PDHonline Course C229 (3 PDH)

Air and Vapor Barrier Basics

Instructor: John Huang, Ph.D., PE and John Poullain, PE

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

5.C.2.1 Vapor Barrier Journal Paper

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MIDWEST RESEARCH INSTITUTE,
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION,
1617 COLE BOULEVARD,
GOLDEN, CO
80401-3393

CONSORTIUM LEADER:
BUILDING SCIENCE CORPORATION
70 MAIN STREET, WESTFORD, MA
(978) 589-5100 / (978) 589-5103 FAX
CONTACT: BETSY PETTIT, AIA

CONSORTIUM MEMBERS:
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Vapor Barriers

The function of a vapor barrier is to retard the 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 the 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 the 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 Quirouette (1985)[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 (1997)[2] regales readers of this history. It is frightening indeed that construction practices can be so dramatically influenced by so little research and reassuring indeed that the inherent robustness of most building assemblies has been able to tolerate such foolishness.

What Do We Really Want to Do?

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

- keep water out
- let water out if it gets in

Water can come in several phases: liquid, solid, vapor and adsorbed. The liquid phase as rain and ground water 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). But 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.

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 put 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 control of water in the sold form is to not let it get solid and if it does – give it space or if it is solid not let it get liquid and if it does drain it away before it can get solid again. A little more difficult to understand, but logical and based on solid research. Examples of this principle is 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.

[1] Quirouette, R.L.; The Difference Between a Vapor Barrier and an Air Barrier; Building Practice Note 54, Division of Building Research, National Research Council of Canada, ISSN 0701-5216, Ottawa, Ontario, Canada, July 1985.
[2] Rose, W.; Moisture Control in the Modern Building Envelope: The History of the Vapor Barrier in the US – 1923 to 1952, APT, Volume XXVIII, Number 4, 1997.

The fundamental principle of control of water in the vapor form is to keep it out and to let it out if it gets in. Simple right? No chance. It gets 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 gets even more complicated because of climate. In general water vapor moves from the warm side of building assemblies to the cold side of building assemblies. 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 have to 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 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, we have vapor barriers, we have vapor permeable we have 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[3]:	The element that is designed and installed in an assembly to retard the movement of water by vapor diffusion.

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):

Class I	Vapor Retarder:	0.1 perm or less
Class II	Vapor Retarder:	1.0 perm or less and greater than 0.1 perm
Class III	Vapor Retarder:	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.

[3] taken somewhat from ASHRAE Fundamentals 2001, Chapter 23

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 ASHRAE Journal, February 02 – Moisture Control for Buildings)[4]:

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 **Appendix I**) 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, office, commercial, school and retail occupancies. The recommendations do not apply to special use enclosures such as spas, pool buildings, museums, hospitals, data processing centers or other engineered enclosures.

The following things are discouraged:

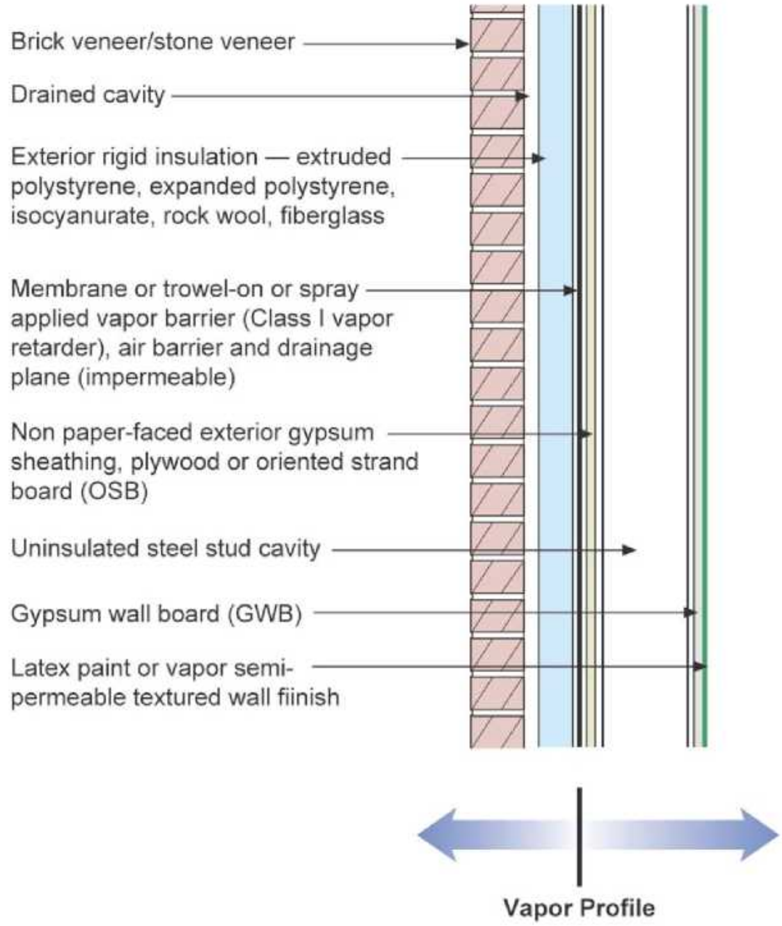
- The installation of vapor barriers on both sides of assemblies – i.e. "double vapor barriers".
- The installation of vapor barriers such as polyethylene vapor barriers, foil faced batt insulation and reflective radiant barrier foil insulation on the interior of air-conditioned assemblies.
- The installation of vinyl wall coverings on the inside of air-conditioned assemblies.
- The placement of a layer of sand between polyethylene vapor barriers and concrete slabs on grade.
- The installation of polyethylene vapor barriers on the interior of internally insulated basements.

The following things are encouraged:

- The construction of assemblies that are able to dry by diffusion to at least one side and in many cases to both sides.
- The ability to use insulating sheathings in cold climates without the creation of "double vapor barriers".
- The ability to use of damp spray insulations in cold climates with insulating sheathings without the creation of "double vapor barriers"

[4] Lstiburek, J.W.; Moisture Control For Buildings; ASHRAE Journal, February, 2002.

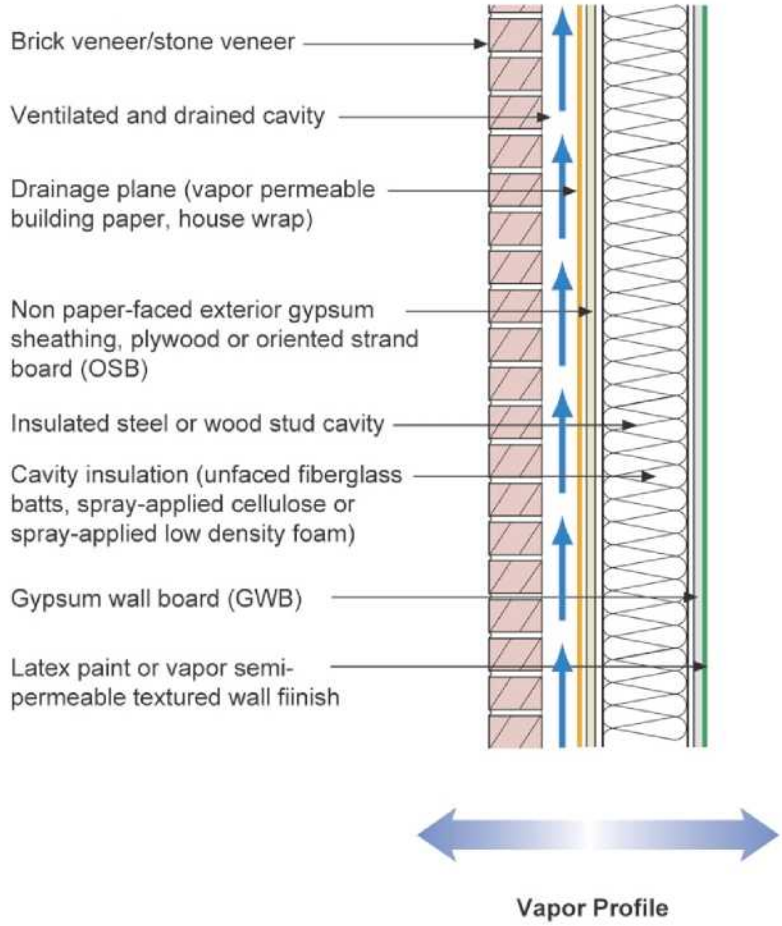
Figure 5
Frame Wall With Exterior Insulation and Brick or Stone Veneer



Applicability: All hygro-thermal regions

This wall is a variation of Figure 1 – but without the moisture storage (or hygric buffer) capacity. This wall is also a robust 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 can also 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.

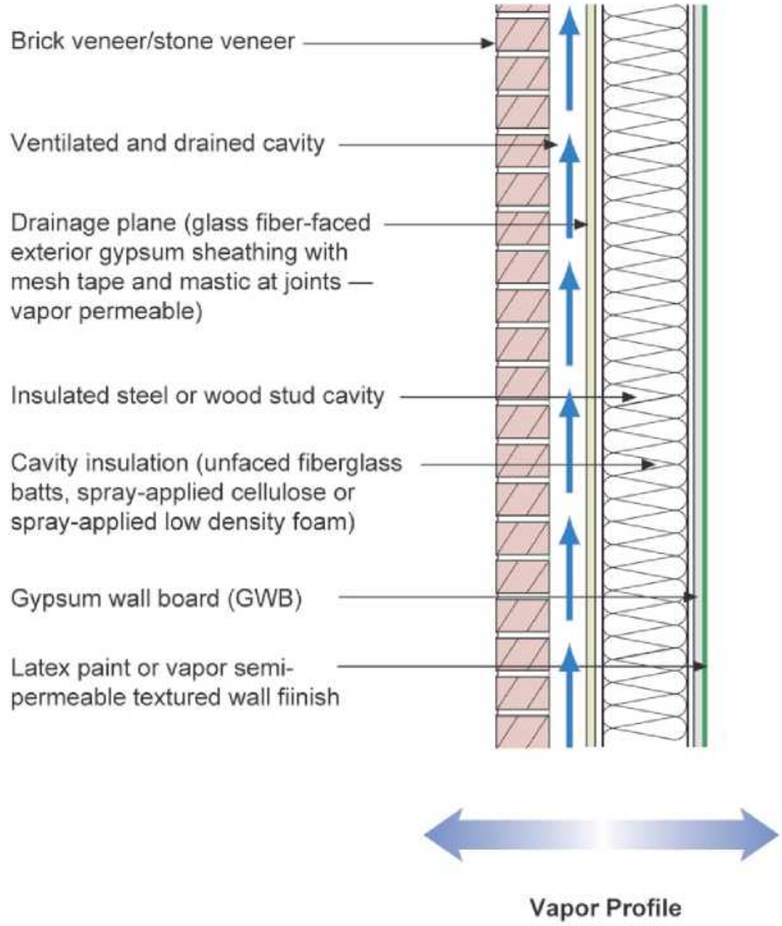
Figure 6
Frame Wall With Cavity Insulation and Brick or Stone Veneer



Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions – can be used with hygro-thermal analysis in some areas in cold regions (Zone 5, but not Zone 6; see **Appendix III**)- 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 wallboard). 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. Experience has shown that this assembly works well when the cavity behind the brick veneer is at least 2 inches wide and is free from mortar droppings. It must also have air inlets at its base and air outlets at its top in order 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 wallboard, the exterior gypsum wallboard or the exterior building wrap.

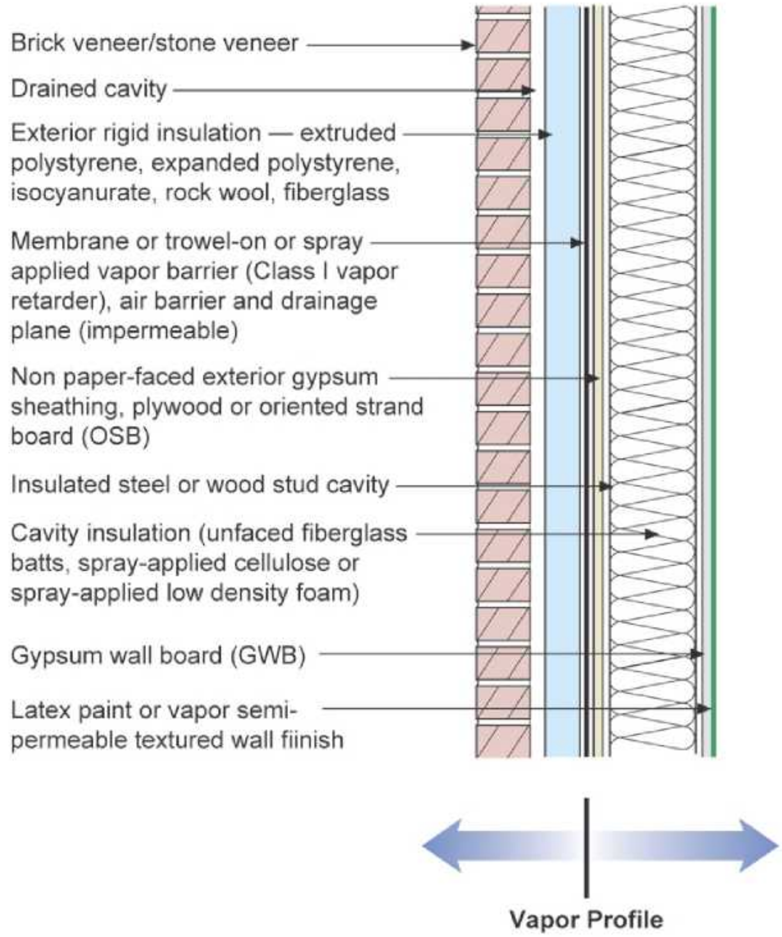
Figure 7
Frame Wall With Cavity Insulation and Brick or Stone Veneer



Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions – can be used with hygro-thermal analysis in some areas in cold regions (Zone 5, but not Zone 6; see **Appendix III**)- should not be used in very cold and subarctic/arctic regions

This wall is a variation of Figure 6. The exterior gypsum sheathing becomes the drainage plane. As in Figure 6 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 wallboard). It is also 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. Experience has shown that this assembly works well when the cavity behind the brick veneer is at least 2 inches wide and is free from mortar droppings. It must also have air inlets at its base and air outlets at its top in order to provide back ventilation of the brick veneer. The air barrier in this assembly can be either the interior gypsum wallboard or the exterior gypsum sheathing.

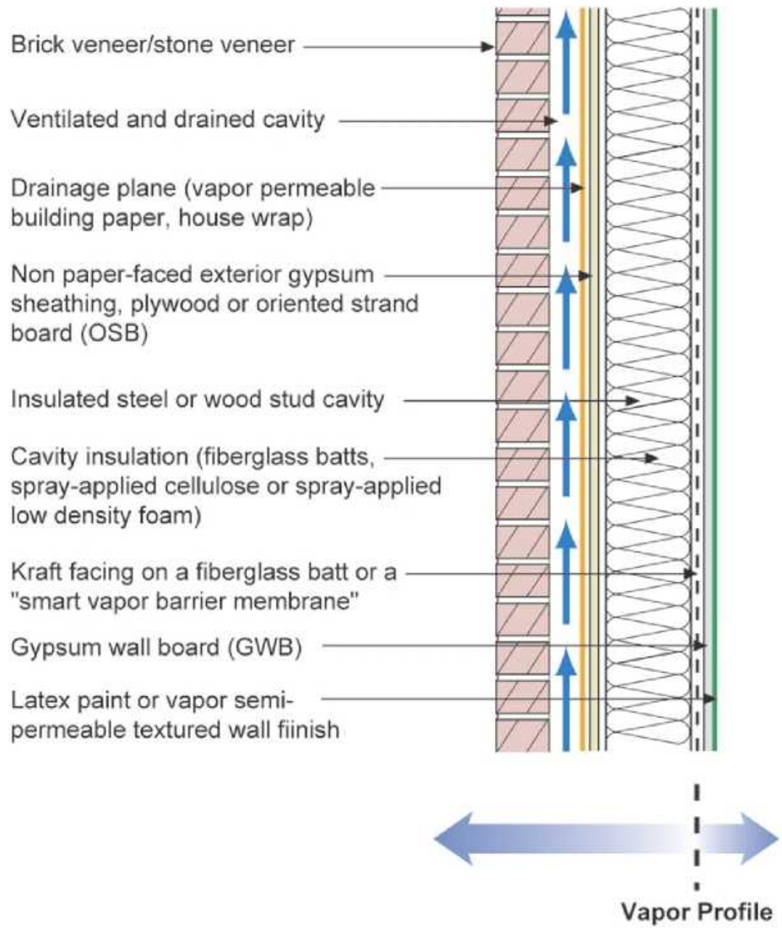
Figure 8
Frame Wall With Exterior Rigid Insulation With Cavity Insulation and Brick or Stone Veneer



Applicability: All hygro-thermal regions except subarctic/arctic – in cold and very cold regions the thickness of the foam sheathing should be determined by hygro-thermal analysis so that the interior surface of the foam sheathing remains above the dew point temperature of the interior air (see **Appendix III – section 4**)

This wall is a variation of Figure 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 Figure 6 and Figure 7. Moisture driven inwards out of the brick veneer will condense on the vapor barrier/drainage plane and be drained outwards.

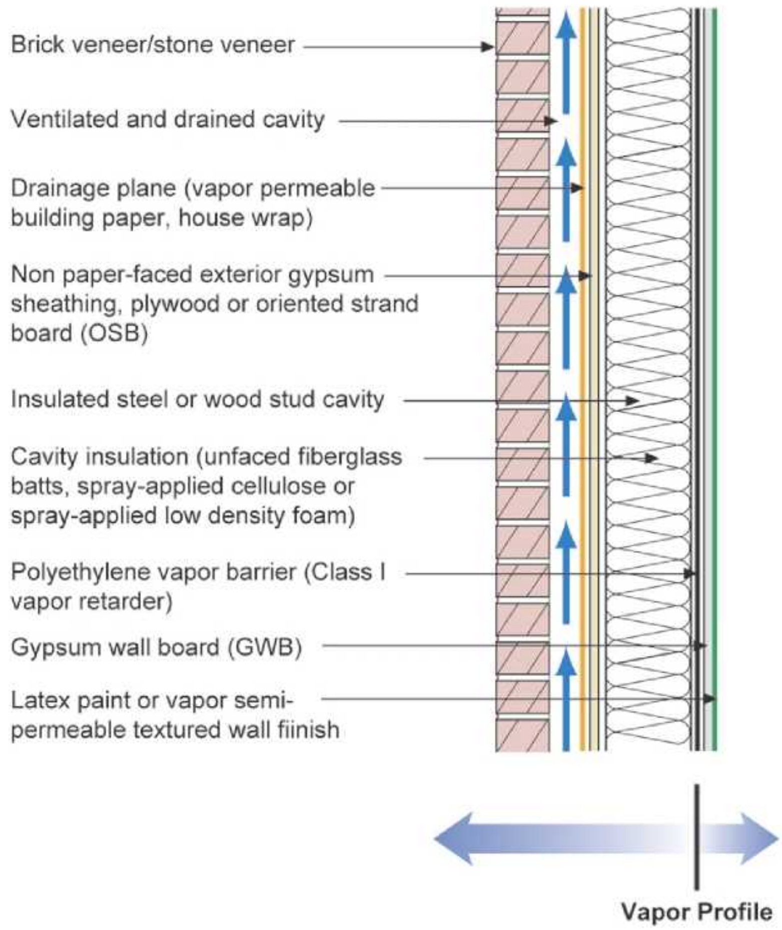
Figure 9
Frame Wall With Cavity Insulation and Brick or Stone Veneer With Interior Vapor Retarder



Applicability: Limited to cold and very cold regions

This wall is a variation of Figure 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 – it can dry to both the exterior and the interior. It is critical in this wall assembly – as in Figure 6 and Figure 7 - that the exterior brick veneer (a "reservoir" cladding) be uncoupled from the wall assembly with a ventilated and drained cavity. Experience has shown that this assembly works well when the cavity behind the brick veneer is at least 2 inches wide and is free from mortar droppings. It must also have air inlets at its base and air outlets at its top in order 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 wallboard, the exterior gypsum wallboard or the exterior building wrap.

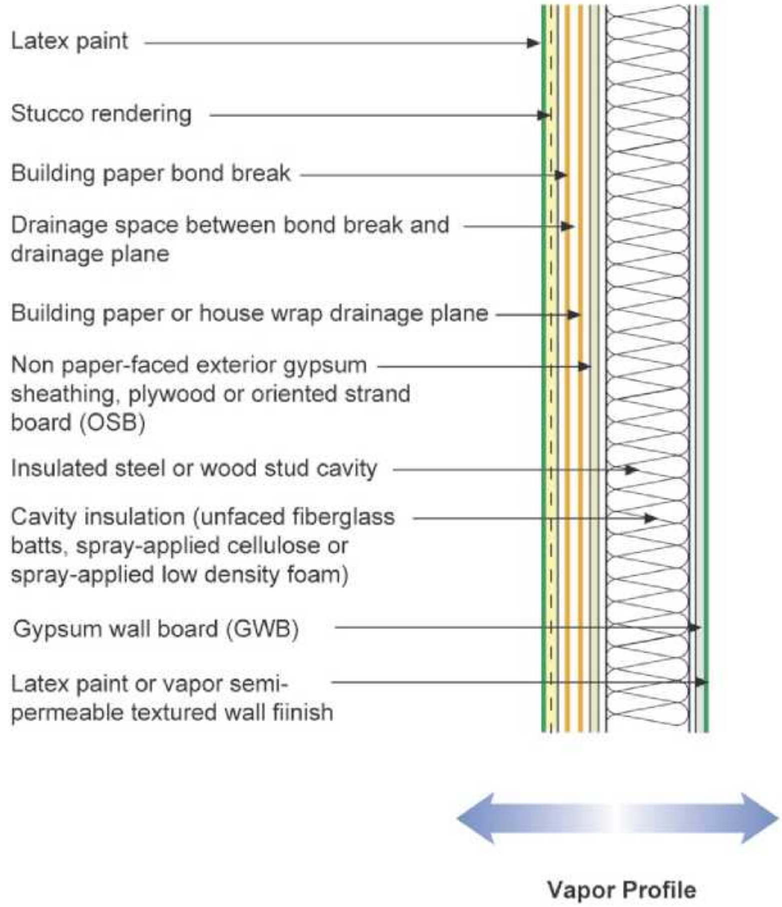
Figure 10
Frame Wall With Cavity Insulation and Brick or Stone Veneer With Interior Vapor Barrier



Applicability: Limited to very cold, subarctic and arctic regions

This wall is a further variation of Figure 6 but now it has a Class I vapor retarder on the interior (a "vapor barrier") completely eliminating any inward drying potential. It is considered the "classic" cold climate wall assembly. It is critical in this wall assembly – as in Figure 6, Figure 7 and Figure 9 - that the exterior brick veneer (a "reservoir" cladding) be uncoupled from the wall assembly with a ventilated and drained cavity. Experience has shown that this assembly works well when the cavity behind the brick veneer is at least 2 inches wide and is free from mortar droppings. It must also have air inlets at its base and air outlets at its top in order 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 wallboard, the exterior gypsum wallboard or the exterior building wrap.

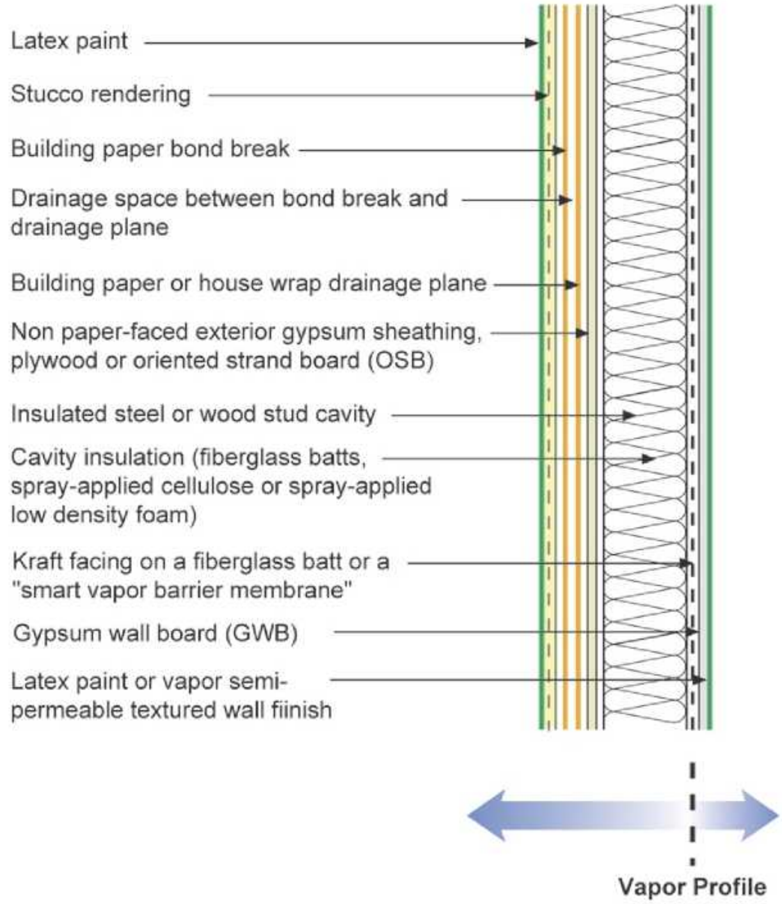
Figure 11
Frame Wall With Cavity Insulation and Stucco



Applicability: Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions – can be used with hygro-thermal analysis in some areas in cold regions (Zone 5, but not Zone 6; see **Appendix III**) – should not be used in very cold, and subarctic/arctic regions

This wall is also a flow through assembly similar to Figure 6 – but 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 wallboard). 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 drainge 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 wallboard, the exterior stucco rendering, the exterior sheathing or the exterior building wrap.

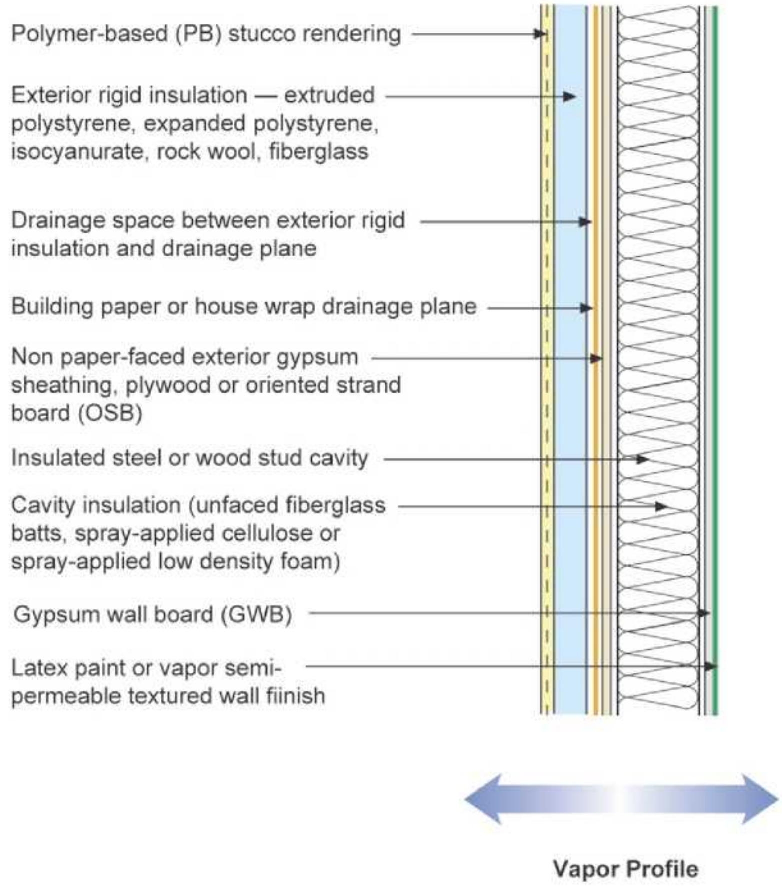
Figure 12
Frame Wall With Cavity Insulation and Stucco With Interior Vapor Retarder



Applicability: Limited to cold and very cold regions

This wall is a variation of Figure 6 and Figure 11 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 – it can dry to both the exterior and the interior. It is critical in this wall assembly – as in Figure 11 – 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 drainge 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 wallboard, the exterior stucco rendering, the exterior sheathing or the exterior building wrap.

Figure 13
Frame Wall With Exterior Rigid Insulation With Cavity Insulation and Stucco

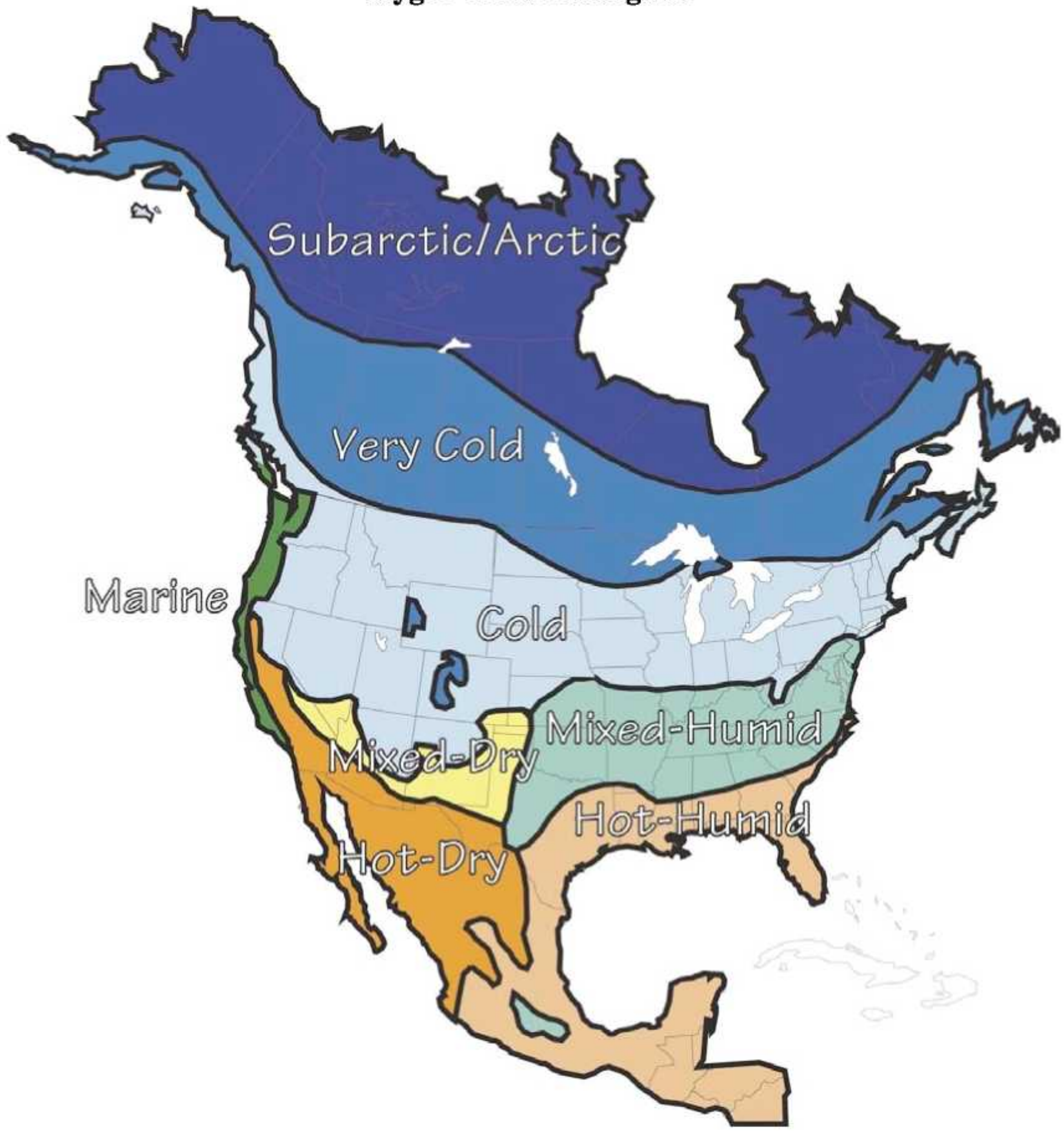


Applicability: All hygro-thermal regions except subarctic/arctic – in cold and very cold regions the thickness of the foam sheathing should be determined by hygro-thermal analysis so that the interior surface of the foam sheathing remains above the dew point temperature of the interior air (see **Appendix III – 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 Figure 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 wallboard). 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 drainge 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 wallboard, the exterior stucco rendering, the exterior sheathing or the exterior building wrap.

Appendix I

Hygro-Thermal Regions



Subarctic and Arctic
A subarctic and arctic climate is defined as a region with approximately 12,600 heating degree days (65 degrees F basis) *[7,000 heating degree days (18 degrees 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 degrees F basis) *[5,000 heating degree days (18 degrees C basis)]* or greater and less than 12,600 heating degree days (65 degrees F basis) *[7,000 heating degree days (18 degrees C basis)]*.

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

approximately 9,000 heating degree days (65 degrees F basis) *[5,000 heating degree days (18 degrees 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 degrees F basis) *[2,500 cooling degree days (10 degrees C basis)]* or greater and less than approximately 6,300 cooling degree days (50 degrees F basis) *[3,500 cooling degree days (10 degrees C basis)]* and less than approximately 5,400 heating degree days (65 degrees F basis) *[3,000 heating degree days (18 degrees C basis)]* and where the average monthly outdoor temperature drops below 45 degrees F *(7 degrees C)* during the winter months.

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

- a mean temperature of the coldest month between 27 degrees F *(-3 degrees C)* and 65 degrees F *(18 degrees C);*
- a mean temperature of the warmest month below 72 degrees F *(18 degrees C);*
- at least four months with mean temperatures over 50 degrees F *(10 degrees 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 inches *(50 cm)* of annual precipitation with approximately 6,300 cooling degree days (50 degrees F basis) *[3,500 cooling degree days (10 degrees C basis)]* or greater and where the monthly average outdoor temperature remains above 45 degrees F *(7 degrees 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 degree F *(19.5 degrees C)* or higher wet bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year; or
- a 73 degree F *(23 degrees 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 inches *(50 cm)* of annual precipitation with approximately 6,300 cooling degree days (50 degrees F basis) *[3,500 cooling degree days (10 degrees C basis)]* or greater and where the monthly average outdoor temperature remains above 45 degrees F *(7 degrees C)* throughout the year.

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

Appendix II

More Definitions – Taking On The Air Barrier

The following is an extension of the definitions proposed in ASHRAE Journal, February 02 – Moisture Control For Buildings[9].

Air barrier systems are systems of materials used to control airflow in building enclosures. They typically completely enclose the air within a building. The physical properties, which distinguish air barriers from other materials, are the ability to resist airflow and air pressure.

Air barrier systems are intended to resist the air pressure differences that act on them. Rigid materials such as gypsum wallboard, exterior sheathing materials like plywood or OSB, and supported flexible barriers (rigid materials on both sides of the barriers) are typically effective air barrier systems if joints and seams are sealed and if they are supported by rigid materials. Their rigidity aids in their ability to resist air pressures, which act on them.

Continuity of air barrier systems at holes, openings and penetrations of building enclosures is a key performance indicator of an effective air barrier.

Often, rubber or bitumen-based membranes are adhered to masonry or sheathing materials to create an air barrier system. These rubber or bitumen-based membranes are also impermeable and are therefore also vapor barriers.

Many, but not all, air barriers are vapor barriers and many, but not all, vapor barriers are air barriers.

Air barrier:	The element in an assembly designed and constructed to control air leakage between a conditioned space and an unconditioned space.
Conditioned Space[†]:	The part of the building that is designed to be thermally conditioned for the comfort of occupants or for other occupancies or for other reasons.
Indoor Air[†]:	Air in a conditioned space.
Outdoor Air[†]:	Air outside the building. It can enter the conditioned space via the ventilation system, or by infiltration through holes in the pressure boundary or designed ventilation openings.

Air barriers typically define the location of the "pressure boundary" of the building enclosure. The pressure boundary is defined as the location where 50 percent or more of the air pressure drop across an assembly occurs.

Pressure Boundary[†]:	Primary air enclosure boundary separating conditioned air and unconditioned air. For example, a volume that has more leakage to the outside than to the conditioned space would be considered outside the pressure boundary such as vented unconditioned attics and vented unconditioned crawlspaces.

[9] Lstiburek, J.W.; Moisture Control For Buildings; ASHRAE Journal, February, 2002.
[†] Taken from ASHRAE Standard 62.2

Air Retarders†:	Materials or systems that reduce air flow or control airflow but do not resist 50 percent or more of the air pressure drop across an assembly.
Occupiable Space†:	Any enclosed space inside the pressure boundary and intended for human activities, including but not limited to, all habitable spaces, toilets, closets, halls, storage and utility areas, and laundry areas.
Habitable Space†:	Building space intended for continual human occupancy. Such space generally includes areas used for living, sleeping, dining, and cooking, but does not generally include bathrooms, toilets, hallways, storage areas, closets, or utility rooms.

And Finally – Defining the Drainage Plane

Drainage planes are water repellant materials (building paper, house wrap, foam insulation, etc), which are located behind the cladding and are designed and constructed to drain water that passes through the cladding. They are interconnected with flashings, window and door openings, and other penetrations of the building enclosure to provide drainage of water to the exterior of the building. The materials that form the drainage plane overlap each other shingle fashion or are sealed so that water flow is down and out of the wall.

† Taken from ASHRAE Standard 62.2