Codes and Standards for Building Envelope Barriers and Flashings

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Introduction

Architects, contractors, builders and developers are faced with a dizzying number of choices for water resistive barriers, flexible flashings and air barriers. Codes, standards and technology are constantly evolving, and available materials and products continue to proliferate. Yesterday's darling is today's reject.

The objective of this paper is to at least sort out the latest code requirements and industry standards relating to building envelope barriers and identify both gaps and works in progress.

In the beginning … frame walls were formless and empty; wind and water swept through clapboards and plaster, creating draughts and chills; discomfort and distraction.

And, the builder said, "Let there be comfort!" and the builder separated the cold and damp from the warm and dry with a barrier he called "building paper." The builder called the inside habitable, and the outside, he called extreme. And it was good.

So, in the beginning, there was -- *building paper*, an asphalt saturated kraft paper that morphed from organic roofing felt into a product specifically intended for use in exterior walls. Like a vestigial organ, organic roofing felt continues to be a prescriptive code option for a water resistive barrier, though it is seldom used for such, and its functional properties are the least known of any alternate material.

Back in the day, areas particularly susceptible to water penetration, such as openings and penetrations were flashed, if at all, with a slightly more robust product made by laminating a thin layer of asphalt between two layers of kraft paper and sometimes reinforcing it with a loose weave of fiberglass or other reinforcement. This was called a "grade A" or "Grade B" building paper."

The building codes initially used the term "weather resistive barrier," because asphalt saturated building paper, roofing felt or fiber boards were effective to some extent in reducing both air and water intrusion. But in the 1980s when air infiltration was recognized as having potentially adverse moisture impacts on wall systems as well as the interior environment, and polymeric house wraps were first marketed as having superior air resistance properties, the primary role of building paper was reduced to resisting water intrusion. The codes were subsequently revised to the generic description of "water resistive barrier."

And, air barriers and vapor barriers (properly, "retarders") also worked their way into codes and standards.

Types of Barriers

Now, in 2014, designers and builders have to sort through a new set of barrier requirements and options, including:

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- Water resistive barriers
- Air barriers
- Vapor retarders (frequently and erroneously called "vapor barriers")

Each has unique primary properties and applications, and materials are readily available that can provide an air barrier function, a vapor retarder function or a water resistive barrier function or any combination of these three functions. Some materials can provide all three of these functions plus others, such as thermal insulation.

Typically, the development and marketing of these materials has preceded the adoption of pertinent codes and standards, so the regulatory world is always playing catch up with the commercial world.

Water Resistive Barriers

Water resistive barriers are materials on the exterior of a building that are intended to resist liquid water that has leaked, penetrated or seeped past the exterior cladding and to keep that water from being absorbed into and damaging the exterior sheathing, framing, insulation or interior finishes. Water resistive barrier materials can be mechanically fastened building wraps or building paper, fluid applied membranes, self-adhered membranes, cellular plastic, or any other material that has been designed to resist liquid water. Water resistive barriers are combined with flashing and other supporting materials to ensure that there is a shingled effect to direct liquid water away from the exterior sheathing.

Testing the water resistance of a material is normally done using the "boat method" (ASTM D779)[2], the "water ponding" method (CCMC 07102 section 6.4.5) or the "hydrostatic head method" (AATCC 127).

Air Barriers

Air barrier materials are materials that are used anywhere in a building assembly to stop the movement of air into or out of the conditioned space (water vapor can also be transported by air). Air barriers can be mechanically fastened building wraps, self-adhered membranes, fluid-applied materials, insulating boardstock, non-insulating boardstock, spray polyurethane foam, poured concrete, metal, glass, and a host of other materials.

Air *permeance* is the amount of air that permeates through a material, whereas air *leakage* is the air that passes through holes or gaps. Any material that has an air permeance that is not greater than 0.02 $L/(s \cdot m^2)$ at a pressure difference of 75 Pa (0.004 cfm/ft^2 at a pressure difference of 1.56 lb/ft^2) when tested in accordance with ASTM E 2178 is an air barrier material.

For additional information, see National Institute of Building Sciences, Whole Building Design Guide, *Air Barrier Design in Buildings*.[3]

Vapor Barriers (Retarders)

Vapor retarders (often erroneously referred to as "vapor barriers") are materials used to slow or reduce the movement of water vapor through a material. Water vapor is also transported by air leakage but this can be resolved by installing an air barrier. The position of the vapor retarder in a building assembly is determined based on the climatic conditions. Vapor retarder materials, when used, are typically installed on the warm side of the insulation in a building assembly when in winter the interior is warmer and more

[2] ASTM D779 has been discontinued, and responsibility has been transferred from Committee D06 to Committee E06, Task Group E06 55 07, which has plans to reinstate it with revisions.
[3] http://www.wbdg.org/resources/airbarriers.php

humid than the exterior. In warmer and more humid climates, vapor retarders, when used, will typically be installed on the exterior.

A vapor retarder can be a mechanically fastened sheet-material, self-adhered membrane, fluid-applied materials, insulating boardstock or spray polyurethane foam.

Water vapor transmission is the measurement of water vapor passing through a material. In most cases, the results are expressed as vapor permeance. The most common test method for measuring water vapor permeance is ASTM E96, tested using either the desiccant and water method with the results reported in the units of ng/(Pa·s·m^2) or *Perms*. The test measures the water vapor that passes through a material at prescribed conditions of temperature and humidity.

Multiple Function Materials

Materials can provide an air barrier function, a vapor barrier function or a water resistive barrier function or any combination of these three functions. Some materials can provide all three of these functions plus the function of a thermal insulation. Other materials may provide all three functions and some materials may provide two functions. It would be unusual for a material to only provide one function.

There are materials that are water resistive barriers but not air barriers and materials that are water resistive barriers that are air barriers. There are materials that are air barriers and are also vapor retarders, and there are materials that are air barriers but are not vapor barriers. There are water resistive barriers that are also vapor barriers and there are materials that are water resistive barriers that are not vapor barriers. The design professional needs to understand the properties of the materials to use them correctly in a building assembly.

A designer should understand the separate functions that the materials may provide and then determine whether the specific material chosen provides more than one function and whether the additional function is required or desired.

Water Resistive Barriers (WRB)

Code Requirements

General

Most low-rise frame buildings, and many mid-rise buildings, in the United States typically incorporate a drainage wall in the exterior envelope. ASTM E2266 - *Standard Guide for Design and Construction of Low-Rise Frame Building*, defines a drainage wall as:

> drainage wall—a wall system in which the cladding provides a substantial barrier to water intrusion, but which also incorporates means for dissipating water that may circumvent the cladding. For purposes of this standard a drainage wall is assumed to incorporate a concealed weather-resistive barrier[4] over which drainage, away from water-sensitive components of the wall, may occur. In addition to drainage behind the cladding, evaporation may play an important role in dissipating moisture in some types of cladding.[5]

Drainage walls typically incorporate, and codes require, a *water resistive barrier* as a component of a drainage wall.

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[4] Current term is "water-resistive barrier"
[5] ASTM E2266 - *Standard Guide for Design and Construction of Low-Rise Frame Building Wall* , 3.2.6

The *International Residential Code* (R703.1) provides for alternative assemblies that provide a water resistive function when tested by ASTM E331.

2012 International Building Code

The 2012 *International Building Code* includes the following:[6]

- Definition – *water resistive barrier*: A material behind an exterior wall covering that is intended to resist liquid water that has penetrated behind the exterior covering from further intruding into the exterior wall assembly.[7]
- *Vapor Permeable*. The property of having a moisture vapor permeance rating of 10 perms (5.7 x 10 -10 kg/Pa·s·m^2) or greater, when tested in accordance with the desiccant method using Procedure A of ASTM E96.
- 1404.2 *Water - resistive barrier* - requirement for a continuous water-resistive barrier behind exterior wood veneer.
- 1403.2: A minimum of one layer of No. 15 asphalt felt, complying with ASTM D226 for Type 1 felt or other approved materials….

2012 International Residential Code[8]

- Definition: *Water-Resistive Barrier*. A material behind an exterior wall covering that is intent to resist liquid water that has penetrated behind the exterior covering from further intruding into the exterior wall assembly.
- Definition. *Vapor Permeable.* The property of having a moisture vapor permeance rating of 5 perms (2.9 x 10-10kg/Pa·s·m^2) or greater, when tested in accordance with the desiccant method using Procedure A of ASTM E96.
- R703.1.1 *Water resistance* - requirement for exterior wall envelope to be designed and constructed in a fashion that has a water-resistive barrier.
- R703.2 *Water-resistive barrier* – requirement and application for a water-resistive barrier
- N1102.4 (R402.4) *Air Leakage* (Mandatory) – design and construction of the building thermal envelopes to limit air leakage
- N1102.4.1.1 (R402.4.1.1) – installation of the air barrier components with manufacturer's instructions
- N1102.4.1.2 (R402.4.1.2) – requirements for air leakage testing of the building envelope

Sheet Materials

AC38 - Water-resistive Barriers

Despite being listed as an approved prescriptive WRB in the IBC, asphalt felt is seldom used as a *water resistive barrier* anymore. "Other approved materials" are typically the subject of ICC Evaluation

[6] http://www.airbarrier.org/library/ABAA%20Technical%20Bulletin%202012-01%20codes%20&%20standards%20updates.pdf
[7] International Building Code, Section 202
[8] http://www.airbarrier.org/library/ABAA%20Technical%20Bulletin%202012-01%20codes%20&%20standards%20updates.pdf

Service[9] reports prepared using Acceptance Criteria.[10,11] For sheet materials, the pertinent Acceptance Criteria is AC38 - *Water-resistive Barriers*.

Section 2510.6 of the *International Building Code*, which pertains exclusively to plaster, the materials specification is slightly different:

> 2510.6 Water-resistive barriers. Water resistive barriers shall be installed as required in Section 1404.2, and, where applied over wood-based sheathing, shall include a water-resistive vapor permeable barrier with a performance at least equivalent to two layer of Grade D paper. The individual layers shall be installed independently such that each layer provides a separate continuous plane and any flashing (installed in accordance with Section 1405.4) intended to drain to the water-resistive barrier is directed between the layers. Exception: Where the water-resistive barrier that is applied over wood-based sheathing has a water resistance equal to or greater than that of 60-minute Grade D paper and is separated from the stucco by an intervening, substantially nonwater-absorbing layer of drainage space.

ASTM E2556 - Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment

The 2102 *International Building Code* does not define either "Grade D paper" or "water resistance," but changes in the 2015 *International Building Code* will remedy some of that by incorporating as a reference standard ASTM E2556 - *Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment*, which defines a water *resistive barrier* as:

> 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.[12]

Paragraph 2510.6 Chapter 25 (Gypsum Board and Plaster) of the 2015 *International Building Code* will be changed to read, "… a water-resistive barrier complying with ASTM E2556, Type I (formerly 10-minute)." The code will continue to exempt stucco with barriers with that have a water resistance equal to or greater ASTM E2556, Type II (formerly 60-minute) with a drainage space.

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[9] ICC-ES is a nonprofit, limited liability company that does technical evaluations of building products, components, methods, and materials. The evaluation process culminates with the issuance of technical reports that, because they directly address the issue of code compliance, are extremely useful to both regulatory agencies and building-product manufacturers. Agencies use evaluation reports to help determine code compliance and enforce building regulations; manufacturers use reports as evidence that their products (and this is especially important if the products are new and innovative) meet code requirements and warrant regulatory approval. ICC-ES evaluation reports are public documents, available free of charge on the worldwide Web, not only to building regulators and manufacturers, but also to contractors, specifiers, architects, engineers, and anyone else with an interest in the building industry. All of these people look to ICC-ES evaluation reports for evidence that products and systems are code-compliant.(http://www.icc-es.org/Help/about.shtml)

[10] Acceptance criteria are developed by the ICC-ES technical staff in consultation with the report applicant and with input from interested parties. New criteria and revisions to criteria are approved by the Evaluation Committee (made up entirely of code officials) during open public hearings or—in selected instances—through an alternate process that involves the solicitation of public comment through this web site. Note that there are firm deadlines for materials that are to be considered by the Evaluation Committee.(http://www.icc-es.org/Criteria_Development/)

[11] Acceptance Criteria are seen by the ICC as an interim tool pending development of a standard specification that can be incorporated into the code as a reference.

[12] ASTM E2556 - Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment, 3.2.6

The National Building Code of Canada refers to water resistive barriers as "wall sheathing paper" or "sheathing membrane, breather type."[13]

Asphalt Saturated Felt

Code references to asphalt saturated felt still refer to ASTM D226, but in 2002 a new standard for asphalt saturated organic felt, *ASTM D4869 Standard Specification for Asphalt-Saturated Organic Felt Underlayment Used in Steep Slope Roofing*, was adopted. Unlike D226, this specification includes a water resistance test ("liquid water transmission test") that involves a 4-hour exposure to a shower without any evidence of wetness on the underside.

Products conforming to both ASTM D226 and D4869, as well as products that conform to neither, are commercially available.

Liquid Applied WRBs

Liquid (or fluid) applied water resistant barriers were first introduced as a component of a drained EIFS system, and dozens of products are now being marketed as general purpose WRB's.

AC209 - Trowel-, Spray- or Roller-applied Water-resistive Coatings Used as Weather-resistive Barriers over Exterior Cementitious Wall Coverings and AC212 - Water-resistive Coatings Used as Water-resistive Barriers over Exterior Sheathing

To be code-conforming, fluid applied WRBs typically go through the ICC-Es evaluation process resulting in an approval recommendation. There are two applicable Acceptance Criteria:

- AC209 - *Trowel-, Spray- or Roller-applied Water-resistive Coatings Used as Weather-resistive Barriers over Exterior Cementitious Wall Coverings*[14]
- AC212 - *Water-resistive Coatings Used as Water-resistive Barriers over Exterior Sheathing*[15]

The former is for coatings over cementitious wall coverings, and the latter for coatings over wood-based and gypsum-based sheathings, and cementitious backer units.

ASTM E2570 – Standard Test Methods for Evaluating Water Resistive Barrier (WRB) Coatings Used under Exterior Insulation and Finish Systems

ASTM E2570 – *Standard Test Methods for Evaluating Water Resistive Barrier (WRB) Coatings Used under Exterior Insulation and Finish Systems (EOFS) or EIFS with Drainage* is a replacement for AC212 and has been incorporates as a reference into the 2012 *International Building Code*.

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[13] Section 9.23.17 *Wall Sheathing paper* CGSB CAN/CGSB-51.32-M77: *Sheathing, Membrane, Breather Type* - … intended for use on the outside of heated buildings under the external finish, as a secondary protective covering against the entry of wind and moisture …

[14] AC209 establishes guidelines for evaluation of trowel-, spray- or roller-applied water-resistive proprietary coating systems that are used on exterior walls as alternatives to water-resistive barriers, weather-resistant sheathing paper, and weather-resistive barriers.

[15] AC212 established guidelines for evaluation of water-resistive coatings used as water-resistive barriers over exterior sheathing. The coatings are covered with either a code-approved exterior wall covering, or one that is recognized in a current ICC-ES evaluation report. Substrates that can be considered under this criteria are wood-based and gypsum-based sheathings, and cementitious backer units complying with ANSI A118.9, or equivalent.

Figure 1- Liquid Applied WRB (Photo Tom Butt)

Rigid Board WRBs

WRBs can also be rigid boards, typically of plastic foam, fiber, or a combination, with taped joints. Some can also be used as structural sheathing. These products have been developed largely in response to the new code requirements for continuous insulation.

AC71 - Foam Plastic Sheathing Panels Used as Weather-resistive Barriers and AC382 - Laminated Fibrous Board Sheathing Material Used as a Water-resistive Barrier

Two ICC Acceptance Criteria have been developed to evaluate the use of board products as water resistive barriers:

- *AC71 - Foam Plastic Sheathing Panels Used as Weather-resistive Barriers*
- *AC382 - Laminated Fibrous Board Sheathing Material Used as a Water-resistive Barrier*

Water Vapor Permeance of WRBs

Although water vapor permeance is not the primary function of WRBs, it is a selection consideration. Unfortunately, the water vapor permeance typically varies, often dramatically, as a function of relative humidity, but the codes do not take this into consideration. . The ICC requires a vapor permeance of 10 perms or greater and the IRC 5 perms or greater when tested according to ASTM E96 using the desiccant method, so based on the test results shown below, many commonly used materials would not comply at certain levels of relative humidity, including 50% RH. For example, some of the prescriptively allowed asphalt saturated felts comply only at the highest humidity levels.

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Table 2. Water vapor permeances of membranes at 23 ± 0.3 °C.

Membrane	Water Vapor Permeance at various RH, kg m^{-2} s^{-1} Pa^{-1} X 10^{-10}									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
10 Min-I	3.18	4.11	5.32	6.93	9.07	11.9	15.9	21.4	29.5	41.7
10 Min-II	2.38	3.17	4.25	5.73	7.78	10.7	14.8	21.0	30.6	47.1
30 Min-I	8.17	9.80	12.2	15.2	18.9	23.7	29.6	37.4	47.6	61.7
30 Min-II	4.41	5.70	7.40	9.67	12.8	17.0	23.1	32.2	46.7	72.3
60 Min-I	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7
60-Min-II	15.1	17.0	19.1	21.6	24.4	27.8	31.8	36.6	42.4	49.5
Felt-I	0.93	1.13	1.39	1.76	2.31	3.15	4.56	7.23	13.4	35.0
Felt-II	0.28	0.29	0.35	0.44	0.59	0.84	1.33	2.44	6.01	40.1
Felt-III	2.91	2.91	2.91	2.91	2.91	2.95	3.98	5.81	11.7	31.1
SBP-I	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
SBP-II	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
SBP-III	8.35	8.35	8.35	8.35	8.35	8.35	8.35	8.35	8.35	8.35
SBP-IV	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7
SBP-V	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7
PAmide	0.24	0.39	0.55	0.76	1.07	1.59	2.61	4.97	12.3	63.2
PerPoly-I	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
PerPoly-II	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
VWP	0.85	1.06	1.35	1.69	2.10	2.59	3.16	3.82	4.60	5.51
Primer*	6.83	11.1	14.9	18.5	22.0	25.4	28.9	32.4	35.9	39.6
Primer & Paint**	1.08	1.50	2.08	2.89	4.04	5.65	7.97	11.4	16.5	24.6

* One coat of the primer on ½ in. gypsum board. **One coat of the primer on ½ in. gypsum board followed by two coats of the paint. Test specimens included the gypsum board as the substrate. Therefore the permeance reported for Primer* is for the combination of primer + gypsum and for Primer & Paint** is for primer + gypsum + paint.

Figure 2 – From M.K. Kumaran, J.C. Lackey, N. Normandin and D. van Reenan, "Vapor Permeances, Air Permeances, and Water Absorption Coefficients of Building Membranes," National Research Council of Canada, 2006

Selection Considerations

Asphalt Saturated Felt

Potential advantages of asphalt saturated felt

- Long history of successful use under normal exposure conditions.
- Explicitly conforms to several model codes.
- Low material cost.
- Long-term durability possibly superior to paper-based materials.

Potential Disadvantages

- Minimal performance test data available for use as a WRB.
- Comparatively high permeance may result in wall cavity condensation under certain service conditions.
- Low resistance to tearing and breaking.
- Low resistance to bending.
- Vulnerable to deterioration after periodic or long-term exposure to water, especially when combined with exposure to air or UV.
- Exposure to surfactants may adversely affect resistance to water penetration.
- May not conform to some building codes

Asphalt Saturated Kraft Paper

Potential advantage of asphalt saturated kraft paper

- Long history of successful use under normal exposure conditions.
- Explicitly conforms to several model codes.
- Low material cost.
- More performance test data available, when used as a WRB, than for felt-based materials.
- Better resistance to bending damage than felt-based materials.
- Comparatively lower permeance, compared to felt-based materials, may reduce chances of wall cavity condensation.

Potential disadvantages of asphalt saturated kraft paper

- Low resistance to tearing.
- Highly vulnerable to deterioration after periodic or long-term exposure to water, especially when combined with exposure to air or UV.
- When used with cement plaster, single layer applications of Grade D paper do not drain as well as double applications, can stick to plaster and are difficult to repair post-construction, particularly when applied as “paper-backed lath” and used without sheathing.

Polymer Sheets

Potential advantage of polymeric sheets

- High resistance to tearing and breaking.
- Manufactured in large sheets – joints are minimized.
- Will not deteriorate with long exposure to water.
- Air barrier functionality.
- High water vapor permeance.

Potential disadvantages of polymeric sheets

- Relatively expensive material cost.
- May deteriorate after long term exposure to UV.
- Surfactants can affect water resistance.

- May retard evaporation of excess water in wall cavities.
- There is some controversy about the water penetration resistance of micro-perforated sheets.

Air Barriers

Code Requirements

International Energy Conservation Code (IECC)

Depending on the state, the building type and the climate zone, the codes in many jurisdictions now require air barriers.[16,17] Unlike water resistive barriers, which are referenced in the *International Building Code*, air barrier requirements are in the related *International Energy Conservation Code*. See http://www.iccsafe.org/gr/documents/stateadoptions.pdf for a list of states that have adopted the *International Energy Conservation Code.* Also see http://www.airbarrier.org/news/news_details_e.php?news_id=83 for progress that states are making in adopting codes that will require air barriers.

- Definition: Air Barrier- Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. And air barrier may be a single material or a combination of materials.
- C402.4 Air leakage (Mandatory)
  - requirement for air leakage of the thermal envelope shall comply with the noted sections of this code.
  - C402.4.1 Air barriers – requirement for continuous air barrier in the listed climate zones and with the noted sections of this code.
  - C402.4.1.1 Air barrier construction – prescriptive measures for a continuous air barrier to be designed and installed.
  - C402.4.1.2.1 Materials – air permeance compliance requirement for the selection of air barrier materials for opaque building envelopes.
  - C402.4.1.2.2 Assemblies – air permeance compliance requirement for the selection of air barrier assemblies for opaque building envelopes.
  - C402.4.1.2.3 Building test - requirements for building envelope air leakage testing
  - C402.4.2 Air barrier penetrations – prescriptive methods for sealing air barrier penetrations and paths of air leakage

2012 International Energy Conservation Code

- R402.4 Air leakage (Mandatory) – requirement for air leakage of the thermal envelope shall comply with the noted sections of this code.
  - R402.4.1 Building thermal envelope – requirement for sealing between dissimilar materials
  - R402.4.1.1 Installation - requirements of the thermal envelope (air barrier) shall be installed as per manufacturer's instructions
  - R402.4.1.2. Testing - requirements for building envelope air leakage testing

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[16] See "Where are Air Barriers Required by Code?" http://www.airbarrier.org/news/news_details_e.php?news_id=83

[17] Air Barrier Association of America. (http://www.airbarrier.org/about/index_e.php) Air Barriers control the unintended movement of air into and out of a building enclosure. Air barrier systems are comprised of a number of materials which are assembled together to provide a complete barrier to air leakage through the building enclosure. The building enclosure includes all six sides of the building and may included separations within a building. This system essentially "wraps" the building shell and ensures that it protects the building from the effects of air leakage. Air leakage can have detrimental effects on how a building functions and reduces the life span of a building.

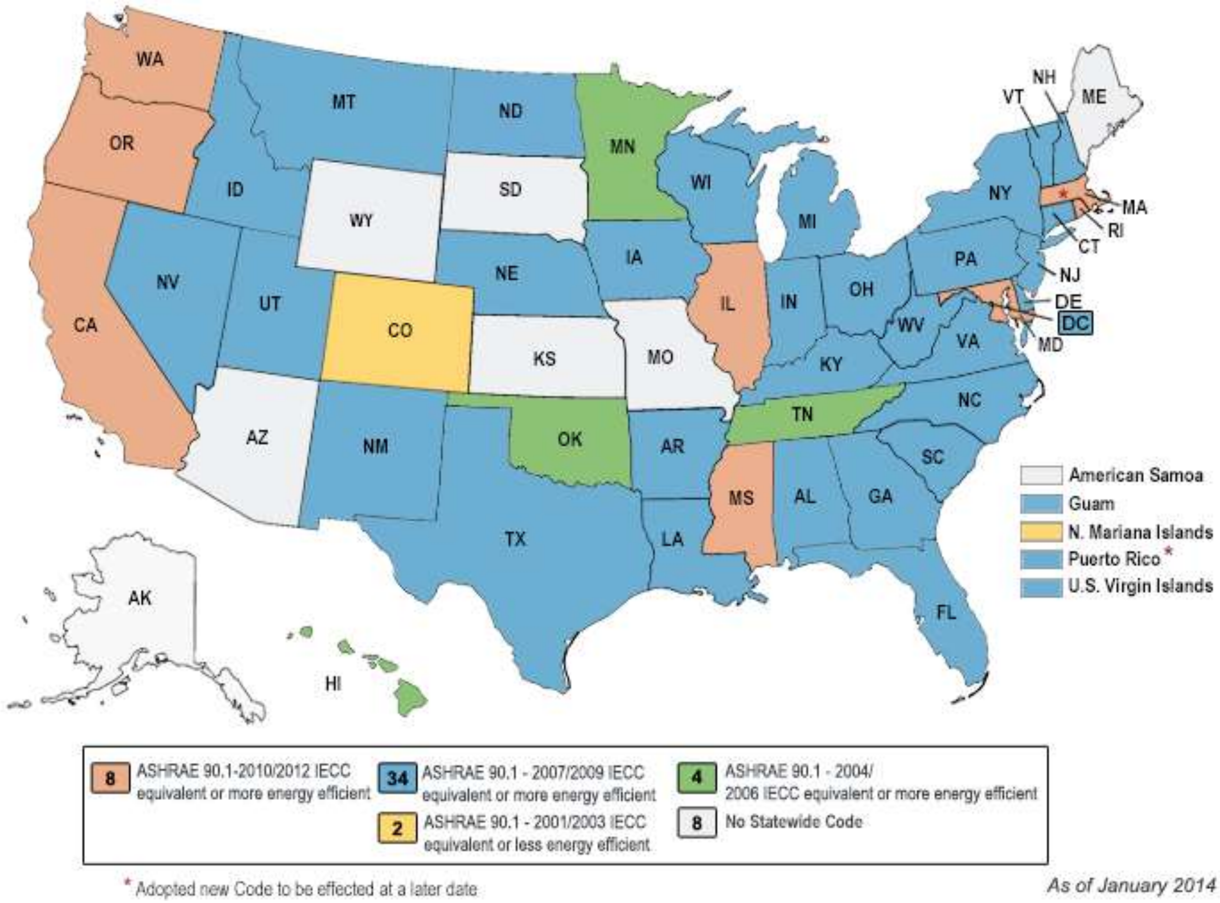

Figure 3. Current Commercial Building Energy Code Adoption Status - U.S. Department of Energy[18]

[18] http://www.energycodes.gov/status-state-energy-code-adoption

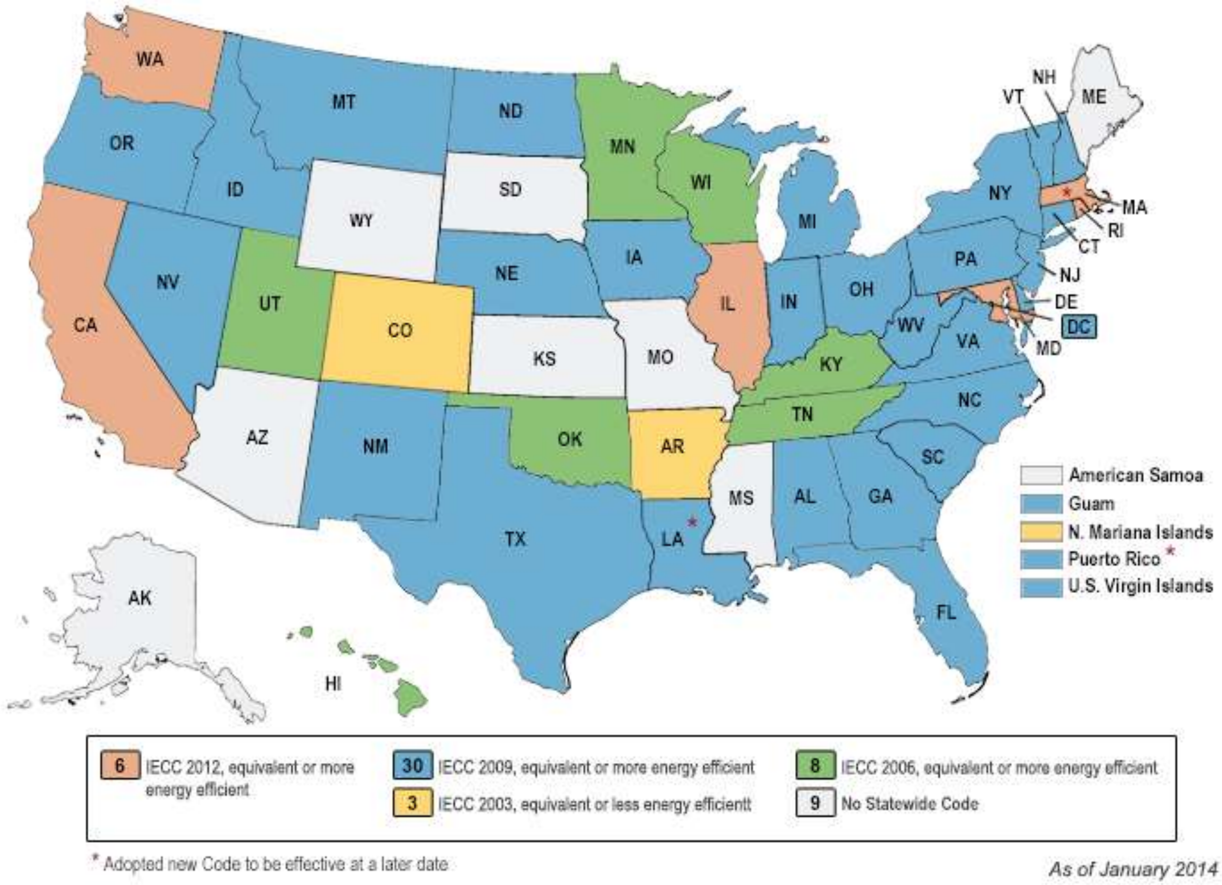

Figure 4. Current Residential Building Energy Code Adoption Status http://www.energycodes.gov/status-state-energy-code-adoption

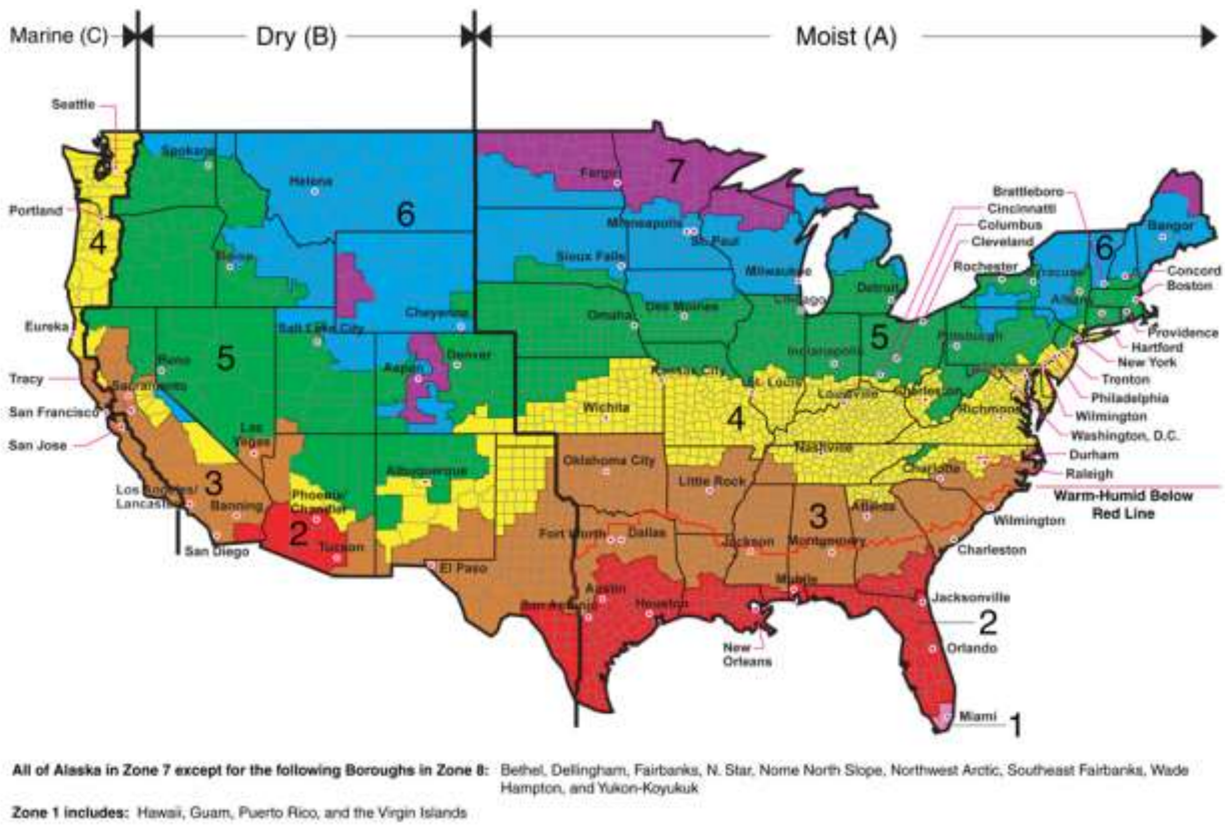

Figure 5 - Air barriers are required in Zones 4 and higher

The 2013 *California Energy Code*, based on the *International Energy Conservation Code* that goes into effect in 2014, requires all buildings to have a “continuous air barrier that is designed and constructed to control air leakage into and out of the building’s conditioned space.”

That doesn’t necessarily mean that the building wall has to incorporate a proprietary material marketed as an “air barrier.” Almost any conventional construction assembly will comply as long as it is sealed.

Exceptions to California Energy Code 140.3(a) (9A include (“provided all joints are sealed and all of the materials are installed as air barriers in accordance with the manufacturer’s instructions”):[19]

1. Plywood – min 3/8 inch thickness.
2. Oriented strand board – min. 3/8 inch thickness.
3. Extruded polystyrene insulation board – min. ½ inch thickness.
4. Foil-back polyisocyanurate insulation board – min. ½ inch thickness.
5. Closed cell spray foam with a minimum density of 2.0 pcf and a min. 2.0 inch thickness.
6. Open sell spray foam with a density of no less than 0.4 pcf and no greater than 1.5 pcf, and a min. 5 ½ inch thickness.
7. Exterior or interior gypsum board min. ½ inch thickness.
8. Cement board – min. ½ inch thickness.
9. Built up roofing membrane.
10. Modified bitumen roofing membrane.
11. Fully adhered single ply roofing membrane.
12. A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inch thickness.
13. Cast-in-place concrete, or precast concrete.

[19] Table 140.3-A Materials Deemed to Comply with Section 140.3(a)(9A)

14. Fully grouted concrete block masonry
15. Sheet steel or sheet aluminum.

Exceptions to California Energy Code 140.3(a)9B include (“provided all joints are sealed and all of the materials are installed as air barriers in accordance with the manufacturer’s instructions”):

1. Concrete masonry walls that have at least two coatings of paint or at least two coatings of sealer coating
2. Concrete masonry walls with integral rigid board insulation
3. Structurally insulated panels
4. Portland cement or Portland cement sand parge, or stucco, or a gypsum plaster, each with min. 1/2inches thickness.

All of the above are deemed to comply, but for prescriptive compliance by other materials, they are required to have:

> …an air permeance not exceeding 0.004 cfm/ft^2, under a pressure differential of 0.3 in. w.g. (1.57 psf) (0.02L/m^2 at 75 Pa), when tested in accordance with ASTM E2178.

For assemblies of other materials, they are required to have:

> …an air permeance not exceeding 0.004 cfm/ft^2, under a pressure differential of 0.3 in. w.g. (1.57 psf) (0.02L/m^2 at 75 Pa), when tested in accordance with ASTM E2357, ASTM E 1677, ASTM E 1680 or ASTM E 283.

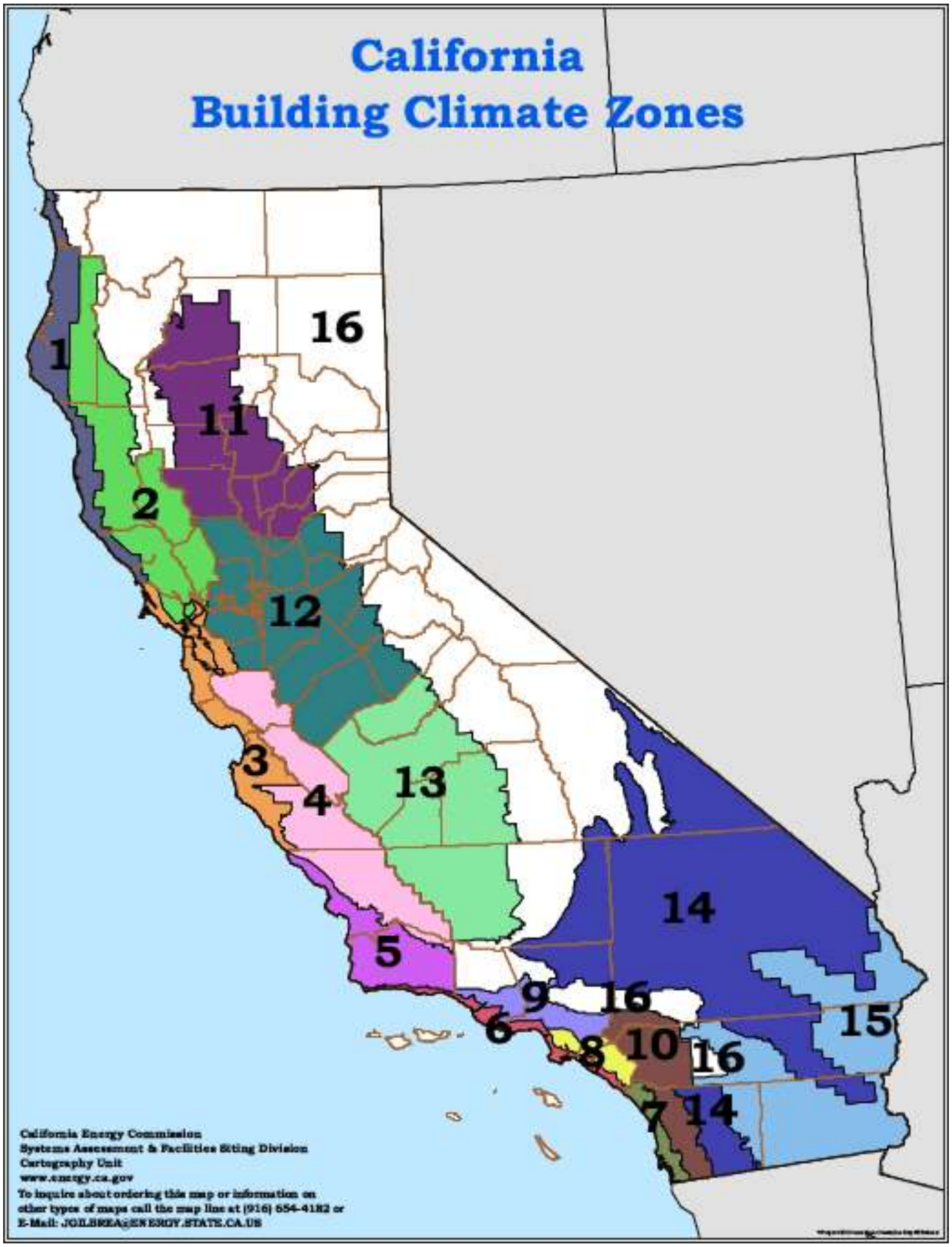

Figure 6. Air barriers are required for non-residential buildings in Zones 10 and above in California

ASHRAE 90.1- 2013 Standard 90.1-2013 -- Energy Standard for Buildings Except Low-Rise Residential Buildings

Instead of adopting the IECC, some jurisdictions a have adopted the provisions of ASHRAE 90.1, which include:

- 5.4.3. Air Leakage 5.4.3.1. Continuous Air Barrier: requirement for continuous air barrier design and construction

- 5.4.3.1.1. Air Barrier Design: requirement for continuous air barrier design, air barrier structural design and documentation on air barrier construction documents.
- 5.4.3.1.2. Air Barrier Installation: requirement for air barrier construction details
- 5.4.3.1.3. Air Barrier Materials and Assemblies: air permeance compliance requirement for the selection of air barrier materials and assemblies for opaque envelopes.

ASHRAE 189.1 – The Green Standard - Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings

- 7.4.2.9. Continuous Air Barrier: requirement for air barrier design and construction in a continuous fashion. Air barrier components shall be clearly identified on construction documents and the joints, interconnections, and penetrations of the air barrier components shall be detailed.
- NORMATIVE APPENDIX B – PRESCRIPTIVE CONTINUOUS AIR BARRIER
- B1. CHARACTERISTICS – requirement for air barrier design and installation
- B2. COMPLIANCE – air permeance compliance requirement for the selection of air barrier materials and assemblies for opaque envelopes requirements for building envelope air leakage testing

International Green Construction Code

- 605.1.2 Air Leakage – requirement for building envelope to sealed in accordance with section C402.4 of the International Energy Conservation Code and the other sections of the IGCC code.
- 605.1.2.1 Air barrier – requirement for building envelope to be designed in buildings in climate zones 1 through 8.
- 605.1.2. Testing requirements for building envelope air leakage testing

Air Barrier Standards

ASTM E2178-13 Standard Test Method for Air Permeance of Building Materials

This test method is to determine the air permeance of building materials at various pressure differentials with the intent of determining an assigned air permeance rate of the material at the reference pressure difference (ΔP) of 75 Pa. The method is intended to assess flexible sheet or rigid panel-type materials using a 1 m × 1 m specimen size.

ASTM E2357-11 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies

This test method covers the determination of the air leakage rate of air barrier assemblies that are used in building enclosures. This procedure measures the air leakage of a representative air barrier assembly before and after exposure to specific conditioning cycles and then assigns a rating dependent upon the results. Although this is a laboratory procedure, the method may also be applied to site mockups.

ASTM E1677-11 Standard Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls

This specification covers the minimum performance and acceptance criteria for an air barrier (AB) material or system for framed walls of low-rise buildings with the service life of the building wall in mind. The provisions contained in this specification are intended to allow the user to design the wall performance criteria and increase AB specifications to accommodate a particular climate location, function, or design of the intended building. This specification focuses mainly on ABs for opaque walls. Other areas of the exterior envelope, such as roofs, floors, and interfaces between these areas are not included in this specification. Also not addressed here are air leakages into the wall cavity, that is, windwashing. Additionally, the specifications in this standard are not intended to be utilized for energy load calculations and are not based on an expected level of energy consumption.

ASTM E1680-11 Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems

This test method covers the determination of the resistance of exterior metal roof panel systems to air infiltration resulting from either positive or negative air pressure differences. The test method described is for tests with constant temperature and humidity across the specimen. This test method is a specialized adaption of Test Method E283. This test method is applicable to any roof area. This test method is intended to measure only the air leakage associated with the field of the roof, including the panel side laps and structural connections; it does not include leakage at the openings or perimeter or any other details.

ASTM E283-04(2012) Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

This test method covers a standard laboratory procedure for determining the air leakage rates of exterior windows, curtain walls, and doors under specified differential pressure conditions across the specimen. The test method described is for tests with constant temperature and humidity across the specimen. This laboratory procedure is applicable to exterior windows, curtain walls, and doors and is intended to measure only such leakage associated with the assembly and not the installation. The test method can be adapted for the latter purpose. This test method is intended for laboratory use. Persons interested in performing field air leakage tests on installed units should reference Test Method E783.

WK16958 - New Specification for Fluid-Applied Air Barrier Materials

Vapor Retarders

After several decades of tentative popularity, the incorporation of vapor retarders in walls assemblies is falling from favor. Only two states now require vapor retarders, and that may be changing.

Vapor retarders are perhaps the most technologically complex and the least understood of wall components.

When life was simpler, the rule of thumb was:

- In cold climates, a vapor retarder on the interior will resist the movement of relatively moist and warm winter interior air into the cold wall cavity where it can condense and cause damage.
- In warm and humid climates, a vapor retarder on the exterior will resist the movement of relatively warm and moist air into the cooler wall cavity of an air conditioned building where it can condense and cause damage. More often, the reverse happened. The stories of buildings on the Gulf Coast with interior vinyl wall coverings being damaged by exterior water vapor condensing on the interior wall have become legendary.

The problem is that climates change seasonally, and not one solution fits all seasons. Even without the use of obviously vapor retardant materials such a polyethylene sheet, highly vapor impermeable materials such as OSB were creating unintended vapor retarders in unintended locations.

With the help of monitored test assemblies and sophisticated hygrothermal modeling, building energy experts determined that air leakage posed a much greater threat to both wetting of wall interiors and energy conservation than did vapor transport. Drying capability of the wall is much more important than keeping water vapor out, and air barriers that are still vapor permeable can be achieved with materials as common as painted gypsum board.

Lstiburek points out, “You would never want to construct a wall with an interior plastic vapor barrier in the lower 48 states where you have air conditioning for more than a couple of weeks. That means interior plastic vapor barriers in the US should be limited to IECC Climate Zones 6 and 7 – or higher. In Canada, that means in zones where the Celsius Heating Degree Days above 18 degrees C are 4000 or higher. So no plastic in Toronto – leave plastic to the folks in Ottawa and Montreal.”[20]

Walls that incorporate exterior vapor retarder functionality with continuous exterior insulation can dry to the interior and function well all climates.

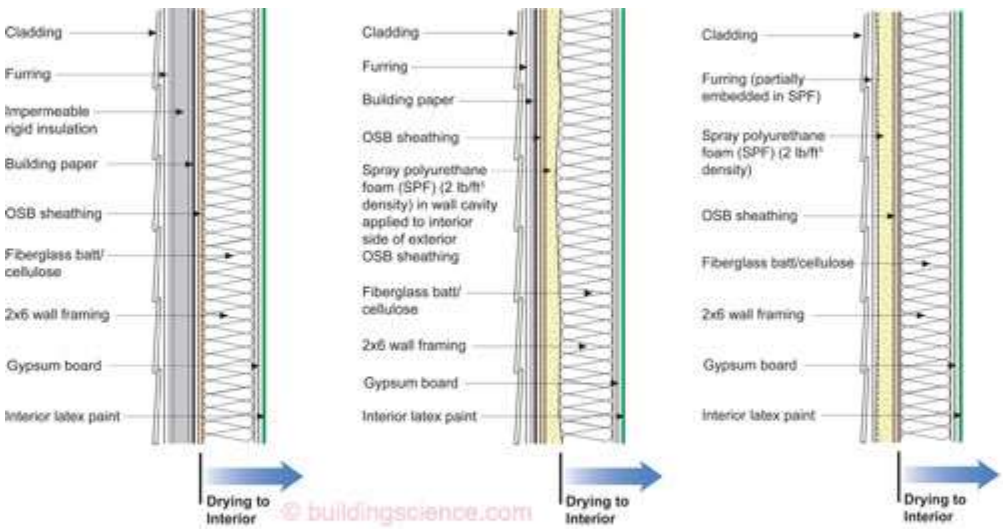

Figure 7. Wall 3a, 3b and 3c from Lstiburek[21]

At least one product on the market claims to:

> …act like a traditional vapor retarder to protect wall cavities, but also allows closed building envelope systems to dramatically increase their drying potential with seasonal climatic changes.

The *International Residential Code* requires vapor retarders on the interior side of frame walls in Climate Zones 5, 6, 7, 8 and Marine 4 (in California, Zones 14 and 16).

The *International Residential Code* lists the following definition of Vapor Retarder Class:

> A measure of the ability of a material or assembly to limit the amount of moisture that can pass through the material or assembly. Vapor retarder class shall be defined using the dessicant method with Procedure A of ASTM E96 as follows:
>
> Class I: 0.1 perm or less
>
> Class II: 0.1 < perm $\leq$ 1.0 perm

[20] Building Science Insights BSI-073: Macbeth Does Vapor Barriers (Double, Double Toil and Trouble)[1By Joseph Lstiburek Created: 2013/11/15

[21] Building Science Insights BSI-073: Macbeth Does Vapor Barriers (Double, Double Toil and Trouble)[1By Joseph Lstiburek Created: 2013/11/15

Class III: 1.0 < perm ≤ 10 perm

Examples of approved materials are:

Class I: 0.1 perm or less (Sheet polyethylene, non-perforated aluminium foil)

Class II: 0.1 perm <= 1.0 perm (Kraft faced fiberglass batts)

Class III: 1.0 perm <= 10 perm (Latex or enamel paint)

The *Code* allows a Type II vapor retarder under the following conditions:

Zone	Class III vapor retarders permitted for:
Marine 4	Vented cladding over OSB
	Vented cladding over plywood
	Vented cladding over fiberboard
	Vented cladding over gypsum
	Insulated sheathing with R-value >= 2.5 over 2x4 wall
	Insulated sheathing with R-value >= 3.75 over 2x6 wall
5	Vented cladding over OSB
	Vented cladding over plywood
	Vented cladding over fiberboard
	Vented cladding over gypsum
	Insulated sheathing with R-value >= 5 over 2x4 wall
	Insulated sheathing with R-value >= 7.5 over 2x6 wall
6	Vented cladding over fiberboard
	Vented cladding over gypsum
	Insulated sheathing with R-value >= 7.5 over 2x4 wall
	Insulated sheathing with R-value >= 11.25 over 2x6 wall
7 and 8	Insulated sheathing with R-value >= 10 over 2x4 wall
	Insulated sheathing with R-value >= 15 over 2x6 wall

Flexible Flashings

Definition

AC148 defines *flashing* as:

> 1.3.1 *Flashing:* Sheet material, integrated with the water-resistive barrier that bridges and protects the joint (gap) between the window or door frame members and the adjacent construction for the purpose of preventing water penetration by draining water away from the window or door.[22]

Flexible flashings are defined in AC148 as:

> 1.3.2 Self-adhering Flashing: Flashing consisting of flexible facing materials coated completely or partially on at least one side with an adhesive material and which do not depend on mechanical fasteners for permanent attachment.
>
> 1.3.3 Mechanically Fastened Flashings: Flexible facing materials which depend upon mechanical fasteners for permanent attachment.

Where water resistive barriers are used, flashings are also typically used. Flexible flashings are distinct from sheet metal flashings, both of which are commonly used in concert with water resistive barriers and air barriers. For water resistance, Sheet metal is typically used where some portion is exposed on the

[22] AC148 – Acceptance Criteria for Flexible Flashing Materials, 1.3.1 (Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes.

exterior, where a particularly robust or durable connection is required or where complex multi-plane joints might be a challenge for flexible flashing materials.

While flexible flashings bend easily and conform well for two intersecting planes, they are a challenge for multiplane joints, which often end up as elaborate “origami.” Many manufacturers offer expandable flexible flashings that conform to multiplane joints, but sheet metal with soldered joints may be more durable with less risk of failure.

The most commonly used flexible flashing products are self-adhering, but mechanically fastened products are also available, used sometimes in combination with self-adhered products. Flexible flashings with adhesive are also referred to as construction tapes, peel-and-stick, self-adhered flashings (SAF), self-adhered (or adhesive) membranes (SAM) or self-adhered sheet membranes (SASM).

If pressed firmly into place, most pressure-sensitive tapes bond well to a range of materials from wood-based products to metal, and accommodate movement from expansion and contraction.

Figure 8. Window pan flashing from rubberized asphalt flexible flashing

Standards

AC148 Flexible Flashing Materials

ACI 148, currently approved February 2011, is the basis for ICC – ER reports on flexible flashing materials.

AAMA 711 - Voluntary Specification for Self Adhering Flashing Used for Installation of Exterior Wall Fenestration Products

In 2013, the American Architectural Manufacturers Association (AAMA) released an updated standard that establishes minimum performance requirements for self-adhering flashing surrounding exterior wall fenestration products. AAMA 711-13, *Voluntary Specification for Self Adhering Flashing Used for Installation of Exterior Wall Fenestration Products* also provides a method to determine the minimum width of the flashing products and to evaluate the influence of environmental factors on the installation of self-adhering flashing products applied under typical field conditions.

IRC Section R708.3, states that self-adhered membranes used as flashing shall comply with AAMA 711.

Updated from the 2007 version, the most significant change made to AAMA 711 was the addition of a modified version of ASTM G155 Xenon Arc Test as an alternative to ASTM G154 for accelerated weatherability testing. AAMA 711 was re-opened in September of 2011 to add an option to test 4-inch-wide specimens in Section 5.3, make general editorial changes in line with AAMA 712 and to review the need to add a Flashing Sealant Compatibility section.[23]

AAMA 711 references important industry documents which include:

- AAMA 800-10, *Voluntary Specifications and Test Methods for Sealants*
- ASTM C734-06(2012), *Standard Test Method for Low-Temperature Flexibility of Latex Sealants After Artificial Weathering*
- ASTM C765-97(2011), *Standard Test Method for Low-Temperature Flexibility of Preformed Tape Sealants*
- ASTM D3330/3330M-04(2010), *Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape*
- ASTM E331-00(2009), *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference*
- ASTM E631-06, *Standard Terminology of Building Constructions*
- ASTM E2112-07, *Standard Practice for Installation of Exterior Windows, Doors and Skylights*
- ASTM G155-05a, *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*

ASTM D1970 - Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection

ASTM D1970/D1970M REV A was originally approved in 1990 and was the first standard pertaining to peel-and-stick building products related to waterproofing. ASTM D1970 covers "polymer modified bituminous sheet materials intended for use as underlayment on roof eaves, or valleys, or both, to prevent leakage of shingle, tile, or metal roofs from water back-up due to ice dams."

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[23] AAMA, http://www.aamanet.org/news/1/10/0/all/969/aama-releases-specification-for-self-adhering-flashing-for-exterior-wall-fenestration-installation

The first use of self-adhered membranes for flashing involved materials developed for roofing and waterproofing that were tested under ASTM D1970, so it became a de facto standard for flashings as well.

AAMA 711 was adopted in 2005 and displaced ASTM D1970 as the material standard for flashings, but AAMA 711 incorporates by reference several test procedures from ASTM D1970.

Flexible Flashing Considerations

Stickiness and temperature tolerance are big issues for self-adhered flashings. In addition to passing a number of basic tests, AAMA 711 rates flashings in two categories and three subcategories, based on substrate adhesion and temperature tolerance.

- Type A Products: Products that pass this specification without use of a primer.
- Type B Products: Products that require a primer to pass any part of this specification

Type A and B are divided into the following classes:

- Level 1: For exposures up to 50º C (122ºF)
- Level 1: For exposures up to 65º C (149ºF)
- Level 1: For exposures up to 80º C (176ºF)

The first self-adhered flashings had rubberized asphalt adhesives but ran into a host of problems. The second generation added better performing butyl as the adhesive, but butyl is more expensive. Most manufacturers hedge their bets now by offering both types.

Comparison of Self-adhered Flexible Flashings

Adhesive Type	Advantages	Disadvantages
Rubberized Asphalt (SBS)	• Less expensive than butyl	• Can have compatibility issues with some PVC products and urethane sealants • May have problems meeting combustibility standards • Messy to install • Questionable durability • A primer may be required to achieve a full bond with some substrate materials, such as oriented strand board (OSB) and concrete, which may present particular problems for certain asphalt flashings. • Have a poor temperature range. According to the *Encyclopedia of Building & Environmental Inspection, Testing, Diagnosis, Repair*, many rubberized asphalt products start to lose stickiness at around 50°F and have problems bonding below 40°F. • Problematic application also applies when subjected to high temperature or direct and prolonged sunlight. The asphalt will soften and begin to flow between 185°F and 210°F. Some asphalt membranes are specially formulated for high-temperature situations and can withstand temperatures

Adhesive Type	Advantages	Disadvantages
		of up to 240°F, though they are typically not as sticky.
Butyl	• Typically compatible with PVC products and urethane sealants • Typically better adhesion than rubberized asphalt, particularly on unprimed surfaces • Compared to asphalt, butyl products form better bonds with difficult substrates and can be peeled off and adjusted during installation. • The temperature range is greater than asphalt, with application from 40 to 120°F, and service from -40 to 200°F. Typical recommendations are to avoid installation below 40°F unless it can be verified that the surface is free of moisture and contaminants. There are some tapes that can be installed in lower temperatures with the use of a primer.	• Susceptible to UV degradation, drying, and degradation adhesive properties • More expensive than asphalt
Acrylic and other polymers	• Water-based, solvent-based, or “solid,” acrylic tapes are becoming increasingly popular. The least expensive acrylic tape is water-based; however, this type of tape may not bond to as many types of substrates as the other varieties. According to BuildingGreen.com, “solid acrylic adhesives can form the strongest adhesive bonds at a wide range of temperatures and even achieve adhesion to damp or wet substrates.” Without solvents, the tapes do not become brittle over time. • Advanced acrylic adhesive is made of highly polar molecules, meaning a magnetic-like attraction pulls the adhesive into the substrate. Some acrylic tapes are formulated to flow into every crevice, increasing total contact area. This helps the tape wet out well, flowing into surface inconsistencies to produce a permanent bond. The result is a superior, lasting seal that is considerably stronger than traditional asphalt and butyl tapes. With both robust adhesion and cohesion, advanced acrylic tapes are internally strong—intertwined	• Not as much history as asphalt and butyl in flashings • Asphalt and butyl tapes have a natural stickiness, while acrylic-based tapes are pressure-activated. When the release paper on an acrylic tape is pulled, the surface doesn’t feel as sticky as that of an asphalt or a butyl tape, but the tape sticks well and is difficult to dislodge once the adhesive has been activated.

Adhesive Type	Advantages	Disadvantages
	polymer chains provide excellent internal strength, adding to the overall reliability of the seal.	

Conclusions

The complexity of interpreting and complying with codes, complying with green building standards and finding the most cost-effective way of doing both for building envelope thermal insulation, air resistance, water resistance and vapor permeance is beyond the capability of most building professionals.

A thorough analysis almost requires the use of sophisticated hygro-thermal modeling software, such as WUFI.[24] Many architects will fall back on prescriptive standards, advice from product vendors, regional practices and their own experience.

The objective of this paper is to at least provide a guide to the codes and standards that provide the basis for the requirements and the properties of materials and assemblies.

[24] http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=362/pagename=alpha_list