Healthy and Affordable Housing: Practical Recommendations for Building, Renovating and Maintaining Housing

READ THIS

BEFORE YOU DESIGN, BUILD OR RENOVATE

U.S. Department of Housing and Urban Development

ARC
Asthma Regional Council of New England

U.S. Department of Energy
Building America
Program Partner

FOREWORD

This pamphlet offers guidance about residential building and remodeling practices that foster healthy homes by reducing the housing occupants' risk of exposure to known hazards. These practices also frequently yield other benefits such as improved durability and reduced operating costs.

It is designed for members of the residential building construction and remodeling industries, as well as owners and managers who work in affordable housing. It presents building guidance for both new construction and rehabilitation, as well as practices that can be used by property maintenance personnel.

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DISCLAIMER

This document and the recommendations within do not represent federal or state government policy. They are the opinions of the authors.

FEEDBACK

The U.S. Department of Housing and Urban Development and the Building America Program at the U.S. Department of Energy welcome feedback on this document. Please send feedback to:

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The Building Connection

Housing and Health

Asthma It is a serious disease that affects millions of Americans, particularly children, and it is increasing at an alarming rate. Asthma is an allergic reaction to certain exposures ("triggers") such as dust, mold, pests (cockroaches, rats, mice), pets (cats and dogs), cold air, and dry heat. These conditions can trigger other allergic reactions that include hayfever symptoms like itching eyes and runny noses. Many air pollutants that are associated with asthma are found at higher levels indoors than outdoors. Among them are the most common asthma triggers: particles from molds, dust mites, mice, rats, roaches and pets.

Other Health Issues Indoor air contains other pollutants — such as carbon monoxide, volatile organic compounds (chemicals released from materials) nitrogen oxides, sulfur oxides, radon, soot and other particles — that can make people sick or make asthma worse. Some pollutants — ozone, sulfur oxides, carbon monoxide, pollens, soot — come from outside. Homes built before 1978 may contain lead-based paint, which during a renovation job can become hazardous if lead dust or paint chips are created by the work. Children or others in the home can easily ingest the duct and paint chips. The federal government has recommended work practices in the Lead Paint Safety Field Guide that help to contain and clean up lead dust and paint during and after rehabilitation work. A copy of the Lead Paint Safety Field Guide can be found at www.hud.gov/offices/lead.

Why Construction and Design Matter We can control many of the sources of pollution that otherwise can make people sick or make asthma worse by good design, construction, renovation, maintenance and operation.

What people bring into their home, how they live in their home and how they clean and maintain their home also affect the quality of the air in their home.

Before You Design, Build or Renovate

The principles for a healthy home are the same for all types of construction: rehabilitation, new construction, low rise, high-rise, single family or multifamily.

The design and construction options for rehabilitation are limited by conditions of the salvaged building and equipment and extent of the rehabilitation. Despite the limitations, the same principles apply to whatever work is done as part of the rehabilitation.

Systems Approach Can Save Money

Applying the principles for a healthy home to design, construction and renovation does not have to result in significant cost increases. By understanding the interactions between building systems we can identify cost saving trade-offs that improve building performance and improve control of interior conditions such as comfort – particularly temperature and interior humidity. Additionally, many of the principles result in reduced callbacks and warranty claims.

The whole is greater than the sum of the parts.

Cost Saving Trade-Offs

Improve Building Envelope	Costs More (+)
Downsize Mechanical System	Costs Less (-)
	Cost Remains the Same

The Seven Steps to a Healthy Home

There are seven steps to a healthy home. Ideally, a healthy home is:

- Dry
- Clean
- Well Ventilated
- Combustion By-Product Free
- Pest Free
- Toxic Chemical Free
- Comfortable

Not all steps can be controlled by design, construction and renovation. How people live in a home also matters. And not all steps can be achieved perfectly or completely or practically — they are goals.

Dry

Water and humidity support the growth of mold, insects, rodents and dust mites. Keeping a home dry controls mold and pests, and discourages dust mites.

Clean

Dust provides food for mold, insects, rodents and dust mites, and in older homes may contain lead. Clutter makes it difficult to clean and in many cases it also may serve as food for pests. Keeping a home clean helps control mold and pests. Smooth and cleanable surfaces make it easier to remove dust.

Well Ventilated

Ventilation provides a mechanism to remove pollutants and control humidity. Windows that open and fans that run control pollutants.

Combustion By-Product Free

Combustion by-products —such as carbon monoxide, sulfur oxides, nitrogen oxides and soot — should not be in a healthy home. Furnaces, water heaters and fireplaces that burn fuel must vent to the outside. Stoves, ovens and cook-tops that burn fuel must be used with fans that vent the combustion by-products to the outside.

Pest Free

Pests can lead to allergic reactions and to the use of pesticides. Food and water attract pests. Controlling food and water helps to minimize pests.

Toxic Chemical Free

We are surrounded by chemicals, no environment can be made completely chemical free. But we can control our exposure. Many things found in houses can be toxic in large doses. Some we can control by design and construction such as selecting materials that don't smell or release chemicals. Others we can control by the way we live in the home. For example, many cleaning compounds, pesticides, oil or alkyd based paints and solvents can lead to problems. Many of the containers that these products are stored in slowly release the chemicals. It is best not to store these products inside. When in doubt, safely dispose of these products. Many municipalities operate household chemical disposal programs.

Comfortable

Uncomfortable homes can make people take action that makes a home unhealthy. Too hot or too cold is usually uncomfortable.

Operable windows can control heat and provide ventilation. But sometimes when it is too cold windows will not be opened, and sometimes when it is too hot even opening windows will not cool the home enough.

And what happens when people are scared to open windows?

Sometimes the outside air has pollutants such as ozone and pollen that may require some people to keep windows closed and filter incoming air.

If people are cold they won't ventilate their home. If people can't afford to heat their home they won't ventilate their home.

A healthy home has windows that open and fans that run – but a healthy home must also be healthy when windows are closed because it is too cold, because it is too hot, because people feel unsafe or because pollutants are present in the outside air.

Uncomfortable can also be too dry or too humid.

When a home is uncomfortably dry, people often humidify. Many times when people humidify they can over-humidify. Over humidifying results in mold and mites and other pests. A properly built or renovated home will not require a humidifier to be comfortable.

When a home is uncomfortably humid, particularly in the summer and fall, it may require a dehumidifier or air conditioner. Even properly built or renovated homes may require a dehumidifier or air conditioner to control humidity in the summer and fall to be comfortable — particularly in the southeast.

Factors That Must be Controlled for a Healthy Home

In order to address the seven steps to a healthy home the design, construction and renovation must control the following factors:

Water
- Rainwater Control
- Groundwater
- Plumbing

Air
- Big Holes
- Cold Surfaces
- Indoor Humidity
- Airborne Pollutants
- Pressures

Combustion
- Combustion Appliances
- Garages
- Smoke

Dust
- Entry Control
- Lead Dust Control
- Cleanable Surfaces
- Filtration

Creatures
- Keeping Them Out
- Reducing Food and Water

Recommendations

Water

Water is a precondition for mold, insects, rodents, dust mites and is arguably the single most important factor in the design and construction of a healthy home. Water is the most important factor affecting the durability of a home and the most important factor affecting maintenance costs.

Control Water =
- → Fewer biological pollutants
- → Increased building durability
- → Lower maintenance costs

The three most important sources of water requiring control are:
- Rainwater Control
- Groundwater
- Plumbing

One of the key elements of water control is the concept of drying. It is common sense to accept that things will get wet. Especially homes. Especially homes under construction or under renovation. All homes will get wet.

The problem is not that something gets wet. It's how long it stays wet and how well it dries. Homes should be designed to dry.

Rainwater Control

The fundamental principle of rainwater control is to shed water by layering materials in such a way that water is directed downwards and outwards from the building or away from the building. It applies to assemblies such as walls, roofs and foundations, as well as to the components that can be found in walls, roofs and foundations such as windows, doors and skylights. It also applies to assemblies that connect to walls, roofs and foundations such as balconies, decks, railings and dormers.

Layering materials to shed water applies to the building as a whole (see **Figure 1**). Overhangs can be used to keep water away from walls. Canopies can be used to keep water away from windows, and site grading can be used to keep water away from foundation perimeters.

When selecting building materials, take into account that building materials may be exposed to rain or other elements during construction. For example, walls without roofs on them will get wet. It is not a good idea to build these walls with exterior gypsum board that is paper-faced since they hold water. This is a major concern with party walls or fire walls in multifamily buildings. Glass-faced gypsum board or other water-resistant alternatives should be used.

Drainage is the key to rainwater control:
- Drain the site (see **Figure 1**)
- Drain the ground
- Drain the building (see **Figure 2**)
- Drain the assembly
- Drain the opening (see **Figure 3**)
- Drain the component
- Drain the material (see **Figure 4**)

Walls All exterior claddings pass some rainwater. Siding leaks, brick leaks, stucco leaks, stone leaks, etc. As such, some control of this penetrating rainwater is required. In most walls, this penetrating rainwater is controlled by a drainage plane that directs the penetrating rainwater downwards and outwards.

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

Reservoirs on the outside of homes are a problem. What are reservoirs? Materials that store rainwater – sponges that get wet when it rains. Once the reservoirs get wet, the stored water can migrate elsewhere and cause problems (see **Figure 5**). Common reservoirs are brick veneers, stuccos, wood siding, wood trim and fiber cement cladding.

How to handle reservoirs? Easy. Get rid of them or disconnect them from the building (see **Figure 6**). Back priming (painting all surfaces, back, front, edges and ends of wood siding, cement siding and all wood trim) gets rid of the moisture storage issue with these materials. No reservoir, no problem.

Back venting brick veneers and installing them over foam sheathings disconnects the brick veneer moisture reservoir from the home (see **Figure 7**). Installing stucco over two layers of building paper or over an appropriate capillary break, such as foam sheathing, similarly addresses stucco reservoirs.

Roofs Roofs should be designed to shed rainwater away from the building. Steep pitches are better than shallow pitches. Crickets should be used to divert water away from chimneys and architectural features.

Roofs should also be designed to protect walls. Large overhangs are better than small overhangs or no overhangs.

Ideally, roofs should have simple geometry. The more complex the roof, the more dormers, ridges and valleys, the more likely a roof will leak. Penetrations should also be minimized or avoided.

Figure 1
Layering materials to shed water applies to whole building

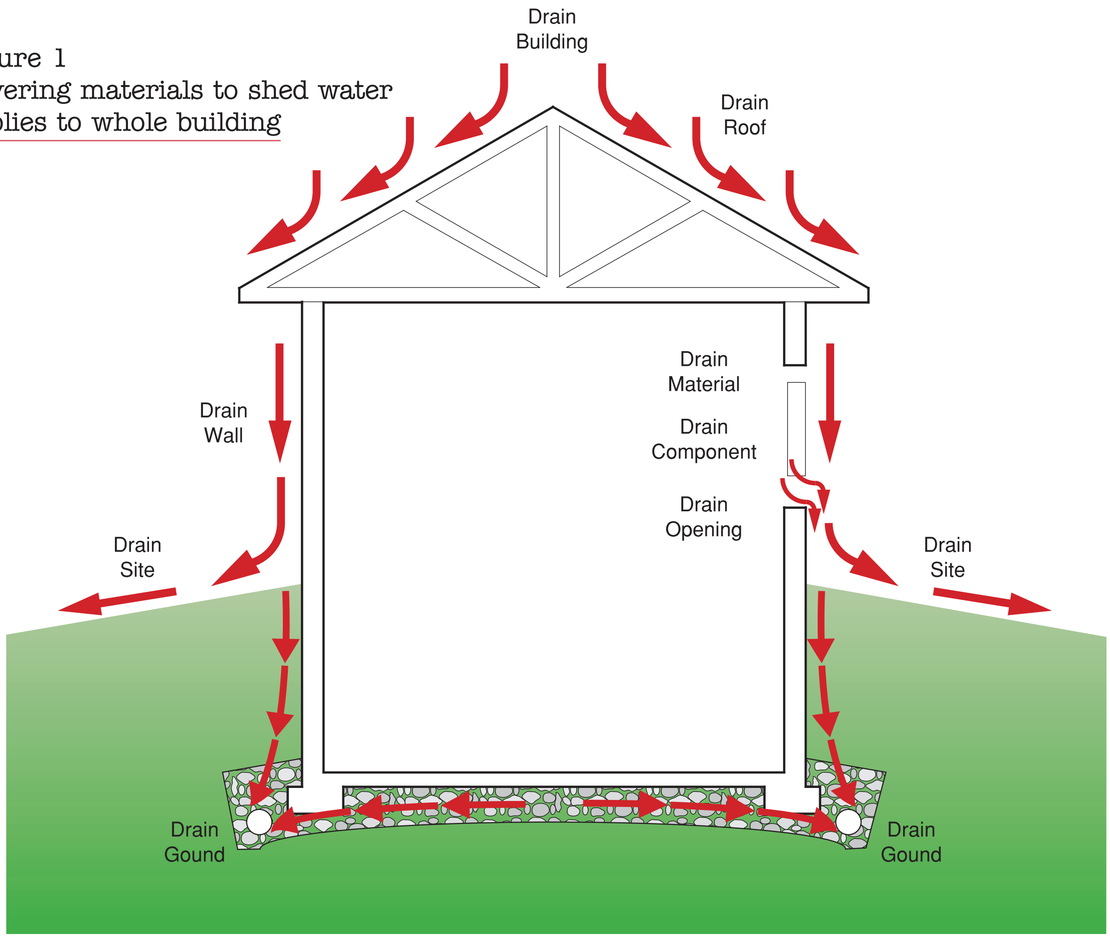
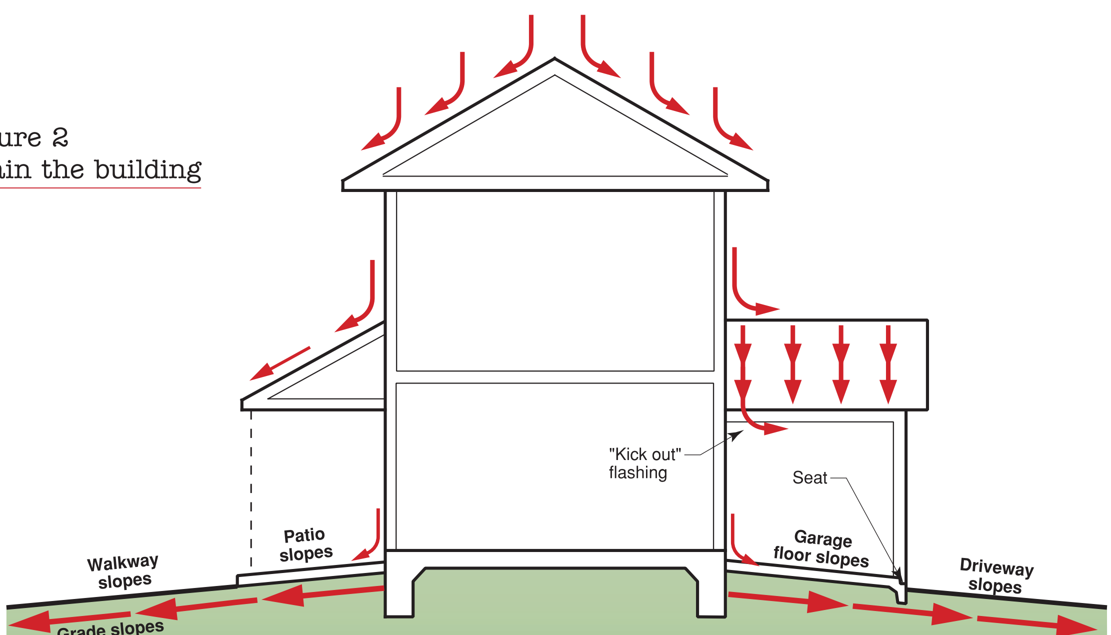


Figure 2
Drain the building



- Patios and decks lower than floors and slope away from building
- Garage floor lower than main floor and slope away from building
- Driveway lower than garage floor and slope away from building
- Grade lower than main floor and slope away from building
- Stoops and walkways lower than main floor and slope away from building
- Kick out flashings or diverters direct water away from walls at roof/wall intersections

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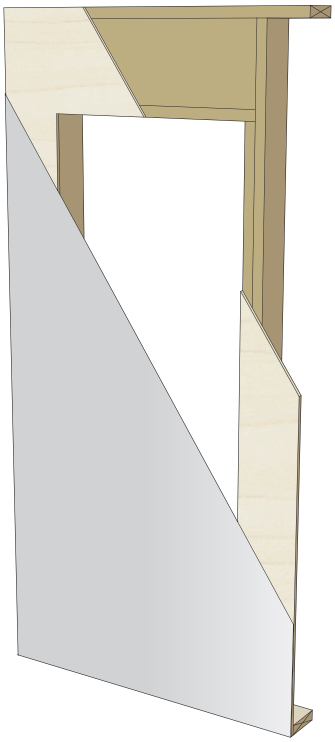
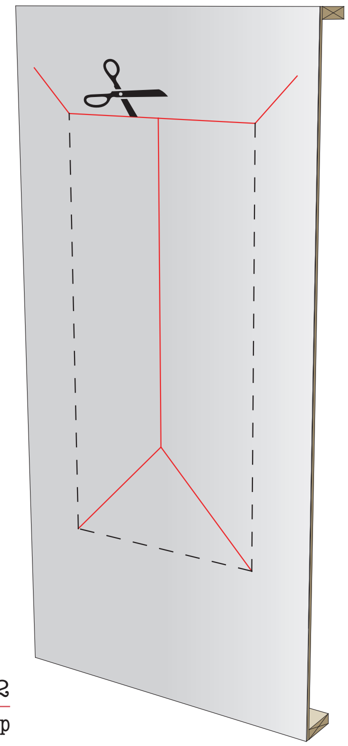
Figure 3
Installing window with housewrap on OSB over a wood frame wall



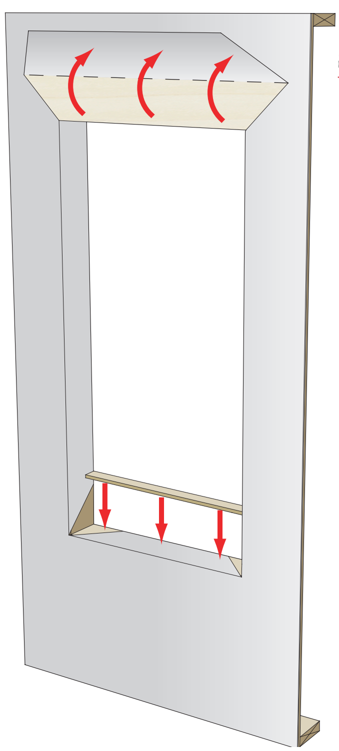
Step 1

- Wood frame wall with OSB and housewrap



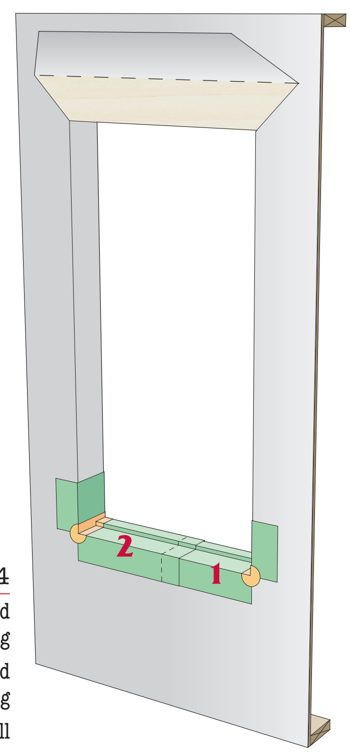
Step 2

Modified "I" cut in housewrap



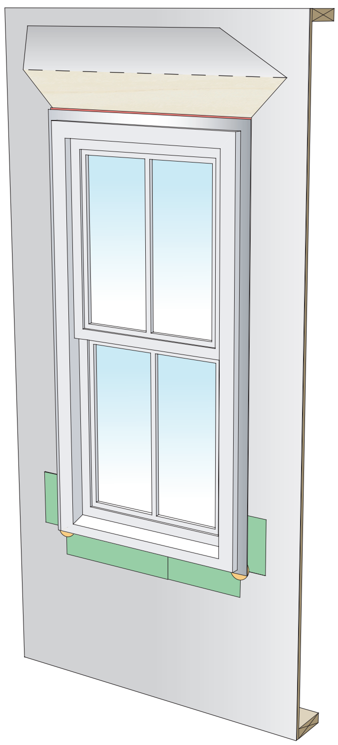
Step 3

- Housewrap folded in; alternately, tuck head flap under
- Install wood backdam

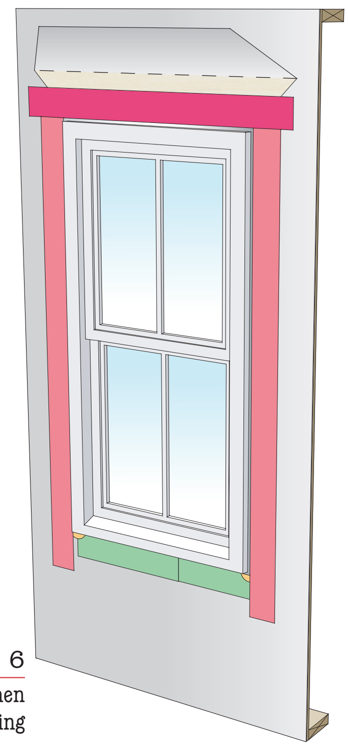


Step 4

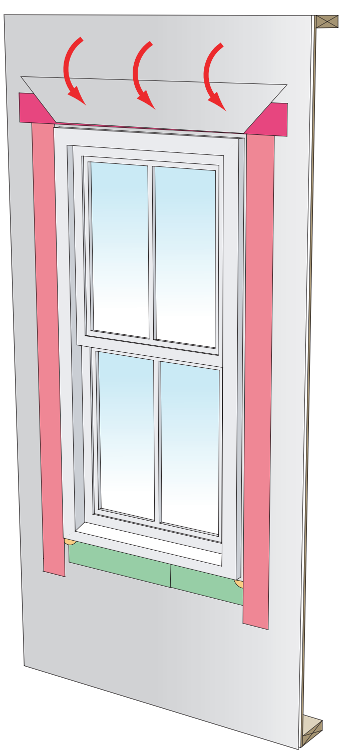
- Install first piece of adhesive-backed flashing
- Install second piece of adhesive-backed sill flashing
- Install corner flashing patches at sill



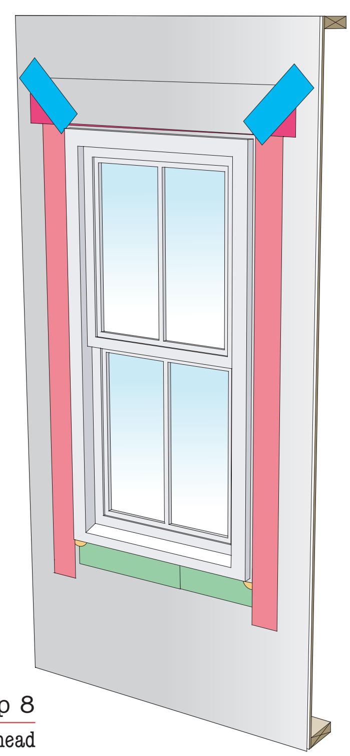
Step 5
Install window



Step 6
Install jamb flashing first then head flashing



Step 7
Fold down head housewrap



Step 8
Apply corner patches at head

Figure 4
Flashing over and under window trim

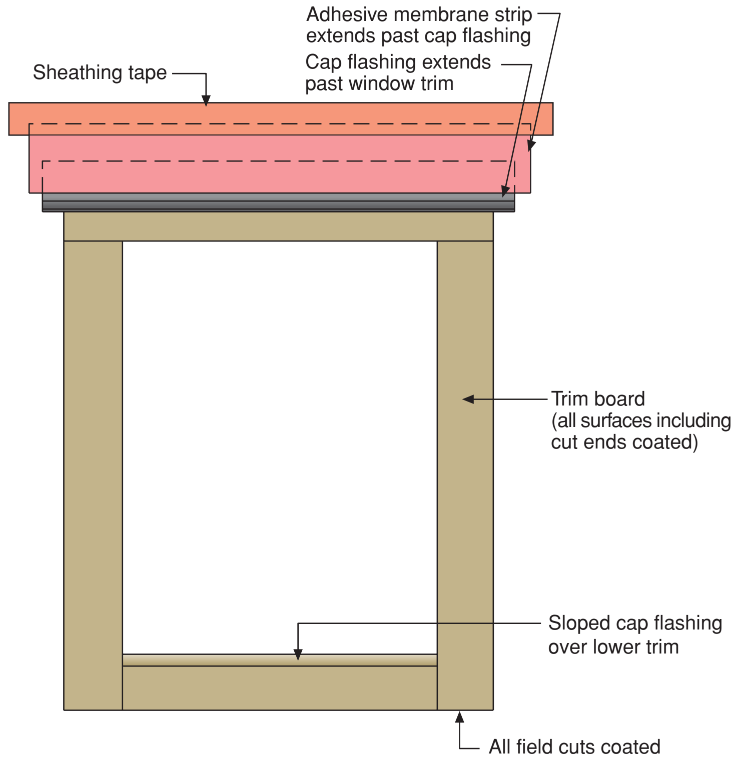
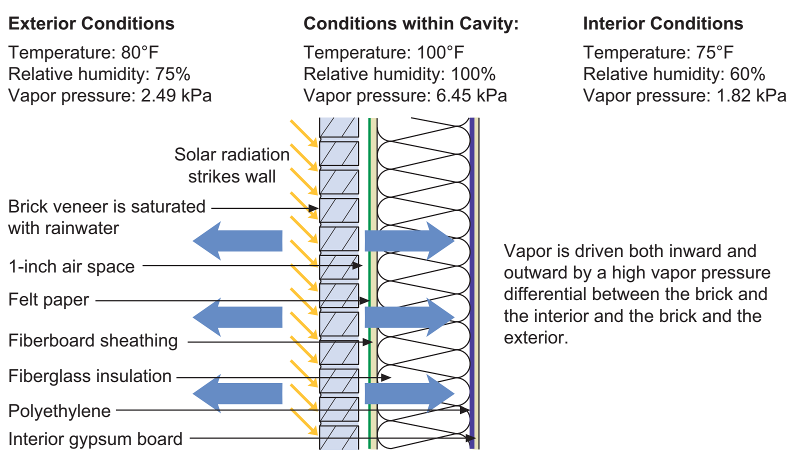
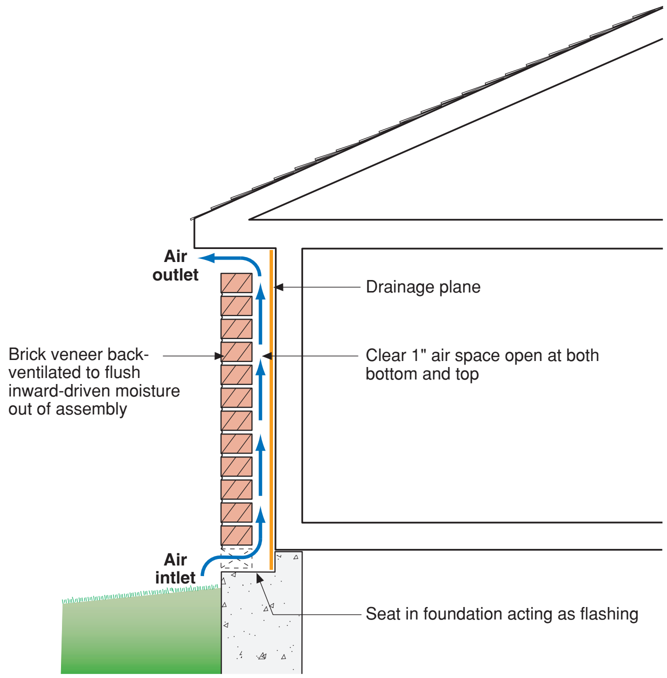


Figure 5
Problems with interior polyethylene:
Inward moisture movement due to solar radiation



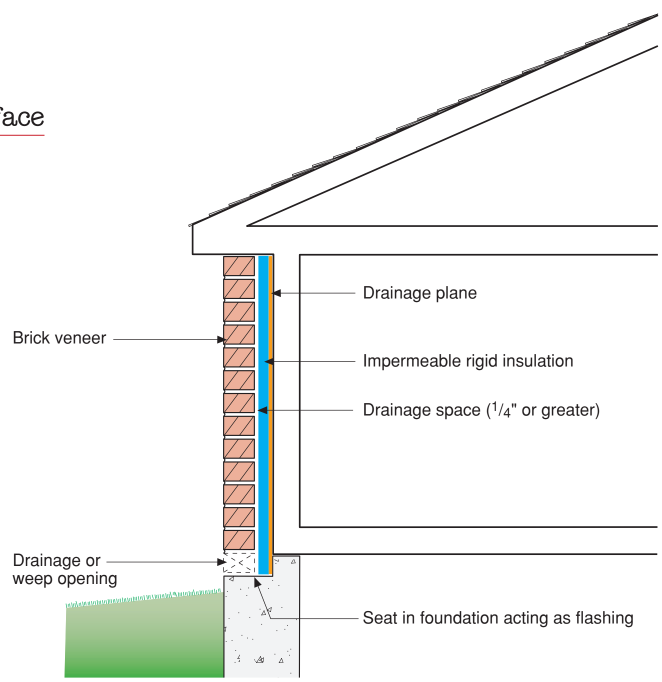
- It is not a good idea to install a vapor barrier (polyethylene) on the inside of an air conditioned assembly. Vinyl wall coverings and foil-backed batt cavity insulation should also be avoided.
- Vapor permeable exterior sheathings, housewraps or building papers should not be used with absorptive claddings such as brick veneers unless a ventilated cavity is provided in conjunction with high inward drying potentials (i.e. no interior polyethylene vapor barriers).
- Failure will occur when brick is installed over a frame wall constructed with felt paper, fiberboard sheathing and an interior polyethylene vapor barrier. Kraft-faced fiberglass batts should be used in place of unfaced batts and a polyethylene vapor barrier. OSB, plywood or foam sheathing should be used in place of the fiberboard sheathing.
- Similar problems occur with stucco.

Figure 6
Ventilated cavity



- To effectively uncouple a brick veneer from a wall system by using back ventilation, a clear cavity must be provided along with both air inlets at the bottom and air outlets at the top

Figure 7
Drained cavity with condensing surface



- To effectively uncouple a brick veneer from a wall system by using a condensing surface, the drainage plane must also be a vapor barrier or a vapor impermeable layer (i.e. rigid insulation) must be installed between the drainage plane and the brick veneer. Alternatively, the rigid insulation can be configured to act as both the drainage plane and vapor impermeable layer.
- When a condensing surface is used to uncouple a brick veneer from a wall system, a ventilated air space is no longer necessary — i.e. the presence of mortar droppings is no longer an issue. Additionally, the width of the drainage space is almost irrelevant.

Groundwater

The fundamental principles of groundwater control are to keep rainwater away from the foundation wall perimeter and to drain groundwater with sub-grade perimeter drains before it gets to the foundation wall. This applies to slabs, crawlspaces and basements (see **Figures 8a, 8b** and **8c**) regardless of whether they are newly constructed or undergoing rehabilitation (see **Figure 9**).

Capillary Breaks Concrete and masonry are sponges – they can absorb or "wick" water due to capillarity (see **Figure 10**). This is the main reason that damp proofing (the black tar-like coating) is applied to exterior basement walls. The damp proofing fills in the pores in the concrete and masonry to reduce ground water absorption. The damp proofing is a capillary break. Under concrete floor slabs, the stone layer combined with polyethylene serves a similar function (they act as capillary breaks). Unfortunately, the capillary rise through footings is typically ignored. This can be a major problem if foundation perimeter wall are finished or insulated.

In new construction a capillary break should be installed on the top of the footing between the footing and the perimeter foundation wall (see **Figure 11**). This can be done by dampproofing the top of the footing or by installing a membrane at this location.

Interior Basement Insulation In new construction, and particularly in renovations, the interior insulation and finishing approach must take into account the moisture migrating up through the footing. This is best accomplished by installing vapor semi-permeable rigid foam insulation on the interior of the assembly to protect the interior finishes and to release the capillary water to the interior in a controlled manner— at a rate that does not damage interior finishes or lead to mold.

The best foams to use have a perm rating of greater than 1 perm for the thickness used. This means limiting extruded polystyrene insulation to less than 1-inch thickness for walls (when they are more than 1-inch thick they do not breathe sufficiently) and making sure that the rigid insulation is not faced with polypropylene skins or foil facings. Additionally, since foams need to be protected from fire, and this is often done with gypsum board, only latex paint should be used on interior gypsum finishes (since latex breathes). This breathability requirement for rigid foams limits the thickness and therefore the thermal resistance of the wall. If higher insulation levels are required, an interior insulated frame wall can be added (see **Figure 20**).

Slab-on-Grade Construction Capillary control also applies to slab-on-grade construction and crawlspaces (see **Figure 12**). Monolithic slabs need plastic ground covers that extend under the perimeter grade beam and upwards to grade. Additionally, the exposed portion of the slab edge that is exposed to the outside must be painted with latex paint to reduce water absorption and a capillary break must be installed under perimeter wall framing.

Interior perimeter drainage can also be used in new construction — particularly where impermeable rigid insulation is used on the interior of the foundation wall. This allows rigid insulation of greater than 1-inch to be used. And, if foil-faced rigid insulation is used — with the appropriate flame-spread and smoke-developed rating — it can be left exposed (i.e. interior gypsum board does not have to be installed as thermal barrier for fire protection. See **Figure 14**).

Also in renovations, the conditions under a slab may be difficult to determine, or once they are determined, it is found that a stone layer or polyethylene is not present. It may be necessary to provide "top side" control of water and vapor. This can be done several ways. If salts are not present in the ground, epoxy coatings or chemical sealers may be used. Salts lead to osmosis and osmotic pressures are typically greater than the bond strength of most coatings and sometimes exceed the cohesive strength of concrete (i.e. the coating is pushed off the slab or the concrete spalls/flakes apart). If salts are present, spacer systems that provide vapor control and drainage can be used over the top of existing slabs (see **Figure 16**).

A "floating floor" (see **Figure 15**) can also be used where moisture flow upwards is small – or where a finished wood floor (or carpet) is to be installed over a slab. Rigid insulation and plywood are installed on the top of the slab. In this assembly extruded polystyrene should be limited to $^3/_4$ - inch or less so that the slab can dry upwards (floors are different than walls with respect to permeability limits). Carpets should never be installed directly on below grade slabs unless slabs are insulated (below or on the top surface). Carpets on uninsulated slabs are cold resulting in sufficiently elevated relative humidities within the carpet to support dust mite and mold growth.

Exterior Drainage It is always better to intercept groundwater before it gets to a foundation wall. Exterior perimeter drainage is always preferable to interior perimeter drainage.

However, in renovations, exterior perimeter drainage may not be present or may not be practical or possible. In such cases, interior perimeter drainage can be used and connected to an interior sump pump. Interior sump pits/crocks must be fitted with airtight gasketed covers to prevent soil gas entry. This interior perimeter drainage may be combined with an interior drainage layer. Where an interior drainage layer is used, it must be gas tight and vapor tight relative to the interior (see **Figure 13**). Another technique is to use an exterior impermeable material to minimize rain and groundwater entering below grade spaces (see **Figure 9**).

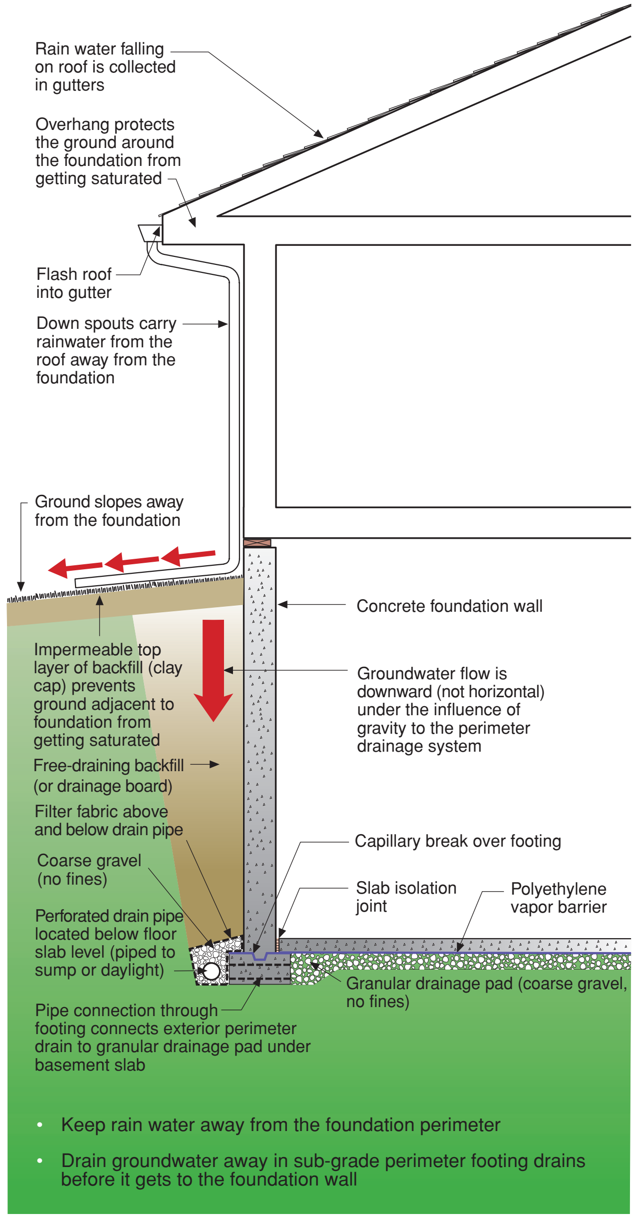


Figure 8a
Groundwater control with basements

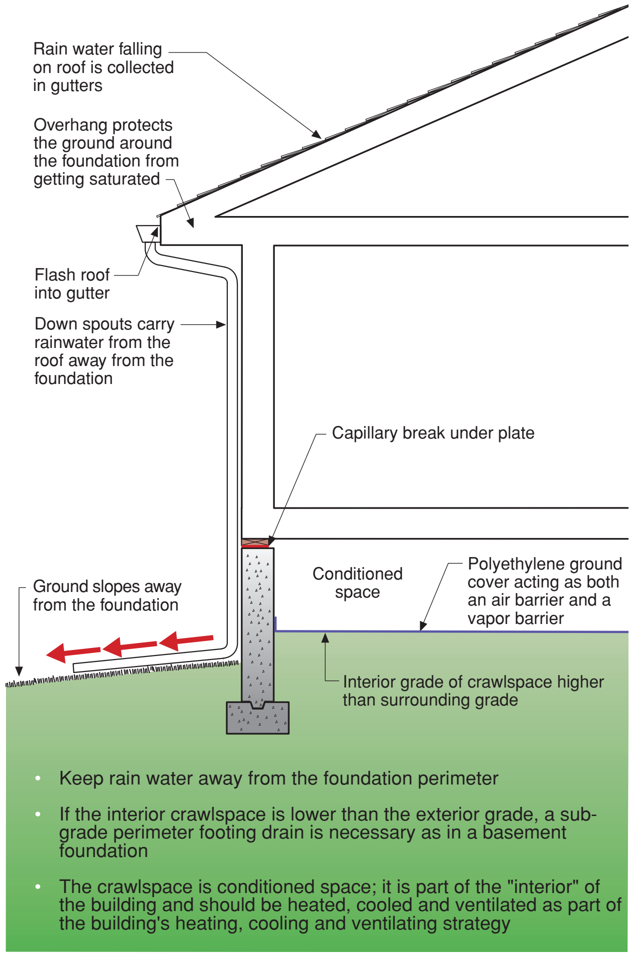


Figure 8b
Groundwater control with crawlspaces

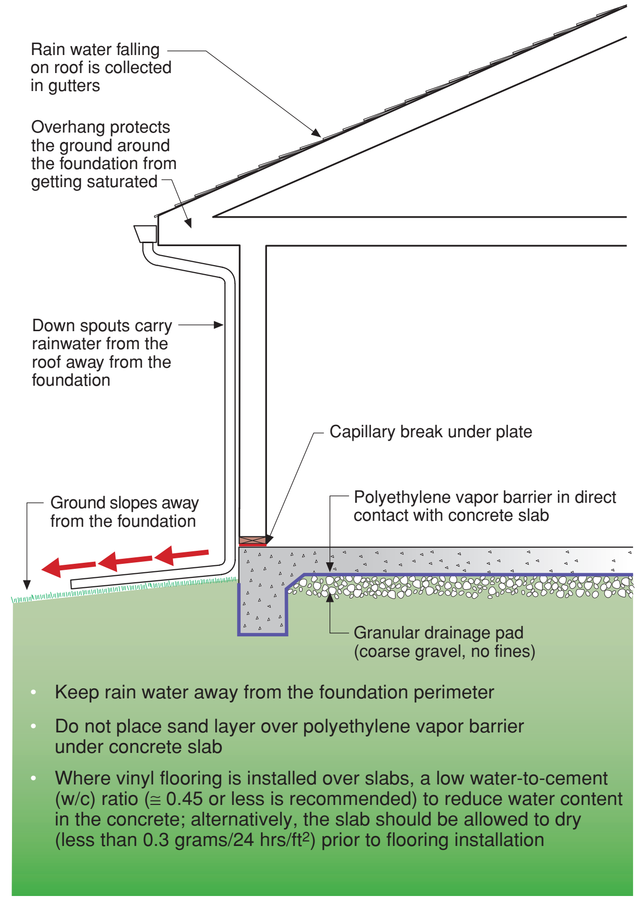


Figure 8c
Groundwater control with slabs

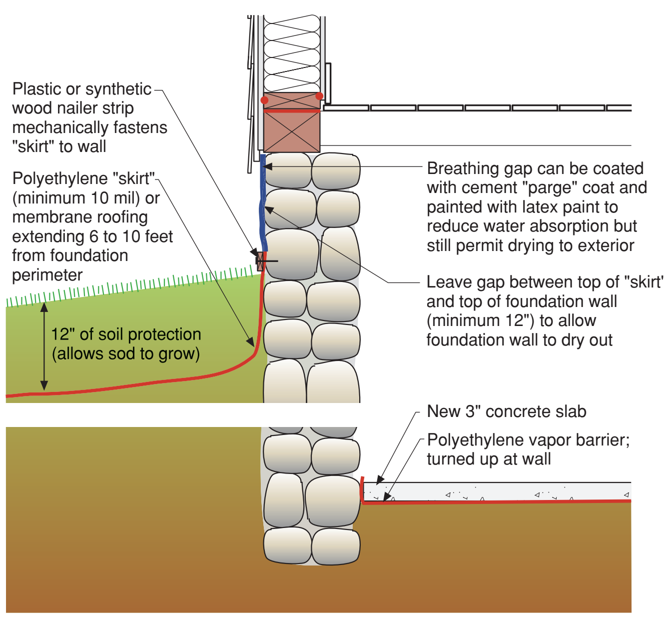


Figure 9
Using an impermeable skirt outside

• Prevents saturation of ground adjacent to existing foundation

Figure 10
Capillary rise through basement footing

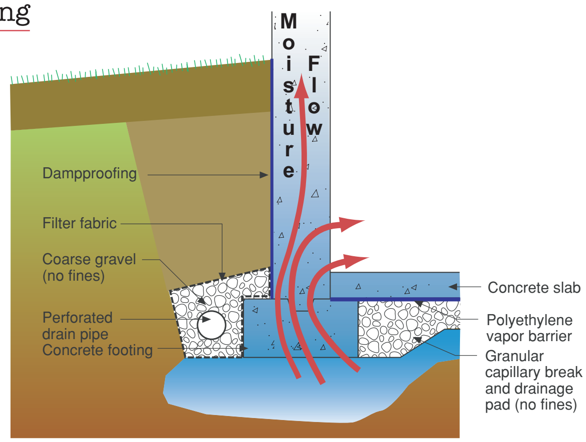


Figure 11
Capillary break over footing

- Concrete wall cold, can only dry to the interior if interior assemblies are vapor semi-permeable (permeance greater than 1 perm — i.e unfaced extruded polystyrene less than 1-inch thick); mold possible if interior assemblies do not permit drying
- Cold concrete wall must be protected from interior moisture-laden air in winter and in summer
- Basement floor slab can dry to the interior
- Thicker foam can be used if drainage is provided between the foam and the foundation wall (see Figure 14)

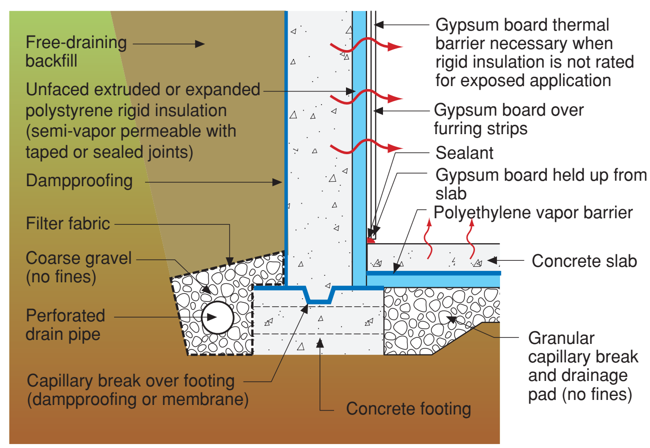


Figure 12
Capillary control for monolithic slab

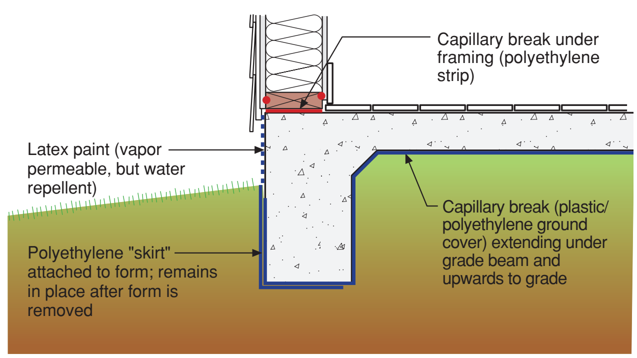


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Figure 13
Interior drainage: Renovation

- Interior membrane waterproofing must be gas tight and vapor tight relative to the interior

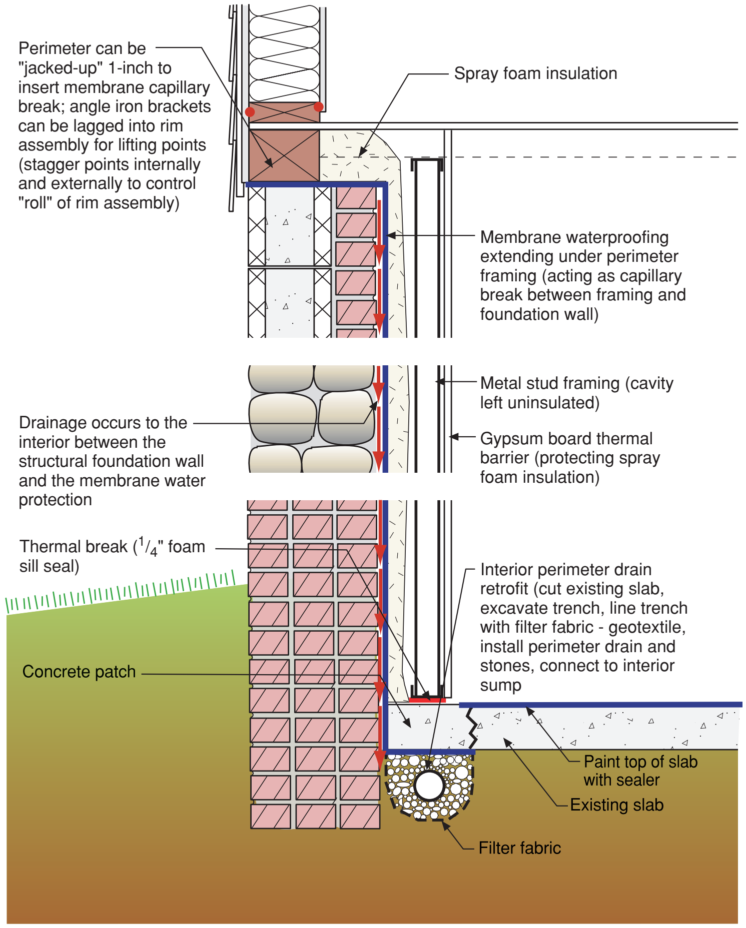


Figure 14
Interior drainage: New construction

- Interior rigid insulation must be gas tight and vapor tight relative to the interior
- This can also be a retrofit approach

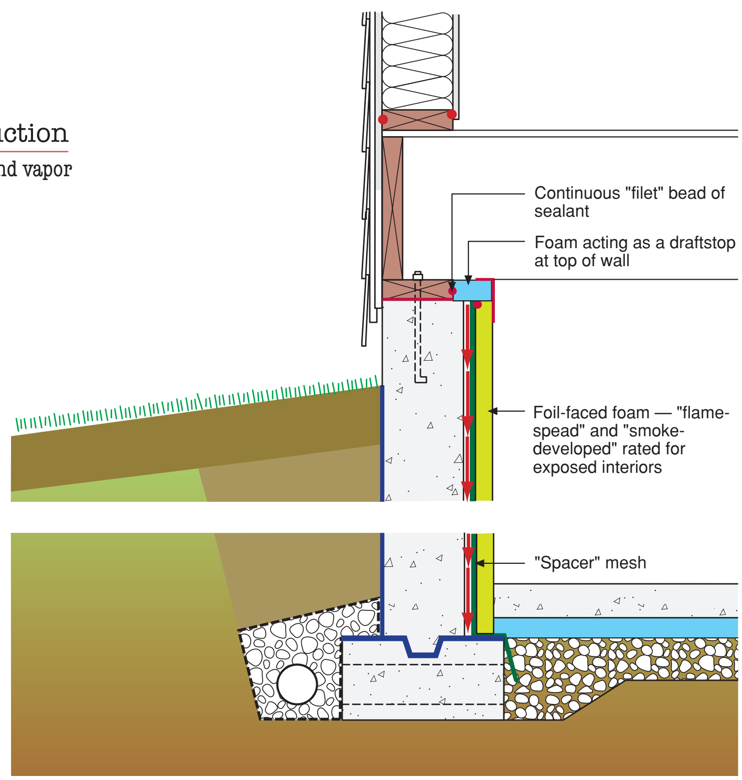


Figure 15

Slab top-side vapor control — Semi-permeable floating floor

- Extruded polystyrene should be used due to its compressive strength (expanded polystyrene can be used if furring spacing is reduced to 12" o.c. or if plywood is supported directly on foam (i.e. no furring)
- Not applicable with visibly wet slabs and where efflorescence (salts) is visible
- Avoid vinyl flooring with this assembly as vinyl flooring does not breathe

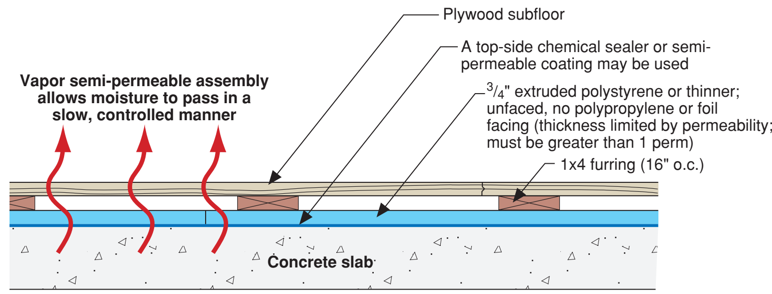
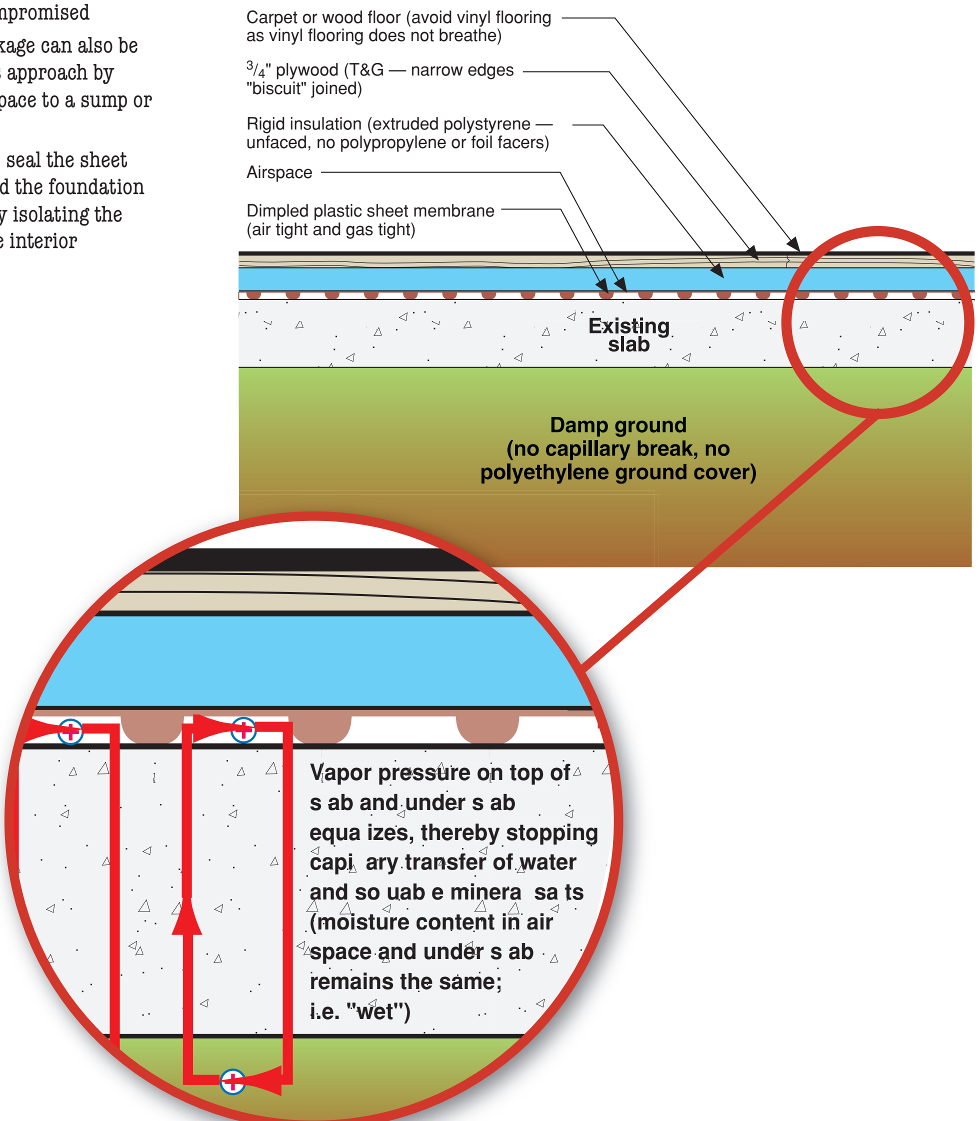


Figure 16

Slab top-side vapor control — Airspace Approach

- Works in both new construction and rehabilitation
- Plywood glued (T&G edges) to itself not mechanically fastened (no screws or nails) through foam and dimpled plastic sheet membrane so that gas barrier/air barrier is not compromised
- Groundwater leakage can also be handled with this approach by draining the airspace to a sump or floor drain
- It is important to seal the sheet membrane around the foundation perimeter thereby isolating the airspace from the interior



Plumbing

Plumbing Location Don't put plumbing in exterior walls or insulated ceilings. Exterior walls contain insulation and are subject to more extreme temperature swings than interior walls making the plumbing more vulnerable. The result can be plumbing leaks and breaks that cause significant water damage and can be the cause of mold growth. To prevent such problems, avoid whenever possible putting any cold or hot water supply pipes, steam lines, hydronic heat pipes, air conditioner condensate lines in outside walls. Not steam lines, not hydronic heat pipes, not air conditioner condensate lines, not anything that carries water.

Put plumbing in interior walls or in floors (see **Figure 17**) so when the plumbing leaks, and make no mistake about it, plumbing will leak, we can see the leak and fix it.

Bathrooms Since plumbing leaks and since we have lots of plumbing in bathrooms we'll probably have leaks in bathrooms – particularly in the–"wet areas". Don't use paper-faced gypsum board or "green board" products in wet areas such as tub and shower enclosures. It is just paper with a green color. It's best to use cement board or fiber cement board or paperless gypsum board or do it the old-fashioned way with cement plaster. Where you do use gypsum board, keep the gypsum board up off floors everywhere at baseboard locations. When the inevitable leak occurs, this space reduces the chance that the paper-faced wallboard will come into contact with water from a leak and suck it up into the wall.

Clothes Washers and Water Heaters Clothes washers can leak, especially the rubber hose connections. Reinforced hose connectors should be used. Clothes washers should also be installed in rooms with drains and floor systems that drain to the drain with floor coverings that are not water sensitive.

It is also good practice not to put laundry rooms up on second floors (despite the convenience of locating them there) because when pipes burst and hoses break everything below them gets water damaged. A good place for laundry rooms is on slabs (at grade or in basements).

Water heaters can leak, especially when they get old, pressure relief valves leak, and drain pans for water heaters leak. Water heaters should also be installed in rooms with drains and floor systems that drain to the drain and with floor coverings that are not water sensitive. In warm

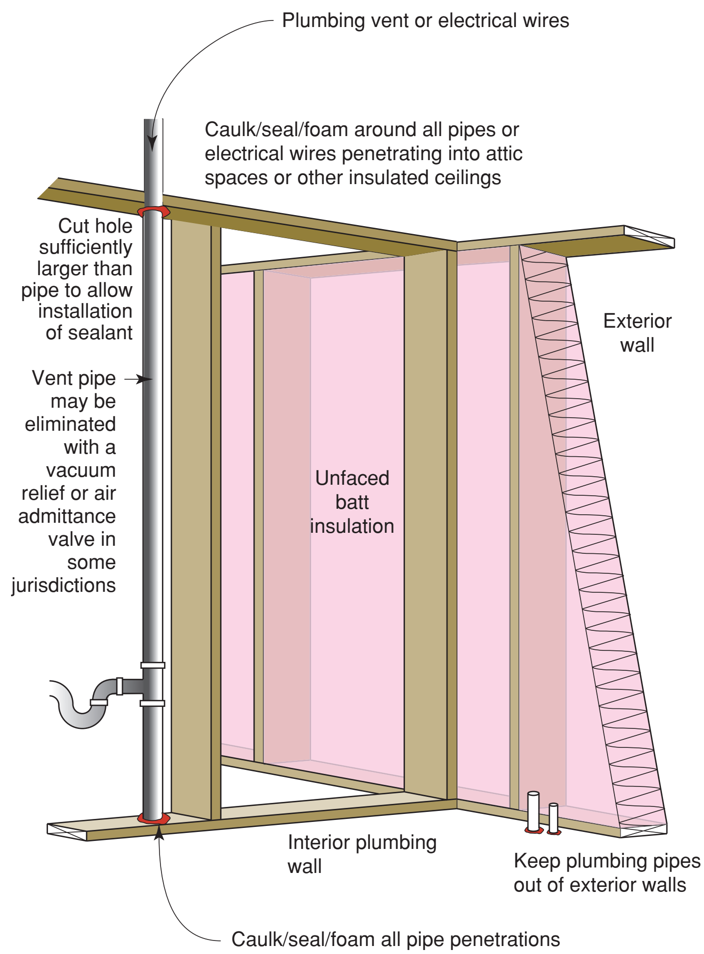


Figure 17
Locating plumbing pipes
• Sealants should be flexible, non-hardening

climates, it is best to install them in garages so when they leak they don't cause much damage. Never, ever install them in attics.

Single-throw shut-off

Because clothes washers leak and water heaters leak, shut off valves that can be used to isolate these devices should be provided. These shut off valves should be easily accessible and visible. Don't hide them behind the clothes washer or hot water heater. Single-throw shut-offs for clothes washers are effective and convenient.

Air Conditioning Systems These systems also can be sources of plumbing leaks. Besides cooling air, they are dehumidifiers that remove moisture in the air by condensing it on a cold coil and draining the condensate to a drain or to the outside. This involves plumbing and drain pans and therefore leakage.

Note: Installing air conditioners in attics where they can leak is as risky as installing water heaters in attics. Wherever they are located, drain pans must be constructed and installed so that they drain.

Drying

Walls Walls get wet from both the outside and the inside. And, in many cases, they start out wet due to the construction process. Therefore, walls should be designed to dry. Walls that are designed to dry to both sides (see **Figures 18** and **19**) typically perform better than walls that are designed to dry only to one side. All walls should be designed to dry to at least one side.

Basements Basements should be designed to dry to the interior (see **Figure 20**). These principles are often in conflict with some common misapplied energy conservation and moisture control practices – for example the use of sheet polyethylene as an interior vapor barrier.

Sheet polyethylene is an almost "perfect" vapor barrier because it does not allow any moisture in the vapor form to pass through it. This is a great feature during cold winters, but are a counterproductive feature during summers and climates that require cooling.

Paper-faced cavity insulation can and should be used in place of plastic interior vapor barriers. Alternatively, cellulose cavity insulation can be used in conjunction with latex paint on gypsum board.

Building codes do not call for the installation of vapor barriers – they call for the installation of vapor retarders – and only in cool and cold climates or colder (5,400 heating degree days or greater – Zone 5 or higher – see **Figure 21**).

Note: A vapor retarder is defined by building codes as a material that has a vapor permeability of 1 perm or less (as tested by ASTM E-96 Test Method A – the desiccant or dry cup method). Sheet polyethylene has a vapor permeability of 0.1 perms— 10 times less than what is called for in the building codes.

Installing interior polyethylene as a vapor barrier on wall assemblies should be limited to very cold climates (9,000 heating degree days or greater– Zone 7 or higher).

Roofs They should be designed to dry. That means roofs should be ventilated. It is possible to design and construct unvented roofs, but this should be done only with professional design and analysis.

Installing polyethylene vapor barriers in vented roof assemblies should be limited to cool and cold climates or colder (5,400 heating degree days or greater— Zone 5 or higher). Even in Zones 5 or higher, polyethylene vapor barriers are not required in vented roof assemblies; the code does not call for their installation, the code calls for only a vapor retarder.

Below-Grade Spaces Sheet polyethylene (or vapor barriers) should never be installed on the interior of interior basement insulation assemblies or on the interior of interior insulation in below grade wall assemblies in any climate as it prevents drying to the interior. The exception to this interior vapor barrier in basements rule is where drainage is provided between the interior vapor

Figure 18
Classic flow-through wall assembly

- Permeable interior surface and finish and semi-permeable exterior sheathing and permeable building paper drainage plane
- Ventilation provides interior air change (dilution) and also limits the interior moisture levels during heating
- Air conditioning/dehumidification limits the interior moisture levels during cooling

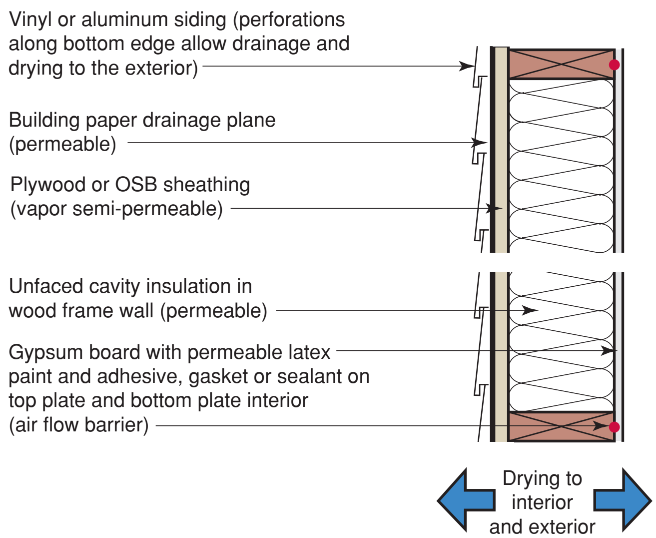
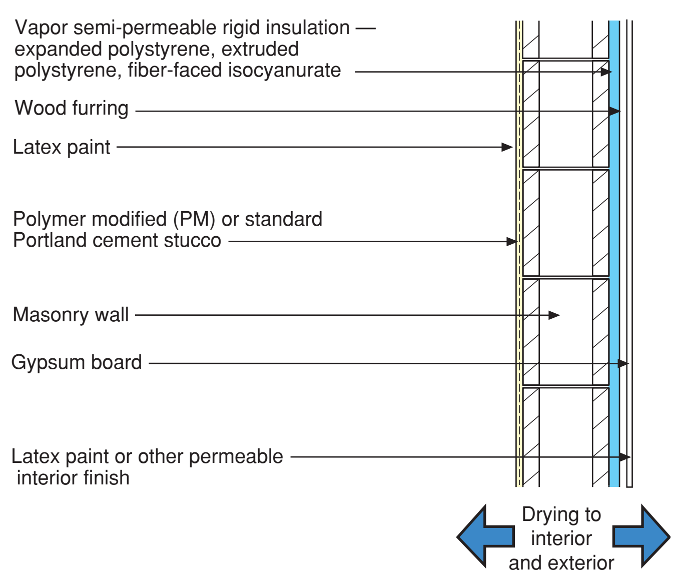


Figure 19
Masonry wall with interior rigid insulation and stucco

- The vapor semi-permeable rigid insulation and interior latex paint permit drying to the interior
- Vapor semi-permeable rigid insulation (1 perm or greater) used on the interior should be unfaced or faced with permeable skins; foil facings and polypropylene skins should be avoided
- Avoid use of metal furring or "hat" channels due to thermal bridging and impermeability; use only wood furring
- Wood furring should be installed over rigid insulation; rigid insulation should not be installed between wood furring, but should be installed directly on interior of masonry
- The exterior latex paint permits drying to the exterior



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barrier and the assembly (i.e. exterior to the vapor barrier – see Figure 13 — **Interior Drainage: Renovations** and Figure 14 — **Interior Drainage: New construction**).

Impermeable interior finishes should be avoided, such as vinyl wall coverings or oil (alkyd) based paints. In a similar vein, vinyl floor coverings should be avoided on basement floor slabs or on slab-on-grade construction unless a low water-to-cement ratio concrete is used (less than 0.45) installed directly over a polyethylene vapor barrier"– and only where slab edges are protected from capillary water (see Figure 13 – **Capillary Control For Monolithic Slab**).

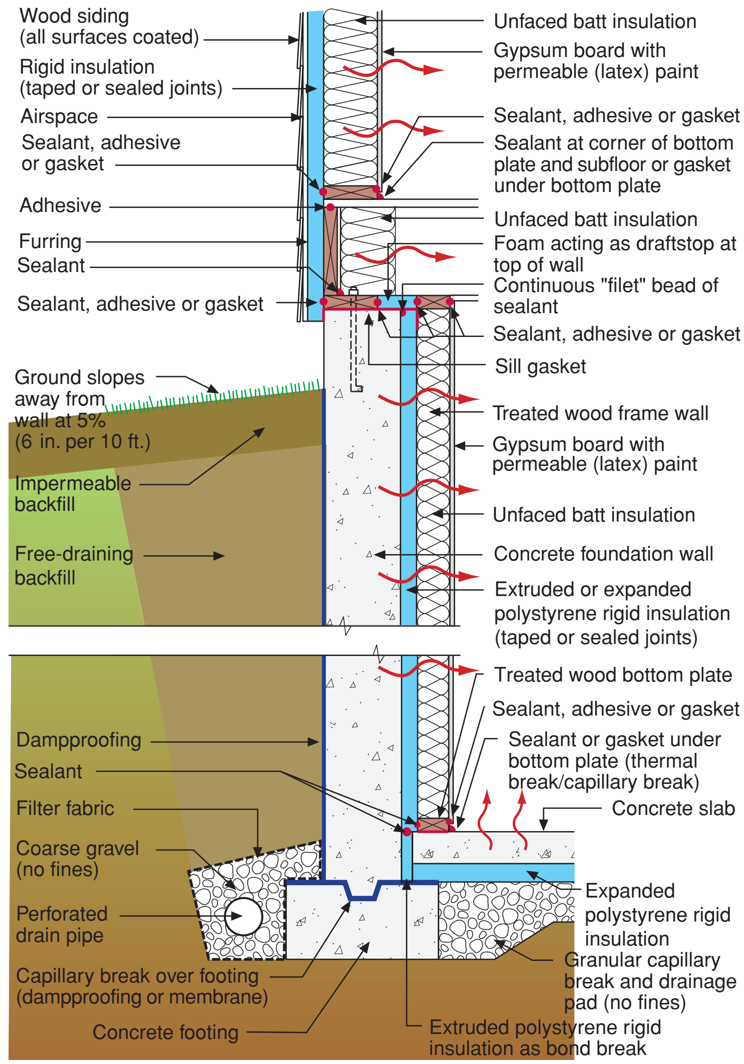

Figure 20
Internally insulated concrete basement with wood siding above

- Concrete wall cold; can only dry to the interior if interior assemblies are vapor semi- permeable; low likelihood of mold
- Cold concrete wall must be protected from interior moisture-laden air in winter and in summer
- Basement floor slab is warm, can dry to the ground (since there is no under slab vapor diffusion retarder) as well as to the interior; lowest likelihood of mold

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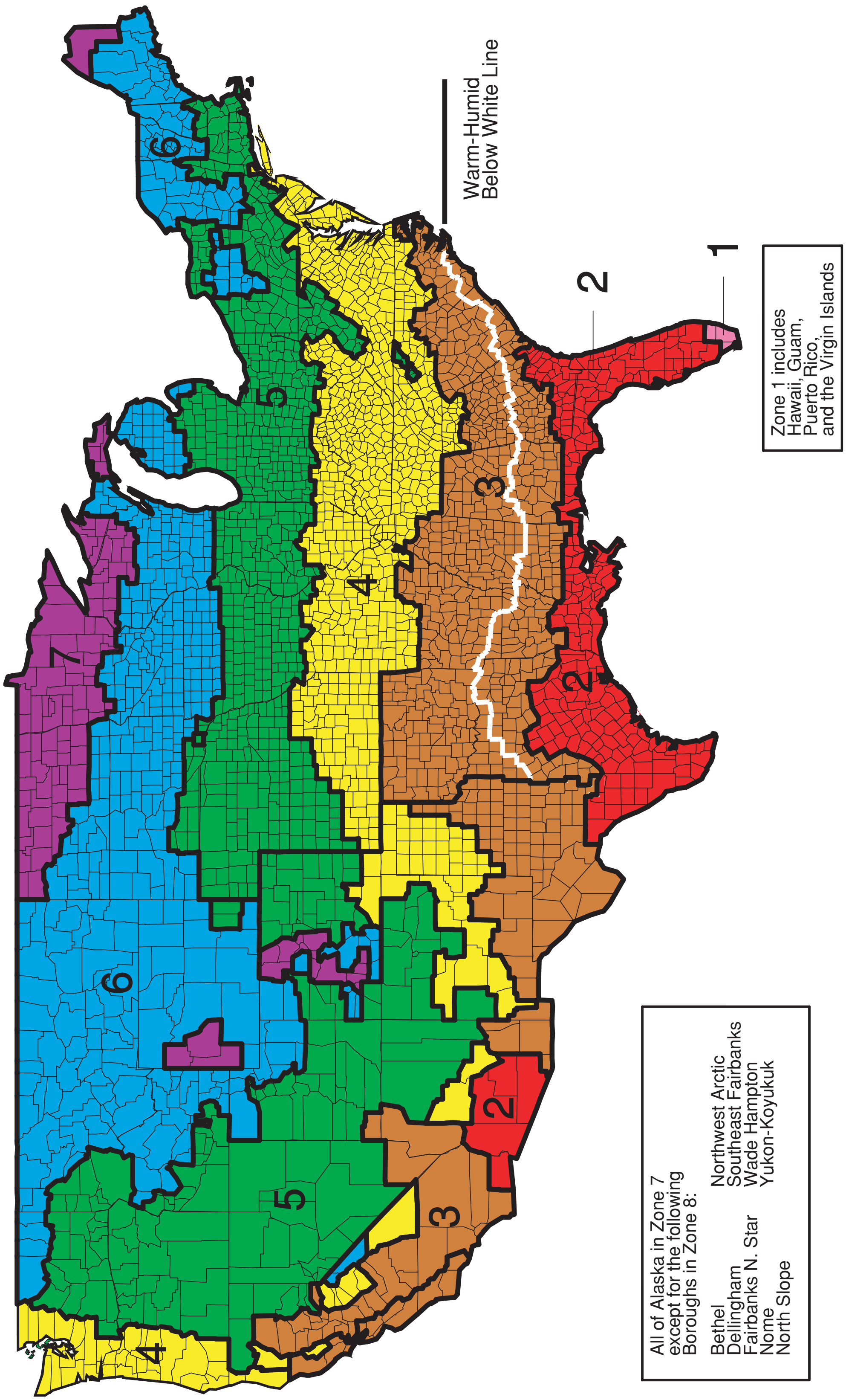
Figure 21
Climate zones map



Air

Air transports pollutants and moisture. In order to control pollutant movement you must first control air. But in order to control air you must first enclose air. That means getting rid of the big holes. Once we get rid of the big holes (and get an "enclosure"), we can control air movement within a home and between the home and the outside.

Then we can concentrate on the cold surfaces (get rid of them by insulating them) or make sure that the indoor air or the outdoor air never gets to the cold surfaces. Why do we not want air seeing cold surfaces? Because we do not want condensation. Condensation, especially the kind we don't see, can cause mold and destroys buildings.

Finally, we can limit indoor humidity and airborne pollutants by controlling air change between the interior and exterior. Dilution is the solution to indoor pollution that cannot otherwise be prevented or removed near the source.

But none of this is possible until we first get rid of the big holes.

Big Holes

The biggest holes in buildings often occur between basements, crawlspaces and living areas. Other major holes include bathtubs on exterior walls, ductwork in attic spaces or exterior walls, soffits, recessed lights, plumbing chases and chimneys.

Basements or Crawlspaces These areas are part of a home – despite repeated attempts over the years to disconnect them. They should be designed and constructed to be dry and conditioned. This is particularly important for basements because mechanical systems are always located in basements. So not install mechanical systems outside of a home in unconditioned space unless there is no practical alternative. If a basement is being used for storage or as living space, it needs to be kept dry to avoid mold and dust mites.

Basements should be insulated on their perimeters – they should not be insulated between floors. Ceiling basement insulation is a bad idea, especially, if the basement is wet. If the basement is wet, make the basement dry. Don't try to disconnect the basement from the home, it only creates problems. Especially if you put mechanical equipment in the basement. The mechanical equipment connects the basement to the house.

Crawlspaces should be designed and constructed as mini-basements (see **Figure 22**). They should be dry and conditioned. They should not be vented to the exterior. They should be insulated on their perimeters and should have a continuous sealed ground cover such as taped polyethylene. They should have perimeter drainage just like a basement (when the crawlspace ground level is below the ground level of the surrounding grade). As part of rehabilitation work, make sure there is good drainage away from crawlspaces.

The important part to understand about crawlspaces is the "conditioned" part. They must be heated and cooled as if they are included as part of the home. Air must be supplied to the crawlspace from the home. This air can be returned back to the home or it can be exhausted (see **Figure 23a** through **Figure 23e**).

Where homes have both a crawlspace and a basement they should be connected together and treated together as a conditioned space (see **Figure 24**).

Another big hole is the utility wall where it intersects exterior walls and ceilings or where exterior walls are padded out to provide space for utilities (see **Figure 25**).

Bathrooms Bathtubs and shower enclosures are rarely draft stopped (air sealed) with rigid materials such as sheathing or gypsum board (see **Figure 26**). Most people forget that cavity insulation is just a filter or screen for air. Just leaving insulation behind a tub is like leaving your front door open – forever.

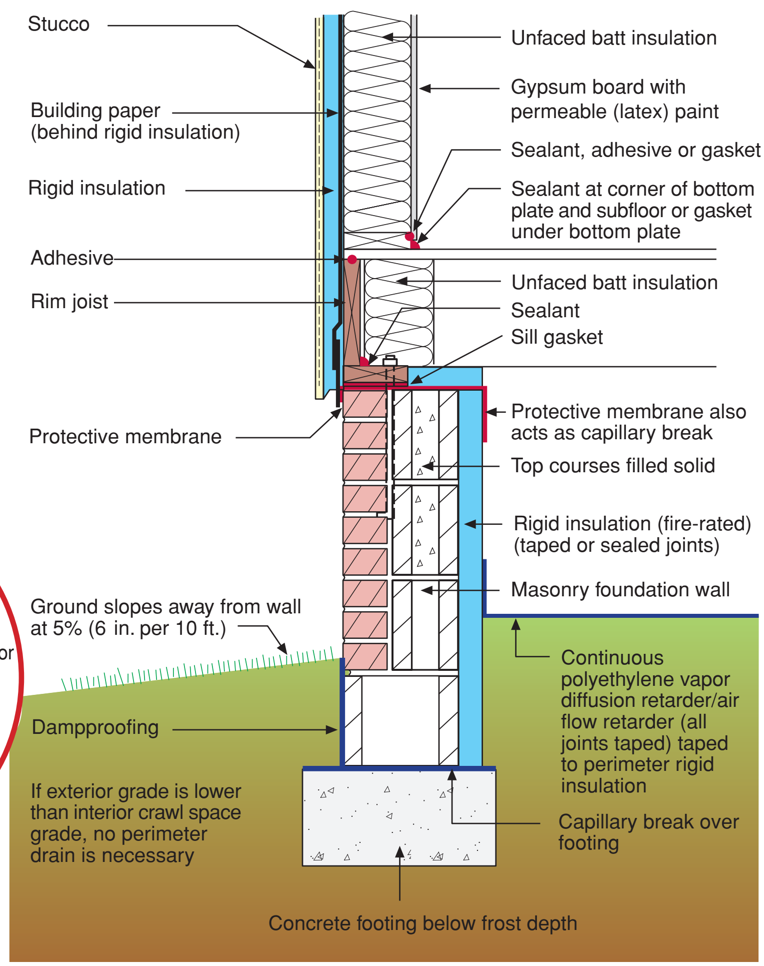
Air Handlers and Ductwork Avoid placing ductwork and air handlers in attics, air handlers in garages or ductwork in walls because leaks are a problem. Leaky ducts and air handlers located in attics are one of the major sources of ice-damming problems. During rehabilitation, move the air handler and ductwork from attic and exterior walls.

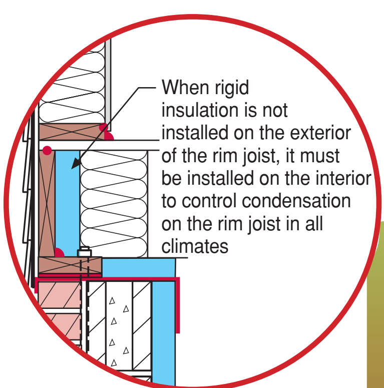
Wherever you install ductwork, ducts should be tight. How tight? Flex duct systems should leak at no more than 5 percent of their flow (as tested by pressurization testing at 25 Pa) and sheet metal duct systems should leak at no more than 10 percent of their flow (as tested by pressurization testing at 25 Pa).

Attics Vented attics should have airtight ceilings that separate the vented attic from the conditioned part of the home. Soffits, chimneys, plumbing vent pipes, chases, dropped ceilings all require draftstops. Similarly, scuttleholes and drop-down stair openings should be air tight.

Figure 22
Internally insulated concrete crawlspace with stucco wall above

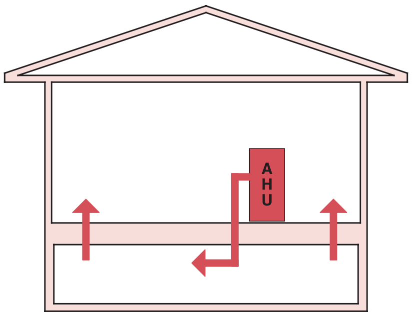
- Masonry wall cold; can dry to exterior; low likelihood of mold
- Protective membrane acts as termite barrier
- Rigid insulation must be fire-rated if it is left exposed on the interior
- Building paper installed shingle fashion acts as drainage plane located behind rigid insulation





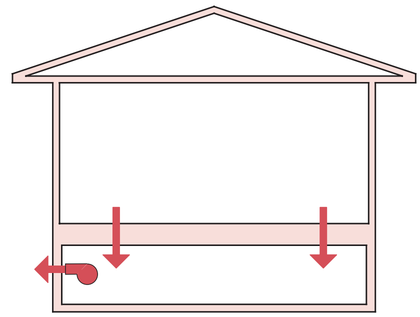
Alternative detail

Figure 23
Conditioning crawlspaces



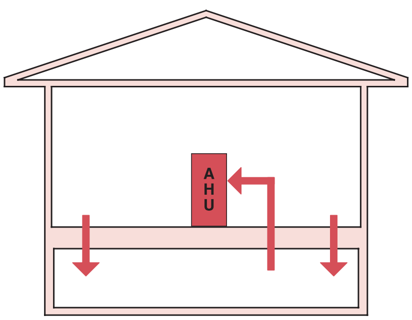
A: Supply air to crawlspace

- Minimum 2 - 4"x8" transfer grilles to house
- 50 cfm of flow per 1,000 ft^2 of crawlspace
- Air handler cycled at 5 minutes per hour



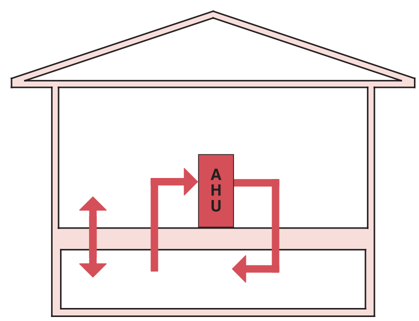
B: Exhaust fan in crawlspace

- Transfer air from house
- Fan sized at ASHRAE 62.2 whole house flow rates: 7.5 cfm/person + 0.01 cfm/ft^2 of conditioned area
- For a 2,000 ft^2 3 bedroom house with 4 occupants:
  4 x 7.5 cfm = 30 cfm
  2,000 ft^2 x 0.01 cfm = 20 cfm
  30 cfm + 20 cfm = 50 cfm (i.e. 50 cfm exhaust fan)
- Fan runs continuously



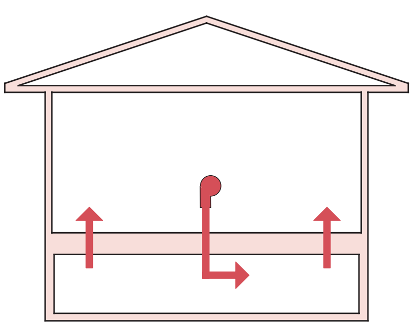
C: Return air from crawlspace

- Minimum 2 - 4"x8" transfer grilles from house
- 50 cfm of flow per 1,000 ft^2 of crawlspace
- Air handler cycled at 5 minutes per hour



D: Supply and return to crawlspace

- Minimum 2 - 4"x8" transfer grilles from house through floor to equalize air pressures
- 50 cfm of flow per 1,000 ft^2 of crawlspace
- Air handler cycled at 5 minutes per hour



E: Supply fan in house and supply air to crawlspace

- Minimum 2 - 4"x8" transfer grilles to house
- 50 cfm of flow per 1,000 ft^2 of crawlspace

Figure 24
Connecting crawlspace and basement

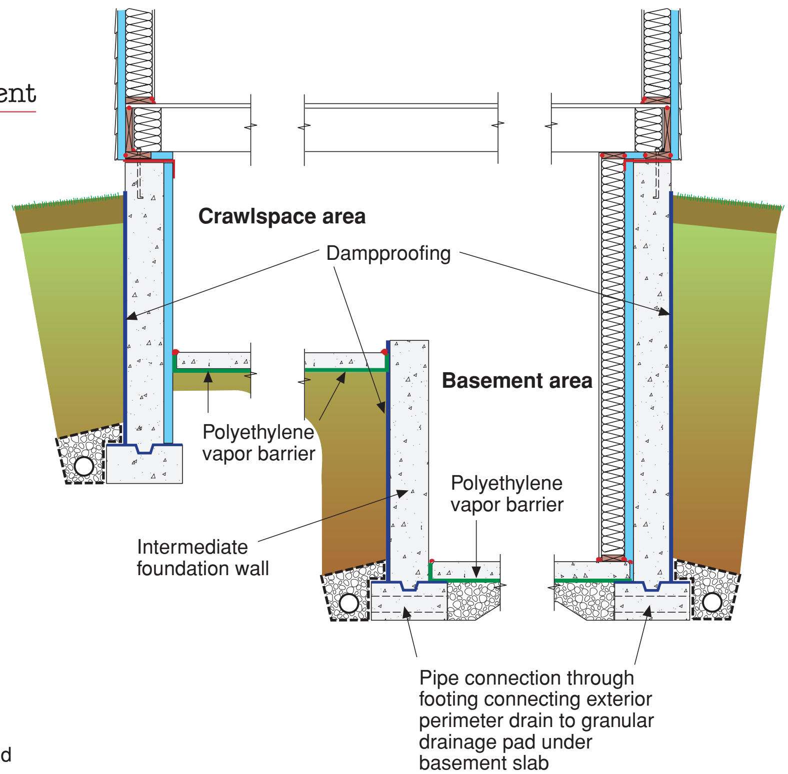
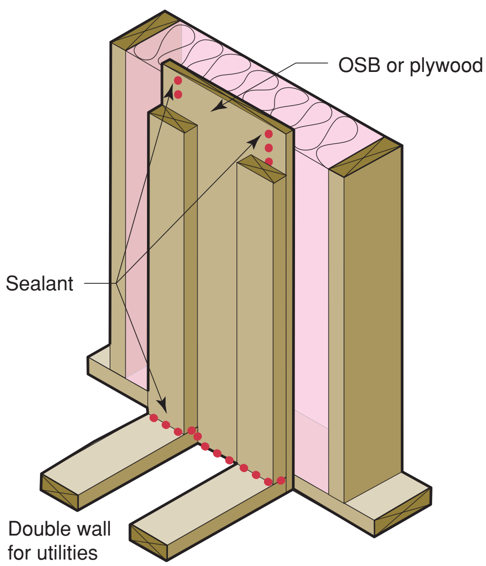


Figure 25
Utility chase construction



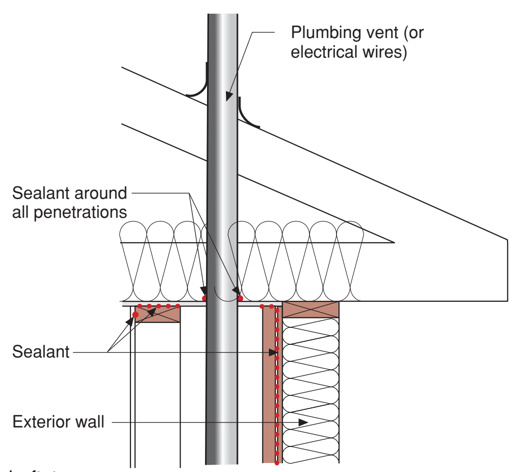


Figure 25a
Section through plumbing vent chase

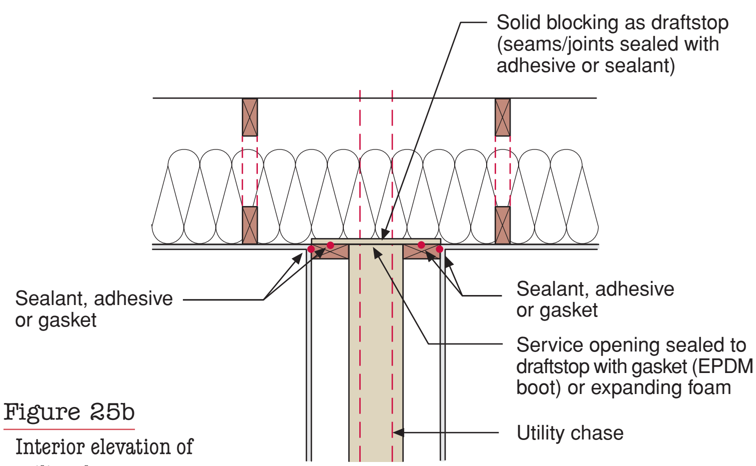
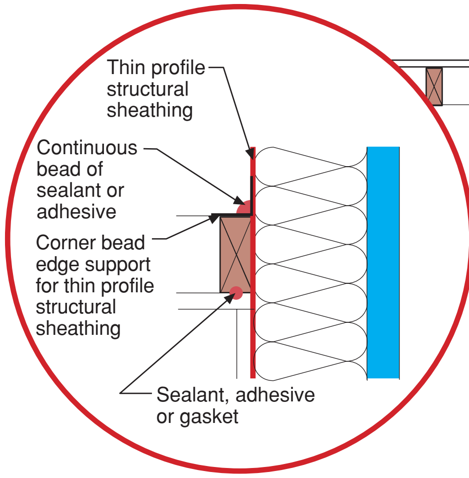


Figure 25b
Interior elevation of utility chase

Figure 26
Tub framing



Detail

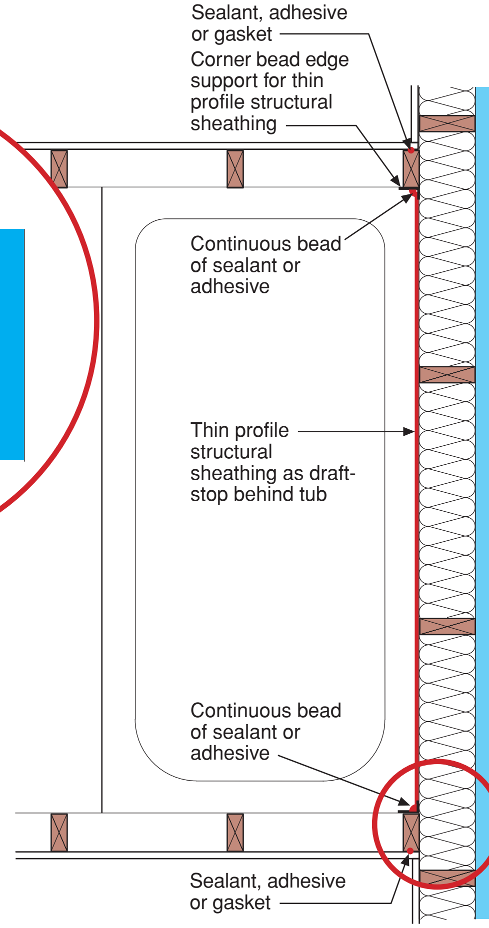


Figure 26a

Plan of tub framing

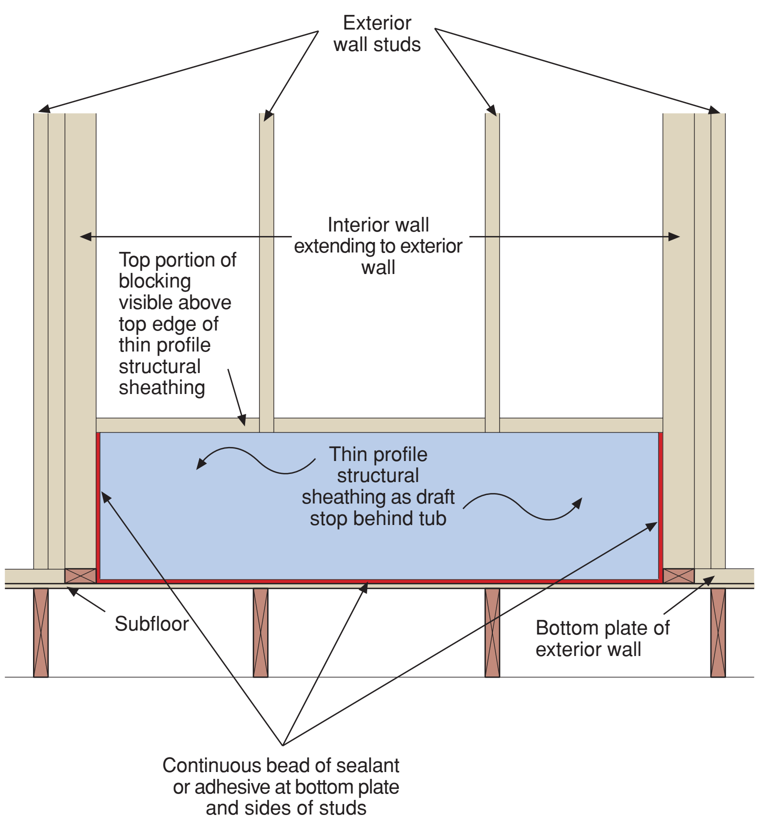


Figure 26b

Interior elevation of tub framing

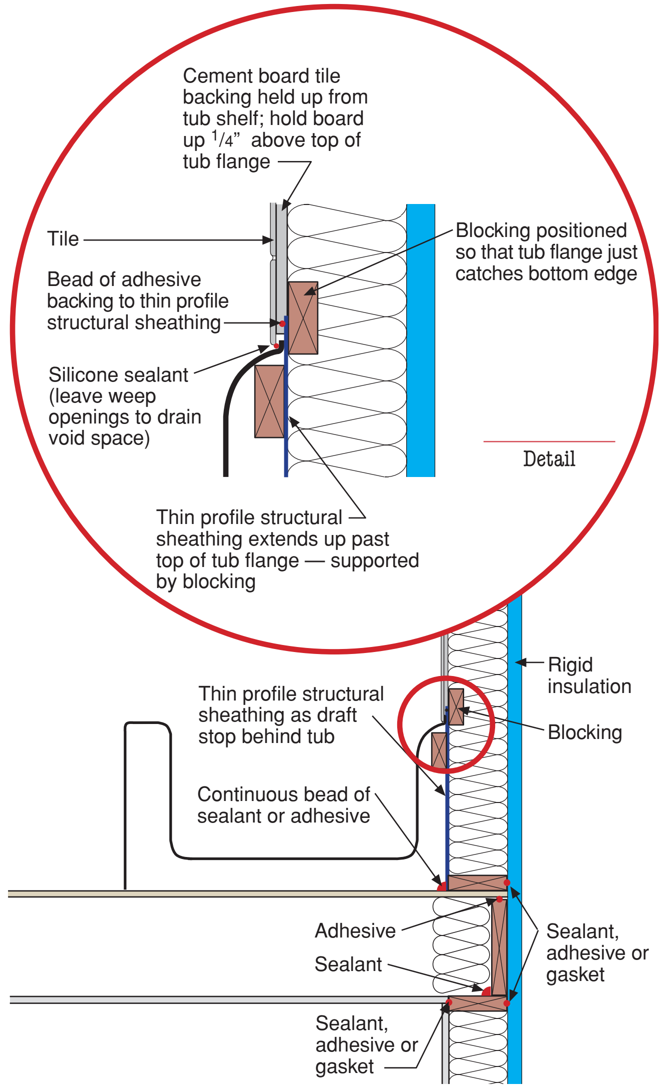


Figure 26c
Section of tub framing
- Flat blocking allows cavity insulation to be installed behind tub draftstop
- Cement board tile backing is recommended. "Green board" should not be used.

Cold Surfaces

Condensation happens on cold surfaces. One of the best techniques for controlling condensation is to eliminate cold surfaces.

Windows The coldest surfaces in homes usually are windows. Windows should never (except for short periods in unusually cold weather) have condensation on the inside. This is a wintertime problem even in warm climates. In hot-humid climates, windows often sweat on the outside during the summer. Interior window surfaces must be warm. At a minimum, windows must be double glazed with non-thermally conductive frames. Avoid aluminum extrusion windows without thermal breaks. Window frames should be constructed from wood, vinyl or fiberglass. Wood windows can be clad with vinyl or aluminum for maintenance reasons.

Older, single pane windows will be cold and will have condensation on them. This problem occurs everywhere, not just in cold climates. They should be replaced, if possible.

In very cold climates (Zone 7 or higher, see **Figure 21**) window glazing should be low E (U-value less than 0.4). In all other climates, window glazing should be low E^2 (spectrally selective, SHGC less than 0.4, U-value less than 0.4). The increased cost of such glazing is readily offset by a reduction in the size of the mechanical conditioning system.

Metal Studs This type of stud is 300 times more conductive than wood studs. They are prone to condensation and ghosting. Metal studs should never be used with cavity insulation because it makes them even colder. If metal studs are used they should be limited to interior walls or to the interior of rigid insulation assemblies. Metal studs should never be used below grade unless they are separated from slabs with thermal breaks ("sill gasket") and separated from foundation perimeter with rigid insulation.

Rigid insulation can be installed in basements above concrete floor slabs and coupled with a floating floor

Below-Grade Walls The main problem with below grade walls comes during the summer when warm moist air comes in contact with basement cold surfaces (see **Figure 27**). Basement walls should be insulated with non-water sensitive insulation that prevents interior air from contacting cold basement surfaces. The best insulations to use are foam based and vapor semi-permeable. Vapor semi-permeable materials allow the basement wall assemblies to dry to the interior. No interior vapor barriers should be installed in basements – ever – because they trap moisture inside the assemblies.

One of the worst assemblies for basement walls from the perspective of mold and moisture problems is a foundation wall that is internally framed and insulated with fiberglass cavity insulation and covered with a plastic vapor barrier. Metal studs only further aggravate the problem. Air gets in behind the framing and condenses on the cold surfaces. Alternatively, moisture from the foundation enters the internal framing. The moisture is trapped within the foundation assembly by the vapor barrier and deterioration occurs.

All bottom plates of below grade frame walls should be thermally isolated from basement floor slabs with thermal breaks. Commonly available "sill gasket" ($^3/_8$ - inch thick foam – $3^1/_2$-inches wide) is an excellent thermal break under bottom plates.

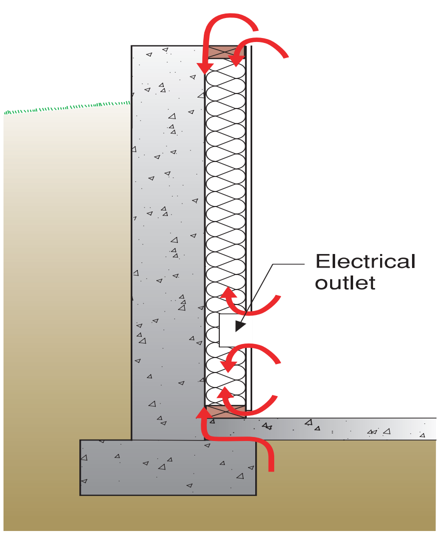


Figure 27
Below grade walls in summer

Concrete Slabs If basement spaces or below grade spaces (garden apartments) are designed and constructed to be occupied, continuous rigid insulation should be installed under concrete floor slabs to raise the temperature of floor coverings to control mold and dust mites. Alternatively, rigid insulation can be installed above concrete floor slabs and coupled with a floating floor.

It is always a good idea to install a dehumidifier in all basement spaces. The dehumidifier should be plumbed directly to a condensate drain.

Other Preventative Measures All cold water pipes should be insulated to control summer condensation.

Wood framing details, particularly in corners, should be constructed "open" in order to allow the installation of insulation and reduce thermal bridging (see **Figure 28** and **Figure 29**). Headers should be designed to accept insulation as shown in **Figure 30**.

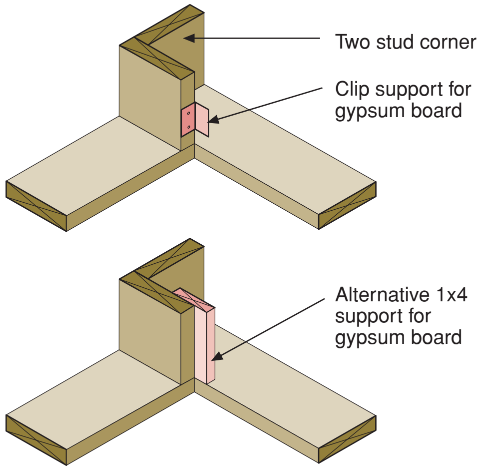


Figure 28
Corner framing

Open to interior to allow insulation installation

Figure 30
Insulated header

Open to the interior

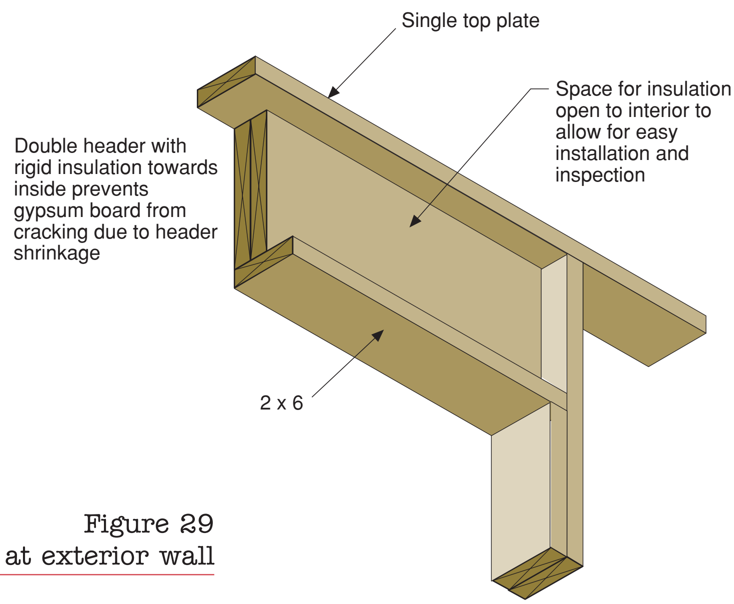
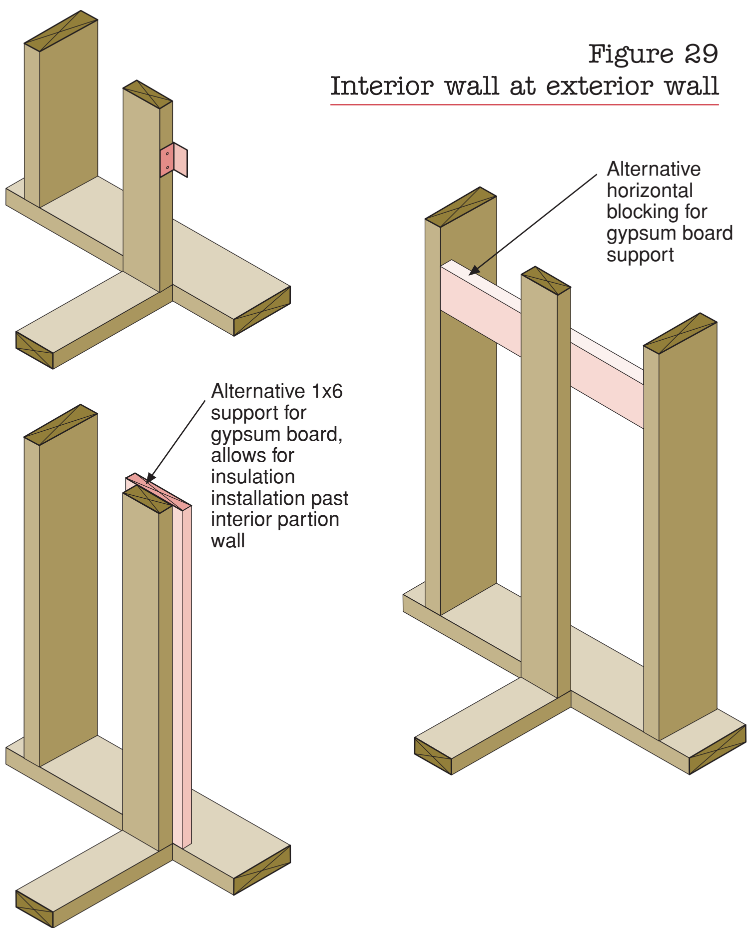


Figure 29
Interior wall at exterior wall



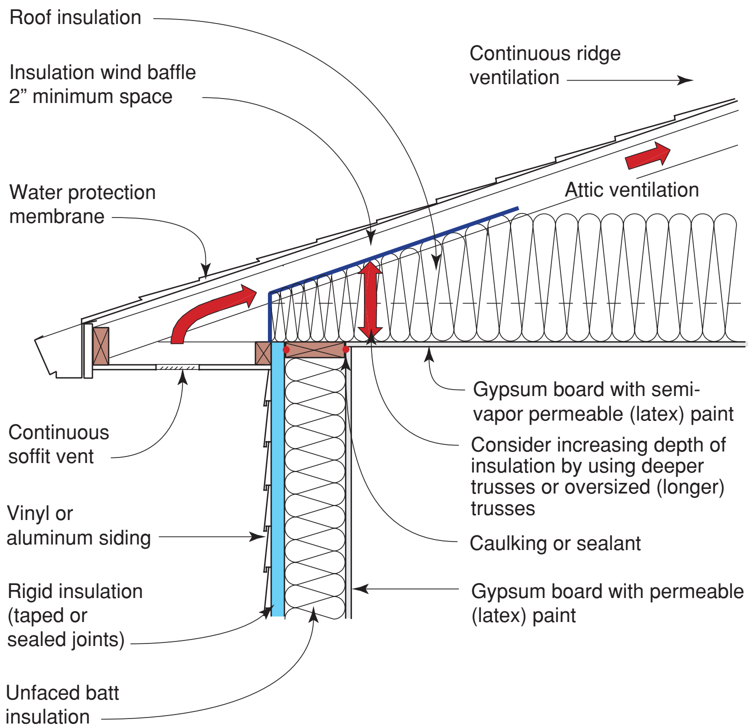


Figure 31
Baffle installation

- Roof insulation thermal resistance (depth) at truss heel (roof perimeter) should be equal or greater to thermal resistance of exterior wall

Attic insulation at exterior walls should be protected from wind wash by placement of a wind baffle (see **Figure 31**).

Indoor Humidity and Airborne Pollutants

Indoor humidity and airborne pollutants are both controlled by ventilation. There are two kinds of ventilation: spot ventilation and dilution ventilation. Both are necessary in a healthy home. Spot ventilation deals with point sources of pollution such as bathrooms and kitchens (see **Figure 32**). Dilution ventilation deals with low-level pollutants throughout the home.

This ventilation is in addition to the use of operable windows.

Kitchen and Bath Fans Every home needs to have exhaust from kitchens and from bathrooms. In kitchens, recirculating fans should be avoided because they become breeding grounds for biologicals, a major source of odors, and in all cases allow grease vapors to coat surfaces throughout the home. Kitchen range hoods must be exhausted to the outside to remove moisture, odors and other pollutants.

Bathroom fans must exhaust to the exterior – even bathrooms with operable windows. No exceptions. Low sone fans (less than 3 sones) are recommended because they are quiet (so they are more likely to be used) and more durable (in order to make them quiet they must be made durable).

Clothes Dryers Always vent dryers to the outside. Clothes dryers are huge sources of moisture as well as pollutants.

Dilution ventilation can be provided three ways: exhaust, supply or balanced (see **Figure 33**). In all cases, it should be continuous and fan powered. ASHRAE Standard 62.2 should be followed to establish dilution ventilation rates – for all homes, new or renovated.

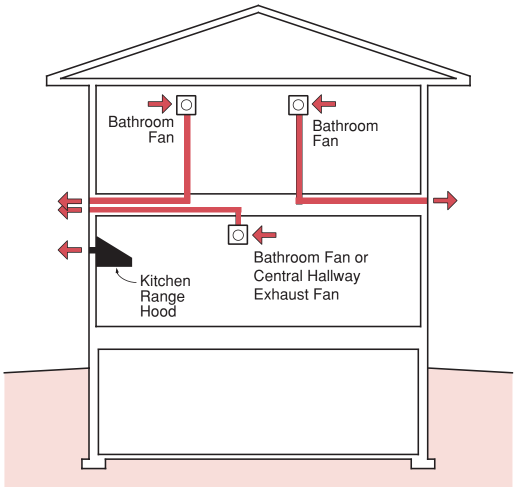


Figure 32
Exhaust ventilation system with point source exhaust

- Individual exhaust fans pull interior air out of bathrooms. One of these fans is selected to also serve as the exhaust ventilation fan for the entire building that operates continuously. Alternatively, an additional centrally located (hallway) exhaust fan can be installed.
- Replacement air is drawn into bathrooms from hallways and bedrooms providing circulation and inducing controlled infiltration of outside air.
- Kitchen range hood provides point source exhaust as needed.

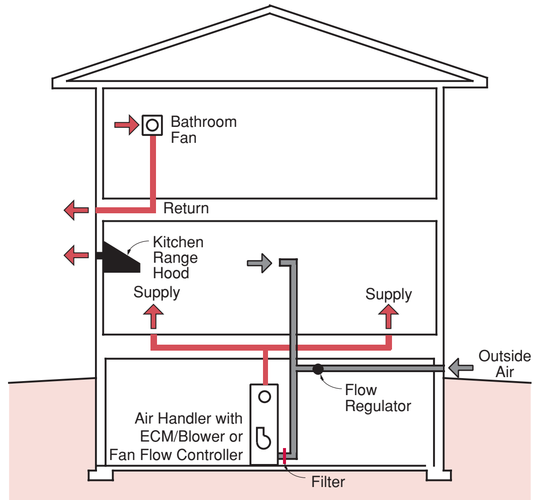
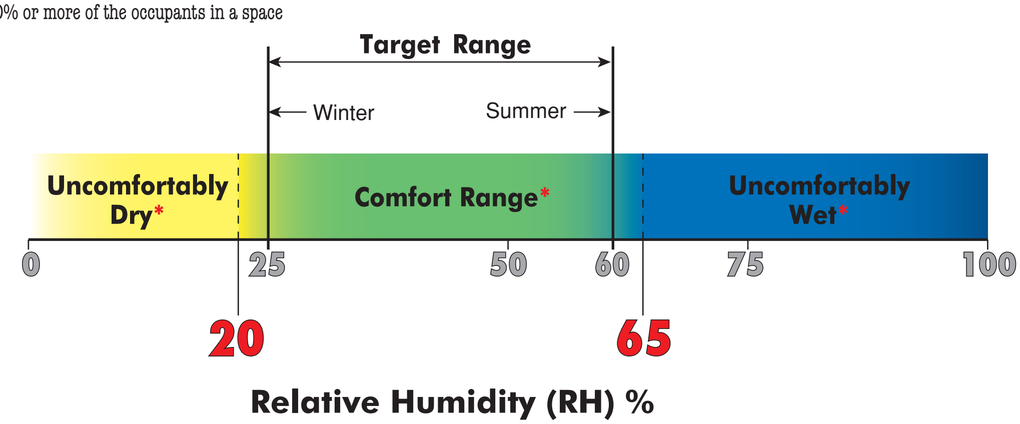


Figure 33
Supply ventilation system integrated with heating and air conditioning

- Air handler with electrically commutated motor (ECM)/ blower runs continuously (or operated based on time of occupancy) pulling outside air into the return system
- A flow regulator provides fixed outside air supply quantities independent of air handler blower speed
- House forced air duct system provides circulation and tempering
- Point source exhaust is provided by individual bathroom fans and a kitchen range hood
- In supply ventilation systems, and with heat recovery ventilation, pre-filtration is recommended as debris can affect duct and fan performance reducing air supply
- Outside air duct should be insulated and positioned so that there is a fall/slope toward the outside to control any potential interior condensation. Avoid using long lengths of flex duct that may have a dip that could create a reservoir for condensation
- Mixed return air temperatures (return air plus outside air) should not be allowed to drop below 50° Fahrenheit at the design temperature in order to control condensation of combustion gases on heat exchanger surfaces

Figure 34
Relative humidity and comfort

* For 80% or more of the occupants in a space



The key to dilution ventilation is good distribution. Outside air should be provided throughout the house. Forced air duct systems can be excellent distribution systems (either by directly providing outside air or by providing mixing of interior air). Where duct distribution systems do not exist, multiport exhaust strategies can be used.

Most individuals are comfortable where relative humidity is in the 20 percent to 65 percent range (see **Figure 34**).

During the coldest part of the winter, indoor relative humidity should be kept low – but in the comfort range (see **Table** below). During summer months, indoor relative humidity (in air conditioned buildings) should not exceed 70 percent for extended periods of time (more than several days). In hot and humid climates this may only be possible with supplemental dehumidification (a stand alone dehumidifier plumbed to a condensate drain) – especially in small units with very little solar heat gain.

	Recommended Not-to-Exceed Interior Relative Humidities*
Zone 5	35% relative humidity
Zone 6	30% relative humidity
Zone 7	25% relative humidity

* During winter (December, January, February)

Formaldehyde and other emissions from particleboard can be harmful. To reduce emissions from particleboard surfaces, reduce the amount of particleboard. Use wire shelving in closets. Wire shelving is easy to clean and permits air circulation. With kitchen and bathroom cabinets constructed from particleboard, the exposed particleboard sources can be sealed with 100 percent acrylic paint or clear sealant.

Pressures

Air pressure differences cause air to move. That is both good and bad. Air change is good when it causes dirty air to be replaced with clean air. Air change is bad when dirty air is brought into a home. The bad air change is commonly associated with high negative air pressures (suction) in homes. High negative pressures can draw pollutants (such as radon and soil gas) into homes from below grade. High negative pressures can also cause problems with furnaces, boilers and water heaters. Additionally, high negative pressures can cause smoke and odors to be drawn from neighboring units.

High negative pressures can be avoided several ways. The first is to seal forced air ductwork, particularly on the return (or suction) side (see **Figure 35**). The second is to provide air pressure balancing between rooms (transfer grilles) when forced air systems are used (see **Figure 36**). The third is to compartmentalize (isolate) multifamily units and high rises to limit airflow between floors.

Good duct layout and proper placement of air handlers provide thermal comfort and avoid the introduction of polluted air into homes (see **Figure 37**).

An effective way to use air pressure differences to capture and vent pollutants is through a sub-slab ventilation system (see **Figure 38a** through **Figure 38c**). It is a good idea to construct all floor slabs, both below grade and on grade, with sub-slab ventilation.

Figure 35

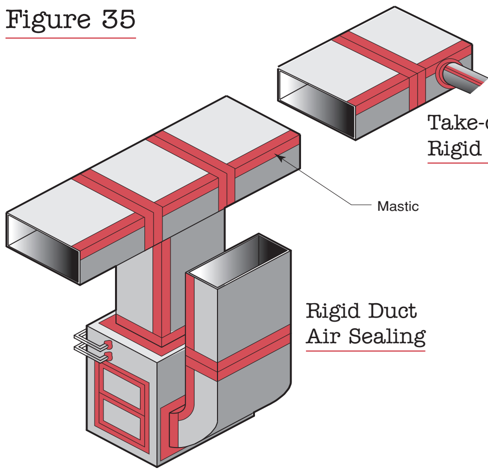
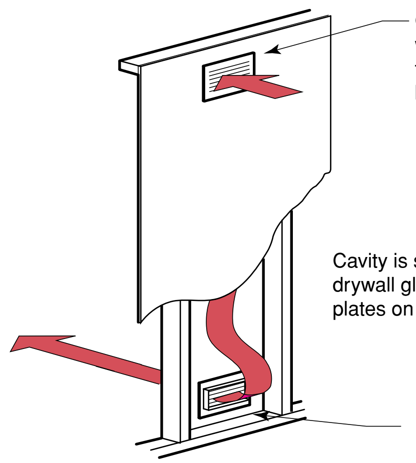


Figure 36
Transfer grille



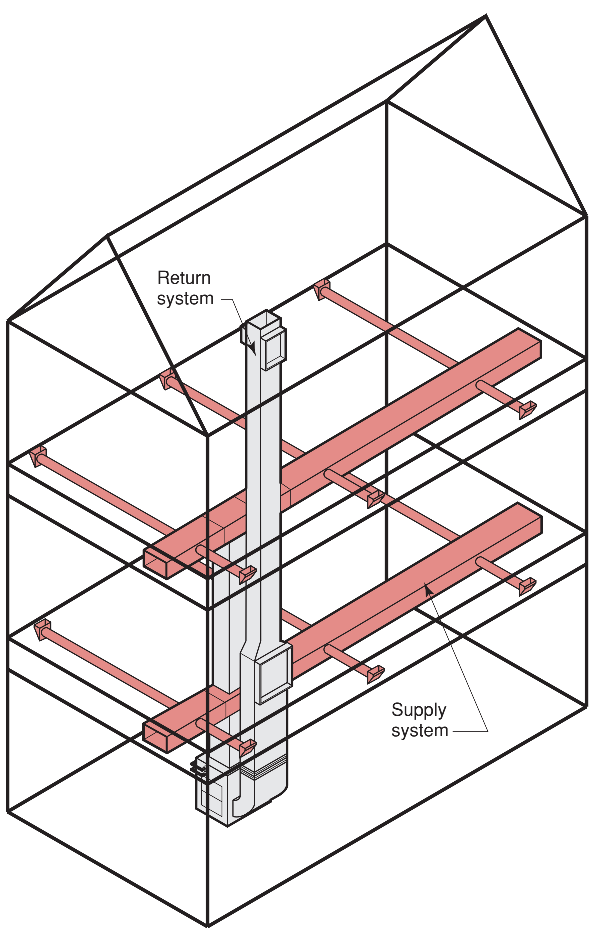


Figure 37
Air handler and duct layout

- Air handler centrally located to minimize duct runs
- No ductwork in exterior walls or attic
- Return high in hallway of upper floor
- Return low in hallway of main level
- Only fully "hard"-ducted returns connected directly to air handler should be used; no panned floor joist returns; no stud cavity returns should be used
- Either return ducts in bedrooms or transfer grilles

Figure 38a
Soil gas ventilation system — basement construction

- Granular drainage pad depressurized by passive stack action of warm vent stack located inside heated space
- Avoid offsets or elbows in vent stack to maximize air flow

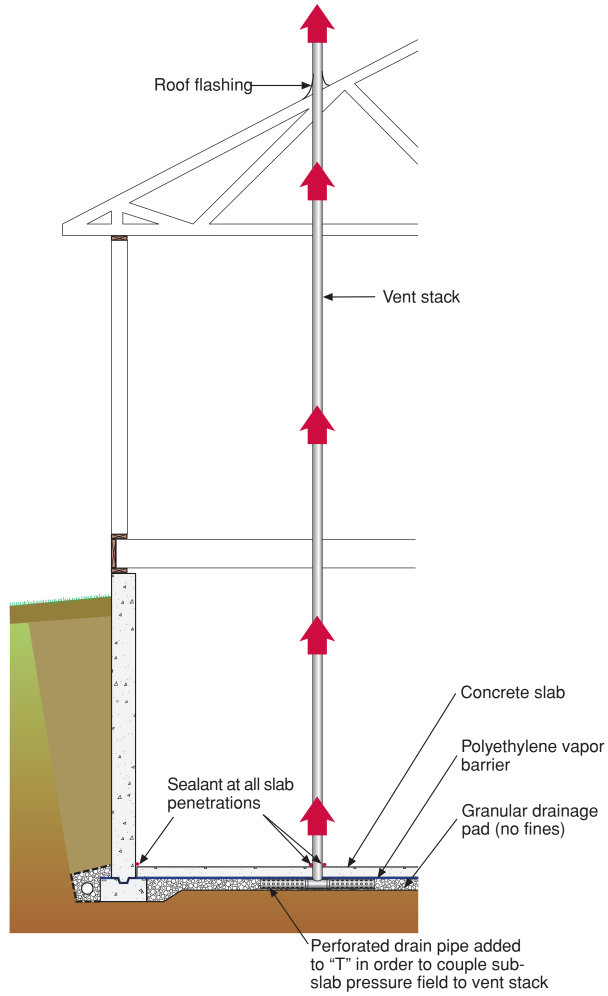


Figure 38b
Soil gas ventilation system — crawlspace construction

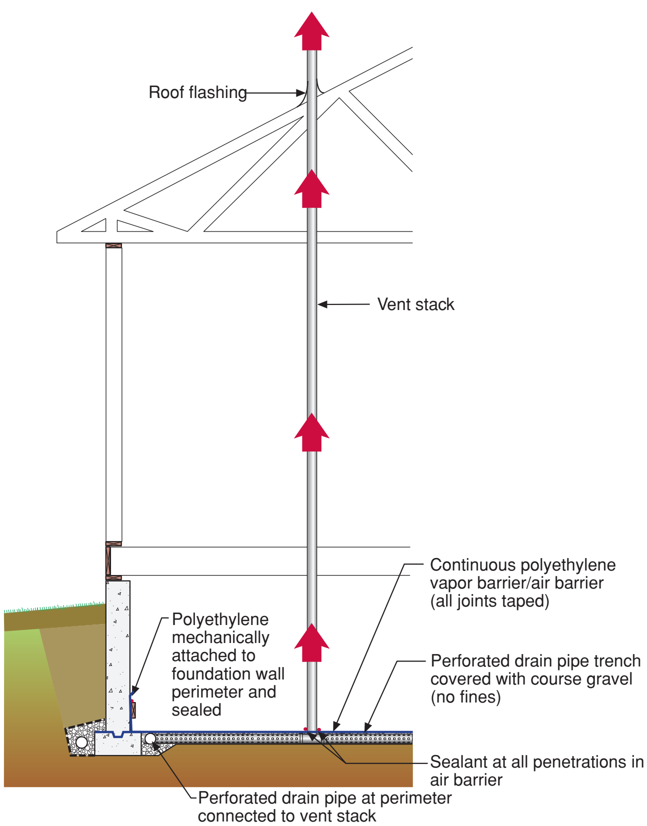
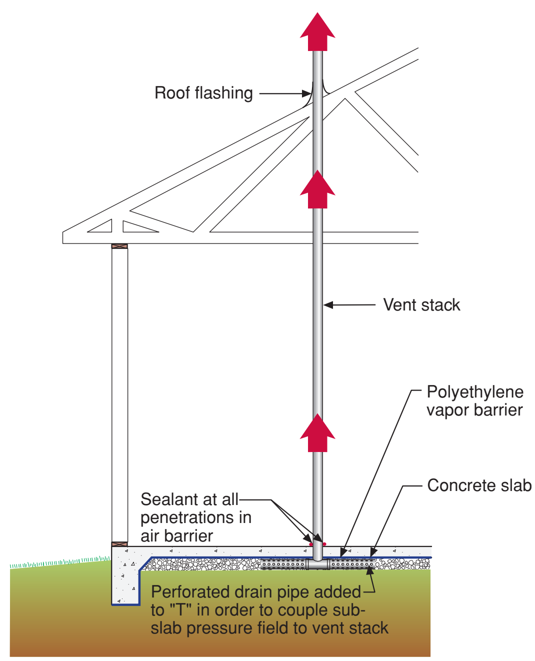


Figure 38c
Soil gas ventilation system — slab-on-grade construction



Combustion

When something is burned it produces by-products of combustion — particularly carbon monoxide and soot — that are unhealthy. Even “clean’ burning flames produce large quantities of water vapor, nitrogen oxides, sulfur oxides and carbon dioxide – all of which can lead to problems for people. Products of combustion should not be found in the indoor air of a healthy home.

Combustion Appliances

Gas cook tops and gas ovens produce products of combustion. They should only be used in combination with exhaust ventilation. Even with exhaust ventilation, some individuals with asthma and other respiratory diseases can be adversely affected. Electric ranges and ovens combined with exhaust ventilation may be the only option for these individuals. All cook tops and ovens should be installed with range fans that are exhausted to the exterior.

Gas furnace, gas boiler and gas water heater vent systems should not communicate with occupied spaces. They should always be sealed combustion or power vented devices (see **Figure 39**).

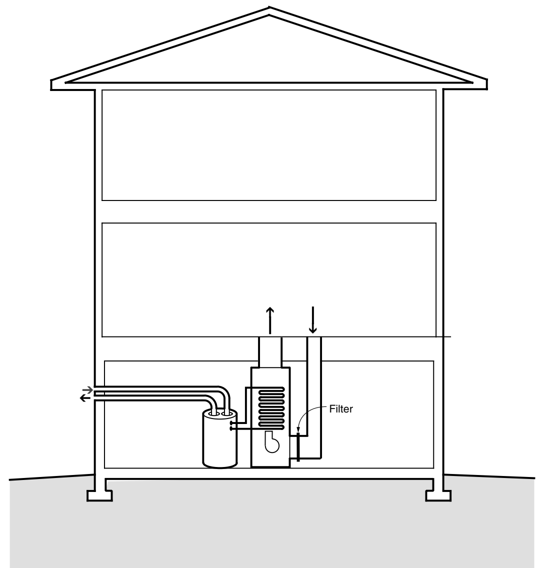


Figure 39
Sealed Combustion Power Vented Gas Water Heater

- Water heater flue gases exhausted to exterior using a fan; combustion air supplied directly to water heater from exterior via duct
- No furnace; heat provided by hot water pumped through a water-to-air heat exchanger (fan-coil)

Fireplaces must be vented to the exterior. Never install ventless gas fireplaces. Large exhaust fans (clothes dryer, kitchen range hood) can backdraft fireplaces and wood stoves or induce spillage of smoke and soot into the house. Operating large exhaust fans should be avoided during fireplace and wood stove use.

Unsealed, leaky return ducts in forced heating and cooling systems can also lead to sufficiently large negative pressures to backdraft and spill fireplaces, wood stoves and other combustion appliances. Using building cavities as returns, such as planned floor joists, should be avoided since they are impossible to seal airtight.

Garages

Ideally, garages should not be connected to a healthy home. Discrete, separate garages constructed away from homes are preferred. If garages are connected to a home, they should be ventilated to the exterior with a passive vent stack (a “chimney” to the outside — 6-inch duct). Air handling devices such as furnaces or air conditioners should never be located in garages. Nor should forced air ductwork. Weatherstrip the door between the garage and the home and air seal the common wall.

When ductwork passes through a chase or a floor above a garage or adjacent to an exterior wall bordering a garage, it is important that the ductwork be sealed airtight against the migration of pollutants from the garage to inside the home.

Smoke

Smoking should not occur in healthy homes. If you must smoke, smoke outside. Candles and incense produce soot as do fireplaces and wood stoves. Soot can be unhealthy.

Dust

Stop the dust at the door. Vacuum and filter the rest away. And make it easy to clean.

Over two thirds of dust in houses originates outdoors, and is tracked in on feet. House dust is known to contain many hazardous materials. House dust is an asthma trigger.

Entry Control

Pave exterior walks. Use exterior grate track off, interior carpet mat and hard surface floors. Design entries so that there is room to remove and store coats, shoes and boots.

Use a three part track-off approach:

1. Permeable, rugged outdoor mat that collects gritty materials (or a grate over a collection hole is an alternative approach);
2. Rugged indoor mat that collects grit and water and;
3. A hard surface, easily mopped floor to collect very fine particles left by drying foot prints.

Lead Dust Control

Homes built before 1978 may contain lead-based paint. Renovation jobs that cut, saw, demolish or sand paint may create lead hazards. Lead may damage the nervous system causing learning and behavior problems. To minimize the risk of creating dust, follow the steps described in the Lead Paint Safety Field Guide which can be obtained from www.hud.gov/offices/lead. This website also contains information about the Lead-Based Paint Disclosure and Lead-Safe Housing regulations.

Cleanable Surfaces

Whenever possible, replace carpets with smooth flooring which is easy to clean and less likely to retain dust. Use window treatments such as blinds or shades that can be easily wiped. Use hard surfaces rather than textiles. Use semi-gloss latex paints instead of flat or matte finishes. Such surfaces are easier to clean using mild soaps.

Filtration

Construct a tight building enclosure to keep out outside dust and provide filtration. Filters should be MERV 6 – 8 (35 percent or better ASHRAE dust spot efficiency).

Creatures

Infestations of cockroaches, dust mites, mice and rats can all cause allergic reactions. Even after the pests are gone, their skin, hair and feces can remain and can trigger allergic reactions.

Making a home pest-resistant produces a healthier home in two ways: it reduces exposure to allergens and asthma triggers released by the pests, and it can reduce the amount of pesticides used by the occupants.

Design and construct the building so it's easy for people to keep pests from colonizing. Take the following steps:

- Make it hard for them to get in by sealing the walls, ceilings, roofs and foundations
- If they do get in, make it hard for them to move around unseen by sealing passages through interior floors, walls and ceilings, kick spaces
- Make it hard for them to find water by: keeping liquid water out, making plumbing easy to inspect and repair, and insulating plumbing pipes to keep them warm (above dewpoint temperatures)
- Make it hard for them to find food using tight food storage, by keeping paper and wood products away from potential moisture sources, and by using pest-resistant materials
- Make directed use of low toxicity pesticides in locations that are heavily infested with problem creatures.

To Know the Critter is to Control The Critter

To actually do the things on the list, you must know the creature. The simplest, safest and most elegant controls are those that work with the creature's natural urges. Creatures that get eaten a lot don't like open spaces. Give them open spaces. No closed-in kick spaces, strips around buildings free of shrubs and organic mulch. Seal around pipes and wires to keep them out of walls.

Keeping Them Out

Keep them out by changing the surrounding landscape and by blocking pest entries and passages. Reduce food and water availability.

Keep bushes and trees at least 3 feet from homes. Bushes and trees near a home provide food, a living place and sheltered passage for pests such as rats, mice, bats, birds, roaches and ants.

Seal utility openings and joints between materials. Use corrosion-proof materials such as copper or stainless steel mesh. Rodents can chew through many materials and squeeze through tiny openings.

Reducing Food and Water

Provide places to store food that are dry and ventilated. Provide a place to store trash and to facilitate recycling.

Design and construct the home to be dry and to dry if and when it gets wet. Absolutely no installed carpet in areas prone to get wet: bathrooms, laundry rooms, kitchens, entryways and damp basements.

In the Northeast, dust mites do not generally colonize buildings because buildings are too dry for much of the year. They colonize bedding, stuffed animals and favorite chairs because we humidify these things with our bodies. Control is by washing these items in hot water (greater than 130° Fahrenheit), which kills the mites and washes away allergens.

Pesticides

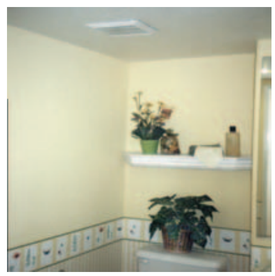
In the design and construction of new buildings, pesticides have a very limited and targeted role to play. In a neighborhood infested with a difficult species, like roaches or termites, use a limited amount of low toxicity pesticide in targeted locations. In high risk termite areas, exclusion and inspection detailing — plus a combination of treated wooden materials and soil treatment — is useful. For roaches, dusting with boric acid in areas that would be hard to treat later is an effective, low risk strategy. For example, dust with boric acid inside the kick space beneath sink, then seal the kick space as completely as possible.

To assess risk factors associated with a pesticide, look at:

- Registration, classification, use, mode of action
- Specificity, effectiveness, repellency
- Toxicity to humans
- Cautions on label
- Toxicity in the environment
- Resistant populations

Look especially for products like insect growth hormone regulators, which are species-specific, effective and have low toxicity for the applicators, occupants and the environment.

Don't spray pesticides; apply them directly to surfaces to be treated.



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