Builder’s Guide to Continuous Insulation

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The information in this guide is intended to be compliant with the International Residential Code (IRC) most recent editions (2009 and 2012). However, it is the user’s responsibility to confirm all matters of compliance with locally-adopted codes and to obtain the necessary approval of the authority having jurisdiction. It is advisable to consult with a designer and the authority having jurisdiction prior to using the information in this guide for code compliance purposes.

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1. About this Guide

The focus of this guide is on residential construction using exterior rigid insulation (continuous insulation) installed over wood structural sheathing (WSP) for one and two-story single family detached construction. With advances in structural bracing requirements for homes over the past 15 years, WSP sheathing (particularly oriented strand board (OSB)) installed as a continuous structural sheathing has become a structurally efficient and preferred method for code compliance among many home builders. Similarly, recent advancements in energy efficiency requirements for homes has renewed interest in continuous insulation as a thermally efficient means of code compliance for standard or higher levels of performance. Both of these advancements in home construction point to the need to combine the best of both technologies—continuous structural sheathing and continuous insulation. Significant literature and guidance already exists for continuous structural sheathing. The purpose of this guide is to provide a complimentary treatment of continuous insulation when used as oversheathing (i.e., placed over continuous WSP sheathing) to result in walls that are structurally and thermally efficient, durable, and code compliant.

To achieve the above purpose, the guide is divided into three sections:

- Part 1 - Principles
- Part 2 – Design
- Part 3 - Construction

The principles and associated physics form the “building science” for the specific construction details and methods presented in the design and construction sections of the guide.
2. Principles

What is a Building?

A building is an environmental separator. It separates the outside from the inside. In order to function as an environmental separator the following must be met:

- control of heat flow
- control of airflow
- control of water vapor flow
- control of rain
- control of ground water
- control of light and solar radiation
- control of noise and vibrations
- control of contaminants, environmental hazards and odors
- control of insects, rodents and vermin
- control of fire
- provide strength and rigidity
- be durable
- be aesthetically pleasing
- be economical

The separation is often referred to as a building enclosure or a building envelope. For wall assemblies, control of rain water, airflow, water vapor flow, and heat flow are hygrothermal factors that are key to providing a durable enclosure. The hygrothermal factors are controlled with four principle control layers.

Control Layers

Wall assemblies must have four principal control layers as overlays to the structure. They are presented in order of importance:

- a water control layer
- an air control layer
- a vapor control layer
- a thermal control layer

The best place for the control layers is to locate them on the outside of the structure in order to protect the structure. The optimum configuration is presented in Figure 2.1.
Controlling rain water is the single most important factor in the design and construction of durable wall assemblies. All exterior claddings pass some rainwater. Siding leaks, brick leaks, stucco leaks and stone leaks. As such, some control of this penetrating rainwater is required.

In most walls, the structure is protected by a water control layer. Water control layers are water repellent materials (building paper, housewrap, sheet membranes, liquid applied coatings, or taped and sealed rigid insulation boards) that 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 water control layer overlap each other shingle fashion or are sealed so that water drains down and out of the wall. The water control layer is often referred to as the “drainage plane” or “water resistant barrier” or water control layer.

In order for the water control layer to be effective, drainage downwards and outwards from behind the cladding is required. The “down” direction harnesses the force of gravity and the “out” direction gets the water away from the building enclosure assemblies, openings, components and materials.

In order for drainage to occur, a drainage space must be provided between the cladding and the water control layer. The width of this space varies depending on cladding type and function. If large enough, the drainage space can also provide ventilation and facilitate the redistribution and removal of absorbed water. Effective drainage of rainwater can occur in drainage spaces as small as $\frac{1}{16}$ to $\frac{1}{8}$-inch (2 or 3 mm). For ventilation a slightly larger gap is required typically around $\frac{3}{8}$-inch or greater (10 mm).

The “out” direction is typically provided by flashings (see Figure 2.2). Flashings are the most under-rated building enclosure component and arguably the most important. Flashings are integrated with water control layers creating for all practical purposes a flashing for the entire assembly (Figure 2.3 and Figure 2.4).
Figure 2.2: The “down” and “out” approach to flashing

Figure 2.3: Flashing integrated with the water control layer with lapped joints

Figure 2.4: Taped rigid insulation water control layer with sealed joints
Controlling airflow in a building enclosure is important because of its influence on heat and moisture flow. Airflow carries moisture that impacts a material’s long-term performance (serviceability) and structural integrity (durability). Airflow also affects building behavior in a fire (spread of smoke and other toxic gases, supply of oxygen), indoor air quality (distribution of pollutants and location of microbial reservoirs) and thermal energy use.

One of the key strategies in the control of airflow is the use of air control layers. Air control layers are systems of materials designed and constructed to control airflow between a conditioned space and an unconditioned space. The air control layer is the primary air enclosure boundary that separates indoor (conditioned) air and outdoor (unconditioned) air.

Air control layers should be:

- Impermeable to air flow
- Continuous over the entire building enclosure
- Able to withstand the forces that may act on them during and after construction
- Durable over the expected lifetime of the building

Air control layers can be located anywhere in the wall assembly – at the exterior surface, the interior surface, or at any location in between. Depending on the climate or wall configuration, air control layers might be required not only to address air flow through the enclosure assembly, but may also be needed to control airflow into or within the enclosure assembly. In some cases providing more than one air control layer may be preferable for optimum vapor control and thermal performance. A common way of doing this is to use both the exterior sheathing and the interior gypsum board finish as air control layers.

Numerous approaches can be used to provide air control layers in buildings. Some of the more common are:

- interior air control layer using gypsum board or supported sheet material (such as polyethylene)
- exterior air control layer using a supported and sealed housewrap
- exterior air control layer using taped and sealed rigid structural sheathing
- exterior air control layer using taped and sealed rigid insulation

The significant advantage of exterior air control layers is the ease of installation and the lack of detailing issues related to intersecting partition walls and service penetrations. The significant disadvantage of exterior air control layers is their inability to control the entry of air-transported moisture into insulated cavities.
from the interior. This concern can be mitigated by insulating on the exterior with rigid insulation in order to control the condensing surface temperature of the wall structural sheathing.

An advantage of interior air control layers over exterior systems is that they control the entry of interior moisture-laden air into insulated assembly cavities during heating periods. The significant disadvantage of interior air control layers is their inability to control wind-washing through cavity insulation and their inability to address the entry of exterior hot-humid air into insulated cavities in hot-humid climates.

Installing both interior and exterior air control layers can address the weakness of each.

**Vapor Control Layer**

The fundamental principle of control of a vapor control layer is to keep water vapor out of an assembly and to also let water vapor out if it gets in. In this regard, the vapor control layer is in reality more of a vapor control “assembly” or “strategy” that uses materials with specific vapor control properties strategically within the assembly.

It can get complicated because sometimes the best strategies to keep water vapor out also trap water vapor in.

Vapor control layers installed on the interior of assemblies prevent assemblies from drying inward. This is a concern in any air-conditioned building or any building at all where there is also a vapor control layer on the exterior – the “double vapor barrier” problem. Moisture retention can cause problems if the assemblies start out wet because of rain or the use of wet materials during construction without allowing sufficient time for materials to dry out prior to close-in.

Controlling vapor movement can become 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, but when vapor flows in both directions during heating and cooling seasons, additional detailing is required. Logically, this means we need different strategies for different climates. We also have to take into account differences between summer and winter.

Finally, vapor control must address materials that can store water. 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 providing a place for safe moisture storage absorbing water lessening moisture shocks.

There are three principle control approaches to dealing with water in the vapor form. The first is to let the water vapor pass through the assembly from the inside out and from the outside in. Where a wall assembly is concerned it is a wall that can dry to both sides. We call these types of assemblies “flow-through” assemblies.
The second is to locate a distinctive vapor control layer to retard the flow of water vapor into the wall assembly from either the inside or from the outside. We call these types of assemblies “vapor control layer” assemblies. The most common location for a vapor control layer is on the inside “warm in winter” side of the thermal insulation.

The third is to control the temperature of the surfaces where condensation is likely to occur by raising the surface temperature with insulation. The most common method of doing this is to use rigid insulation on the exterior of assemblies. We call these types of assemblies “control of condensing surface temperature” assemblies (see Figure 2.5).

Controlling the condensing surface temperature is the most versatile strategy and works well in all climate zones. In cold climates it also provides the best protection against air leakage condensation problems, since instead of limiting the movement of moisture, it functions by preventing condensation.

**Control of condensing surface temperature**

Vapor drive from the interior to the exterior can also be controlled by installing rigid insulation on the exterior of the structural framing. This rigid insulation raises the temperature of the wall cavity surfaces where condensation is likely to occur.

As an example a wall assembly located in Chicago, IL was examined. When condensation from interior humidity occurs, it occurs on the interior surface of the exterior structural sheathing (see Figure 2.6a). The exterior structural sheathing has little or no thermal resistance, and so the temperature of the interior surface (“condensing surface of interest”) is approximately the same as the outside temperature.

Confusion on the issue of vapor control layers and air control layers 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 control layers are also vapor control layers when they control the transport of moisture-laden air.
When exterior rigid insulation is added to the exterior of the structural sheathing, the interior surface temperature of the structural sheathing is increased since the insulation keeps the sheathing warmer (see Figure 2.6b). By raising the temperature of the condensing surface of interest sufficiently, condensation from interior water vapor migrating into the wall assembly does not occur. This allows assemblies to be constructed in cold climates without interior vapor control layers. The model building codes recognize this and provide guidance on the minimum thermal resistance values of rigid insulation required to control condensation, when Class I and II vapor retarders are replaced with Class III retarders in specific regions.

Table 2.1 is information taken from Table R601.3.1 Class III Vapor Retarders of the 2009 IRC and Table R702.7.1 Class III Vapor Retarders of the 2012 IRC and provides guidance for thermal resistance values to control condensation for Climate Zones 5, 6, 7, 8 and Marine 4.

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Framing Rigid Insulation</th>
<th>Minimum R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4C</td>
<td>2x4</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>3.75</td>
</tr>
<tr>
<td>5</td>
<td>2x4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>2x4</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>11.25</td>
</tr>
<tr>
<td>7/8</td>
<td>2x4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>15</td>
</tr>
</tbody>
</table>

Figure 2.6a: Condensing surface of interest with non-insulating exterior sheathing
The function of the thermal control layer is to control the flow of heat from both the inside to the outside and from the outside to the inside. As with the other control layers, the most important factor to consider when dealing with the thermal control layer is its continuity.

**Thermal bridges**

Gaps and discontinuities in the thermal control layer are called thermal bridges. The most common thermal bridges in residential buildings are from the framing members. In wood framed construction, the framing, while not highly conductive, still provide less thermal resistance than common cavity insulation materials and therefore reduces the effective thermal resistance of the wall assembly.

The framing portion of the typical “opaque” portion of the building enclosure when framing on 16-inch centers (not including windows and doors) is approximately 25 percent and the insulated cavity portion of the building enclosure is 75 percent. This is often expressed as a “framing factor” of 25 percent. With wood frame buildings a framing factor of 25 percent results in a reduction of the nominal insulation value of the cavity insulation by approximately 20 percent for a standard 2x6 framed wall and 15 percent for a standard 2x4 wall. As an example, a nominal 2x4 wall with R-13 fiberglass batt insulation will have an effective thermal resistance of around R-11.

The addition of exterior rigid insulation to a framed wall assembly can have a significant impact on the effective thermal resistance of the wall assembly. Since there is minimal thermal bridging of the rigid insulating sheathing, the nominal R-Value of the material will be near the effective R-Value added to the wall assembly. Taking the 2x4 wall example above, adding R-5 insulating sheathing...
would increase the nominal insulation value to R-18 (R-13 + R-5), and the effective thermal resistance to R-17 (R-11 + R-5). This results in a 50% increase in the effective thermal resistance of the wall.
3. Climate Zones and Building Environments

Buildings should be suited to their environment. Design and construction should be responsive to wind loads, snow loads and seismic loads. It should also be responsive to soil conditions and frost depth, orientation and solar radiation. Finally, design and construction should consider temperature, humidity, rain and interior conditions.

Building enclosures and mechanical systems should be designed for a specific hygrothermal region (Figure 3.1), rain exposure zone (Figure 3.2) and interior climate in addition to the structural requirements already mentioned.

The interior climate for this guide is assumed to be residential. Interiors are assumed to be conditioned to 70°F in the winter and 75°F in the summer. Relative humidities are assumed to be limited to 35 percent (no higher) during the coldest month in winter and 65 percent (no higher) in the summer. These conditions also form the basis for the requirements delineated in the model building codes.

High occupant loadings can lead to high interior relative humidities during winter months. High interior relative humidities due to high occupant loading should be controlled by dilution ventilation. The greater the occupant density the greater the dilution ventilation rate required.

This guide does not address high occupant loadings or special use buildings that have high interior levels of moisture such as buildings with spas, indoor swimming pools or buildings that are humidified beyond 35 percent relative humidity during the coldest month in the winter.

The model building codes are also based on the hygrothermal regions noted in Figure 3.1. The model codes further subdivide the regions for energy conservation purposes. Specific “code” climate zones are referenced in the 2009 IECC and the 2012 IECC (Figure 3.3). The practices described in this guide are designed to meet the hygrothermal requirements and interior conditions for each IRC and IECC zone noted for each practice.

The model building codes do not currently recognize different rain exposures (Figure 3.2). However, the wall designs presented in this guide are all designed to work in all rain exposures when properly executed on plans and in the field.

Table 3.1 contains the minimum thermal resistance (R-value) requirements specified in the 2009 IECC and the 2012 IECC.

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Framed Wall Minimum R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009 IECC</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>13</td>
</tr>
<tr>
<td>5 and Marine 4</td>
<td>20 or 13+5</td>
</tr>
<tr>
<td>6</td>
<td>20 or 13+5</td>
</tr>
<tr>
<td>7 and 8</td>
<td>21</td>
</tr>
</tbody>
</table>
Legend

**Subarctic/Arctic**
A subarctic and arctic climate is defined as a region with approximately 12,600 heating degree days (65°F basis) or greater.

**Very Cold**
A very cold climate is defined as a region with approximately 9,000 heating degree days (65°F basis) or greater and less than approximately 12,600 heating degree days (65°F basis).

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

**Mixed-Humid**
A mixed-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or less, and where the monthly average outdoor temperature drops below 45°F (7°C) during the winter months.

**Marine**
A marine climate meets all of the following criteria:
- A mean temperature of the coldest month between 27°F (-3°C) and 65°F (18°C)
- A warmest month mean of less than 72°F (22°C)
- At least four months with mean temperatures over 50°F (10°C)
- A dry season in 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 in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

**Hot-Humid**
A hot-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation and 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.
* These last two criteria are identical to those used in the ASHRAE definition of warm-humid climates and are very closely aligned with a region where monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

**Mixed-Dry**
A mixed-dry climate is defined as a region that receives less than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or less, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

**Hot-Dry**
A hot-dry climate is defined as a region that receives less than 20 inches (50 cm) of annual precipitation and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

---

1 Celsius: 7,000 heating degree days (18°C basis)
2 Celsius: 5,000 heating degree days (18°C basis)
3 Celsius: 3,000 heating degree days (18°C basis)
4 Celsius: 5,000 heating degree days (18°C basis)
5 Celsius: 3,000 heating degree days (18°C basis)
Figure 3.1: Hygrothermal map
Figure 3.2: Rainfall map

Figure 3.3: Department of Energy climate zones
4. Design

The following chapter covers recommended designs for wood framed wall assemblies insulated with exterior rigid insulation.

**Water Control Layer**

The most common water control layer historically is “tar paper” or building paper. More recently, the terms “housewrap” and “building wrap” have been introduced to describe building papers that are not asphalt impregnated felts or coated papers such as Grade D paper. In addition to “housewraps”, fully adhered sheet membranes, or trowel, paint and spray applied coatings applied over structural sheathings such as plywood and OSB can act as water control layers. Water control layers can also be created by sealing or layering water resistant sheathings such as a rigid insulation or coated structural sheathings.

For walls that are over-sheathed with rigid insulation, there are several options for the water control layer. The placement of the water control layer is at the discretion of the designer and will typically be located behind or exterior of the rigid insulation. A third option of placing the water control layer in between two layers of insulation is also possible, but can lead to significant confusion and coordination problems during construction and is for the most part, not recommended. The choice of the location of the water control layer will affect many other enclosure connection details. The strategy should be clear and consistent throughout the entire project and detailed for continuity at all penetrations and intersections where joints occur; refer to Section 5 and Section 6 for detailing guidance.

**Air Control Layer**

For walls with exterior rigid insulation only a single air control layer is required. It is often located at the structural sheathing or can be the exterior rigid insulation itself.

Airflow control at the exterior structural sheathing can be provided by several different methods. The first method is by taping or sealing all of the joints in the exterior structural sheathing. This has been found to provide very good overall building air-tightness as many of the complicated details at partition walls and floor separations are eliminated as the work is all completed from the exterior. This air control layer can in some cases be part of the water control layer (taped and sealed building warps, fully adhered sheet membranes, or liquid applied membranes, or taped structural sheathings with integral water resistant surfacing), but is not required to be. A second method is by sealing of the structural sheathing from the interior through the use of sealants or spray polyurethane foams. This approach also can work well, but more attention to detail is usually required at interior partition walls, rim boards, band joints, and doubled or tripled up framing members.
Figure 4.1: Water control layer behind the insulation

Figure 4.2: Water control layer in front of the insulation

Figure 4.3: Water control layer using the face of the foam with taped joints

Figure 4.4: Water control layer in between the layers of insulation
Providing air flow control at the interior finish surfaces is another good approach. The recommended strategy is to caulk and seal the interior gypsum sheathing to the wood structural framing. Penetrations such as electrical boxes should be sealed or gasketed.

The rigid insulation could also be used to provide an air control layer for the wall assembly. This approach can be effective in the field of the wall, but may require more complicated detailing at interfaces with other building elements. This is also not practical if the water control layer is located behind the rigid insulation.
VAPOR CONTROL LAYER

Vapor control for assemblies with exterior rigid insulation functions predominantly on controlling the condensing surface temperature of the exterior structural sheathing. This is arguably the most effective means of condensation control from both air transported vapor (air leakage) and vapor diffusion. The amount of exterior rigid insulation needed is a function of the climate and the amount of insulation added to the interior in the wall cavities. There are multiple methods that can be used to determine the appropriate amount of insulation required for condensation control, however analyses for most common wall assemblies is not required. The 2009 IRC and 2012 IRC provide guidance for the most common wall framing dimensions and cavity insulation (Table 4.1).

Table 4.1: Minimum exterior insulation required for common wall framing dimensions

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Framing and Insulating Sheathing</th>
<th>Minimum R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4C</td>
<td>2x4</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>3.75</td>
</tr>
<tr>
<td>5</td>
<td>2x4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>2x4</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>11.25</td>
</tr>
</tbody>
</table>

For assemblies that have higher levels of cavity insulation (2x8 walls or double stud walls), additional analysis may be required. Hygrothermal computer modeling, when used appropriately, would provide the most refined analysis of the risk. Analysis at this level is seldom required for residential construction. Other methods such as a dewpoint calculation that looks to limit the sheathing temperature to 45°F based on the average temperature over the coldest three months of the year (assumed interior conditions of 35% RH and 70°F) has also been used as a reasonable check against condensation risks.

If a sheet product is used as the air control layer in lieu of the interior gypsum, the product is recommended to be a Class III vapor retarder (1.0 to 10.0 perms) and at most should be a Class II vapor retarder (0.1 to 1.0 perm). A Class I vapor retarder (less than 0.1 perms) would not be recommended as it will prevent drying of the wall assembly to the interior. See Vapor Control section for additional information.
**THERMAL CONTROL LAYER**

The addition of exterior rigid insulation can significantly improve the wall assembly thermal performance because it provides a continuous insulation layer that diminishes the impact of thermal bridges caused by framing.

Typical thermal resistance of common rigid insulation materials can be seen in Table 4.2.

<table>
<thead>
<tr>
<th>Material</th>
<th>R-Value/Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foil-faced polyisocyanurate (PIC)</td>
<td>6.5</td>
</tr>
<tr>
<td>Extruded polystyrene (XPS)</td>
<td>5.0</td>
</tr>
<tr>
<td>Expanded polystyrene (EPS)</td>
<td>4.0</td>
</tr>
<tr>
<td>Mineral fiber (MF)</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Dewpoint calculations that use design temperatures will inevitably result in ultra-conservative answers, and should not be used as a measure of assembly risk assessment.

The amount of exterior thermal rigid insulation added to the assembly will be dependent on the climate zone and design goals for the project.

The minimum levels provided should be based on the minimum requirements for vapor control (see previous section) and minimum requirements based on the current adopted building code and energy code, respectively, for the project. Additional insulation
can be added above these minimums to create high R-Value wall assemblies. High-R wall assemblies commonly can add 4” or more of exterior rigid insulation.

The following is a list of recommended assemblies as well as code minimum assemblies based on climate zone. In all assemblies, the water control layer is shown at the face of the exterior rigid insulation (see Section 5.0), but can also be located behind the rigid insulation (see Section 6.0).
**RECOMMENDED ASSEMBLIES**

The following is a list of recommended assemblies as well as code minimum assemblies based on climate zone. In all assemblies, the water control layer can also be placed behind the rigid insulation. See Section 6 for construction details.

**Assembly 1 – High Performance**

The following assembly is considered a high performance assembly. It incorporates all of the recommended best practices for water control, air control, vapor control and thermal control.

- Exterior cladding
- 1x3 wood furring strip (cladding attachment location, drainage/ventilation space)
- 2 layers of 2” rigid exterior insulation (exterior face taped and sealed to function as the wall water control layer – all joints in the insulation offset and staggered)
- 7/16” wood structural sheathing (all joints taped or sealed to function as the air control layer)
- 2x6 wood framing (15% to 20% framing fraction - following advanced framing techniques)
- R-2 cavity insulation (open- or closed-cell spray polyurethane foam, blown-in cellulose, blown-in fiberglass or fiberglass batts)
- ½” interior gypsum (caulked and sealant to wood framing for additional air control layer and painted with latex paint to provide a Class III vapor retarder)

**Effective Thermal Performance**

<table>
<thead>
<tr>
<th>Exterior insulation type</th>
<th>Effective thermal resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foil-faced polyisocyanurate (PIC)</td>
<td>45</td>
</tr>
<tr>
<td>Extruded polystyrene (XPS)</td>
<td>39</td>
</tr>
<tr>
<td>Expanded polystyrene (EPS)</td>
<td>35</td>
</tr>
<tr>
<td>Mineral fiber (MF)</td>
<td>35</td>
</tr>
</tbody>
</table>

Figure 4.6: Recommended high performance wall assembly
Assembly 2 – Good Performance

The following is an example of a good performance wall assembly. It incorporates recommended practices for water control, air control, vapor control, and thermal control while still being practical to common construction practices and cost.

- Exterior cladding
- \( \frac{3}{8} \)" furring strips or drainage mat (drainage/ventilation space)
- 1½” rigid exterior insulation (exterior face taped and sealed to function as the wall water control layer or covered with a building wrap)
- \( \frac{7}{10} \)" wood structural sheathing (all joints taped or sealed to function as the air control layer)
- 2x6 wood framing (25% framing fraction – standard framing techniques)
- R-20 cavity insulation (open- or closed-cell spray polyurethane foam, blown-in cellulose, blown-in fiberglass, or fiberglass batts)
- \( \frac{1}{2} \)” interior gypsum (painted with latex paint to provide a Class III vapor retarder)

Effective Thermal Performance

<table>
<thead>
<tr>
<th>Exterior insulation type</th>
<th>Effective thermal resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foil-faced polyisocyanurate (PIC)</td>
<td>27</td>
</tr>
<tr>
<td>Extruded polystyrene (XPS)</td>
<td>25</td>
</tr>
<tr>
<td>Expanded polystyrene (EPS)</td>
<td>23</td>
</tr>
<tr>
<td>Mineral fiber (MF)</td>
<td>23</td>
</tr>
</tbody>
</table>

Figure 4.7: Recommended good performance wall assembly
Assembly 3 – Code Minimum

The following is an example of a code compliant wall assembly:

- Exterior cladding
- Rigid exterior insulation (as required based on climate zone – exterior face taped and sealed to function as the wall water control layer or covered with a building wrap)
- 7/16” wood structural sheathing
- 2x4 or 2x6 wood framing (25% framing fraction – standard framing techniques)
- Code minimum cavity insulation
- Vapor retarder (as required based on climate zone)
- ½” interior gypsum

Effective Thermal Performance

A series of tables for code compliant wall assemblies was created. The tables are divided into 2x4 and 2x6 framing types, and 2009 and 2012 IECC Code Compliance. The tables provide the minimum amount of exterior insulating sheathing required by code.

Figure 4.8: Code minimum wall assembly
### 2009 IECC compliance minimum insulation and vapor retarder requirements

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>2x4 Construction</th>
<th>2x6 Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class III Vapor Retarder</td>
<td>Class I, II Vapor Retarder</td>
</tr>
<tr>
<td>1, 2, 3, 4 (except Marine)</td>
<td>13 (R-11)</td>
<td>13 (R-11)</td>
</tr>
<tr>
<td>Marine 4</td>
<td>13 + 5 (R-17)</td>
<td>13 + 5 (R-17)</td>
</tr>
<tr>
<td>3</td>
<td>13 + 5 (R-17)</td>
<td>13 + 5 (R-17)</td>
</tr>
<tr>
<td>6</td>
<td>13 + 7.5 (R-19)</td>
<td>13 + 5 (R-17)</td>
</tr>
<tr>
<td>7 and 8</td>
<td>13 + 10 (R-22)</td>
<td>13 + 5 (R-17)</td>
</tr>
</tbody>
</table>

1. Effective R-values in parenthesis

---

### 2012 IECC compliance minimum insulation and vapor retarder requirements

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>2x4 Construction</th>
<th>2x6 Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class III Vapor Retarder</td>
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<td>3, 4 (except Marine)</td>
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<tr>
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<tr>
<td>6</td>
<td>13 + 7.5 (R-19)</td>
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<tr>
<td>7 and 8</td>
<td>13 + 10 (R-22)</td>
<td>13 + 10 (R-22)</td>
</tr>
</tbody>
</table>

1. Effective R-values in parenthesis
5. Construction: Water Control Layer Exterior of the Rigid Insulation

The intent of this guide is to leverage many of the benefits of continuous structural sheathing and continuous exterior rigid insulation. While it is recognized that other means of providing structural resistance to wind and lateral loads are possible, the intent is to maintain standard construction practice as much as possible with the addition of continuous exterior rigid insulation.

In addition, the location of the water control layer for the assemblies has many implications on the construction detailing. To address this, the construction portion of this guide is separated into two sections:

1. Water control layer exterior of the rigid insulation
2. Water control layer behind the rigid insulation (see Section 6: Construction: Water Control Layer Behind the Rigid Insulation)

The intent is to group all associated details into a single section for easier reference and consistency of design details. As such, there is some repetition of information, however it is felt that this will provide easier reference for designers and builders who are looking to incorporate exterior continuous rigid insulation in their projects.

Structure

The use of continuous wood structural sheathing provides a simple and robust means for wall bracing and wind resistance for a variety of home styles and design conditions, and is standard practice for most of the residential building industry. The application of continuous exterior rigid insulation can be simply added to any home with a code compliant structural design.

Attachment of Insulation

There are no specific requirements for the attachment of the insulation. The design of the system uses the structural wood sheathing for the wind load resistance. In addition all cladding attachment must either be directly through the insulation back to the structure or to a secondary cladding support system such as wood furring strips, that are attached through the insulation back to the structure. In either case, the requirements of the cladding attachment will function to clamp the rigid insulation in place. The attachment of the rigid insulation is really only needed as a temporary measure to hold the insulation on the wall until the cladding is installed.

Still, it is recommended to use either cap nails, screw with washers or plates, or other larger head fasteners to prevent overdriving through the outer face of the insulation materials.

The exterior rigid insulation can either be installed in a single layer, or in multiple layers. For multi-layer applications it is recommended to offset all the joints in the insulation boards (see Figures 5.1 and 5.2).
When the water control layer is located in front of the rigid insulation, then two water control layer approaches can be used:

1. Installation of a building paper or housewrap over the top of the rigid insulation;

or

2. Taping or sealing the joints of the rigid insulation to act as the water control layer.

For option 1 there is a practical limit of 1 1/2” thick rigid insulation. Above this thickness and finding common cap nails or staples that are typically used in the installation of the building paper or housewrap becomes difficult. Therefore, for installations of rigid insulation in excess of 1 1/2”, taping and sealing of the face of the rigid insulation is recommended (see Figures 5.3 and 5.4).

All flashing and other water control interfaces for the building will need to connect to the wall water control layer.
**WINDOW INTEGRATION**

With the water control layer positioned at the face of the insulation, the best location for the window installation is at the face of the rigid insulation. Windows installed at the plane of the rigid insulation would follow industry standards for integration with the wall water control layer. It is recommended that all windows are installed in a pan flashed and drained opening with the jambs and head of the frame taped or sealed to the wall water control layer (see sequences in Figures 5.5; see also Figures 5.7, 5.8, and 5.9).

Moving the windows further to the interior while maintaining the water control layer at the plane of the rigid insulation would require a recessed opening for flanged windows (see sequences in Figures 5.6). For non-flanged windows, the window frame could be placed at any location within the opening provided that the water control layer is wrapped into the rough opening.
Figure 5.5a: Step 1—Pan flashing installed at the sill

Figure 5.5b: Step 2—Window installed

Figure 5.5c: Step 3—Flanges integrated into water control layer

Figure 5.6a: Step 1—Water control layer wrapped into rough opening; pan flashing installed at the sill

Figure 5.6b: Step 2—Window installed; flanges integrated into water control layer

Figure 5.6c: Step 3—Head flashing installed and integrated into water control layer
Figure 5.7: Window head water control layer in front of rigid insulation

Figure 5.8: Window sill water control layer in front of rigid insulation
Where the roof is above the wall, the termination of the exterior insulation does not change significantly regardless of the attic being vented or unvented. The differences would mostly be associated with the attic design and not the wall design.

For vented attics, the rigid insulation will need to terminate below the level of the roof sheathing in order to provide a ventilation opening. Extending the rigid insulation up as high as possible (leaving not less than a 2-inch gap for attic ventilation) has some additional benefits though, including increased thermal resistance at the roof to wall connection, and it can act as an insulation stop and baffle for the attic insulation (see Figure 5.10). For gable ends, while having additional thermal resistance is not needed, it is often practical to simply maintain the rigid insulation up the full height to keep the cladding aligned.

For unvented attics, the rigid insulation can be run tight to the underside of the roof sheathing. In this configuration it can act as an insulation stop for spray polyurethane foam (if used) (see Figure 5.13).

Where the roof is below the wall, the termination details are critical and will depend greatly on the design of the attic below. For vented attics or porch roofs, the intent is to maintain the continuity of the insulation past the roof line as the wall above and the continuation of the wall below the roof are both considered...
Figure 5.10: Vented attic water control layer in front of rigid insulation

Figure 5.11: Unvented attic water control layer in front of rigid insulation
exterior wall assemblies (see Figure 5.12). For unvented attics, the insulation will follow the plane of the intersecting roof sheathing (see Figure 5.13).

With the water control layer at the face of the rigid insulation, the step flashing and shingles are installed up to the rigid insulation. While the details installation details are typical, the construction sequence may create a problem as the rigid insulation may not be installed at the time that the roof is installed. If this is the case, then a curb of insulation is required to be installed so that the roofing can be completed. In addition, a temporary weather seal at the top of the insulation curb is also required to prevent water infiltration into the structure prior to installation of the wall rigid insulation. It is also helpful to install a nail base for the step flashing so that extra long nails are not required for step flashing attachment (see sequence in Figure 5.14).
Figure 5.13: Unvented attic water control layer in front of rigid insulation
Figure 5.14a: Fully-adhered membrane and insulation curb installed prior to the roof shingles

Figure 5.14b: Fully-adhered membrane installed over insulation curb to provide temporary waterproofing until the wall insulation is installed

Figure 5.14c: Roof assembly and step flashing installed following industry standard practice

Figure 5.14d: Insulation added to the wall assembly and sealed over step flashing
Balconies

Balcony interfaces will need to be addressed in a similar manner to walls above lower roofs. Since the water control layer is at the face of the rigid insulation, all deck waterproofing should be returned up the face of the rigid insulation (see Figure 5.15 and 5.16).

Figure 5.15: Balcony water control layer in front of rigid insulation
With decks the ledger can be installed either outboard or inboard of the rigid insulation depending on loads. With large loads an inboard location may be necessary. In general, locating the ledger outboard of the rigid insulation is preferred (see Figure 5.17 and Figure 5.18). In addition, a fully-adhered waterproof membrane is recommended to be installed between the ledger and the face of the rigid insulation.

A flashing can be placed over the deck ledger to help control surface run off of rain water from the cladding. In this case the flashing only needs to be lapped behind the siding to maintain continuity of the shingle lapping.
Figure 5.17: Ledger outboard of rigid insulation

Figure 5.18: Ledger inboard of rigid insulation
**CLADDING ATTACHMENT**

For thinner thicknesses of insulation, the cladding can often be attached directly through the rigid insulation back to the structure. The practical limit of this approach is around \(1\frac{1}{2}\)” of rigid insulation due to a limitation on fastener lengths for many pneumatic nail guns (see Figure 5.19 and 5.20).

For insulation over \(1\frac{1}{2}\)” in thickness, the use of vertical wood furring strips (for horizontal siding) and horizontal wood furring strips (for vertical siding) has been a common approach for providing cladding attachment (see Figure 5.21).

For wood shingles a continuous nail base will be required. This additional layer of sheathing is installed directly over the insulation in place of wood furring strips. A drainage mat is installed over the additional layer of sheathing between the wood shingles and the additional layer of sheathing to provide cladding drainage and ventilation. The additional layer of wood sheathing will need to be protected from rain water absorption by either installing a building paper or housewrap under the drainage mat and over the additional layer of wood sheathing.

In order to adequately support the cladding, the furring strips are recommended to be attached back to the structure using either #10 or greater wood screws that are sized to maintain a \(1\frac{1}{4}\)” minimum embedment into the structural framing. As an example, a 6-inch long wood screw can be used to attach up to 4” of insulation. A 4-inch screw would be adequate for 2” of rigid insulation.

The furring strips are recommended to be attached directly back to the wood framing. This means that the horizontal spacing will generally either be 24” on center or 16” on center. The following table provides a quick reference to recommended vertical screw spacing based on framing spacing and cladding type.

**Table 5.1: Vertical screw spacing for attachment of wood furring strips to the structure for up to 4” of rigid insulation**

<table>
<thead>
<tr>
<th>Cladding</th>
<th>16” o.c. stud spacing</th>
<th>24” o.c. stud spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood, vinyl and fiber cement (up to 5 lb/ft²)</td>
<td>24”</td>
<td>18”</td>
</tr>
<tr>
<td>Stucco (up to 10 lb/ft²)</td>
<td>12”</td>
<td>9”</td>
</tr>
<tr>
<td>Adhered stone veneer (up to 20 lb/ft²)</td>
<td>6”</td>
<td>4”</td>
</tr>
</tbody>
</table>

**CODE REQUIREMENTS FOR CLADDING ATTACHMENT**

ARE FOUND IN SECTION R703 OF THE 2009 IRC AND 2012 IRC. TABLE R703.4 PROVIDES GUIDANCE FOR ATTACHMENT OF CLADDING DIRECTLY THROUGH EXTERIOR RIGID INSULATION.
Larger spacing can be used if less insulation is used. For claddings in excess of 20 psf additional design is recommended. For additional options for fastener type, spacing, and thickness of insulation please see Appendix 3.

For claddings that may need additional support such as adhered stone veneers additional furring strips can be installed (see Figure 5.22).
**Cladding Drainage and Ventilation**

It is recommended to provide a drainage space behind all cladding assemblies regardless of position of the water control layer. If possible, back ventilating the cladding is also recommended. The use of vertical wood furring strips by its nature creates a ventilation and drainage space. Other techniques such as non structural furring (e.g. strips of 3/8” rigid insulation) or drainage mats are other potential options. The drainage space is particularly important for vertical siding, panel siding, stucco claddings, and adhered stone veneers (see Figure 5.22).

Flashing, such as at the top of the window trim or water tables, is not required to be integrated with the water control layer, though in this configuration it may be easy to do. The purpose of this flashing is to protect the top edge of the trim material by maintaining the shingle lapping of the cladding with the trim (see Figure 5:23).

![Figure 5.23: Window trim head flashing does not need to be tied back to water control layer](image-url)
6. **Construction: Water Control Layer Behind the Rigid Insulation**

The intent of this guide is to leverage many of the benefits of continuous structural sheathing and continuous exterior rigid insulation. While it is recognized that other means of providing structural resistance to wind and lateral loads are possible, the intent is to maintain standard construction practice as much as possible with the introduction of continuous exterior rigid insulation.

In addition, the location of the water control layer for the assemblies has many implications on the construction detailing. To address this, the construction portion of this guide is separated into two sections:

1. Water control layer exterior of the rigid insulation (see Section 5: Construction: Water Control Layer exterior of the rigid insulation)
2. Water control layer behind the rigid insulation

The intent is to group all associated details into a single section for easier reference and consistency of design details. As such, there is some repetition of information, however it is felt that this will provide easier reference for designers and builders who are looking to incorporate exterior continuous rigid insulation in their projects.

**Structure**

The use of continuous wood structural sheathing provides a simple and robust means for wall bracing and wind resistance for a variety of home styles and design conditions, and is standard practice for most of the residential building industry. The application of continuous exterior rigid insulation can be simply added to any home with a code compliant structural design.

**Attachment of Insulation**

There are no specific requirements for the attachment of the insulation. The design of the system uses the structural wood sheathing for the wind load resistance. In addition all cladding attachment must either be directly through the insulation back to the structure or to a secondary cladding support system such as wood furring strips, that are attached through the insulation back to the structure. In either case, the requirements of the cladding attachment will function to clamp the rigid insulation in place. The attachment of the rigid insulation is really only needed as a temporary measure to hold the insulation on the wall until the cladding is installed.

Still, it is recommended to use either cap nails, screw with washers or plates, or other larger head fasteners to prevent overdriving through the outer face of the insulation materials.

The exterior rigid insulation can either be installed in a single layer, or in multiple layers. For multi-layer applications it is recommended to offset all the joints in the insulation boards.

**Code Requirements**

For wall bracing are found in section 602.10 of the 2009 IRC and 2012 IRC. There are various other resources to assist in achieving code-compliant wall bracing:
- APA Simplified Bracing Guide
- ICC Wall Bracing Guide
- FSC Wall Bracing Guide
Water Resistive Barriers

When the water control layer is located behind the rigid insulation any number of products or systems can be used. Most common would be building paper or housewrap. Fully adhered membrane, liquid applied membranes, or taped and sealed joints of faced structural panels would also be options. The installation of these products would follow industry standard practice and would be independent of the installation of the rigid insulation. All flashing and other water control interfaces for the building will need to connect to the wall water control layer.

While installing the water control layer behind the insulation may seem straightforward, it actually can be more difficult in the long run as many of the common building interface details (roofs, windows, decks, balconies, etc.) will require flashing to be run through the rigid insulation to the exterior. These details deviate from common building practice, which can often lead to confusion during construction.
**WINDOw INTEGRATION**

Windows installed at the plane of the structural sheathing would follow industry standards for integration with the wall water control layer. It is recommended that all windows are installed in a pan flashed and drained opening with the jambs and head of the frame taped or sealed to the wall water control layer.

Moving the windows further to the exterior while maintaining the water control layer at the structural sheathing plane would require extension bucks to be installed in the window rough opening. At the head it is recommended to slope the top surface to the exterior. The extension bucks would need to be covered with a waterproof membrane. Liquid applied membranes are particularly well suited for this application. The window is then flashed into the rough opening following the same recommendation as shown in figures (see sequences in Figures 6.5 and 6.6; see also Figure 6.7, 6.8 and 6.9).
Figure 6.5a: Step 1—Water control layer wrapped into the rough opening; pan flashing installed at the sill

Figure 6.5b: Step 2—Window installed; flanges taped to water control layer

Figure 6.5c: Step 3—Exterior rigid insulation installed

Figure 6.6a: Step 1—Water control layer wrapped around rough opening extension buck; pan flashing installed at the sill

Figure 6.6b: Step 2—Window installed; flanges taped to water control layer

Figure 6.6c: Step 3—Exterior rigid insulation installed
CONSTRUCTION: WATER CONTROL LAYER BEHIND THE RIGID INSULATION

Figure 6.7: Window head water control layer behind rigid insulation

Figure 6.8: Window sill water control layer behind rigid insulation
**Roofs**

Where the roof is above the wall, the termination of the exterior insulation does not change significantly regardless of the attic being vented or unvented. The differences would mostly be associated with the attic design and not the wall design.

For vented attics, the rigid insulation will need to terminate below the level of the roof sheathing in order to provide a ventilation opening. Extending the rigid insulation up as high as possible has some additional benefits though, including increased thermal resistance at the roof to wall connection, and it can act as an insulation stop and baffle for the attic insulation (see Figure 6.10). For gable ends, while having additional thermal resistance is not needed, it is often practical to simply maintain the rigid insulation up the full height to keep the cladding aligned.

For unvented attics, the rigid insulation can be run tight to the underside of the roof sheathing. In this configuration it can act as an insulation stop for spray polyurethane foam (if used). At the gable ends, continuing the rigid insulation will provide additional thermal resistance for the attic assembly (see Figure 6.11).

Where the wall is above a roof, the termination details at the base of the wall are critical and will depend greatly on the design of the attic below. For vented attics or porch roofs, the intent is to maintain the continuity of the insulation past the roof line as the wall above and the continuation of the wall below the roof are both considered exterior assemblies (see Figure 6.12). For unvented attics, the insulation will follow the plane of the intersecting roof sheathing (see Figure 6.13).

With the water control layer behind the insulation, the step flashing and shingles must extend back to the plane of the structural sheathing. A consideration for the detailing of this interface is the future need to re-roof the building. The
Figure 6.10: Vented attic water control layer behind rigid insulation

Figure 6.11: Unvented attic water control layer behind rigid insulation
roof covering will undoubtedly have a shorter service life compared to the wall cladding, therefore a means to access the roof to wall interface back behind the exterior insulation should be provided so that future work can be completed without disrupting the primary siding installation. A minimum 8” band of siding and insulation is recommended to be installed at the roof to wall interface to provide a removable termination to allow for future access to the flashing at the roof to wall interface (sequence shown in Figure 6.14a through 6.14d; see also Figure 6.12 and Figure 6.13). This band has a secondary benefit as it provides an easy detail for the installation of a kick out flashing should the end of the roof terminate in the field of the wall.

Figure 6.12: Vented attic or porch water control layer behind rigid insulation
Figure 6.13: Unvented attic water control layer behind rigid insulation
Figure 6.14a: Fully-adhered membrane at roof to wall connection; kick-out flashing stripped in at roof termination

Figure 6.14b: Roof assembly and step flashing installed following industry standard practice

Figure 6.14c: Insulation added to the wall assembly

Figure 6.14d: Removable 8” strip of insulation will allow for future re-roofing of the assembly
**Balconies**

Balcony interfaces need to be addressed in a similar manner to walls above lower roofs. Again, providing a removable strip of insulation and cladding at the wall to balcony interface will allow for future replacement of the balcony waterproofing system (see Figure 6.15 and Figure 6.16).

![Figure 6.15: Balcony water control layer behind rigid insulation](image)

Figure 6.15: Balcony water control layer behind rigid insulation
**DECKS**

The water control layer is recommended to run continuous past the deck ledger. A flashing can be placed over the deck ledger to help control surface run off of rain water from the cladding. In this case the flashing only needs to be lapped behind the siding to maintain continuity of the shingle lapping. It is not necessary to run the flashing all the way back to the water control layer (see Figure 6.17).
Figure 6.17: Deck water control layer behind rigid insulation; deck attached before the insulation

Figure 6.18: Deck water control layer behind rigid insulation; deck attached after the insulation
CLADDING ATTACHMENT

For thinner thicknesses of insulation, the cladding can often be attached directly through the rigid insulation back to the structure. The practical limit of this approach is around 1 1/2” of rigid insulation due to a limitation on fastener lengths for many pneumatic nail guns (see Figures 6.19 and 6.20).

For insulation over 1 1/2” in thickness, the use of vertical wood furring strips (for horizontal siding) and horizontal wood furring strips (for vertical siding) has been a common approach for providing cladding attachment (see Figure 6.21).

For wood shingles a continuous nail base will be required. This additional layer of sheathing is installed directly over the insulation in place of wood furring strips. A drainage mat is installed over the additional layer of sheathing between the wood shingles and the additional layer of sheathing to provide cladding drainage and ventilation. The additional layer of wood sheathing will need to be protected from rain water absorption by either installing a building paper or housewrap under the drainage mat and over the additional layer of wood sheathing.

In order to adequately support the cladding, the furring strips are recommended to be attached back to the structure using either #10 or greater wood screws that are sized to maintain a 1 1/4” minimum embedment into the structural framing. As an example, a 6-inch long wood screw can be used to attach up to 4” of insulation. A 4-inch screw would be adequate for 2” of rigid insulation.

The furring strips are recommended to be attached directly back to the wood framing. This means that the horizontal spacing will generally either be 24” on center or 16” on center. The following table provides a quick reference to recommended vertical screw spacing based on framing spacing and cladding type.

<table>
<thead>
<tr>
<th>Cladding</th>
<th>16” o.c. stud spacing</th>
<th>24” o.c. stud spacing</th>
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<tr>
<td>Adhered stone veneer (up to 20 lb/ft²)</td>
<td>6”</td>
<td>4”</td>
</tr>
</tbody>
</table>

Larger spacing can be used if less insulation is used. For claddings in excess of 20 psf additional design is recommended. For additional options for fastener type, spacing, and thickness of insulation please see Appendix 3.

For claddings that may need additional support such as adhered stone veneers additional furring strips can be installed (see Figure 6:22).
CONSTRUCTION: WATER CONTROL LAYER BEHIND THE RIGID INSULATION

Figure 6.19: Lap siding attached directly through rigid insulation

Figure 6.20: Stucco attached directly through rigid insulation

Figure 6.21: Furring strips attachment location for lap siding

Figure 6.22: Additional furring for support of adhered stone veneers needs to be attached to horizontal blocking within stud framing
**Cladding Drainage and Ventilation**

It is recommended to provide a drainage space behind all cladding assemblies regardless of position of the water control layer. If possible, back ventilating the cladding is also recommended. The use of vertical wood furring strips by its nature creates a ventilation and drainage space. Other techniques such as non-structural furring (e.g. strips of 3/8” rigid insulation) or drainage mats are other potential options for claddings that are directly attached back through the insulation to the structure. The drainage space is particularly important for vertical siding, panel siding, stucco claddings, and adhered stone veneers.

Flashing, such as at the top of the window trim or water table, is not required to be integrated with the water control layer. The purpose of these flashings are to maintain the shingle lapping of the cladding with the trim (see Figure 6.23).

![Figure 6.23: Window trim head flashing does not need to be tied-back to water control layer](image)
APPENDICES

APPENDIX 1: PARALLEL PATHS U-FACTOR AND EFFECTIVE R-VALUE EXAMPLES

The parallel paths method is a two-dimensional steady state conductive heat transfer analysis. The analysis works by calculating the area weighted heat flow through various paths in the assembly (i.e. through the cavity insulation and through the wood studs) and adding them up to determine the total heat flow (or thermal conductance). The thermal conductance is described as the U-factor. The thermal resistance is described as the R-Value. The R-Value is the reciprocal of the U-factor.

To determine the effective R-Value of an assembly using the parallel paths method, the total R-Value of each path is first calculated by adding the R-Value of each material layer included in the path:

\[ R_{1\text{cavity}}, R_{2\text{framing}} \]

The total conductance of the assembly is determined by summing the U-factor of each path multiplied by the area weighted percentage of each path:

\[ U_{\text{assembly}} = \left( \frac{1}{R_1} \right) * A_1 + \left( \frac{1}{R_2} \right) * A_2 \]

The effective R-Value of the assembly is the reciprocal of the U-factor of the assembly:

\[ R_{\text{assembly}} = \frac{1}{U_{\text{assembly}}} \]

The following are some worked examples of the parallel paths method of determining equivalent U-Factors and effective R-Values for several wall assemblies. The parallel paths method is described in ASHRAE Fundamentals (2013) Chapter 27. In all examples, the cladding is omitted from the analysis.
Assembly 1 – High Performance

The following is an example of a recommended high performance wall assembly:

- Two layers of 2” PIC rigid insulation
- 7/16” wood structural sheathing
- 2x6 wood framing (following advanced framing techniques)
- Blown-in cellulose insulation
- 1/2” interior gypsum

Figure A.1.1: High performance wall assembly

For this assembly the nominal R-Value would be listed as:

R-20 + R-26 = R-46
The equivalent U-Factor and effective R-Value as determined by the parallel paths method:

<table>
<thead>
<tr>
<th>Material</th>
<th>Nominal R-Value/ inch</th>
<th>Thickness (in)</th>
<th>R1 (cavity)</th>
<th>R2 (framing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor air film</td>
<td>-</td>
<td>-</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Rigid insulation</td>
<td>6.5</td>
<td>4</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>7/16” wood structural sheathing</td>
<td>-</td>
<td>-</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>Wood stud framing</td>
<td>1.25</td>
<td>5.5</td>
<td>6.88</td>
<td></td>
</tr>
<tr>
<td>Blown-in cellulose</td>
<td>3.7</td>
<td>5.5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1/2” gypsum board</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Interior air film</td>
<td>-</td>
<td>-</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>R-total per path</strong></td>
<td></td>
<td></td>
<td><strong>47.9</strong></td>
<td><strong>34.8</strong></td>
</tr>
<tr>
<td>U-factor per path</td>
<td></td>
<td></td>
<td>0.021</td>
<td>0.029</td>
</tr>
<tr>
<td>Framing fraction per path*</td>
<td></td>
<td></td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>Weighted U-factor</td>
<td></td>
<td></td>
<td>0.017</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Equivalent U-factor</strong></td>
<td></td>
<td></td>
<td><strong>0.022</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Effective R-Value</strong></td>
<td></td>
<td></td>
<td><strong>44.6</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Advanced framing can significantly reduce the area ratio between wood framing and cavity insulation. The advanced wood wall framing factor can range from 15-20%, and depends on the combination of 24” o.c. spacing between studs, insulated corners, insulated interior-exterior wall intersections, single top plates, headers placed in the rim cavity, aligned framing and limited cripple supports at door and window openings. The APA Advanced Framing Construction Guide has additional details. Advanced wood wall framing factors below 20% should be verified for each project, and are subject to approval by the authority having jurisdiction.
Assembly 2 – Good Performance (2x6 framing)

The following is an example of a recommended good performance assembly:

- One layer of 1\(\frac{1}{2}\)” XPS rigid insulation
- 7/16” wood structural sheathing
- 2x6 wood framing (standard framing)
- Blown-in cellulose insulation
- ½” interior gypsum

For this assembly the nominal R-Value would be listed as:

\[ R-20 + R-7.5 = R-27.5 \]
The equivalent U-Factor and effective R-Value as determined by the parallel paths method:

<table>
<thead>
<tr>
<th>Material</th>
<th>Nominal R-Value/ inch</th>
<th>Thickness (in)</th>
<th>R1 (cavity)</th>
<th>R2 (framing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor air film</td>
<td>-</td>
<td>-</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Rigid insulation</td>
<td>5</td>
<td>1.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>7/16&quot; wood structural sheathing</td>
<td>-</td>
<td>-</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>Wood stud framing</td>
<td>1.25</td>
<td>5.5</td>
<td></td>
<td>6.88</td>
</tr>
<tr>
<td>Blown-in cellulose</td>
<td>3.7</td>
<td>5.5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1/2&quot; gypsum board</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Interior air film</td>
<td>-</td>
<td>-</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>R-total per path</strong></td>
<td></td>
<td>29.4</td>
<td>16.3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>U-factor per path</th>
<th>Framing fraction per path</th>
<th>Weighted U-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R-total per path</strong></td>
<td>0.034</td>
<td>75%</td>
<td>0.025</td>
</tr>
<tr>
<td><strong>Equivalent U-factor</strong></td>
<td><strong>0.041</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effective R-Value</strong></td>
<td><strong>24.5</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Assembly 3 – Good Performance (2x4 framing)

The following is an example of a recommended good performance assembly:

- One layer of 1” XPS rigid insulation
- 7/16” wood structural sheathing
- 2x4 wood framing (standard framing)
- Blown-in cellulose insulation
- 1/2” interior gypsum

For this assembly the nominal R-Value would be listed as:

$R_{13} + R_{-5} = R_{18}$
The equivalent U-Factor and effective R-Value as determined by the parallel paths method:

<table>
<thead>
<tr>
<th>Nominal R-Value/inch</th>
<th>Thickness (in)</th>
<th>R1 (cavity)</th>
<th>R2 (framing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor air film</td>
<td>-</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Rigid insulation</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>7/16&quot; wood structural sheathing</td>
<td>-</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>Wood stud framing</td>
<td>1.25</td>
<td>3.5</td>
<td>4.38</td>
</tr>
<tr>
<td>Blown-in cellulose</td>
<td>3.7</td>
<td>3.5</td>
<td>13</td>
</tr>
<tr>
<td>1/2&quot; gypsum board</td>
<td>-</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Interior air film</td>
<td>-</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>R-total per path</strong></td>
<td></td>
<td><strong>19.9</strong></td>
<td><strong>11.3</strong></td>
</tr>
</tbody>
</table>

| U-factor per path    | 0.050          | 0.089       |
| Framing fraction per path | 75%        | 25%         |
| Weighted U-factor    | 0.038          | 0.022       |

**Equivalent U-factor** 0.060  
**Effective R-Value** 16.7
Assembly 4 – Standard Wall (2x6 framing)

The following is an example of a recommended good performance assembly:

- 7/16” wood structural sheathing
- 2x6 wood framing (standard framing)
- Fiberglass batt cavity insulation
- 1/2” interior gypsum

For this assembly the nominal R-Value would be listed as:

R-20
The equivalent U-Factor and effective R-Value as determined by the parallel paths method:

<table>
<thead>
<tr>
<th>Material</th>
<th>Nominal R-Value/ inch</th>
<th>Thickness (in)</th>
<th>R1 (cavity)</th>
<th>R2 (framing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor air film</td>
<td>-</td>
<td>-</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>( \frac{7}{16} )&quot; wood structural sheathing</td>
<td>-</td>
<td>-</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>Wood stud framing</td>
<td>1.25</td>
<td>5.5</td>
<td></td>
<td>6.88</td>
</tr>
<tr>
<td>Fiberglass batt</td>
<td>3.7</td>
<td>5.5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>( \frac{1}{2} )&quot; gypsum board</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Interior air film</td>
<td>-</td>
<td>-</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>R-total per path</strong></td>
<td><strong>21.9</strong></td>
<td></td>
<td></td>
<td><strong>8.8</strong></td>
</tr>
<tr>
<td><strong>U-factor per path</strong></td>
<td><strong>0.046</strong></td>
<td></td>
<td><strong>0.114</strong></td>
<td></td>
</tr>
<tr>
<td>Framing fraction per path</td>
<td></td>
<td></td>
<td><strong>75%</strong></td>
<td><strong>25%</strong></td>
</tr>
<tr>
<td>Weighted U-factor</td>
<td></td>
<td></td>
<td><strong>0.034</strong></td>
<td><strong>0.028</strong></td>
</tr>
<tr>
<td><strong>Equivalent U-factor</strong></td>
<td><strong>0.063</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effective R-Value</strong></td>
<td><strong>16.0</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Assembly 5 – Standard Wall (2x4 framing)

The following is an example of a recommended good performance assembly:

- \(\frac{7}{16}\)” wood structural sheathing
- 2x4 wood framing (standard framing)
- Fiberglass batt cavity insulation
- \(\frac{1}{2}\)” interior gypsum

For this assembly the nominal R-Value would be listed as:

R-13
The equivalent U-Factor and effective R-Value as determined by the parallel paths method:

<table>
<thead>
<tr>
<th></th>
<th>Nominal R-Value/ inch</th>
<th>Thickness (in)</th>
<th>R1 (cavity)</th>
<th>R2 (framing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor air film</td>
<td>-</td>
<td>-</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>&quot;7/16&quot; wood structural sheathing</td>
<td>-</td>
<td>-</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>Wood stud framing</td>
<td>1.25</td>
<td>3.5</td>
<td>4.38</td>
<td></td>
</tr>
<tr>
<td>Fiberglass batt</td>
<td>3.7</td>
<td>3.5</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>&quot;1/2&quot; gypsum board</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Interior air film</td>
<td>-</td>
<td>-</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td>R-total per path</td>
<td></td>
<td></td>
<td>14.9</td>
<td>6.3</td>
</tr>
<tr>
<td>U-factor per path</td>
<td></td>
<td></td>
<td>0.067</td>
<td>0.159</td>
</tr>
<tr>
<td>Framing fraction per path</td>
<td></td>
<td></td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>Weighted U-factor</td>
<td></td>
<td></td>
<td>0.050</td>
<td>0.040</td>
</tr>
<tr>
<td>Equivalent U-factor</td>
<td></td>
<td></td>
<td>0.090</td>
<td></td>
</tr>
<tr>
<td>Effective R-Value</td>
<td></td>
<td></td>
<td>11.1</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 2: CODE REFERENCES

Wall bracing
• Section 602.10 of the 2009 IRC and 2012 IRC

Water resistant barriers
• Section R703 of the 2009 IRC and 2012 IRC

Air leakage
• Section 402.4 of the 2009 IECC
• Section R402.4 of the 2012 IECC

Vapor retarders
• Section R601.3 of the 2009 IRC
• Section R702.7 of the 2012 IRC

Thermal insulation
• Section 402 of the 2009 IECC
• Section R402 of the 2012 IECC

Cladding attachment
• Section R703 of the 2009 IRC and 2012 IRC
APPENDIX 3: CLADDING ATTACHMENT

Minimum Furring and Attachment Requirements to Resist Maximum 30 PSF Design Wind Load\(^1,2\)

<table>
<thead>
<tr>
<th>Connection Method</th>
<th>16&quot; Furring Spacing</th>
<th>24&quot; Furring Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1x3 wood furring</td>
<td>1x4 wood furring</td>
</tr>
<tr>
<td>8d common nail ((2\frac{1}{4}''\times0.131'')), minimum 1&quot; penetration</td>
<td>1 at 12&quot; o.c. or 2 at 16&quot; o.c.</td>
<td>2 at 24&quot; o.c.</td>
</tr>
<tr>
<td>#10 wood screw (minimum 1&quot; penetration)</td>
<td>1 at 16&quot; o.c.</td>
<td>1 at 24&quot; o.c.</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4mm

1. Wood furring and wall framing shall be Spruce-Pine-Fir or any wood species with a specific gravity of 0.42 or greater in accordance with AFPA/NDS. Wood structural panel wall sheathing of equal or greater effective specific gravity for withdrawal shall be permitted to be included in the penetration depth. The span of 1x4 furring across studs or between fastening points shall not exceed 24" for a maximum 16"o.c. furring spacing. In all other cases, 1x3 or 1x4 wood furring shall not exceed a 16" span across studs or between fastening points.

2. Where the required cladding fastener penetration into wood material exceeds \(\frac{3}{4}''\) (19.1 mm) and is not more than \(\frac{3}{8}''\) (38.1 mm), a minimum 2x3 wood furring shall be used or an approved design. Minimum fastener penetration into wall framing shall not be reduced with use of thicker furring member.

Cladding Minimum Fastening Requirements for Direct Attachment

Over Foam Plastic Sheathing to Support Cladding Weight\(^1\)

<table>
<thead>
<tr>
<th>Cladding fastener through foam sheathing into:</th>
<th>Cladding fastener type and minimum size(^2)</th>
<th>Maximum thickness of foam sheathing(^3) (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cladding fastener type vertical spacing (inches)</td>
<td>16&quot; o.c. fastener horizontal spacing</td>
</tr>
<tr>
<td></td>
<td>3 psf</td>
<td>11 psf</td>
</tr>
<tr>
<td>Wood framing (minimum 1(\frac{1}{4})'' penetration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.113'' diameter nail</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>0.120'' diameter nail</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>0.131'' diameter nail</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>0.162'' diameter nail</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm; 1 pound per square foot (psf) = 0.0479 kPa
DR = design required
o.c. = on center

1. Wood framing shall be Spruce-Pine-Fir or any wood species with a specific gravity of 0.42 or greater in accordance with AFPA/NDS.

2. Nail fasteners shall comply with ASTM F1667, except nail length shall be permitted to exceed ASTM F1667 standard lengths.

3. Foam sheathing shall have a minimum compressive strength of 15 psi in accordance with ASTM C 578 or ASTM C 1289.
**Furring Minimum Fastening Requirements for Application Over Foam Plastic Sheathing to Support Cladding Weight**

<table>
<thead>
<tr>
<th>Furring material</th>
<th>Framing member</th>
<th>Cladding fastener type and minimum size</th>
<th>Minimum penetration into wall framing (inches)</th>
<th>Fastener spacing into furring (inches)</th>
<th>Maximum thickness of foam sheathing (inches)</th>
<th>16” o.c. furring</th>
<th>24” o.c. furring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum 1x wood furring</td>
<td>Minimum 2x wood stud</td>
<td>0.131” diameter nail</td>
<td>1 ¼</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>4</td>
<td>1.5</td>
<td>DR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>DR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.162” diameter nail</td>
<td>1 ¼</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>0.75</td>
<td>11 psf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>4</td>
<td>1.5</td>
<td>DR</td>
<td>25 psf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10” wood screw</td>
<td>1</td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>4</td>
<td>1.5</td>
<td>DR</td>
<td>11 psf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>4</td>
<td>1</td>
<td>DR</td>
<td>25 psf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>¼” lag screw</td>
<td>1 ½</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>4</td>
<td>1.5</td>
<td>DR</td>
<td>11 psf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>4</td>
<td>1.5</td>
<td>DR</td>
<td>25 psf</td>
</tr>
</tbody>
</table>

For SI: 1” = 25.4 mm; 1 pound per square foot (psf) = 0.0479 kPa.

DR = design required

1. Wood framing and furring shall be Spruce-Pine-Fir or any wood species with a specific gravity of 0.42 or greater in accordance with AFPA/NDS.
2. Nail fasteners shall comply with ASTM F1667, except nail length shall be permitted to exceed ASTM F1667 standard lengths.
3. Where the required cladding fastener penetration into wood material exceeds ¾” (19.1 mm) and is not more than 1½” inches (38.1 mm), a minimum 2x wood furring shall be used or an approved design.
4. Foam sheathing shall have a minimum compressive strength of 15 psi in accordance with ASTM C 578 or ASTM C 1289.
5. Furring shall be spaced a maximum of 24” (610 mm) on center, in a vertical or horizontal orientation. In a vertical orientation, furring shall be located over wall studs and attached with the required fastener spacing. In a horizontal orientation, the indicated 8” (203.2 mm) and 12” (304.8 mm) fastener spacing in furring shall be achieved by use of two fasteners into studs at 16” (406.4 mm) and 24” (610 mm) on center, respectively.