MASS SAVE DEEP ENERGY RETROFIT BUILDER GUIDE

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FORWARD

The purpose of this guide is to provide useful examples of high performance retrofit techniques for the building enclosure of wood frame residential construction in a cold and somewhat wet climate. The examples demonstrate effective management of liquid water (rain and ground water), airflow, water vapor flow and heat flow. Retrofit ventilation approaches are reviewed because mechanical ventilation is taken to be a necessary component in high performance buildings. This guide does not address mechanical heating, cooling or water heating systems beyond outlining basic combustion safety measures.

Existing homes present an incredible variety of conditions. The variations of building techniques over time and across different regions combined with the inherent individuality among builders lends to a mind-boggling variety of configurations in existing housing stock. Rather than try to encompass all of the possible solutions responding to each of various existing conditions, this guide details a limited number of options for deep energy retrofit of common configurations found in wood framed New England homes. Through its experience in guiding high performance retrofit projects, BSC has found the solutions in this guide to be applicable to the vast majority of circumstances. Some retrofit projects will require solutions that are not described in this guide.

Successful retrofit is a challenging endeavor. Successful high performance retrofit poses further challenges. This guide is not intended as a comprehensive guide to all challenges, hazards and constraints that may be encountered in the course of high performance retrofit. Contractors implementing deep energy retrofit (DER) projects must be able to recognize structural conditions and hazards - such as, but not limited to hazardous materials, faulty electrical or plumbing systems - that pose a risk to the building or occupants. This guide does not provide guidance on techniques for remediation or assessment of structural, electrical or plumbing systems nor does it describe the appropriate remediation of hazardous materials.

Despite every effort to describe proven and robust techniques, the guide cannot replace sound judgment. Neither can the guide compensate for lack of training. Individuals performing services directed to deep energy retrofit will need to exercise good judgment and draw upon appropriate training in implementing measures described in this guide.

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Finally, we would like to acknowledge the foundation for the present work established in the work of Dr. Joseph Lstiburek and Ms. Betsy Pettit, FAIA, founding partners of BSC as well as Armin Rudd, Christopher Schumacher and Dr. John Straube. If portions of this guide bear resemblance to articles or presentations by Dr. Joe, Betsy, Armin, Chris or Professor Straube, it is not merely coincidence. Rather it is a consequence of the profound influence that their work has had on our understanding of buildings.

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PART I:
DER CONCEPTS

INTRODUCTION TO DER

Massachusetts gas and electric utilities are sponsoring a limited Deep Energy Retrofit (DER) program to provide support to customers who wish to incorporate a deep energy retrofit as part of regular maintenance or remodeling activities. This guide is intended to provide the technical framework for this program.

The guide is composed of two parts. Part 1 explains fundamental DER concepts and outlines prerequisite measures for DER projects participating in the DER program. Part 2 provides specific technical guidance for the high performance retrofit of residential building enclosures. This technical guidance is presented in the form of illustrated schematic details accompanied by explanatory text and notes.

WHAT IS A DEEP ENERGY RETROFIT?

Deep Energy Retrofit (DER) refers to the retrofit of the building enclosure and other building systems in a way that results in a high performance building. A successful DER will result in very low post-retrofit energy use and also provide benefits to building durability, comfort, and indoor air quality (IAQ). DER may also increase the usable space or amenity of a building. For example, retrofitting the thermal enclosure of attic or basement spaces may make it possible to expand finished living area into these spaces where it had not been possible before.

DER achieves performance on par with best-in-class new construction. That is, the performance resulting from DER will exceed new construction code standards and rival the performance of high-performance new construction. In fact, many of the techniques and strategies illustrated in this guide have been adapted from proven high-performance and super-insulation techniques used in exemplary new construction projects.

What levels of thermal performance constitute “high performance”? Years of helping builders, developers and designers to reach high performance goals involving tens of thousands of homes has led BSC to identify a set of performance targets for major building enclosures components. The set of performance targets is often expressed as “1.5-5-10-20-40-60” where 5 refers to the target R-value for windows and doors; 10, the target R-value for slabs; 20, the target R-value for foundation wall assemblies; 40, the target R-value for wall assemblies; 60, the target R-value of the attic/roof assembly; and, 1.5, the target air tightness of the building enclosure system measured in terms of air changes per hour at 50 Pascals (ACH50). These targets provide a framework for identifying high performance enclosures—enclosures that reduce the heating and cooling load of the enclosure system to a practical minimum. When we want to describe the performance goals for a DER enclosure, it suffices to use the expression “1.5-5-10-20-40-60”. These are the levels of thermal performance that are represented in the guidance and illustrations contained in this guide.

While the enclosure measures in a DER are aimed at reducing heating and cooling loads, DER also addresses the mechanical systems that serve those loads. A comprehensive DER will also replace older and standard efficiency heating, cooling and water heating systems with efficient equipment configured to provide efficient performance.

Finally, since the essential purpose of the enclosure system as well as the heating and cooling systems is to allow users of a building to control the indoor environment, we cannot neglect the fundamental importance of air quality in the indoor environment. At the most basic level, we need to think of air quality as it pertains to life safety. It is also important to provide for control of moisture and dilution of contaminants through ventilation. A DER must provide robust combustion safety as well as effective mechanical ventilation (see *Prerequisites for High Performance Enclosure Retrofit* below).

A DER project need not be a comprehensive building enclosure renovation project. In fact, most DER projects address only one or two major components of the enclosure such as the roof or walls and windows or basement walls and slab. As a matter of health, safety and fundamental performance, the prerequisite for any DER project – even limited DER projects – will be to ensure combustion safety and to provide the means for effective ventilation.

WHY DEEP ENERGY RETROFIT?

As the name would imply, DER measures are intended to provide deep reductions to energy use. Energy savings are not the only reason to undertake a DER, however. A DER project typically provides many benefits beyond energy savings. A successful DER will bring important improvements to comfort within the home and to durability of components affected by the DER. A DER project may be undertaken in pursuit of passive survivability, to reduce carbon footprint, to eliminate maintenance burdens, or to make strides toward energy independence. DER measures may be incorporated into projects bringing long-sought aesthetic updates (such as installing new siding) or improvements (such as remodeling a basement) to a home. Persons undertaking retrofit projects do so for many different reasons. And DER projects are capable of delivering benefits responding to a variety of different objectives. In considering the investment in DER, it is only logical that the comprehensive costs for the project be evaluated relative to all the benefits. Although there may not be specific quantitative methods to apportion costs among various benefits, the cost should be recognized as shared among various benefits.

WHEN IS THE TIME FOR DEEP ENERGY RETROFIT

The best time to perform a DER for a major building system is when repairs or renovations are needed for that building system. For example, a re-roofing project (made necessary by the existing roof condition) is likely to represent the best opportunity to provide a super-insulated roof and bring the attic into conditioned space. If homeowners desire to remodel and finish a basement space, DER methods can provide guidance for achieving high levels of performance while avoiding typical finished basement problems. The cost for superinsulation of exterior walls (for an existing home) is typically lowest when siding and trim are being replaced. In fact, even when facing the expense of re-painting an exterior, it is worth considering whether those resources might be directed toward a DER for the exterior wall that will essentially eliminate the need for painting for many years into the future.

One of the early participants in the National Grid Deep Energy Retrofit Pilot program observed that significant expenditures to replace (as in siding or windows) or renovate (such as a basement or attic) a building component essentially prevents that building component from receiving further performance improvement for the life of the component. In other words, once windows are replaced, a roof is re-roofed, or siding is re-moved and reinstalled on an exterior wall, it is very unlikely that these systems will be upgraded for a long time. Certainly, once the renovation or replacement has been implemented, the most cost effective opportunity for high performance retrofit is past.

This is why the DER program is designed to capture opportunities presented by typical home maintenance activities such as re-roofing, re-siding and remodeling or finishing basement and attic spaces. When resources are already allocated for repairs or renovations to a major building system to meet non-energy-related needs, the benefits of DER can be achieved at a relatively small increment.

WHAT DOES A DEEP ENERGY RETROFIT MEAN FOR THE EXISTING BUILDING?

A DER causes a home to leapfrog well beyond the level of performance typical for current building practices. DER extends the useful life of the building or the building component by positioning it to perform, and perform well, for another 50-100 years.

What is important to keep in mind is that significant changes to the building enclosure will have profound effect on the dynamics of water, air, vapor and heat flow within the home. What may have worked before the retrofit – e.g. a leaking window where the water was able to dry through an uninsulated wall – may not work after the retrofit. By virtue of the fact that the building is standing and people are living in it, we can guess that the building is working. But we may not know exactly how it is working. So one must approach DER with a healthy dose of humility. It is important to be aware of ways in which the DER could change the dynamics of the building. Modifications to the building must aim to always reduce known risks.

PLAN FOR THE FUTURE—DER AND LONG-TERM GOALS FOR THE BUILDING

The DER project should be undertaken in the context of a comprehensive plan toward a longer-term vision for the building. Goals may not be defined in terms of energy savings alone. Comfort, usability of space, reduced maintenance, aesthetic improvement or changes, etc. may factor into the goals for the building. This guide is directed to homeowners whose long-term goals include high performance in terms of energy, health and safety and durability.

Like any plans for a major journey, the plan for the long term evolution home should include safe stopping points. Few will have resources to take on a comprehensive DER in a single project. For most, an incremental or phased approach is more feasible. This guide includes many suggestions for detailing measures in a way that allows later measures to pick up where earlier measures left off.

Owners of older homes encounter many reasons to make major repairs or improvements. A leaky roof, wet basement, tired siding, desire for more space or more usability of space, etc. might be the motivation for a major renovation project. Significant improvements, maintenance or changes to the building should be seized as opportunities to make steps toward the larger goals for the building. Otherwise, undirected expediency – addressing the most pressing needs with the least costly, least difficult means – might block opportunities thus making it more difficult, and ultimately more costly to progress toward long-term objectives. If there is a plan in place that charts a path toward long-term objectives, the odds are much better that even immediate problems can be addressed in a way that facilitates the next step toward the long-term goals.

In plotting the best route to long-term objectives, the order of changes does matter. For some typical building problems or items on the long-term "to do" list, a DER project can be used as a means to address the issue. Other typical problems or potential problems must be addressed before undertaking a DER project.

PREREQUISITES FOR HIGH PERFORMANCE ENCLOSURE RETROFIT

Changes to the building enclosure will have a significant impact on the dynamics of water, air, vapor and heat flow within the home. Upgrades to the mechanical systems will also affect these dynamics Certain measures should be implemented prior to or as part of any DER project to ensure that these changing dynamics do not have negative ramifications for health and safety. These prerequisite measures for DER projects are outlined below. The measures relate to:

- Remediation of existing hazardous conditions,
- Combustion Safety, and
- Indoor air quality.

The measures described to address indoor air quality include mechanical ventilation and soil gas control. These are, by no means, the only means to ensure good indoor air quality. However, effective mechanical ventilation and soil gas control are essential aspects of the building (as contrasted to furnishings, equipment, materials, etc. that people might bring into a building) that provide the occupants a means to control contaminants and respond to indoor air conditions.

REMEDIATE HAZARDOUS CONDITIONS

Prior to embarking on a DER project, it is important to remediate any hazardous conditions that will be affected (e.g. exposed or aggravated) by the planned DER work. Also, it is wise to ensure that there are not more serious problems lurking. A DER project – however worthy the goals may be – should not divert resources from where they are more urgently needed.

Before embarking on a DER project, inspect and assess the building for:

- Structural integrity of frame and foundation,
- Safety and serviceability of the electrical system,
- Presence of hazardous materials (e.g. lead, radon, asbestos),
- Roof or plumbing water leaks,
- Rot or decay in framing, and
- Insect/pest damage/activity.

The structural system must be structurally sound before high performance retrofit work can begin. Similarly, the electrical system must provide basic electrical safety. Ideally, the electrical system would be brought up to date with current code and brought into alignment with current and projected building needs. The presence of knob-and-tube wiring will preclude retrofit of the enclosure. Hazardous materials that will be affected by the DER work or that may impact the indoor air quality must be remediated and/or removed. Any water leaks, either weather-related leaks or plumbing system leaks should be repaired prior to the DER work unless the DER work will remove the source of the water leak (e.g. if the roof surface or leaking section of plumbing is to be replaced as part of the project). Any framing that shows signs of rot or decay should be replaced. This frequently applies to the framing sill in older buildings. Also, any framing that exhibits pre-conditions for rot or decay – i.e. damp wood – will require remediation. Past insect/pest damage must be evaluated for impact on the building. Current insect/pest activity must be remediated before DER work can proceed.

Follow applicable laws and industry procedures for mitigation of hazardous materials. Engage the services of a qualified professional when needed.

COMBUSTION SAFETY

Atmospherically vented (or naturally aspirated) combustion appliances are not appropriate for high-performance homes. With the exception of gas stoves and cooktops, combustion appliances in a DER home must be sealed combustion, induced draft, or power-vented. The best approach is to replace existing natural draft appliances with sealed combustion, induced draft, or power-vented equipment. These types of appliances are significantly more energy efficient than natural draft appliances. If replacing equipment is not feasible, draft inducer retrofit kits can provide fail-safe forced-draft performance for some types of combustion appliances. While this can address the combustion safety, adding forced-draft operation alone is unlikely to have a significant impact on energy performance.

Gas stoves and cook tops must be equipped with a range hood that is ducted to the outside.

Solid fuel-burning stoves (e.g. wood stoves and pellet stoves) if not equipped with a fail-safe draft inducer, must have a tight fitting loading door (and no permanent openings or leaks into the firebox or flue) and outdoor combustion air ducted to the firebox.

Solid fuel-burning hearth fireplaces require special treatment to be acceptable in a DER home. The following minimum measures are recommended for fireplaces:

1. Flue liner in good condition (flue liner may need to be repaired or a flue liner may need to be installed in older chimneys).
2. Air tight hearth doors.
3. Outdoor combustion air ducted to firebox.
4. Operable flue damper.

If the house has combustion appliances of any kind, carbon monoxide alarms complying with UL 2034 are required in close proximity to the combustion appliances and outside each separate sleeping area in the immediate vicinity of the bedrooms.[1]

1. The combustion safety measures related to carbon monoxide alarms presented in this guide extend beyond the 2012 IRC by indicating alarms not just outside each separate

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VENTILATION

Mechanical ventilation is an essential feature of high performance homes. Ventilation is needed for source control at the location of contaminant sources (e.g. kitchens, bathrooms, craft areas) as well as for distribution of fresh air and dilution of general contaminants. The distribution of fresh air and dilution of general contaminant is referred to as "background" or "whole-house" ventilation.

The 2012 International Residential Code (2012 IRC) provides code minimum requirements for ventilation systems including the ventilation rate capacity for both background/whole house ventilation and source control ventilation. This guide aims to provide additional guidance toward meeting the high performance objectives of DER projects.

Source Control Ventilation

Controlling contaminants at the source is the most effective means to control contaminants in a home. Source control ventilation systems are exhaust systems that are located near a fixed contaminant source (or fixed contaminant source location) and vented directly to the outdoors. There can be a number of different areas in a home that represent a need for source control ventilation. This guide addresses those areas requiring source control that are common to all homes: kitchens and bath/toilet rooms.

Bathroom exhaust

Exhaust ventilation in bathrooms is needed to control odors and excess humidity. The bathroom exhaust system typically benefits from a door that can be closed to help contain indoor contaminants and make the exhaust ventilation more effective. A bathroom exhaust ventilation system that is operated intermittently (e.g. by a manual switch or humidity control) must have a capacity to exhaust at a rate of at least 50 cfm. Where the exhaust system is operated manually, it is a good idea to use a delay-off switch or crank timer to operate the bathroom exhaust system for a set period of time after use without having the system run continuously.

A bathroom exhaust may also be provided by a ventilation system that operates continuously. The minimum acceptable exhaust rate for a continuously operating system is 20 cfm. However, this ventilation rate is not likely to prevent fogging of mirrors or to rapidly clear steam and odors from a bathroom.

Kitchen exhaust

Cooking releases volatile compounds into the air. Cooking is also a source of moisture. Gas cooking appliances produce large amounts of moisture and

continued

sleeping area in the immediate vicinity of the bedrooms but also in the vicinity of the combustion appliance. The IRC also references "fuel-fired appliances" whereas this guide indicates carbon monoxide alarm requirements relative to any combustion appliance.

carbon dioxide and can also contribute other products of combustion. On occasion, cooking – even by experienced cooks or bakers – will produce smoke. Source control exhaust ventilation in a kitchen is needed to control these contaminants. The kitchen exhaust can also benefit the indoor environment and energy performance of the home during cooling periods by reducing the amount of heat that cooking contributes to the interior.

To be effective, the source control exhaust should be conducted through a capture hood located as close as feasible to the cooking surface – closer to the cooking surface provides better capture of contaminants but too close detracts from the usability of the cooking surface. The minimum acceptable ventilation rate capacity of a kitchen exhaust system is 100 cfm.

The Home Ventilating Institute (HVI) recommends 100 cfm for per lineal foot of cooktop for wall-mounted hoods and 150 cfm per lineal foot of cooktop for island hoods. HVI recommends additional capacity for gas cook tops based on capacity of the burners. While higher exhaust rates can improve source control, one should also consider the energy and make-up air implications of higher exhaust rates. For example, the 2012 IRC requires makeup air for exhaust hood systems capable of exhausting in excess of 400 cfm.

Background or Whole-house Ventilation

Background or whole-house ventilation is needed to provide distribution of fresh air as well as dilution of general contaminants. General contaminants, in this context, are those that derive from things that are widespread, such as building finishes and furnishings, or that move, such as people and pets. The keys to effective background/whole house ventilation are adequate capacity, appropriate control, and effective distribution.

The required ventilation rate capacity indicated in the 2012 IRC for background/whole house ventilation is determined from the number of bedrooms and the conditioned floor area of the dwelling unit (i.e. home or apartment). The relevant table in the 2012 IRC is derived from the following formula:

$$Q = (N_{br}+1) \times 7.5 + 0.01 \times FA$$

Where

Q = the continuous ventilation rate in cubic feet per minute (cfm),

N_{br} = the number of bedrooms, and

FA = the conditioned floor area in square feet (sf).

While the IRC addresses the design capacity of the ventilation system, it does not dictate how the system is operated. BSC recommends that background/whole house ventilation systems be designed and installed to provide a ventilation capacity that is 125-200% of the ventilation rate given by the formula above and that the controls of the ventilation system allow it to be operated at a lower rate most of the time. BSC's experience has shown that satisfactory indoor air quality and moisture control is typically achieved with a background/whole house ventilation rate that is 30-60% of the rate given by the formula above. Certain situations, however, such as large gatherings, cooking mishaps, installation of new furnishings, hockey players returning from practice, etc. may require much higher ventilation rates on a temporary basis.

Operating the ventilation system at a rate that is too low is typically noticeable to occupants by signs such as condensation on windows, accumulation of odors, or feeling of "stuffiness". Operating the ventilation system at a higher rate than needed wastes energy and can lead to undesirable decrease or increase in indoor humidity. In many cases, however, excessive ventilation may not be noticeable—except on energy bills. The controls for the ventilation system should allow residents to operate the system at a lower rate when the lower rate is adequate and also to boost the ventilation rate on a temporary basis when a higher rate of ventilation is needed.

Another critical parameter of the ventilation system that the IRC does not address is distribution. A single point exhaust or supply ventilation system may provide adequate distribution of fresh air in a smaller home with a compact and open floor plan and where doors are left open. In most residential situations, some form of ventilation distribution is needed. Dedicated ventilation ductwork can ensure effective distribution of the ventilation air and provide a measure of air mixing with operation of the ventilation system. Mixing of interior air is also important for comfort and temperature uniformity. Periodic mixing of the interior air allows the conditioning systems (i.e. heating, cooling, dehumidification, filtration) of the home to better condition the interior air. The distribution and air mixing can be achieved by a separate system such as a ducted forced-air heating/cooling system in which the air handler fan is periodically cycled on. A ventilation system may also be integrated with a ducted central heating/cooling system to use the central system fan and ductwork to provide distribution of ventilation air and mixing of the interior air.

Ventilation System Schematics

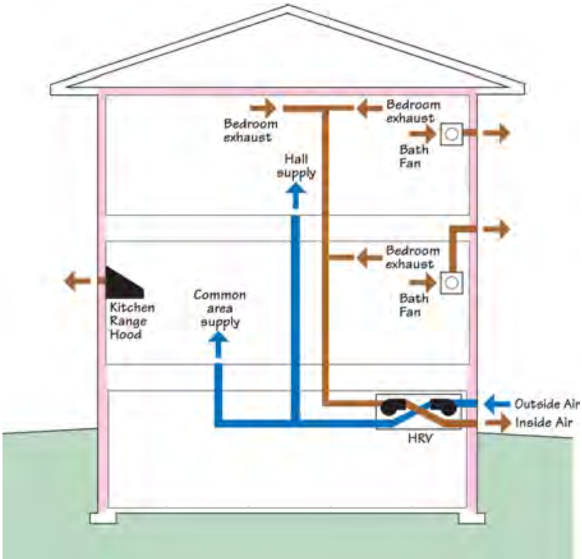
On the following pages are schematic descriptions of four ventilation system configurations that can provide effective ventilation in DER homes. These configurations are designated as:

- **Ventilation System 1** – balanced heat recovery or energy recovery ventilation with dedicated ductwork
- **Ventilation System 2** – balanced heat recovery or energy recovery ventilation integrated with forced-air heating and cooling.
- **Ventilation System 3** – supply ventilation integrated with the central fan of a forced-air heating and/or cooling system. This is also called central-fan-integrated supply ventilation or CFIS ventilation.
- **Ventilation System 4** – non-distributed exhaust-only or balanced ventilation.

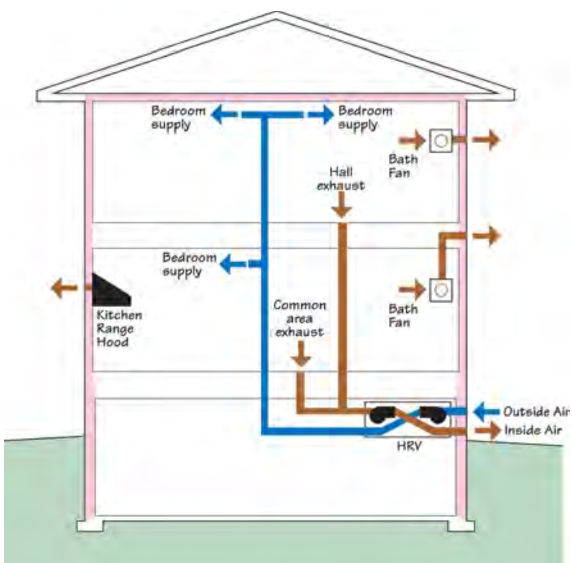
Ventilation System 1: Balanced heat/energy recovery ventilation with dedicated ductwork

This system consists of heat- or energy recovery ventilation equipment with dedicated ventilation distribution ductwork. Two variations of this system are defined by the direction of ventilation with respect to the bedrooms. Ventilation System 1a locates ventilation air returns (stale air pick-up) in bedrooms. Ventilation System 1b locates ventilation air supply registers in bedrooms.

Required Attributes	Outside air intake through side wall, above expected snow depth and away from contaminant sources (see *BSC Info Sheet 606: Placement of Intake and Exhaust Vents* available from www.buildingscience.com). Controls: timer for intermittent operation if system does not otherwise allow user to adjust between IRC background/whole house ventilation rates and lesser ventilation rates. Minimum 60% sensible recovery.
Recommended Attributes	High efficiency fan motors in HRV/ERV unit. Separate bathroom exhaust.
Performance Verification	Measure and record the ventilation airflow through the outdoor air duct. Compare to within the lesser of +/- 10% or 10 cfm of the design airflow.
Advantages	Uses known and controlled source of ventilation air. Provides ventilation distribution and air mixing. Heat/energy recovery on background/whole house ventilation. Operation is independent of heating/cooling system. Opportunity for filtration of ventilation air (depending upon HRV/ERV unit).
Disadvantages/ Challenges	Higher installation cost. May be difficult to locate distribution ductwork in retrofit situation.
Additional Considerations	Some HRV/ERV units use significant electrical energy to recover a modest amount of thermal energy. Total system fan efficacy is important criteria in selection of HRV/ERV equipment. Good total system fan efficacy is < 1 Watt per cfm. Better total system fan efficacy is <0.5 Watt per cfm. HRV/ERV units require a modest amount of maintenance to keep intake and exhaust grilles clear (interior and exterior) and to periodically change the filters. Avoid comfort problems: ensure that ventilation air is not directed to beds or other locations where occupants are likely to be sedentary. An HRV/ERV will temper the ventilation air but even well tempered ventilation supply airflow will be perceived as a cool draft to a stationary person. An ERV should not be used to provide source control exhaust for bathrooms because the ERV will be less effective at removing moisture. By design, the ERV recovers moisture from the exhaust stream.



Ventilation System 1a: balanced heat recovery ventilation system with dedicated ductwork and ventilation air returns located in bedrooms



Ventilation System 1b: balanced heat recovery ventilation system with dedicated ductwork and ventilation supplies located in bedrooms

Ventilation System 2: Balanced heat/energy recovery ventilation integrated with forced-air heating and cooling

This system employs a heat- or energy recovery unit that is connected to the ductwork of a ducted forced-air central heating/cooling system. This system is only applicable to situations where there is a ducted forced-air central heating/cooling system. Two variations of this approach are defined by whether the ventilation system is connected to both the supply and return plenum of the central heating/cooling system – Ventilation System 2a – or whether the ventilation system is connected to the return plenum only – Ventilation System 2b.

Required Attributes	Outside air intake through side wall, above expected snow depth and away from contaminant sources (see *BSC Info Sheet 606: Placement of Intake and Exhaust Vents* available from www.buildingscience.com). Motorized dampers or backdraft dampers between HRV/ERV and central system supply/return plenum that close the connection to the outside when the ventilation fan is off. Controls: timer for intermittent operation if system does not otherwise allow user to adjust between IRC background/whole house ventilation rates and lesser ventilation rates. Minimum 60% sensible recovery. ***Ventilation System 2a:*** Interlock control to operate air handler with HRV/ERV. Separate bathroom exhaust.
Recommended Attributes	High efficiency fan motors in HRV/ERV unit and central air handler. Controls: ventilation control, timer to coordinate HRV/ERV operation with air handler heating/cooling operation in order to achieve full distribution with minimal fan energy. ***Ventilation System 2b:*** Separate bathroom exhaust.
Performance Verification	Measure and record the ventilation airflow through the outdoor air duct. Compare to within the lesser of +/- 10% or 10 cfm of the design airflow.
Advantages	Uses known and controlled source of ventilation air. Provides ventilation distribution and air mixing when operation is coordinated with central air handler operation. Heat/energy recovery on background/whole house ventilation. Opportunity for filtration of ventilation air (depending upon HRV/ERV unit). Operation is independent of source control exhaust (applies to Ventilation System 2a, may also apply to 2b).

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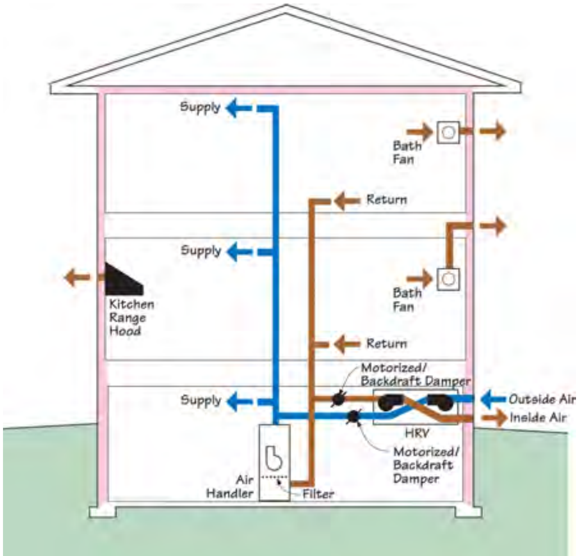
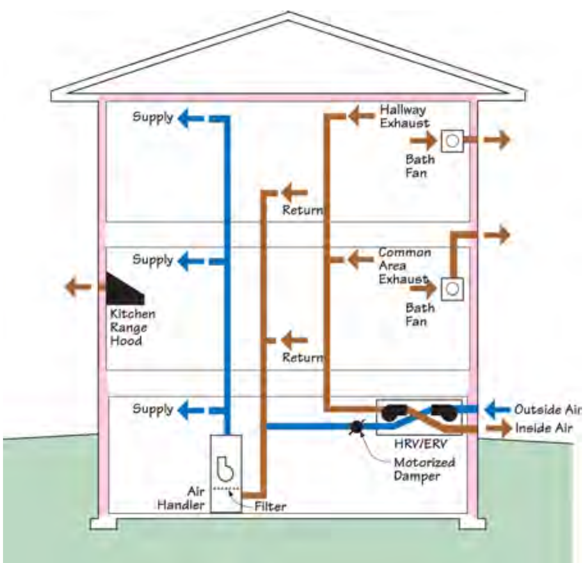


Ventilation System 2a: balanced heat recovery ventilation integrated with forced-air heating and cooling distribution ductwork



Ventilation System 2b: balanced heat recovery ventilation semi-integrated with forced-air heating and cooling supply distribution ductwork

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Disadvantages/ Challenges	Higher installation cost. May result in higher electrical energy use for ventilation due to the need to use the HRV/ERV and central air handler fans for distribution. Ventilation System 2a requires interlock with air handler unit fan to provide distribution. Because the HRV/ERV provides connections between the pressurized/depressurized heating and cooling ductwork, tight closing dampers are needed to prevent the HRV/ERV from acting as gross duct leakage.
Additional Considerations	Some HRV/ERV units use significant electrical energy to recover a modest amount of thermal energy. Total system fan efficacy is important criteria in selection of HRV/ERV equipment. Good total system fan efficacy is < 1 Watt per cfm. Better total system fan efficacy is <0.5 Watt per cfm. HRV/ERV units require a modest amount of maintenance to keep intake and exhaust grilles clear (interior and exterior) and to periodically change the filters. Avoid comfort problems: ensure that ventilation air is not directed to beds or other locations where occupants are likely to be sedentary. Even room temperature airflow could be perceived as a cool draft. An HRV/ERV will temper the ventilation air but the tempered ventilation air will be cooler than room air in cold weather. An ERV should not be used to provide source control exhaust for bathrooms because the ERV will be less effective at removing moisture. By design, the ERV recovers moisture from the exhaust stream.

Ventilation System 3: Central Fan-Integraged Supply (CFIS) Ventilation

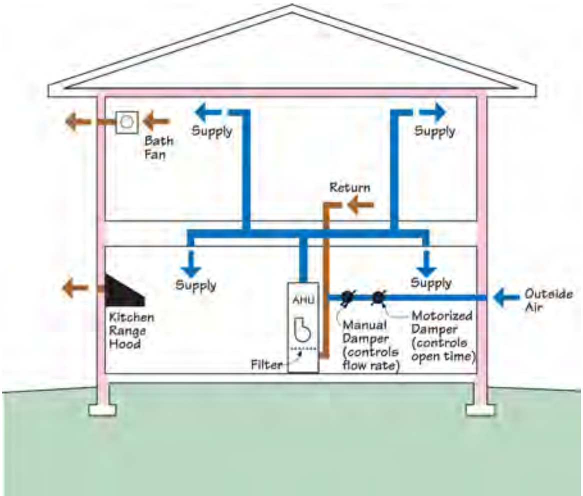
This system uses an outdoor air duct, a motorized damper and supplemental air handler fan control to provide and distribute a controlled amount of ventilation through the ductwork of a ducted forced-air central heating/cooling system. This ventilation system is only applicable to situations where there is a ducted forced-air central heating/cooling system. For additional description of this ventilation system see *BSC Information Sheet 610: Central Fan Integrated Ventilation Systems* available from www.buildingscience.com.

Required Attributes	6" diameter (min.) insulated outdoor air duct connected to return plenum not closer than 3 feet to the air handler unit inlet. There should be no take-off or branch on the return between the outdoor air duct connection and the air handler unit inlet. Outside air intake through side wall, above expected snow depth and away from contaminant sources (see *BSC Info Sheet 606: Placement of Intake and Exhaust Vents* available from www.buildingscience.com) Fan cycling control to operate the air handler fan a programmed minimum amount of time as determined by the desired ventilation rate and the rate of intake through the outdoor air duct. Motorized damper in outdoor air duct controlled by the fan cycling control to close the damper and prevent over ventilation of the house during times of significant space conditioning demands. Balancing damper in outdoor air duct between motorized damper and connection to return plenum to allow adjustment of ventilation airflow rate.
Recommended Attributes	High efficiency central air handler fan motor.
Performance Verification	Measure and record the ventilation airflow through the outdoor air duct with the air handler operating at both heating and cooling speeds. Compare to within the lesser of +/- 10% or 10 cfm of the design airflow.
Advantages	Uses known and controlled source of ventilation air. Provides ventilation distribution and air mixing. System operation is independent of source control exhaust. Opportunity for filtration of ventilation air. Relatively low installed cost.
Disadvantages/ Challenges	In low load homes, CFIS may result in higher electrical energy use for ventilation due to operation of central air handler fan for distribution.

continued

continued

Additional Considerations	Outdoor air should not exceed 15% of total air handler return air flow. Outside air duct should be positioned so that there is a fall/slope toward the outside to drain any potential condensation due to blown snow. CFIS controls may not be compatible with HVAC equipment that uses proprietary wiring such as in many mini-split systems. Avoid comfort problems: ensure that supply registers do not direct air to beds or other locations where occupants are likely to be sedentary. Even room temperature airflow could be perceived as a cool draft. Ventilation air from the CFIS is tempered with air handler return air but the mixed air will be cooler than room air in cold weather.



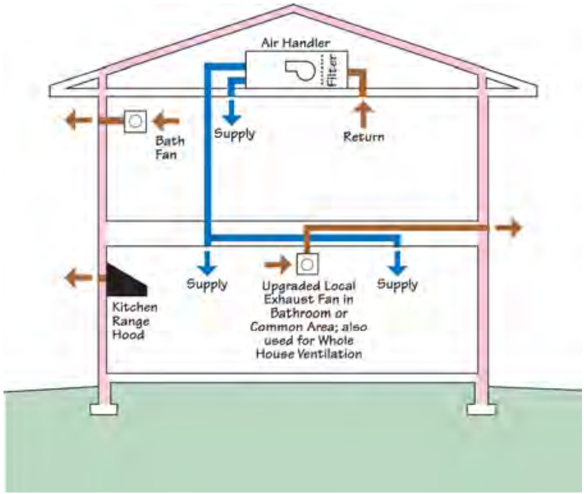
Ventilation System 3: Central Fan-Integrated Supply (CFIS) Ventilation

Outdoor air inlet

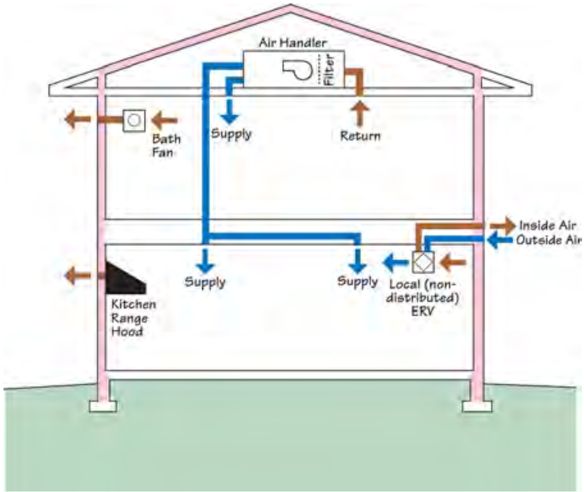
Ventilation System 4: Non-distributed exhaust-only or balanced ventilation

This system uses either exhaust-only ventilation (Ventilation System 4a) or balanced ventilation (Ventilation System 4b) with a single point distribution. These configurations are appropriate only in situations where either 1) the floor plan is open and compact and interior doors between rooms are seldom closed, or 2) there is a ducted heating/cooling system with an air handler fan that can be cycled to provide ventilation air distribution.

Required Attributes	Fan control to operate ventilation fan as needed to achieve desired ventilation rate. Manual override for operation of ventilation fan. Compact and open floor plan **OR** ducted forced-air heating or cooling system with fan cycling control on central air handler. ***Ventilation System 4a:*** **Use of this system requires monitoring for radon. Implementation of soil gas venting is strongly recommended if this ventilation system is employed.** ***Ventilation System 4b:*** Outside air intake through side wall, above expected snow depth and away from contaminant sources (see *BSC Info Sheet 606: Placement of Intake and Exhaust Vents* available from www.buildingscience.com). Supply or return grille must be located in non-enclosed central space.
Recommended Attributes	Fan cycling control for central air handler to provide ventilation air distribution: 50-70% recirculation turnover, or cycle central fan on for at least 10 minutes per hour.
Performance Verification	Measure and record the ventilation airflow through the exhaust grille (Ventilation System 4a) or outdoor air duct (Ventilation System 4b). Compare to within the lesser of +/- 10% or 10 cfm of the design airflow.
Advantages	Low installed cost.
Disadvantages/ Challenges	Source of ventilation air is unknown and uncontrolled (Ventilation System 4a). System does not provide air mixing or distribution of ventilation air. May result in higher electrical energy use for ventilation due to operation of central air handler fan for distribution.
Additional Considerations	Exhaust air duct should be positioned so that there is a fall/slope toward the outside to drain any potential condensation. External fan cycling controls may not be compatible with HVAC equipment that uses proprietary wiring such as the case with many mini-split systems. ***Ventilation System 4a:*** If exhaust fan is located in a bathroom/toilet room, the door should be left open when the room is not in use. Special attention to prevent problems such as intake of soil gases (see Soil Gas Control below) or intake of air from an attached garage.



Ventilation System 4a: Exhaust-only single point ventilation system



Ventilation System 4b: Non-distributed heat recovery ventilation system

SOIL GAS CONTROL

Prior to any DER project, measures must be taken to prevent entry of soil gases into the home. Radon is a soil gas with significant and well-documented health risks. Air moving through soil also carries significant moisture and may carry other contaminants such as mold spores, herbicides, pesticides, methane, etc.

As a minimum soil gas control measure, cracks and holes in the foundation walls and basement slab must be sealed. Because of the need for soil gas control, it is important that any penetrations made through ground-contact assemblies (slabs and foundation walls) are sealed. Sump pits must have airtight and gasketed covers.

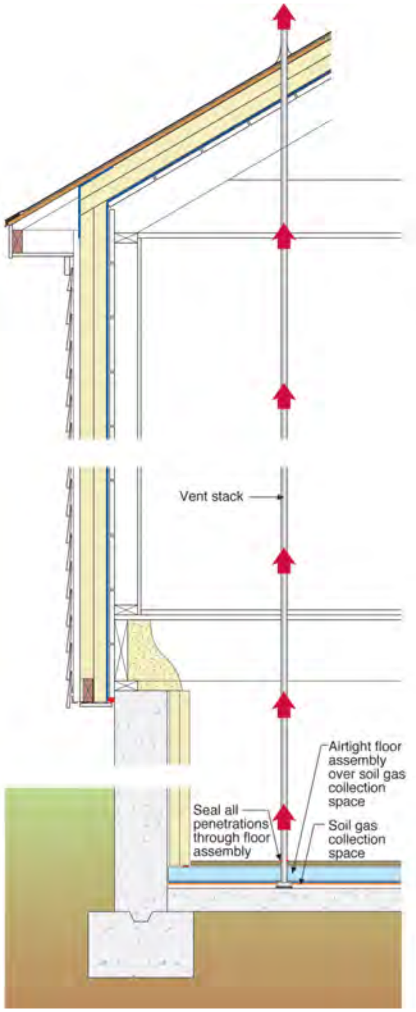
Implementation of a soil gas venting system is *strongly recommended*. Any significant work to the roof or basement/crawlspace provides an opportunity to establish such a system.

A soil gas venting system essentially provides the soil gas with an express lane bypass to the outside so that it does not move through the indoor living space. If needed, a fan can be added to the vent pipe to actively move soil gases from beneath the basement floor to the outside.

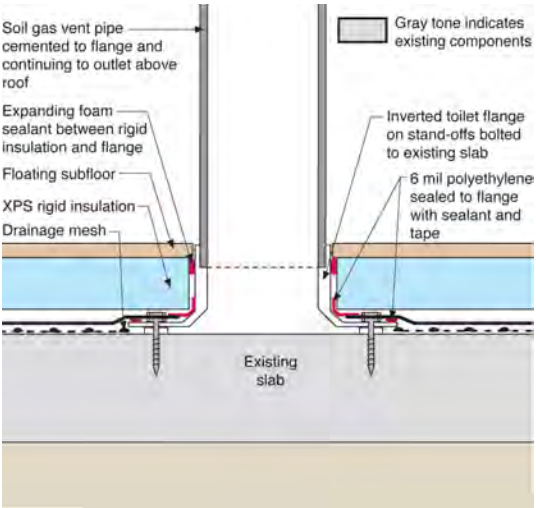
Soil gas venting system

A retrofit soil gas venting system works as follows:

- A soil gas collection space is established. This can be
  - o a drainage space created by a dimple mat or drainage mesh above an existing slab, or
  - o a sump pit connected to gravelly or sandy soil below an existing slab.
- The soil gas collection space must be thoroughly air sealed from the living space.
- The soil gas collection space is passively depressurized by passive stack action of a warm vent stack located inside heated space for as great a vertical distance as practical.
- The vent stack extends from the soil gas collection space to an outlet at the roof with as few offsets and elbows as possible. Avoid 90-degree elbows. Sweeps are preferred if turns are needed.
- The vent stack extends through the roof at least 2 feet above the roof. A screened rain cap is provided at the termination to prevent rain entry or the obstruction of the outlet by nesting animals.
- If the vent stack extends through an unconditioned attic, insulate the stack in this space to control condensation inside the pipe.



Soil gas vent stack



Soil gas vent connection to a collection space created by a drainage mesh under polyethylene above an existing slab

For additional information on soil gas control consult *Build Radon Out* produced by the US EPA and available for download at http://www.epa.gov/radon/pubs/#index4.

BUILDING ENCLOSURE FUNCTIONS

INTRODUCTION

Requirements of the enclosure do not change between retrofit and new construction. In both cases, the building enclosure must perform four critical control functions:

- Water control
- Air control
- Vapor control
- Thermal control

High performance building enclosures perform these control functions exceptionally well.

The order of these enclosure control functions is important. Water represents a very destructive force for buildings and is also the cause of many indoor air quality problems. If water is not controlled, the other control functions become irrelevant.

Air control is critical because if we want to condition the indoor air, we first need to contain it. Airflow is a very effective way to move heat energy and moisture. It does not make much sense to worry about heat loss through conduction if we don't have a good handle on airflow. Similarly, since airflow through a small hole can move much more moisture than can diffuse through a large surface area of material, air must be controlled to avoid the moisture problems we might otherwise associate with water vapor.

It is important to control water vapor because at temperatures colder than the dew point, water vapor can condense into water or ice leading to damage, mold or decay. Elevated humidity (water vapor pressure) can also create conditions favorable to mold growth and other decay/contaminant vectors. We must control water vapor to avoid conditions of elevated humidity in the interior environment or within walls, roofs, and floors.

Once we have an enclosure that controls water and air and manages water vapor, then and only then does it makes sense to focus on reducing the conductive heat flow through the use of insulation.

Another control function that applies to some parts of the building enclosure is:

- Critter control

Animal pests can represent a risk to life safety and to durability of the structure (e.g. by degrading structural elements or corrupting the safety measures in the electrical system). Pests can also represent contaminant vectors that impact the health of people. Pests can cause bypasses in the enclosure control functions (e.g. nesting in cavities created by removing insulation). In many ways, critters can be a real nuisance for a building and its human occupants. There are certain elements of the building enclosure that are more vulnerable to damage from animal pests or that represent access points.

Understanding these control functions is essential for the successful design and implementation of high performance retrofit. It is also useful to know that existing low performance homes may be able to get away with performing some of these control functions poorly. Or, problems related to poor control functions might be masked by other issues in the building. In high performance, there is less room for error.

A brief discussion of each of the control functions is provided below. A visual key and labels are used to identify these control functions in the illustrations throughout Part 2 of this guide.

WATER CONTROL

Controlling rain and ground water are the most important factors in the design, construction and retrofit of durable buildings and in the control of mold.

Rain Water

Water that comes from the sky – in the form of rain or snow – is something that every building must control. In wood frame construction the rain water control system typically consists of a rain-shedding layer, which we call cladding, and then, behind the cladding, a water control layer (or layers) that prevents water that passes through the cladding layer from penetrating further into the assembly. Water that collects on the water control layer – sometimes called "drainage plane" – is drained by gravity and conveyed back to the exterior by flashings.[2] In addition to an effective water control layer or drainage plane, drainage from the assembly also requires a drainage space. Together, the water shedding layer, the water control layer, the flashings and the drainage space constitute the water control system (WCS).

The concept of water control and drainage applies to assemblies such as walls,

2. It is a safe bet that some amount of water will penetrate the cladding. Therefore, it is wise to plan for this with properly lapped and flashed water control layers. Attempting in wood frame construction to construct a barrier system where water is controlled at the surface of the cladding for the life of the building is ill advised given that the underlying structure will move (due to thermal and moisture cycling as well as creep) and that the underlying structure is fundamentally moisture sensitive.

roofs and foundations. The concept applies to the components that can be found in walls, roofs and foundations such as windows, doors and skylights. It also applies to the openings for the windows, doors and skylights. And it applies to assemblies that connect to walls, roofs and foundations such as balconies, decks, railings and dormers. Finally, drainage also applies to the building as a whole. Overhangs can be used to drain water away from walls. Canopies can be used to drain water away from windows, and site grading can be used to drain water away from foundation perimeters.

Knowing where the water control layer is in a particular assembly, component or building element is essential to maintaining continuous water control from one building element to the next. For example, understanding where to locate step flashing at a roof-to-wall intersection requires understanding the location of the water control layer in the wall assembly. In this guide, illustrations of retrofit details indicate the location of the water control layer in order to reinforce the awareness of the water control layer and demonstrate how the connections are made.

A word about project scope relative to water control:

Anyone undertaking retrofit of an existing home should be aware that good practice details are not necessarily common practice. For example, roofs can concentrate water where roofs intersect walls, yet kick-out flashings – flashings that direct or "kick" the concentrated water away from the wall – are very frequently absent. In many older structures, a continuous wood, cast stone, or stone sill serves as a flashing to direct water out of the window opening and out over the wall assembly. More modern windows, however, are seldom installed with pan flashing or, even proper head and jamb flashing. Other water management elements that may have been properly implemented initially, can fail over time and when these systems fail they can represent a significant moisture risk. For example, gutters with leaking joints, missing end caps or broken rain leaders can concentrate water on vulnerable assemblies. When evaluating the measures to be implemented on a project, it is important to include remediation of any failures or lapses in the water control system even if these are outside of the planned area of DER work..

A word about materials:

In order to control liquid water and effectively convey it back to the exterior, water control layers and flashing must be 1) properly lapped, 2) comprised of non-moisture sensitive materials, and 3) comprised of non-water absorptive or non-capillary materials.

Builders today have adhered flashing membranes that can facilitate robust water control and flashing. Modern "self-sealing" membranes can accommodate fastener penetrations without losing the water control function. An important consideration when using any type of peel-and-stick bituminous or butyl or self-sealing membrane is that these do not eliminate the need for proper lapping at the water control layer. Through thermal cycling, edges of these membranes tend to curl away from the substrate. This is generally not a problem on downward facing or vertical edges of adhered water control membranes. However, at the upward facing edges, this curl can create a lip that retains water in the assembly and concentrates water on moisture sensitive elements. It can also be difficult – or nearly impossible – to install a self-adhered sheet membrane without wrinkles. Wrinkles at the edge of a flashing membrane can act like tiny scoops that catch water and channel it to where it is not wanted. To manage these issues inherent with peel-and-stick membranes, ALL upward facing edges of bituminous or butyl membranes used in the water control system should be either lapped by another water control membrane or taped to the underlying water control layer with a reliable and compatible sheathing tape.

When using sheathing tapes to tape seams of insulating sheathing in order to create the water control layer, the tapes must be at least 2½" wide and must be recommended by the manufacturer for use with foam sheathings (or foil facings as the case may be). At horizontal seams, the tape should not be centered on the seam. Rather, the tape should be positioned so that about $^{2}/_{3}$ of the width is adhered to the upper piece of sheathing and about $^{1}/_{3}$ of the width is over the lower piece.

Ground Water

Ground water is the other important exterior source of water that the building must manage. Water in saturated soil against a foundation wall can be wicked to the building interior or to moisture sensitive framing elements through capillary action. Surface water or water below the surface near a building can work its way into a building through cracks or voids in the foundation. Because water is lazy, it will follow the path of least resistance as it flows down. Therefore, if water is present in the soil around the building and if the path of least resistance is through the basement, the basement will get wet. A water table that rises above the basement slab creates hydrostatic pressure on the slab and foundation. This pressure will force water through cracks and holes. It may also exert structural stresses on the slab and foundation.

The best techniques to manage groundwater include the following:

- Build the building with the foundation above the water table.
- Slope the grade away from the building on all sides with a slope of 5% or more for a distance of at least 10' from the building.
- Provide a capillary break such as damp proofing, washed course gravel, or heavy-duty polyethylene between the foundation and ground and between the slab and ground. The capillary break should be beneath the foundation wall as well as on the face of it.
- Provide free-draining back fill around the foundation and a perimeter foundation drain that drains to daylight, to a drywell or to a sump.

Retrofit situations seldom present opportunities to implement these techniques. The retrofit, therefore, must make the most of opportunities presented by the existing situation. Rather than trying to resist water penetration through foundation walls and slabs, the primary water control strategy for interior retrofit of foundation walls and slabs is to anticipate water penetrating through the foundation and provide a means to direct it to drains.[3] It may also be possible in retrofit to relieve water pressure on foundation walls and slabs by installing an interior foundation drain below the level of the slab.

Water wicking through the basement slab can be controlled by using a coating on top of the slab – such as an epoxy paint – or by creating a drainage space and capillary break above the slab – such as by installing a well sealed, high-density polyethylene dimple mat above the slab.

Special Consideration: Protecting the framing sill from capillary moisture

Controlling water that wicks from the soil through the foundation wall can be more complicated. The major complicating factor is that water sensitive materials – in the form of a structural wood frame – are typically sitting on top of the foundation wall. Measures to control liquid water and insulate the foundation wall at the interior side also reduce the ability of water to dry from the foundation to the interior. This increases the likelihood that water will be wicked further up the foundation wall to where it could impact the framing. In new construction, placing a capillary break – such as sheet metal or a bituminous membrane – between the foundation wall and the wood framing effectively protects the wood framing from water that is wicked through the foundation. This happens to be the best approach, in terms of robust water control, for retrofit as well.

Capillary breaks have been successfully installed between foundation walls and framing sills in existing buildings. This is done by jacking the frame – working a small section at a time – just enough to slide an ice and water membrane or sheet metal capillary break between the foundation wall and framing.

Whether inserting a capillary break at the top of the foundation wall is necessary is a matter of judgment. It depends on an evaluation of the risk factors, the sensitivity of the structure, and the risk tolerance of the building owner or stakeholders.

Risk factors pertinent to water wicking through the foundation to the structure include the following:

1. **The foundation wall is constructed of capillary (wicking) materials.** Brick and concrete are capillary materials. Mortar and grout are capillary materials. Some stones are capillary materials. Igneous stone, like granite, is not a capillary material but one should be wary of foundation walls with granite facers and rubble or brick infill.
2. **Liquid water is in contact with the foundation wall.** No water, no wicking problems. Liquid water can be in contact with the foundation wall if the water table is above the bottom of the foundation, if the soil adjacent to the foundation is saturated (not well drained), if surface

3. Resisting water penetration can increase the hydrostatic pressure on the foundation and thus increase structural stresses.

Lifting a sill to insert a capillary break

Note that some of the sill pictured here had deteriorated and needed to be replaced. Assessing the condition of the sill and making repairs where needed is something that must be done prior to retrofitting the frame wall or foundation wall. Any sill that is replaced must be provided with a capillary break between the sill and the foundation wall.

water is not drained away from the foundation, or if the exposed part of the foundation wall is subject to splash-back from roof drainage, for example.

3. **Water vapor condensing in or on the foundation wall.** This is a variation of the second risk factor. It occurs when moist interior air is allowed to contact cold foundation surfaces or when foundations are insulated with vapor permeable insulations.
4. **Limited drying of the foundation wall.** Generally speaking, foundations do not dry into the ground but they can dry into the air. If the exposed exterior surface of the foundation wall above grade is less than 1½ times the thickness of the foundation wall, then the drying of the foundation wall is limited. The drying of the foundation wall would also be limited if vapor impermeable coatings or coverings are applied to the above-grade portion of the foundation wall.

Where insertion of a capillary break is not feasible and risk factors are moderate, framing resting on the foundation should be insulated in a way that promotes drying to the exterior. If water can dry from the framing at a faster rate than water is wicked to the framing, then moisture will not accumulate. Part 2 of this guide, contains special case details that show insulation at the base of a frame wall in a manner that promotes drying of the framing sill (see "Special Case: Provide Drying for Framing Sill" in the Exterior Frame Wall-to-Foundation Wall Transitions section).

Special Consideration: Protecting brick foundations from freeze-thaw damage

Brick foundation walls present a special consideration for retrofit. Some older bricks – but not all – can be susceptible to freeze-thaw damage if exposed to excessive water and cycles of freezing temperatures. Foundation walls are typically subject to wetting from the sources discussed above. In existing pre-retrofit homes, uninsulated brick foundation walls are typically protected from freeze-thaw damage by heat from the building or by waste heat given off by inefficient heating systems.[4] When the heating system is replaced with a more efficient system or when the foundation wall is insulated to the interior, the foundation wall becomes colder. This may increase the risk of freeze-thaw damage for brick foundation walls. The risk is only increased if water wets the brick. Whether the brick foundation wall will develop freeze-thaw damage is determined by how wet the brick gets. Control the water and you control the risk.

The following minimum measures are recommended to protect brick foundation walls from water:

- Slope grade away from foundation walls to prevent surface water from wetting the brick.
- Provide overhangs to prevent rain from falling on wall surfaces.
- Provide and maintain gutters and rain leaders to direct water away from building or provide a drip trench of gravel and surface drain at grade to reduce splash back and convey water away from the foundation.[5]

Additional measures to prevent water from soaking the brick should also be considered. These include:

- Provide free-draining back fill and a sub-surface drain to the exterior of brick foundation walls.
- Provide a capillary break – e.g. damp proofing, dimple mat, or gravel wrapped in filter fabric – between below-grade brick and wet soil.
- Paint the above-grade brick with latex paint to prevent the brick from soaking up water from its surface but still allow some drying from the brick.

It is far better to manage the freeze-thaw risk by keeping the brick from getting wet than to attempt to manage the risk by keeping the brick warm with lack of insulation or wasteful heating systems.

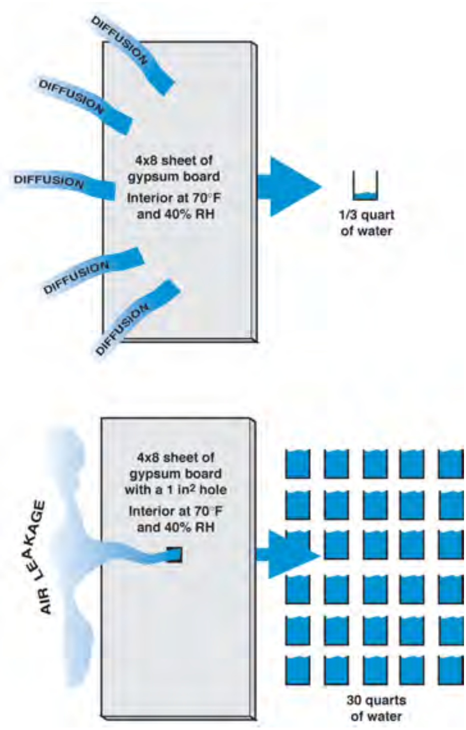
4. Older homes with steam heating systems and steam boilers in the basement often appear to have a snow melt system around the perimeter of the building.

5. Gutter and rain leader systems that are not maintained can actually be much more detrimental to a building than having no gutters and rain leaders. This is because malfunctioning gutters or rain leaders can concentrate water on the building. Surface drains and drip trenches also require some periodic maintenance to maintain function.

AIR CONTROL

Controlling the flow of air into and out of a building enclosure is essential to reducing the heating and cooling load within the enclosure. It is generally understood that air leaking out of a building takes a lot of the heating and cooling energy with it and that drafts into a building can be a significant detriment to comfort.

It is also important to control airflows in order to control the entry of airborne contaminants – some of which have critical impact on health and safety – into the living space. For example, airflow control between an attached garage and living space is needed to prevent the migration of carbon monoxide (CO) – a deadly odorless gas – from the garage into the living space. In multi-unit buildings, air flow control is needed to prevent cross-contamination or the movement of airborne contaminants (e.g. tobacco smoke, cleaning products) and odors between dwelling units as well as between dwelling units and other



Diffusion versus Air Leakage

Over the course of a heating season in most cold climates and under normal operating conditions, air leaking through a 1 in^2 hole moves much more moisture than is moved by diffusion through a 4x8 sheet of gypsum wall board.

spaces in the building. The ground on which buildings are built can be a source of radon and other undesirable soil gases. The building enclosure must resist penetration of these soil gases through the foundation and slab.

Airflow control is also important to building durability. Significant amounts of moisture can be carried by air moving into or out of the building. Dr. Joseph Lstiburek has written "Air movement as a moisture transport mechanism is typically far more important than vapor diffusion in many (but not all) conditions. The movement of water vapor through a 1-inch square hole as a result of a 10 Pascal air pressure differential is 100 times greater than the movement of water vapor as a result of vapor diffusion through a 32-square-foot sheet of gypsum board under normal heating or cooling conditions." This movement of moisture by airflow can lead to elevated humidity or condensation on moisture sensitive materials.

Airflow into and out of the building is governed by the airtightness of the building enclosure and pressure relationships. The ability to control pressure relationships depends on the airtightness of the building enclosure. Airtightness of the building enclosure is provided by the air control system (ACS). The ACS is comprised of materials and building components that are designed and constructed to provide a durable and uninterrupted separation between the air in the living space and air outside of the living space: between inside and outside; between inside and an attached garage; between inside and the ground; and, in the case of multi-unit buildings, between individual dwelling units and other units, common spaces, service shafts, etc.

In order to provide the needed function, materials and components comprising the ACS must be:

- Air impermeable,
- Able to withstand forces that will act on them during construction/renovation and in service,
- Durable (e.g. expected to perform for the life of the assembly), and
- Joined in a durable and airtight manner to adjacent ACS materials or components.

Generally speaking, flexible membranes – such as house wraps, tapes, liquid membranes, etc. – must be either fully adhered to rigid materials or sandwiched between rigid materials to function as part of the ACS. Materials that resist air flow but are not air impermeable – such as dense packed cellulose insulation – are not suitable components of the ACS. Spray-applied foam insulation in framing cavities can be a component of an ACS for an assembly in which it is applied, but other materials will be needed to make airtight connections between adjacent framing members in that assembly.

In order to provide the uninterrupted air tightness essential to the ACS, the ACS component must always connect to adjacent ACS components. Within an assembly the succession of connected ACS components is referred to as the air control layer. In order to make an airtight connection between assemblies or to make penetrations through the assembly air tight, it is necessary to know where the air control layer is in each assembly. The air control layer is identified in the retrofit details illustrated in this guide in order to reinforce an awareness of the air control layer location at transitions between retrofit assemblies as well as at penetrations or interruptions in retrofit assemblies.

VAPOR CONTROL

One purpose of vapor control is to prevent condensation on or elevated humidity near the surface of moisture-sensitive materials. Another purpose of vapor control in building assemblies is to allow moisture-sensitive materials to dry should they get wet. So vapor control is about controlling the flow of moisture in the vapor form: sometimes restricting the flow of vapor, sometimes promoting it.

In order to control the flow of moisture in the vapor form, it is useful to understand how vapor moves. Water vapor moves with airflow – or by convection. Water vapor also moves through air and vapor permeable materials by diffusion. As already discussed above, the magnitude of vapor movement by airflow tends to be much greater than vapor movement by diffusion.

In addition to understanding how vapor moves, it is also useful to understand the direction that vapor moves. Airflow, therefore the movement of water vapor by convection, is always in the direction from higher pressure to lower pressure. Water vapor moves by diffusion from higher concentration to lower concentration (more to less) and from warm to cold. In a typical cold climate situation, air tends to leak out of a building near the top and into the building near the bottom in winter. In summer the leakage direction is reversed. For the above grade enclosure, diffusion vapor flow tends to be to the outside (warm to cold) in the heating season and for much of the year. However, in warm weather and in homes with air conditioning, diffusion vapor flow at the above grade enclosure tends to be to the inside. For ground contact assemblies like foundation walls and slabs, diffusion vapor movement is nearly always outside to in (high concentration to lower concentration). However since ground-coupled foundation walls and slabs are usually cooler than conditioned space, water vapor will also tend to move toward these surfaces from the interior.

The strategies for vapor control are

1) Controlling airflow,
2) Controlling vapor diffusion, and
3) Controlling the temperature of moisture sensitive materials and cavities within assemblies.

Controlling airflow relies upon using air barrier materials that resist airflow (see discussion of Air Control above). Airflow may also be controlled by manipulating air pressures.

Airflow might also be promoted to assist in removal of moisture as in a vented attic or vented wall cladding.

Control of vapor diffusion (either restricting or promoting) is a function of the vapor permeability (sometimes referred to as simply "permeability") of materials in an assembly. For above-grade portions of the building, using materials with low vapor permeability to the typically-warmer side of moisture-sensitive materials restricts the diffusion vapor movement toward the moisture-sensitive material. Use of highly vapor permeable materials to the typically-cooler or the ventilated side of moisture-sensitive materials promotes the diffusion vapor movement away – or drying – from the moisture-sensitive material. It is wise to use a low permeability membrane or coating between any moisture sensitive materials and concrete that is in contact with the ground because the ground typically has a higher vapor concentration than the interior.[6]

Controlling the temperature of moisture sensitive materials and assemblies is achieved by the amount and position of insulation relative to the moisture sensitive material or assembly and conditioned space. Placing insulation to the outside of moisture-sensitive materials tends to make these materials generally warmer and, therefore, dryer. Placing moisture-sensitive materials to the outside of insulation tends to make these materials generally cooler and, therefore, wetter.

THERMAL CONTROL

Once the necessary Water Control, Air Control, and Vapor Control are achieved for the building enclosure, then it is appropriate to focus on reducing conduction heat flow through the building enclosure. Conduction heat flow is reduced through the use of insulation. More insulation results in less heat conduction. Less heat conduction means the home is better at retaining heat in winter and keeping excess heat out in summer.

While thermal control is subordinate in importance to vapor control, insulation sometimes provides the necessary vapor control strategies by controlling the temperature of moisture-sensitive materials. Sometimes vapor control strategies dictate higher levels of insulation than would be needed to meet thermal control or energy performance goals.

CRITTER CONTROL

We all want to be able to control who comes in our homes. It is also important to prevent damage to assemblies that can be caused by insects and rodents. Animal pests can also represent disease vectors or asthma triggers.

Not all parts of the building enclosure represent places where pests are likely to gain access to the building assemblies or interior. The techniques for controlling pests at likely access points depend upon which kind of threat must be controlled. This guide illustrates minimum basic measures to be included in a DER project. Some situations will require measures beyond those represented in this guide.

6. The ground always has a high *relative humidity* – hovering near 100%. Relative humidity is the water vapor concentration relative to the capacity of the air volume to hold water vapor.

PART 2: RETROFIT ASSEMBLIES AND DETAILS

RETROFIT ASSEMBLIES AND DETAILS

INTRODUCTION

The illustrations and explanatory notes in Part 2 of this guide demonstrate the application of the building enclosure functions in high performance retrofit. The assemblies and details illustrated represent configurations commonly found in wood framed New England homes. Part 2 is structured into three sections:

- Retrofit Assemblies
- Transitions between Retrofit Assemblies
- Interruptions to Retrofit Assemblies

Retrofit Assemblies are the basic building blocks of a retrofit project. They define the basic strategies for major building enclosure components such as roofs, walls, foundation walls, etc. The strategies of the retrofit assemblies selected for a particular project determine the strategies for *Transitions between Retrofit Assemblies* and for *Interruptions to the Retrofit Assemblies*.

The illustrations and notes for ***Transitions between Retrofit Assemblies*** show how the critical control functions are transferred between major component assemblies. Maintaining continuity of the control function through transitions is essential to performance.

Interruptions to Retrofit Assemblies are building elements, service penetrations, or other "holes" generally occurring in the field of an assembly that pose a challenge to continuity of the control functions. Examples of these interruptions include windows and doors, deck attachments and exhaust ducts. Special attention is needed at interruptions to ensure that control functions are not lost.

Lapses in the control functions, particularly lapses in the water and air control functions, lead to problems.

Throughout the illustrations, Water Control System components, Air Control System components, Vapor Control System components, and Thermal Control System components are clearly designated.

RETROFIT ASSEMBLIES

In this section, the Retrofit Assemblies are presented in categories of major building enclosure components including the following:

- Attic/Roof,
- Exterior Frame Wall,
- Foundation Walls,
- Slabs,
- Crawlspace Floors and
- Other Assemblies including reasonably common enclosure components such as:
    - o Overhanging Floor,
    - o Separation Between Conditioned Space and Garage.

These categories are also indicated on the long edge of the page to aid in navigating through this section. The retrofit assemblies form the basic building blocks for a building enclosure DER project. Retrofit assemblies from different categories can be assembled to form a DER enclosure system. Later sections of this guide illustrate how to make effective transitions between different assemblies of the enclosure system (e.g. between roof and wall assemblies) and also how to maintain the building enclosure functions at interruptions to the wall assembly (such as windows).

Careful consideration should be given to the selection of retrofit assemblies for a given project. Each retrofit assembly will have certain advantages and challenges. Not every retrofit assembly will be appropriate to every situation. Furthermore, the transition and interruption strategies that can be used are specific to the retrofit assemblies chosen It is a good idea to review the applicable transitions and interruptions associated with a retrofit assembly before selecting that assembly.

CONTROL SYSTEM COMPONENT LEGEND

It is important to understand how each retrofit assembly performs the necessary building enclosure control functions. Components of the assembly performing critical control functions are identified in the Retrofit Assembly illustrations using the following key:

WCS Component of water control system

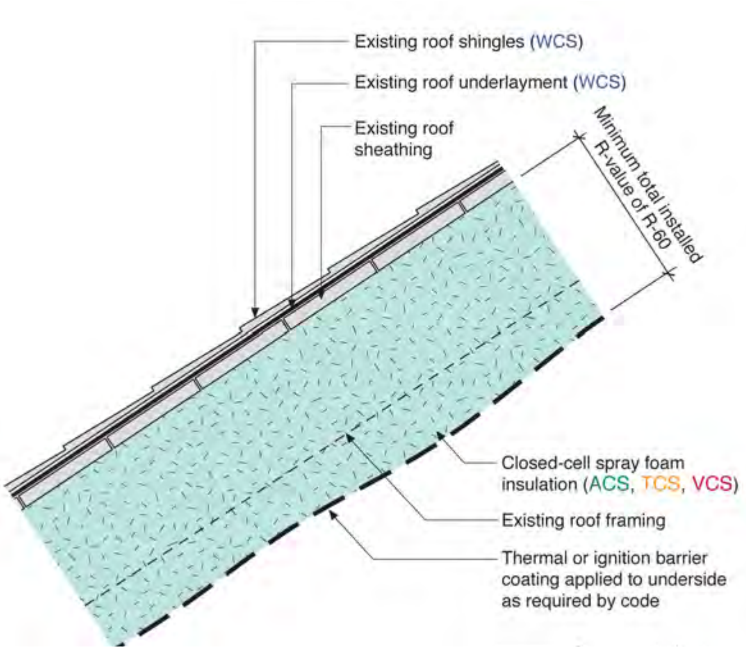
ACS Component of air control system

VCS Component of vapor control system

TCS Component of thermal control system

CCS Component of critter control system

For example:



Attic / Roof

There are three retrofit assemblies in the guide for the attic/roof: vented attic with insulation and air sealing at the attic floor (Attic 1), unvented attic with exterior roof insulation (Roof 1 or Roof 1 Alternate), and unvented attic with interior-only roof insulation. (Roof 2 or Roof 2 Alternate)

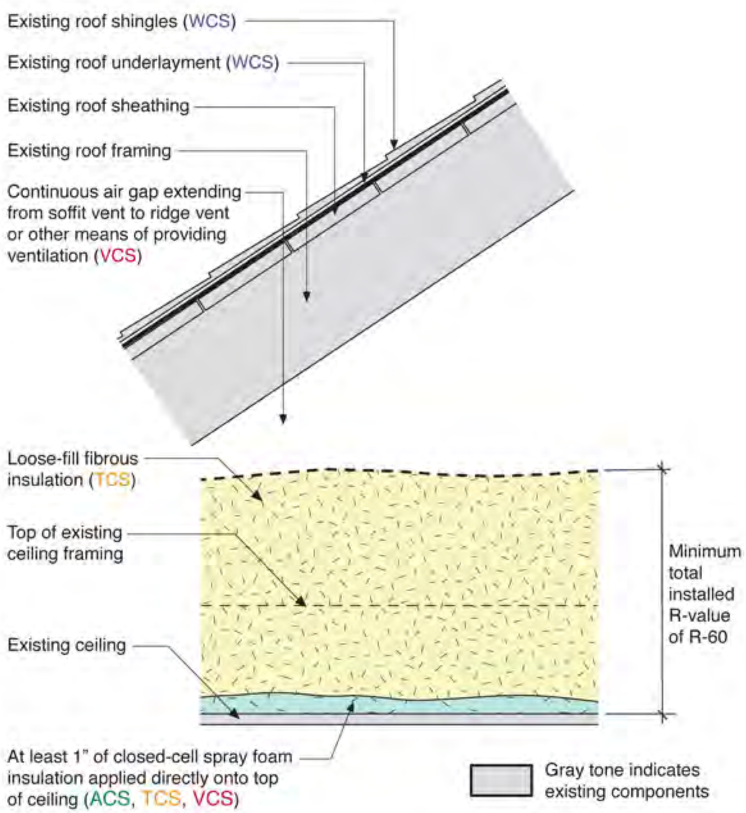
Before selecting the retrofit assembly to use, one must decide whether the attic will be vented or unvented. In cold climates, the primary purpose of a vented attic is to prevent ice dams caused by heat loss from conditioned space and to ventilate moisture out of the attic space. With careful detailing of the air, vapor and thermal control layers for the attic, these two potential problems can be minimized so that the decision for a vented or unvented attic can be made for functional reasons instead.

If the attic will be used for habitable space, contains mechanical equipment or ductwork, or the roof structure is complex, an unvented attic assembly should be considered. Another consideration is that the roof structure may not provide sufficient space for required insulation needed for the attic retrofit assembly, especially at the eaves, where insufficient insulation can contribute to ice damming.

The best performing attic/roof retrofit assembly is the unvented attic assembly with exterior roof insulation – Roof 1. This assembly locates most of the control functions to the exterior so that it is easy to correctly establish continuous air, vapor and thermal control layers. However, since this is applied over the existing roof sheathing, this assembly is only appropriate for DER projects that include replacement of the existing roofing. The other unvented attic retrofit assembly, Roof 2, applies all of the insulation to the interior side of the roof. For this assembly, as well as for the vented attic assembly, replacement of the roofing is not required.

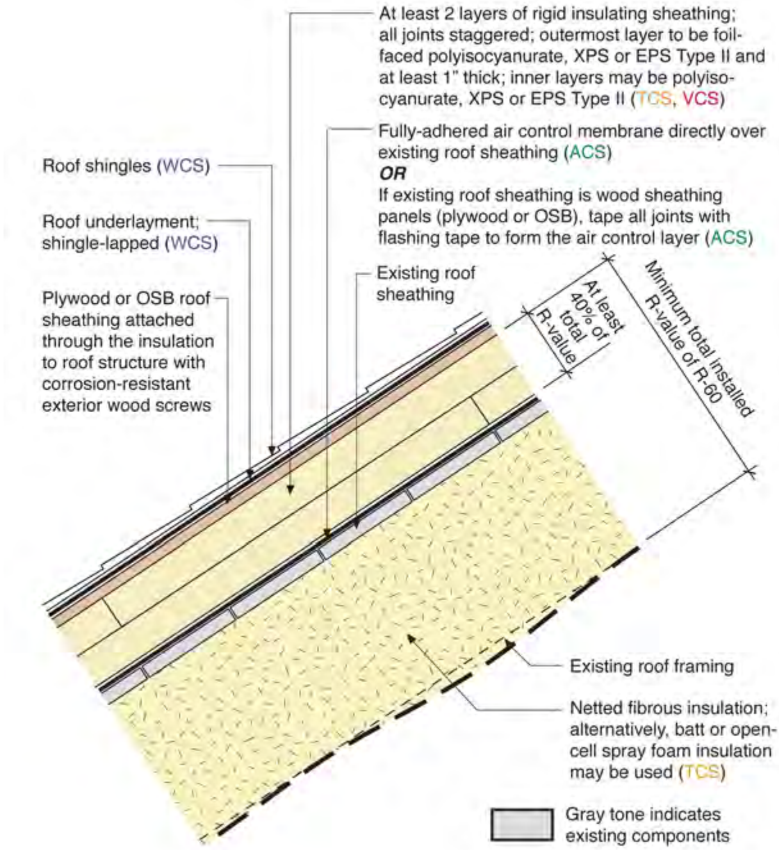
If the DER project includes, or will include in the future, an upgrade to the exterior walls, an extension of the overhangs at the eaves and/or at the rakes may be needed because retrofit walls are thicker than standard construction. If this extension lowers the elevation of the soffit at the eaves, it may conflict with the existing window head heights or head trim. This needs to be taken into account during planning for the overall DER. Typically, this situation can be avoided if the roof is raised several inches, as is the case when the retrofit Roof 1 assembly is used.

In the drawings, the roof cladding is represented as shingles, but other roof claddings would be acceptable provided that the attachment of the roof cladding does not result in horizontal obstructions on the water control layer beneath the cladding.



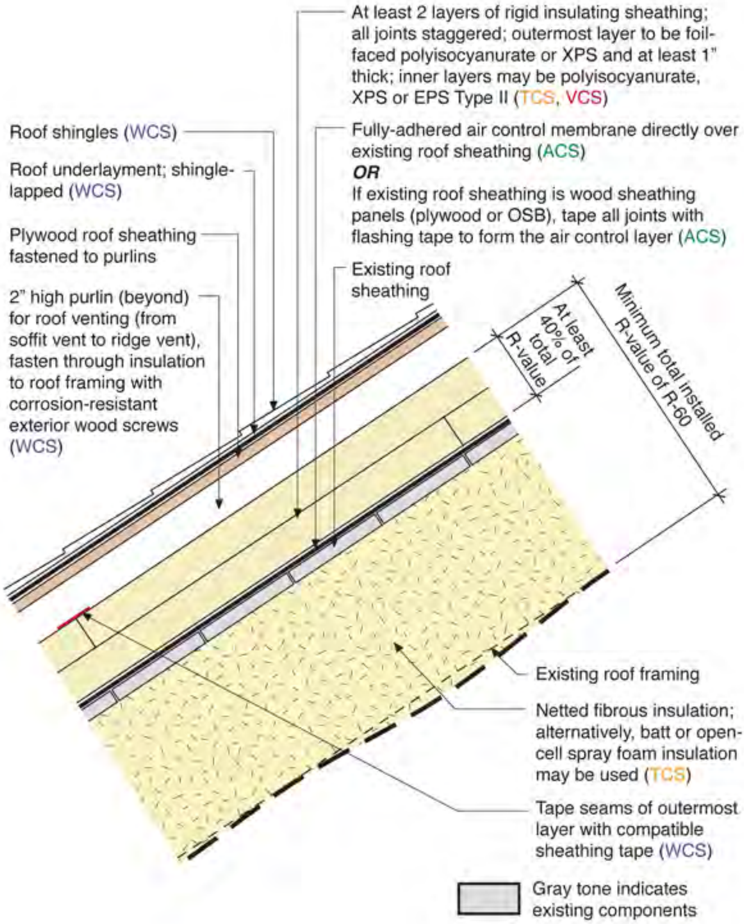
Attic 1: Vented Attic with Insulation and Air Sealing at Attic Floor

- This assembly should not be used if there is ductwork or mechanical equipment in the attic.
- This assembly requires that there be sufficient height (typically at least 8 1/2") between the underside of the roof deck and the top plate at the eave to maintain the air gap for ventilation and insulation with an R-value of at least R-40.
- If there is any history or evidence of leakage at the roof, this must be corrected since the assembly depends on the existing roof for the water control function.
- If existing bath fans vent into the attic, these must be vented to the outside.
- Provide attic ventilation per the applicable building code. If the vent area cannot be split evenly between the low and high vents, it is better to have greater vent area low than high.



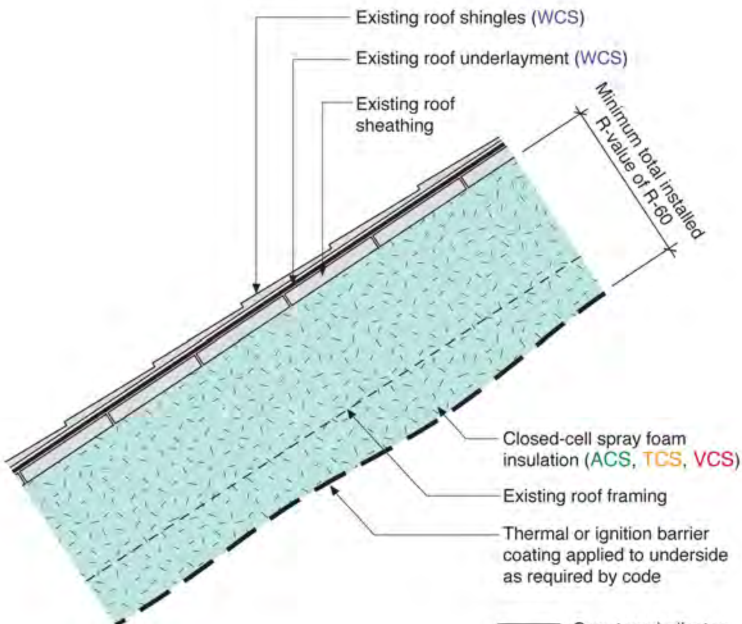
Roof 1: Unvented Attic with Insulation Exterior to Roof Sheathing

- Existing roofing and roof underlayment should be removed.
- If the roof rafters bear directly on the exterior walls, a “chainsaw” retrofit approach is recommended for this assembly.
- If the exterior walls are part of the DER project now or in the future and the eave and/or rake overhangs do not extend far enough to protect a DER wall, overhangs should be extended as part of the DER roof assembly.
- If the existing rafter cavity includes closed-cell spray foam insulation, the existing roof sheathing should have a moisture content of 12% or lower before the exterior insulating sheathing is applied.
- If closed-cell spray foam is to be applied in the rafter cavities, it should be applied after the exterior insulation and water control is in place and the roof sheathing must have a moisture content of 12% or lower.
- In locations with ground snow load of 50 psf or greater, Roof 1 Alternate assembly should be used instead of the Roof 1 assembly.



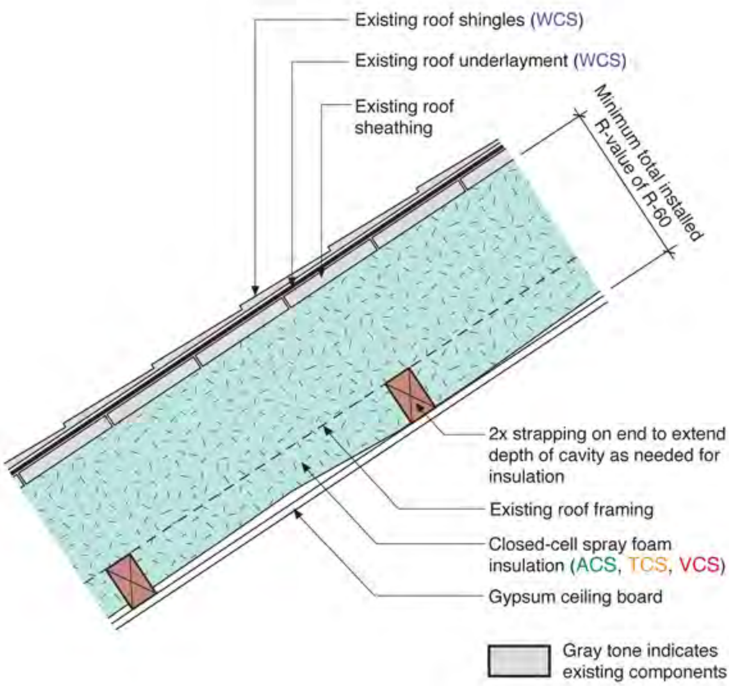
Roof 1 Alternate: Roof 1 Assembly with Vented Roof

- This is the same as Roof 1 except that roof ventilation is provided by placing “vertical purlins” (parallel to the rafters) between the exterior insulation and the new roof sheathing.
- This assembly can be used if vented roof cladding is desired.
- To prevent ice damming, this alternate assembly is required in locations for which the ground snow load is 50 psf or greater.
- Also see notes for Roof 1



Roof 2: Unvented Attic with Insulation Interior to Roof Sheathing

- This assembly requires that there be sufficient height (typically at least 6½") between the underside of the roof deck and the top plate at the eave for closed-cell spray foam insulation with a total R-value of at least R-40.
- If there is any history or evidence of leakage at the roof, this must be corrected since the water control function is provided by the existing roofing and roof underlayment.
- In order to achieve R-60, the rafters will need to be encapsulated by the spray foam for most existing homes.



Roof 2 Alternate: Roof 2 with Strapping for Ceiling Board Attachment

- This is similar to Roof 2 except that it supports a sloped ceiling or use of a gypsum board as the thermal/ignition barrier.
- Also see notes for Roof 2.

Exterior Frame Wall

The most effective location for the enclosure control functions – water, air, vapor, and thermal -- for the exterior walls of a house is to the exterior of the existing structure. Some advantages to this approach for a DER include minimizing the impact of the wall retrofit on the interior finishes of the existing house, supporting continuity of the water and air control layers, reducing thermal bridges, and lowering the risk of water damage and condensation within the existing wall structure. This is the approach used for the DER exterior wall assembly in this guide.

In the retrofit wall assembly, the air control layer is applied directly over the existing wall sheathing and then covered by at least two layers of insulating sheathing held in place by vertical furring strips. The vertical furring strips also provide the means of attachment for the exterior siding

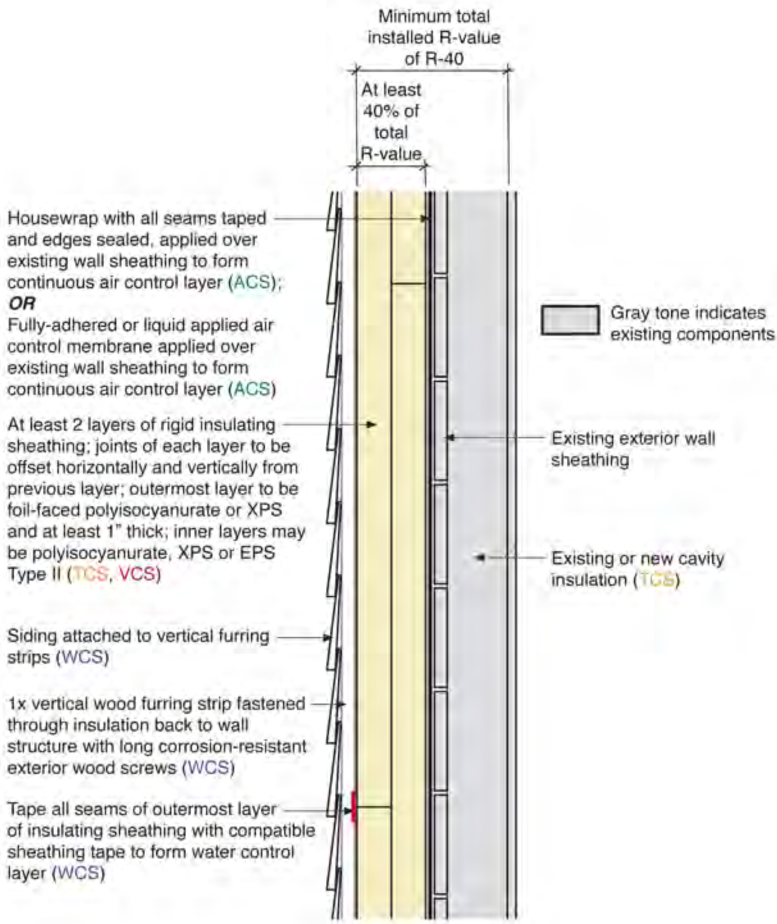
In the drawings, the wall siding is represented as lap siding which could be wood, vinyl or fiber cement lap siding. Other types of siding that can be attached using the vertical furring strips may be used as well provided the weight of the siding is less than 10 lb/ft^2

There are two possible locations for the water control layer for this retrofit wall assembly – at the outer face of the insulating sheathing or between the insulating sheathing and the existing exterior wall. The location of the water control layer has implications about how the water control function is handled at transitions and interruptions. For example, in window installation, if the water control layer is over the existing sheathing, the windows are installed within the existing wall framing whereas if the water control layer is at the face of the insulating sheathing, the windows are installed within the insulating sheathing layer of the wall. This is because the window flashing needs to be integrated into the water control layer.

In this guide, both locations of the water control layer are supported. Wall 1A is the retrofit wall assembly with the water control layer on the face of the insulating sheathing. Wall 1B is the retrofit wall assembly with the water control layer applied to the face of the existing wall sheathing. For Wall 1B, the water control layer is also the air control layer. Once the location of the water control layer for the wall has been established, it is essential that only compatible transition and interruption details be selected for use. For example, if Wall 1A is selected as the wall assembly for the DER project, only drawings, sequences, and details that are labeled either for Wall 1 or for Wall 1A should be used. Those that are labeled for use with Wall 1B are not compatible and should not be used.

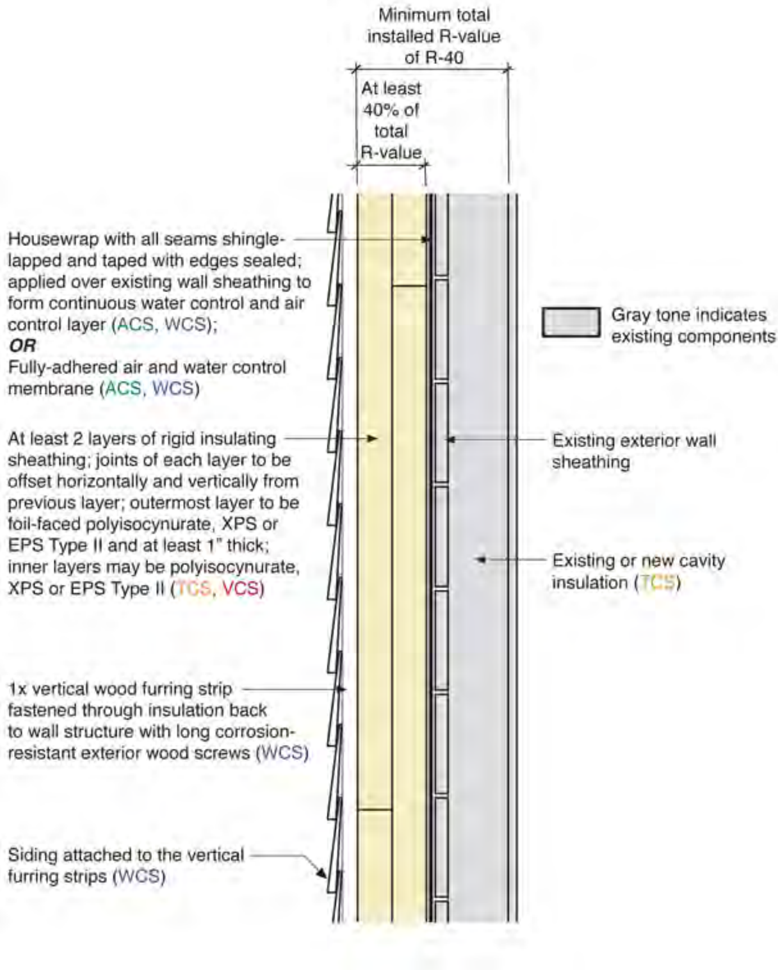
The retrofit wall assembly calls for multiple layers of insulating sheathing to be applied to the exterior of the existing wall. This creates a vapor impermeable layer on the exterior of the wall. If there is a wetting event (e.g. a plumbing leak) that causes the existing wall structure to become wet, it is important that the wall is able to dry to the inside. For this reason, any new or existing application of closed cell spray foam in the wall cavities should be limited to a thickness of one inch. In general, any spray foam insulation applied to the wall cavity should have a vapor permeability of at least 1.0 perms for the installed thickness. Open cell spray foam insulation meets this criteria for typical framed wall cavity depths.

It is advisable to avoid use of an interior side vapor barrier and vapor impermeable wall coverings, including non-latex paint and some wallpapers, with this retrofit wall since these limit the drying potential to the interior as well. These types of wall coverings may contribute to problems if the interior space has high humidity, there is a history of water leakage in the wall, or the exterior wall has gotten wet during construction.



Wall 1A: Cavity Insulation and Insulating Sheathing with Water Control at Face of Insulating Sheathing

- No more than 1” of closed-cell spray foam insulation (new or existing) should be used in the wall cavity; for other types of spray foam insulation, the vapor permeance of the installed thickness must be at least 1.0 perm; this may not be the case for some medium density spray foams.
- This retrofit wall assembly is not advised for use on walls for which there is an existing interior side vapor barrier (including certain paints and wall paper) if the interior space has high humidity, there is a history of water leakage in the wall, or the wall has gotten wet during construction.
- Application of a continuous vapor impermeable wall covering, including certain paints and wall paper, should be avoided if the interior space has high humidity, there is a history of water leakage in the wall, or the wall has gotten wet during construction.



Wall 1B: Cavity Insulation and Insulating Sheathing with Water Control Between Sheathing and Insulating Sheathing

- The air and water control layers are the same in this retrofit assembly
- See also notes for Wall 1A.

Basements and Crawlspaces

Basements can account for one quarter of energy use in a typical house. Therefore insulating foundation walls is a critical measure for a DER project. In addition, damp basements – due to bulk water entry, moisture transfer through the walls or slab, or condensation – contribute to indoor air quality problems and durability issues. As with all of the retrofit assemblies, basement assemblies address all four of the enclosure functions. However, since the majority of a basement is below grade, the primary purpose of the air control function in the basement is to prevent the entry of soil gases.

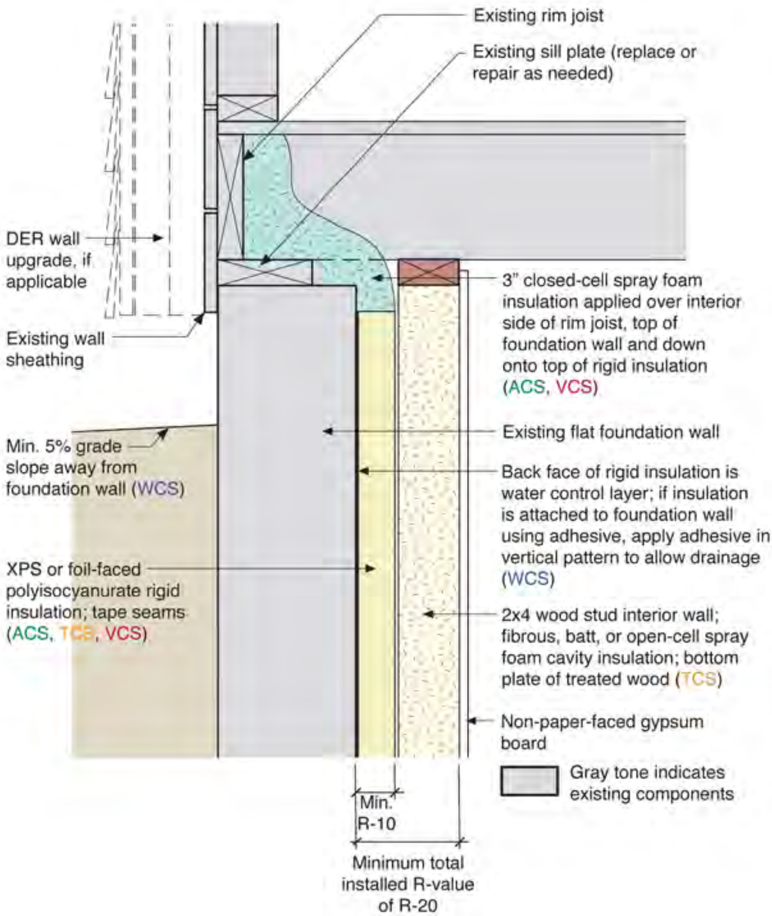
This guide describes assemblies for insulating basements but does not provide recommendations for retrofitting insulation to the separation between the basement (or crawlspace) and the living space. This is because research by BSC and experience by others has found that even apparently well-implemented basement ceiling retrofits do not provide effective air separation between the basement and the living space. At the same time, excluding the basement or crawlspace from the thermal enclosure tends to increase air quality problems in these spaces. Therefore, for reasons of thermal performance and indoor air quality, this guide recommends that basements and crawlspaces be included in the thermal enclosure.

Foundation Walls

Most existing houses have concrete foundation walls (cast concrete or concrete block) or walls constructed of irregular discrete pieces – fieldstone, brick or rubble. For the retrofit foundation assemblies, the primary distinctions between these is the character of the surface of the wall – either a flat surface or an irregular surface – and the water permeability of the wall, which is quite high for the walls built of irregular discrete pieces. The two retrofit assemblies that use rigid insulation (XPS) – either to the interior (Foundation Wall 1) or to the exterior (Foundation Wall 3) – are only appropriate for a flat surface whereas the retrofit assembly for that uses an interior application of closed-cell spray foam insulation applied directly over the wall (Foundation Wall 2) can be used for both types of foundation walls.

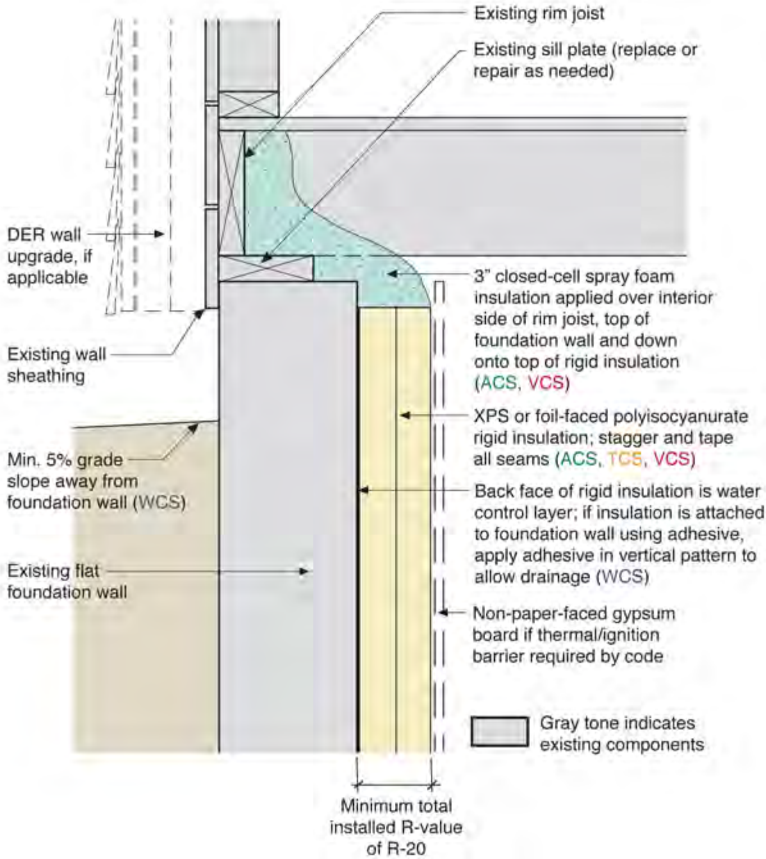
Even though foundation wall materials are water tolerant, as part of the water control function for basements, measures should be taken to protect the walls from bulk water. If the grade around the perimeter does not slope away from the house, make grading adjustments so that it slopes away at 5% grade for at least the first 3 feet and if possible, 10 feet. If gutters are installed, the system must direct water away from the perimeter of the house and the gutter system must be regularly maintained to prevent overflowing, leaks, or breaks in the system as these can concentrate water onto the building. Another protective measure is to provide a trench of gravel around the perimeter that extends out at least as far as the roof drip edge. This helps disperse bulk water that comes from the roof so that the top of the foundation wall is not continually splashed. It is especially important to keep bulk water away from the exposed part of stone or brick foundation walls since this reduces the risk of freeze thaw cycles.

Before proceeding with the foundation wall retrofit, an assessment should be made of the condition of the sill. If there is no capillary break under the sill and/or if the sill is within 12” of the ground, it is possible that it has suffered water damage. If so, the damaged pieces should be replaced and, at the same time, a capillary break installed under the new pieces. If these conditions exist but there is no indication of damage, then it is likely that the sill has been able to dry. However, the retrofit foundation wall assembly limits drying to the interior, so special treatment may be required at the base of the exterior wall. This is further discussed in Transitions section.



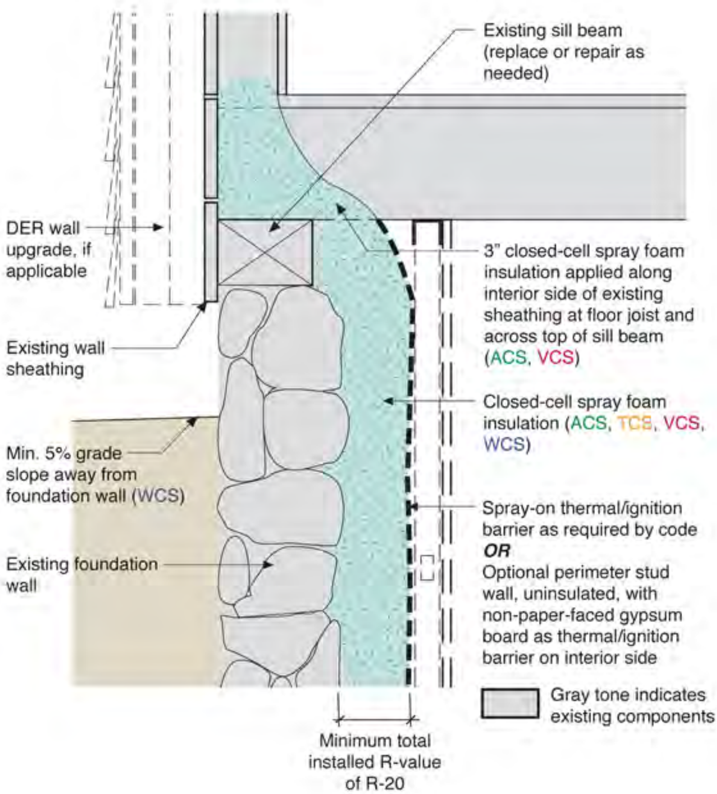
Foundation Wall 1: Rigid Board Insulation with Insulated Stud Wall to Interior of Flat Foundation Wall

- This assembly is not applicable for basements subject to flooding.
- Any cracks in the foundation wall should be patched.
- Do not use a cavity insulation that is vapor impermeable.
- If metal rather than wood studs are used for the interior wall, leave at least a 1" gap between the metal studs and the rigid insulation to avoid degrading the overall R-value due to conductivity of the metal studs.
- For brick walls, take measures to protect the exposed part of the foundation wall from bulk water to reduce the risk of freeze-thaw cycles and to reduce capillarity.



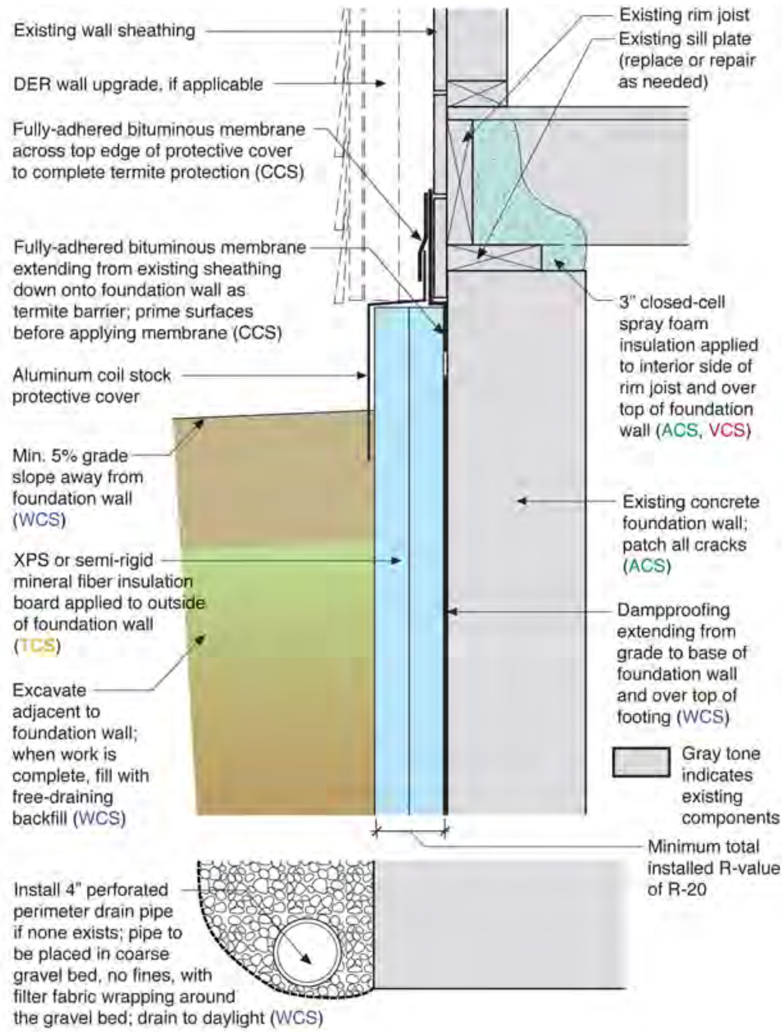
Foundation Wall 1 Alternate: Rigid Board Insulation to Interior of Flat Foundation Wall

- For brick walls, take measures to protect the exposed part of the foundation wall from bulk water to reduce the risk of freeze-thaw cycles and to reduce capillarity.



Foundation Wall 2: Closed-Cell Spray Foam to Interior of Foundation Wall

- This assembly is appropriate for stone or rubble foundation walls as well as for flat foundation walls.
- If the house has balloon framing, the spray foam insulation at the top of the foundation wall needs to extend into the base of the wall cavity above and seal to the back side of the existing wall sheathing, as shown.
- If the optional metal interior stud wall is provided, the stud wall should not be insulated unless the metal studs are placed at least 1” to the interior side of the foundation wall insulation.
- For stone or brick walls, take measures to protect the exposed part of the foundation wall from bulk water to reduce the risk of freeze-thaw cycles and to reduce capillarity.



Foundation Wall 3: Rigid Insulation to Exterior of Flat Foundation Wall

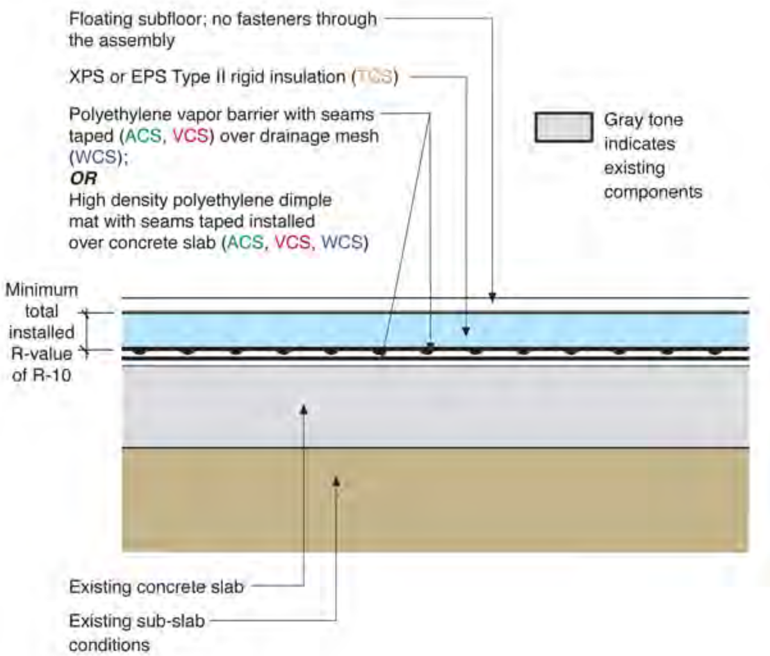
- This assembly should only be used on a flat foundation wall.
- While appropriate for new construction, this method is rarely applied to a retrofit because of the cost and logistical difficulties.
- An alternative type of protective cover may be used, but flashing across the top of the exterior insulation must be provided and it must be sealed at the top with membrane as shown.
- For a concrete block or brick foundation wall, an air control layer, such as a parge coat, should be applied on the interior with a continuous transition to the spray foam at the top of the wall for air control.

Slabs

Today, basement slabs are constructed over gravel, insulation, and a vapor barrier. This treatment minimizes moisture transfer and heat loss through the concrete slab. However, homes built before the 1990's typically did not use these techniques so most retrofits cannot assume this type of treatment exists under the slab. Therefore, the retrofit of the basement slab needs to address both moisture transfer and heat loss through the slab. In addition, it may need to support the water control strategy of the basement walls.

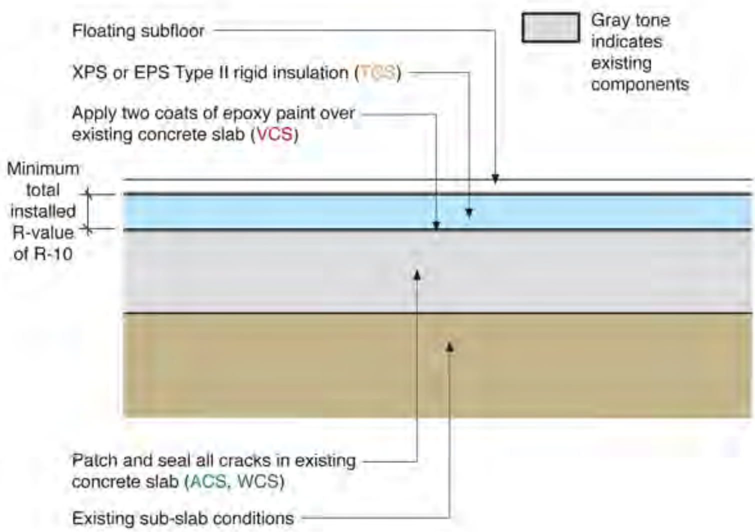
If the existing basement slab is uninsulated, there are two options for adding insulation: one is to remove the existing slab, excavate below and construct an insulated slab along with other appropriate moisture transfer protection below; the other is to provide insulation and water control on top of the existing slab. Replacing the slab is generally not a feasible approach for a retrofit. Therefore, the two retrofit assemblies supported in this guide are insulated above the existing slab by applying 2" of XPS insulation over the existing slab and covering it with a subfloor material. Basement Slab 1 includes a water drainage space underneath the insulation to allow water to be drained over the existing slab to a sump or other drainage system. This drainage space is completely isolated from the interior by vapor and air impermeable materials. Basement Slab 2 does not include the water management on top of the slab and thus requires installation of a perimeter drain system tied into a sump or other drainage system.

In some cases, it is not possible to add insulation over the existing basement slab due to insufficient head height in the basement. There are risks associated with a slab that is exposed to the interior and in contact with cooler damp soil. These risks are managed by 1) treatment of the slab, 2) control of conditions in the basement, and 3) separating sensitive materials from the slab. If the post-retrofit basement slab is uninsulated, at a minimum, the slab should be patched and sealed to the foundation wall for soil gas control and an epoxy paint should be applied to the surface for moisture transfer control. The homeowner should consider the use of a dehumidifier in the basement during the summer. If the basement slab is already insulated, the application of epoxy paint is recommended but not required.



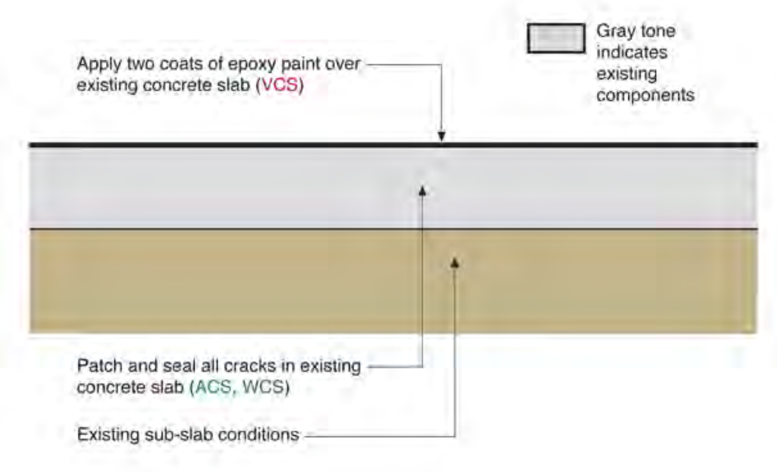
Slab 1: Insulation Over Existing Slab with Drainage Layer Between Insulation and Existing Slab

- The above-slab drainage layer (drainage mesh or dimple mat) must be connected to an interior sump pit. The interior sump pit must have an air tight and gasketed cover.
- Through-assembly fasteners should not be used because these would puncture the air and vapor control layers potentially admitting soil gas that is collected in the air space below (drainage mesh or dimple mat).



Slab 2: Insulation Directly Over Existing Slab

- Use of this slab assembly requires a sub-slab drainage system.

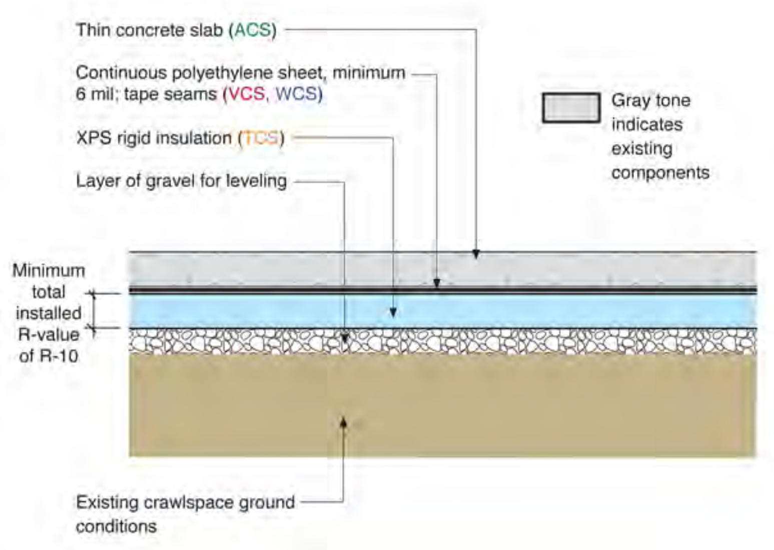


Uninsulated (or Existing Insulated) Slab Assembly

- If the existing slab has continuous insulation below the slab, then the epoxy paint is recommended, but not required.
- Water sensitive materials should not be placed in direct contact with the slab

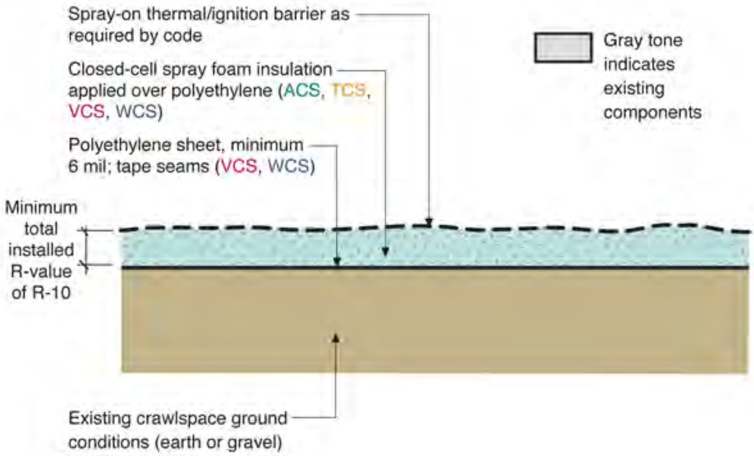
Crawlspace Floor

Because it is important to include the crawlspace in the thermal enclosure, measures are needed to treat the floor of this space. In many cases, the crawlspace may be treated as a short basement and retrofit foundation wall and retrofit slab assemblies as described above may be applied. In other situations, the existing conditions require other solutions. Below are two assemblies appropriate for retrofit of crawlspaces having exposed dirt or gravel floors.



Crawlspace Floor 1: Insulation and Thin Slab Over Dirt/Gravel

- This crawlspace floor assembly provides a surface suitable for light storage.
- If there is a history of flooding or water leakage in the crawlspace and there is no functioning perimeter drainage system, a drainage system (e.g. an interior perimeter drain or gravel layer connected to an interior sump pit) must be installed under this assembly. An interior sump pit must have an airtight and gasketed cover.



Crawlspace Floor 2: Closed-Cell Spray Foam Over Dirt/Gravel

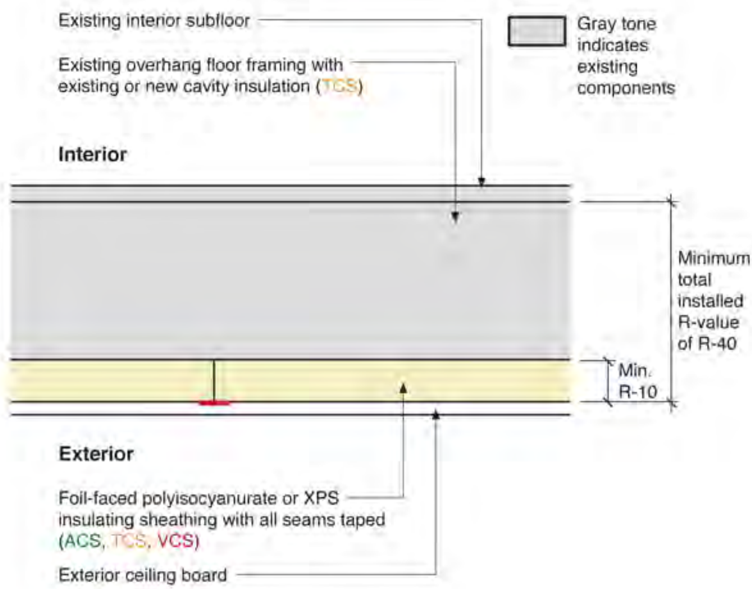
- This crawlspace floor assembly is to be used with treatment of crawlspace walls as described for Foundation Wall 2.
- This assembly should not be used under a (future) concrete slab.
- This assembly is not appropriate in a crawlspace that needs to be frequently accessed.
- If there is a history of flooding or water leakage in the crawlspace and there is no functioning perimeter drainage system, a drainage system (e.g. an interior perimeter drain or gravel layer connected to an interior sump pit) must be installed under this assembly. An interior sump pit must have an airtight and gasketed cover.

Other Assemblies

The following assemblies address building enclosure components that are reasonably common but may not be represented in every home.

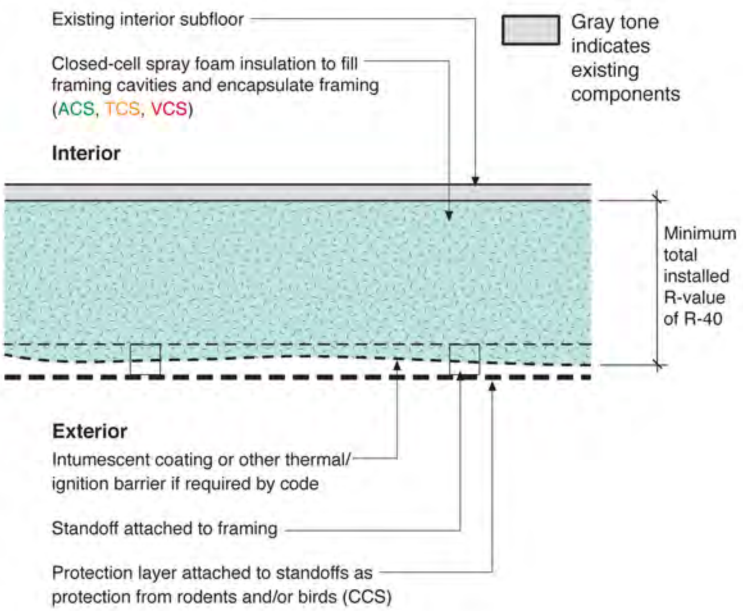
Overhanging Floor

In a project that includes a retrofit of the exterior walls, all above-grade overhangs should also be included in the DER. Configurations where these overhangs occur include the second floor overhang of a garrison colonial house, the underside of a projecting bay, the ceiling of an inset porch, and the ceiling of a vented crawlspace with conditioned space above. The following DER overhang assemblies support these conditions.



Overhanging Floor 1: Rigid Insulation Below Framing and Cavity Insulation, Finish Material to Underside of Overhang

- This assembly is typical for a porch ceiling under conditioned space or the overhang of the second floor of a garrison colonial.
- The existing finish is removed to minimize the change in elevation of the overhang.



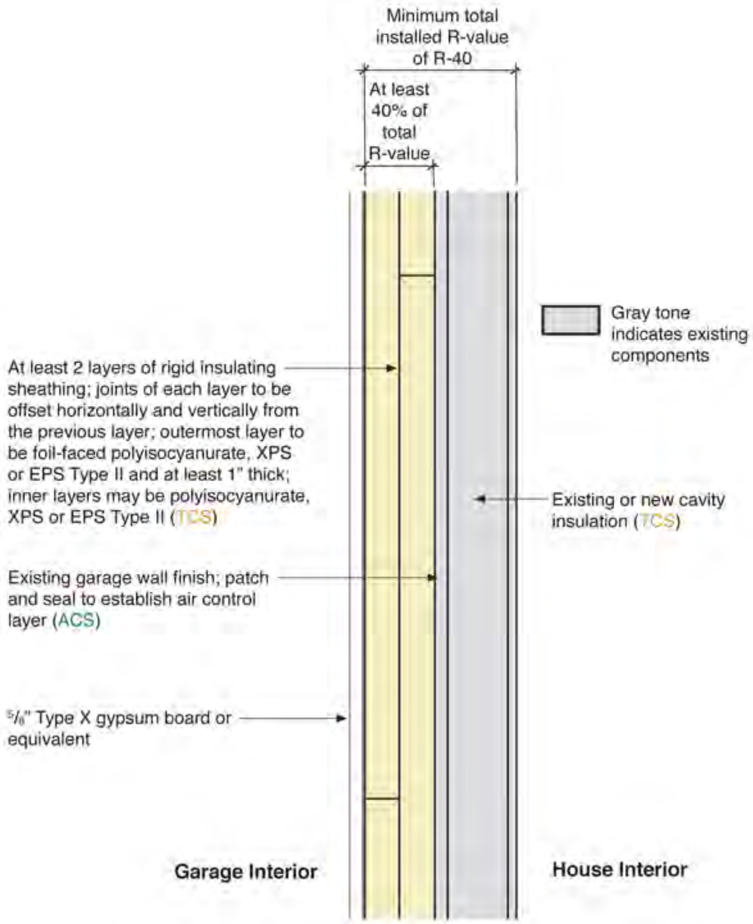
Overhanging Floor 2: Closed-Cell Spray Foam Insulation in Cavities and Encapsulating Framing

- This assembly is typical under a first floor bay or for a vented crawlspace with conditioned space above.
- Encapsulation of the framing is required here to decouple the framing from the ground and crawlspace thermal and moisture conditions.
- The standoffs may be replaced with 2x2 furring if needed for attaching the protection layer (e.g. cement board).

Separations between Conditioned Space and Garage

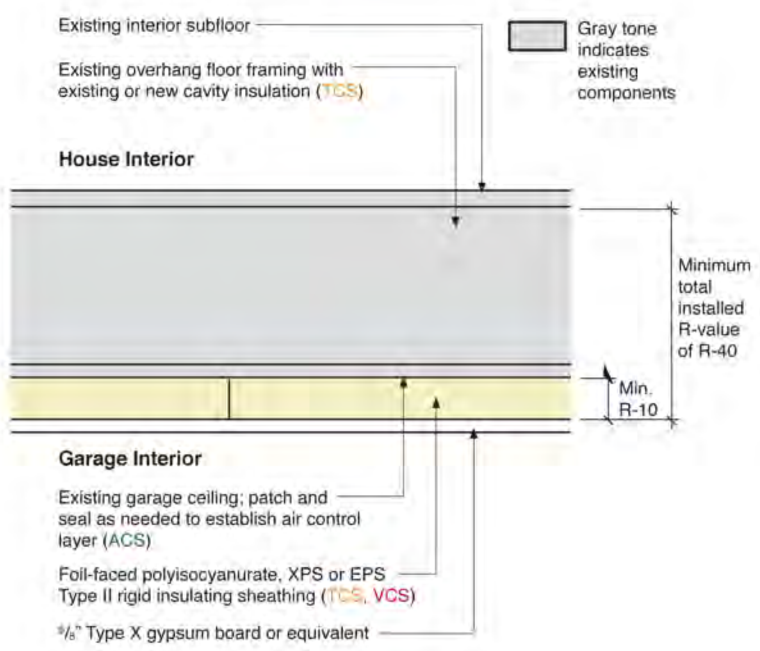
Even a partial DER increases the airtightness of a house and thus changes the dynamics of the existing enclosure. If the house has an attached garage, steps must be taken to ensure that the combustion safety and health of the house occupants will not be compromised by the DER. At a minimum, fire protection as required by the applicable code must be provided. In addition, airtightness of all walls and ceilings and doors which are common between the attached garage and the interior of the house should be verified and improved, if needed.

If the DER project includes an upgrade of the exterior walls, then any garage walls or ceiling that are common between the garage and the house should be included as part of the DER project. The retrofit assembly differs from that for exterior walls and overhangs in that the fire protection requirements must be met and the water control function is not required because there is no direct exposure to the weather.



Garage Wall 1: Insulating Sheathing and Fire Protection Layer Installed Over Existing Wall

- This assembly is for common/shared wall between the interior of the house and the interior of an attached garage.
- If the existing garage wall finish is removed, the innermost layer of insulating sheathing will need to be detailed as the air control layer in which case the insulating sheathing must be foil-faced polyisocyanurate or XPS with seams taped.



Garage Ceiling 1: Insulating Sheathing and Fire Protection Layer Installed Over Existing Ceiling

- This assembly is for a garage ceiling when a portion of the interior of the house is located directly above the attached garage.
- Blocking will be needed for reinstallation of existing services and attachments on the ceiling.
- If the existing garage ceiling is removed, the layer of insulating sheathing will need to be foil-faced polyisocyanurate or XPS and detailed as the air control layer with seams taped.

TRANSITIONS

This section illustrates effective transitions between the various Retrofit Assemblies as well as between Retrofit Assemblies and adjacent non-retrofit assemblies. Effective transitions maintain critical building enclosure control functions at the intersection of different assemblies. Effective transitions between the Retrofit Assemblies and non-retrofit components are necessary for a high performance DER enclosure system.

In this section the Transitions are arranged into categories according to the type of transition as determined by where it occurs on the enclosure as follows:

- Attic/Roof-to-Exterior Frame Wall,
- Exterior Frame Wall-to-Lower Roof,
- Transitions Involving Overhanging Floor
- Transitions Involving Garage Enclosures,
- Exterior Frame Wall-to-Foundation Wall,
- Foundation Wall-to-Slab and Foundation Wall-to-Crawlspace Floor.

These categories are also indicated on the long edge of the page to aid in navigating through this section.

Included in the Exterior Frame Wall-to-Foundation Wall category are illustrations that demonstrate a special case of providing insulation at the base of a frame wall that promotes drying of the framing sill.

CONTROL SYSTEM COMPONENT LEGEND

It is essential that the continuity of the water control and air control are maintained at transitions. The location of the water control layer and air control layer is identified for each of the adjoining assemblies. Within each Transition illustration, the measures or materials critical to maintaining necessary building enclosure control functions are identified using the following key:

WCS Component of water control system

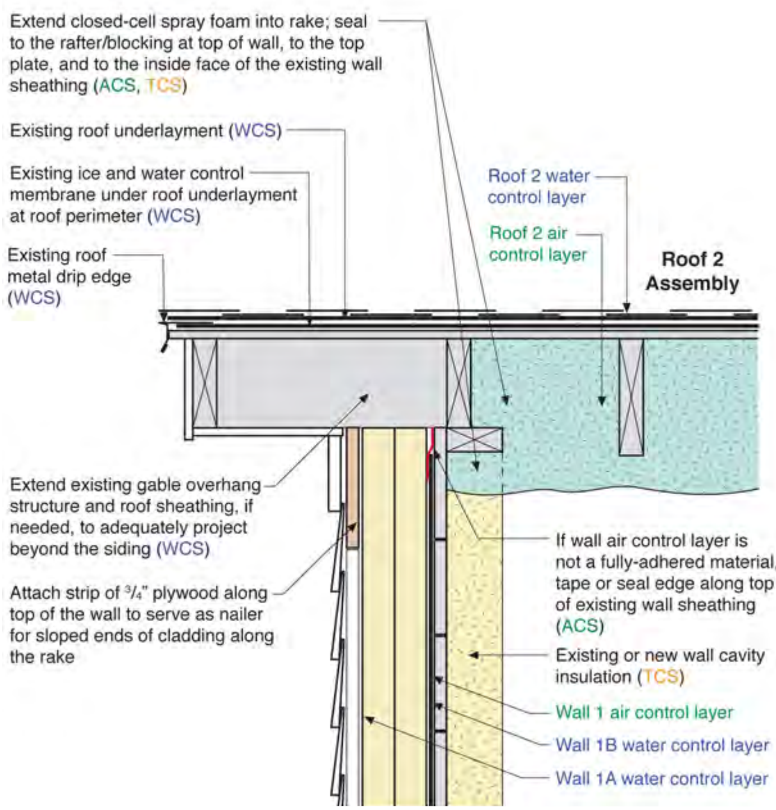
ACS Component of air control system

VCS Component of vapor control system

TCS Component of thermal control system

CCS Component of critter control system

For example:



Attic/Roof-to-Exterior Frame Wall

Where the roof meets the wall, the water control layer of the roof is not connected to the water control layer of the wall. The water control function is "transitioned" to the wall by providing overhangs to protect the top of the wall. Essentially, the roof overhang is like a large flashing over the top of the wall.

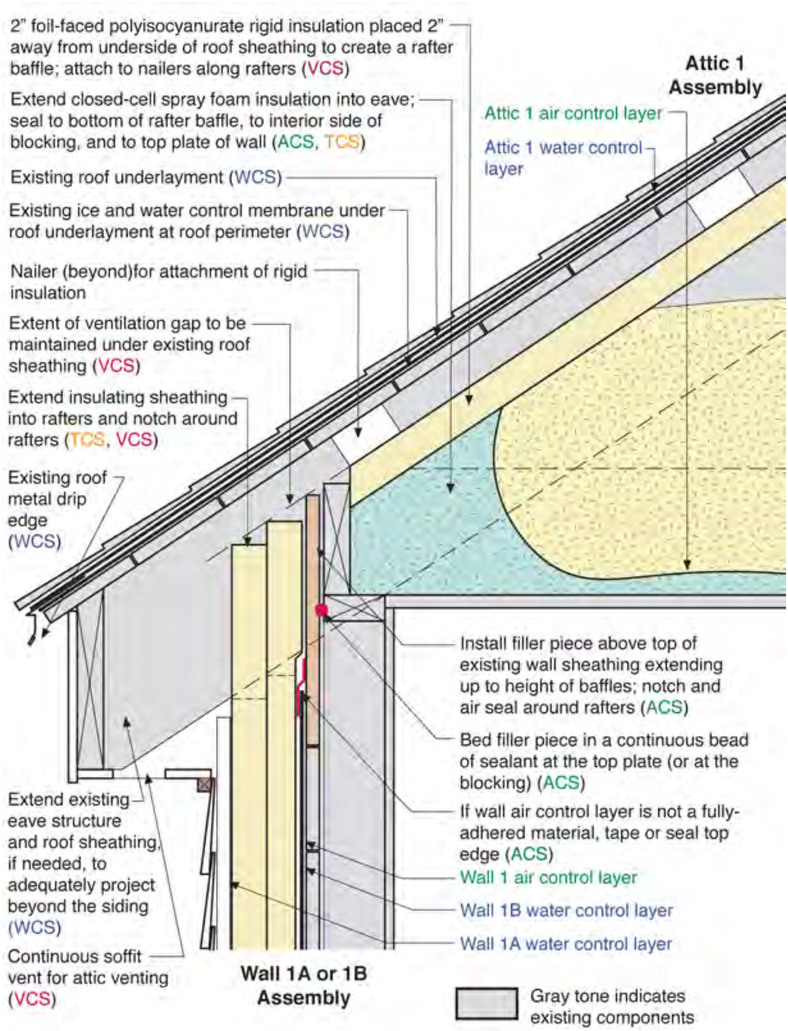
Because the water control layer of the roof is not connected to the water control layer of the wall, the transition detail for the roof-to-wall intersection is not affected by the position of the water control layer in the wall assembly. The illustrations in this section depicting a transition to a retrofit wall are equally applicable to DER projects employing the wall retrofit assembly Wall 1A as to those employing Wall 1B.

The transition of air control is both critical and difficult at the roof-wall intersection. Continuous air control at the top of the building is critical to performance because the difference between interior and exterior pressure during the heating season tends to be greatest at the top of the building. These pressure differences are the driving force behind air leakage. Implementing uninterrupted air control can be complicated by the geometry of the roof overhang, by the location of the air control layer in the wall being on a different side of the enclosure than it is for the attic or roof, and by intervening framing.

The most effective way to address or remove these complications is to pursue what is often called a "chainsaw" roof-wall connection. In this approach, the overhang of the existing roof is cut back flush with the face of the exterior wall sheathing. Then an air control membrane can be wrapped from the surface of the existing roof sheathing to the surface of the existing wall sheathing without interruption. Insulation can also be placed in a continuous, uninterrupted manner over this intersection with the roof cladding and overhang installed to the outside of the insulation. This approach is only practical where the roof is insulated and re-clad above the existing roof sheathing (Roof 1 assembly) and where the roof rafters are not supported beyond the face of the exterior wall (as when the rafters bear on cantilevered ceiling joists).

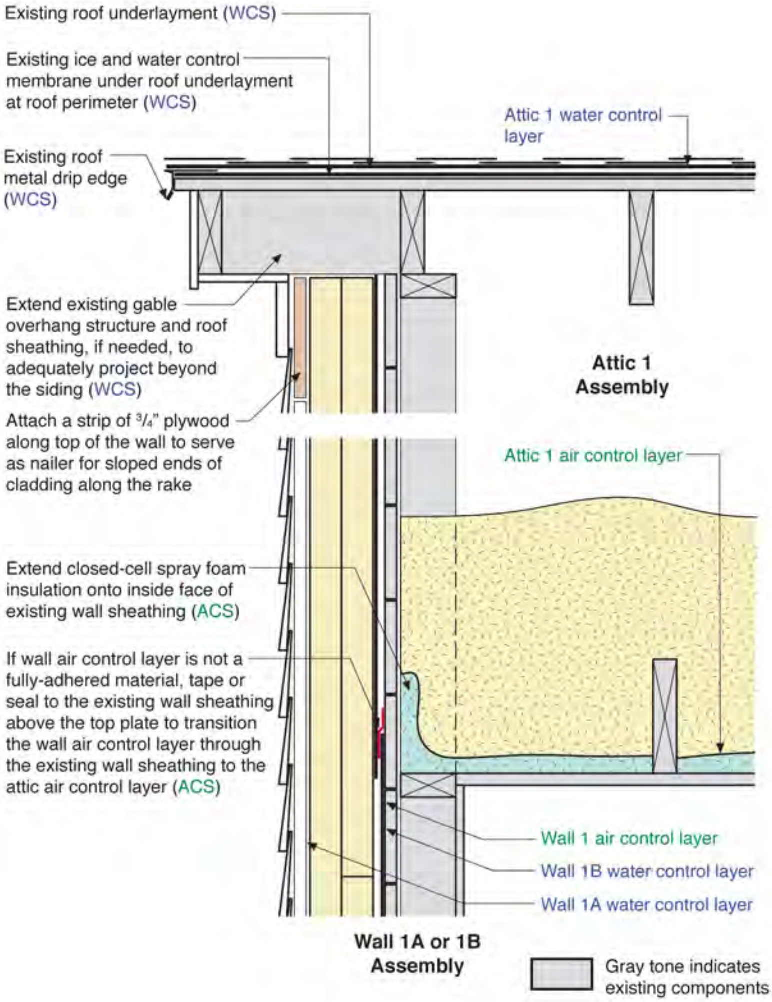
This section illustrates both "chainsaw" and non-chainsaw approaches to the roof-wall transition. Because of the enormous variety of framing conditions at the roof-wall intersection, the illustrations in this section are necessarily schematic in nature.

Particularly in the non-chainsaw roof-wall transitions, effective continuity of the air control will rely on careful implementation and an understanding of the many connections that must be made airtight in order to connect the air control of the wall to that of the attic or roof.



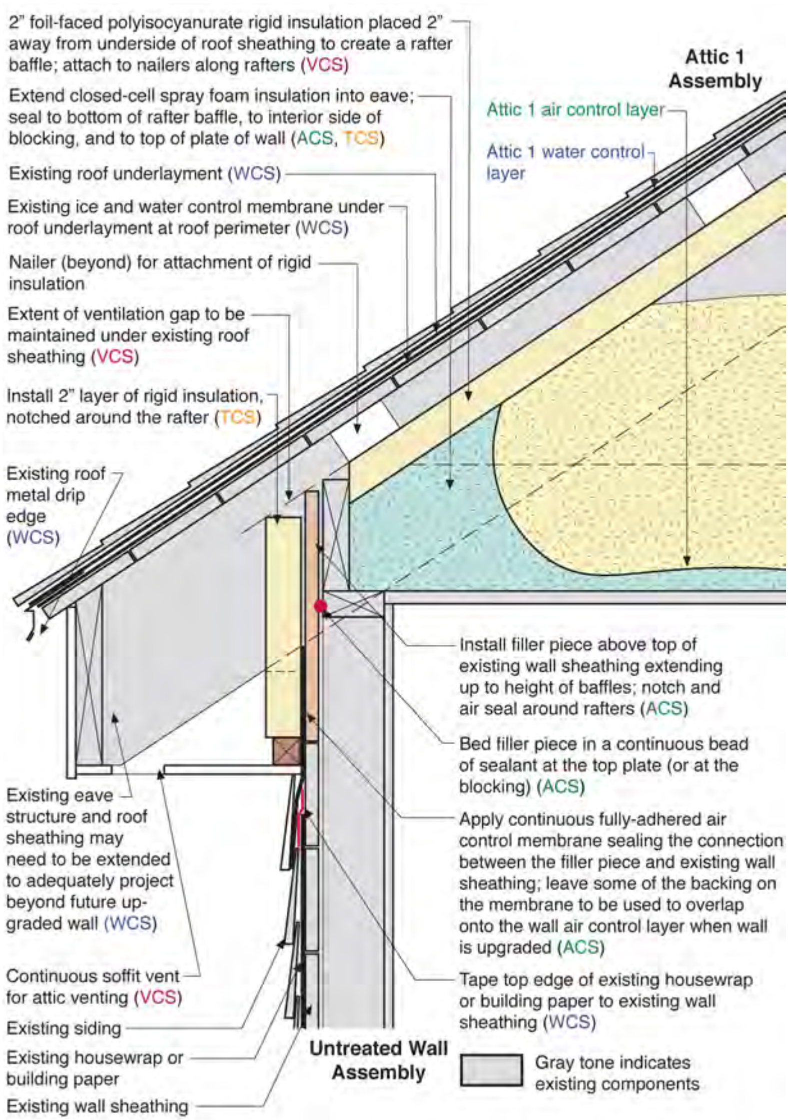
Attic 1 to Wall 1—Eave

- This transition applies for both Wall 1A and to Wall 1B.
- Modify or relocate blocking between the rafters as needed in order to maintain the 2" ventilation space across each rafter bay.
- Total R-value at top of wall, including R-value of rafter baffle and spray foam, should be at least R-40.



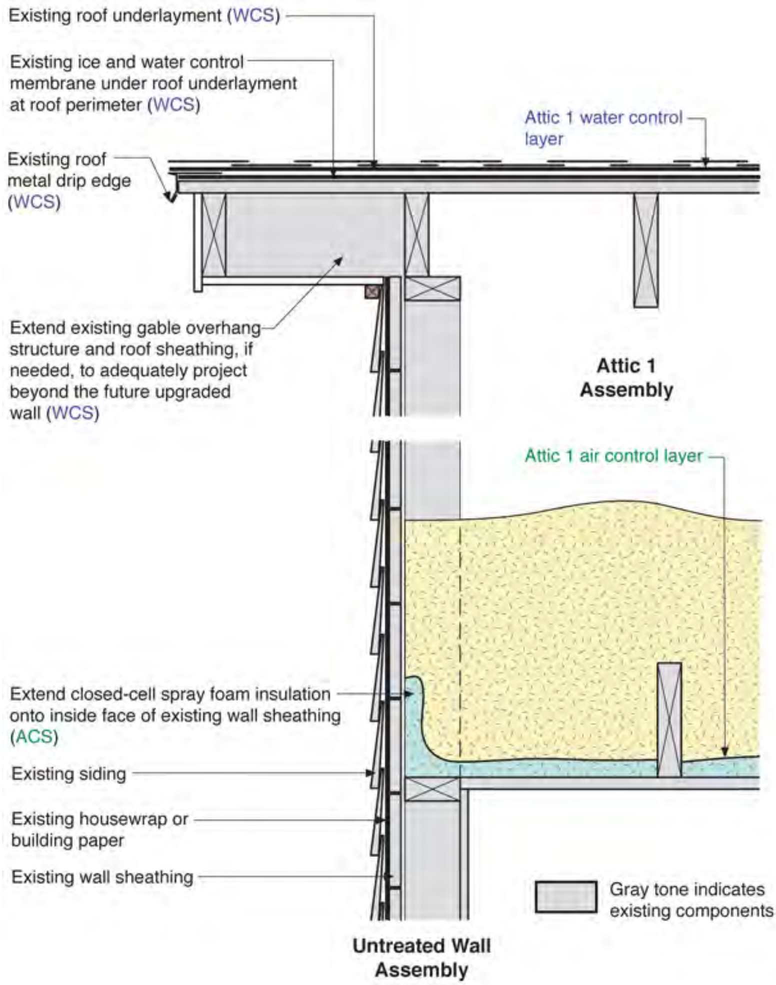
Attic 1 to Wall 1—Rake

- This transition applies for both Wall 1A and Wall 1B

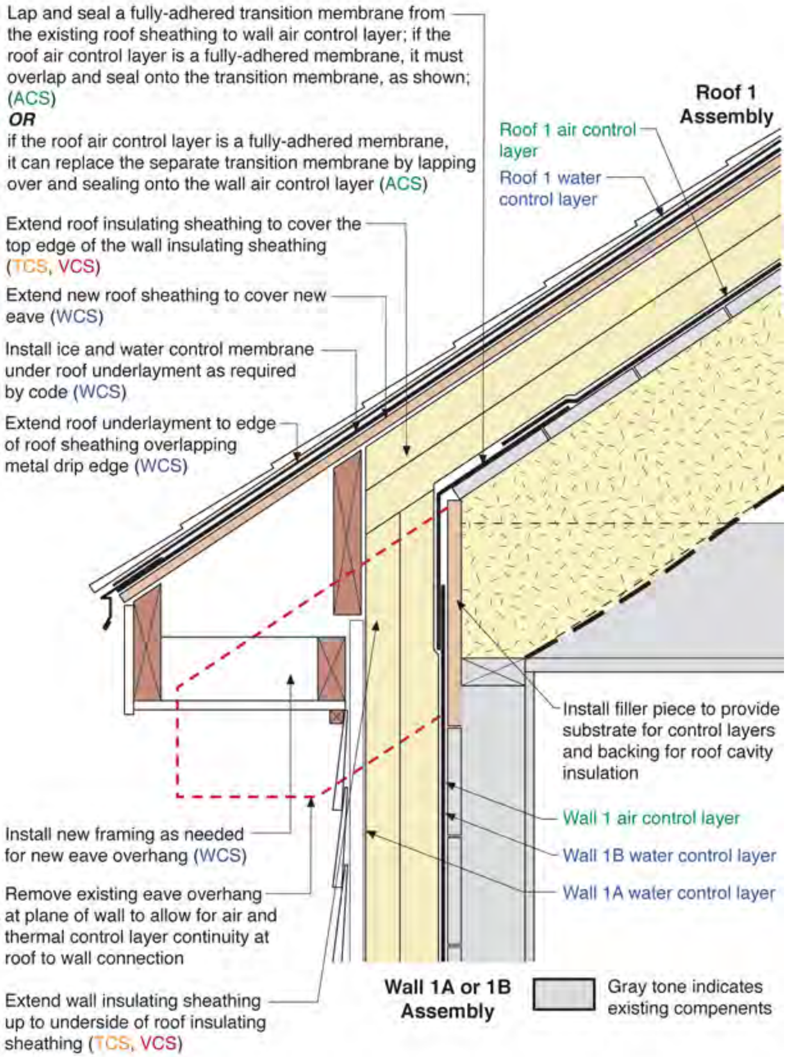


Attic 1 to Untreated Wall—Eave

- It may be necessary to modify or relocate blocking between the rafters in order to maintain the 2" ventilation space across each rafter bay.
- Temporarily remove siding at top of wall as needed for access to the existing housewrap or building paper.
- Total R-value at top of wall, including R-value of rafter baffle and spray foam, should be at least R-40.

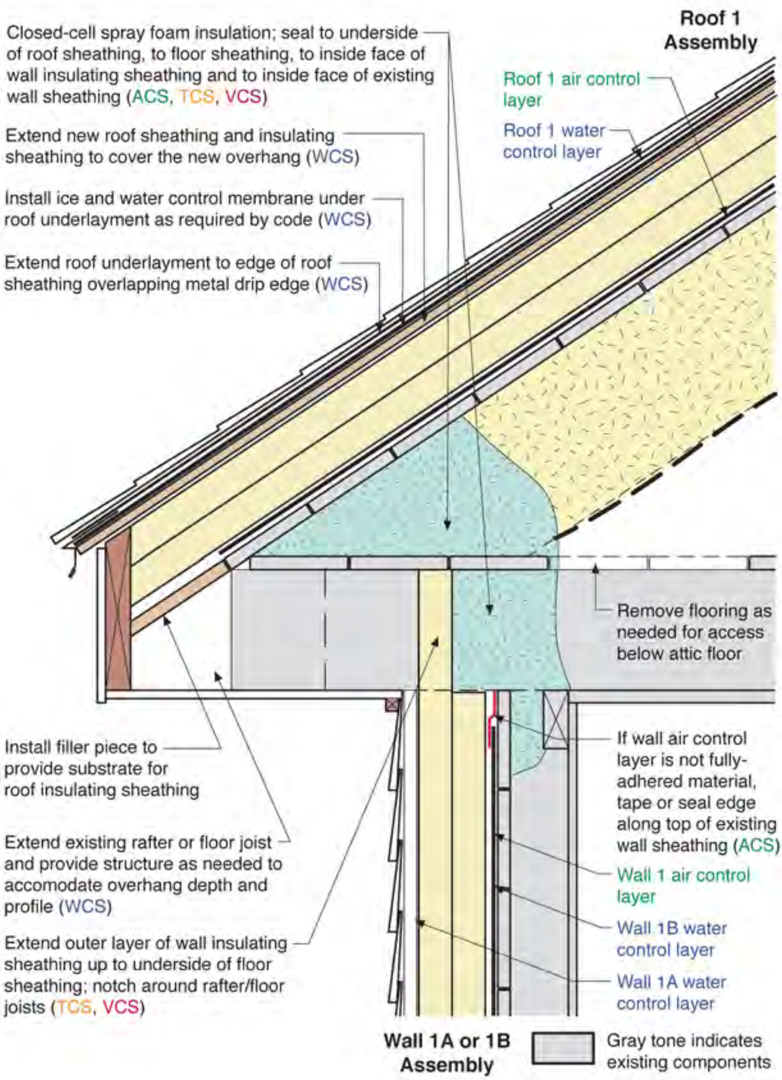


Attic 1 to Untreated Wall—Rake



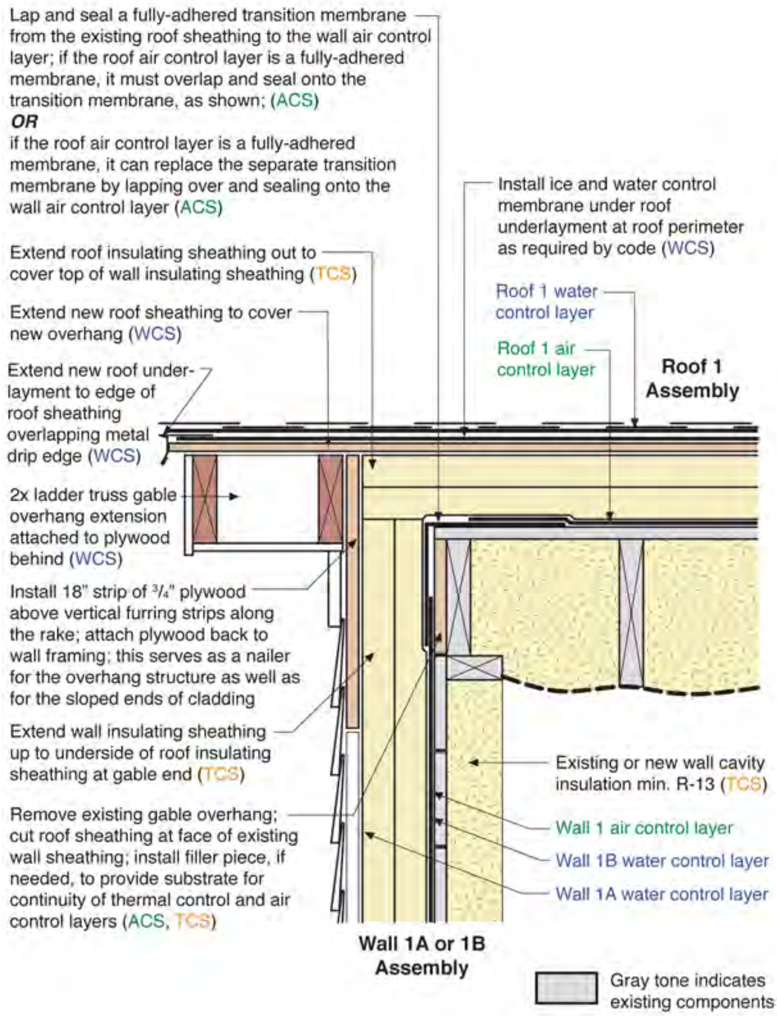
Roof 1 to Wall 1 (Chainsaw)—Eave

- This transition applies for both Wall 1A and Wall 1B
- This transition only applies if the rafter tails can be cut off without compromising the roof framing structure.
- Chainsaw air control and thermal control functions are more robust than those for the non-chainsaw retrofit.



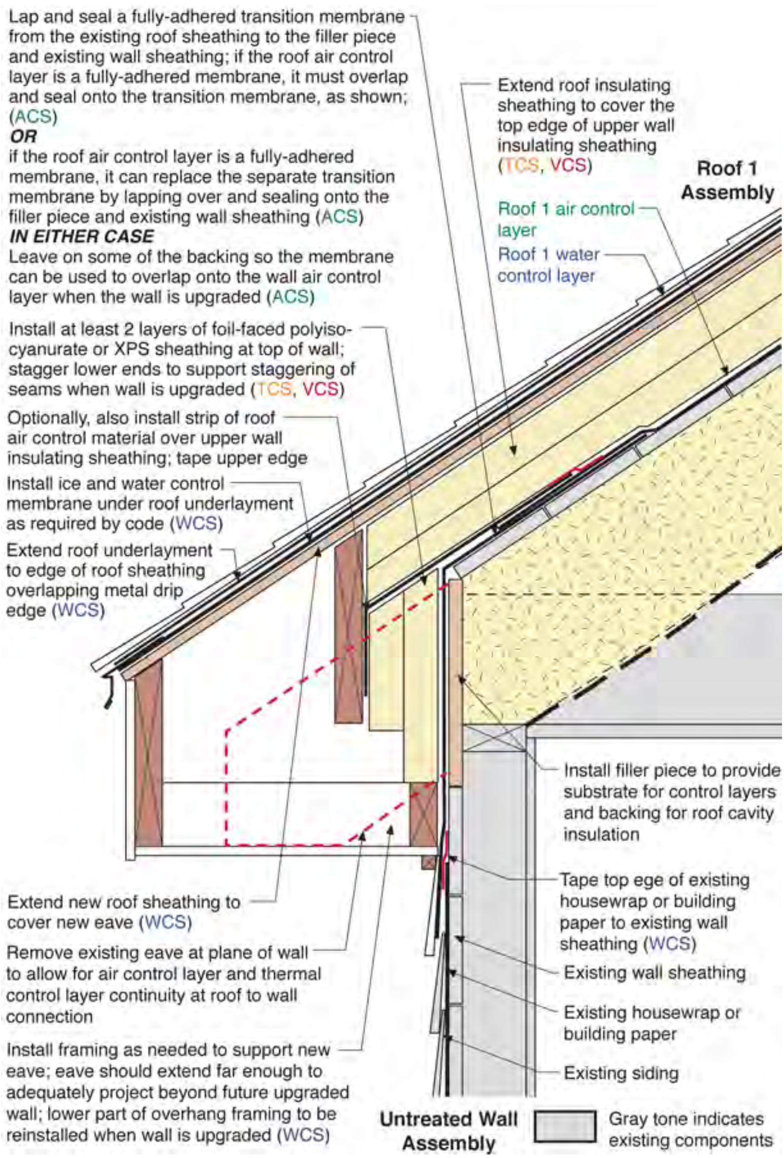
Roof 1 to Wall 1 (Non-Chainsaw)—Eave

- This transition applies for both Wall 1A and Wall 1B
- This transition is to be used if roof framing structure cantilevers beyond the walls.
- Some existing insulation at the top of the exterior wall may need to be removed so that the closed-cell spray foam establishes a seal with the back side of the wall sheathing.



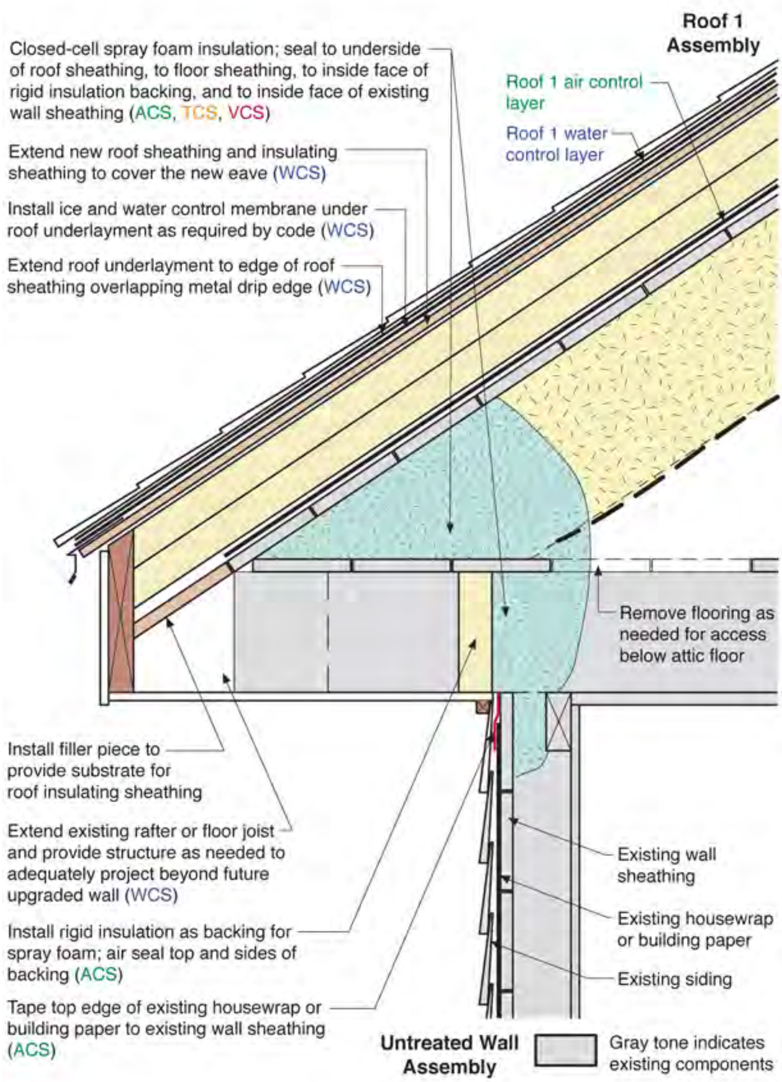
Roof 1 to Wall 1—Rake

- This transition applies for both Wall 1A and Wall 1B.
- Even if the attic is unfinished space, cavity insulation of the gable wall is required; if closed-cell spray foam is used, it should be limited to a thickness of 1" so that the wall can dry to the interior.



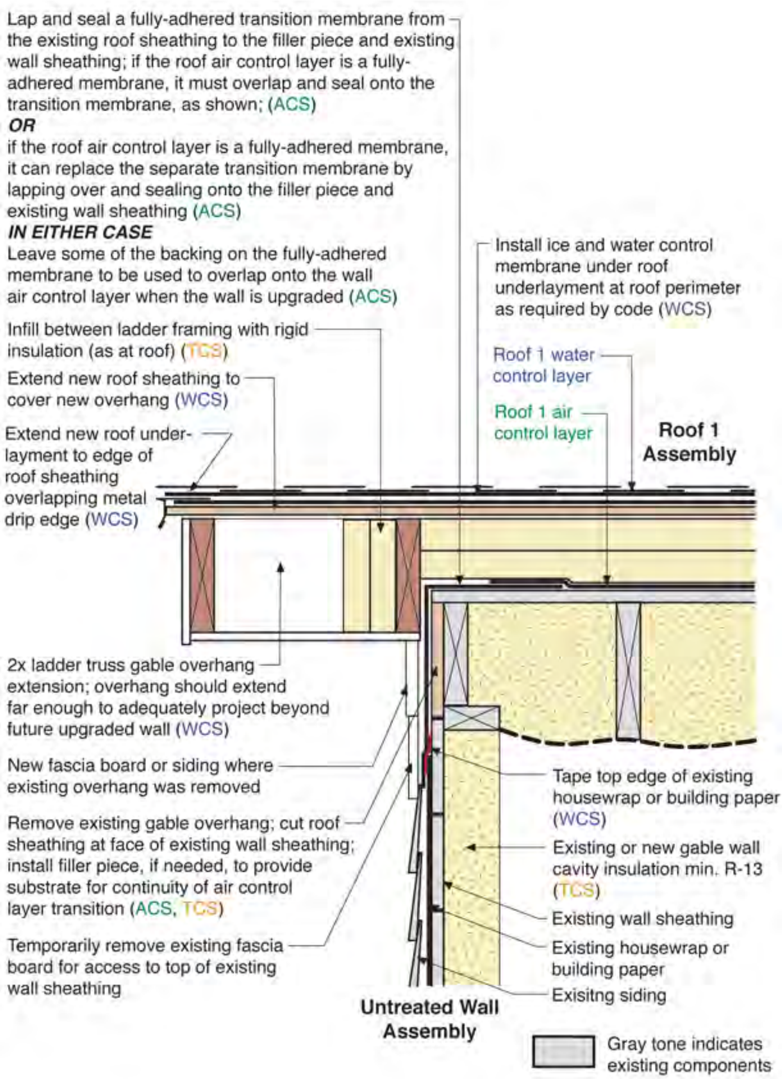
Roof 1 to Untreated Wall (Chainsaw)—Eave

- This transition only applies if the rafter tails can be cut off without compromising the roof framing structure.
- Chainsaw air control and thermal control functions are more robust than those for the non-chainsaw retrofit.
- The insulating sheathing installed at the top of the wall should be as thick as the insulating sheathing that will be used for the upgraded wall.



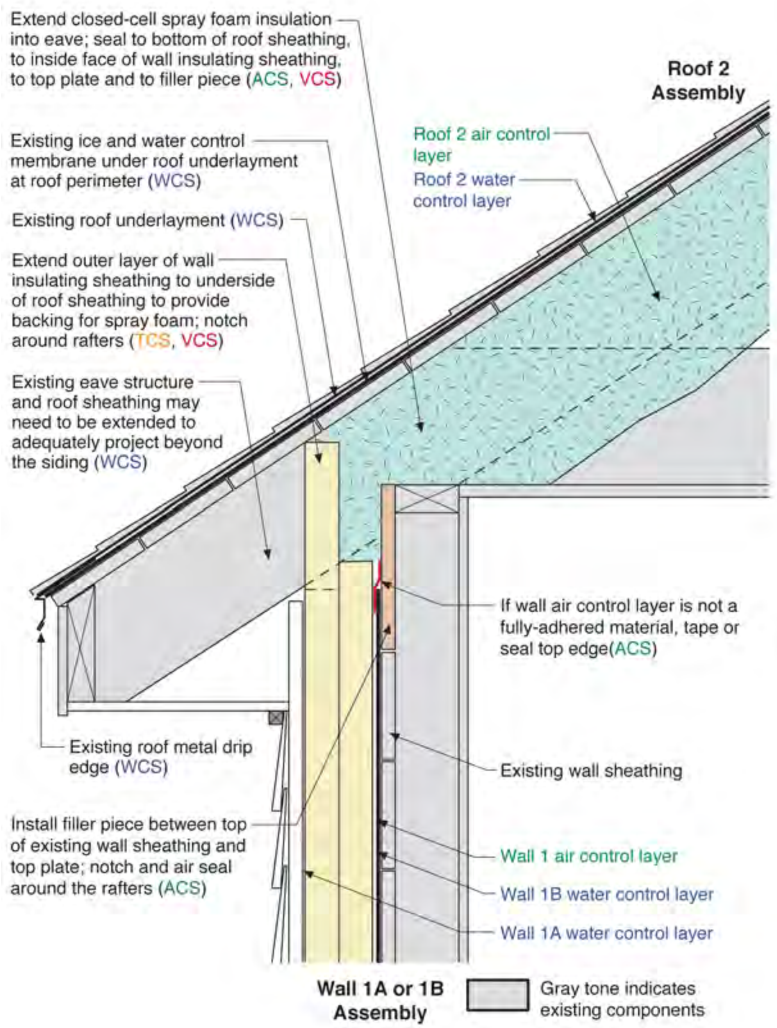
Roof 1 to Untreated Wall (Non-Chainsaw)—Eave

- This transition is to be used if roof framing structure cantilevers beyond the walls.
- Some existing insulation at the top of the exterior wall may need to be removed so that the closed-cell spray foam establishes a seal with the back side of the wall sheathing.



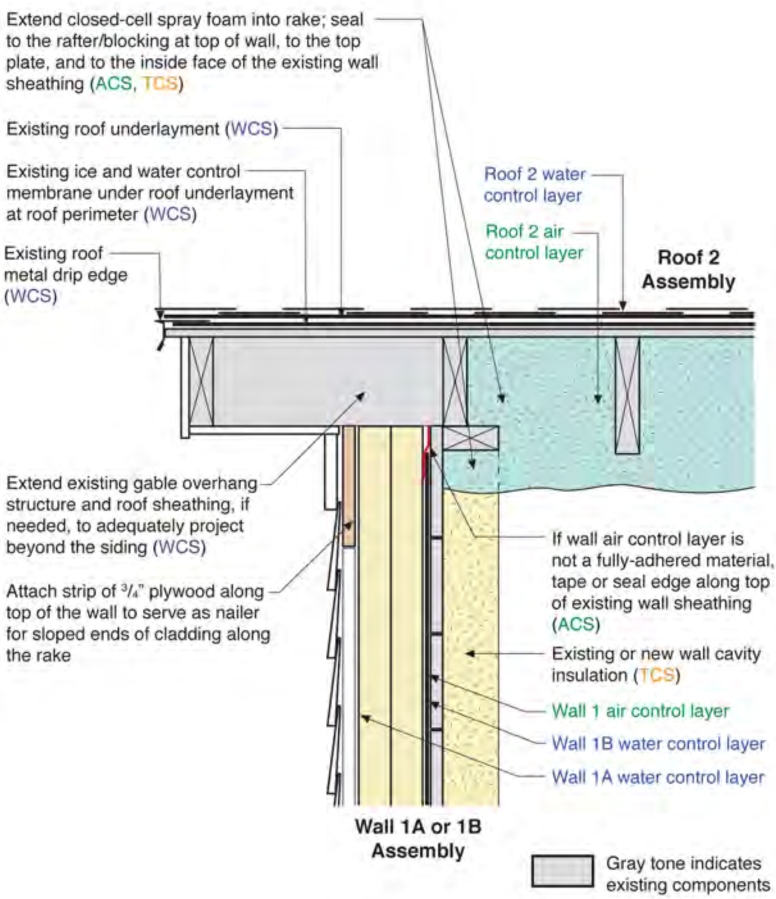
Roof 1 to Untreated Wall—Rake

- Even if the attic is unfinished space, cavity insulation of the gable wall is required; if closed-cell spray foam is used, it should be limited to a thickness of 1” so that existing condition for drying to the inside is not changed
- Temporarily remove siding at top of wall as needed for access to the existing housewrap or building paper.



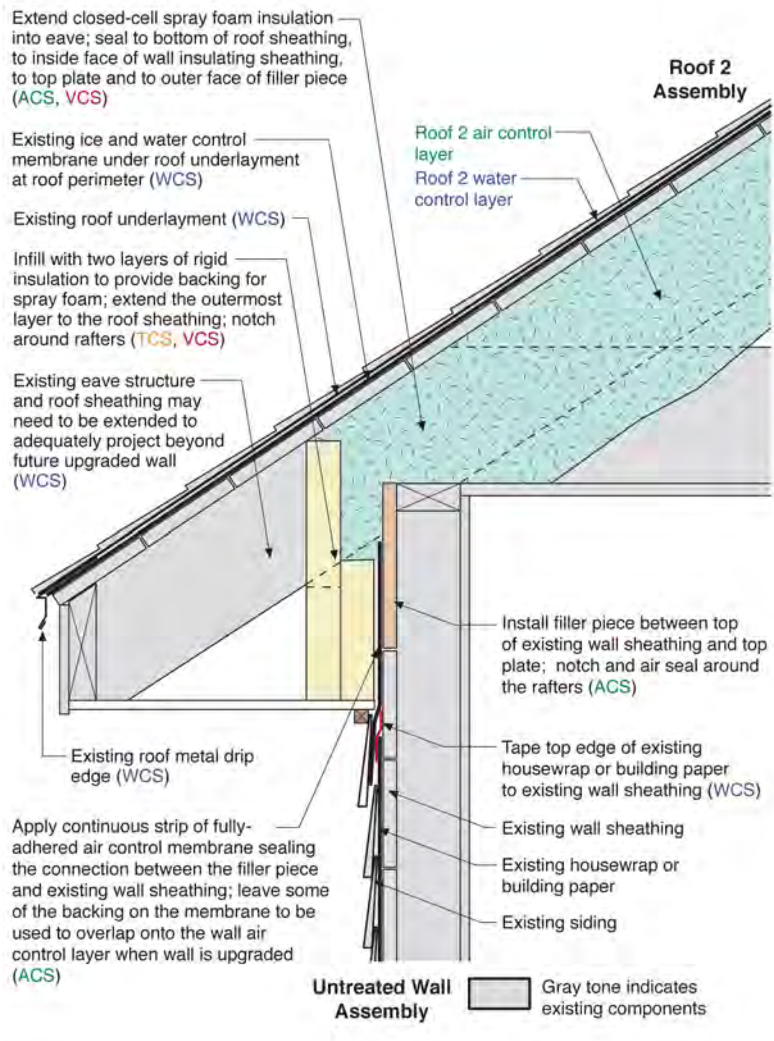
Roof 2 to Wall 1—Eave

- This transition applies for both Wall 1A and Wall 1B.

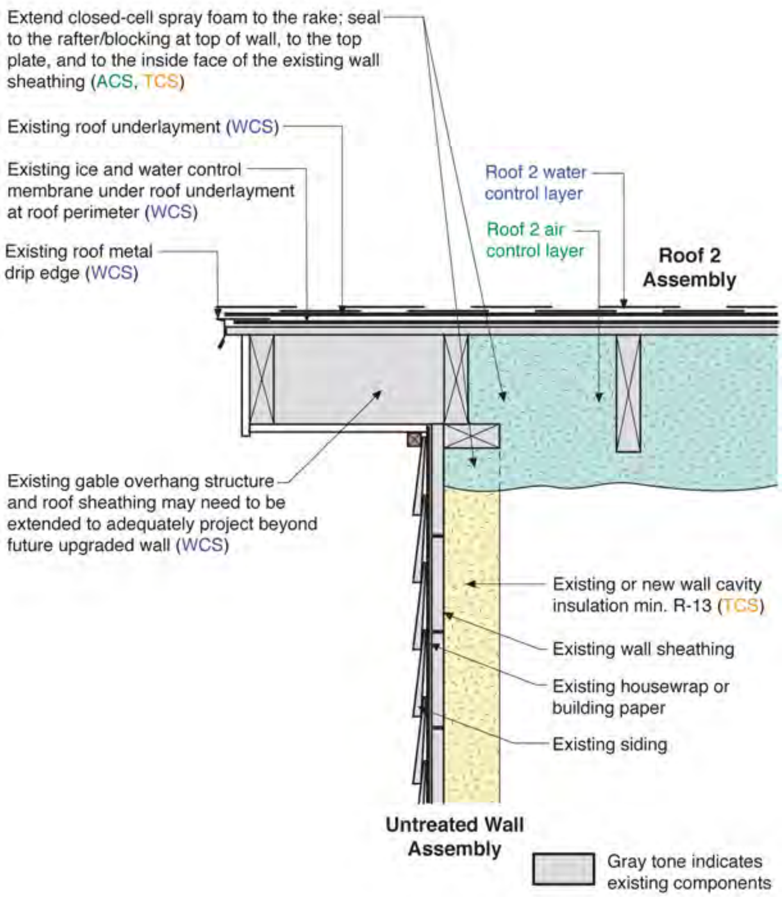


Roof 2 to Wall 1—Rake

- This transition applies for both Wall 1A and Wall 1B.
- If the gable has existing insulation, some of this must be removed at the top so the closed-cell spray foam establishes a seal with the back side of the existing wall sheathing.
- Even if the attic is unfinished space, cavity insulation of the gable wall is required; if closed-cell spray foam is used in the gable wall cavity, it should be limited to a thickness of 1" so that the wall can dry to the interior.

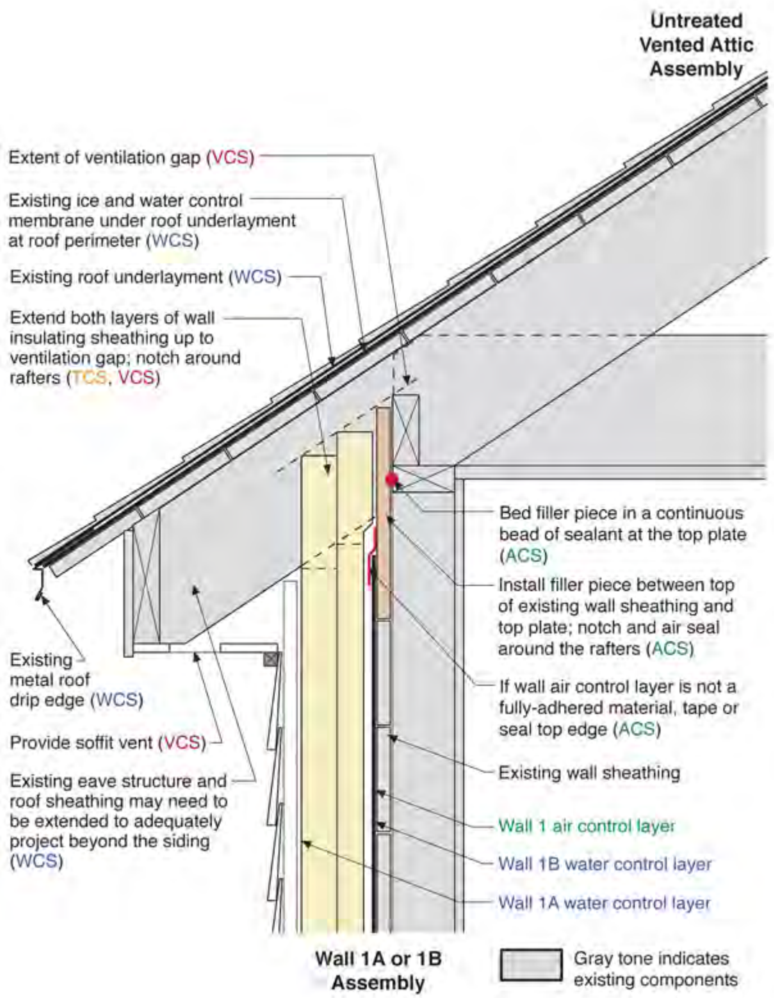


Roof 2 to Untreated Wall—Eave



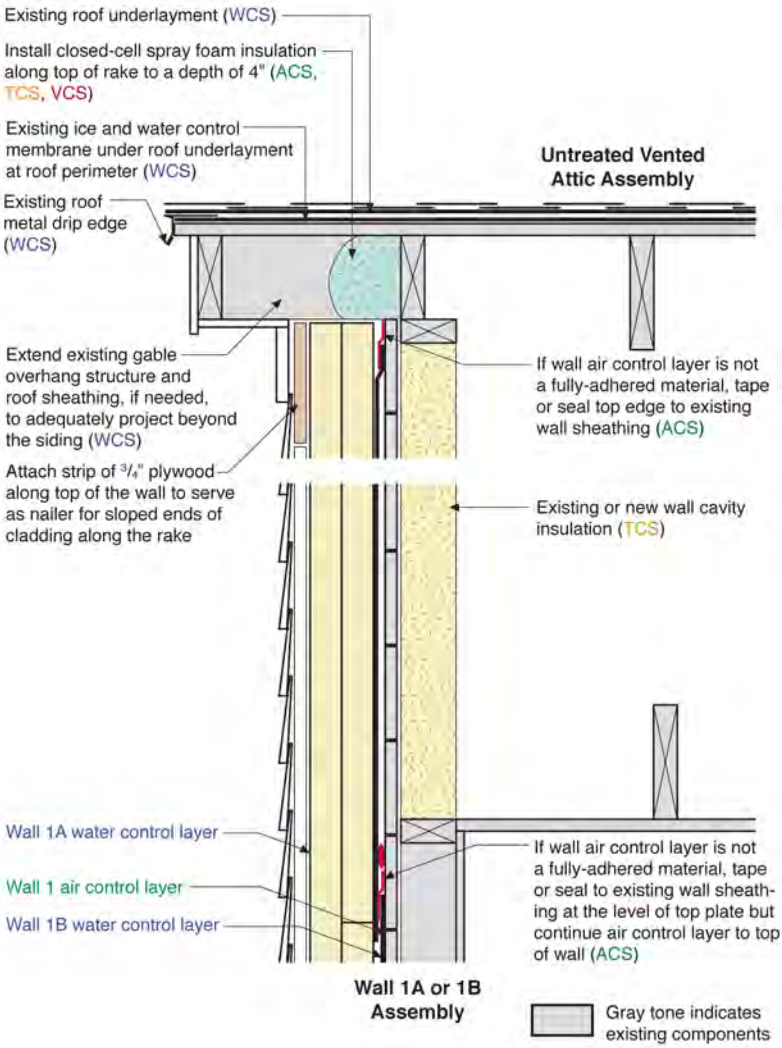
Roof 2 to Untreated Wall—Rake

- If the gable has existing insulation, some of this must be removed at the top so the closed-cell spray foam establishes a seal with the back side of the existing wall sheathing.
- Even if the attic is unfinished space, cavity insulation of the gable wall is required; if closed-cell spray foam is used in the gable wall cavity, it should be limited to a thickness of 1” so that existing conditions for drying to the inside are not changed.



Untreated Roof/Attic to Wall 1—Eave

- This transition applies for both Wall 1A and Wall 1B.
- If the untreated attic/roof is vented, the top of the insulating sheathing must be cut back to maintain the existing ventilation gap.



Untreated Roof/Attic to Wall 1—Rake

- This transition applies for both Wall 1A and Wall 1B.
- Even if the attic is unfinished space, cavity insulation of the gable wall is required; if closed-cell spray foam is used in the gable wall cavity, it should be limited to a thickness of 1” so that the wall can dry to the interior.

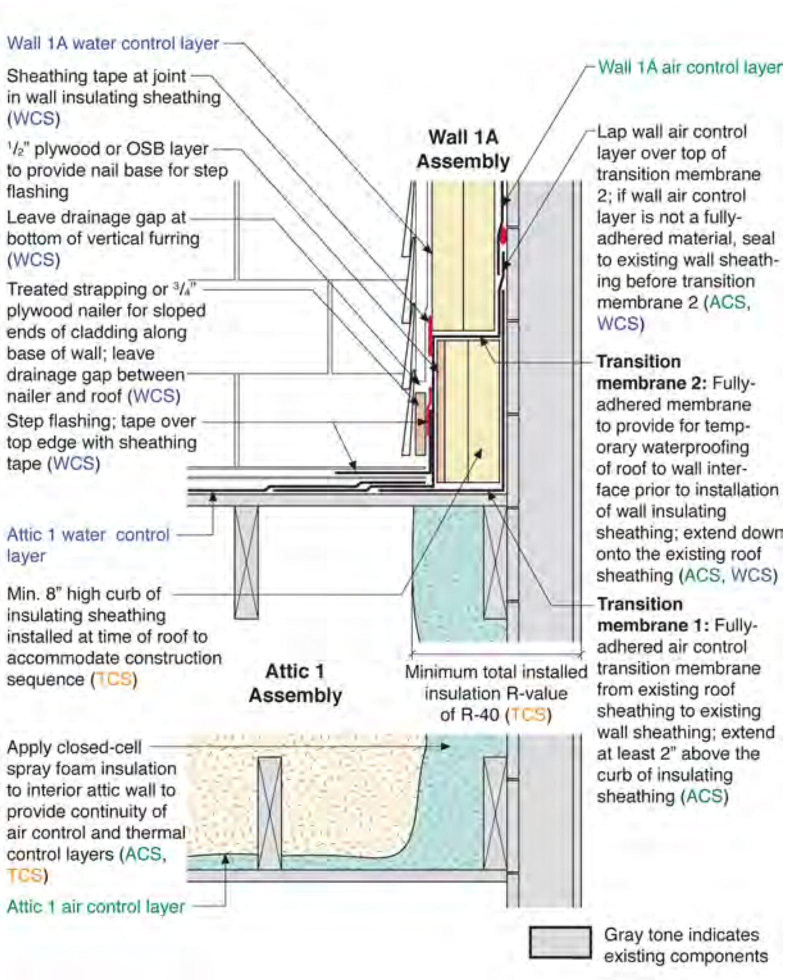
Exterior Frame Wall-to-Lower Roof

A wall-to-lower roof intersection occurs, for example, where a one story portion of a home meets a 2 story portion and where the walls of a dormer meet the roof.

Effective transitions in this type of intersection have been particularly problematic in high performance and DER projects because the proper location and sequencing of roof to wall flashing is "not the way we usually do it." In other words, careful coordination is going to be needed between contractors and roofing subcontractors to implement details that are different than what is done in "conventional" construction and renovation. It is also likely that planning and advanced preparation will be required.

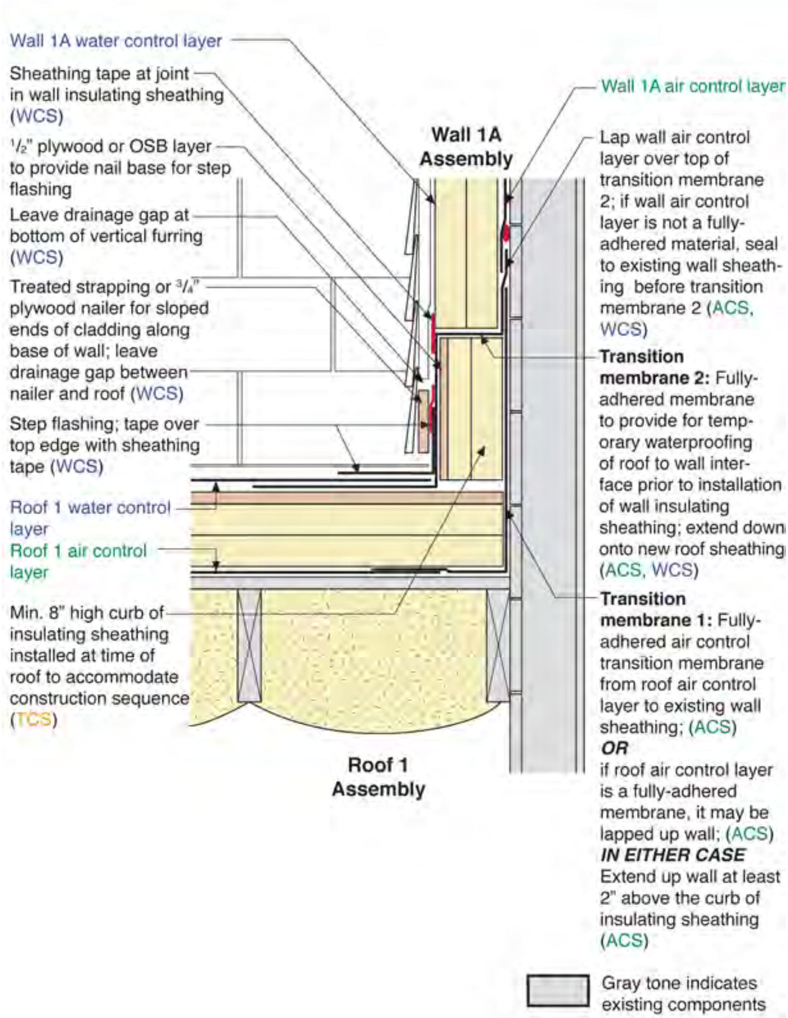
When the water control layer of the wall is at the outer face of the insulating sheathing, the roof flashing must connect at the face of the insulating sheathing, not at the wall sheathing behind the insulation. This presents a sequence challenge if – as is usually the case – roofing is installed prior to the insulating sheathing and water control layer of the wall.

When the water control layer of the wall is located at the face of the existing wall sheathing and behind exterior insulation, the step flashing can be located at a familiar location (against the wall sheathing). However, kick-out flashing will need to anticipate the additional thickness of the insulation so that the kick-out diverts water beyond the face of wall cladding. Another consideration that factors into the design of the transition is future replacement of the roof. This will require access to the connection between the water control layer of roof and that of the wall – which is behind a thick layer of exterior insulation. Without clear access, a contractor replacing the roof at some point in the future might cut through the insulation layers (and probably the water control layer) or install the step flashing at the face of the foam insulation. Either of these would subvert the water control system implemented in the DER measure. A removable and labeled section of insulation just above the roof surface facilitates access to the step flashing.



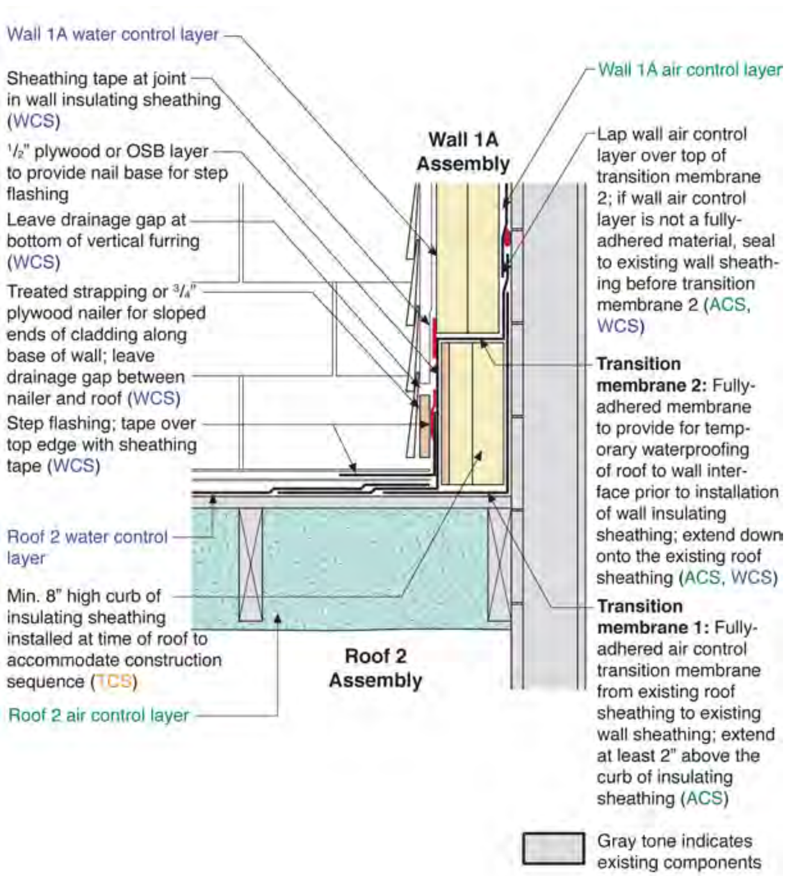
Wall 1A to Attic 1

- Curb of insulating sheathing is necessary to support installation of step and kickout flashing in the construction sequence.
- While, in general, Attic 1 does not require removal or replacement of roof shingles or underlayment, this transition does require removal of existing roof shingles and underlayment along the intersection with the upgraded wall.



Wall 1A to Roof 1

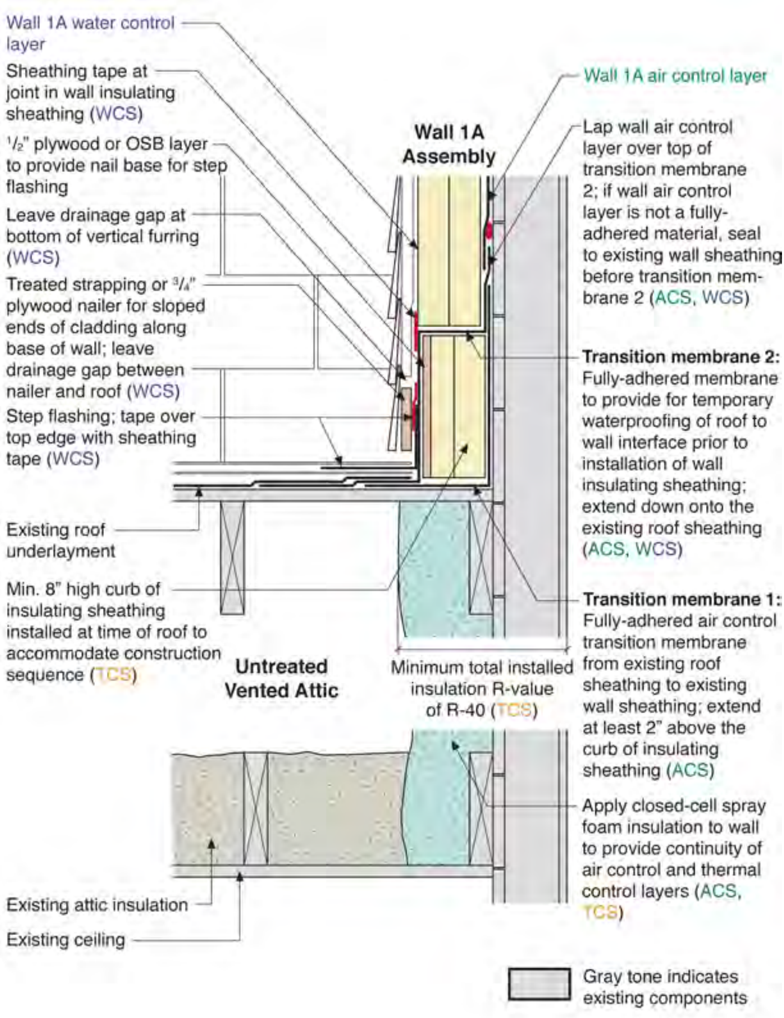
- Curb of insulating sheathing is necessary to support installation of step and kickout flashing in the construction sequence.



Wall 1A to Roof 2

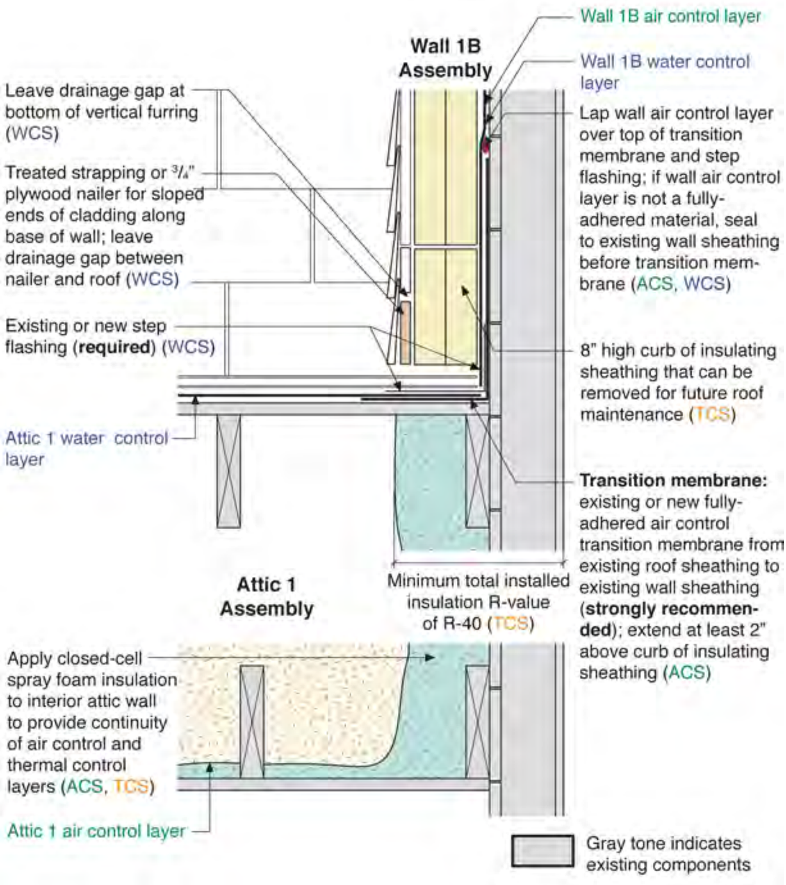
- Curb of insulating sheathing is necessary to support installation of step and kickout flashing in the construction sequence.
- While, in general, Roof 2 does not require removal or replacement of roof shingles or underlayment, this transition does require removal of existing roof shingles and underlayment along the intersection with the upgraded wall

.



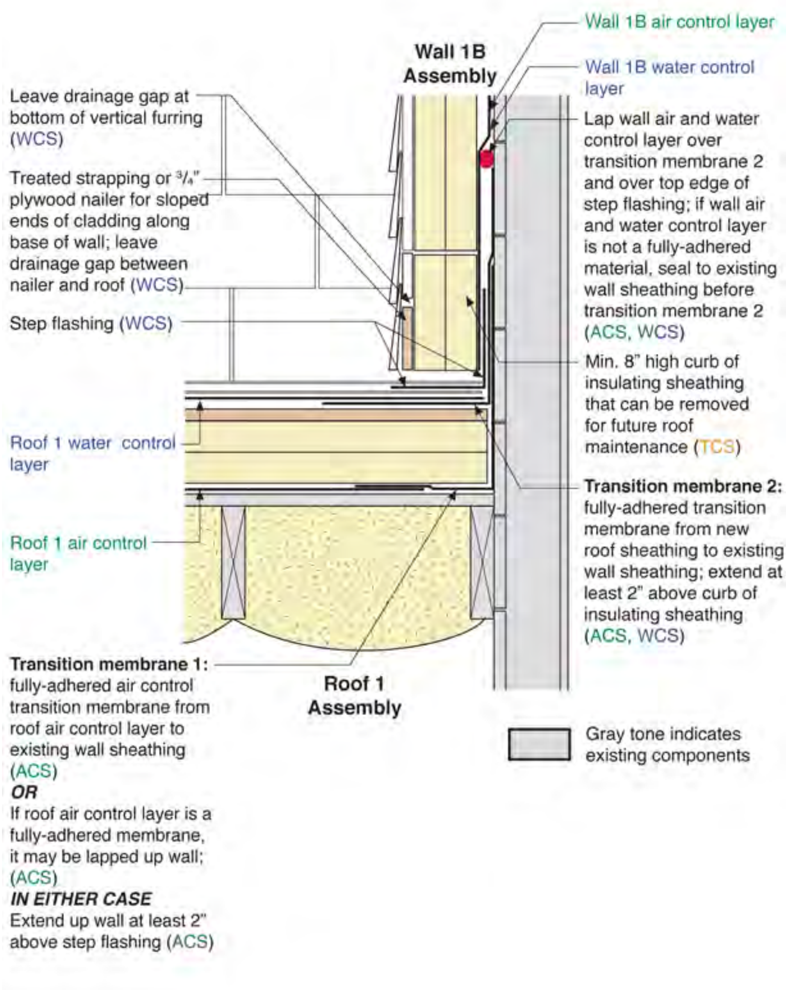
Wall 1A to Untreated Roof/Attic

- Curb of insulating sheathing is necessary to support installation of step and kickout flashing in the construction sequence.
- Existing attic floor insulation at the wall in the attic space needs to be temporarily removed to allow a continuous application of the closed cell spray foam from the roof sheathing down to the top of the ceiling below the attic floor joists.



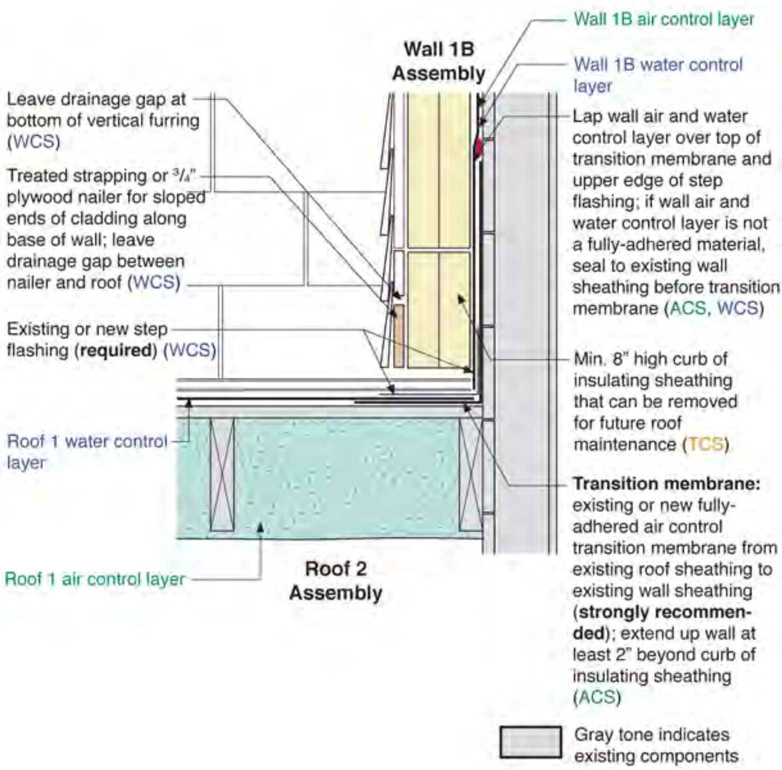
Wall 1B to Attic 1

- Curb of insulating sheathing is provided to allow access to step flashing during re-roofing of lower roof at a future date.



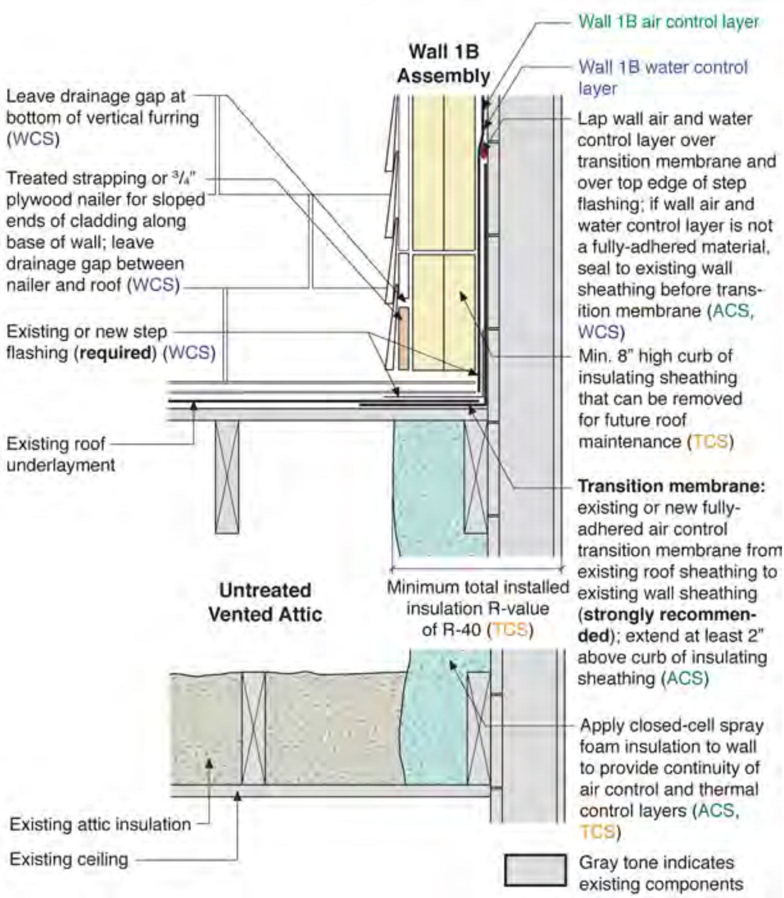
Wall 1B to Roof 1

- Curb of insulating sheathing is provided to allow access to step flashing during re-roofing of lower roof at a future date.



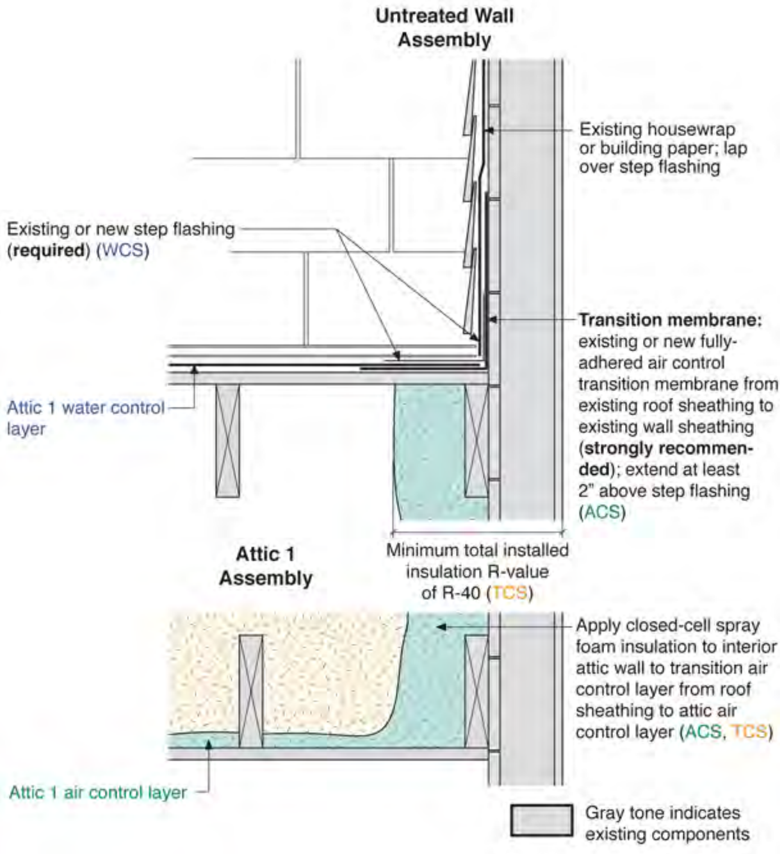
Wall 1B to Roof 2

- Curb of insulating sheathing is provided to allow access to step flashing during re-roofing of lower roof at a future date.
- While, in general, Roof 2 does not require removal or replacement of roof shingles or underlayment, if there is no transition membrane at the intersection of existing roof and wall sheathing, failure to provide one will compromise the air control at the lower roof to wall connection.



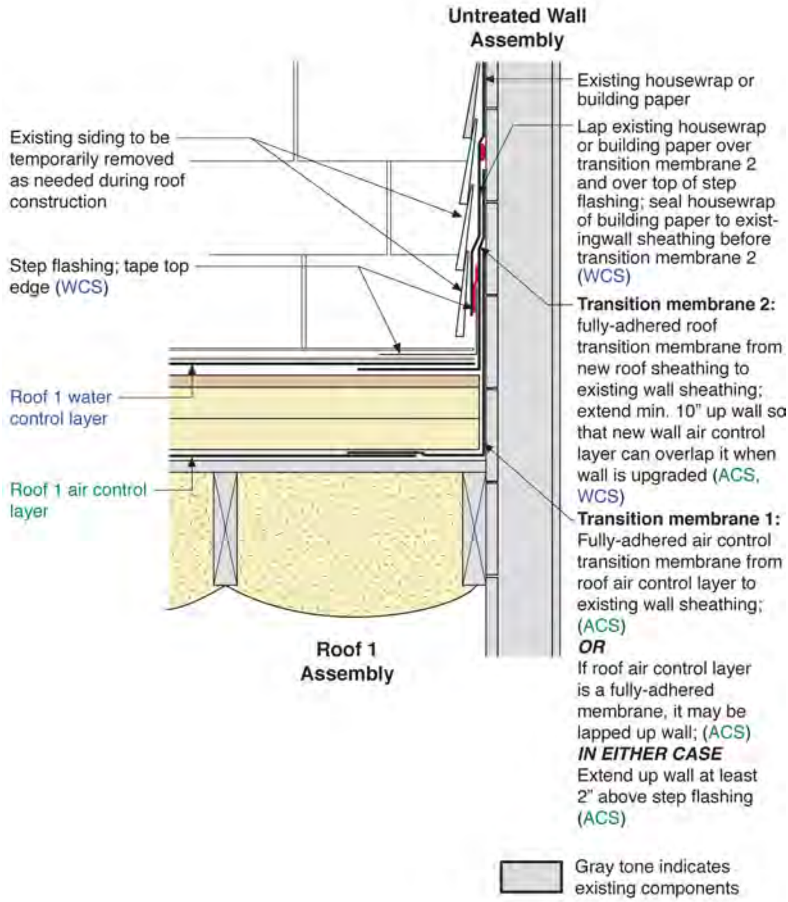
Wall 1B to Untreated Roof/Attic

- Curb of insulating sheathing is provided to allow access to step flashing during re-roofing of lower roof at a future date.
- Existing attic floor insulation at the wall in the attic space needs to be temporarily removed to allow a continuous application of the closed cell spray foam from the roof sheathing down to the top of the ceiling below the attic floor joists.

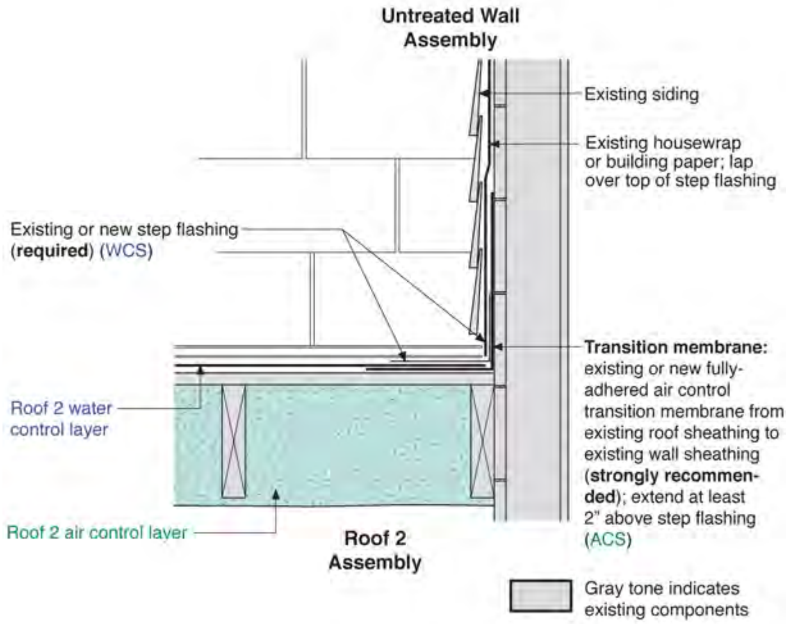


Untreated Wall to Attic 1

- If there is no transition membrane at the existing wall to roof intersection, failure to provide one in the scope of the DER project increases the risk of air leakage at that intersection.



Untreated Wall to Roof 1



Untreated Wall to Roof 2

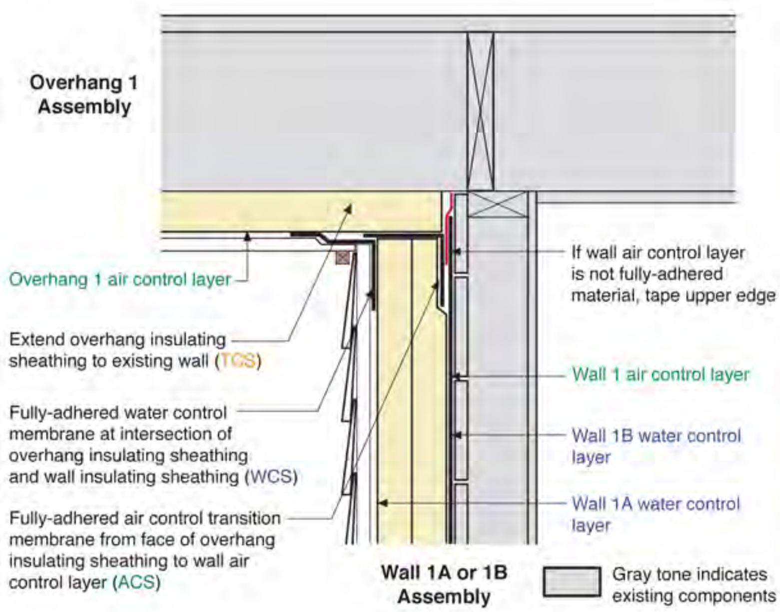
- If there is no transition membrane at the existing wall to roof intersection, failure to provide one in the scope of the DER project may increase the risk of air and/or water leakage at that intersection.

Transitions Involving Overhanging Floor

At the base of a wall adjacent to an overhanging floor, the water control of the wall must terminate in a way that directs water away from the building. The overhang protects the top of the wall beneath the overhang from rain water just as the overhang of a roof so the water control of the wall above the overhang need not connect to the water control of the wall below. Splash back onto the surface of the overhanging floor assembly may be a concern for overhanging floors located close to grade.

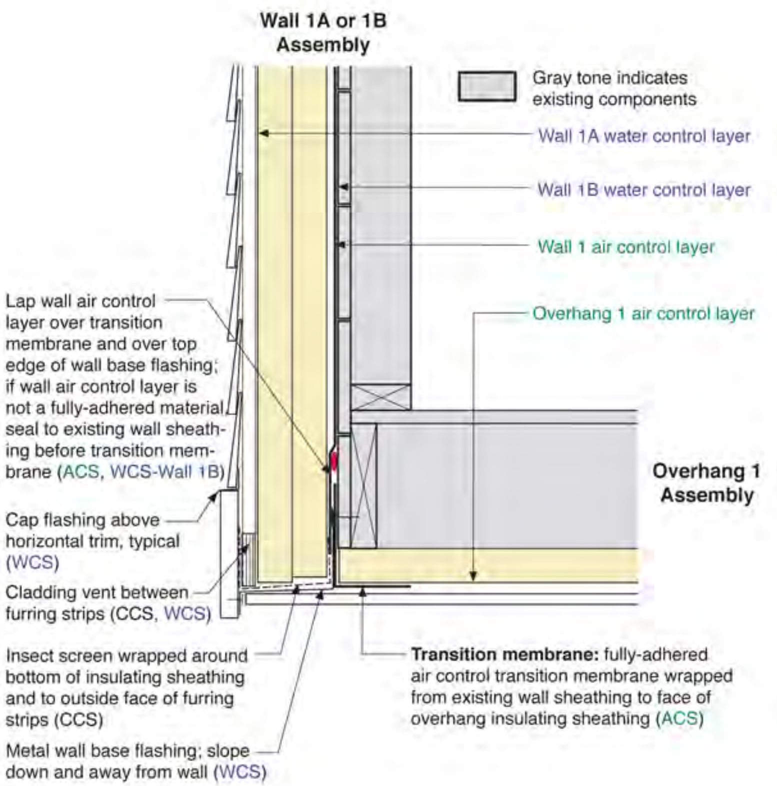
Maintaining continuity of the other building enclosure control functions can be challenging at overhanging floors. At the building side, the overhanging floor might return to an exterior frame wall assembly or a foundation wall. This section presents schematic details that will be applicable to *many* but not all overhanging floor conditions. As with the roof-wall transitions, effective continuity of the air control will rely on careful implementation and an understanding of the many connections that must be made airtight in order to connect the air control layer of the wall above the overhang to that of the overhang itself and on to the wall or foundation beneath the overhang.

The underside of the overhanging floor might receive a finish material or be left unfinished. If left unfinished, the overhanging floor assembly will still need to be protected. Where the overhanging floor is close to grade and not protected with a solid finish material, some other means of critter protection must be provided.



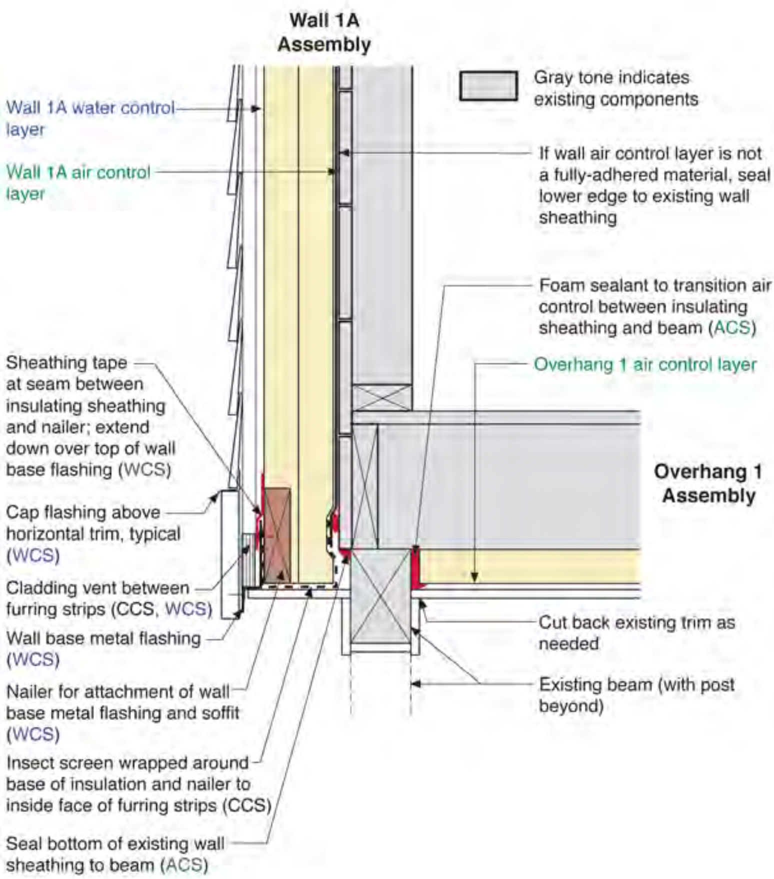
Wall 1 to Overhanging Floor 1 at Inside Corner

- This transition applies for Wall 1A and Wall 1B.

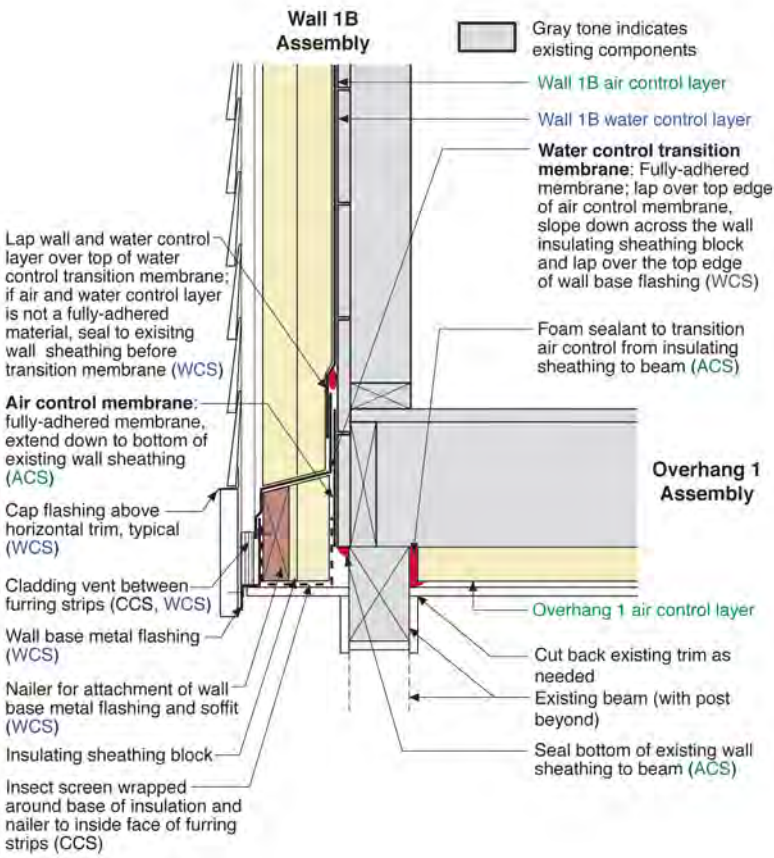


Wall 1 to Overhanging Floor 1 at Outside Corner

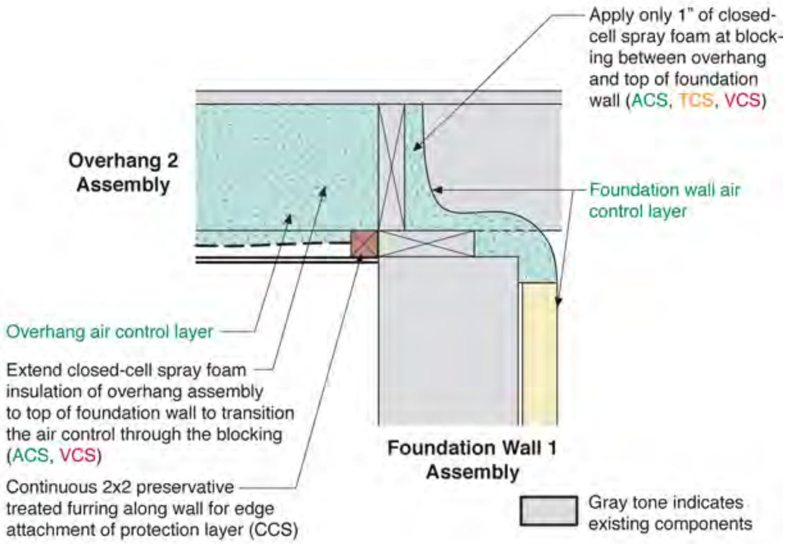
- This transition applies for Wall 1A and Wall 1B.



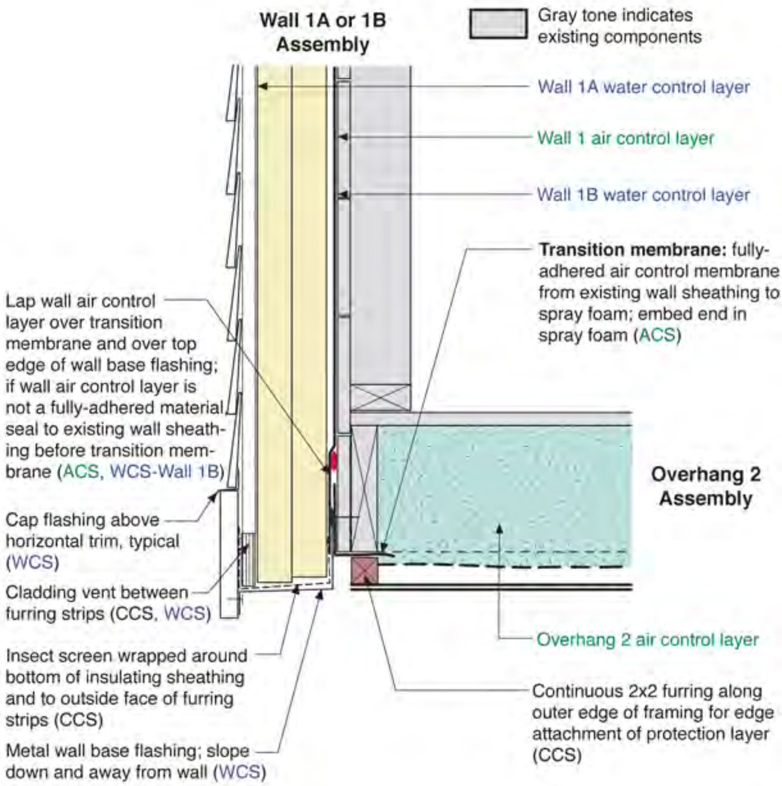
Wall 1A to Overhanging Floor 1 with Beam at Outside Corner



Wall 1B to Overhanging Floor 1 with Beam at Outside Corner



Foundation Wall 1 to Overhanging Floor 2 at Inside Corner



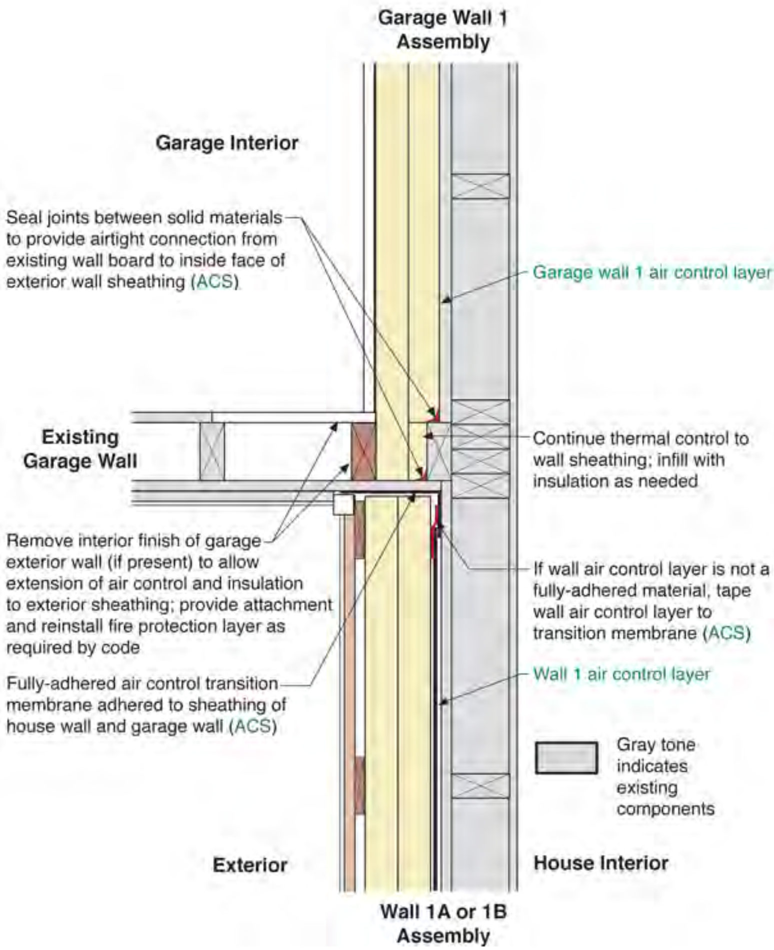
Wall 1 to Overhanging Floor 2 at Outside Corner

- This transition applies for Wall 1A and Wall 1B.

Transitions Involving Garage Enclosures

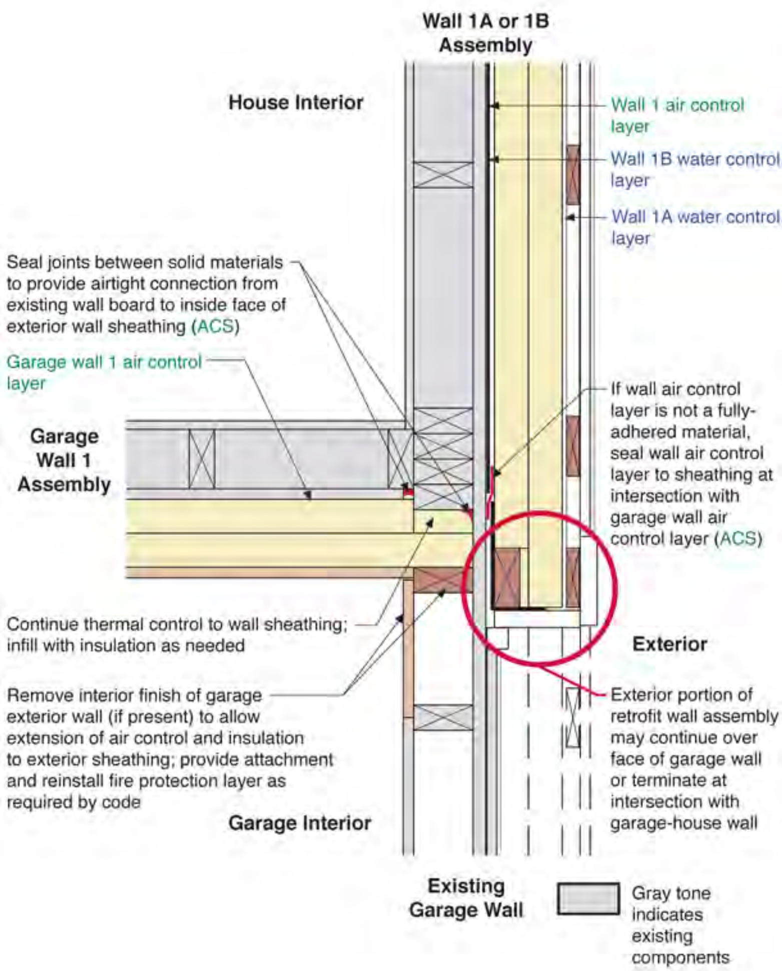
The most important building enclosure function for the separations between living space and the garage is air control. This is because air control is necessary for a health and safety with respect to attached garages. Water control is not needed because the garage is, by nature, protected from the weather. Assemblies separating the garage from living space have (or, should have) a fire protection layer. The retrofit assemblies for the garage-house separation use this layer as the air control layer. This layer may be able to provide air control in the field of the wall or in the field of the ceiling above a garage, but it is unlikely that this layer continues to surrounding wall or roof sheathing. Certainly, it would not be expected to be sealed to the adjacent sheathing or, in the case of the house-garage wall, the foundation. Providing air control that is continuous all the way to exterior wall sheathing (for a ceiling over a garage or wall between house and garage), foundation, or roof sheathing that bounds the house-garage separation is crucial.

It is also important to limit thermal bridging by making the thermal control layer (insulation) as continuous as possible at the intersection of assemblies. While in some cases it is possible to pursue a “chainsaw” type approach to the garage – where the sheathing and framing are removed to allow control layers to continue uninterrupted from the exterior wall to the garage-house wall – this guide presents details that assume the sheathing and structure is remaining in place. Transitions around an attached garage enclosure may involve transitions from insulated to uninsulated assemblies. Treatment at the perimeter of the garage-house separation assemblies does not change. Insulated retrofit assemblies intersecting a garage enclosure, however, will require special attention for proper termination of control layers.



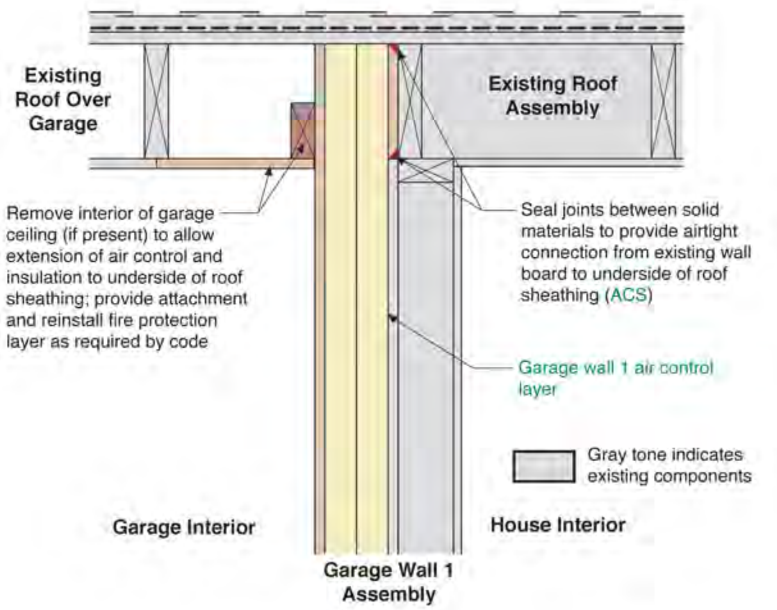
Garage Wall 1 to Wall 1/Garage Exterior—Plan View

- This transition applies for Wall 1A and Wall 1B.
- The project may choose to cut back the existing garage wall where it meets the house wall and extend the exterior insulating sheathing through the intersection; this requires a continuous transition between the Wall 1 air control layer and the Garage Wall air control layer.



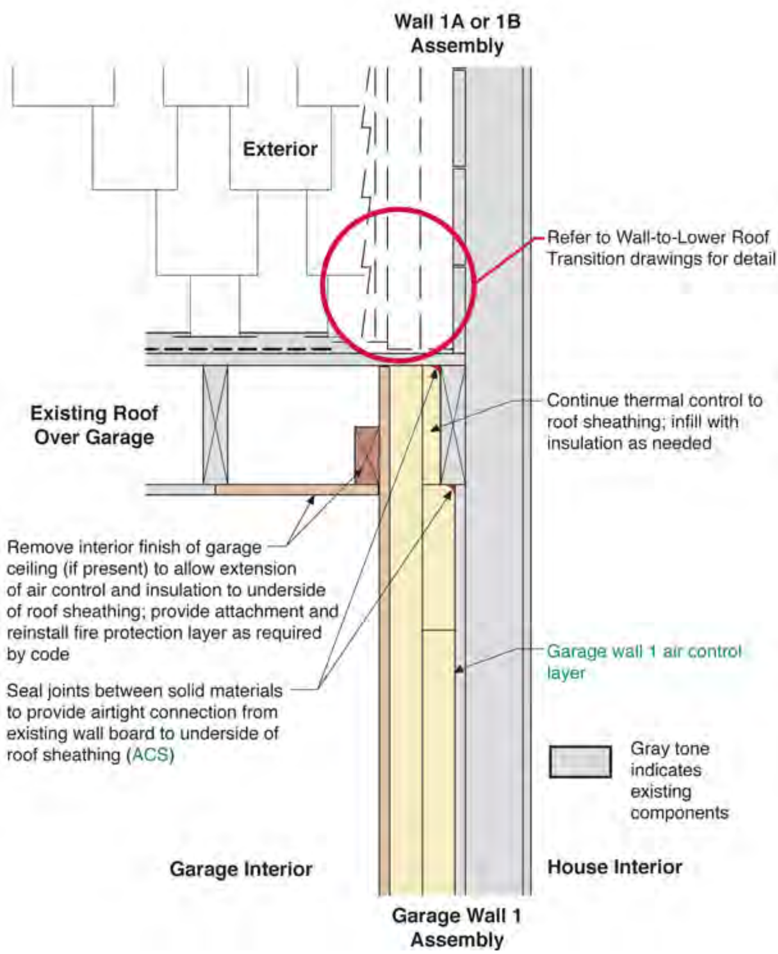
Garage Wall 1 to Wall 1/Garage Exterior Intersection—Plan View

- This transition applies for Wall 1A and Wall 1B.
- The project may choose to extend the retrofit wall along the exterior garage wall or may terminate the retrofit wall after the common retrofit wall between the garage and house interior.



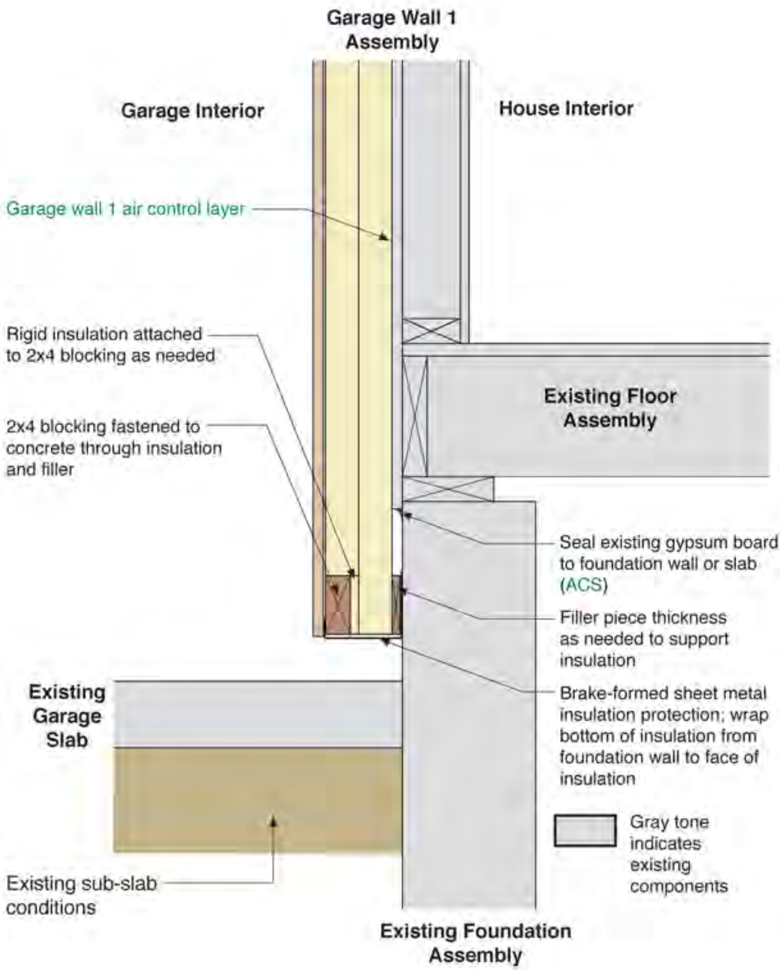
Garage Wall 1 to Roof (Shared Roof)

- This transition applies to any roof assembly for which the air control layer of the roof assembly is at the roof sheathing and is sealed to the roof sheathing at the top of the common garage/house wall.



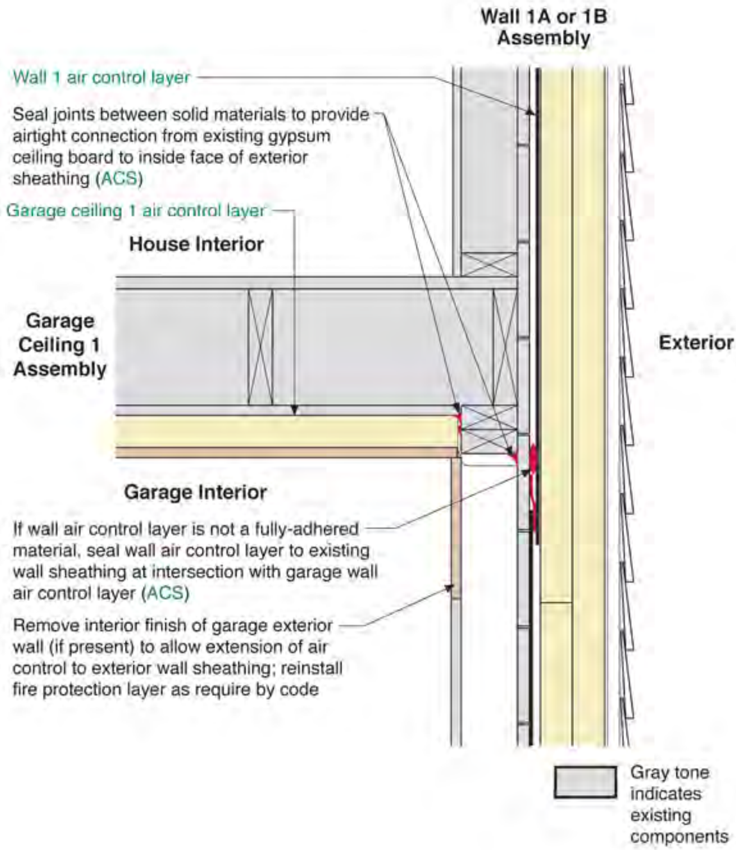
Garage Wall 1 to Garage Roof/Wall 1

- This transition applies for Wall 1A or Wall 1B.



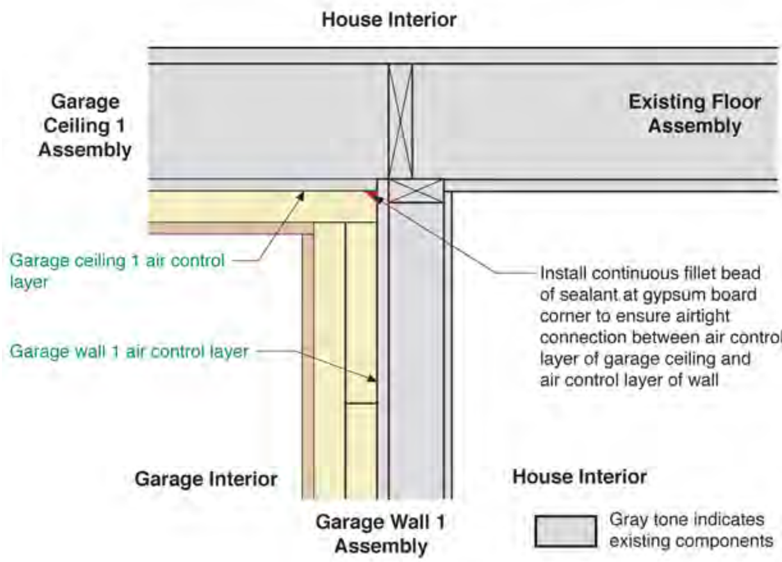
Garage Wall 1 to Foundation Wall

- This transition applies for any foundation wall
- Garage Wall 1 exterior insulation can be terminated above garage slab. Continuing to slab requires the use of preservative treated blocking.



Garage Ceiling 1 to Uninsulated Garage Wall/Wall 1

- This transition applies for Wall 1A or Wall 1B.



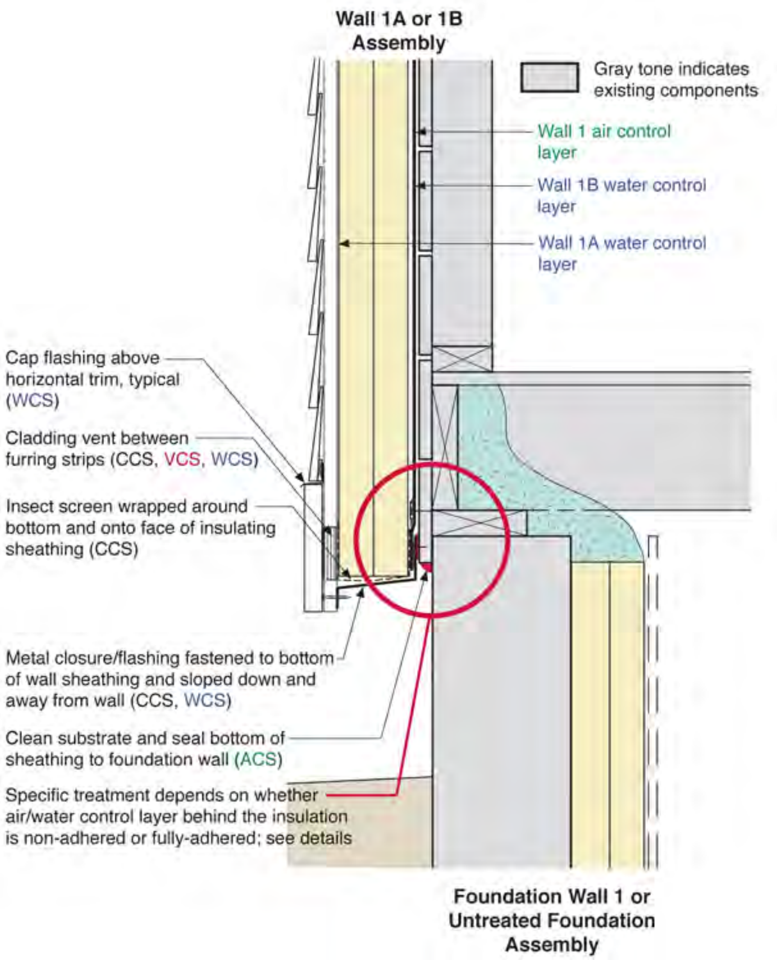
Garage Ceiling 1 to Garage Wall 1

Exterior Frame Wall-to-Foundation Wall

At the base of the frame wall, the water control layer of the wall must terminate in a way that directs water away from the building. The air control layer is transitioned either to the foundation wall (in the case of a flat foundation wall such as a cast concrete foundation wall) or to the framing sill (in the case of an irregular surface foundation wall such as one constructed of field stone or split block).

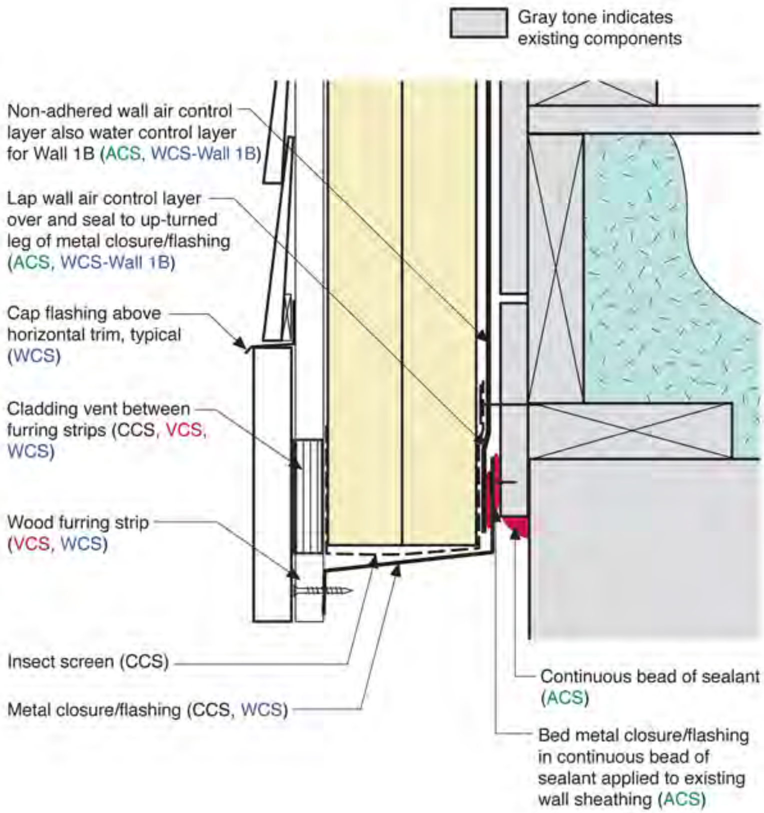
The transition details for the base of the wall are largely independent of the treatment to the inside of the foundation wall. The transition details are impacted by whether the wall air control layer is fully-adhered or non-fully-adhered. In the case of a frame wall-to-foundation wall transition where the base of the wall must promote drying to the exterior, the transition details are most impacted by whether or not the air control layer of the wall is vapor permeable.

Note that the frame wall-to-foundation wall transition is where "critter control" is important.



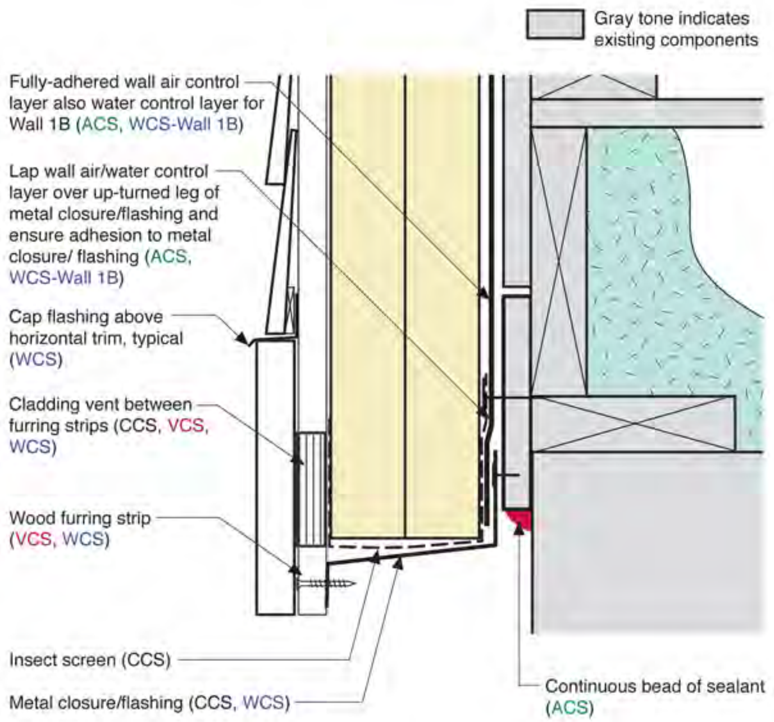
Wall 1 to Foundation Wall 1 or Untreated Flat Foundation Wall

- This transition drawing applies for Wall 1A and Wall 1B.
- Protection of the above-grade wall structure from termites relies upon a clear separation distance between the ground and the wall structure.



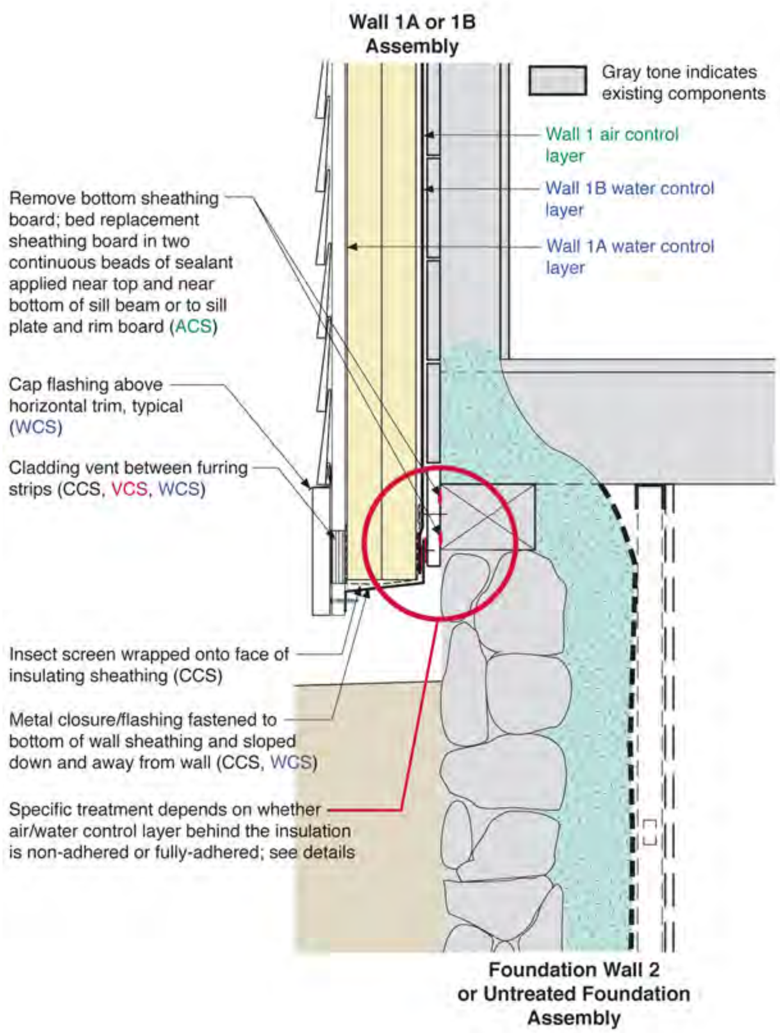
Wall 1 to Foundation Wall 1 or Untreated Flat Foundation Wall–Detail for Non-Adhered Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



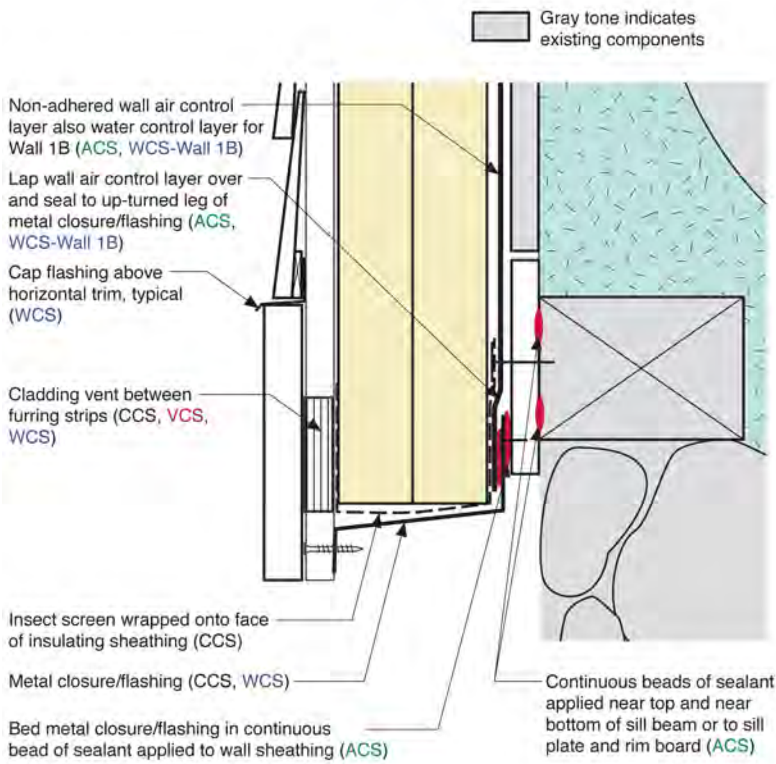
Wall 1 to Foundation Wall 1 or Untreated Flat Foundation Wall–Detail for Fully-Adhered Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



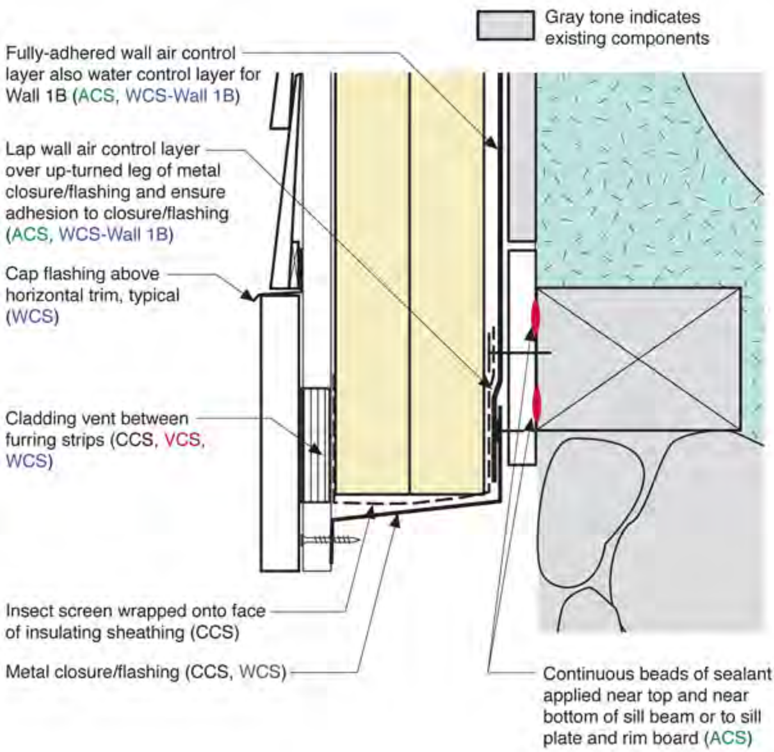
Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall

- This transition drawing applies for Wall 1A and Wall 1B.
- Protection of the above-grade wall structure from termites relies upon a clear separation distance between the ground and the wall structure
- The bottom sheathing board must be removed to provide air control transition from the retrofit foundation wall, through the sill, to the retrofit wall.
- When the bottom sheathing board is removed, inspect the sill for damage and repair/replace as needed.



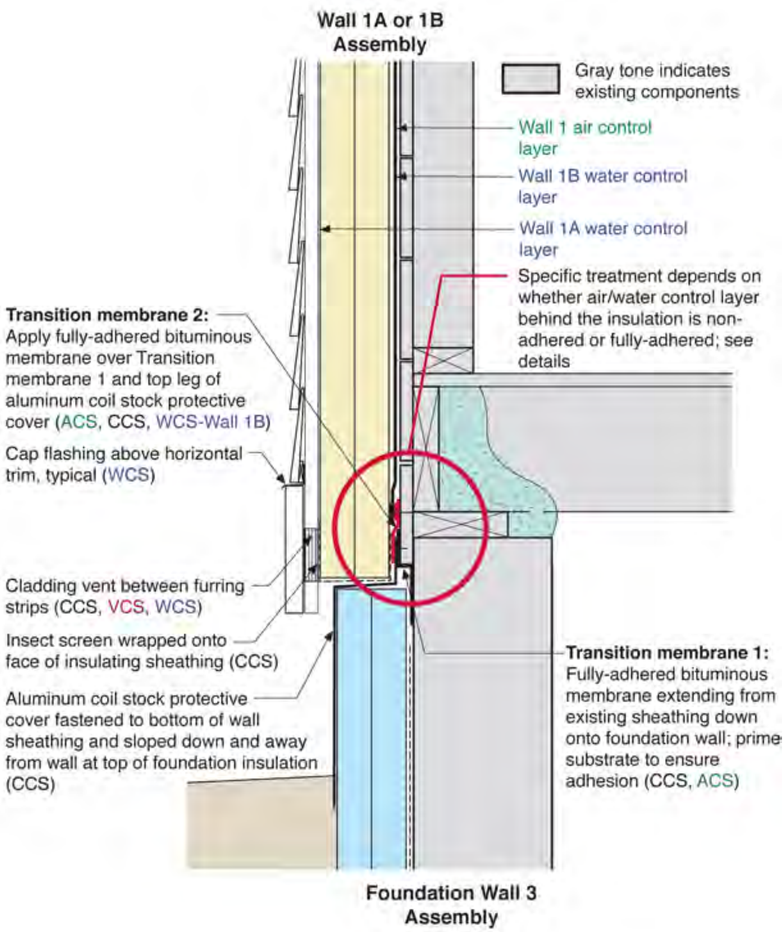
Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall–Detail for Non-Adhered Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



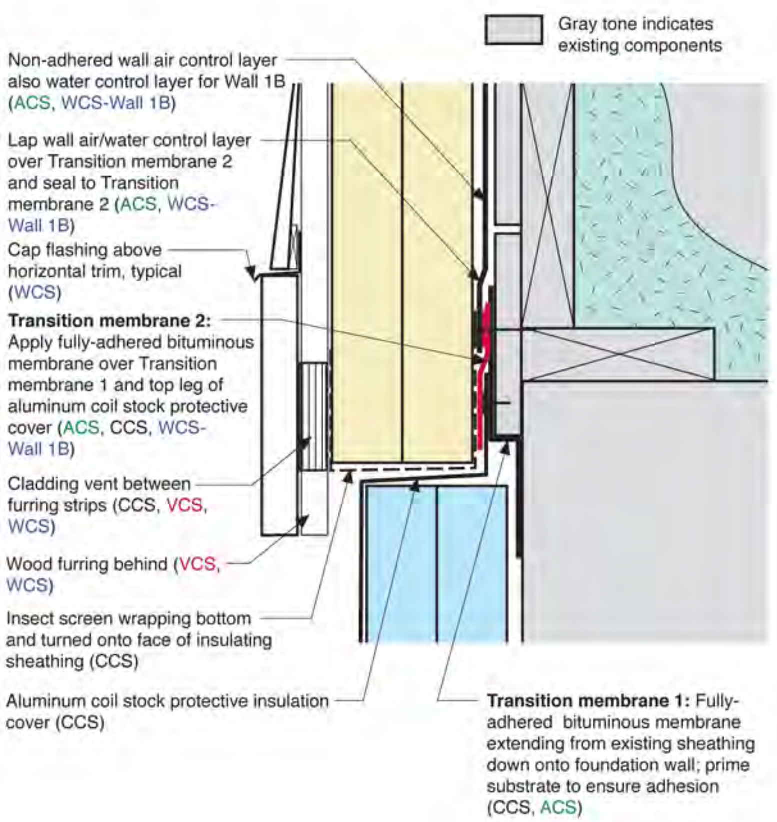
Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall–Detail for Fully-Adhered Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



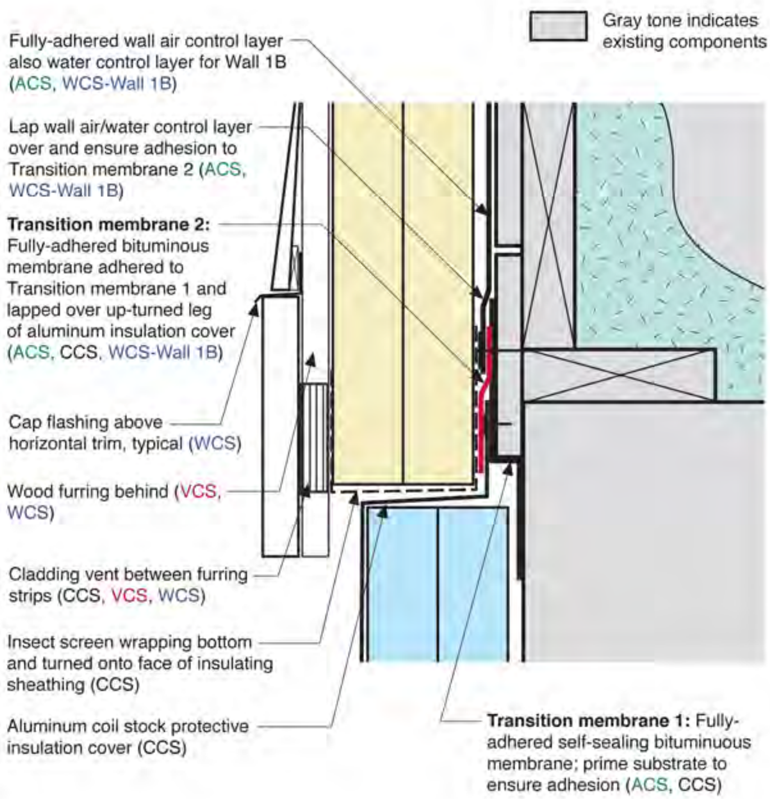
Wall 1 to Foundation Wall 3

- This transition drawing applies for Wall 1A and Wall 1B.



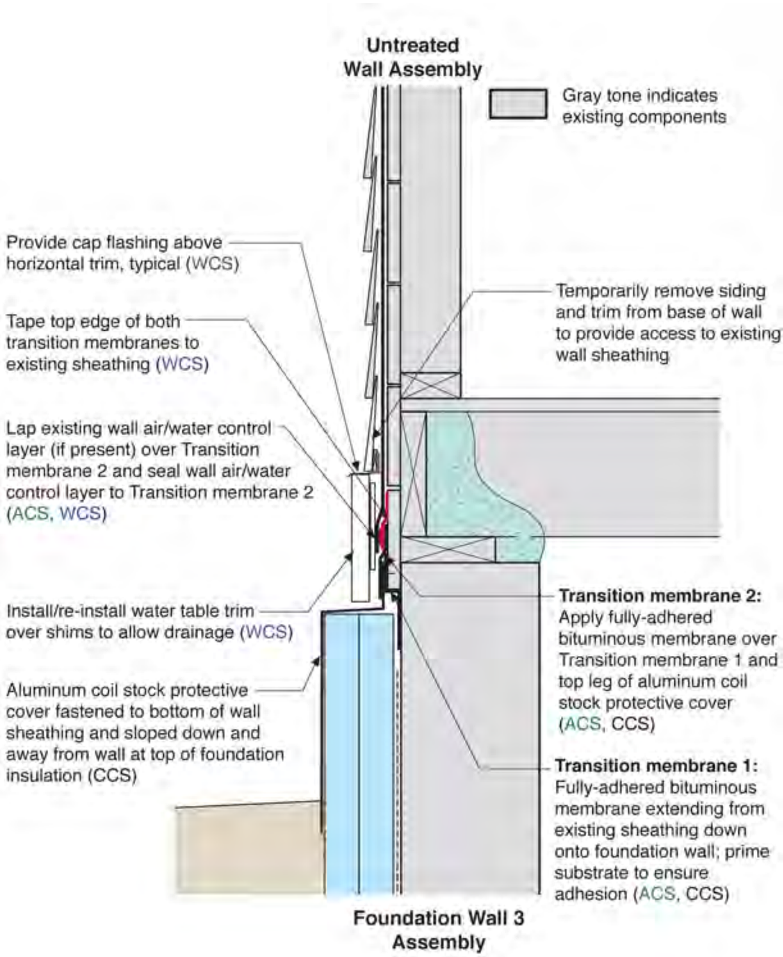
Wall 1 to Foundation Wall 3– Detail for Non-Adhered Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



Wall 1 to Foundation Wall 3– Detail for Fully-Adhered Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



Untreated Wall to Foundation Wall 3

- Siding and trim at the base of the wall must be temporarily removed to access the base of the wall sheathing.

Special Case: Provide Drying for Framing Sill

The retrofit treatments of the foundation wall and of the framing sill tend to severely limit or eliminate the ability of the these components to dry to the inside. Foundation walls that are subject to capillary transfer of water (wicking) risk transferring moisture to framing that is on top of the foundation wall if there is no capillary break between the foundation and the framing and if the moisture is not able to dry out of the foundation wall before it reaches the framing. If moisture is transferred to the framing faster than the framing is able to dry, moisture will accumulate leading to decay.

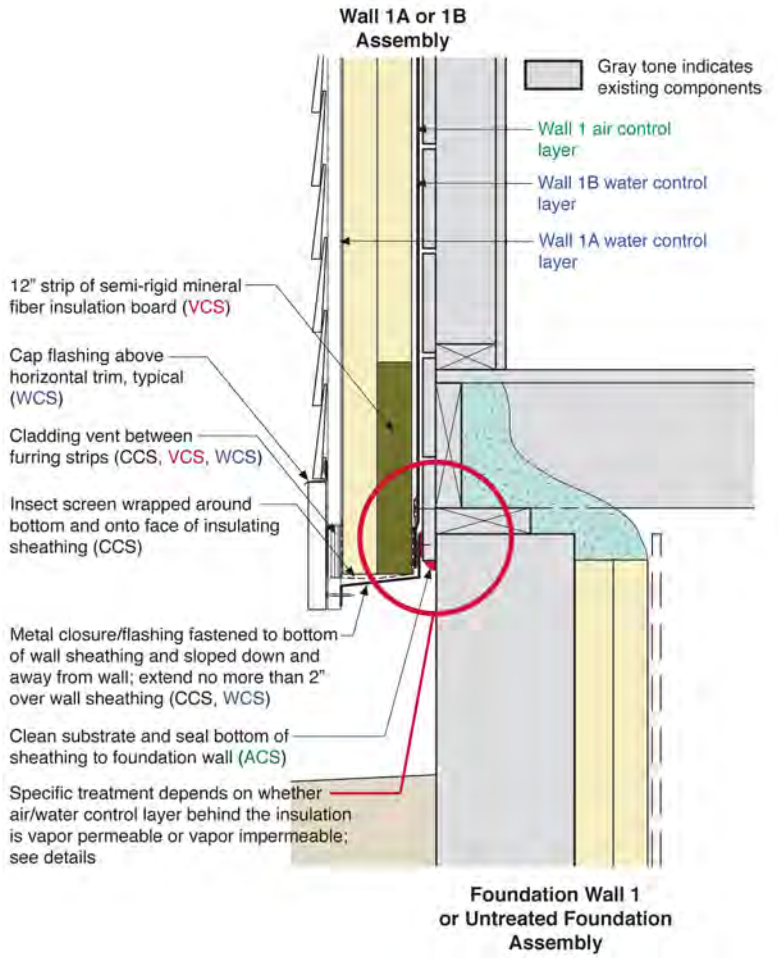
Foundation walls that are subject to capillary transfer of water are 1) constructed of wicking materials such as, for example, concrete, concrete block, brick, sedimentary stone, significant proportions of mortar; and 2) in contact with liquid water such as in the form of ground water, surface water or incident rainwater.

Capillary moisture generally evaporates from the exterior surface of a foundation wall if the foundation wall has appreciable exposure above grade (e.g. height of the exposed exterior portion of wall is greater than 1 ½ times the thickness of the wall) and it is not covered by a layer or material that would inhibit drying (e.g. it is not covered with epoxy paint).

For more discussion of capillary moisture as it relates to the frame wall-foundation wall interface refer to the Building Enclosure Functions section in Part 1 of this guide or *Building Science Insight-011: Capillarity—Small Sacrifices* and *Building Science Insight-041: Rubble Foundations* both of which are available at www.buildingscience.com.

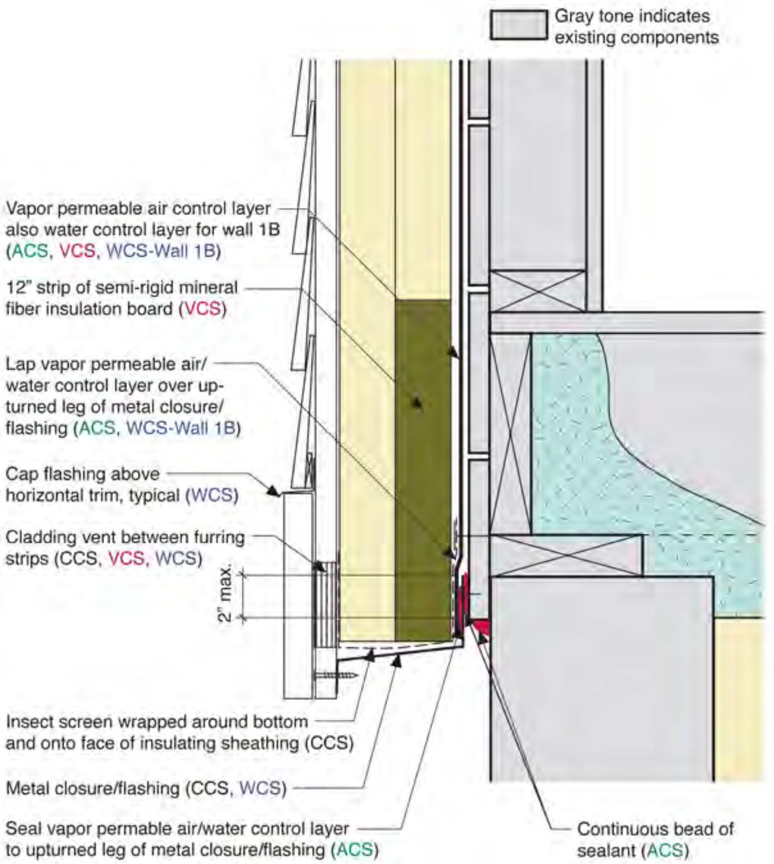
Moderate levels of moisture transfer to the framing might be managed by insulating the framing in a way that promotes drying to the exterior. If water can dry from the framing at a faster rate than water is wicked to the framing, then moisture will not accumulate. Below are details that demonstrate this approach for both flat and irregular surface foundation walls.

It must be noted that the methods presented below address moderate levels of risk. In situations where the capillary transfer of moisture through the foundation wall to the framing is significant, insertion of a capillary break and/or other measures will be necessary.



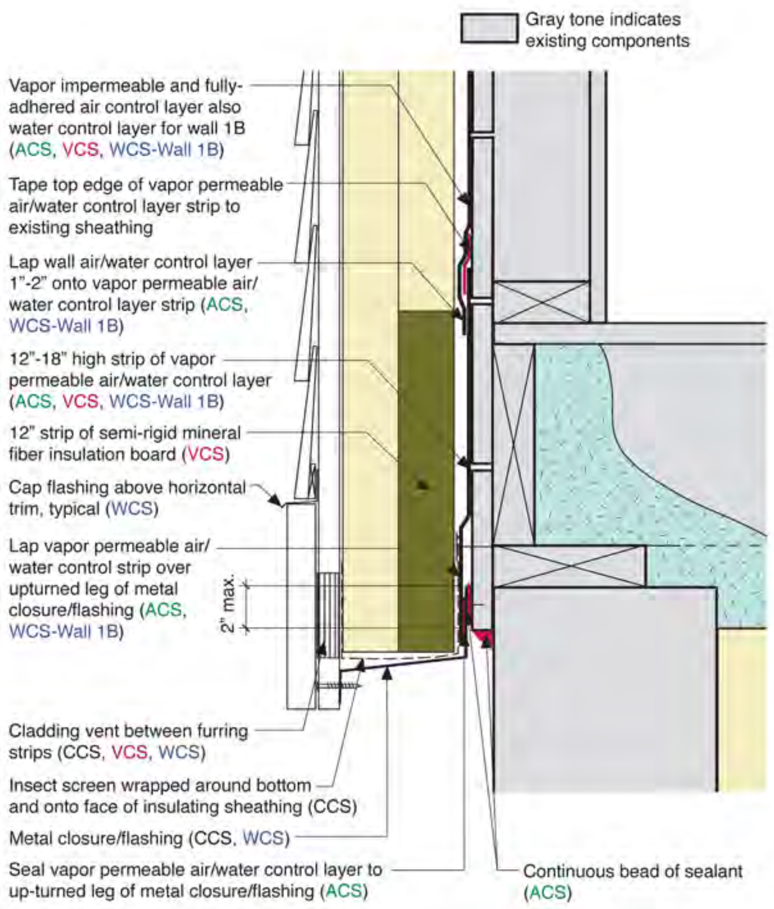
Drying for Sill: Wall 1 to Foundation Wall 1 or Untreated Flat Foundation Wall

- This transition drawing applies for Wall 1A and Wall 1B.



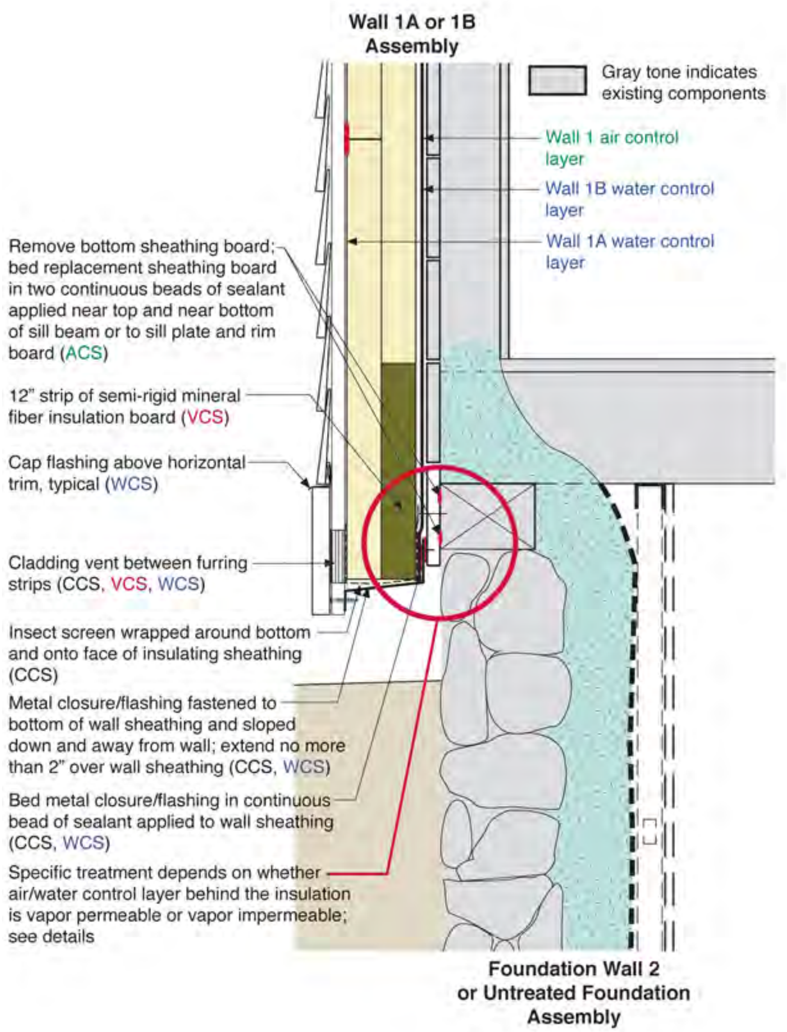
Drying for Sill: Wall 1 to Foundation Wall 1 or Untreated Flat Foundation Wall–Detail for Vapor Permeable Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.



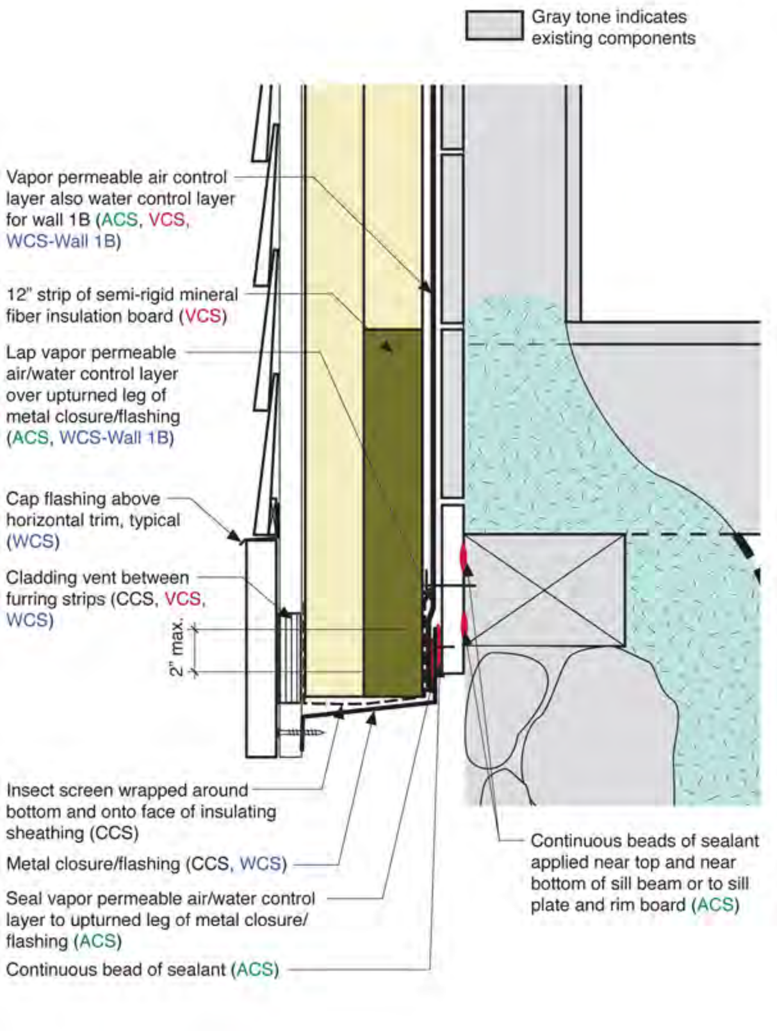
Drying for Sill: Wall 1 to Foundation Wall 1 or Untreated Flat Foundation Wall–Detail for Vapor Impermeable Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.
- The vapor permeable air control layer should extend up beyond the first floor framing.



Drying for Sill: Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall

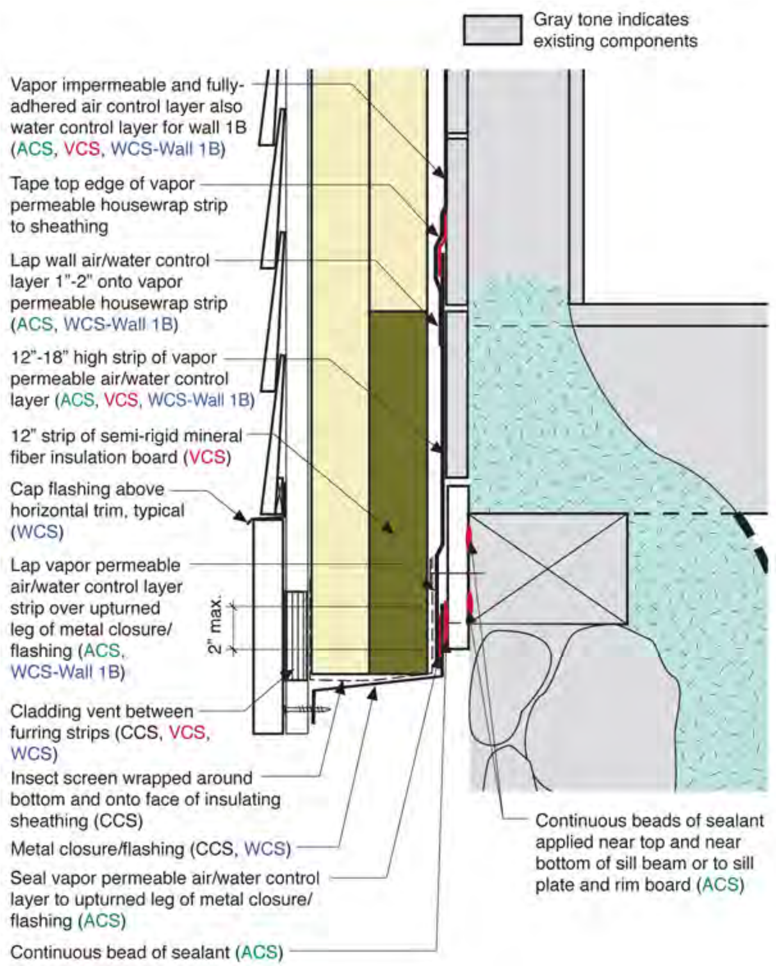
- This transition applies for Wall 1A and Wall 1B.
- The replacement sheathing board that is installed over the sill must be solid sawn wood and not OSB or plywood.



Drying for Sill: Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall—Detail for Vapor Permeable Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.

Drying for Sill: Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall–Detail for Vapor Impermeable Wall Air Control Layer



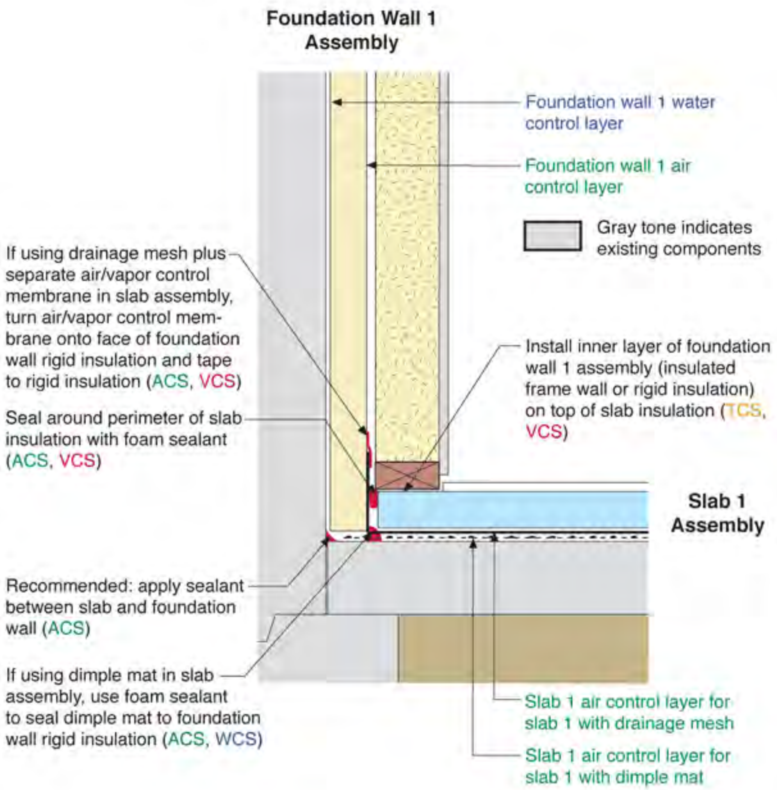
Drying for Sill: Wall 1 to Foundation Wall 2 or Untreated Irregular Foundation Wall –Detail for Vapor Impermeable Wall Air Control Layer

- This detail applies for Wall 1A and Wall 1B.
- The vapor permeable air control layer should extend up beyond the first floor framing.

Foundation Wall-to-Slab and Foundation Wall-to-Crawlspace Floor

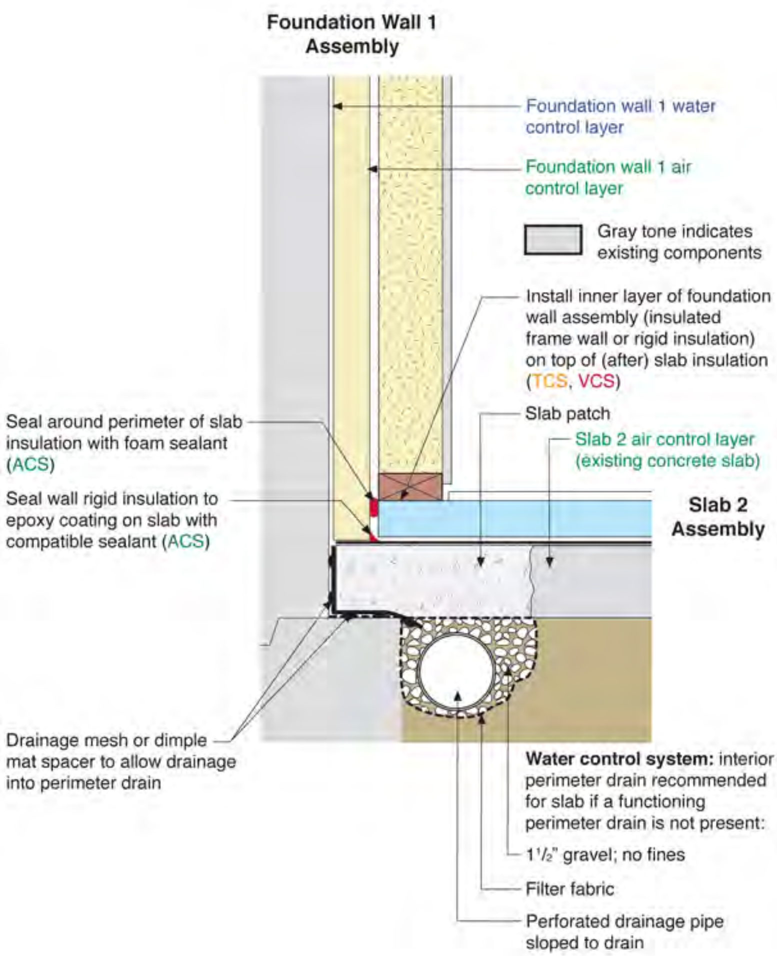
As with any major assembly transition, the challenge at this interface is to maintain the continuity of water control and air control. But there are some special challenges when it comes to basements and crawlspaces. Water control, air control, vapor control, and, to an extent, thermal control need to be able to work in different ways than they do on most other parts of the building enclosure.

Water control may be to inside of foundation wall or to outside of foundation wall. Water control may be to the underside of the slab or it may be on the topside of the slab. Primary air control needs to be to the inside of the water control in order to control soil gases, odors and the migration of moisture by convection. But we also want to have air control to the inside of thermal control so that interior air cannot circulate behind the insulation. This is because the surfaces of the thermally conductive ground coupled foundations and slabs tend to be colder than indoor conditions all the time. Moisture in the interior air could condense and accumulate on these surfaces. Vapor control is needed to control vapor drive that acts from the exterior to the interior all the time. Finally, we need to be very careful about placing moisture sensitive materials on the correct side of the control layers. All this can be challenging in basements and crawlspaces.



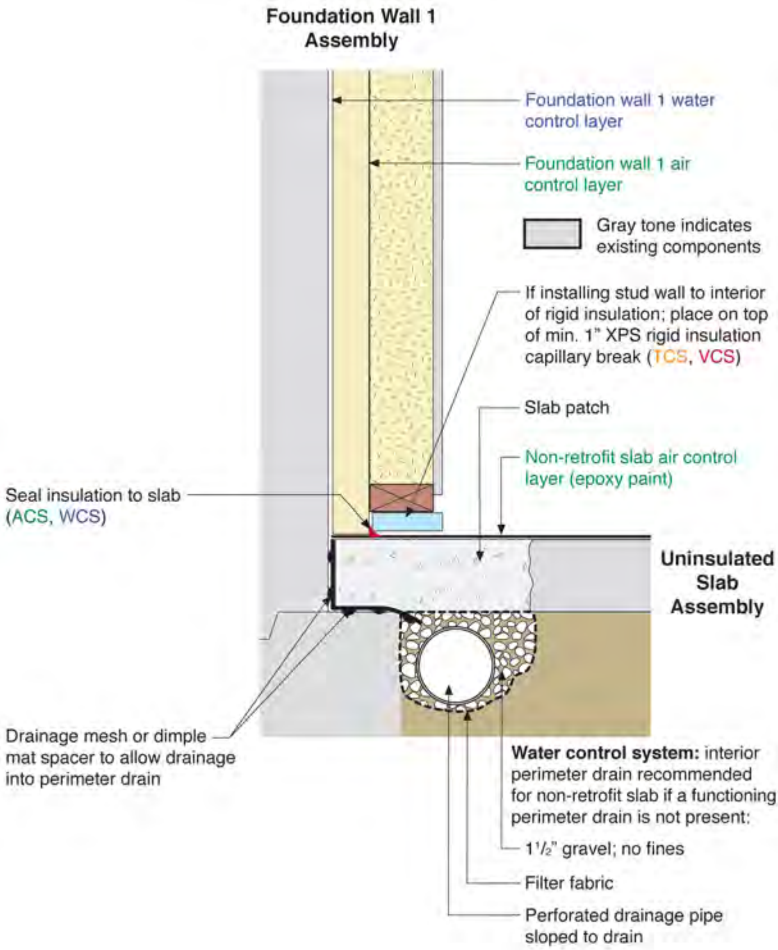
Foundation Wall 1 to Slab 1

- The Slab 1 Assembly requires that the above-slab drainage layer (drainage mesh or dimple mat) be connected to an interior sump pit. The interior sump pit must have an airtight and gasketed cover.



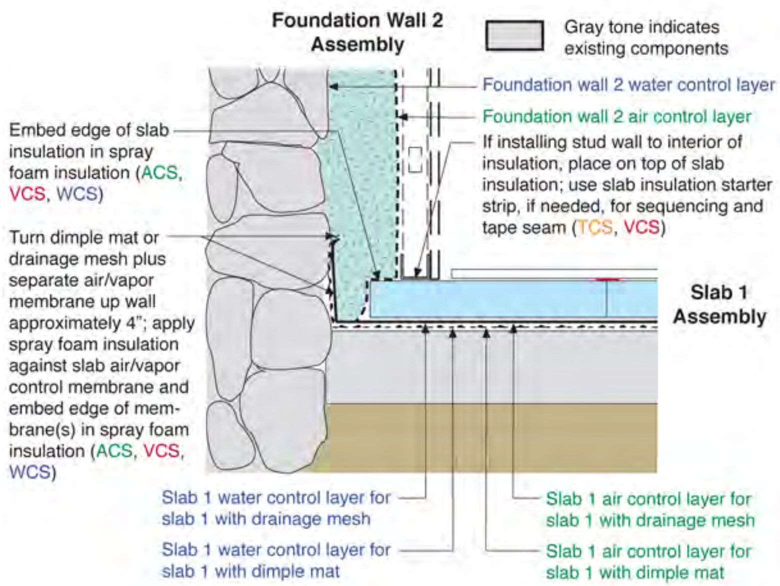
Foundation Wall 1 to Slab 2

- The interior perimeter drain should connect to an interior sump pit. The interior sump pit must have an air tight and gasketed cover.



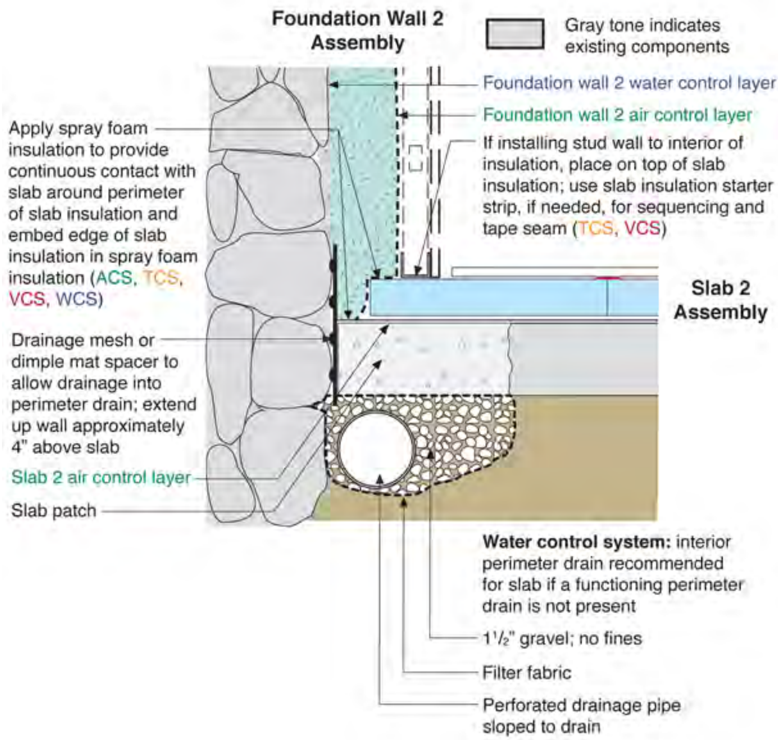
Foundation Wall 1 to Uninsulated Slab

- If the water control strategy does not include a perimeter drain, seal the slab to the foundation wall and provide small weep holes approximately 4' o.c. in the seal between the rigid insulation and the slab.
- The interior perimeter drain should connect to an interior sump pit. The interior sump pit must have an air tight and gasketed cover.
- If the foundation wall is cast concrete and has no history or evidence of previous water leakage or there is a functioning perimeter drainage system, the sub-slab drainage system may not be needed. It might still be advisable to create an interior sump pit as a contingency.



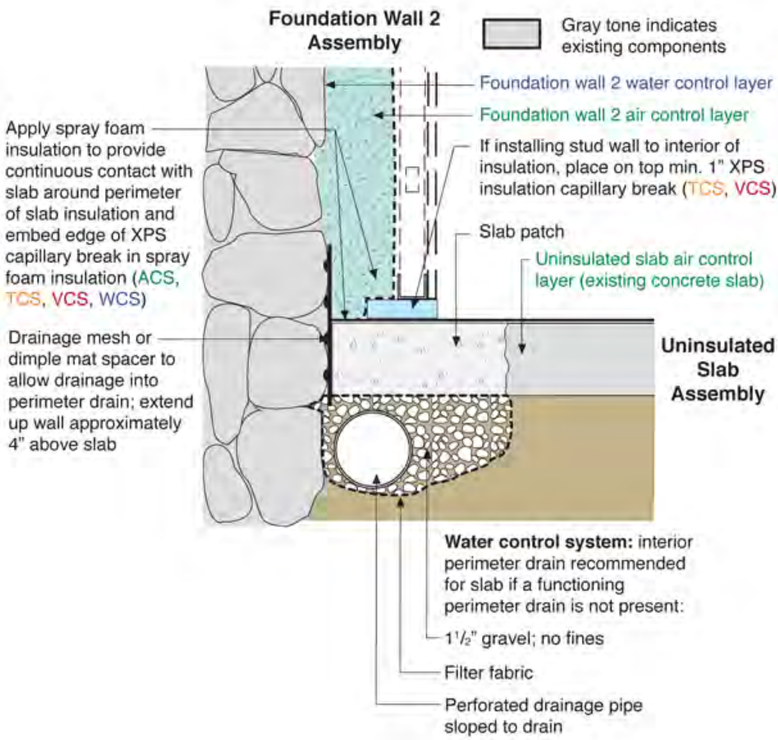
Foundation Wall 2 to Slab 1

- The Slab 1 Assembly requires that the above-slab drainage layer (drainage mesh or dimple mat) be connected to an interior sump pit. The interior sump pit must have an airtight and gasketed cover.



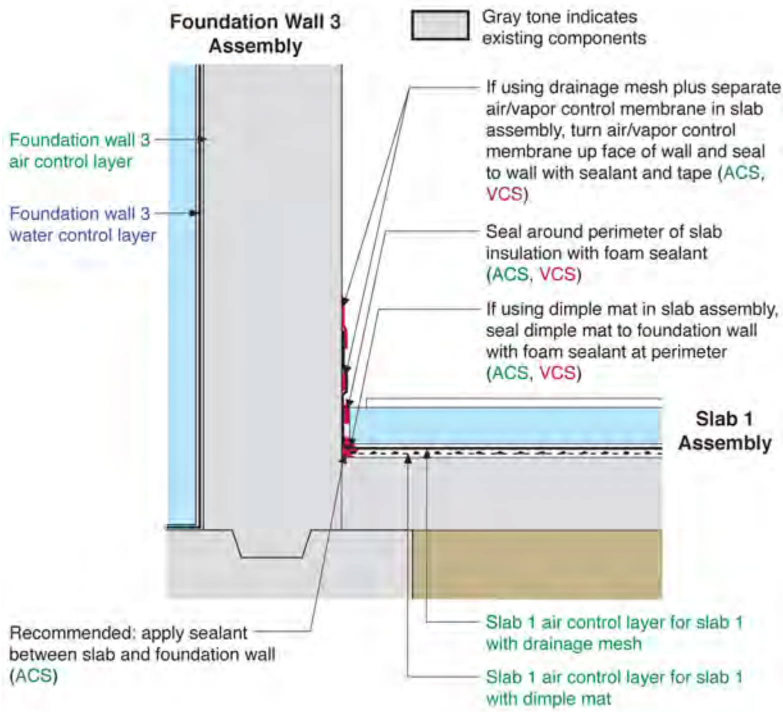
Foundation Wall 2 to Slab 2

- The interior perimeter drain should connect to an interior sump pit. The interior sump pit must have an air tight and gasketed cover.



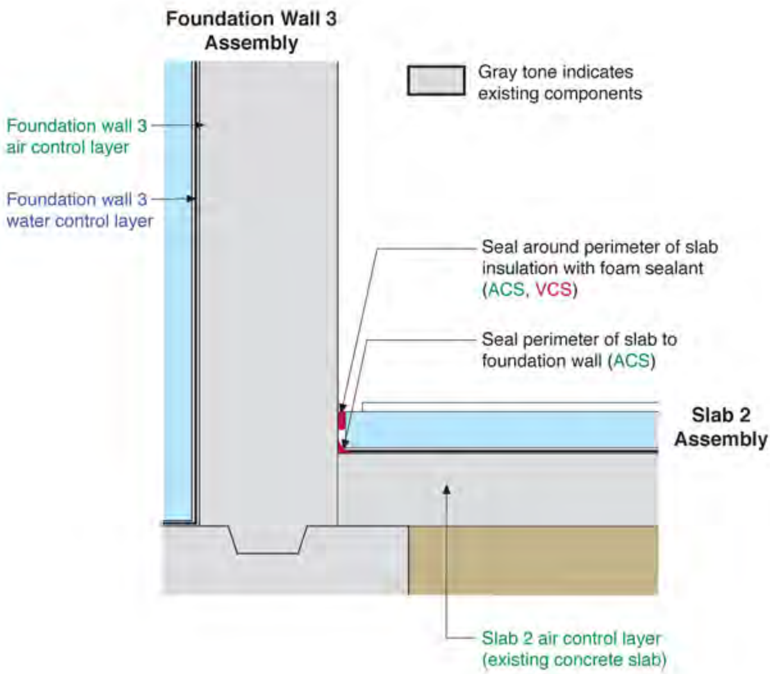
Foundation Wall 2 to Uninsulated Slab

- The interior perimeter drain should connect to an interior sump pit. The interior sump pit must have an air tight and gasketed cover.



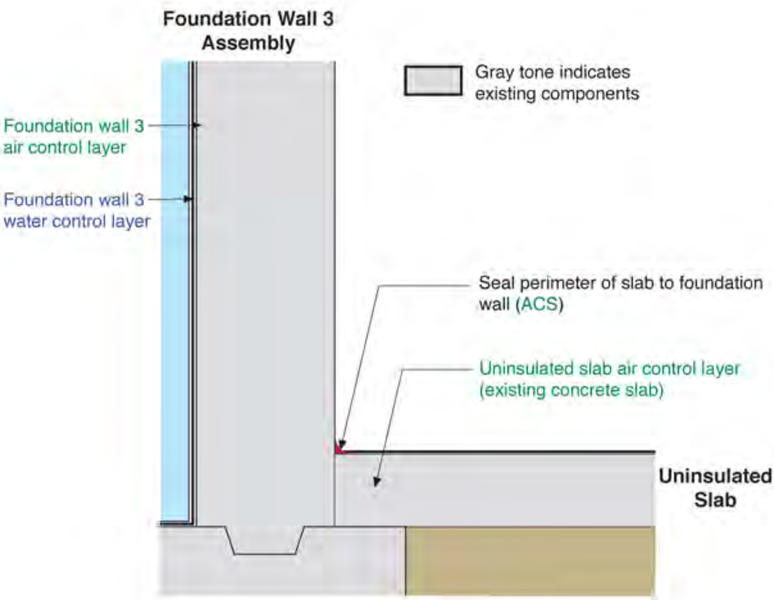
Foundation Wall 3 to Slab 1

- The Slab 1 Assembly requires that the above-slab drainage layer (drainage mesh or dimple mat) be connected to an interior sump pit. The interior sump pit must have an airtight and gasketed cover.



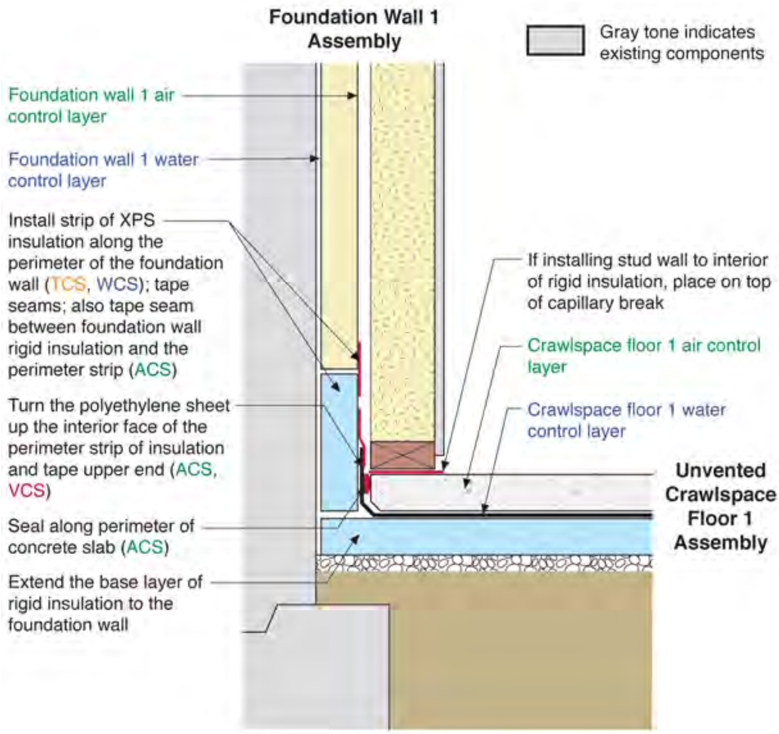
Foundation Wall 3 to Slab 2

- Since Foundation Wall 3 includes an exterior perimeter drain, installation of an interior sub-slab perimeter drain is not required; it may still be advisable to maintain an interior sump pit as a contingency to handle interior bulk water events. An interior sump pit must have an air tight and gasketed cover.

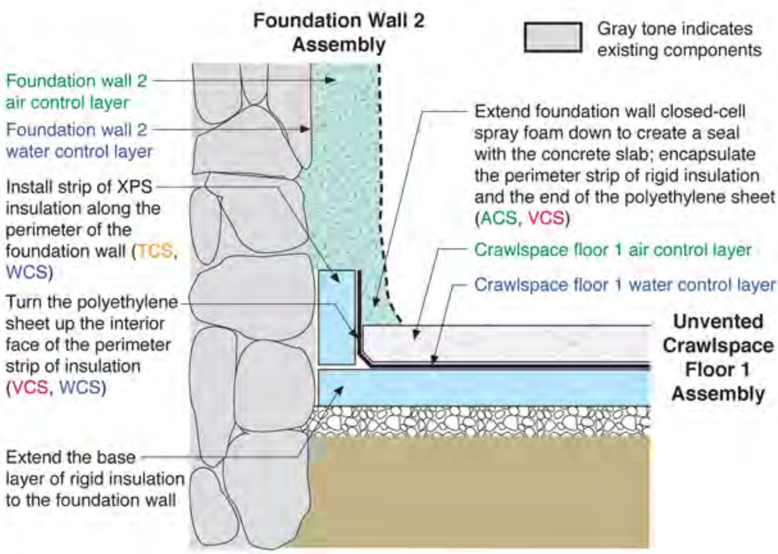


Foundation Wall 3 to Uninsulated Slab

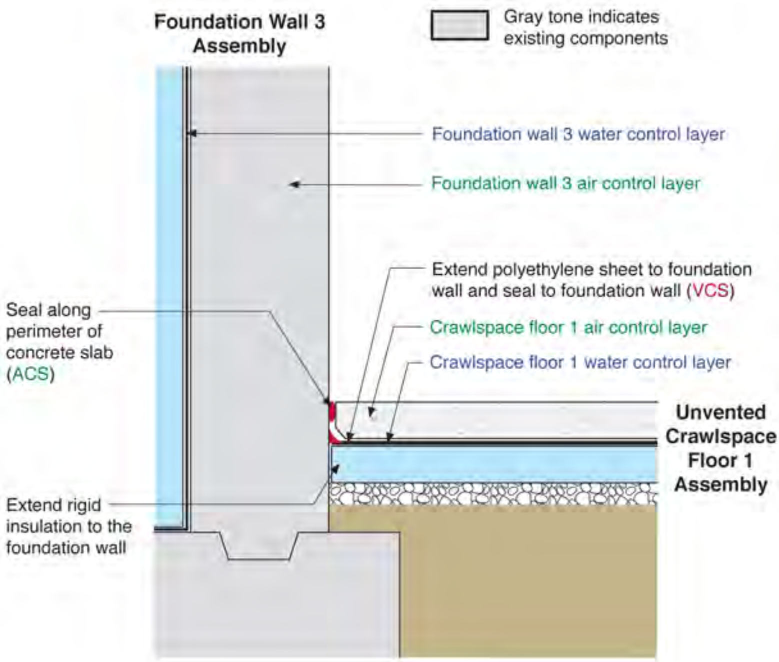
- Foundation Wall 3 includes an exterior perimeter drain; however, it may still be advisable to maintain an interior sump pit as a contingency to handle interior bulk water events. An interior sump pit must have an air tight and gasketed cover.



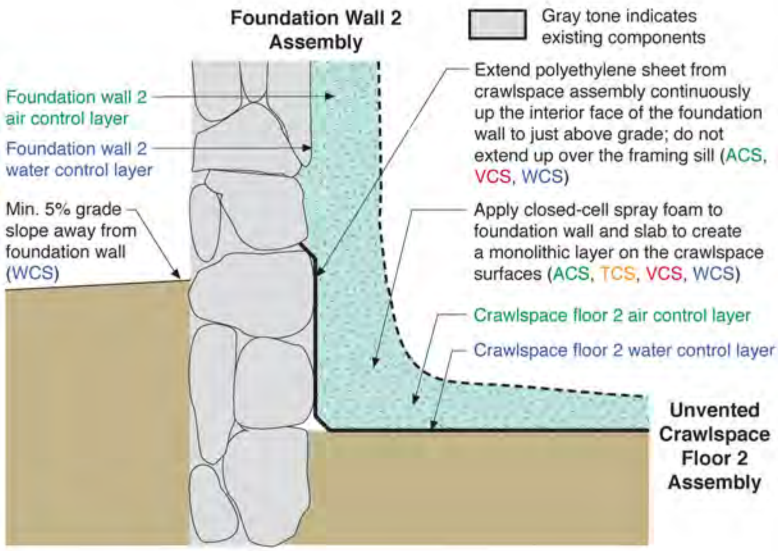
Foundation Wall 1 to Crawlspace Floor 1



Foundation Wall 2 to Crawlspace Floor 1



Foundation Wall 3 to Crawlspace Floor 1



Foundation Wall 2 to Crawlspace Floor 2

INTERRUPTIONS (CONNECTIONS AND PENETRATIONS)

Within the field of a wall, there are elements that "interrupt" the wall assembly. While these elements are needed for functional reasons and to add character and amenity to buildings, they can complicate the continuity of the building enclosure functions. This section illustrates details for common retrofit wall assembly interruptions that maintain critical building enclosure control functions. The interruptions detailed include:

- Porch Roof/Ceiling Connection,
- Deck Connection to Field of Wall,
- Deck Connection to Base of Wall,
- Windows,
- Doors,
- Exterior Electric Box,
- Trim Block with Wire Penetration, and
- Duct/Pipe Penetration.

Schematic construction sequences are also provided for some of these assembly interruptions.

This section is divided into two sub-sections to address Wall 1A interruptions and Wall 1B interruptions separately. The difference in location of the water control layer between these two retrofit wall assemblies has important implications for the design and implementation of these details.

Within each sub-section, the interruption featured in this section are grouped into categories:

- Porch and Deck Connections,
- Windows and Doors, and
- Wire and Duct/Pipe Penetrations.

These categories are also indicated on the long edge of the page to aid in navigating through this section.

NOTE THAT DETAILS FOR PORCH ROOF, PORCH CEILING AND DECK CONNECTIONS DO NOT PROVIDE GUIDANCE RELATIVE TO STRUCTURAL SUPPORT. PERSONS IMPLEMENTING THESE DETAILS SHOULD SEEK ADVICE OF A QUALIFIED PROFESSIONAL TO DETERMINE NECESSARY STRUCTURAL SUPPORT AND CONNECTIONS.

CONTROL SYSTEM COMPONENT LEGEND

Because of the primary importance of maintaining continuity of the water control and air control at assembly interruptions, the location of the water control layer and air control layer in the retrofit wall assembly is identified for each of the assembly interruption details. Within each assembly interruption detail illustration, the measures or materials critical to maintaining necessary building enclosure control functions are identified using the following key:

WCS Component of water control system

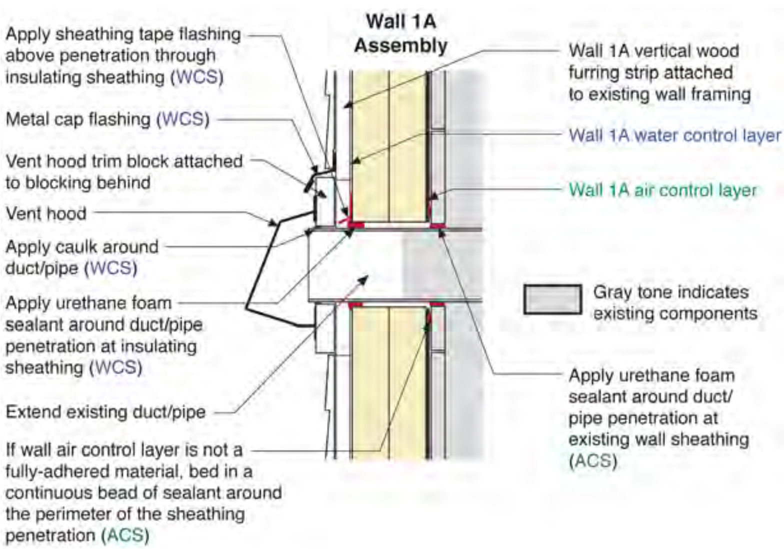
ACS Component of air control system

VCS Component of vapor control system

TCS Component of thermal control system

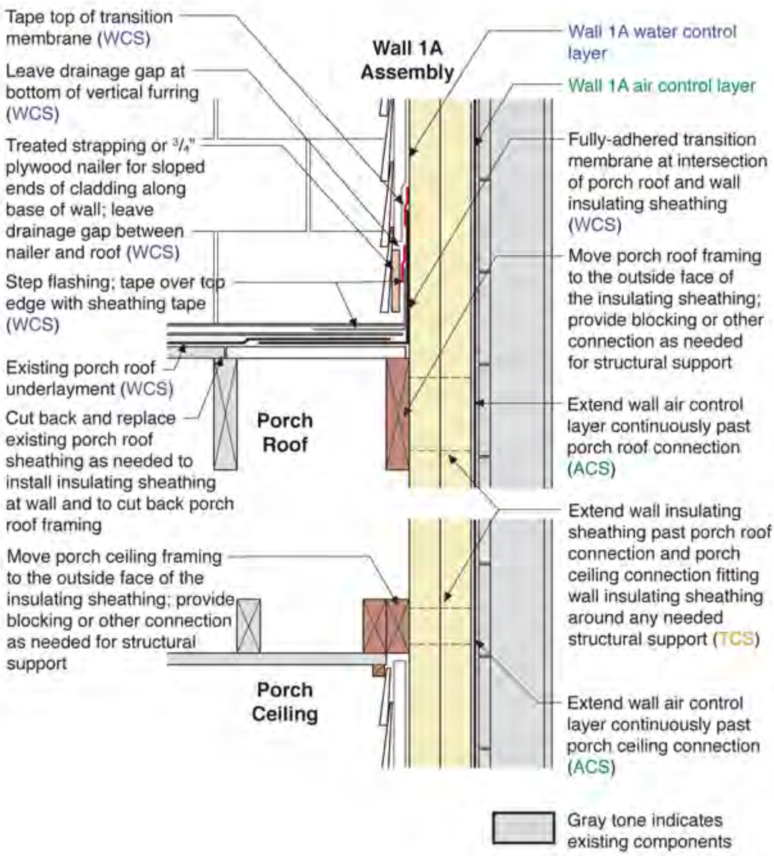
CCS Component of critter control system

For example:



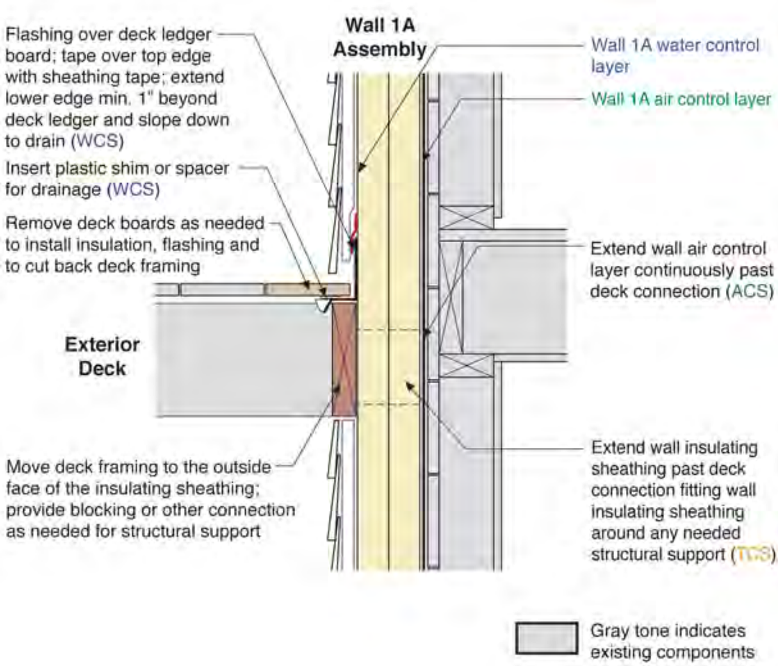
Wall 1A Interruptions

In this retrofit wall assembly, the water control layer is the outer face of the insulating sheathing. Therefore all of the flashing details must connect to the face of the insulating sheathing. Air sealing is needed at other layers.



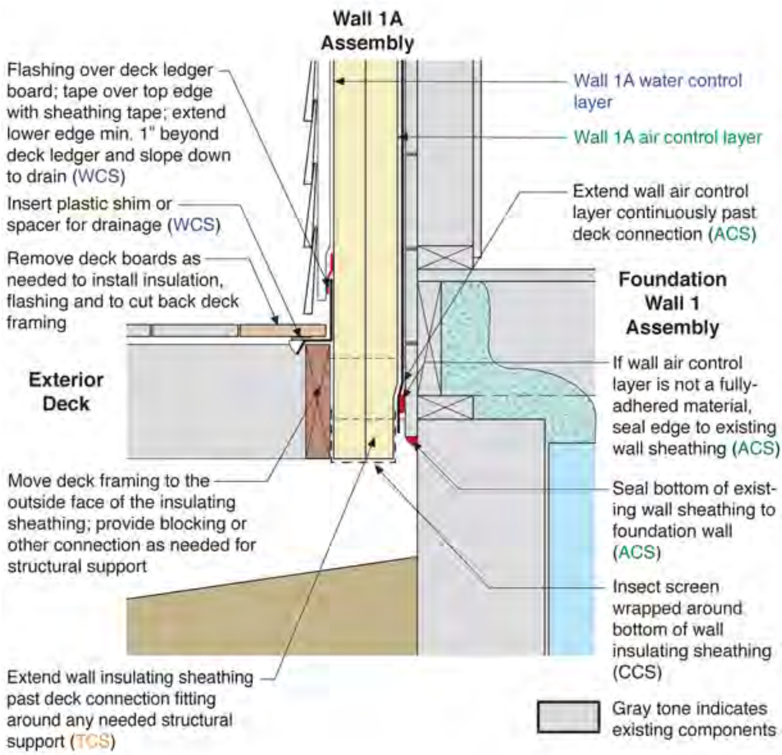
Porch Roof/Ceiling Connection to Wall 1A

- The porch roof and ceiling are separated from the existing wall structure to allow a continuous wall air control layer and insulating sheathing between the porch roof/ceiling and the wall.
- Reattaching the porch roof structure may require engineered support connection or independent support.



Deck Connection to Field of Wall 1A

- The deck is separated from the wall structure to allow a continuous wall air control layer and insulating sheathing between the deck and the wall.
- Reattaching the deck structure may require engineered support connection or independent support.

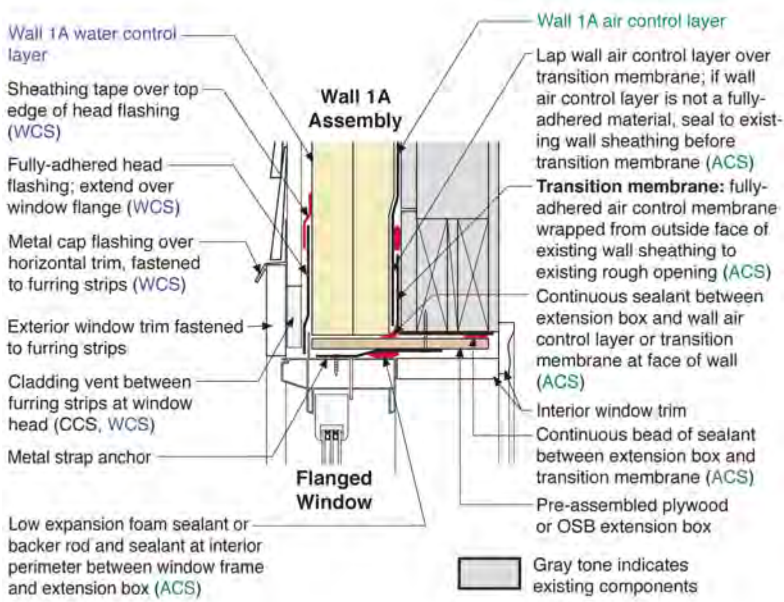


Deck Connection to Base of Wall 1A

- The deck is separated from the wall structure to allow a continuous wall air control layer and insulating sheathing between the deck and the wall.
- Reattaching the deck structure may require engineered support connection or independent support.

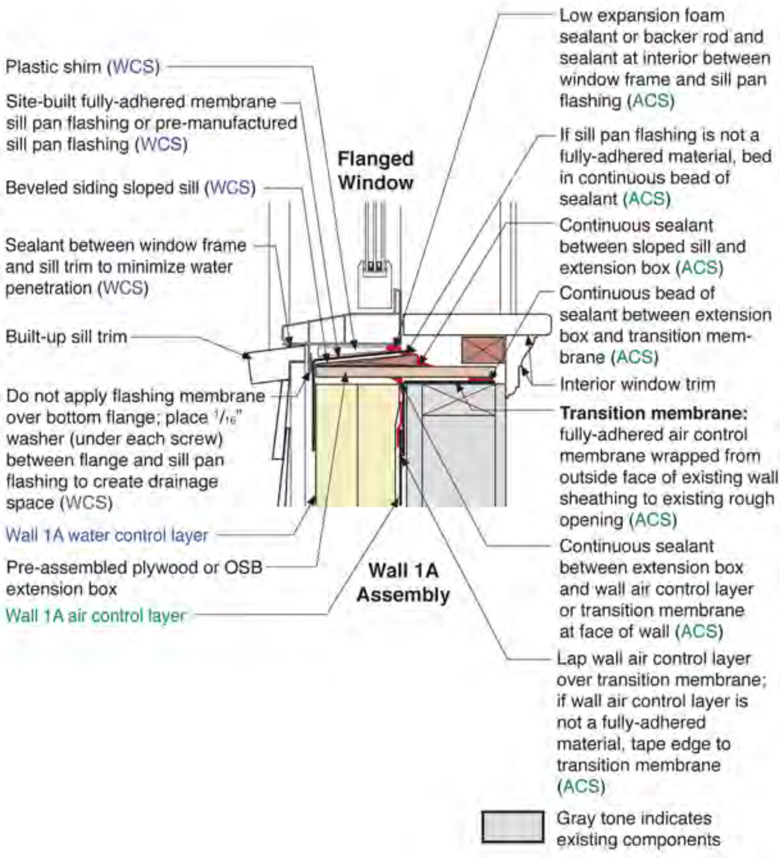
Wall 1A Windows and Doors

There are two kinds of windows—windows that leak, windows that will leak. This can be said of doors as well. Because of this, it is necessary to flash the window or door opening such that it is a drained opening – when the window or door leaks, water is controlled and the wall system is protected. Sill pan flashing, jamb flashing and head flashing form the water control system for the opening. The sill pan flashing is especially tricky because it must conform to the three dimensional corner configuration at the intersection of the sill and jamb of the opening. Also window and door frames tend to have sharp corners – if the sill pan flashing is not tight to the corner of the opening, the window or door frame could cause a tear in the flashing precisely at the most vulnerable location of the opening. For this reason, one should not attempt to provide pan flashing with flat peel-and-stick membranes. The corners of the sill pan flashing should be executed with pre-manufactured corner flashing, liquid-applied flashing membrane, or flexible flashing membrane.



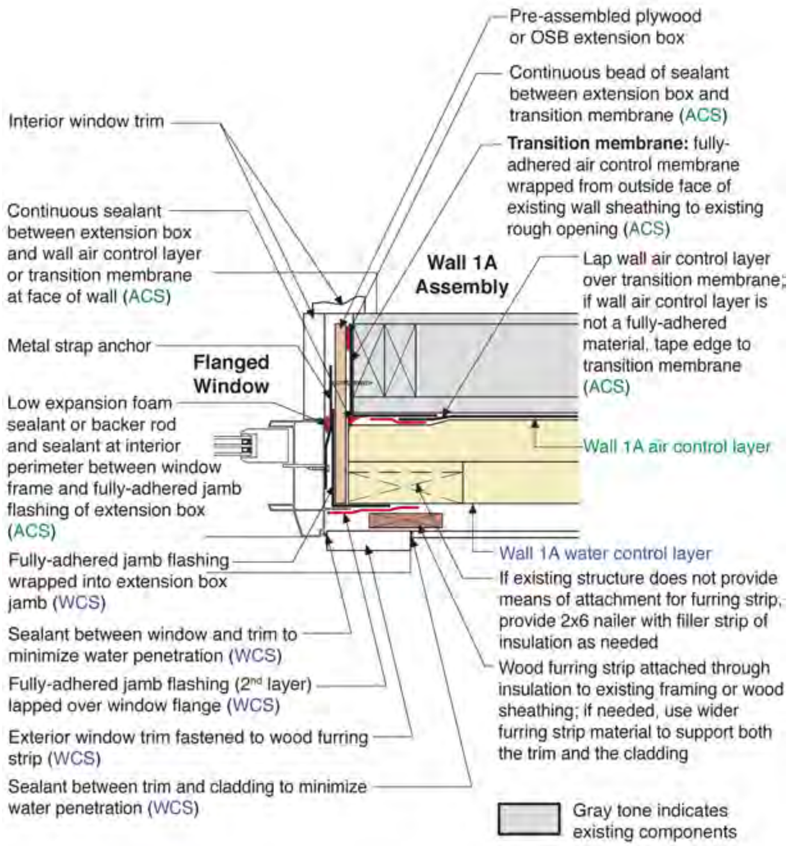
Flanged Window with Extension Box in Wall 1A—Head

- The pre-assembled extension box is described in Flanged Window with Extension Box—Installation Sequence.
- Also see Flanged Window with Extension Box in Wall 1A - Installation Sequence.



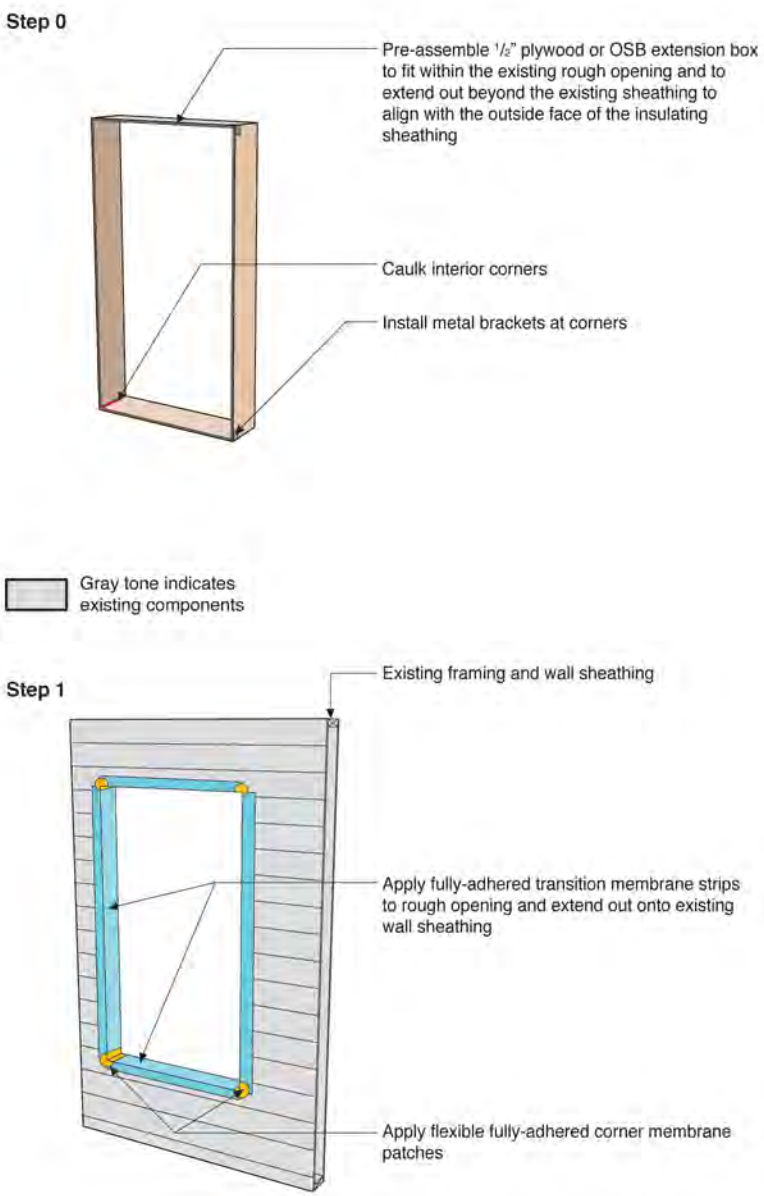
Flanged Window with Extension Box in Wall 1A—Sill

- The pre-assembled extension box is described in Flanged Window with Extension Box—Installation Sequence.
- Also see Flanged Window with Extension Box in Wall 1A - Installation Sequence.



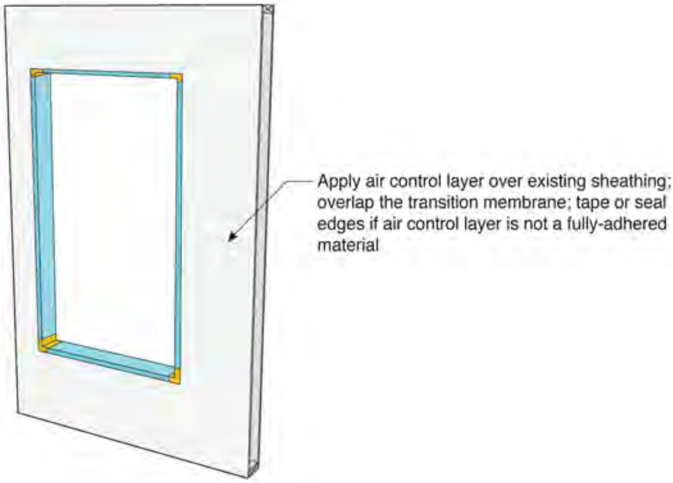
Flanged Window with Extension Box in Wall 1A—Jamb

- The pre-assembled extension box is described in Flanged Window with Extension Box—Installation Sequence.
- Also see Flanged Window with Extension Box in Wall 1A - Installation Sequence.



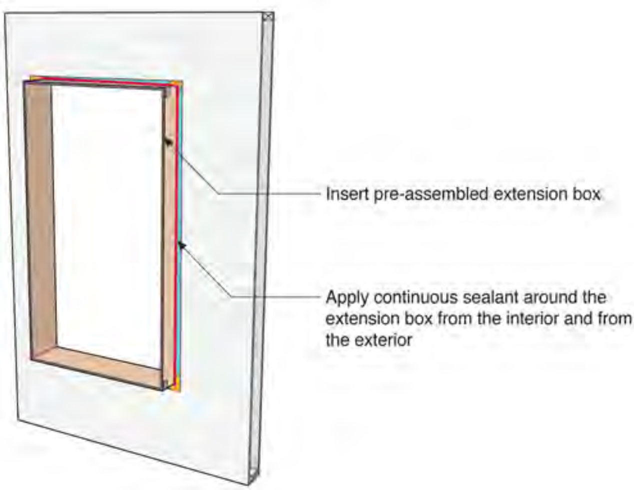
Flanged Window with Extension Box in Wall 1A—Installation Sequence

Step 2

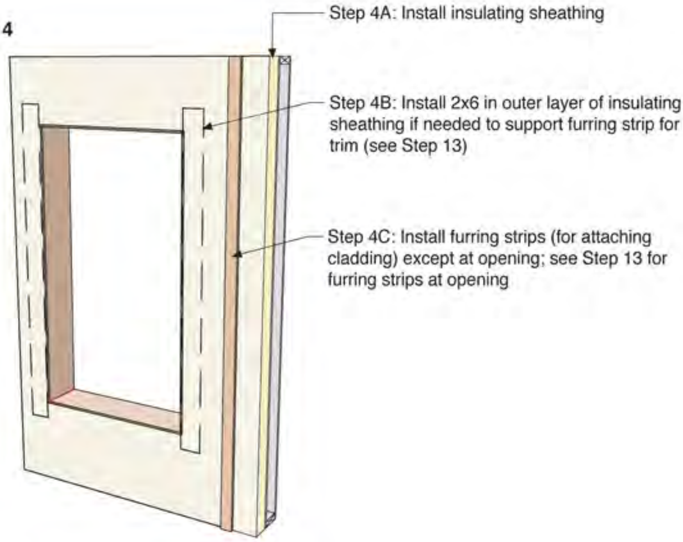

Apply air control layer over existing sheathing; overlap the transition membrane; tape or seal edges if air control layer is not a fully-adhered material


Gray tone indicates existing components

Step 3

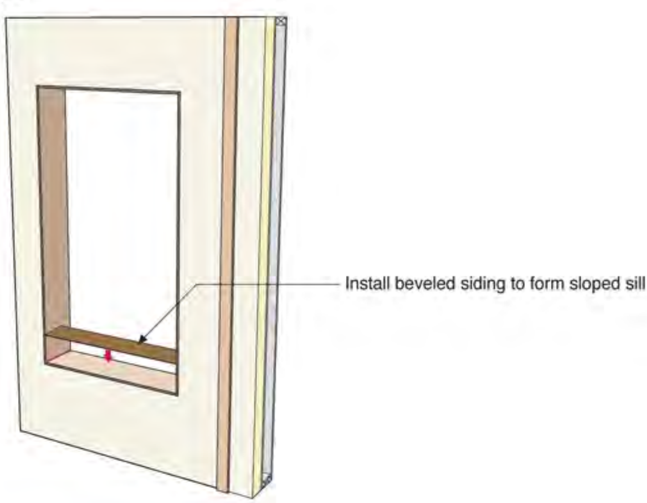

Insert pre-assembled extension box
Apply continuous sealant around the extension box from the interior and from the exterior

Step 4

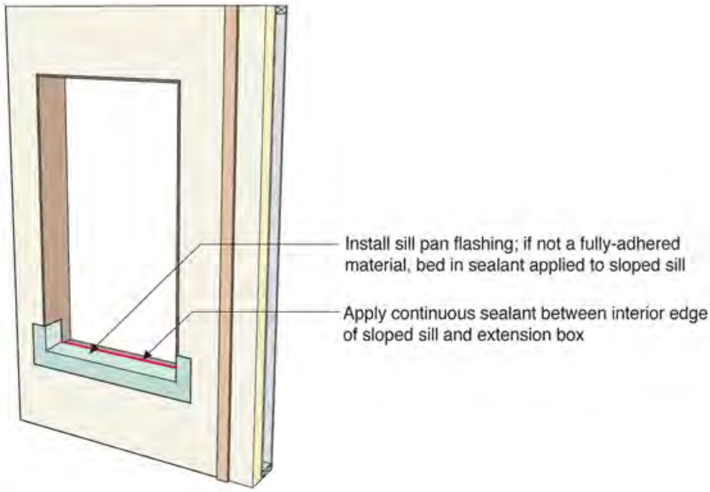


Gray tone indicates existing components

Step 5

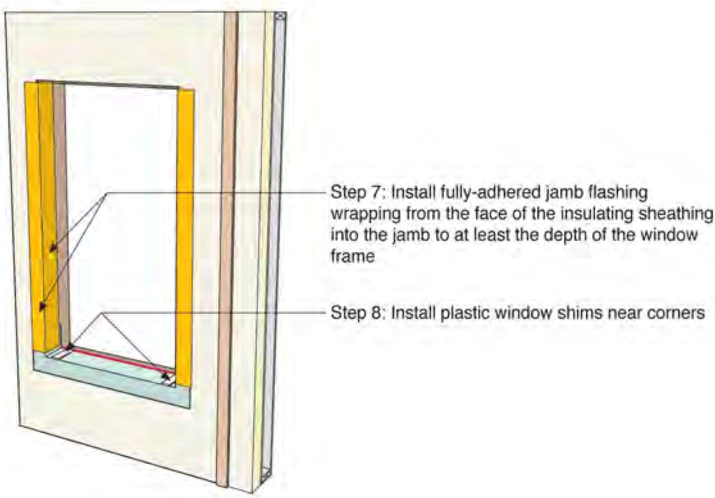


Step 6

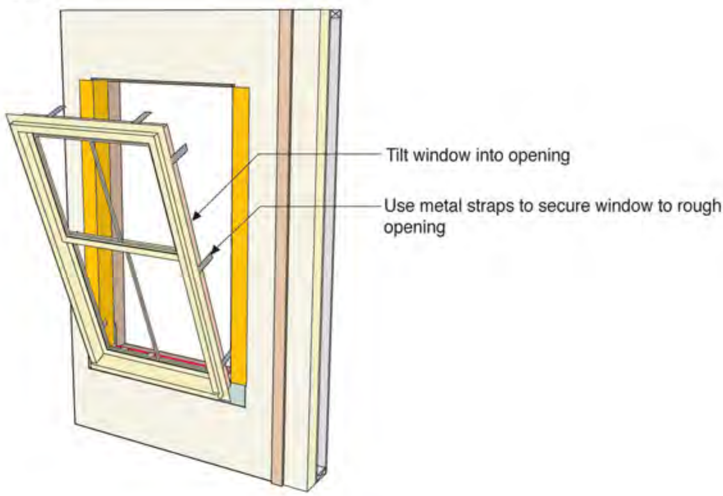


Gray tone indicates existing components

Steps 7 & 8

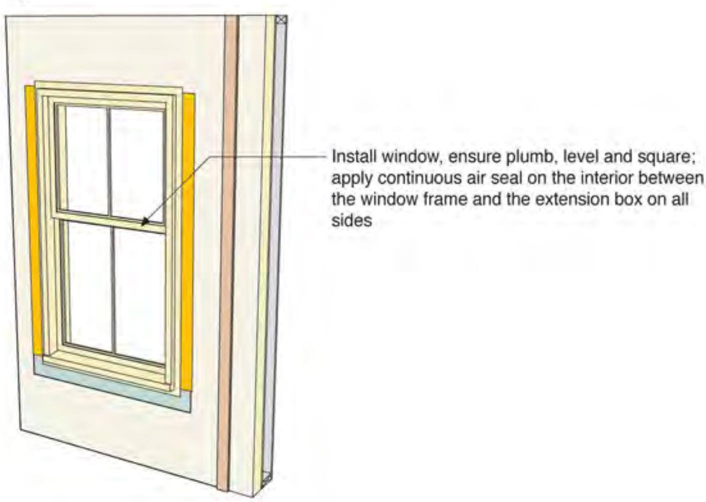


Step 9

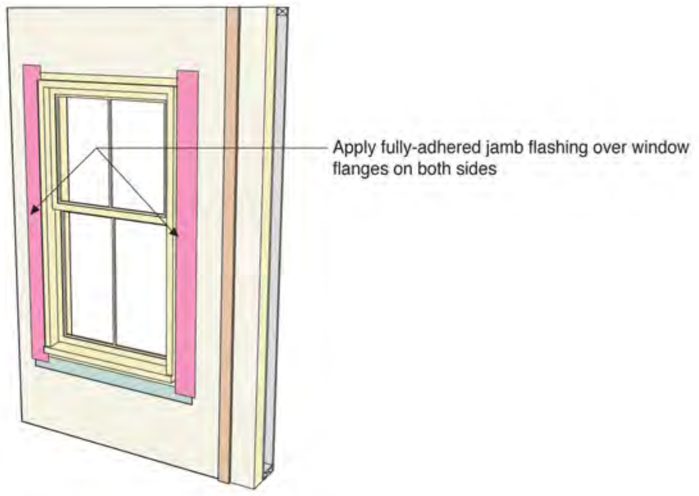


Gray tone indicates existing components

Step 10

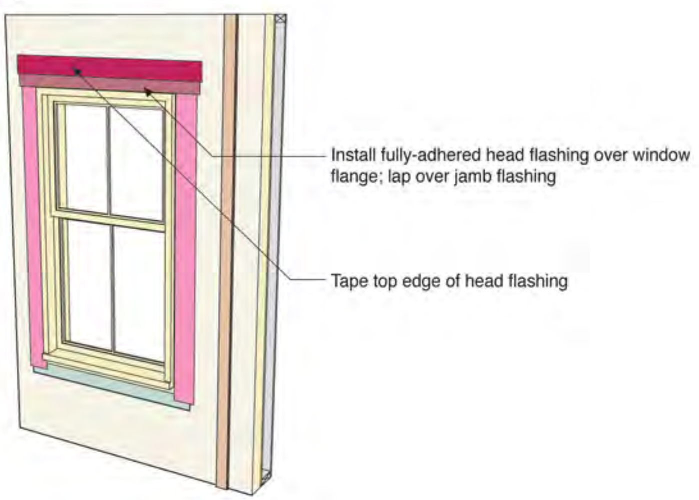


Step 11

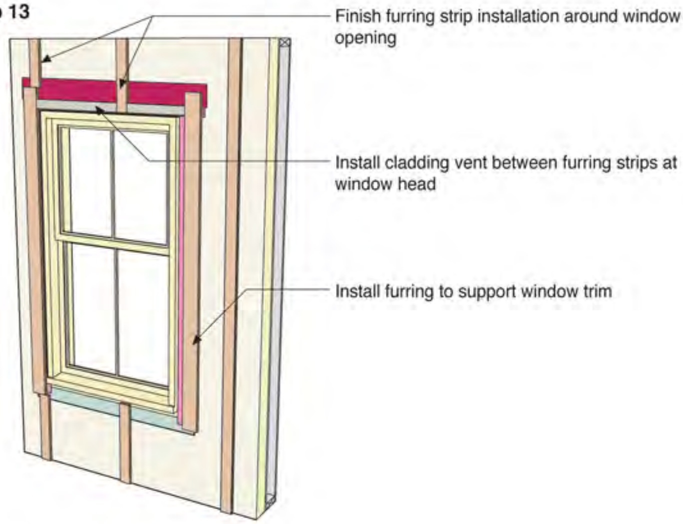


Gray tone indicates existing components

Step 12

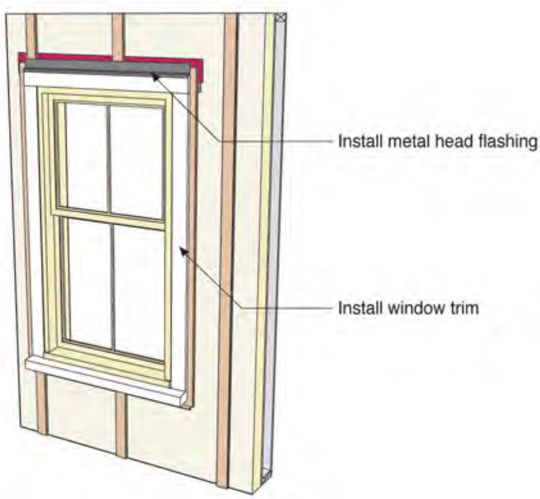


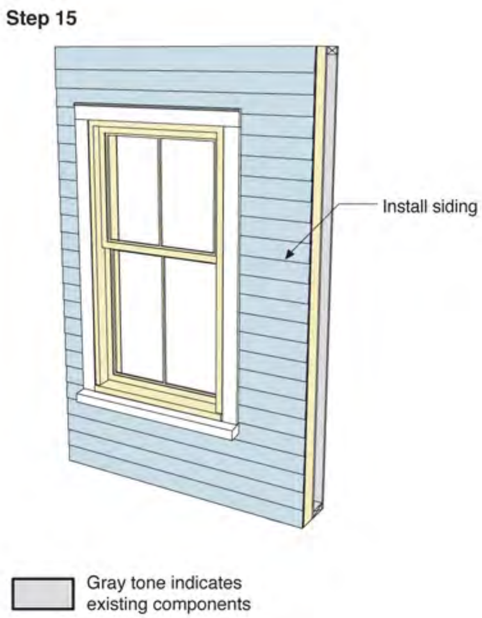
Step 13

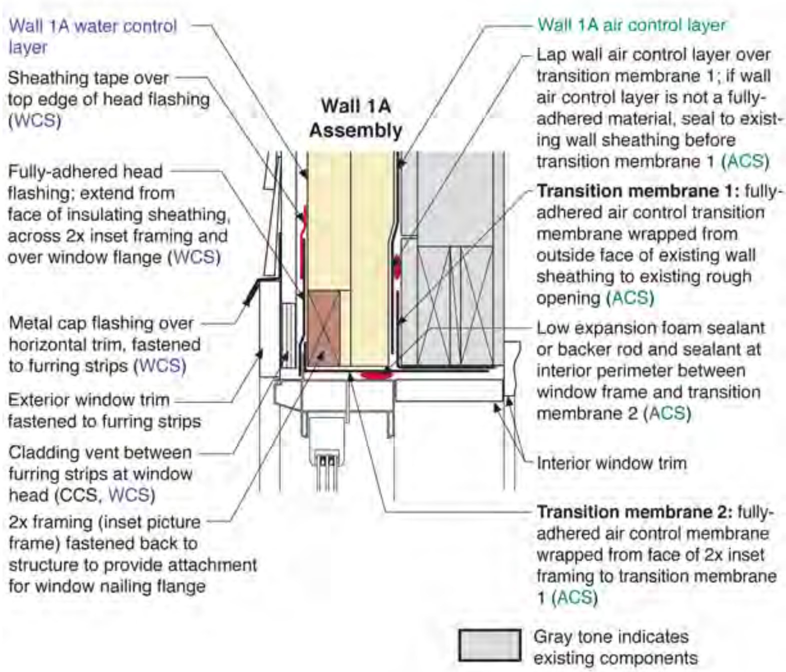


Gray tone indicates existing components

Step 14

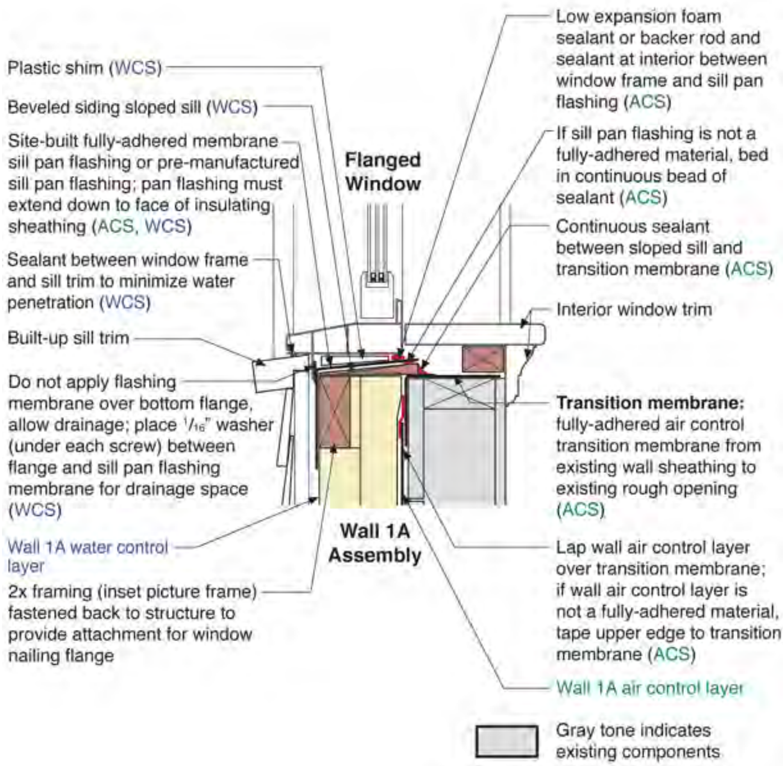



Step 15
Install siding
Gray tone indicates existing components



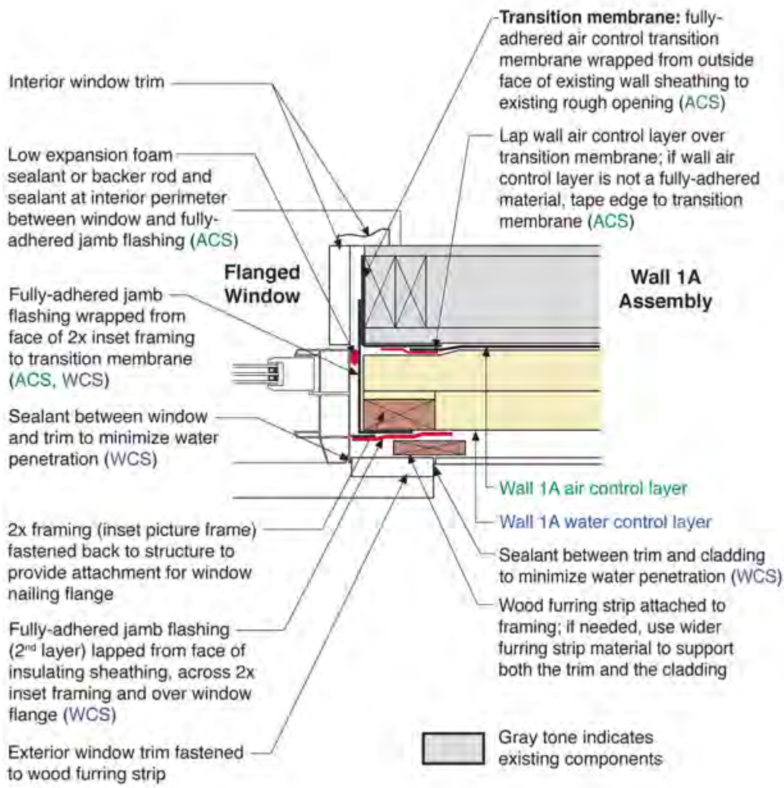
Flanged Window with Inset Picture Frame in Wall 1A—Head

- The window installation sequence for the flanged window with inset picture frame is similar to that shown in Flanged Window with Extension Box in Wall 1A—Installation Sequence except that Step 0 and Step 3 should be eliminated and Step 4B should be replaced with the installation of the inset picture frame. Also the transition membrane wrapping from the picture frame into the head of the opening should be installed after Step 7.



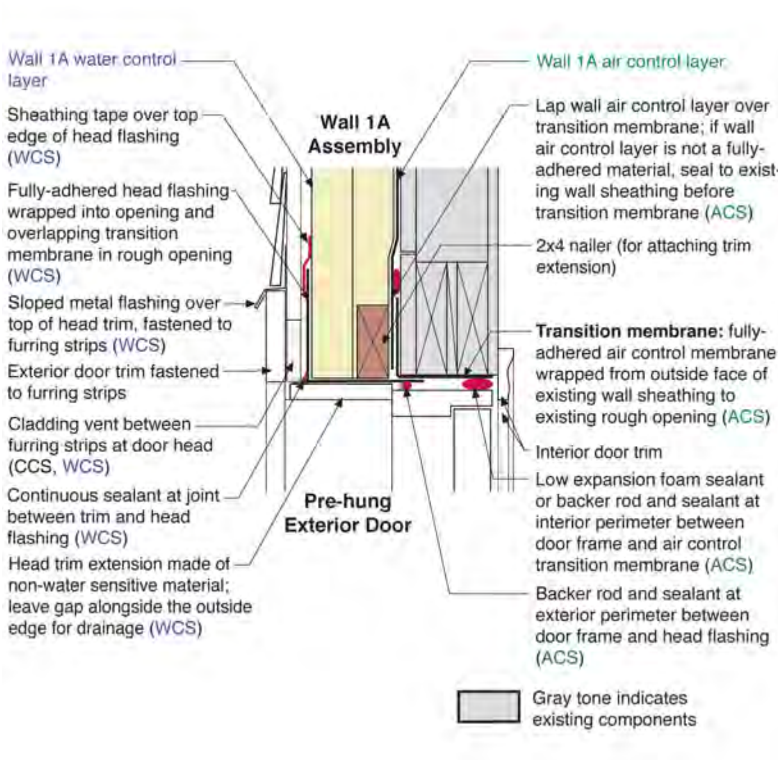
Flanged Window with Inset Picture Frame in Wall 1A—Sill

- The window installation sequence for the flanged window with inset picture frame is similar to that shown in Flanged Window with Extension Box in Wall 1A —Installation Sequence except that Step 0 and Step 3 should be eliminated and Step 4B should be replaced with the installation of the inset picture frame. Also the transition membrane wrapping from the picture frame into the head of the opening should be installed after Step 7.



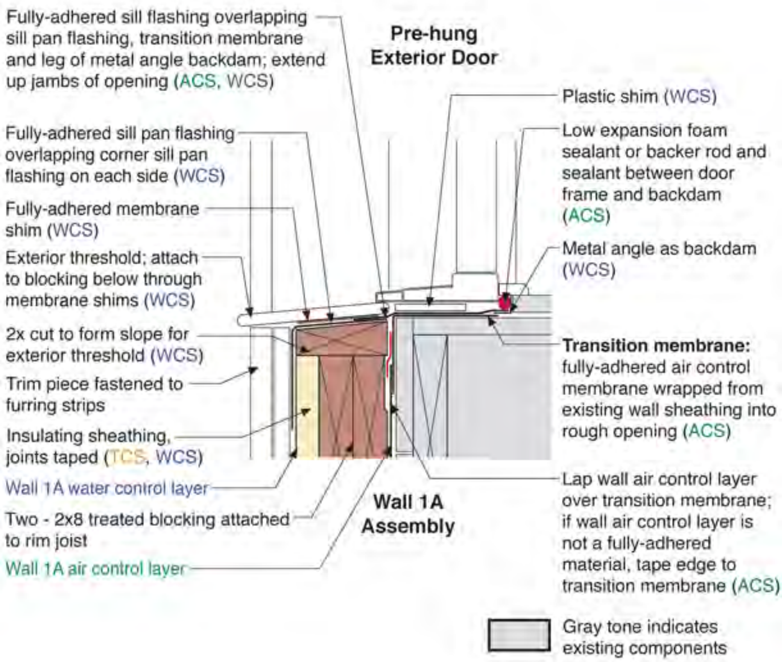
Flanged Window with Inset Picture Frame in Wall 1A—Jamb

- The window installation sequence for the flanged window with inset picture frame is similar to that shown in Flanged Window with Extension Box in Wall 1A— Installation Sequence except that Step 0 and Step 3 should be eliminated and Step 4B should be replaced with the installation of the inset picture frame. Also the transition membrane wrapping from the picture frame into the head of the opening should be installed after Step 7.



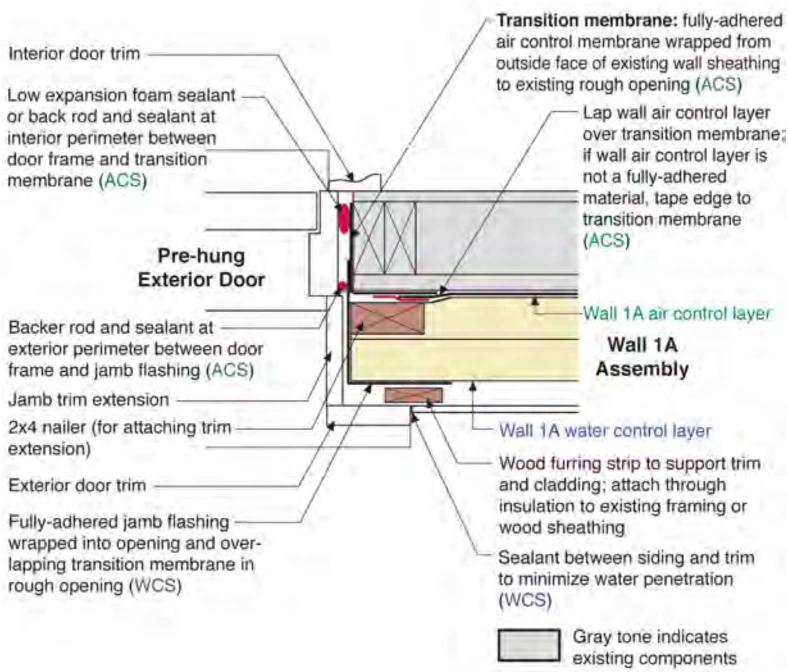
Exterior Door in Wall 1A—Head

- Also see Exterior Door in Wall 1A - Installation Sequence.



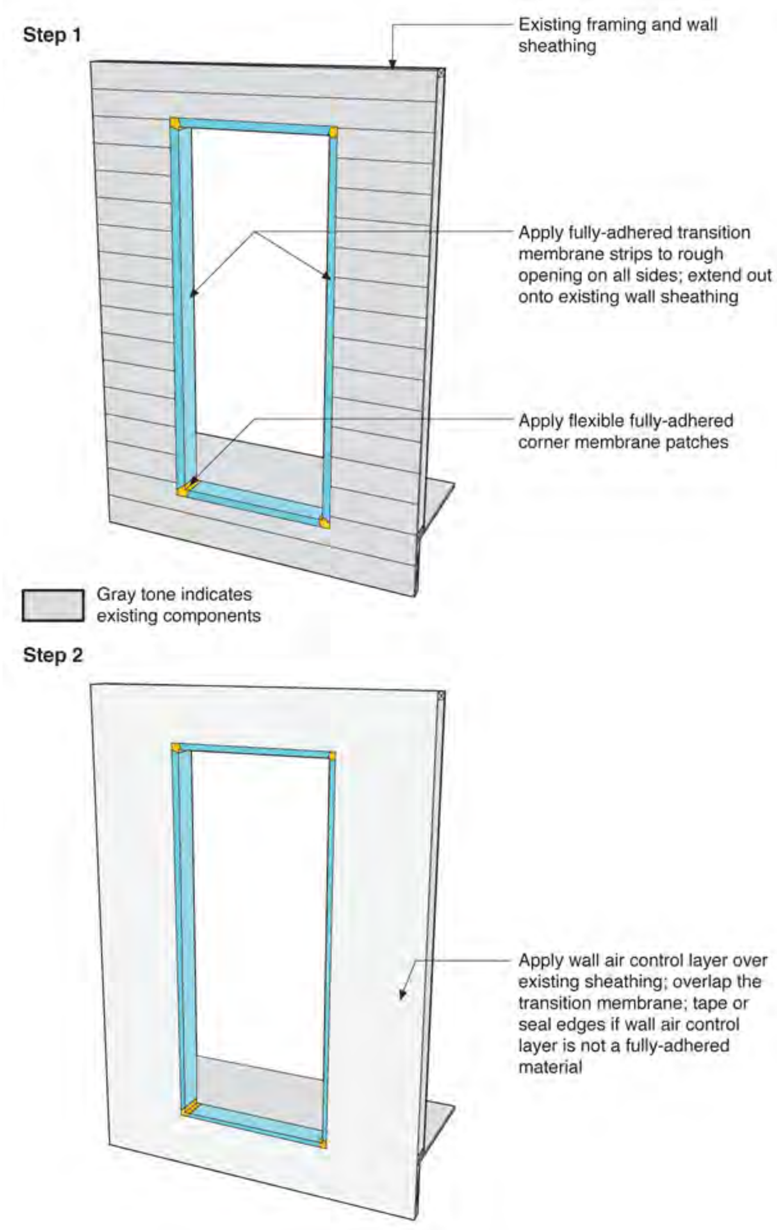
Exterior Door in Wall 1A—Sill

- Also see Exterior Door in Wall 1A - Installation Sequence.



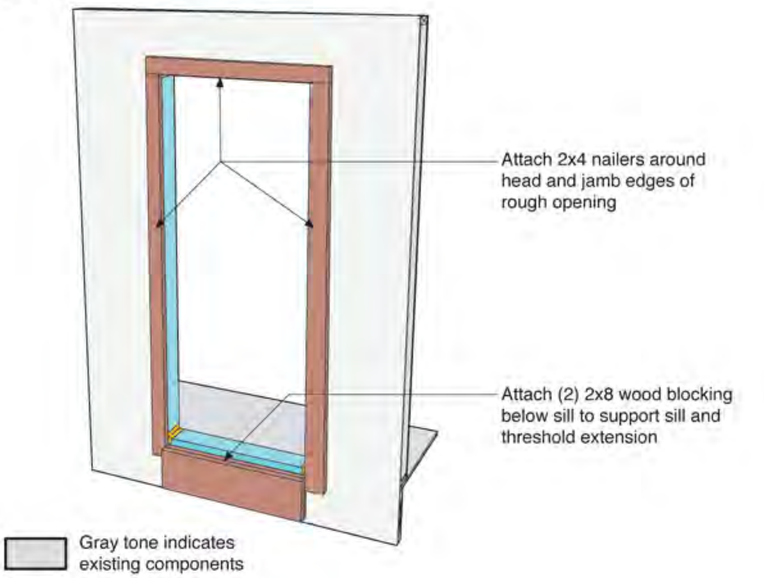
Exterior Door in Wall 1A—Jamb

- Also see Exterior Door in Wall 1A - Installation Sequence.

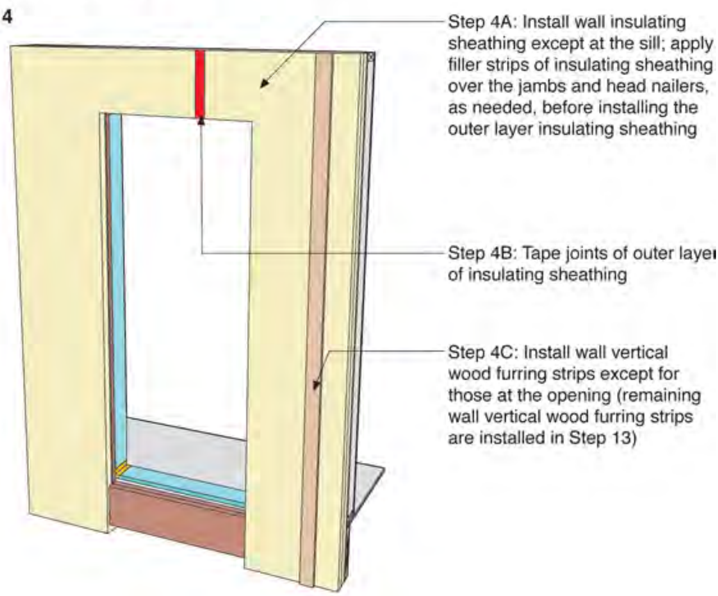


Exterior Door in Wall 1A—Installation Sequence

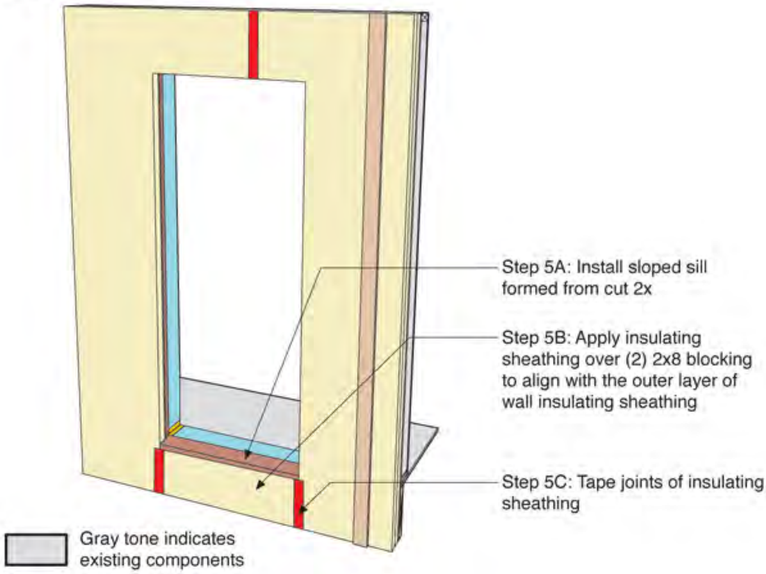
Step 3


Attach 2x4 nailers around head and jamb edges of rough opening
Attach (2) 2x8 wood blocking below sill to support sill and threshold extension
Gray tone indicates existing components

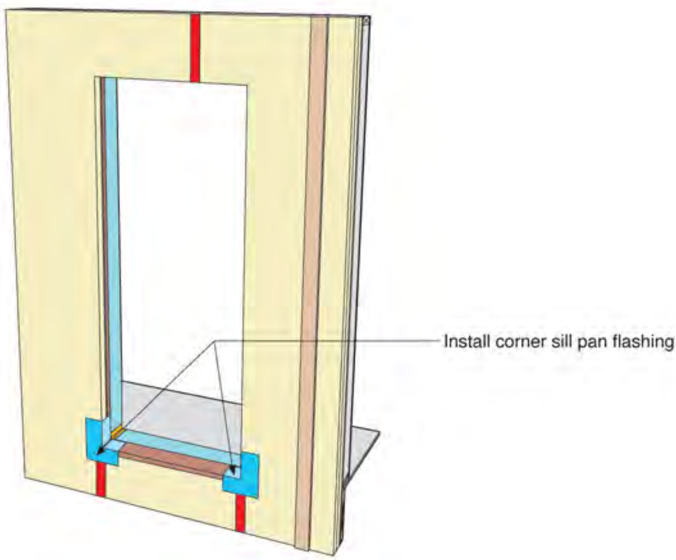
Step 4


Step 4A: Install wall insulating sheathing except at the sill; apply filler strips of insulating sheathing over the jambs and head nailers, as needed, before installing the outer layer insulating sheathing
Step 4B: Tape joints of outer layer of insulating sheathing
Step 4C: Install wall vertical wood furring strips except for those at the opening (remaining wall vertical wood furring strips are installed in Step 13)

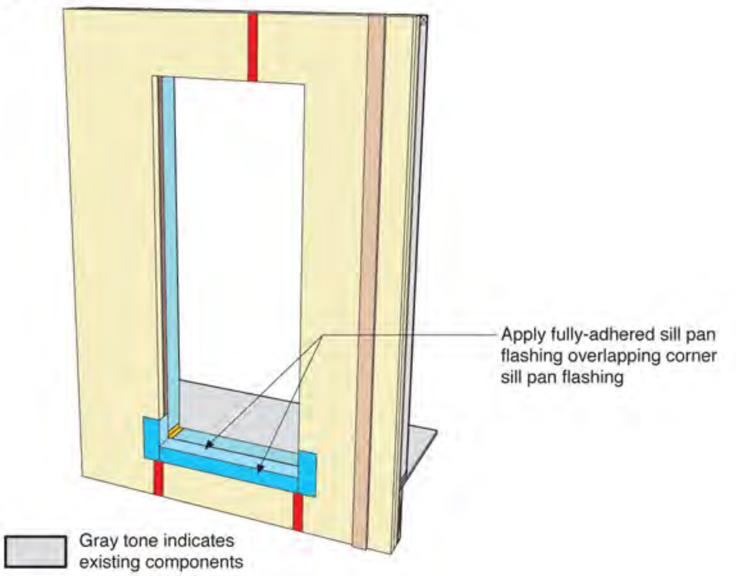
Step 5


Step 5A: Install sloped sill formed from cut 2x
Step 5B: Apply insulating sheathing over (2) 2x8 blocking to align with the outer layer of wall insulating sheathing
Step 5C: Tape joints of insulating sheathing
Gray tone indicates existing components

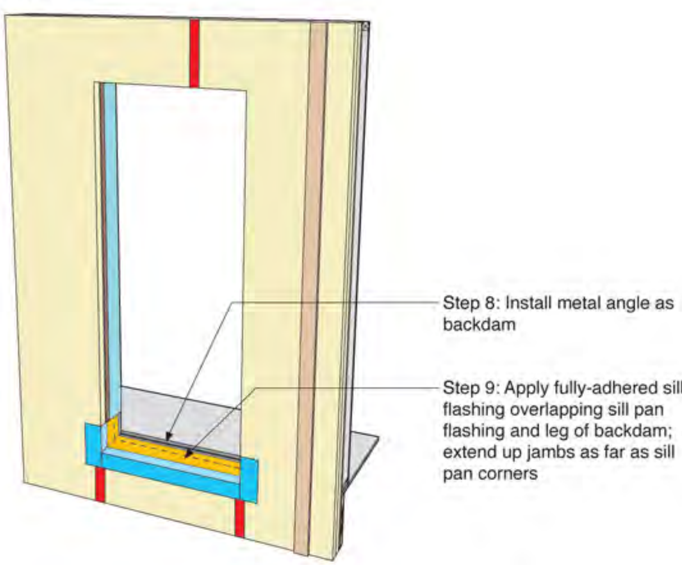
Step 6


Install corner sill pan flashing

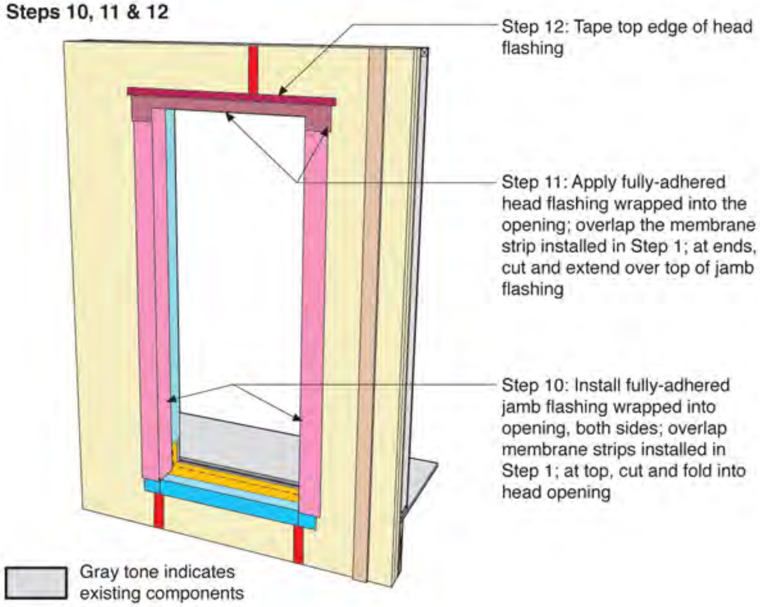
Step 7



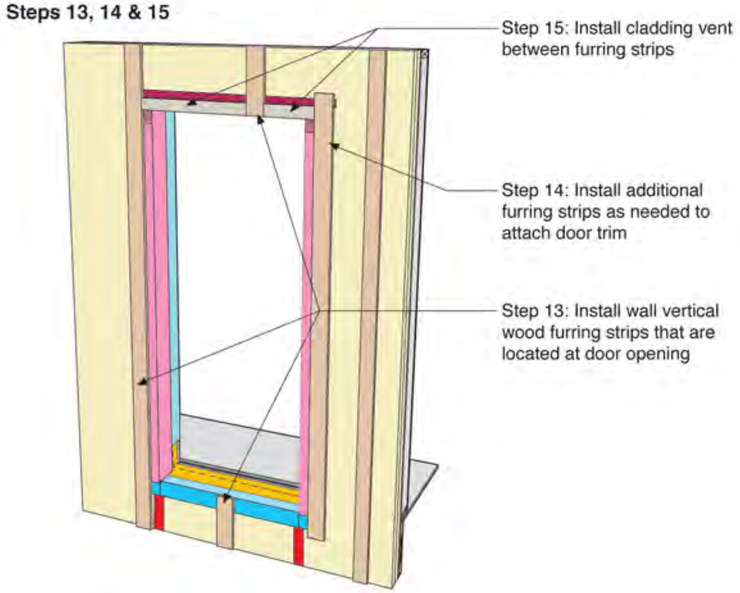
Steps 8 & 9



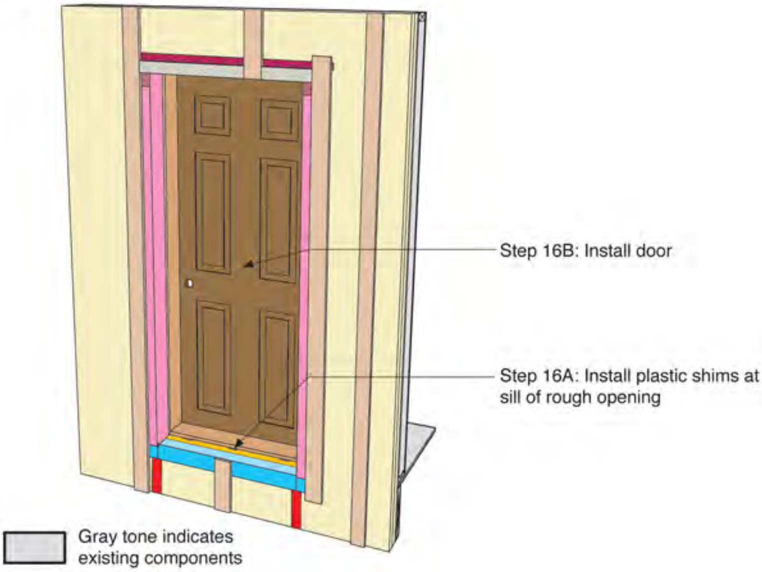
Steps 10, 11 & 12



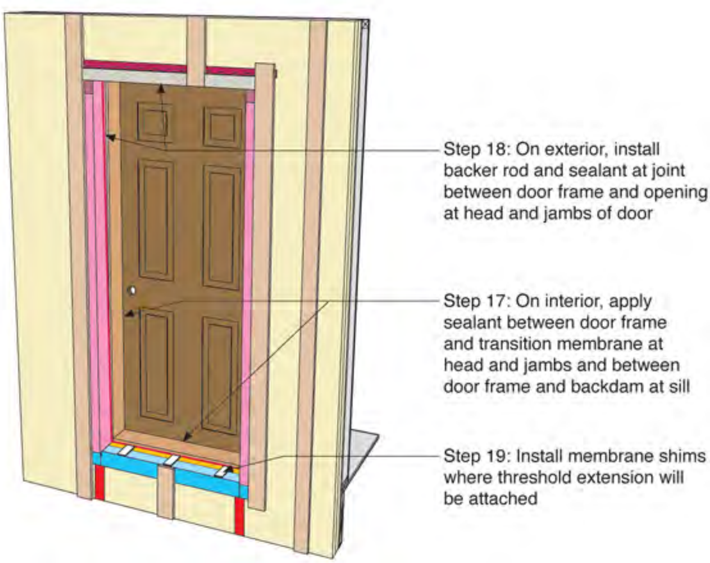
Steps 13, 14 & 15

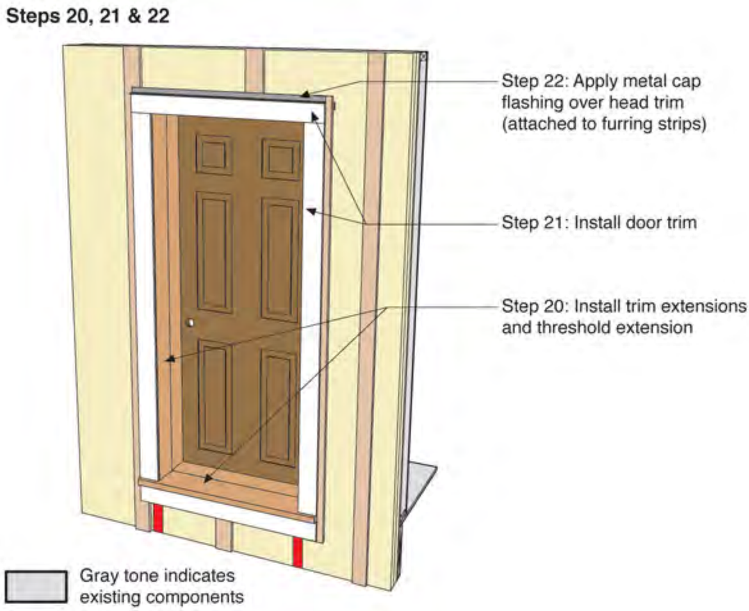


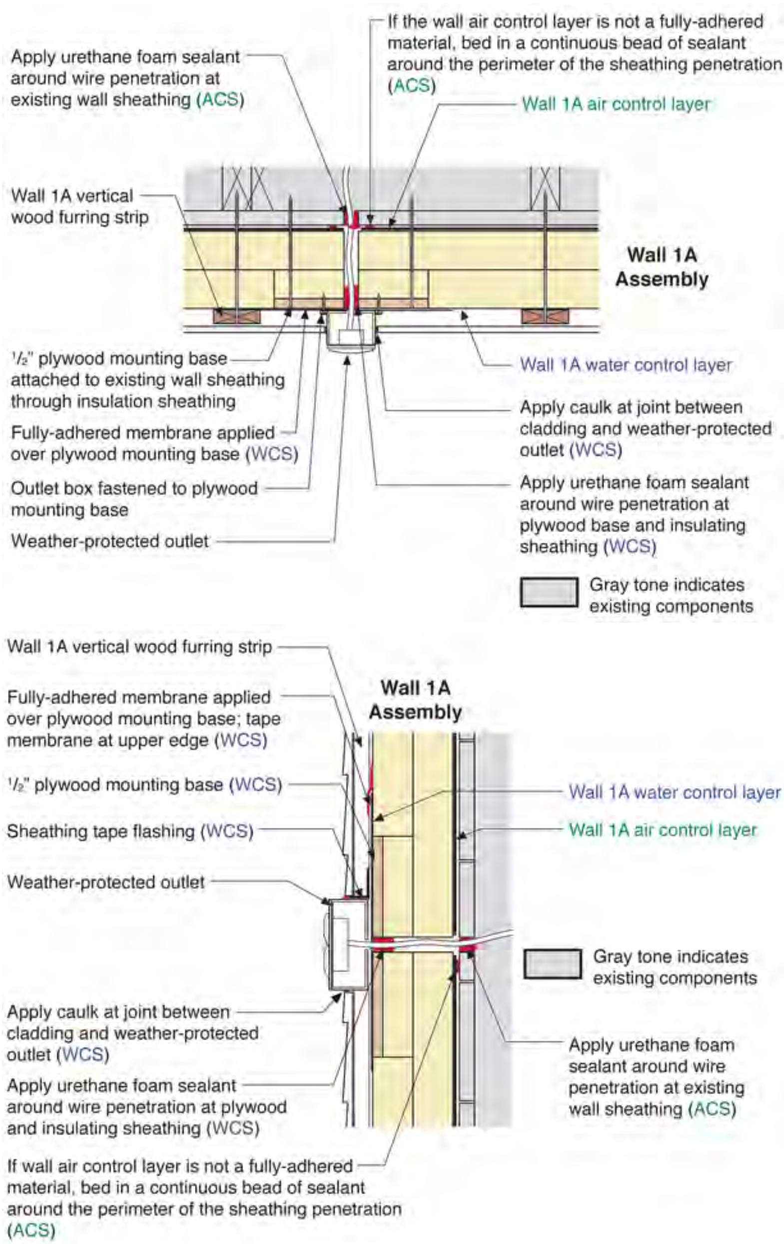
Step 16



Steps 17, 18 & 19

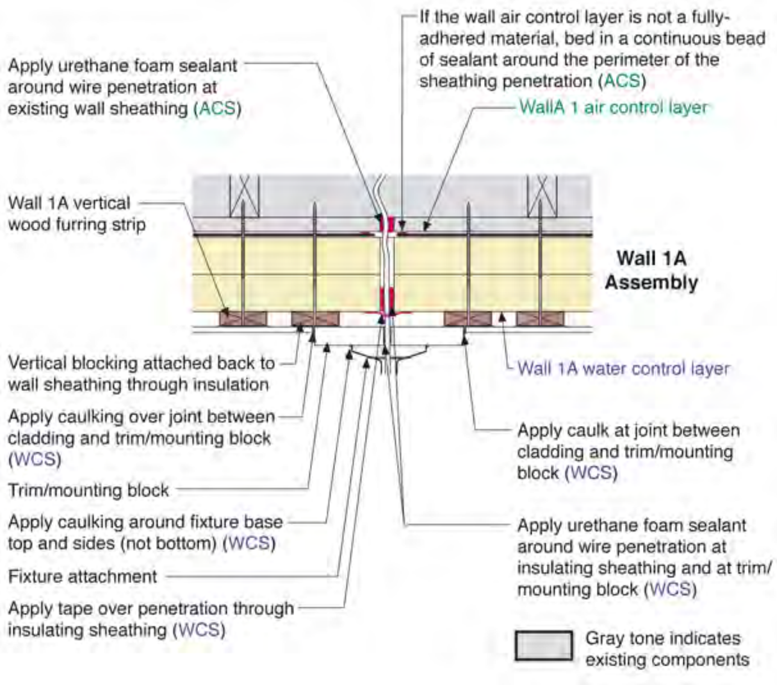


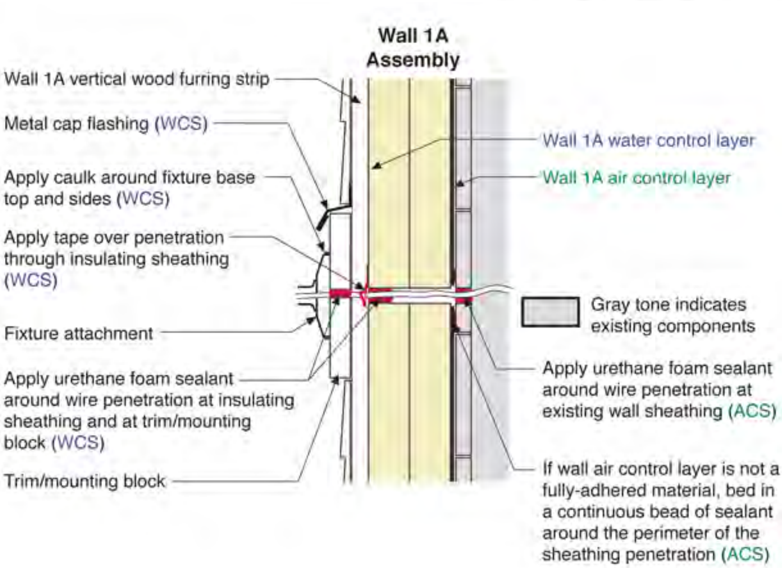

Steps 20, 21 & 22
Step 22: Apply metal cap flashing over head trim (attached to furring strips)
Step 21: Install door trim
Step 20: Install trim extensions and threshold extension
Gray tone indicates existing components



Exterior Electric Box Through Wall 1A–Plan and Section

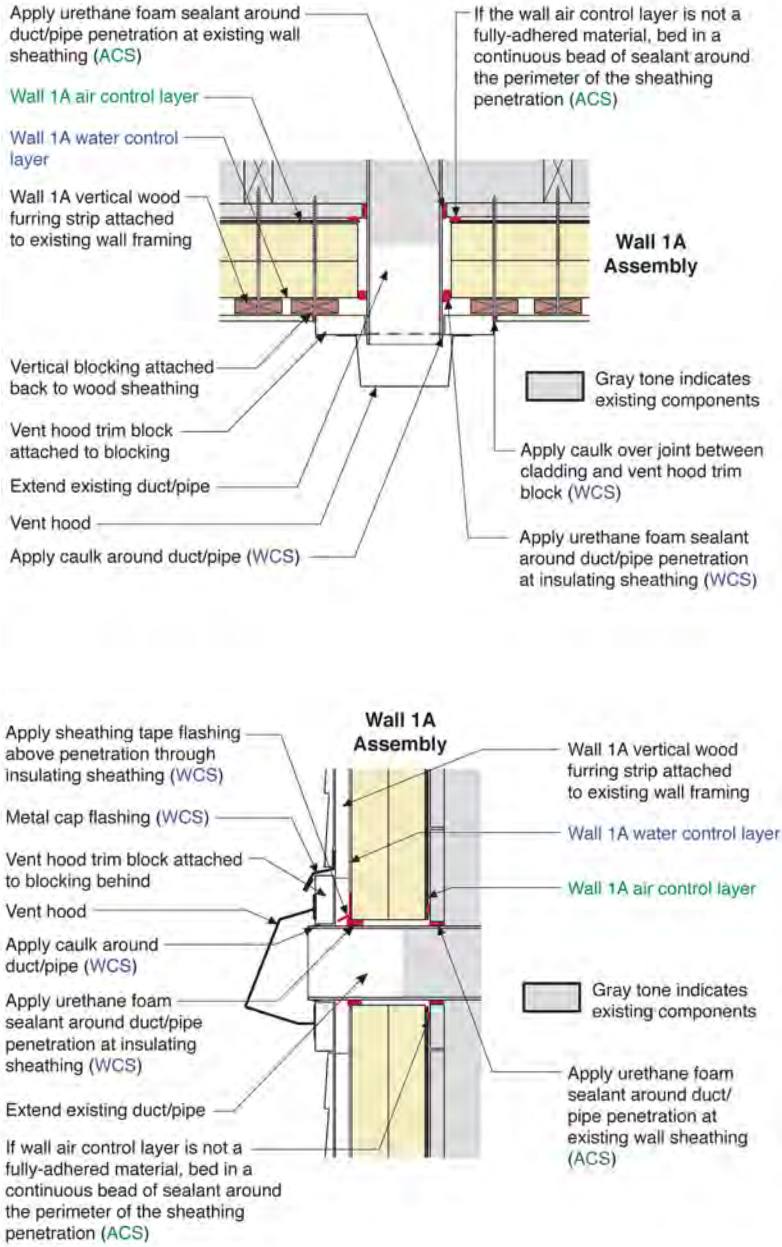
- Vertical furring strips may be provided as needed for attaching ends of cladding at electric box; leave space for drainage between the box and any added furring strips.





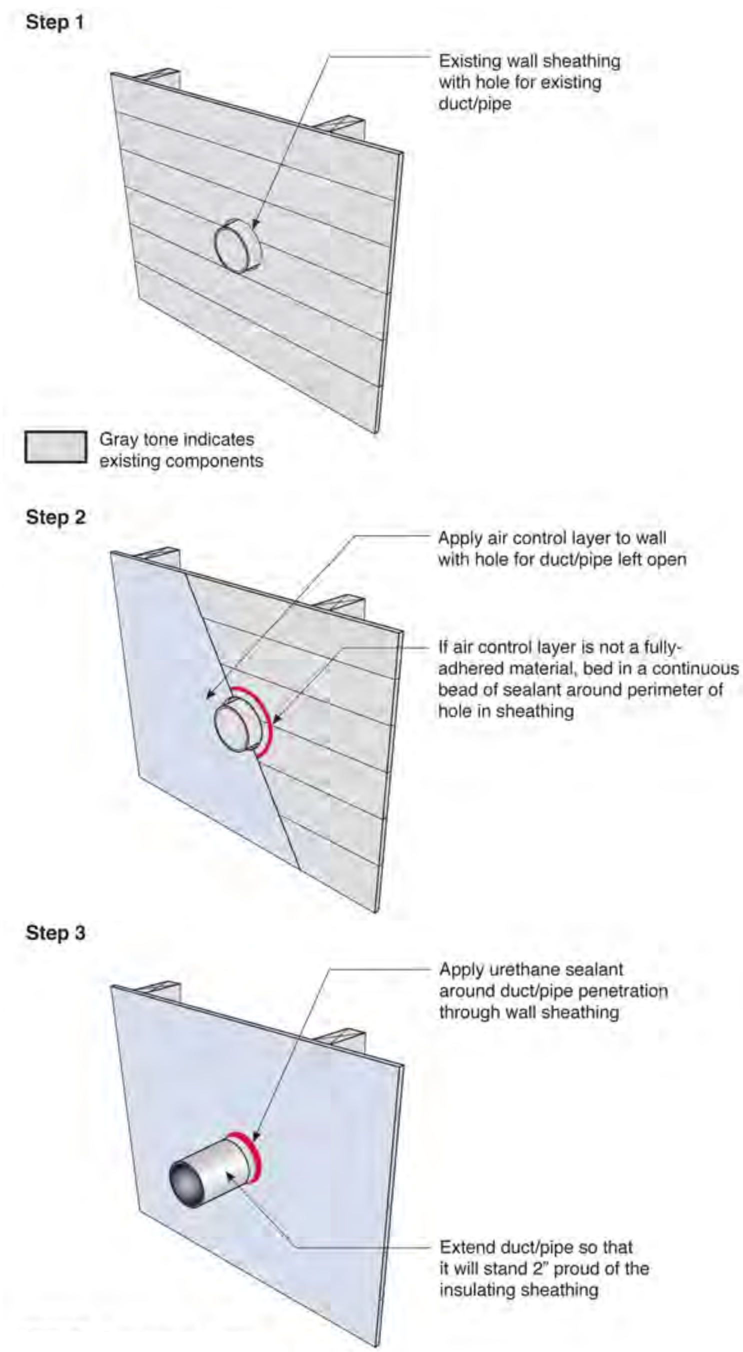
Trim Block with Wire Penetration Through Wall 1A–Plan and Section

- This is for attachment of exterior lighting fixtures or other exterior electrical devices to be installed over a trim block.



Duct/Pipe Penetration Through Wall 1A—Plan and Section

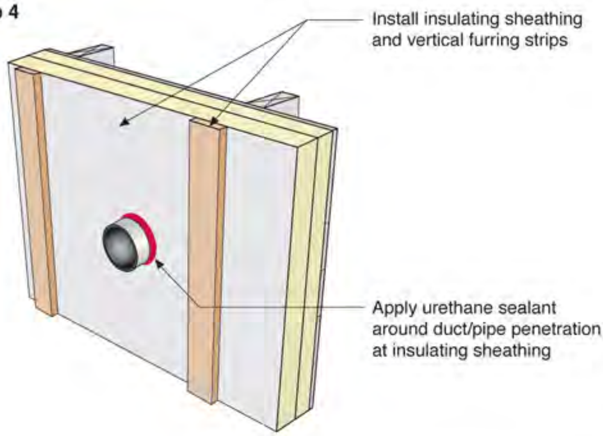
- Also see Duct/Pipe Penetration Through Wall 1A–Installation Sequence.



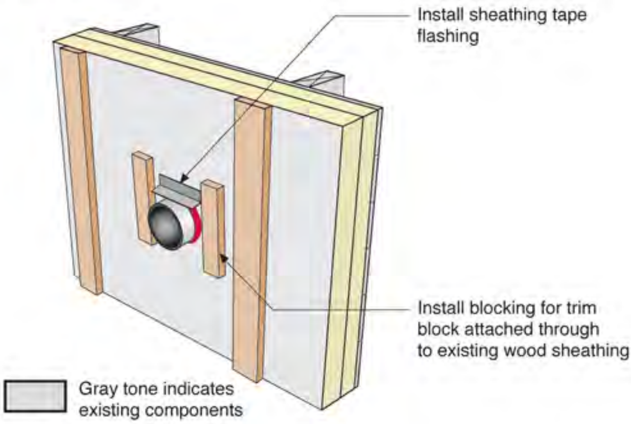
Duct/Pipe Penetration Through Wall 1A–Installation Sequence

Duct/Pipe Penetration Through Wall 1A–Installation Sequence

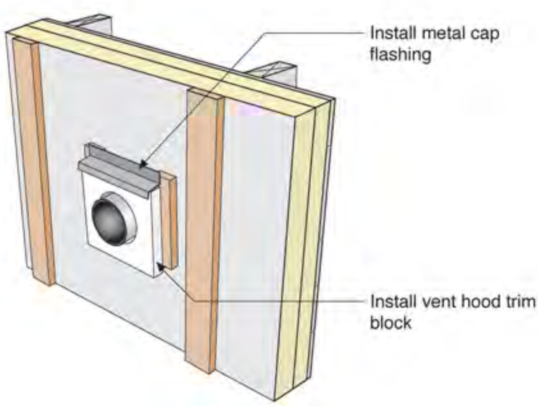
Step 4



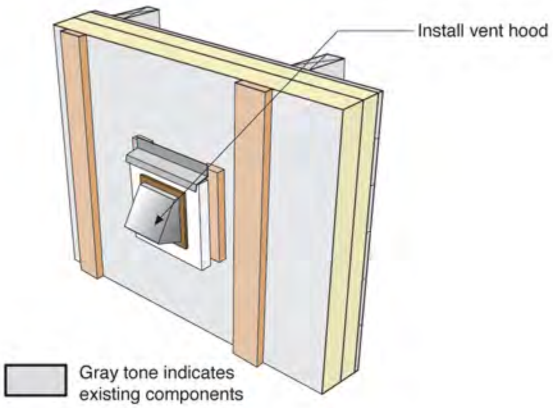
Step 5



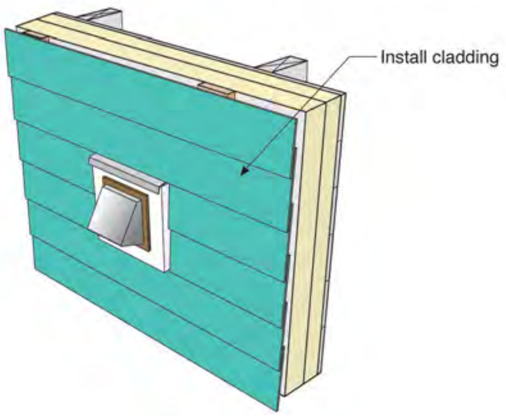
Step 6



Step 7

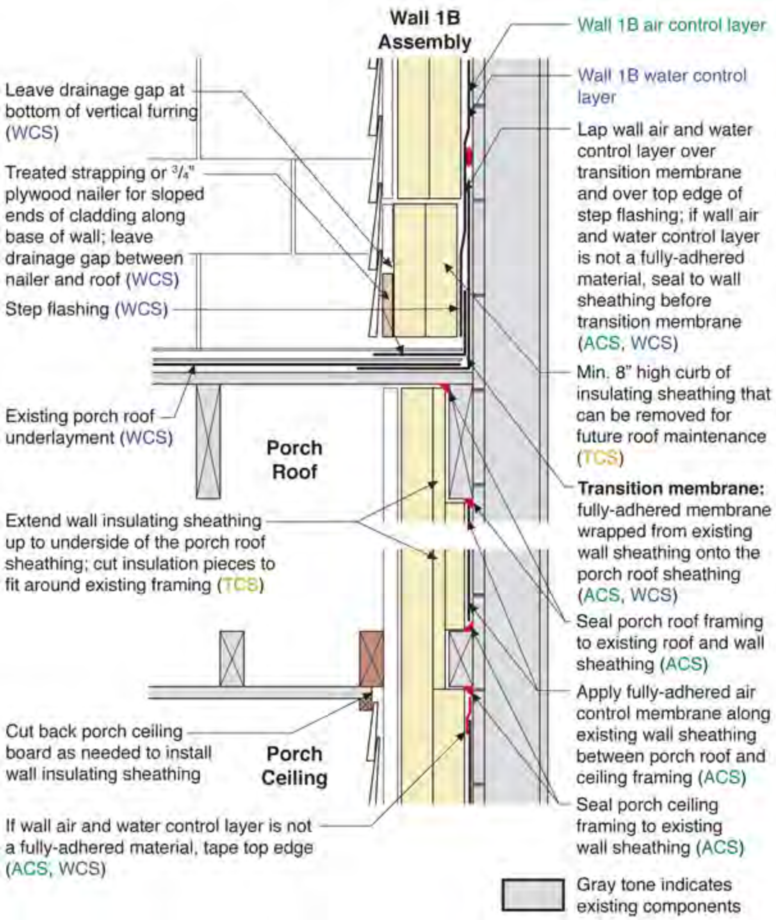

Install vent hood
Gray tone indicates
existing components

Step 8


Install cladding

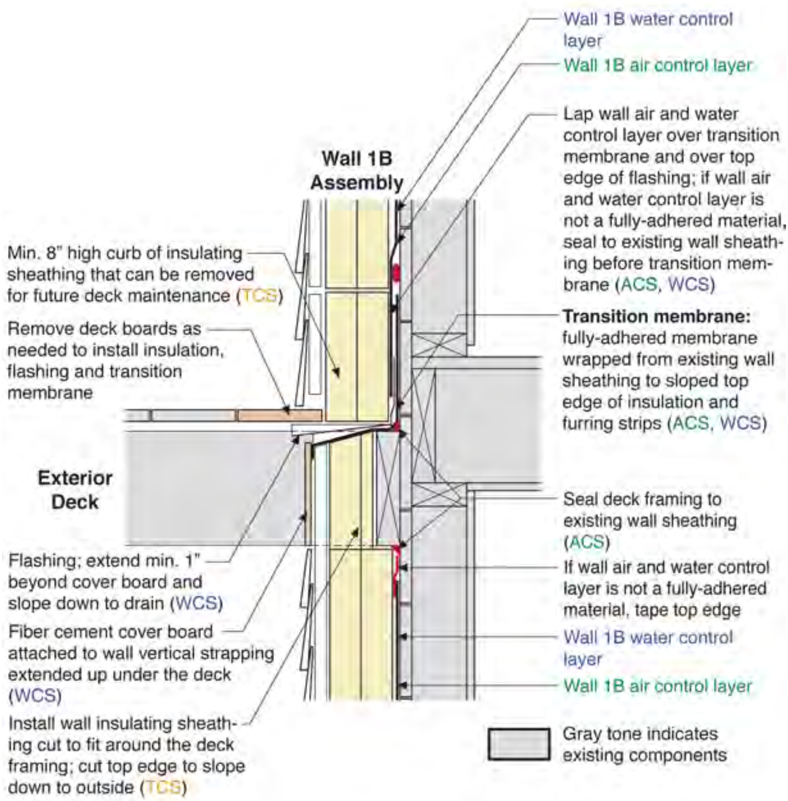
Wall 1B Interruptions

In this retrofit wall assembly, the water control layer is in a familiar position relative to the sheathing of the wall but at an unfamiliar position relative to the rain shedding or cladding layer. All of the flashing details must connect to the water control layer at the wall sheathing and behind the insulating sheathing. As this water control layer is also the air control layer, particular attention is needed to maintain the airflow control through flashings.



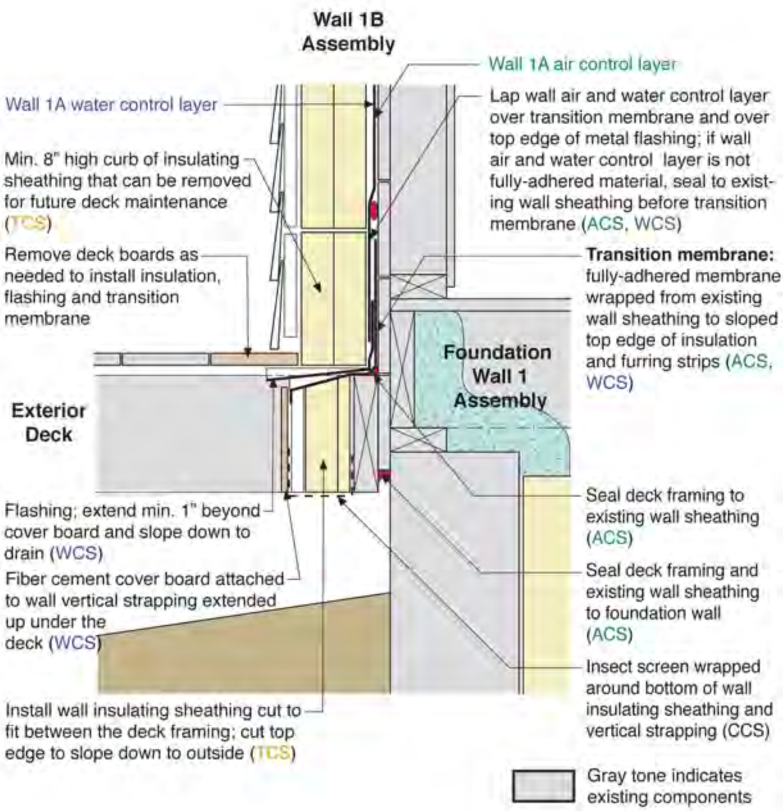
Porch Roof/Ceiling Connection to Wall 1B

- Curb of insulating sheathing is provided to allow access to step flashing during re-roofing of porch roof at a future date.



Deck Connection in Field of Wall 1B

- Curb of insulating sheathing is provided to allow access to the deck structure for future maintenance.



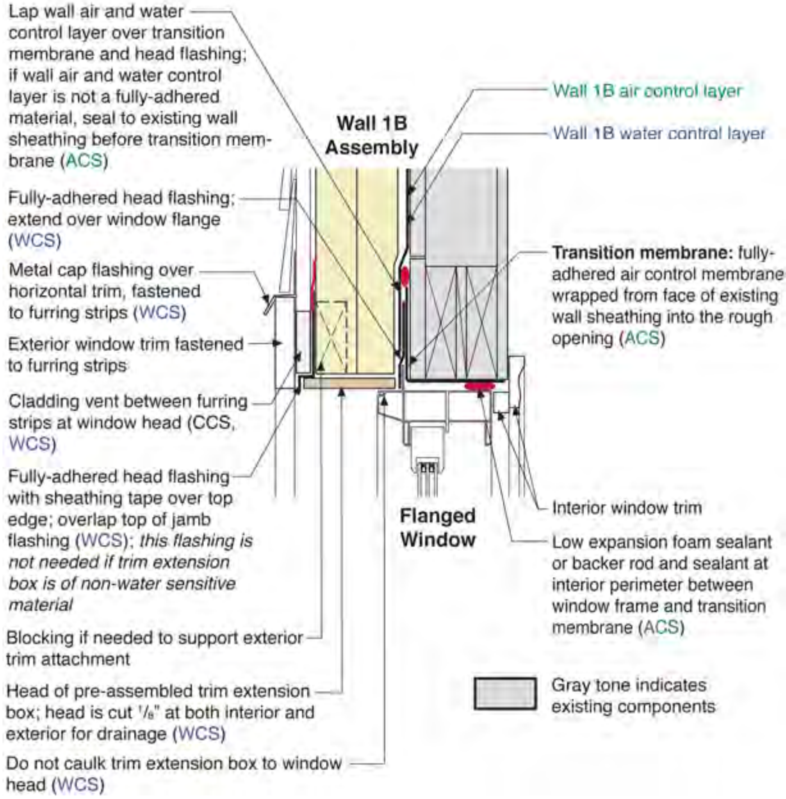
Deck Connection to Base of Wall 1B

- Curb of insulating sheathing is provided to allow access to the deck structure for future maintenance.

Wall 1B Windows and Doors

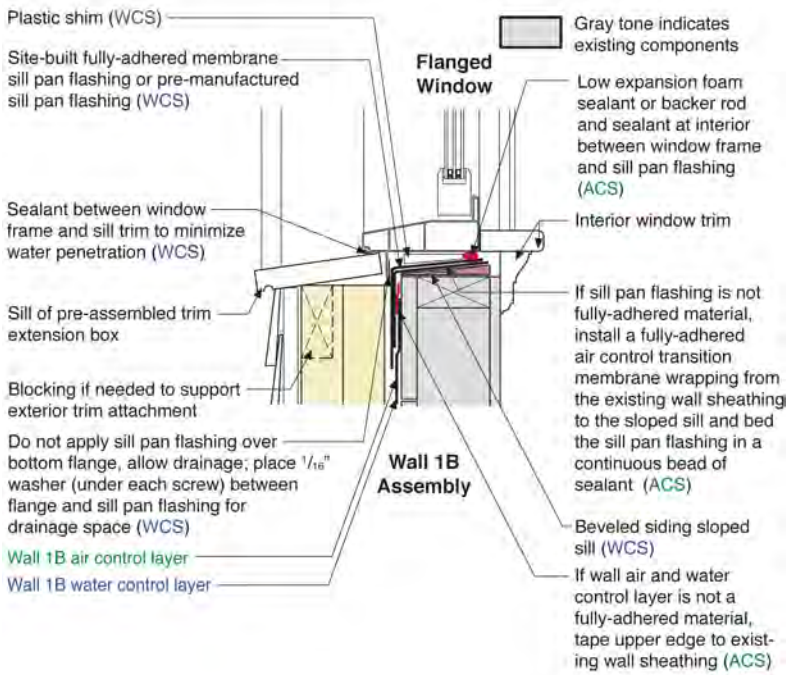
There are two kinds of windows—windows that leak, windows that will leak. This can be said of doors as well. Because of this, it is necessary to flash the window or door opening such that it is a drained opening – when the window or door leaks, water is controlled and the wall system is protected. Sill pan flashing, jamb flashing and head flashing form the water control system for the opening. The sill pan flashing is especially tricky because it must conform to the three dimensional corner configuration at the intersection of the sill and jamb of the opening. Also window and door frames tend to have sharp corners – if the sill pan flashing is not tight to the corner of the opening, the window or door frame could cause a tear in the flashing precisely at the most vulnerable location of the opening. For this reason, one should not attempt to provide pan flashing with flat peel-and-stick membranes. The corners of the sill pan flashing should be executed with pre-manufactured corner flashing, liquid-applied flashing membrane, or flexible flashing membrane.

When existing windows are retained, there may be a compromise to the water management of the wall. Even today (sadly) it is not common practice to install pan flashing in window openings. Older wood windows typically incorporate a continuous wood sill that is sloped to the outside and includes a drip reglet on the underside of the front edge. If properly maintained, such a wood sill may serve to direct water that leaks into the window (e.g. under or around window sash) back to the exterior. Where an existing window is retained within a wall to be retrofitted with insulating sheathing and new cladding, the details around the window should facilitate a minimally disruptive replacement of the window at some point in the future.



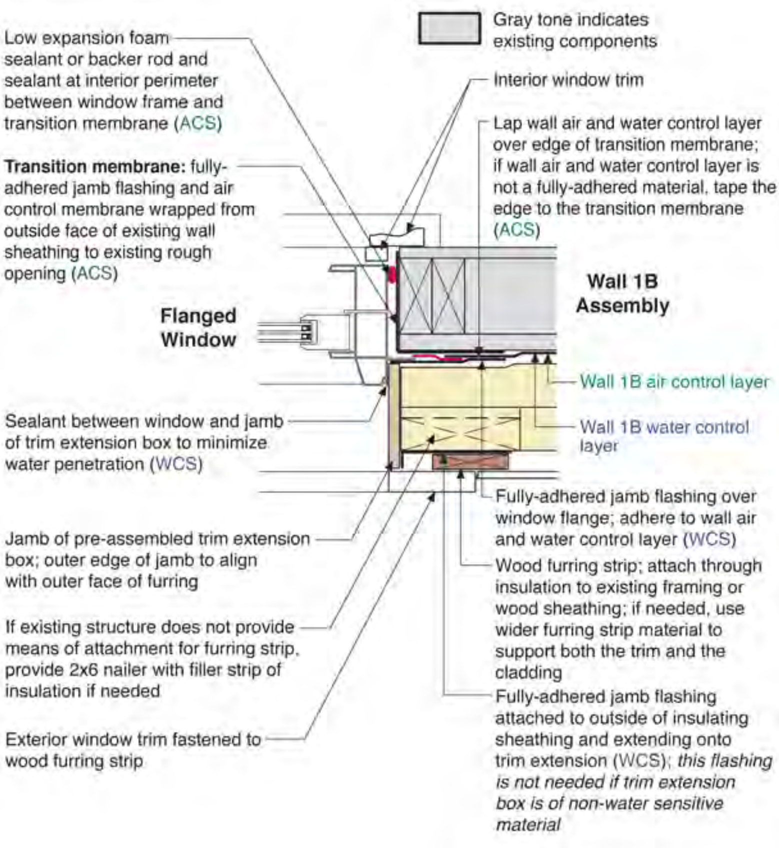
Flanged Window in Wall 1B—Head

- The pre-assembled trim extension box is described in Flanged Window in Wall 1B Trim Installation Sequence.
- Also see Flanged Window in Wall 1B - Installation Sequence.



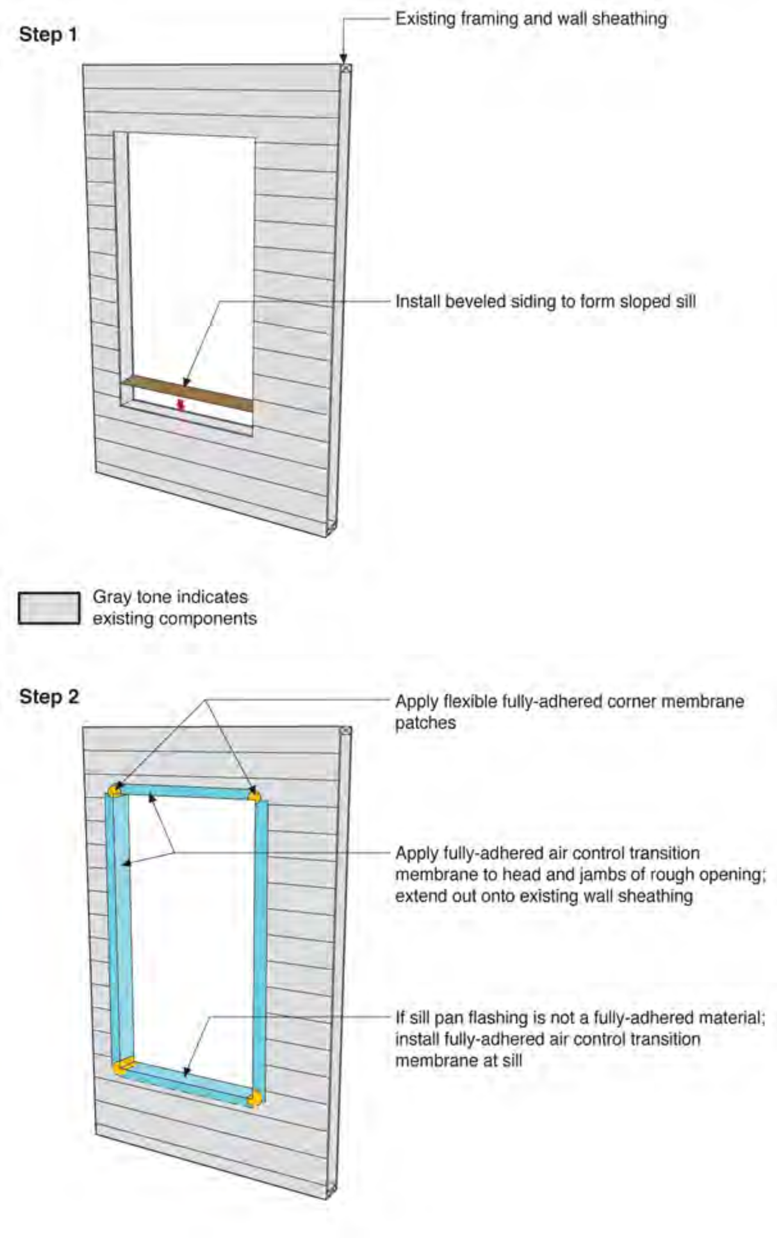
Flanged Window in Wall 1B—Sill

- The pre-assembled trim extension box is described in Flanged Window in Wall 1B Trim Installation Sequence.
- Also see Flanged Window in Wall 1B - Installation Sequence.



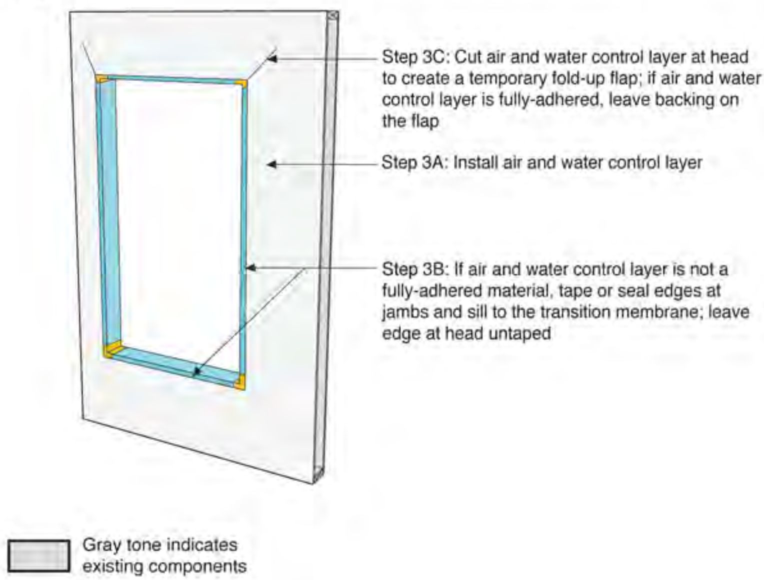
Flanged Window in Wall 1B—Jamb

- The pre-assembled trim extension box is described in Flanged Window in Wall 1B Trim Installation Sequence.
- Also see Flanged Window in Wall 1B - Installation Sequence.

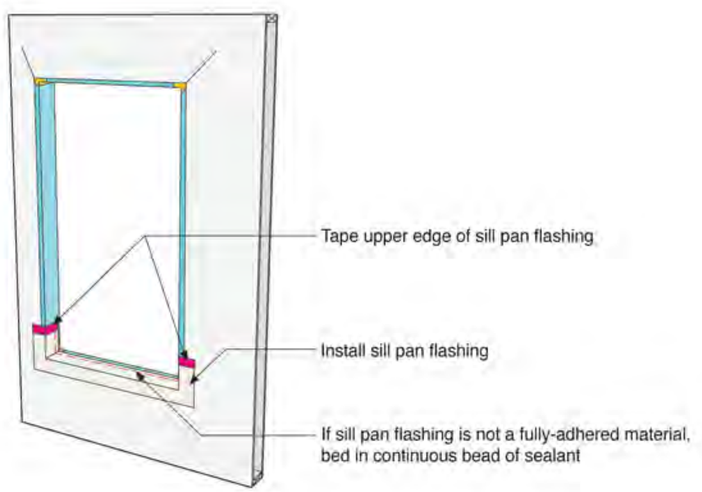


Flanged Window in Wall 1B—Installation Sequence

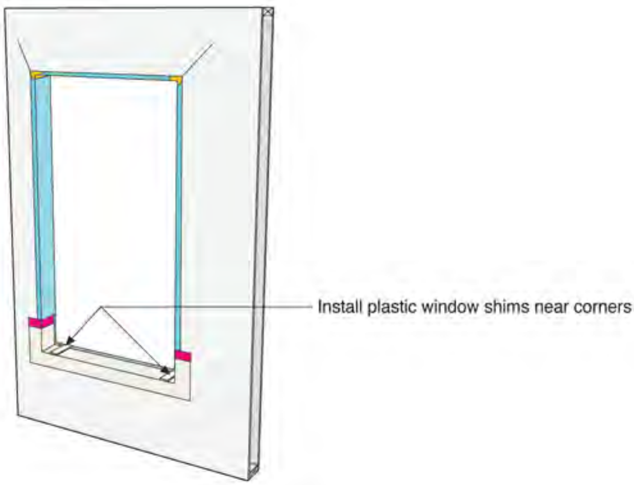
Step 3


Step 3C: Cut air and water control layer at head to create a temporary fold-up flap; if air and water control layer is fully-adhered, leave backing on the flap
Step 3A: Install air and water control layer
Step 3B: If air and water control layer is not a fully-adhered material, tape or seal edges at jambs and sill to the transition membrane; leave edge at head untaped
Gray tone indicates existing components

Step 4

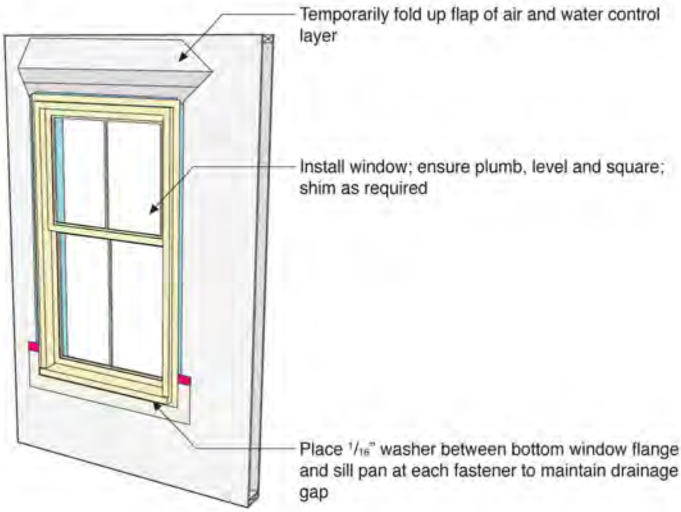

Tape upper edge of sill pan flashing
Install sill pan flashing
If sill pan flashing is not a fully-adhered material, bed in continuous bead of sealant

Step 5

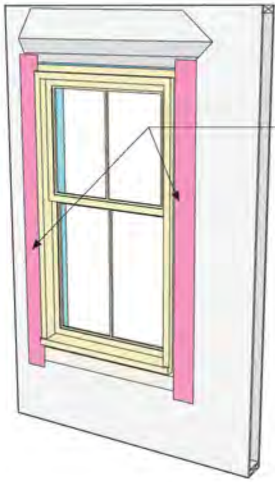

Install plastic window shims near corners


Gray tone indicates
existing components

Step 6

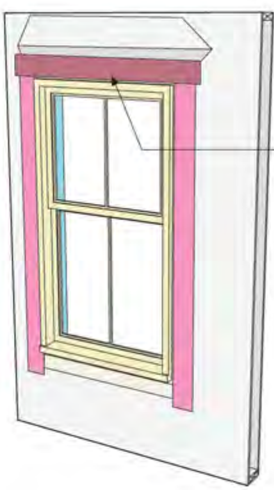

Temporarily fold up flap of air and water control layer
Install window; ensure plumb, level and square; shim as required
Place 1/16" washer between bottom window flange and sill pan at each fastener to maintain drainage gap

Step 7

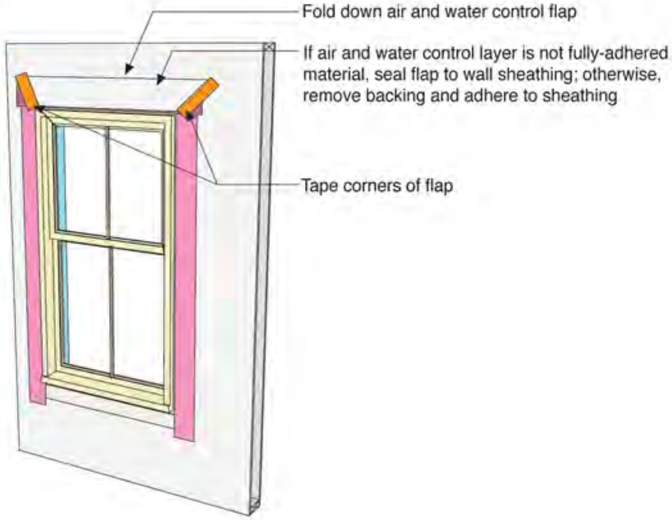


Gray tone indicates existing components

Step 8

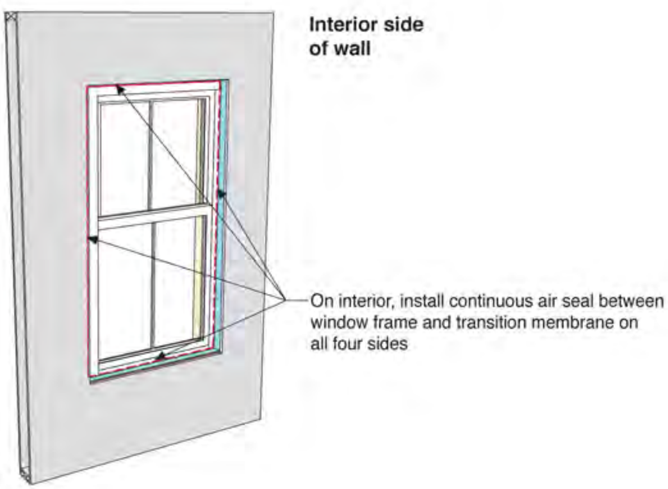


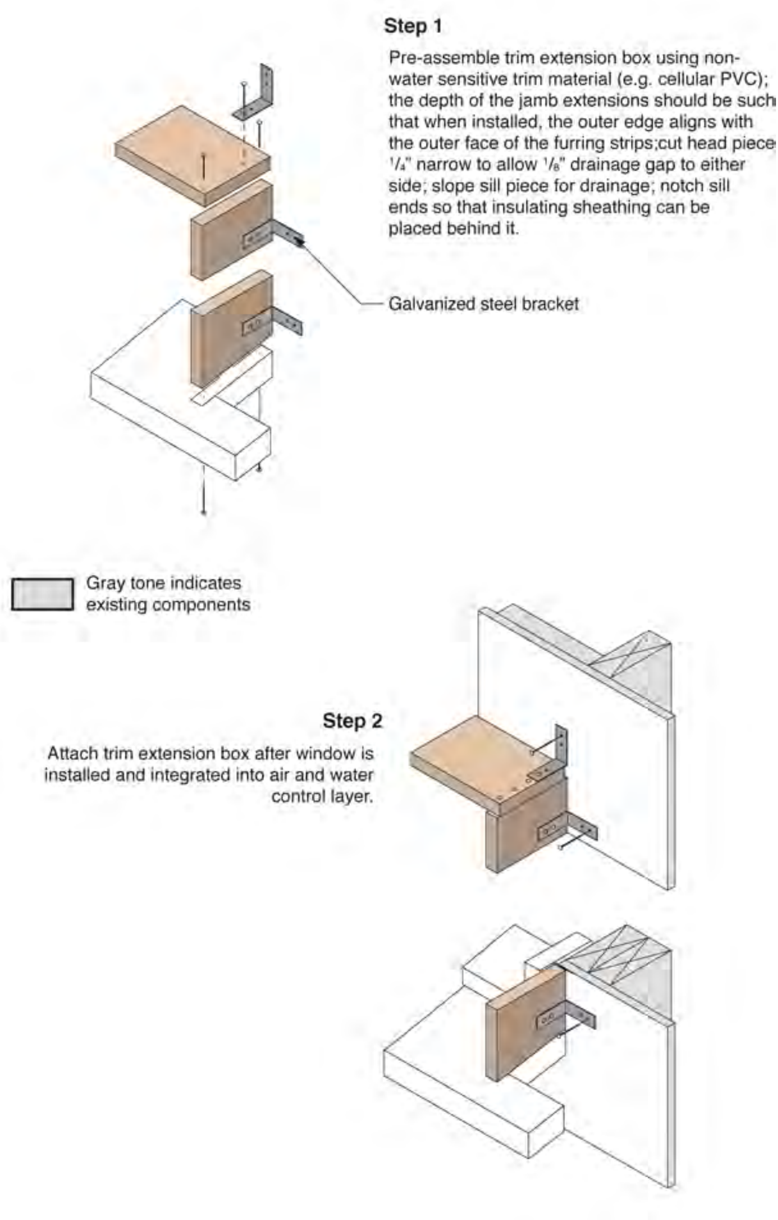
Step 9



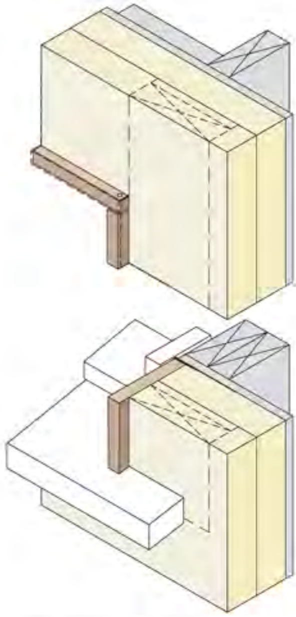
Gray tone indicates existing components

Step 10





Flanged Window in Wall 1B—Trim Installation Sequence



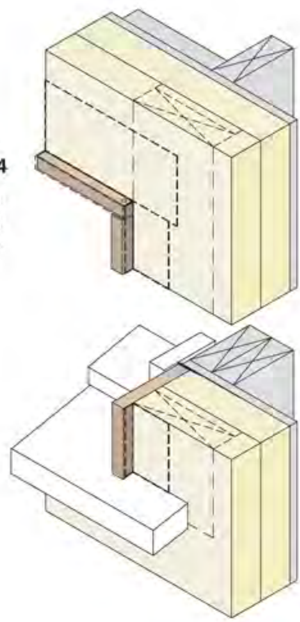
Step 3

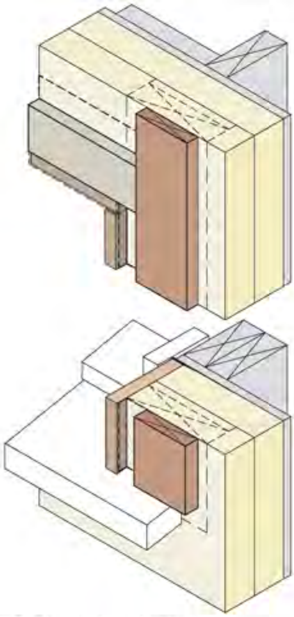
Install insulating sheathing up tight to the trim extension box; if optional nailer is needed, install in the plane of the outer layer of insulating sheathing.

Gray tone indicates existing structure

Step 4

If trim extension box is a water sensitive material, apply head and jamb flashing over insulating sheathing.





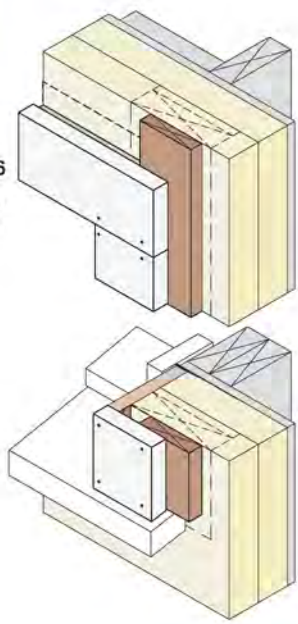
Step 5

Install furring to support window trim and cladding; leave space for drainage between the furring and the trim extension box; install cladding vent between furring strips at window head.

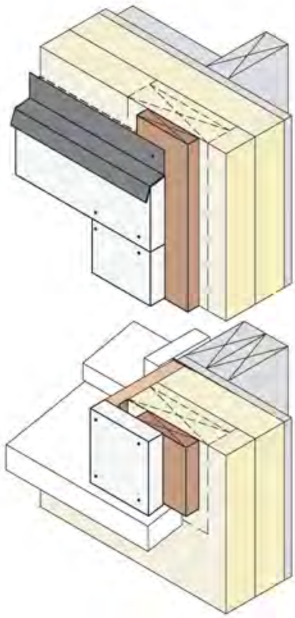
Gray tone indicates existing structure

Step 6

Install window trim; fasten to trim extension box and furring.



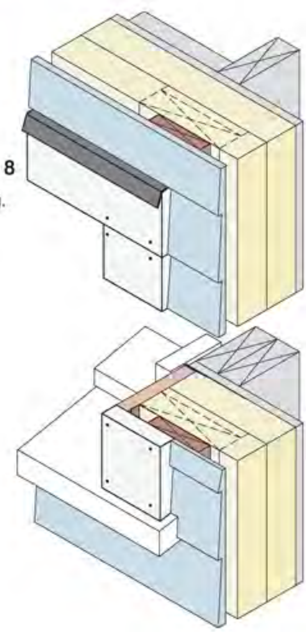
Flanged Window Wall 1B—Trim Installation Sequence



Step 7

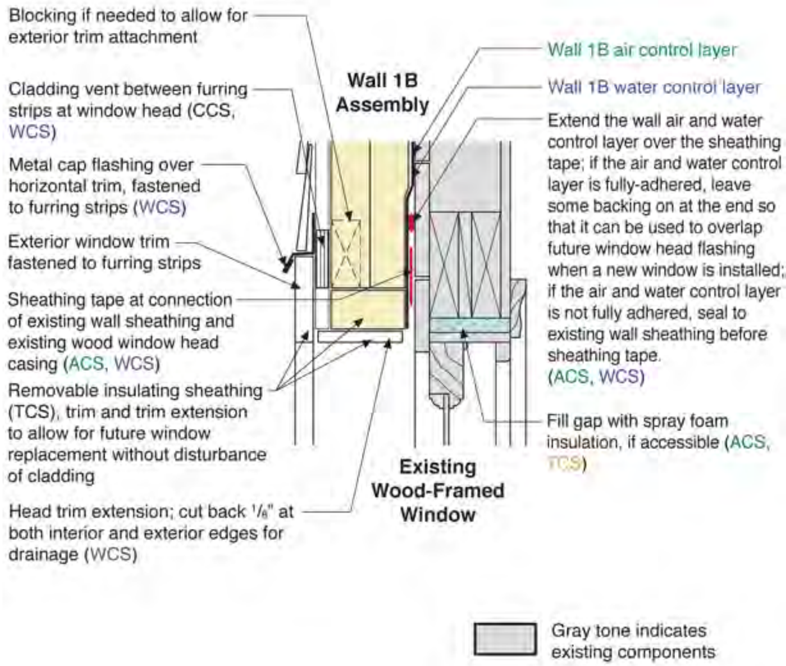
Install sloped metal drip edge over head trim; fasten to furring strips.

Gray tone indicates existing structure



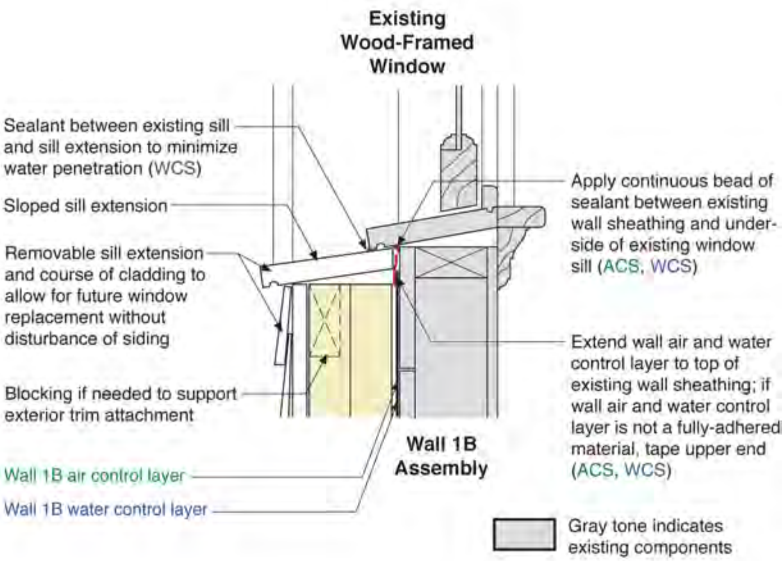
Step 8

Install cladding.



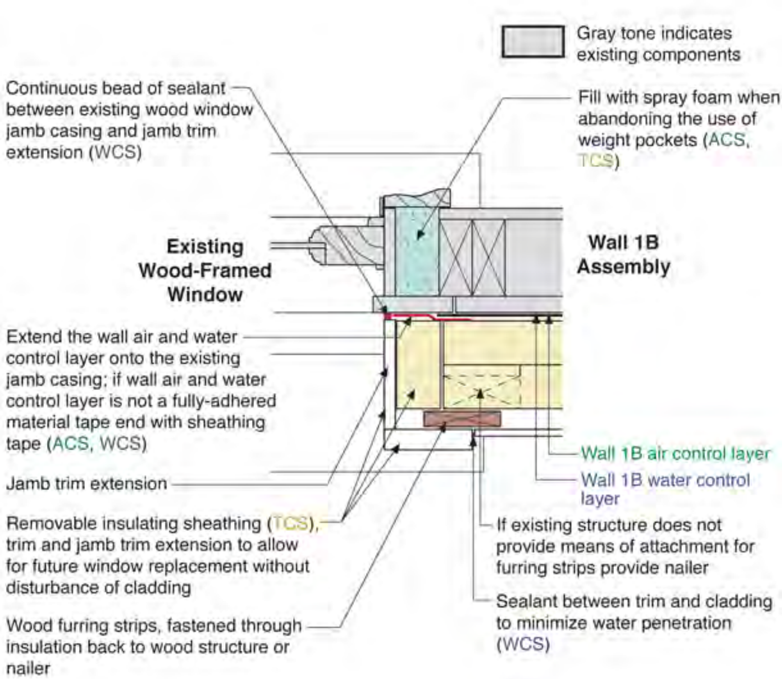
Existing Wood-Framed Window in Wall 1B—Head

- Replacement windows can be installed within the existing wood window frame without disturbing the cladding, exterior window trim, or trim extension.
- It is recommended that the trim extension be made of a non-water sensitive material.



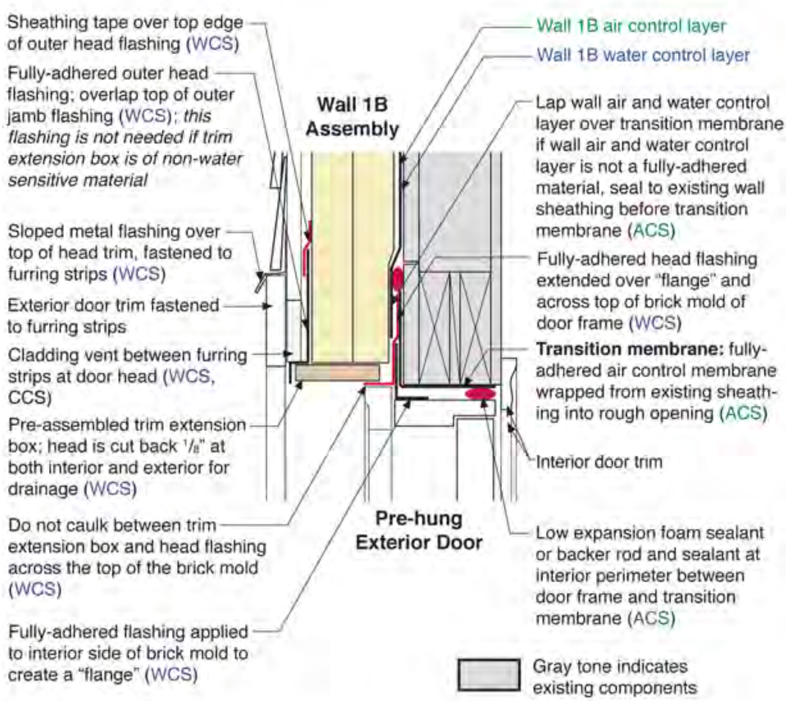
Existing Wood-Framed Window in Wall 1B—Sill

- Replacement windows can be installed within the existing wood window frame without disturbing the cladding, exterior window trim, or trim extension.
- To facilitate removal, the cladding piece below the sill extension should terminate beneath the exterior jamb trim to either side of the window. Alternatively, a removable apron trim piece may be used.



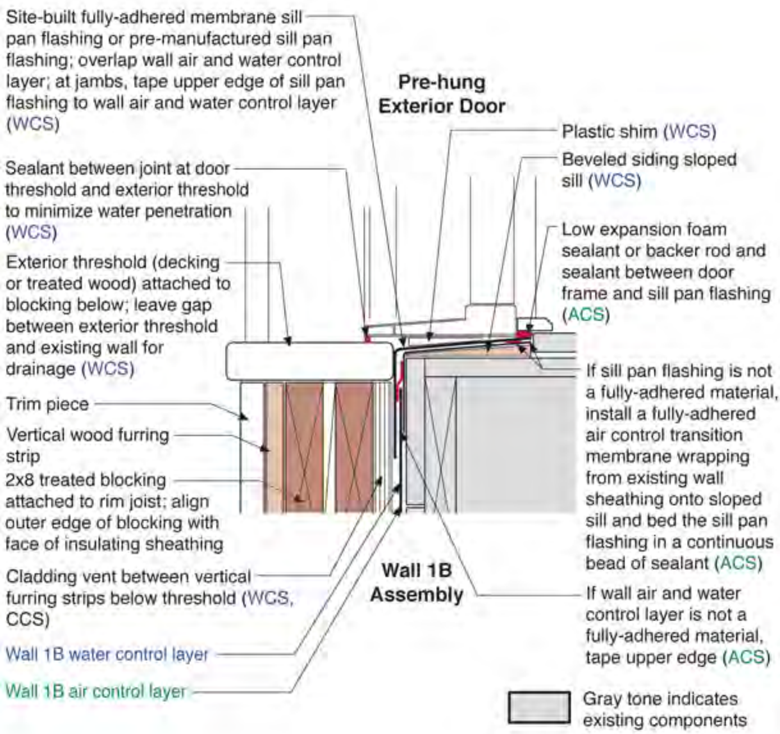
Existing Wood-Framed Window in Wall 1B—Jamb

- Replacement windows can be installed within the existing wood window frame without disturbing the cladding, exterior window trim or trim extension.
- It is recommended that the trim extension be made of a non-water sensitive material.



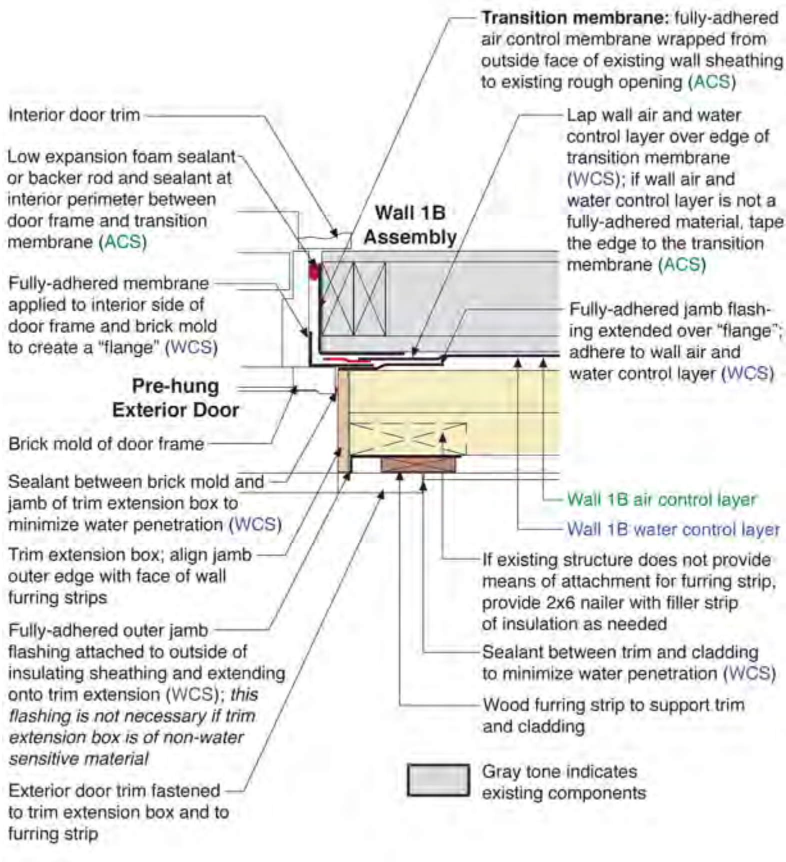
Exterior Door in Wall 1B—Head

- The pre-assembled trim extension box is described in Exterior Door in Wall 1B Trim Installation Sequence.
- Also see Exterior Door in Wall 1B - Installation Sequence.



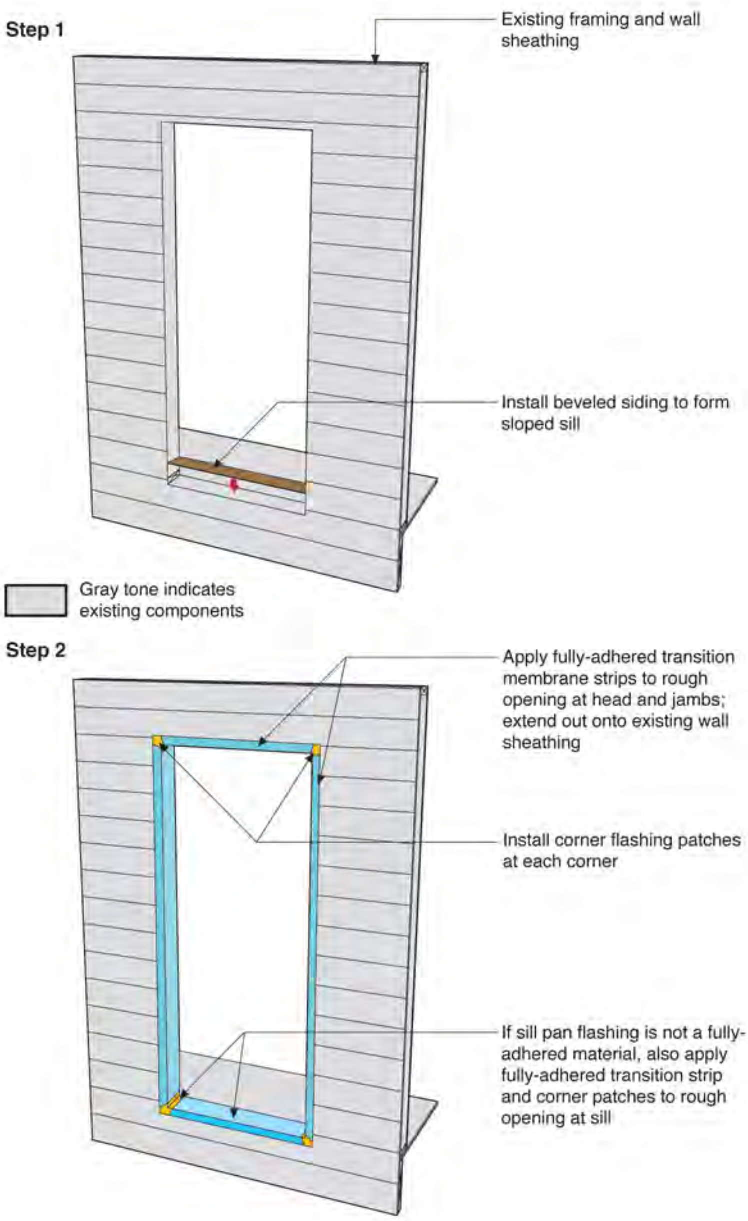
Exterior Door in Wall 1B—Sill

- Also see Exterior Door in Wall 1B - Installation Sequence.



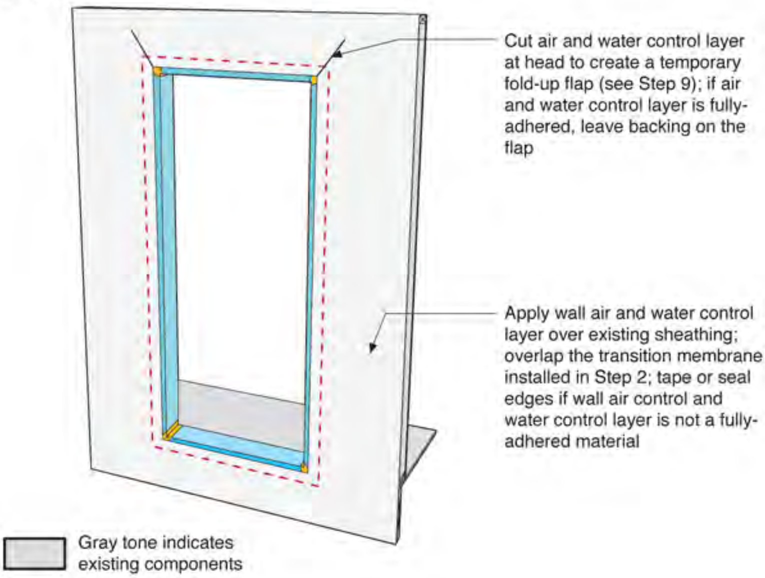
Exterior Door in Wall 1B—Jamb

- The pre-assembled trim extension box is described in Exterior Door in Wall 1B Trim Installation Sequence
- Also see Exterior Door in Wall 1B - Installation Sequence..

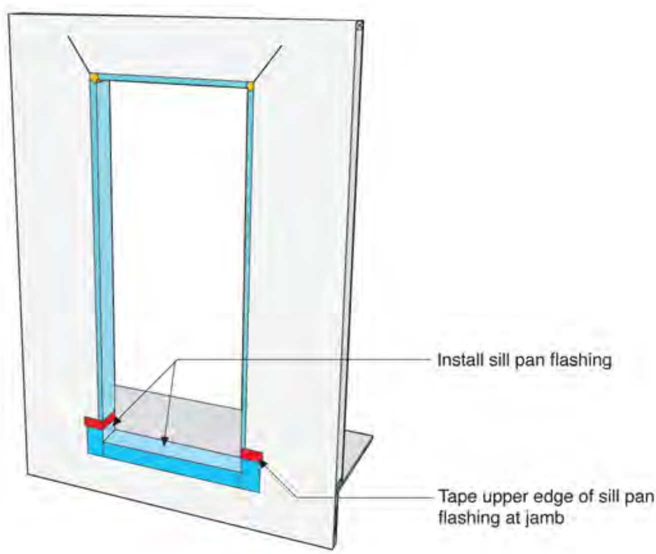


Exterior Door in Wall 1B—Installation Sequence

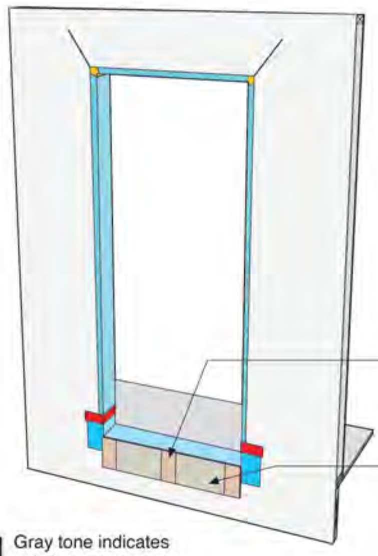
Step 3


Cut air and water control layer at head to create a temporary fold-up flap (see Step 9); if air and water control layer is fully-adhered, leave backing on the flap
Apply wall air and water control layer over existing sheathing; overlap the transition membrane installed in Step 2; tape or seal edges if wall air control and water control layer is not a fully-adhered material
Gray tone indicates existing components

Step 4

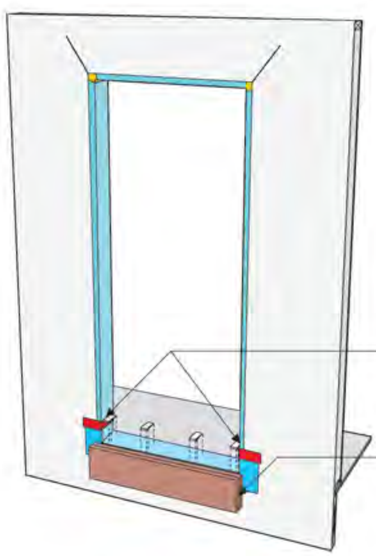

Install sill pan flashing
Tape upper edge of sill pan flashing at jamb

Step 5

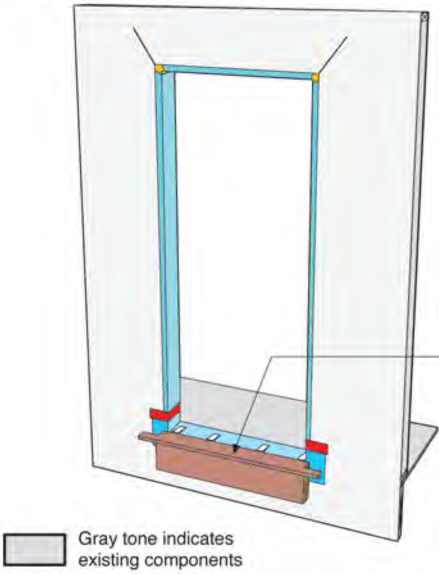


Gray tone indicates existing components

Step 6

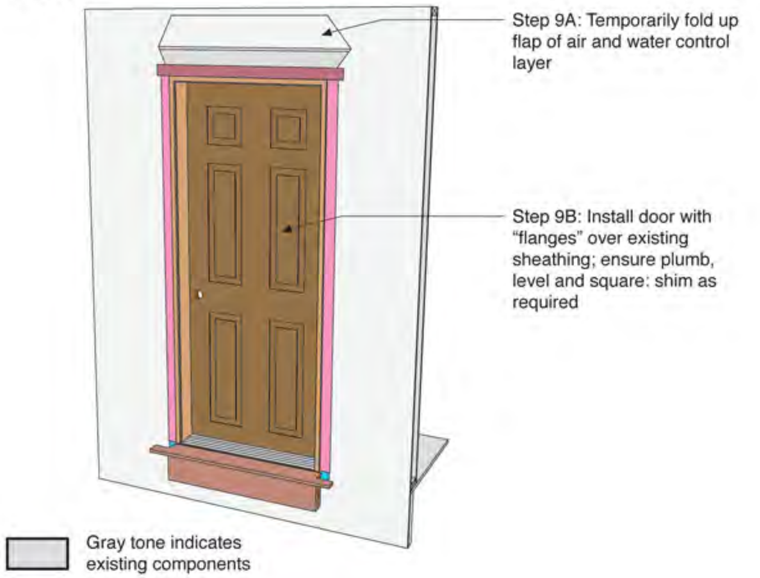


Step 7

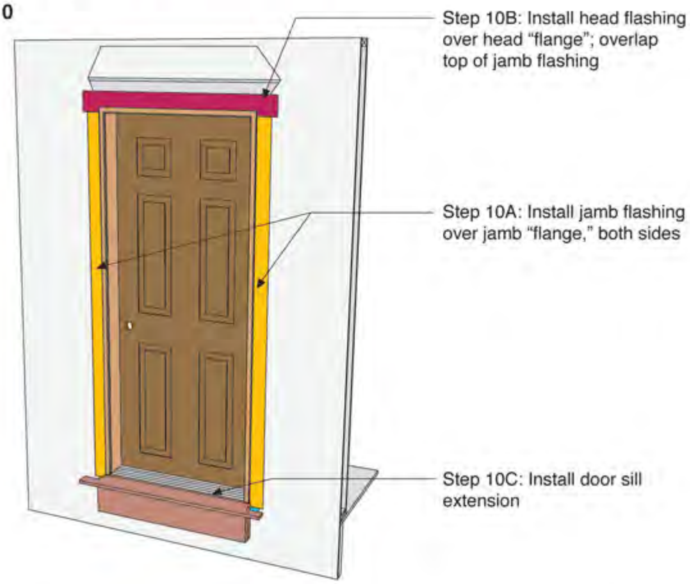


Step 8 (reverse view)

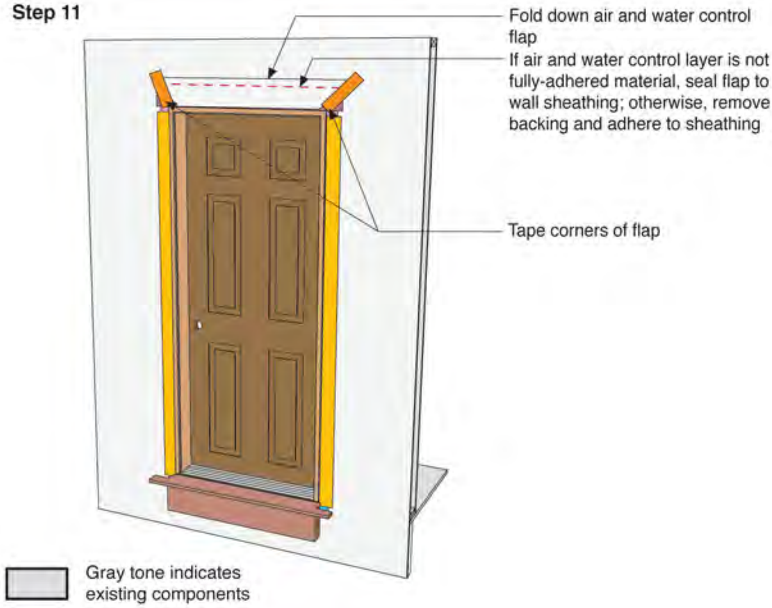
Step 9



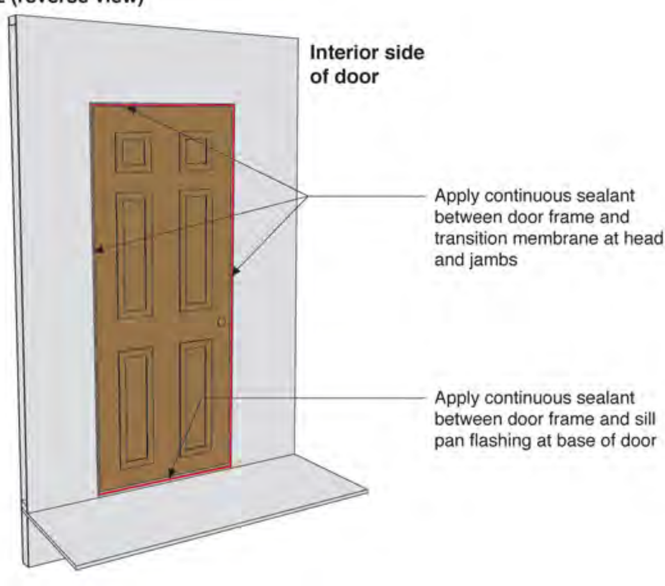
Step 10

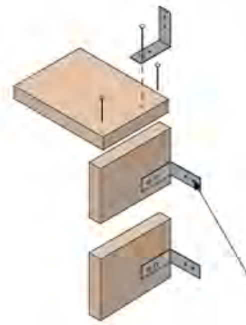


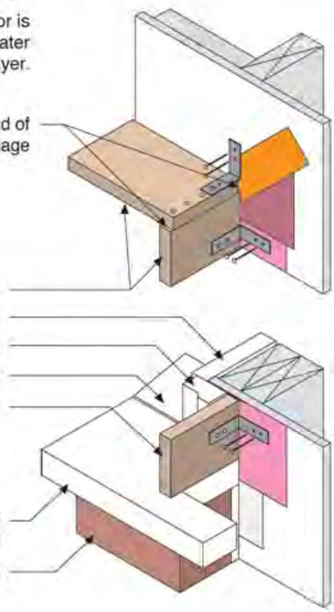
Step 11



Step 12 (reverse view)

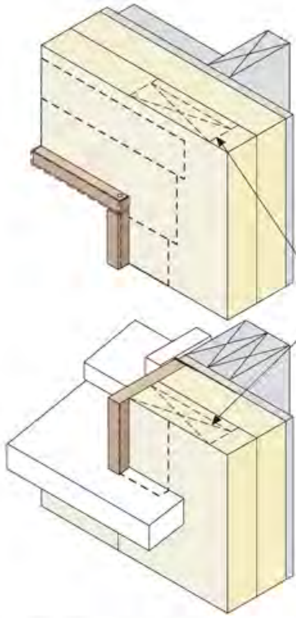






Exterior Door in Wall 1B—Trim Installation Sequence

Exterior Door in Wall 1B—Trim Installation Sequence



Step 3

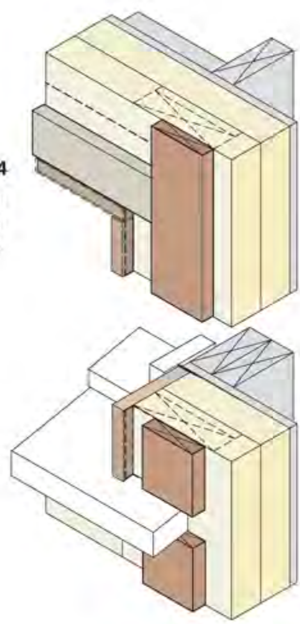
Install insulating sheathing up tight to the trim extension box, threshold, and the blocking under threshold; if trim extension is of water sensitive material, apply head and jamb flashing over insulating sheathing.

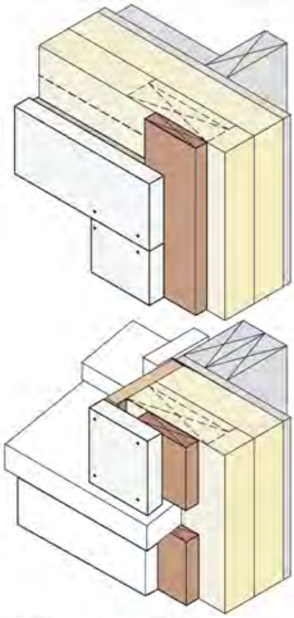
If existing structure doesn't provide means of attachment for furring strip, install 2x6 nailer with filler strip of insulation behind as needed; attach extension box directly to nailer

Gray tone indicates existing structure

Step 4

Install 1x4 furring to support door trim and cladding. Install cladding vent between furring strips at door head.





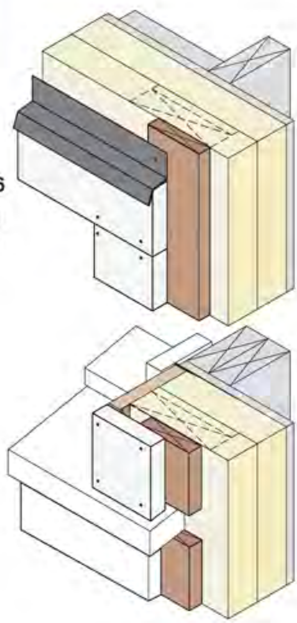
Step 5

Install door trim; fasten to trim extesion box and furring strips.

Gray tone indicates existing structure

Step 6

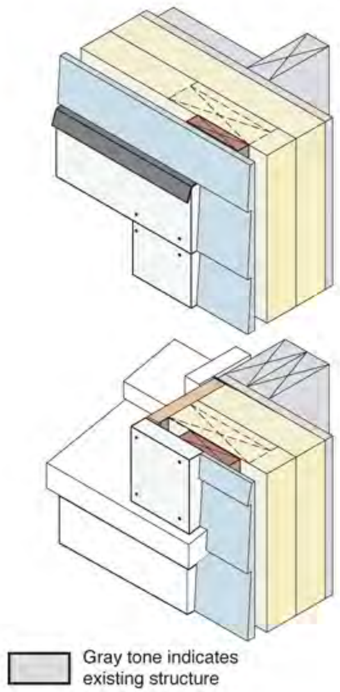
Install sloped metal cap flashing over head trim, fasten to furring strips.

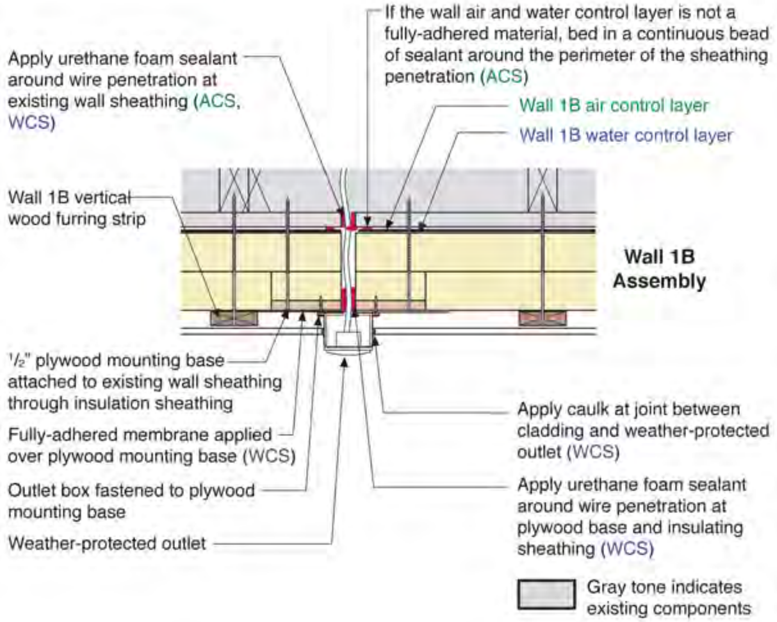


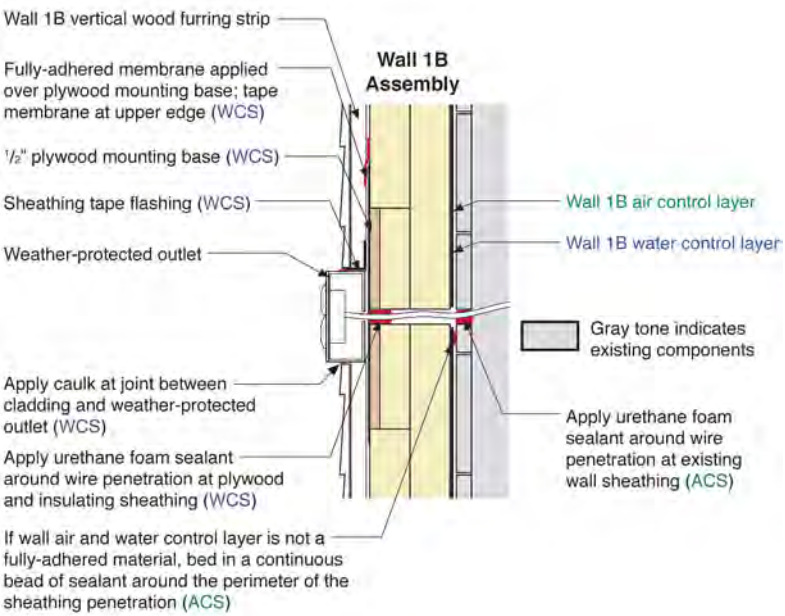
Exterior Door in Wall 1B—Trim Installation Sequence

Step 7

Install cladding

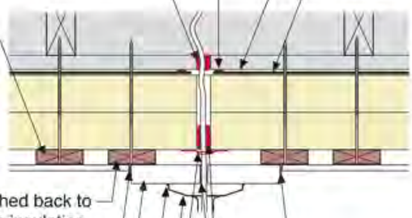


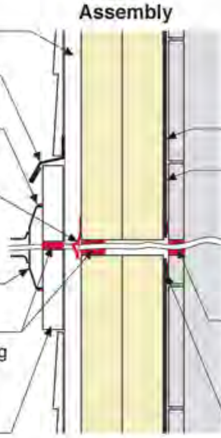




Exterior Electric Box Through Wall 1B–Plan and Section

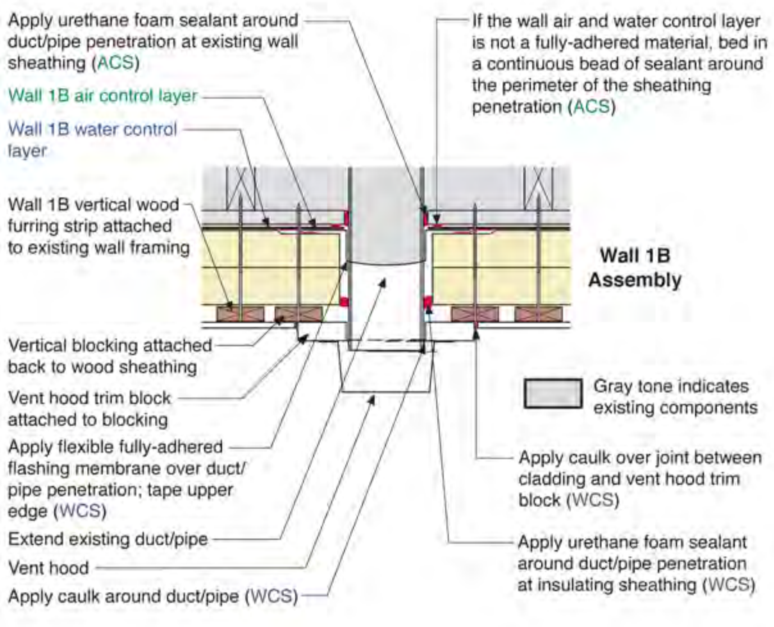
- Vertical furring strips may be provided as needed for attaching ends of cladding at electric box; leave space for drainage between the box and any added furring strips.

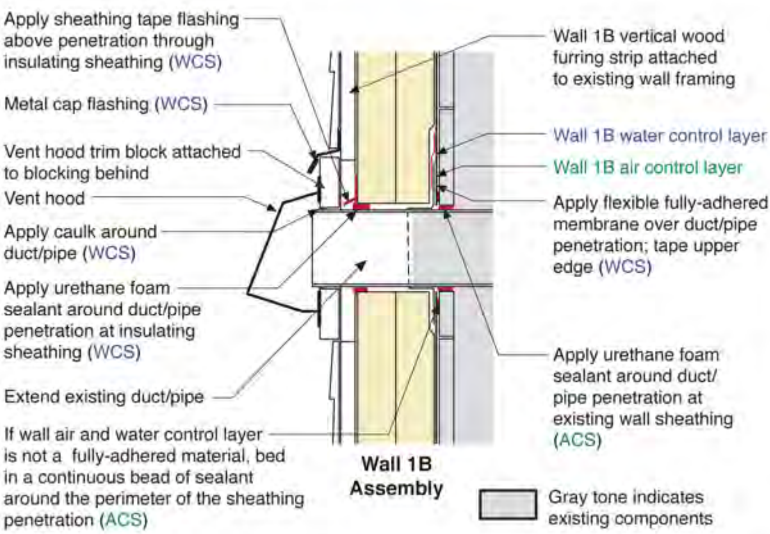




Trim Block with Wire Penetration Through Wall 1B–Plan and Section

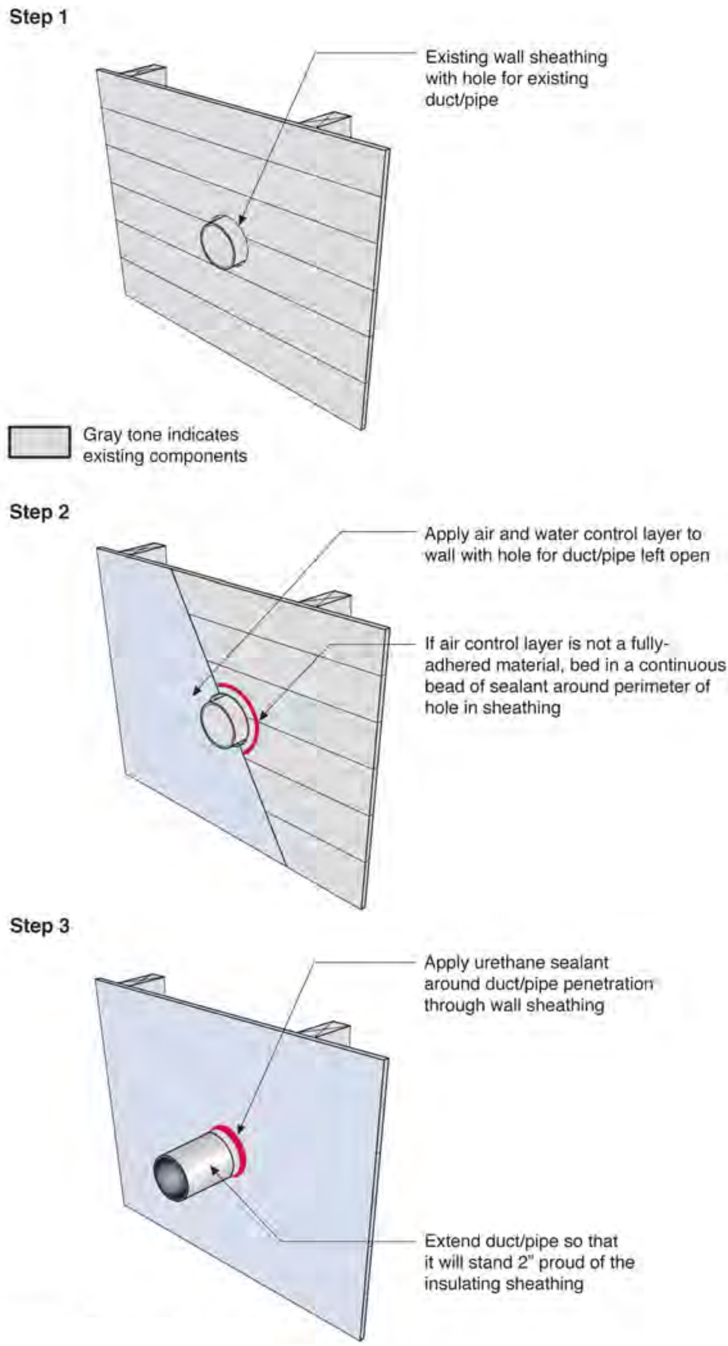
- This is for attachment of exterior lighting fixtures or other exterior electrical devices to be installed over a trim block.





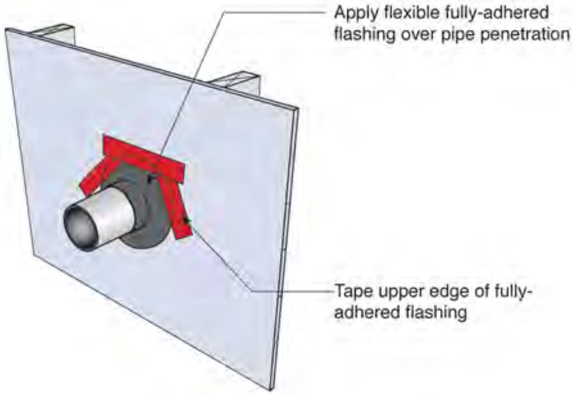
Duct/Pipe Penetration Through Wall 1B–Plan and Section

- Also see Duct/Pipe Penetration Through Wall 1B – Installation Sequence.

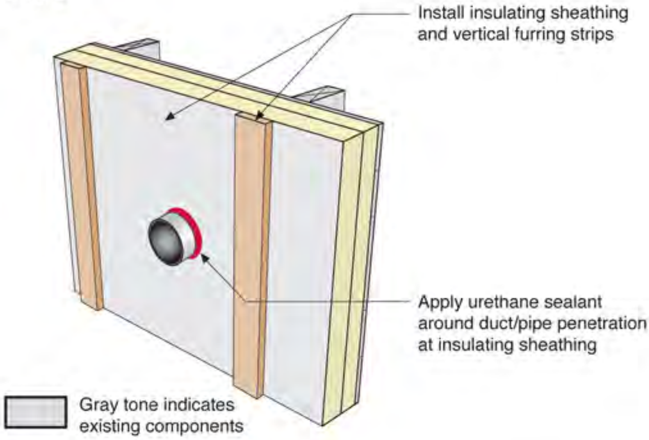


Duct/Pipe Penetration Through Wall 1B–Installation Sequence

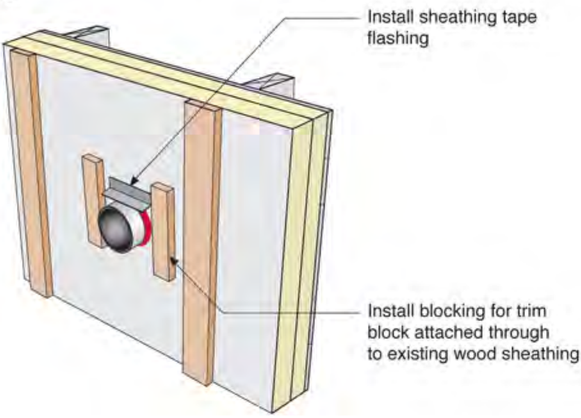
Step 4



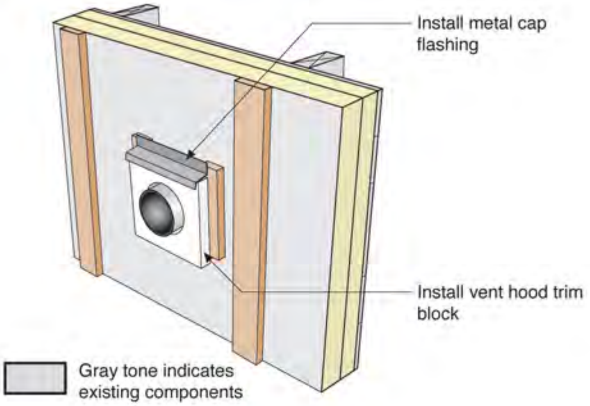
Step 5



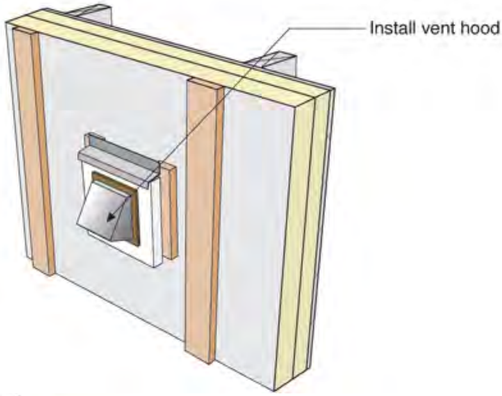
Step 6



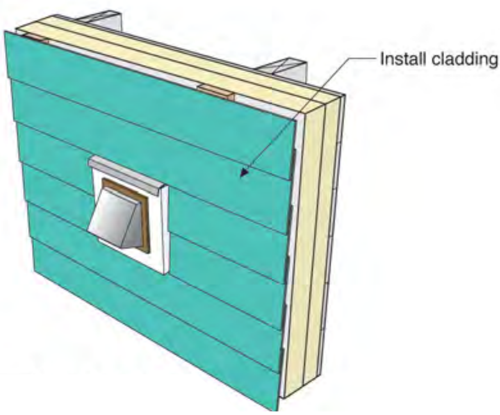
Step 7



Step 8



Step 9



APPENDIX A: MATERIAL GLOSSARY

INTRODUCTION

This appendix provides descriptions and performance parameters for many of the materials and components identified generically in the illustrations. It is intended that the information listed here provide guidance for selecting suitable materials to use in DER.

Air control material A material that has sufficiently low air permeance and adequate strength that it can be part of an air control layer system. Examples: gypsum board, plywood/OSB, foam board, duct board (with a facing flame spread rating of 25 or less), sheet metal or dimensional lumber. Recommended maximum air permeance for an Air Control Material is 0.02 l/(s m^2) @ 75 Pa (0.004 cfm/ft^2 @ 0.3” WC) when tested according to ASTM E 2178 or E 283.
Air-impermeable material Air permeance equal to or less than 0.02 l/s m^2 @ 75 Pa (0.004 cfm/ft^2 @ 0.3” WC) when tested according to ASTM E 2178 or E 283.
Aluminum coil stock Aluminum coil stock, as used in this guide, refers to thin aluminum metal sheet that is coated to resist corrosion and suitable for forming into various shapes on a metal brake or a roller-extrusion die. Aluminum coil stock is typically manufactured in rolls or “coils”.
Bituminuous membrane A self-adhered membrane composed of rubberized asphalt adhesive; typical material has a polyethylene facer, and is vapor impermeable.
Building paper Also known as “tar paper,” asphalt-saturated Kraft paper, or asphalt-impregnated cellulose fiber; a paper (cellulose fiber) and asphalt-based drainage plane or water control layer.
Butyl membrane A self-adhered membrane based on synthetic rubber (elastomer); typical material has a polyethylene facer, and is vapor impermeable. Butyl rubber adhesives (as opposed to asphalt) typically have fewer chemical compatibility issues than asphalt-based adhered membranes.
Closed-cell spray foam insulation Spray-applied foam insulation where the cured foam is of predominantly closed cell structure. Characterized by low vapor permeability. Density is generally between 1.5 and 2.5 lb. per cubic foot. The typical range for R-value is 5.6 - 6.3 depending on product and installation. Vapor permeance is less than 1 at approximately 2” thickness or greater.
Dampproofing A coating, typically asphaltic, that is applied to a foundation wall and that significantly reduces or totally prevents the wall surface from wicking water from the soil. Although typically marketed as “water proofing” the more reliable function of these coatings is preventing capillary transfer (wicking) to the foundation wall surface. Dampproofing is typically not able to withstand significant hydrostatic head pressure, which makes the use of drainage very critical.
Dense-packed fibrous insulation Fibrous insulation that is installed to a non-settling density, usually 3-4 lb/ft^3. Although dense-packed fibrous insulation cannot be used as an air control material it typically does inhibit airflow through cavities.

Dimple mat A plastic sheet that is formed with uniform protruding dimples to one side to allow the dimple mat to create a uniform separation between the surface of the dimples and the surface of the sheet. A dimple mat also provides a compressive strength of at least 10 psi / 10% deflection. Most commonly used to establish a drainage space between soil and below-ground structures, dimple mats can also be used to create a drainage space between layers of built assembly such as in the case of the slab retrofit assembly illustrated in this guide. Because of the continuous nature of the plastic sheet, a dimple mat can also be used to establish a water, air or vapor control layer
Drainage mesh A non-moisture sensitive material that has an open structure allowing the passage of liquid water and that provides a compressive strength of at least 10 psi / 10% deflection. Its application is similar to that of a dimple mat with the exception that a drainage mesh does not, without a top sheet, provide resistance to water, air or vapor flow.
Epoxy paint or coating A durable paint or coating that is capable of resisting hydrostatic pressure and vapor pressure
Expanded polystyrene (EPS) A foam plastic insulation material formed of styrene beads expanded in a mold. EPS is produced to differing properties according to the recognized types of EPS. Type I EPS is most common but also the lowest recognized density, thermal resistance and compressive strength of the recognized EPS types. Because of its poor compressive and flexural strength, Type I EPS is not recommended for use as insulating sheathing or as a rigid board insulation. Type II EPS is suitable in some conditions for use as an insulating sheathing and as rigid board insulation. Type II EPS has a minimum compressive strength of 15 psi and a minimum thermal resistance of R-3.5 per inch. EPS is not suitable for ground contact or applications where it is subject to immersion in water.
Extruded polystyrene (XPS) A foam plastic insulation material formed by extruding foamed styrene through a die. XPS is generally stronger, has greater thermal resistance and is less vapor permeable than EPS. Typical thermal resistance ranges from R-5 to R-5.6 per inch depending on manufacturer and specific product.
Flashing tape A thin flexible membrane strip with contact or pressure sensitive adhesive. Both the membrane strip and adhesive must be impervious to water.
Flashing membrane A flexible membrane that is impervious to water.

Foil-faced polyisocyanurate Polyisocyanurate insulation board material with foil facing laminated to both sides. The foil facing provides dimensional and shape stability to the polyisocyanurate insulation boards. Foil-faced polyisocyanurate board typically has a greater R-value than other types of polyisocyanurate insulation board material and is also vapor impermeable (less than 0.1 perm). For some foil-faced polyisocyanurate insulation board products, the foil facing is intended as a finish, in other products, the facing contributes to the ignition barrier of the foam.
Free-draining backfill A back fill material that provides very little resistance to the movement of water by gravity.
Fully-adhered membrane/material A flexible film or sheet building material that is adhered to or incorporated with its substrate in a continuous manner. The membrane bridges minor gaps and cracks. A fully-adhered membrane may be a peel-and-stick type membrane or a liquid applied membrane.
Fully-adhered air control membrane An air control membrane that is adhered to or incorporated with its substrate in a continuous manner. It must be durable and capable of withstanding pressures and minor building movement to which it would be subject in operation.
Fully-adhered water control membrane A water control membrane that is adhered to or incorporated with its substrate in a continuous manner. It must be durable and capable of withstanding pressures and minor building movement to which it would be subject in operation.
Furring strip (or vertical furring strip) A strip of material having uniform thickness used to create a uniform separation between a cladding or finish material and substrate. A furring strip also typically provides an attachment structure for the cladding or finish material.
Housewrap Any of the numerous artificial polymer rolled sheet goods designed to function as drainage planes, a class of sheathing membranes. Some are also used as part of an air barrier system. Can be made of spun-fiber polyolefin, perforated plastic films, or coated and micro-perforated polymers. Housewraps made of visibly perforated (macroscopic hole) plastic films are not recommended.
Insulating sheathing Non-structural insulating board products with varying R-values and a wide variation in vapor permeability and drainage characteristics. Materials include expanded polystyrene (EPS) excluding Type I, extruded polystyrene (XPS), polyisocyanurate, rigid fiberglass, and mineral wool.

Insulation Any material which significantly slows down or retards the flow or transfer of heat. Building insulation types are classified according to form (e.g., loose-fill, batt, flexible, rigid, reflective, and foamed-in-place) or material (fiber glass, rock and slag wool, organic fiber, foam plastic).
Installed R-value A metric commonly referenced in building codes and used by industry. This is simply the R-value labeled on the product installed in the assembly.
Loose-fill fibrous insulation Fibrous insulation material that is installed with blower equipment or poured in place.
Liquid-applied air control membrane/material See ***fully-adhered air control membrane*** above.
Low expansion foam sealant A foam sealant that has been engineered to cure with minimal expansion and minimal expansive force.
Mastic Heavy-consistency compound that may remain adhesive and pliable with age. Typically an airtight, waterproof compound that is applied to exterior walls and roof surfaces or used to provide a robust and durable air seal to air duct distribution systems.
Non-moisture-sensitive material A material that is not degraded by prolonged contact with liquid state water. Most, but not all, plastics are non-moisture-sensitive materials. EPS and polyisocyanurate foam insulations are somewhat moisture sensitive and should not be used in applications were they will be subject to extreme vapor pressures, submersion in water or ground contact. Wood materials remain water sensitive regardless of treatment.
Open-cell spray foam insulation Spray-applied foam insulation where the cured foam is of predominantly open cell structure. Characterized by high vapor permeability - 6-29 perms at 3” thickness, 4-18 perms at 5” thickness. Density is generally between 0.5 and 1.0 lb per cubic foot. Typical R-value ranges from 3.8 to 4.0 per inch depending on product and installation.
Polyisocyanurate A closed-cell foam insulation material typically sold in rigid boards. R-value can range from R-5.6 to R-6.5 per inch, depending on the manufacturer, the age of the foam, and the presence or absence of foil facings. Polyisocyanurate is somewhat moisture-sensitive and not suitable for installation in ground contact or where it is subject to immersion in water.
Rigid Board Insulation See ***insulating sheathing*** above.
Rigid Foam Rigid board material that provides thermal resistance and compressive strength of 15 psi at 10% deformation. Examples include foam plastic insulation such as EPS (excluding Type I), XPS, and polyisocyanurate.

Roof Underlayment The materials installed beneath roof cladding capable of protecting the cladding substrate from liquid water. At the perimeter of the roof, at valleys, penetrations, and wall-roof intersections, the underlayment must be a self-sealing ice and water control membrane. In the field of the roof, away from edges, valley, penetrations and intersections with walls, the roof underlayment may be an ice and water control membrane, roofing felt, or an engineered roof wrap.
Sealant Any flexible product which when applied to the join of two or more materials will adhere and permanently seal the joint to the passage of air. Examples: caulk, foam, and mastic. Within the construction industry, the use of the term to describe products is regulated (Relevant test methods: For foam sealants - ASTM C1642; for acrylic, silicone, and urethane caulk - ASTM C-920).
Self-adhered water control membrane See ***fully-adhered water control membrane*** above.
Self-adhered air control membrane See ***fully-adhered air control membrane*** above.
Self-sealing ice and water control membrane A membrane capable of maintaining air and water tightness around installed fasteners that penetrate the membrane. It must be noted that self-sealing membranes typically do not self-seal over a hole left by a fastener that has penetrated the membrane then, subsequently been removed. Self-sealing membranes typically include bituminous or butyl compositions.
Semi-rigid mineral fiber insulation A type of insulation that is sold in formed boards composed of mineral fibers (typically fiberglass or rock wool). Normally used for its non-combustible properties.
Sheathing tape A thin film tape usually with an acrylic adhesive that is compatible with the sheathing material used.
Sill pan flashing A flashing that covers the bottom of a window or door opening and that includes end dams to either side of the opening as well as a back dam (toward the inside) and/or slope to the exterior.
Spray Foam Insulation See ***closed-cell spray foam insulation*** and ***open-cell spray foam insulation*** above.
Tape In this guide “tape” designates a durable thin film strip with a durable adhesive that is compatible with the substrate materials.
Vapor impermeable Describes materials with a permeance of 0.1 perm or less (e.g. rubber membrane, polyethylene film, glass, aluminum foil).

Vapor permeable Describes materials with a permeance greater than 10 perms (e.g. most housewraps, building papers).
Vapor semi-impermeable Describes materials with a permeance of 1.0 perm or less and greater than 0.1 perm (e.g. oil-based paints, most vinyl coverings)
Vapor semi-permeable Describes materials with a permeance of 10 or less and greater than 1.0 perm (e.g. plywood, OSB, most latex-based paints).