfate papers, although primarily descriptive of the basic grades of unbleached sulfate papers where strength is the chief factor and cleanliness and color are secondary. Kraft pulp is pulp cooked by an alkaline liquor consisting essentially of a mixture of caustic soda and sodium sulfide. The make-up chemical is traditionally sodium sulfate, which is reduced to a sulfide in the chemical recovery process; hence the alternative designation, sulfate pulp.

X3.2.2 Building paper, as opposed to asphalt-saturated felt, was first manufactured in the 1950s (**8**). The kraft paper used as a base for building paper is made to an exacting manufacturing specification and result in a consistent product. In the last 50 years, asphalt-saturated kraft paper has eclipsed felt as an organic, asphalt treated WRB. It remains the WRB of choice in many parts of the United States, particularly California and the western states.

X3.2.3 Demand for increased durability has resulted in the introduction of "30-min" and "60-min" asphalt-saturated kraft papers with water resistance increased over the 10 mins required for once popular Grade D papers having 10-min water resistance, still the standard in most U.S. building codes.

X3.3 Polymer Sheets

X3.3.1 The term "weather resistive barrier" as used in the building codes was originally understood to mean "water-resistive barrier." Tests, when referenced, were originally limited to water vapor permeance and water resistance.

X3.3.2 The energy crisis of the early 1970s spawned a number of building energy conservation techniques and materials, including what are commonly known as "housewraps." One product was described as an "energy-saving air infiltration barrier." Housewraps were originally marketed for their energy saving properties but tested for water resistance by their manufacturers to obtain equivalency recommendations from building code organizations for use as weather resistive barriers required by codes.

X3.3.3 Housewraps typically are thin, lightweight fabrics made of polyolefin fibers or extruded polyethylene films that are spun, woven, laminated or fiber reinforced. Some have fiber properties that allow diffusion of water vapor, and others require mechanically punched micro-perforations to provide the desired level of water vapor permeance.

X3.3.4 The air barrier functionality of housewraps is intended primarily to block random air movement through building cavities. If the air barrier is to perform its intended role, it must meet a number of requirements: continuity, structural integrity, air impermeability, and durability. Moderate water vapor permeance has also come to be an accepted desirable functionality of air barriers. The theory is that the air resistance functionality limits passage of potentially damaging volumes of airborne water vapor into walls but promotes drying by allowing passage of smaller amounts of water vapor to the exterior. This specification does not address the air barrier function of these membranes as that is addressed in Specification E1677. Also ICC-ES Acceptance Criteria AC38 contains provisions for the evaluation of a WRBs as an air barrier material in addition to use as a water-resistive barrier.

X3.3.5 An air barrier may consist of a single material or two or more materials, which, when assembled together, make up an air impermeable, structurally adequate barrier. Many common construction materials, such as structural wood panels, gypsum board, foam board, and even WRBs and paint can function as air barriers, but joints, laps, and discontinuities with the same and different materials compromise the integrity of the air resistance of the whole building. Flexible sheet materials in comparatively large sizes with taped seams largely solve the integrity problem.

X3.3.6 The National Building Code of Canada has required air barriers since 1986 and many polymer-based water-resistive barriers have also been identified as air barrier materials. Although the International Energy Conservation Code (Sections 402.4.1 and 502.4.3) and International Residential Code (Section N1102.4) provide some provisions for the air sealing, including options for areas that require sealing to be "caulked, gasketed, weatherstripped, or otherwise sealed with an air barrier material, suitable film, or solid material."

X3.3.7 Additionally some states have requirement for air barriers that WRBs may fulfill. Examples include:

X3.3.7.1 The Massachusetts Energy Code (780 CMR) that states, "1304.3.1 Air Barriers: The building envelope shall be designed and constructed with a continuous air barrier to control air leakage into, or out of, the conditioned space."

X3.3.7.2 The Minnesota Energy Code that states, "A barrier must be provided to resist wind wash. Where sealing is required, the wind wash barrier must be caulked, be gasketed, have sealed exterior wrap, or be otherwise sealed in an approved manner to provide a permanent air seal and to prevent entry of wind and wind-driven rain."

X3.3.7.3 The Washington Energy Code that states, "Other exterior joints and seams shall be similarly treated, or taped, or covered with moisture vapor permeable housewrap."

X3.3.7.4 The 1998 California Energy Efficiency Standards reference Specification E1677 in an air retarding wrap credit, "Air Retarding Wrap Credit If compliance credit is not taken for reduced building envelope air leakage through diagnostic testing, a special "default" compliance credit can be taken for building envelope leakage reduction resulting from installation of an air retarding wrap (that is, housewrap). To qualify for the "default" compliance credit, an air retarding wrap must be tested and labeled by the manufacturer to comply with Specification E1677 and have a minimum perm rating of 10. Insulative sheathing and building paper do not qualify as air retarding wraps."

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