Moisture Control Strategies
and Design Recommendations

CavityComplete® Wall System Design Strategies

This bulletin reviews moisture control objectives and design strategies for wall systems. Design recommendations for the CavityComplete® Wall System presented are based on results produced via WUFI® simulations.

Two common design strategies to control moisture are:

- Flow-Through: A strategy that allows water vapor to pass through the wall assembly from the inside out and from the outside in, enabling the wall to dry to both sides.
- Control Layer: A strategy that controls condensation by either:
    - Locating a distinctive vapor control layer that retards the flow of water vapor into the wall assembly from either the inside or from the outside. In heating dominated climates, the most common location for a vapor control layer is on the inside, or "warm in winter", side of the thermal insulation.

      or,
    - By controlling the temperature of the surfaces where condensation is likely to occur. This is commonly accomplished by raising the surface temperature using continuous insulation on the exterior surface of wall assemblies.

WUFI,® A Design Tool

Design recommendations for the CavityComplete® wall system were created using WUFI.® WUFI® (Wärme und Feuchte instationär, which essentially means "thermal and moisture instationary") is a software family which allows realistic calculation of the transient coupled one and two dimensional heat and moisture transport in multi-layer building components exposed to natural weather. It is based on the newest findings regarding vapor diffusion and liquid transport in building materials and has been validated by detailed comparison with measurements obtained in the laboratory and real building walls. With its primary focus on moisture performance it is a hygrothermal (heat, air and moisture) model that predicts thermal and moisture distribution. It estimates vapor and liquid transport while considering all three phases of moisture and phase changes. It not only has the ability to include U-value and permeance characteristics of layers, but it also incorporates the thermal and moisture reservoir capacity of building materials. In the final analysis it provides a moisture accumulation model over a period of years and translates it into mold growth and corrosion potential.

WUFI® contains detailed hourly climatic data, including temperature, precipitation, wind, solar and sky radiation data, for 105 locations in North America. WUFI® performs hourly simulations of the dynamic movement of moisture flow that may reverse direction during day and night scenarios, over a period of years for a given wall construction in a given climate, taking into consideration hygrothermal dynamics, thermal and moisture storage capacity of building materials, modeling realistic events such as rain water absorption or intrusion via defects, and the ventilation of cavities. To utilize WUFI® a wall system design is input into the software, along with the appropriate interior thermal and moisture loads. Understanding the internal load levels is important because incorrect assumptions may make an inadequate design appear adequate, or vice-versa. To demonstrate the significant influence that interior moisture load assumptions can have on wall design recommendations, a "Supplemental Table" is provided to compare 2X normal moisture loads to Table 1 "Normal Moisture Load".

Moisture Control Design Considerations

The function of a vapor retarder, or, vapor control layer, is to manage (retard) the migration of water vapor. Vapor control layers are primarily intended to prevent wall assemblies from getting wet. However, they may also prevent wall assemblies from drying. Where the vapor retarder should be located in an assembly and its appropriate permeability is a function of climate, the interior conditions, and the hygrothermal characteristics of all of the materials that comprise the wall assembly. Incorrect placement and/or perm rating of vapor control layers can lead to an increase in moisture related problems. For example, vapor control layers installed on the interior of assemblies prevent assemblies from drying inward. This may cause a problem in any air-conditioned enclosure. Also, where there are other layers in the wall such as air barriers or foam plastic continuous insulation, their perm ratings must also be considered with regard to creating a "double vapor retarder".

Vapor Barrier vs Air Barrier

Vapor control layers are not typically intended to retard the migration of air. That is the function of air control layers (air barriers). The difference between vapor control layers and air control layers is often confused. The confusion arises because air often holds a large amount of moisture vapor. When air moves from location to location driven by an air pressure difference, the vapor moves with it. That is a type of migration of water vapor, so, in the strictest sense, air control layers are also vapor control layers when they control the transport of moisture-laden air. Further, air barriers may also be impermeable, semi-permeable, or permeable. Although not primarily intended to control vapor movement, their level of permeability must be considered in the overall design.

Foam Plastic Insulation, Is Not A "Double Vapor Retarder" Concern

Where there are other impermeable or semi-permeable layers in the wall such as foam plastic continuous insulation, its perm rating must be considered with regard to creating a "double vapor retarder". A double vapor retarder is when there are two retarding layers in a wall, separated from each other by some distance, thus creating the possibility that migrating vapor may pass one layer, and in the process of migrating, toward a colder temperature in the wall, condense on the next. However, in the case of continuous foam plastic insulating sheathing, the potential for condensation is often reduced rather than increased when installed over the exterior of the structural framing. Foam plastic insulation insulates, raising the temperature of the framing and framing cavity, and raises the temperature of potential condensing surfaces, thus minimizing the likelihood of condensation from interior water vapor migrating into the wall.

Different Strategies for Different Situations

The fundamental principle of managing water vapor is to keep it out of wall assemblies, and conversely, to let it out if it gets in. However, designs get complicated because sometimes the best strategies to keep water vapor out also trap water vapor in. This situation may be exacerbated if the wall assembly starts out wet because of rain or the use of materials that absorb water while exposed during construction, such as polyisocyanurate (iso) or expanded polystyrene (EPS) sheathing versus water resistant extruded polystyrene (XPS). 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, for some climates, it is difficult to know what side of a wall is predominately the cold or warm side. The analysis is further complicated by building materials that can store water. A cladding system such as a brick veneer may act as a reservoir after a rainstorm and influence the hygrothermal performance of the wall. Alternatively, the masonry may act as a hygric buffer absorbing water and lessening potential moisture shocks. Therefore, there is a need to understand wall system science, and produce different design recommendations for different climates.

Vapor Control Strategy #1

Flow Through Wall System

This concept is a wall assembly that is vapor open on both the interior and exterior and whose cavity is insulated with a vapor open insulation such as an EcoTouch® fiberglass batt and a vapor permeable air barrier such as Tremco® ExoAir® 230. Gypsum board installed on the interior, painted with latex paint, is also semi vapor permeable and is suitable for this strategy. The key to a flow-though assembly is the exterior cladding layer and its attachment. Many exterior claddings can retard the flow of vapor. However, systems like the CavityComplete® Wall System, with brick veneer that utilizes MortarNet® mortar droppings protection keeping weep openings at the bottom and top clear, creates back ventilation, allowing the assembly to dry to the exterior. Note that walls that contain a layer of foam plastic insulation such as FOAMULAR® 250 XPS are generally not considered a "flow through" wall system due to its relatively low permeance (< 1.0) compared to other material layers in the wall.

Limitations of the Flow Through Wall System

Flow-through assemblies perform well in most climates. However, they can be overwhelmed in certain conditions. For example, in climates with cold winters where interior moisture levels can get high compared to exterior during the winter months, more moisture can enter the CavityComplete® Wall System from the interior than can leave the wall to the exterior. In such situations it is common to limit the vapor flow into the CavityComplete® Wall System from the interior by installing a vapor control layer on the interior which is discussed in Vapor Control Strategy #2.

Another example where a flow-through assembly can be overwhelmed is when a "reservoir" cladding is located on the exterior of semi vapor permeable water control layers. For example, consider the brick veneer becoming saturated after a rainstorm. It acts as a reservoir storing water. When the sun shines on the rain wetted brick veneer it raises the temperature of the water stored in the brick, driving it out of the brick in both directions. The outward drive does not harm the wall, but the inward drive may. Water vapor driven inward will cross the air space behind the brick, and possibly drive sufficient moisture into the assembly to create condensation problems. MortarNet® mortar droppings protection and WeepVent™ in the CavityComplete® Wall System are an effective way of addressing this issue. These products keep the weep vents open, clear of mortar droppings in the cavity behind the brick veneer, ensuring that it is vented at the top and bottom. The moisture driven inward out of the brick can then be intercepted by a moving stream of ventilation air that dries the assembly to the exterior.

The CavityComplete® Wall System has an additional method of effectively addressing this issue using FOAMULAR® 250 XPS continuous insulation installed behind the brick veneer. The FOAMULAR® XPS layer slows inward vapor drive. (Note that the preceding discussion is about water vapor, not liquid rain water. The Tremco® ExoAir® 230 air barrier, behind the FOAMULAR® 250 XPS, is the effective weather barrier (liquid water control layer) that effectively resists rain water penetration.)

If relying on the flow through strategy, the building management team should be aware of the need to manage interior finishes. Low perm paint layers, or, multiple paint layers over time, or vinyl wall coverings may substantially alter the perm rating of the interior wall surface and reduce the ability of the wall to dry to the interior.

Vapor Control Strategy #2

Control Layer Wall System

In more extreme climates, such as cold climates where vapor drive from the interior towards the exterior occurs for extended periods of time during the winter months, outward vapor drive can be controlled by installing a vapor control layer on the interior of the insulation. CavityComplete® Wall System control layer options include EcoTouch® Flame Spread 25 faced fiber glass insulation, or unfaced EcoTouch® with vapor retarding interior paint. See Table 1, Designs 1 through 3.

Limitations of the Control Layer Wall System

The concern with inwardly located vapor control layers is that if they are too impermeable, such as sheet polyethylene or low perm foil-scrim-kraft (FSK) laminates, they may trap moisture in the wall system and inhibit inward drying. Effective methods to address this issue include the use a semi-permeable vapor retarding material on the inner face such as a 1 perm paint layer, or the use of a layer that changes its permeance seasonally, a material that reacts to the typical differences in interior relative humidity between winter and summer months.

If paint is relied upon to be the vapor control layer, the building management team should be aware of the need to manage interior finishes. Altering the interior finish, either to a higher or lower perm (stripping paint layers over time, or replacing with vinyl wall coverings) may substantially alter the perm rating of the interior wall surface and may either positively or negatively alter the effectiveness of this design strategy.

Control of Condensing Surface Temperature Wall System

The possibility of condensation due to vapor drive from the interior to the exterior can also be controlled by utilizing a layer of FOAMULAR® 250 XPS continuous insulation over the exterior gypsum sheathing and steel stud framing. The continuous XPS layer insulates and raises the temperature of the wall cavity surfaces where condensation is likely to occur. It effectively "controls the condensing surface temperature", keeping it above the dew point temperature for the vast majority of the time, if not all of the time. By sufficiently raising the temperature of the likely condensing surface (i.e., the back of the exterior gypsum sheathing), condensation from interior vapor migration into the wall assembly is not likely to occur. This strategy, with enough R-value in the outboard foam insulation, enables assemblies to be constructed in cold climates with minimal or without interior vapor control layers.

CavityComplete® Wall System

Moisture Control Regional Design Recommendations

Table 1 provides vapor control regional design recommendations for the CavityComplete® Wall System for Steel Stud with Masonry Veneer as shown in Figure 1. Three design options are presented with varying internal vapor retarder permeance levels. Six different climate zones, and several hygric regions as shown in Figure 2 are represented. The recommendations are based on an EcoTouch® FIBERGLAS™ batt, R-13, in the stud cavity, and 1-1/2" thick, R-7.5, FOAMULAR® 250 XPS continuous insulation. Those insulation levels are presented as a representative example of the most commonly occurring prescriptive insulation levels in current energy conservation design standards. (See Table 2.) Additional insulation variations will be assessed and these recommendations expanded in the future to optimize wall designs.

The color coded design recommendations shown in Table 1 are based on WUFI® simulations that estimate multi-year wetting and drying cycles, resulting in estimated moisture accumulation based on hourly and location specific, weather data. The amount of interior moisture load for the simulations in Table 1 are in the "normal range" for normal ventilation and occupant loads as defined in ASHRAE 160, Criteria for Moisture-Control Design Analysis in Buildings. The quantity of accumulated moisture is then used in a model that estimates the potential for mold growth using temperature, relative humidity, time, surface quality and material parameters. Time of wetness (TOW) is also estimated based on accumulated time in hours per year when the temperature is above freezing, while relative humidity is above 80%. From TOW, corrosion risks can be estimated using ISO 9223[1]. A given design is "recommended" if all three assessment categories of moisture accumulation, potential for mold growth, and potential for corrosion all qualify as "green". If a given design is deficient in any of the categories, it is not "recommended". Note that ideal conditions were analyzed which do not include risk assessment to account for workmanship and other possible construction defects.

Note that the modeling capabilities of WUFI® have changed insights into wall system performance from those commonly held just a few years ago. For example, the design flexibility shown in Table 1 with regard to the acceptable performance of a variety of vapor retarding levels is due to the presence of 1-1/2" of FOAMULAR® 250 XPS continuous insulation. During condensation prone seasons the XPS maintains higher cavity temperatures, which makes the wall more tolerant of moisture (less likely to condense), which in turn enables higher perm interior vapor retarding layers, which in turn enables drying to the inside when necessary, which makes the wall design more forgiving.

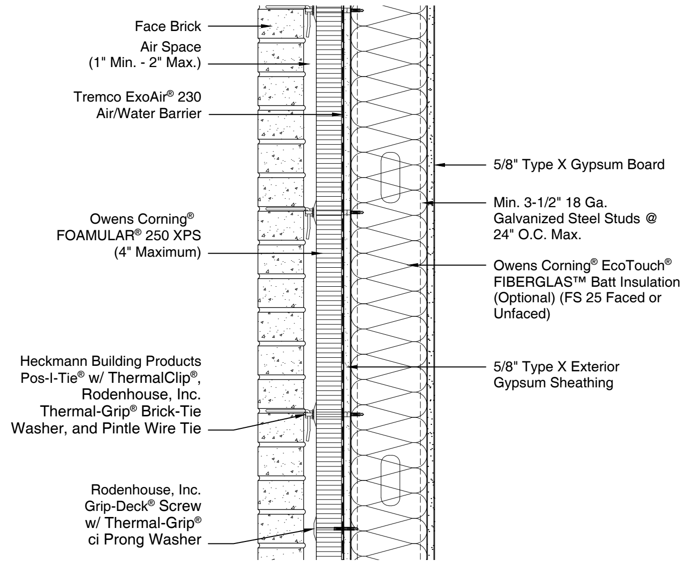


Figure 1: CavityComplete® Wall System

Table 1

Moisture Control Regional Design Recommendations

Normal Interior Moisture Load (for R13 + 7.5 ci wall systems)

City	Climate Zone	**Design 1:** Interior face .02 perm Flame Spread 25 (FSK)	**Design 2:** Interior Face .5 to 1.0 perm (paint or other)	**Design 3:** Interior Face 10 perm (paint or other)
Miami	1A			
New Orleans	2A			
Atlanta	3A			
San Francisco	3C			
Baltimore	4A			
Seattle	4C			
Chicago	5A			
Minneapolis	6A			

Supplemental Table

This table is provided to demonstrate the difference that variables can make in design recommendations, in this case a 2X normal interior moisture load compared to Table 1, normal interior moisture load.

2X Normal Interior Moisture Load (for R13 + 7.5 ci wall systems)

City	Climate Zone	**Design 1:** Interior face .02 perm Flame Spread 25 (FSK)	**Design 2:** Interior Face .5 to 1.0 perm (paint or other)	**Design 3:** Interior Face 10 perm (paint or other)
Miami	1A			
New Orleans	2A			
Atlanta	3A			
San Francisco	3C			
Baltimore	4A			
Seattle	4C			
Chicago	5A			
Minneapolis	6A			

Recommended Design   Caution, Not Preferred   Not Recommended

Table 2

Envelope Thermal Performance

Table 2 charts R by climate zone for steel framed walls as listed in ASHRAE 90.1[2], the IECC[3], and ASHRAE 189.1[4] when used as an alternate to the IgCC[5]. Because the edition adopted varies by jurisdiction, several 90.1 editions are summarized including 2004, 2007, 2010 and 2013. The IECC-2012, and ASHRAE 189.1-2011 are also summarized. The table shows prescribed stud cavity R-value as the first number, and continuous insulation R as the second number. (Example: 13 +7.5). The table shows only the prescriptive requirements for "non-residential" (commercial) and "residential" (as defined by ASHRAE 90.1) buildings. This table applies to buildings that are heated and/or cooled. The standards also provide prescriptive insulation values for "semi-heated" buildings that are not shown in this table. This technical bulletin does not provide complete compliance requirements. See the applicable standard for complete building performance and design compliance requirements.

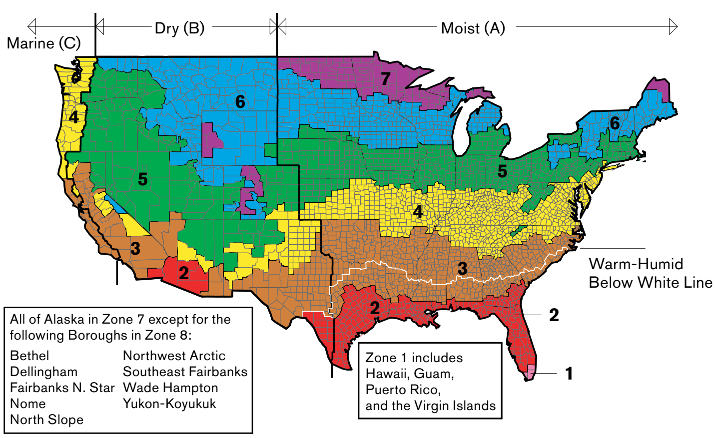
Prescriptive R (minimum) Requirements for Steel Framed Walls, Above Grade

ZONE	ASHRAE 90.1 – 2004		ASHRAE 90.1 – 2007 & 2010		ASHRAE 90.1 – 2013		IECC – 2012		ASHRAE 189.1-2011 (alternate to IgCC – 2012)*	
	Non-Residential	Residential	Non-Residential	Residential	Non-Residential	Residential	Non-Residential	Residential	Non-Residential	Residential
1	13	13	13	13	13	13	13 + 5.0	13 + 5.0	13 + 5.0	13 + 5.0
2	13	13	13	13 + 7.5	13 + 3.8	13 + 7.5	13 + 5.0	13 + 7.5	13 + 5.0	13 + 10.0
3	13	13 + 3.8	13 + 3.8	13 + 7.5	13 + 5.0	13 + 7.5	13 + 7.5	13 + 7.5	13 + 5.0	13 + 10.0
4	13	13 + 7.5	13 + 7.5	13 + 7.5	13 + 7.5	13 + 7.5	13 + 7.5	13 + 7.5	13 + 10.0	13 + 10.0
5	13 + 3.8	13 + 7.5	13 + 7.5	13 + 7.5	13 + 10.0	13 + 10.0	13 + 7.5	13 + 7.5	13 + 10.0	13 + 10.0
6	13 + 3.8	13 + 7.5	13 + 7.5	13 + 7.5	13 + 12.5	13 + 12.5	13 + 7.5	13 + 7.5	13 + 10.0	13 + 10.0
7	13 + 7.5	13 + 7.5	13 + 7.5	13 + 15.6	13 + 12.5	13 + 15.6	13 + 7.5	13 + 15.6	13 + 10.0	13 + 18.8
8	13 + 7.5	13 + 10.0	13 + 7.5	13 + 18.8	13 + 18.8	13 + 18.8	13 + 7.5	13 + 17.5	13 + 10.0	13 + 21.9

*Section 605.1.1 of the IgCC-2012, regarding "Building Envelope Systems, Prescriptive Compliance", states that when the IgCC is used, the building thermal envelope R shall exceed the requirements of the IECC by not less than 10%.

Figure 2

United States Climate Zones



References
1 ISO 9223, Corrosion of Metals and Alloys, Corrosivity of Atmospheres, Classification , Determination, Estimation; International Organization for Standardization; ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56 - CH-1211 Geneva 20, Switzerland
2 ASHRAE Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; 1791 Tullie Circle NE, Atlanta, GA 30329
3 International Energy Conservation Code; International Code Council, Inc.; 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795
4 ASHRAE 189.1, Standard for the Design of High-Performance Green Buildings; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; 1791 Tullie Circle NE, Atlanta, GA 30329
5 International Green Construction Code; International Code Council, Inc.; 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795

The CavityComplete® Wall System excludes the masonry veneer, steel studs and interior and exterior gypsum board. A detailed list of the components is available at www.CavityComplete.com.

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