small building applications

Understanding Vapor Barriers

By Joseph W. Lstiburek, Ph.D., P.Eng., Member ASHRAE

The function of a vapor barrier is to retard migration of water vapor. Where it is located in an assembly and its permeability is a function of climate, the characteristics of the materials that comprise the assembly and the interior conditions. Vapor barriers are not typically intended to retard migration of air. That is the function of air barriers.

Confusion on the issue of vapor barriers and air barriers is common. The confusion arises because air often holds a great deal of moisture in vapor form. When this air moves from location to location, due to an air pressure difference, the vapor moves with it. This is a type of migration of water vapor. In the strictest sense air barriers are also vapor barriers when they control the transport of moisture-laden air.

An excellent discussion about the differences between vapor barriers and air barriers can be found in Quirrouette.[1]

Vapor barriers are also a cold climate artifact that have diffused into other climates more from ignorance than need. The history of cold climate vapor barriers itself is a story based more on personalities than physics. Rose[2] regales readers of this history. It is frightening that construction practices can be so dramatically influenced by so little research and reassuring that the inherent robustness of most building assemblies has been able to tolerate such foolishness.

So What is The Problem?

Incorrect use of vapor barriers is leading to an increase in moisture-related problems. Vapor barriers were originally intended to prevent assemblies from getting wet. However, they often prevent assemblies from drying. Vapor barriers installed on the interior of assemblies prevent assemblies from drying inward. This can be a problem in any air-conditioned enclosure, in any below grade space, or when a vapor barrier is also on the exterior. Additionally, this can be a problem where brick is installed over building paper and vapor permeable sheathing.

What Do We Really Want to Do?

Two seemingly simple requirements for building enclosures bedevil engineers and architects almost endlessly:

- Keep water out, and
- Let water out if it gets in.

Water can come in several phases: liq-

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uid, solid, vapor and adsorbed. The liquid phase as rain and groundwater has driven everyone crazy for hundreds of years but can be readily understood — drain everything and remember the humble flashing.

The solid phase also drives everyone crazy when we have to shovel it or melt it, but at least most professionals understand the related building problems (ice damming, frost heave, freeze-thaw damage).

However, the vapor phase is in a class of craziness all by itself. We will conveniently ignore the adsorbed phase and leave it for someone else to deal with. Note that adsorbed water is different than absorbed water.[3]

The fundamental principle of control of water in the liquid form is to drain it out if it gets in — and let us make it perfectly clear — it will get in if you build where it rains or if you place your building in the ground where there is water in the ground. This is easy to understand, logical, with a long historical basis.

The fundamental principle of water control in the solid form is to not let it become solid. And, if it does, give it space. Or, if it is solid, do not let it become liquid. If it does become liquid, drain it away before it can become solid again. This is a little more difficult to understand, but logical and based on solid research. Examples of this principle include the use of air entrained concrete to control freeze-thaw damage and the use of attic venting to provide cold roof decks to control ice damming.

The fundamental principle of water control in the vapor form is to keep it out and to let it out if it gets in. Simple, right? No chance. It becomes complicated because sometimes the best strategies to keep water vapor out also trap water vapor in. This can be a real problem if the assemblies start out wet because of rain or the use of wet materials.

It becomes even more complicated because of climate. In general, water vapor moves from the warm side of building assemblies to the cold side. This is simple to understand, except we have trouble deciding what side of a wall is the cold or warm side. Logically, this means we need different strategies for different climates. We also must take into account differences between summer and winter.

Finally, complications arise when materials can store water. This can be both good and bad. A cladding system such as a brick veneer can act as a reservoir after a rainstorm and significantly complicate wall design. Alternatively, wood framing or masonry can act as a hygric buffer absorbing water and lessening moisture shocks.

What is required is to define vapor control measures on a more regional climatic basis and to define the vapor control measures more precisely.

Part of the problem is that we struggle with names and terms. We have vapor retarders, vapor barriers, vapor permeable, vapor impermeable, etc. What do these terms mean? It depends on whom you ask and whether they are selling something, or arguing with a building official. In an attempt to clear up some of the confusion, the following definitions are proposed:

Vapor Retarder*: *The element that is designed and installed in an assembly to retard the movement of water by vapor diffusion.*

* taken somewhat from *2001 ASHRAE Handbook—Fundamentals*, Chapter 23.

The unit of measurement typically used in characterizing the water vapor permeance of materials is the "perm." It is further proposed here that there should be several classes of vapor retarders. (This is nothing new. It is an extension and modification of the Canadian General Standards Board approach that specifies Type I and Type II vapor retarders. The numbers here are a little different, however.).These classes are:

Class I	0.1 perm or less
Class II	1.0 perm or less and greater than 0.1 perm
Class III	10 perm or less and greater than 1.0 perm

Test procedure for vapor retarders: ASTM E-96 Test Method A (the desiccant method or dry cup method)

Finally, a vapor barrier is defined as:

Vapor Barrier: A Class I vapor retarder.

The current International Building Code (and its derivative codes) defines a vapor retarder as 1.0 perm or less (using the same test procedure). In other words, the current code definition of a vapor retarder is equivalent to the definition of a Class II vapor retarder proposed by the author.

Continuing in the spirit of finally defining terms that are tossed around in the enclosure business, it is also proposed that materials be separated into four general classes based on their permeance (again nothing new, this is an extension of the discussion in a previous *ASHRAE Journal* article[4]):

Photo credit: IBACOS

"Incorrect use of vapor barriers is leading to an increase in moisture-related problems."

Vapor impermeable:	0.1 perm or less
Vapor semi-impermeable:	1.0 perm or less and greater than 0.1 perm
Vapor semi-permeable:	10 perms or less and greater than 1.0 perm
Vapor permeable:	greater than 10 perms

Recommendations for Building Enclosures

The following building assembly recommendations are climatically based (see sidebar, "Hygrothermal Regions") and are sensitive to cladding type (brick or stone veneer, stucco) and structure (concrete block, steel or wood frame, precast concrete).

The recommendations apply to residential, business, assembly, educational and mercantile occupancies. The recommendations do not apply to special use enclosures such as spas, pool buildings, museums, hospitals, data processing centers or other engineered enclosures such as factory, storage or utility enclosures.

The recommendations are based on the following principles:

• Avoiding use of vapor barriers where vapor retarders will provide satisfactory performance. Avoiding use of vapor retarders where vapor permeable materials will provide satisfactory performance. (thereby, encouraging drying mechanisms over wetting-prevention mechanisms).

• Avoiding the installation of vapor barriers on both sides of assemblies, i.e., "double vapor barriers," to facilitate assembly drying in at least one direction.

• Avoiding installation of vapor barriers such as polyethylene vapor barriers, foil faced batt insulation and reflective radiant

Hygrothermal Regions

Subarctic and Arctic

A subarctic and arctic climate is defined as a region with approximately 12,600 heating degree days (65°F basis) (7,000 heating degree days [18°C basis]) or greater.

Very Cold

A very cold climate is defined as a region with approximately 9,000 heating degree days or greater (65°F basis) (5,000 heating degree days [18°C basis]) or greater and less than 12,600 heating degree days (65°F basis) (7,000 heating degree days [18°C basis]).

Cold

A cold climate is defined as a region with approximately 5,400 heating degree days (65°F basis) (3,000 heating degree days [18°C basis]) or greater and less than approximately 9,000 heating degree days (65°F basis) (5,000 heating degree days [18°C basis]).

Mixed-Humid

A mixed-humid and warm-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation with approximately 4,500 cooling degree days (50°F basis) (2,500 cooling degree days [10°C basis]) or greater and less than approximately 6,300 cooling degree days (50°F basis) (3,500 cooling degree days [10°C basis]) and less than approximately 5,400 heating degree days (65°F basis) (3,000 heating degree days [18°C basis]) and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

Marine

A marine climate is defined as a region where all of the following occur:

- A mean temperature of the coldest month between 27°F (–3°C) and 65°F (18°C);
- A mean temperature of the warmest month below 72°F (18°C);
- At least four months with mean temperatures over 50°F (10°C); and
- A dry season in the summer, the month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation.

Hot-Humid

A hot-humid climate is defined as a region that receives more than 20 in. (50 cm) of annual precipitation with approximately 6,300 cooling degree days (50°F basis) [3,500 cooling degree days (10°C basis)] or greater and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

This definition characterizes a region that is similar to the ASHRAE definition of hot-humid climates where one or both of the following occur:

- A 67°F (19.5°C) or higher wet-bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year; or
- A 73°F (23°C) or higher wet-bulb temperature for 1,500 or more hours during the warmest six consecutive months of the year.

Hot-Dry, Warm-Dry and Mixed-Dry

A hot-dry climate is defined as region that receives less than 20 in. (50 cm) of annual precipitation with approximately 6,300 cooling degree days (50°F basis) [3,500 cooling degree days (10°C basis)] or greater and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

A warm-dry and mixed-dry climate is defined as a region that receives less than 20 in. (50 cm) of annual precipitation with approximately 4,500 cooling degree days (50°F basis) [2,500 cooling degree day (10°C basis)] or greater and less than approximately 6,300 cooling degree days (50°F basis) [3,500 cooling degree days (10°C basis)] and less than approximately 5,400 heating degree days (65°F basis) [3,000 heating degree days (18°C basis)] and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

barrier foil insulation on the interior of air-conditioned assemblies (a practice that has been linked with moldy buildings).[5]

• Avoiding installation of vinyl wall coverings on the inside of air-conditioned assemblies (a practice that has been linked with moldy buildings).[6]

• Enclosures are ventilated meeting ASHRAE Standards 62.1 or 62.2.

Each of the recommended building assemblies was evaluated using dynamic hygrothermal modeling. The moisture content of building materials that comprise the building assemblies all remained below the equilibrium moisture content the materials as specified in ASHRAE proposed Standard 160P, Design Criteria for Moisture Control in Buildings, under this evaluation approach. Interior air conditions and exterior air conditions as specified by 160P were used. WUFI was used as the modeling program.[7]

More significantly, each of the recommended building assemblies have been found by the author to provide satisfactory performance under the limitations noted. Satisfactory performance is defined as no moisture problems reported or observed during at least a 10-year period. The only exceptions relate to the assemblies containing low density spray applied foams. The author has only been familiar with their use in assemblies less than five years old.

References

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2. Rose, W. 1997. "Moisture control in the modern building envelope: the history of the vapor barrier in the U.S. – 1923 to 1952." *APT* XXVIII(4).

3. Kumaran, M.K., G.P. Mitalas, and M.T. Bomberg. 1994. "Fundamentals of transport and storage of moisture in building materials and components." *Moisture Control in Buildings*, ASTM Manual Series: MNL 18, ASTM Publication Code (PCN) 28-018094-10, Philadelphia.

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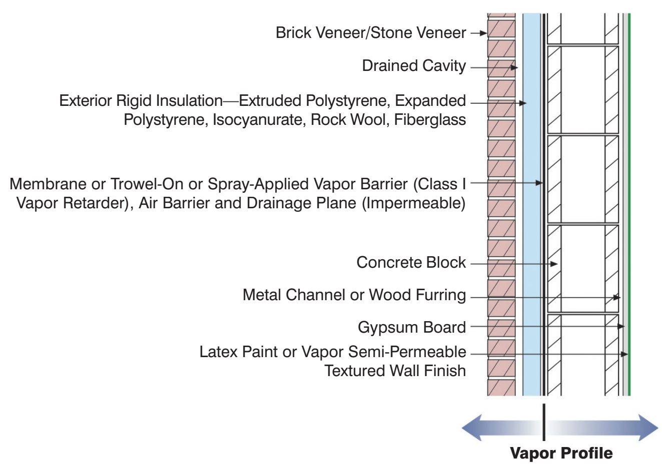
6. Lstiburek, J.W. 1993. "Humidity Control in the Humid South," Workshop Proceedings—Bugs, Mold & Rot II, BETEC, Washington.

7. Kunzel, H.M. 1999. WUFI: PC Program for Calculating the Coupled Heat and Moisture Transfer in Building Components; Fraunhofer Institute for Building Physics, Holzkirchen, Germany, 1999.

Assembly 1: Concrete Block With Exterior Insulation and Brick or Stone Veneer

Applicability: all hygrothermal regions.

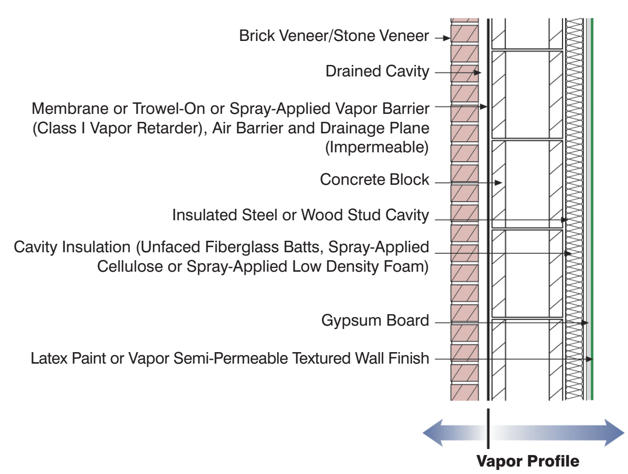
This is arguably the most durable wall assembly. It is constructed from non-water sensitive materials, and due to the block construction, has a large moisture storage (or hygric buffer) capacity. It can be constructed virtually anywhere. In cold climates condensation is limited on the interior side of the vapor barrier as a result of installing all of the thermal insulation on the exterior side of the vapor barrier (which is also the drainage plane and air barrier in this assembly). In hot climates any moisture that condenses on the exterior side of the vapor barrier will be drained to the exterior since the vapor barrier is also a drainage plane. This wall assembly will dry from the vapor barrier inwards and will dry from the vapor barrier outwards.



Assembly 2: Concrete Block With Interior Frame Wall Cavity Insulation and Brick or Stone Veneer

Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions; should not be used in cold, very cold, and subarctic/arctic regions.

This wall assembly has all of the thermal insulation installed to the interior of the vapor barrier, and therefore, should not be used in cold regions or colder. It is also a durable assembly due to the block construction and the associated moisture storage (hygric buffer) capacity. The wall assembly does contain water sensitive cavity insulation (except where spray foam is used) and it is important that this assembly can dry inwards—therefore, vapor semi-impermeable interior finishes such as vinyl wall coverings should be avoided. In this wall assembly the vapor barrier is also the drainage plane and air barrier.

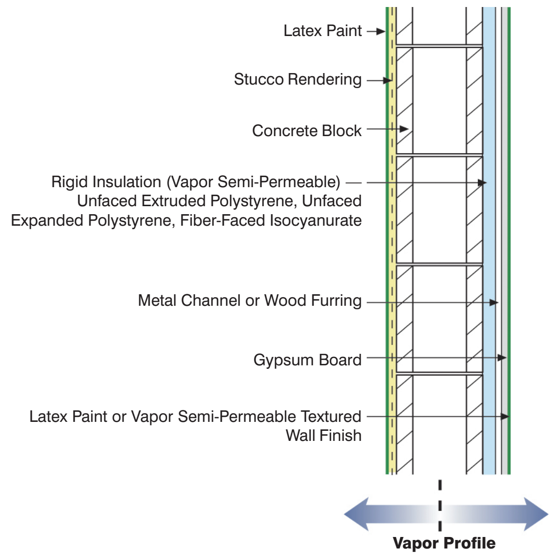


Assembly 3: Concrete Block With Interior Rigid Insulation and Stucco

*Applicability: all hygrothermal regions.**

This assembly has all of the thermal insulation installed on the interior of the concrete block construction but differs from *Assembly 2* since it does not have a vapor barrier on the exterior. The assembly also does not have a vapor barrier on the interior of the assembly. It has a large moisture storage (hygric buffer) capacity due to the block construction. The rigid insulation installed on the interior should be non-moisture sensitive and allow the wall to dry inwards, hence, the recommended use of vapor semi permeable foam sheathing. Note that the foam sheathing is not faced with aluminum foil or polypropylene skins. It is important that this assembly can dry inwards except in very cold and subarctic/arctic regions. Therefore, vapor semi-impermeable interior finishes such as vinyl wall coverings should be avoided in assemblies—except in very cold and subarctic/arctic regions. Vapor impermeable foam sheathings should be used in place of the vapor semi permeable foam sheathings in very cold and subarctic/arctic regions. The drainage plane in this assembly is the latex painted stucco rendering. A Class III vapor retarder is located on both the interior and exterior of the assembly (the latex paint on the stucco and on the interior gypsum board).

* In very cold and subarctic/arctic regions vapor impermeable foam sheathings are recommended.

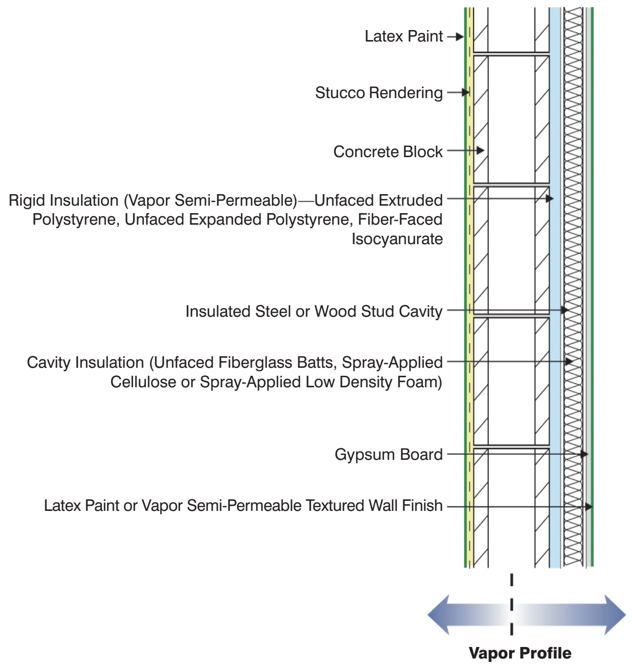


Assembly 4: Concrete Block With Interior Rigid Insulation/Frame Wall With Cavity Insulation and Stucco

*Applicability: all hygrothermal regions.**

This assembly is a variation of *Assembly 3*. It also has all of the thermal insulation installed on the interior of the concrete block construction but differs from *Assembly 3* due to the addition of a frame wall to the interior of the rigid insulation. This assembly also does not have a vapor barrier on the exterior. The assembly also does not have a vapor barrier on the interior of the assembly. It has a large moisture storage (hygric buffer) capacity due to the block construction. The rigid insulation installed on the interior should be non-moisture sensitive and allow the wall to dry inwards, hence, the recommended use of vapor semi permeable foam sheathing. Note that the foam sheathing is not faced with aluminum foil or polypropylene skins. It is important that this assembly can dry inwards even in very cold and subarctic/arctic regions. Therefore, vapor semi-impermeable interior finishes such as vinyl wall coverings should be avoided in assemblies. Vapor impermeable foam sheathings should be used in place of the vapor semi permeable foam sheathings in very cold and subarctic/arctic regions. The drainage plane in this assembly is the latex painted stucco rendering. A Class III vapor retarder is located on both the interior and exterior of the assembly (the latex paint on the stucco and on the interior gypsum board.

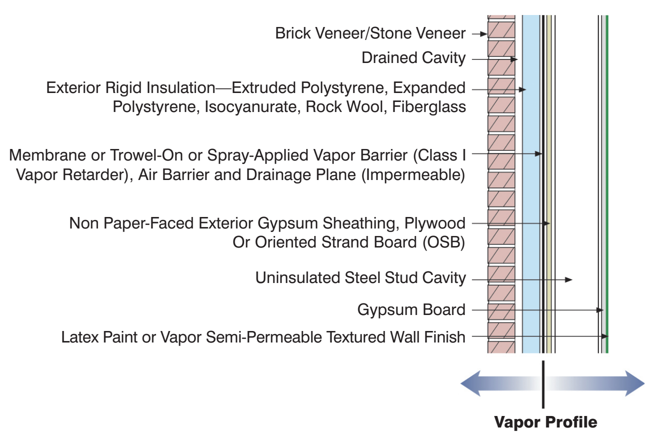
* In very cold and sub-arctic/arctic regions vapor impermeable foam sheathings are recommended—additionally the thickness of the foam sheathing should be determined by hygrothermal analysis so that the interior surface of the foam sheathing remains above the dew point temperature of the interior air (see sidebar, "Proposed Building Code Requirements for Vapor Retarders," see *Figures 2* and *3*).



Assembly 5: Frame Wall With Exterior Insulation and Brick or Stone Veneer

Applicability: all hygrothermal regions.

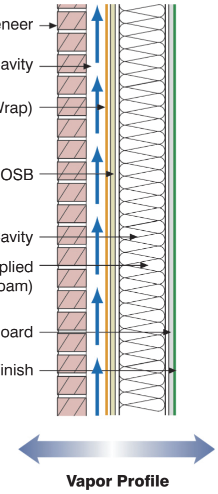
This wall is a variation of *Assembly 1* but without the moisture storage (or hygric buffer) capacity. This wall is also a durable wall assembly. It is constructed from non-water sensitive materials and has a high drying potential inwards due to the frame wall cavity not being insulated. It also can be constructed virtually anywhere. In cold climates condensation is limited on the interior side of the vapor barrier as a result of installing all of the thermal insulation on the exterior side of the vapor barrier (which is also the drainage plane and air barrier in this assembly). In hot climates any moisture that condenses on the exterior side of the vapor barrier will be drained to the exterior since the vapor barrier is also a drainage plane. This wall assembly will dry from the vapor barrier inwards and will dry from the vapor barrier outwards.



Assembly 6: Frame Wall With Cavity Insulation and Brick or Stone Veneer

Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions. It can be used with hygrothermal analysis in some areas in cold regions (Zone 5, but not Zone 6. See sidebar, "Proposed Building Code Requirements for Vapor Retarders"); should not be used in very cold and subarctic/arctic regions.

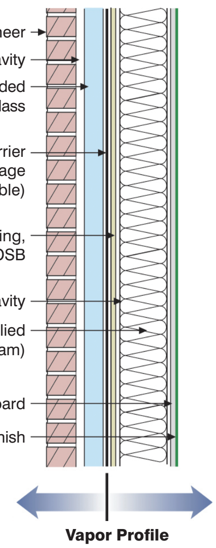
This wall is a flow-through assembly. It can dry to both the exterior and the interior. It has a Class III vapor retarder on the interior of the assembly (the latex paint on the gypsum board). It is critical in this wall assembly that the exterior brick veneer (a "reservoir" cladding) be uncoupled from the wall assembly with a ventilated and drained cavity. The cavity behind the brick veneer should be at least 2 in. (51 mm) wide (source: Brick Institute of America) and free from mortar droppings. It also must have air inlets ("weep holes") at its base and air outlets ("weep holes") at its top to provide back ventilation of the brick veneer. The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior gypsum board, the exterior gypsum wallboard or the exterior building wrap.



Assembly 7: Frame Wall With Exterior Rigid Insulation With Cavity Insulation and Brick or Stone Veneer

Applicability: all hygrothermal regions except subarctic/arctic. In cold and very cold regions, the thickness of the foam sheathing should be determined by hygrothermal analysis so that the interior surface of the foam sheathing remains above the dew-point temperature of the interior air (see sidebar, "Proposed Building Code Requirements for Vapor Retarders," see Figures 2 *and* 3*).*

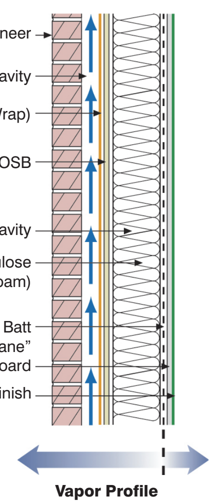
This wall is a variation of *Assembly 5*. In cold climates condensation is limited on the interior side of the vapor barrier as a result of installing some of the thermal insulation on the exterior side of the vapor barrier (which is also the drainage plane and air barrier in this assembly). In hot climates any moisture that condenses on the exterior side of the vapor barrier will be drained to the exterior since the vapor barrier is also a drainage plane. This wall assembly will dry from the vapor barrier inwards and will dry from the vapor barrier outwards. Since this wall assembly has a vapor barrier that is also a drainage plane it is not necessary to back vent the brick veneer reservoir cladding as in *Assembly 6*. Moisture driven inwards out of the brick veneer will condense on the vapor barrier/drainage plane and be drained outwards.



Assembly 8: Frame Wall With Cavity Insulation and Brick or Stone Veneer With Interior Vapor Retarder

Applicability: Limited to cold and very cold regions.

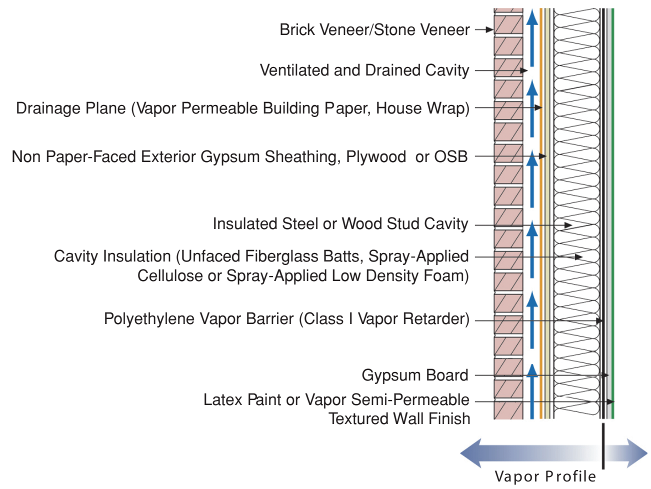
This wall is a variation of *Assembly 6* except it has a Class II vapor retarder on the interior limiting its inward drying potential—but not eliminating it. It still considered a flow-through assembly because it can dry to both the exterior and the interior. It is critical in this wall assembly, as in *Assembly 6,* that the exterior brick veneer (a "reservoir" cladding) be uncoupled from the wall assembly with a ventilated and drained cavity. The cavity behind the brick veneer should be at least 2 in. (51 mm) wide (source: Brick Institute of America) and free from mortar droppings. It also must have air inlets ("weep holes") at its base and air outlets ("weep holes") at its top to provide back ventilation of the brick veneer. The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior gypsum board, the exterior gypsum board or the exterior building wrap.



Assembly 9: Frame Wall With Cavity Insulation and Brick or Stone Veneer With Interior Vapor Barrier

Applicability: Limited to very cold, subarctic and arctic regions.

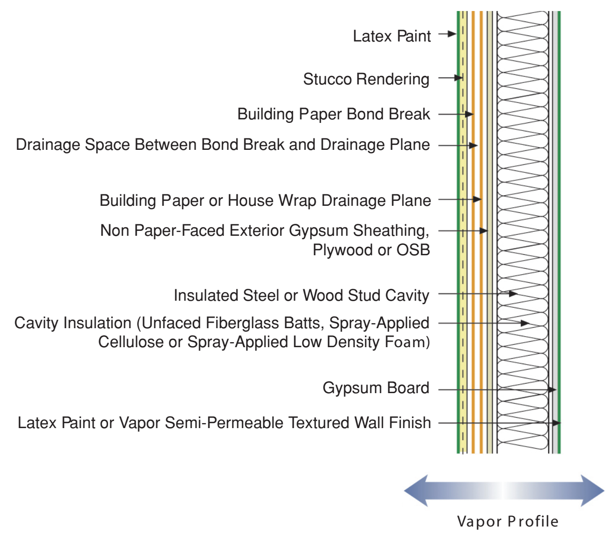
This wall is a further variation of Assembly 6 but now it has a Class I vapor retarder on the interior (a ìvapor barrierî) completely eliminating any inward drying potential. It is considered the "classic" cold climate wall assembly. It is critical in this wall assembly, as in Assemblies 6 and 8, that the exterior brick veneer (a ìreservoirî cladding) be uncoupled from the wall assembly with a ventilated and drained cavity. The cavity behind the brick veneer should be at least 2 in. (51 mm) wide (source: Brick Institute of America) and free from mortar droppings. It also must have air inlets at its base and air outlets at its top to provide back ventilation of the brick veneer. The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior polyethylene vapor barrier, the interior gypsum board, the exterior gypsum board or the exterior building wrap.



Assembly 10: Frame Wall With Cavity Insulation and Stucco

Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions. It can be used with hygrothermal analysis in some areas in cold regions (Zone 5, but not Zone 6; See sidebar, ìProposed Building Code Requirements for Vapor Retardersî); should not be used in very cold, and subarctic/arctic regions.

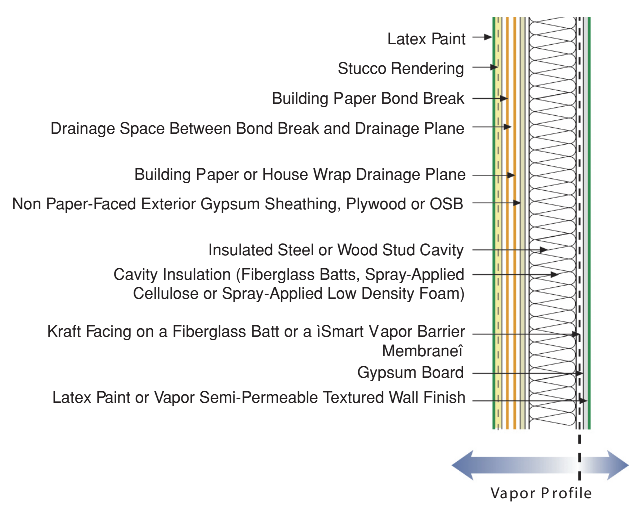
This wall is also a flow-through assembly similar to Assembly 6óbut without the brick veneer. It has a stucco cladding. It can dry to both the exterior and the interior. It has a Class III vapor retarder on the interior of the assembly (the latex paint on the gypsum board). It is critical in this wall assembly that a drainage space be provided between the stucco rendering and the drainage plane. This can be accomplished by installing a bond break (a layer of tar paper) between the drainage plane and the stucco. A spacer mat can also be used to increase drainability. Alternatively, a textured or profiled drainage plane (building wrap) can be used. The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior gypsum board, the exterior stucco rendering, the exterior sheathing or the exterior building wrap.



Assembly 11: Frame Wall With Cavity Insulation and Stucco With Interior Vapor Retarder

Applicability: Limited to cold, very cold regions and marine.

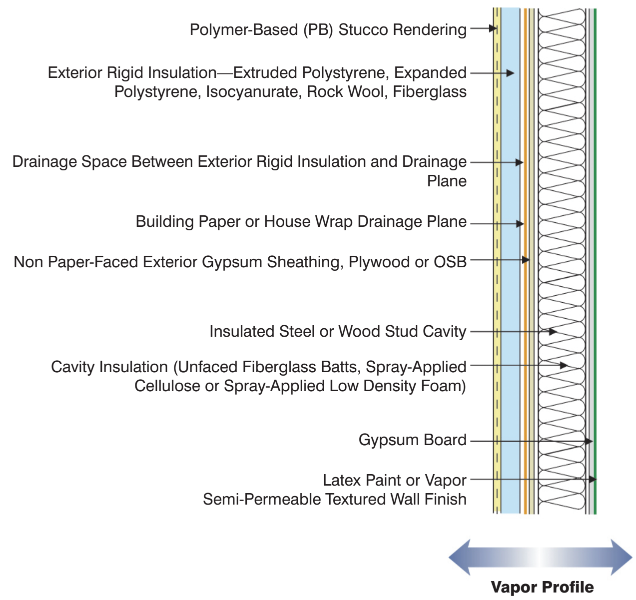
This wall is a variation of Assemblies 6 and 10 except it has a Class II vapor retarder on the interior limiting its inward drying potentialóbut not eliminating it. It still considered a flow-through assembly. It can dry to both the exterior and the interior. It is critical in this wall assembly, as in Assembly 10, that a drainage space be provided between the stucco rendering and the drainage plane. This can be accomplished by installing a bond break (a layer of tar paper) between the drainage plane and the stucco. A spacer mat also can be used to increase drainability. Alternatively, a textured or profiled drainage plane (building wrap) can be used. The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior gypsum board, the exterior stucco rendering, the exterior sheathing or the exterior building wrap.



Assembly 12: Frame Wall With Exterior Rigid Insulation With Cavity Insulation and Stucco

Applicability: all hygrothermal regions except subarctic/arctic - in cold and very cold regions the thickness of the foam sheathing should be determined by hygrothermal analysis so that the interior surface of the foam sheathing remains above the dew point temperature of the interior air (see sidebar, "Proposed Building Code Requirements for Vapor Retarders," Section 4).

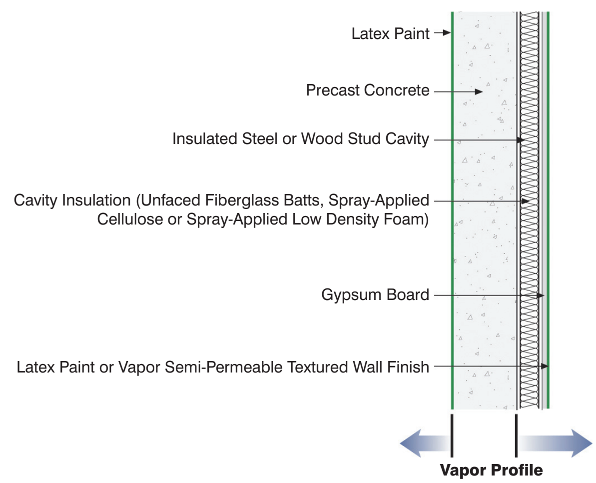
This is a water managed exterior insulation finish system (EIFS). Unlike "face-sealed" EIFS this wall has a drainage plane inboard of the exterior stucco skin that is drained to the exterior. It is also a flow-through assembly similar to *Assembly 6*. It can dry to both the exterior and the interior. It has a Class III vapor retarder on the interior of the assembly (the latex paint on the gypsum board). It is critical in this wall assembly that a drainage space be provided between the exterior rigid insulation and the drainage plane. This can be accomplished by installing a spacer mat or by providing drainage channels in the back of the rigid insulation. Alternatively, a textured or profiled drainage plane (building wrap) can be used. The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior gypsum board, the exterior stucco rendering, the exterior sheathing or the exterior building wrap.



Assembly 13: Precast Concrete With Interior Frame Wall Cavity Insulation

Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions; should not be used in cold, very cold, and subarctic/arctic regions.

The vapor barrier in this assembly is the precast concrete itself. Therefore, this wall assembly has all of the thermal insulation installed to the interior of the vapor barrier. Of particular concern is the fact that the thermal insulation is air permeable (except where spray foam is used). Therefore, this wall assembly should not be used in cold regions or colder. It has a small moisture storage (hygric buffer) capacity due to the precast concrete construction. The wall assembly does contain water sensitive cavity insulation (except where spray foam is used) and it is important that this assembly can dry inwards. Therefore, vapor semi-impermeable interior finishes such as vinyl wall coverings should be avoided. In this wall assembly the precast concrete is also the drainage plane and air barrier.

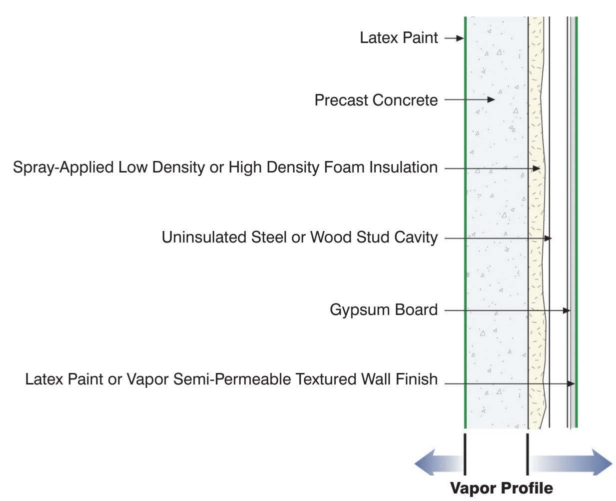


Assembly 14: Precast Concrete With Interior Spray Applied Foam Insulation

*Applicability: all hygrothermal regions.**

This assembly has all of the thermal insulation installed on the interior of the precast concrete. The assembly also does not have a vapor barrier on the interior of the assembly. It has a small moisture storage (hygric buffer) capacity due to the precast concrete construction. The spray foam insulation installed on the interior of the precast concrete is non-moisture sensitive and allows the wall to dry inwards. It is important that this assembly can dry inwards except in very cold and subarctic/arctic regions. Therefore, vapor semi-impermeable interior finishes such as vinyl wall coverings should be avoided in assemblies except in very cold and subarctic/arctic regions. High-density spray foam, due to its vapor semi-impermeable characteristics should be used in place of low-density foam in very cold and subarctic/arctic regions. The drainage plane in this assembly is the latex painted precast concrete. A Class III vapor retarder is located on both the interior and exterior of the assembly (the latex paint on the stucco and on the interior gypsum board).

* In very cold and subarctic/arctic regions, high-density spray foam (vapor semi-impermeable) is recommended.



Proposed Building Code Requirements For Vapor Retarders

The proposed building code requirements are based on a combination of field experience and laboratory testing. The requirements were also evaluated using dynamic hygrothermal modeling. The modeling program used was WUFI.[1] Under the modeling evaluation, the moisture content of building materials that comprise the building assemblies evaluated all remained below the equilibrium moisture content of the materials as specified in ASHRAE proposed Standard 160P, Design Criteria for Moisture Control in Buildings. Interior air conditions and exterior air conditions as specified by 160P were used. Enclosures are ventilated to meet ASHRAE Standards 62.1 or 62.2.

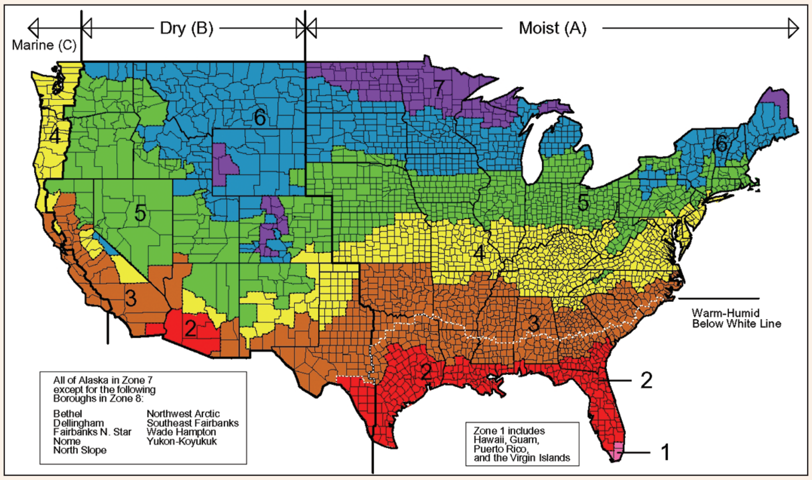


Figure 1: Department of Energy's proposed climate zone map.

The climate zones referenced are the U.S. Department of Energy climate zones as proposed for adoption in the 2006 International Residential Code (IRC) and International Energy Conservation Code (IECC). Their development is the subject of two ASHRAE papers.[2,3] An accompanying map defines the climate zones.

Note that vapor retarders are defined and classed using ASTM E-96 Test Method A (the desiccant method or dry cup method) consistent with the current code language. However, exterior sheathing/cladding assemblies are defined and classed using Test Method B (the "wet cup" method) to take advantage of the ability of some sheathings to "breathe" as they are exposed to high relative humidities.

1. Zones 1, 2, and 3 do not require any class of vapor retarder on the interior surface of insulation in insulated assemblies (this recommendation has already been accepted by the code committee at the code hearings in Nashville, September 2003 and Kansas City, May 2004).

Zone 4 (marine)	40% RH at 70°F	Dew Point 45°F
Zone 5	30% RH at 70°F	Dew Point 37°F
Zone 6	25% RH at 70°F	Dew Point 32°F
Zone 7	10% RH at 70°F	Dew Point 28°F

Table 1: Design conditions for steady-state design procedure (wall and floor assemblies).

Zone 5	35% RH at 70°F	Dew Point 39°F
Zone 6	30% RH at 70°F	Dew Point 37°F
Zone 7	25% RH at 70°F	Dew Point 32°F

Table 2: Design conditions for steady-state design procedure (roof and attic assemblies).

2. Zone 4 (not marine) requires a Class III (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies.

3. Zone 4 (marine) requires a Class III (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies where the permeance of the exterior sheathing/cladding assembly is greater than 1.0 perm as tested by Test Method B (the "wet cup" method of ASTM E-96).

4. Zone 4 (marine) requires a Class II (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies where the permeance of the exterior sheathing/cladding assembly is less than or equal to 1.0 perm and greater than 0.1 perm as tested by Test Method B (the "wet cup" method) of ASTM E-96).

5. Zone 4 (marine) requires a Class III (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies where the permeance of the exterior sheathing is 0.1 perm or less as tested by Test Method B (the "wet cup" method) of ASTM E-96) and the interior surface of the exterior sheathing shall be maintained above the dew-point temperature of the interior air. Under this design approach assume steady-state heat transfer, interior air at a temperature of 70°F (21°C), at a relative humidity specified in *Table 1* and exterior air at a temperature that is equal to the average outdoor temperature for the location during the coldest three months of the year (e.g., December, January and February).

6. Zone 5 requires a Class III (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies where the permeance of the exterior sheathing is greater than 1.0 perm as tested by Test Method B (the "wet cup" method) of ASTM E-96.

7. Zones 6 and 7 require a Class II (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies where the permeance of the exterior sheathing is greater than 1.0 perm as tested by Test Method B (the "wet cup" method) of ASTM E-96.

8. Zones 5, 6 and 7 require a Class II (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor as-

Zone	Wall Assembly Exterior Sheathing >1.0 Perm	≤1.0 Perm>0.1 Perm	Wall Assembly ≤0.1 Perm
1	Not Required	Not Required	Not Required
2	Not Required	Not Required	Not Required
3	Not Required	Not Required	Not Required
4 (Not Marine)	Class III	Class III	Class III
4 (Marine)	Class III	Class II	Class III*
5	Class III	Class II	Class II*
6	Class II	Class II	Class II*
7	Class II	Class II	Class II*

* Additionally, the interior surface of the exterior sheathing shall be maintained above the dew-point temperature of the interior air (see *Table 1*).

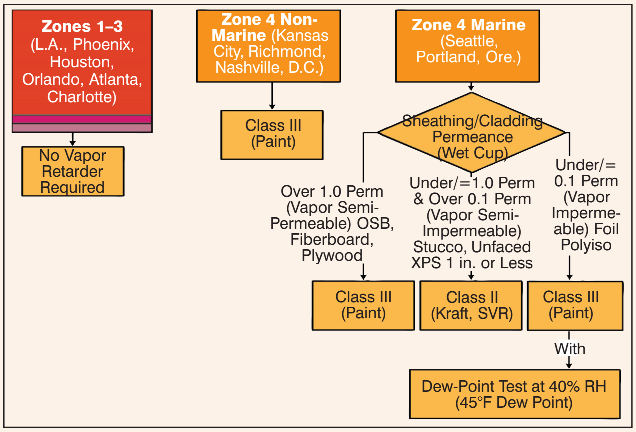


Table 3 (left): Summary of recommendations for vapor retarders on the interior of wall assemblies. Figure 2 (right): Vapor barrier flow chart, Zones 1–4.

semblies where the permeance of the exterior sheathing/cladding assembly is less than or equal to 1.0 perm and greater than 0.1 perm as tested by Test Method B (the "wet cup" method) of ASTM E-96.

9. Zones 5, 6 and 7 require a Class II (or lower) vapor retarder on the interior surface of insulation in insulated wall and floor assemblies, where the permeance of the exterior sheathing is 0.1 perm or less as tested by Test Method B (the "wet cup" method) of ASTM E-96 and the interior surface of the exterior sheathing shall be maintained above the dew-point temperature of the interior air. Under this design approach, assume steady-state heat transfer, interior air at a temperature of 70°F (21°C), at a relative humidity specified in *Table 1,* and exterior air at a temperature that is equal to the average outdoor temperature for the location during the coldest three months of the year (e.g., December, January and February).

10. Zone 5 requires a Class III (or lower) vapor retarder on the interior surface of insulation in ventilated insulated roof or attic assemblies.

11. Zone 5 require a Class III (or lower) vapor retarder on the interior surface of insulation in unvented insulated roof or attic assemblies and the condensing surface shall be maintained above the dew-point temperature of the interior air. The condensing surface is defined as either the interior surface of the structural roof deck or the interior surface of an air-impermeable insulation applied in direct contact to the underside/interior of the structural roof deck. “Air-impermeable” is quantitatively defined by ASTM E 283. Under this design approach assume steady-state heat transfer, interior air at a temperature of 70°F (21°C), at a relative humidity specified in *Table 2* and exterior air at a temperature that is equal to the average outdoor temperature for the location during the coldest three months of the year (e.g., December, January and February).

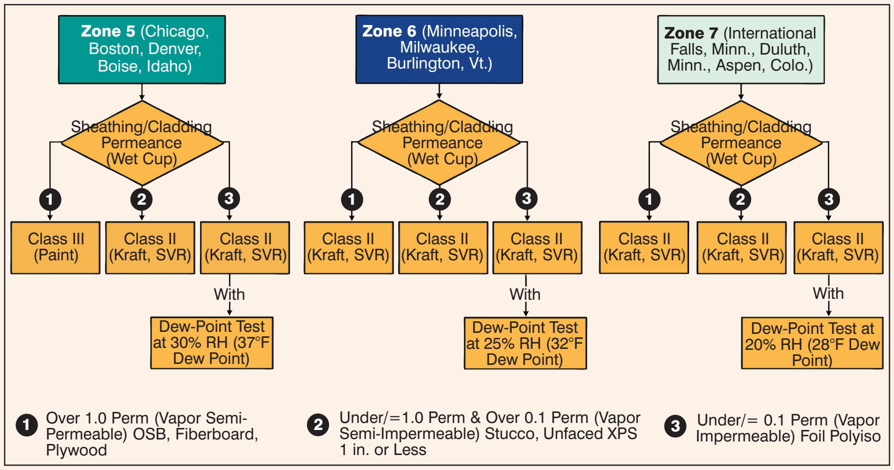


Figure 3: Vapor barrier flow chart, Zones 5–7.

12. Zones 6 and 7 require a Class II (or lower) vapor retarder on the interior surface of insulation in unvented insulated roof or attic assemblies and the condensing surface shall be maintained above the dew-point temperature of the interior air. The condensing surface is defined as either the interior surface of the structural roof deck or the interior surface of an air-impermeable insulation applied in direct contact to the underside/interior of the structural roof deck. “Air-impermeable” is quantitatively defined by ASTM E 283. Under this design approach assume steady-state heat transfer, interior air at a temperature of 70°F (21°C), at a relative humidity specified in *Table 2* and exterior air at a temperature that is equal to the average outdoor temperature for the location during the coldest three months of the year (e.g., December, January and February).

13. Zones 6 and 7 require a Class II (or lower) vapor retarder on the interior surface of insulation in ventilated insulated roof or attic assemblies.

14. Zones 5, 6 and 7 require a Class III (or lower) vapor retarder on the interior surface of insulation in internally insulated below grade masonry and concrete walls. Frame walls (i.e. “stem walls”) that are constructed on the top of concrete or masonry foundation walls are not considered below grade walls.

15. Exceptions to the above requirements shall be allowed when assemblies are evaluated by dynamic hygrothermal modeling. The moisture content of building materials that comprise the building assembly shall remain below the equilibrium moisture content the materials as specified in 160P under this evaluation approach. Interior air conditions and exterior air conditions as specified by 160P shall be used.

What This Means From a Practical Perspective

Polyethylene is a Class I vapor retarder. A kraft-faced fiberglass batt is a Class II vapor retarder. Latex painted gypsum board (one coat of latex paint) is a Class III vapor retarder.

Plywood sheathing and oriented strand board (OSB) have perm values of greater than 1 perm when using the wet cup test (similarly for exterior gypsum sheathing or fiberboard sheathing).

Extruded polystyrene of 1 in. (25 mm) thick or thicker has a perm value of 1.0 perm or less. Film faced extruded polystyrenes of 0.5 in. (13 mm) thickness that have perforated facings have perm values of greater than 1 perm. Non-perforated foil and polypropylene faced rigid insulations have perm values of less than 0.1 perms.

Three-coat hard-coat stucco installed over two layers of Type D asphalt saturated kraft paper and OSB has a combined perm value of less than 1.0 under a wet cup test. Therefore the sheathing/cladding assembly is less than or equal to 1.0 as tested by Test Method B of ASTM E-96.

Foil-faced isocyanurate 0.5 thick (R 3.5) installed over a 2x4 frame wall meets Requirement 9 in Chicago. Therefore, a kraft-faced batt (Class II vapor retarder) is required on the interior of this assembly.

Foil-faced isocyanurate 1 in. (25 mm) thick (R 6) installed over a 2x6 frame wall (R 19) meets Requirement 9 in Minneapolis. Therefore, a kraft-faced batt (Class II vapor retarder) is required on the interior of this assembly.

In Chicago where plywood or OSB exterior sheathing is used, an unfaced fiberglass batt can be installed within the wall cavity and gypsum board painted with latex paint (Class III vapor retarder) is required on the interior of this assembly. If this assembly is moved to Minneapolis, a Class II vapor retarder is required on the interior (a kraft paper faced fiberglass batt).

References

1. Kunzel, H.M. 1999. WUFI: PC Program for Calculating the Coupled Heat and Moisture Transfer in Building Components; Fraunhofer Institute for Building Physics, Holzkirchen, Germany.

2. Briggs, R.S., R.G. Lucas, and T. Taylor. 2003. “Climate classification for building energy codes and standards: part 1 – development process.” *ASHRAE Transactions.*

3. Briggs, R.S., R.G. Lucas, and T. Taylor. 2003. “Climate classification for building energy codes and standards: part 2 – zone definitions, maps and comparisons.” *ASHRAE Transactions.*