Combustion Safety

Gas- or oil-fired appliances, such as furnaces, water heaters, or boilers, need combustion air. Without sufficient combustion air, the appliance can produce carbon monoxide or fail to draft properly. Advanced Energy has documented numerous cases in which combustion equipment in wall-vented crawl spaces

1. did not have sufficient combustion air volume or openings to the outside per mechanical code requirements,

2. generated unacceptably high levels of carbon monoxide, or

3. did not draft acceptably due to air pressures created by duct leakage or stack effect.

A properly air-sealed closed crawl space is much tighter than a wall vented crawl space and can even be tighter than the house above. As a result, Advanced Energy recommends that:

✚ ***Atmospheric or "natural" draft appliances should not be installed in a closed crawl space.***

✔ Fuel-burning appliances located in a closed crawl space shall obtain combustion air from outdoors per the North Carolina Mechanical Code. Note that the use of passive combustion air openings is not acceptable because it violates the air-sealing requirements for the perimeter wall around and the floor above the closed crawl space.

✚ Specify direct-vent ("two-pipe") models to ensure adequate combustion air when fuel-fired appliances are used. All air for combustion should be piped directly from outside into the appliance and all combustion exhaust gases should be piped directly from the appliance to outside. Some manufacturers have separate cabinets or enclosures that can be used to convert non-direct-vent appliances to direct-vent operation.

The two large PVC pipes entering this direct-vent furnace bring combustion air from outside and take exhaust gases to outside to ensure that the furnace will not backdraft or burn inefficiently in the presence of negative building pressures.
Photo credit: Bill Warren.

General Combustion Safety

Regardless of whether or not a home has a closed crawl space foundation, combustion safety is a serious issue. Over 200 people die every year in the U.S. from carbon monoxide (CO) poisoning due to faulty combustion appliances in the home. Thousands of people require emergency room treatment for exposure to high levels of CO, and researchers are still working to understand the potentially serious effects of chronic low-level exposure to CO.

✚ Advanced Energy recommends the use of carbon monoxide low-level monitors or alarms in any home (including homes with slab or basement foundations) that has an attached garage or any fuel-fired cook stove, furnace, boiler, water heater, fireplace, or other appliance.

★ For additional protection, consider using a fuel-gas alarm when there are gas-fired appliances or gas lines in a home. These alarms can detect leaks of propane or natural gas and alert occupants to the problem.

Thermal Insulation

The North Carolina residential code allows insulation in a closed crawl space to be located at the sub-floor or at the perimeter wall. This conflicts with the 2004 Supplement to the International Residential Code, which requires insulation in an "unvented" crawl space to be located at the perimeter wall only. The research results in Section 6 showed that closed crawl spaces with either floor or wall insulation similarly outperform wall-vented crawl spaces with floor insulation in central North Carolina.

✔ Perimeter wall insulation may be located on any combination of the interior surface, exterior surface or inside of the perimeter wall, or the perimeter wall itself may provide the required R-value.

✔ If the perimeter wall is insulated, then insulation must be installed on the band joist. See "Pest Control" above for notes on options for band joist insulation.

✔ Perimeter walls that are partially masonry and partially wood framed (the wood framed portion is commonly referred to as a "pony wall") do not require insulation on masonry wall heights of 9 inches or less.

✚ Use non-porous insulation (for example, a closed-cell foam insulation) if the inside of the perimeter wall is insulated. This reduces the risk of contamination or other damage to the insulation if there is a water leak or flood.

✚ Install insulation at the sub-floor without gaps or compression and in full contact with the sub-floor to achieve the nominal R-value. Insulating open-web floor truss systems with batt insulation is discouraged due to the difficulty in insulating the openings in the truss structure. Better options for insulating open-web floor truss systems include using spray foam or netting the bottom of the trusses and completely filling the cavity with blown insulation. These strategies would likely also improve insulation performance in wooden I-beam floor structures.

Fire Safety

A key element in residential fire safety is fireblocking between different levels in a home. Fireblocking requirements already exist in the residential building code, but allow the use of porous materials like fiberglass or rock wool insulation. North Carolina has improved these requirements to require the use of non-porous materials for fireblocking in crawl spaces.

Foam plastic insulation receives special scrutiny in residential building codes because some foam insulations have the potential to release toxic or flammable gases when heated, or they can accelerate the spread of a fire if they ignite. To reduce these risks, most codes require a thermal barrier (typically 1/2 inch [13 mm] gypsum board or equivalent) or an ignition barrier (typically 3/8 inch [10 mm] gypsum board or equivalent) over foam insulation. However, several foam insulation products have been designed and tested to reduce or eliminate those risks. Such products can be installed without a thermal barrier or ignition barrier with the appropriate documentation.

✔ Seal all plumbing, electrical, duct, plenum, gas line and other wiring penetrations through the subfloor with non-porous materials. Rock wool or fiberglass insulation alone is not sufficient.

✔ Provide documentation of product fire-ratings (in the International Code Council National Evaluation Report (ICC NER) for the product) to allow installation of exposed foam insulation without a thermal barrier or an ignition barrier, if applicable

✔ Provide documentation of fire-rating to allow installation of exposed facing materials on batt insulation in the band joist or pony walls, if applicable

✚ Do not use a crawl space to store gasoline, solvents, or any tools or materials that present a fire hazard.

Radon Safety

Radon is an odorless, colorless gas that is the second most common cause of lung cancer in the United States, resulting in over 20,000 deaths per year. An estimated 1 in 15 U.S. homes has a high level of radon. For these reasons, the U.S. Surgeon General and the Environmental Protection Agency (EPA) recommend that all homes be tested for radon.

For jurisdictions where radon-resistant construction is required, radon control methods are specified in Appendix F of the International Residential Code. Table AF101(1) lists the counties identified by the Environmental Protection Agency (EPA) as High Radon Potential (Zone 1) counties. The High Radon Potential designation indicates areas with expected radon concentrations of 4 pCi/L (picocuries per liter) or greater, where it is likely that radon-resistant construction will be required.

The EPA recommends that all homes with radon concentrations of 4 pCi/L and greater be mitigated. The EPA also recommends that the county listing be supplemented with other available state and local data, for example, data from state radon offices, public health agencies or cooperative extension services, to further understand the radon potential of Zone 1 areas.

When radon mitigation is required, the requirements for floor sealing, duct sealing, ground vapor retarder, access door air sealing, and damp proofing of a closed crawl space system are compatible with the requirements of Appendix F. Sub-slab or sub-membrane depressurization systems may be utilized in a closed crawl space in the same manner as in a slab, basement or wall-vented crawl space foundation. Local jurisdictions may require additional measures for the ground substrate, foundation wall, concrete joints, condensate drains, or sump pits in wall-vented or closed crawl spaces.

Summary

The dozens of individual components that make up a complete and effective closed crawl space system fall into six general categories of function:

- Moisture management
- Pest control
- Combustion safety
- Thermal insulation
- Fire safety
- Radon safety

You might be wondering “Do I really need to follow all of the recommendations in this section to have a closed crawl space that works?” The short answer is “no.” There are other designs that will perform successfully. The key for acceptable moisture management is that the rate of moisture removal from the crawl space must be at least as much as the rate of moisture entry. So for example, if you choose not to install a wall vapor retarder, then you need to ensure that the drying mechanism you install is sufficient to provide the desired moisture management despite the extra moisture load of the exposed perimeter walls. This may require a trial and error approach since there are no readily available tools to accurately predict such moisture loads and size the drying mechanism.

Altogether, these recommendations represent closed crawl space components that have proven their performance in real-world field tests. They perform as a system, and although it’s obvious that some components, like preventing water intrusion, are critical, we have not experimented to determine which of the other components could be sacrificed without compromising the system as a whole.

It is important to keep in mind that these sample design elements were tested in small homes with very simple foundation plans. To ensure success, builders of the more complex homes typically found in mainstream residential construction will likely need to adjust the designs to accommodate local site conditions, code requirements, home design, construction processes and occupant needs.

Section 2

Implementing a Closed Crawl Space

Overview

It would be wonderful if simply having a good design guaranteed a closed crawl space that controls moisture and saves energy. But in the real world the end result also depends on the materials, process and workmanship that put the good design into practice.

There is no trade association or industry-accepted set of standards for implementing closed crawl space systems beyond the requirements of the residential building code. The residential building code specifies minimum requirements for what must be done, not necessarily the process for how it must be done. Therefore, the implementation guidelines Advanced Energy recommends in this section are not legal requirements, but are likely to be critical to the successful implementation of a closed crawl space.

Property owners, general contractors, or others can adapt the design and implementation recommendations in this guide to their specific circumstances to create a closed crawl space or they can seek a professional installer to do the work. In some regions, owners and builders may have to do the work themselves due to a lack of local experienced installers.

Advanced Energy divides implementation guidelines into six broad topics:

- Defining the design
- Working with code officials
- Overcoming conventional wisdom
- Managing labor
- Managing job site logistics
- Quality assurance

A seventh topic applies when you hire an installer:

- Establishing a clear contract and pricing.

Defining the Design

You or your installer may prefer one closed crawl space design to others, but should also be able to customize the choice of materials or drying mechanism to suit the needs of the house design or local residential code requirements. Factors like site conditions,

Finding a Quality Installer

More and more businesses are offering the service of closing crawl spaces. Currently, you could purchase a closed crawl space in central North Carolina from:

- Home performance contractors
- Pest management contractors
- General contractors
- Professional engineers
- Mechanical (HVAC) contractors
- Insulation contractors
- Foundation repair/waterproofing contractors

Although hiring an installer to provide a closed crawl space may be more expensive up front than doing it yourself, the knowledge and experience of a quality installer can be well worth the additional expense.

Finding a quality installer typically requires identifying providers of closed crawl spaces in your area and then getting proposals from several providers for the specific job at hand to make an apples-to-apples comparison. Ideally you would look at previous work and talk with previous clients to assess the provider's performance. Assess the knowledge, experience and integrity of the provider with regard to the seven implementation topics described in this section. The potential benefits and risks of installing a closed crawl space demand that the work is performed the right way at the right time. Advanced Energy recommends that you think of the closed crawl space installer as a partner in moisture management, not as just another "sub" on the project.

occupant requirements, or cost will also influence the design. For example, a homeowner with severe allergies may choose a dehumidifier to dry the crawl space instead of a supply air strategy. A home on a steeply sloped site may require such a large amount of wall insulation that it is financially advantageous to use a floor-insulated design.

Working with Code Officials

You or your installer will need to work with your local code officials to ensure that your closed crawl space design is acceptable and either meets or exceeds all code requirements. Coming to agreement early and avoiding surprises during construction are key strategies for preventing any delay in the issuance of a certificate of occupancy at the end of construction. In some cases, local code officials may require or accept a stamped letter of approval from a registered professional engineer as an alternate path for permitting and inspection.

Note that software programs for energy analysis may not accurately predict the energy savings associated with a closed crawl space. If the home is required to meet a particular Model Energy Code or International Energy Conservation Code standard, the software might require additional efficiency measures in the house. Arguably, these measures are not necessary and this may require negotiation to avoid installing the additional efficiency measures.

If you are hiring an installer, ask candidates how they ensure acceptance of their work by code officials.

Overcoming Conventional Wisdom

At some point in the process, you or your installer may need to overcome the conventional wisdom of construction professionals who still believe that crawl spaces need ventilation with outside air, or who do not recognize the potential risks of wall-vented crawl spaces. For example, a pest management professional may refuse to treat or provide a warranty on a home with a closed crawl space. In some cases you may be able to use the information in this guide or other resources to convince the professional of the acceptability and benefits of closed crawl spaces, but in other cases you may need to switch to another service provider to keep the project on schedule.

Managing Labor

You or your installer need to ensure that employees are trained in the use of the materials and processes required to install a closed crawl space system. Naturally, crawl space work is difficult due to the confined nature of the space. It may also present respiratory hazards. Advanced Energy has not tested mold levels in new closed crawl spaces during construction, but given the high levels of airborne mold spores measured in our crawl space research projects whenever settled dust is disturbed in finished crawl spaces, Advanced Energy recommends that workers wear respiratory protection in both new and existing crawl spaces. We recommend combined High-Efficiency Particulate Arrestance (HEPA) and activated carbon filters at a minimum. Those with beards should consider using full-face powered air-purifying respirators. Workers may need to be tested for respirator fit and lung function according to applicable Occupational Safety and Health Administration (OSHA) regulations.

Managing Job-Site Logistics

You or your installer will need a process for coordinating with the other building trades to ensure proper scheduling and to reduce the risk of damage to the closed crawl space system during construction or after the house is turned over to a customer. Contractors you may need to coordinate with include the:

- Site grading and preparation contractor
- Foundation or masonry contractor

- Pest management company
- Framer
- Plumber
- Electrician
- Insulator
- Mechanical contractor
- Gutter installation contractor
- Landscaping and/or irrigation contractors
- Cable TV, security system, or computer network wiring contractors

In particular, you or your installer must coordinate as soon as possible with the pest management professional to ensure that the closed crawl space system does not interfere with their treatment or affect their warranty, if applicable. For properties under a service contract or warranty, the pest management contractor may be held responsible for any and all damage that occurs to the property after the date of their treatment. This discourages them from contracting on properties with hidden or obstructed areas. In new construction projects, pest management contractors may be reluctant to provide soil pre-treatment, wood pre-treatment, or an alternative pre-construction treatment unless they have sufficient information about the closed crawl space design to believe that they will have adequate access for the pre-treatment or for future inspections or treatments.

Managing moisture during the process of construction is critical, because all crawl spaces, including closed crawl spaces, can become ideal environments for growing mold as soon as the sub-flooring is installed. Mold can grow on all surfaces in the crawl space, but it is most readily noticed when it grows on the wood framing or subfloor. When excess humidity drives up the wood moisture content to 19% or more, conditions are right for surface mold to appear. In some cases, dramatic mold blooms can grow in as little as 48 hours. Seeing surface mold on the crawl space wood in the past was seldom an issue with homebuyers, but now public concerns about mold can slow or prevent a home sale. Mortgage providers may even require a mold test prior to a home purchase.

Often, the processing, transport and job-site storage of wood framing and subfloor materials exposes them to rain for long periods of time. The materials may arrive on the job site already contaminated with mold growth or wet enough to foster germination of the mold spores that they will inevitably be exposed to. Using wet moldy lumber defeats the purpose of any recommended moisture management practices.

Beware of Long Construction Schedules

Volunteer-built homes and large homes, particularly large custom homes, often have long construction periods before they are dried in. This makes it even more likely that the crawl space will be wet before the house is dried in. Building over long time periods requires a process that includes early rain water management, ground cover and dehumidification to successfully avoid mold contamination.

Another strategy could be to build such homes with a temporary ground vapor retarder and foundation vents and leave the vents open prior to dry-in, at which time you could begin the conversion to a closed crawl space. This approach might provide enough drying potential to avoid mold growth during the dry times of the year or in dry climates, but likely won't when construction occurs primarily in spring or summer.

In some cases, the only feasible strategy for implementing a closed crawl space may be to just build the house with a traditional wall-vented crawl space, and either perform some mold control or cleanup activities during construction, or to wait until the house is complete and then convert the wall-vented crawl space to a closed crawl space, with any desired cleanup. . In these cases, it may be possible to suppress mold growth in the floor structure prior to the crawl space being closed by using pre-treated wood products or applying fungicidal coatings to untreated wood products.

If feasible, provide a waterproof covering, secured to resist wind damage, to prevent rain from entering the crawl space when construction will stop for a prolonged period. In such cases, a dehumidifier may also be needed to prevent mold growth.

Even when you install dry materials, once the subfloor is installed the crawl space becomes an enclosed space that can trap moisture. The subfloor prevents excess water from drying with sunlight, and there is much less potential for liquid water or water vapor to leave the space. The crawl space is vulnerable to major rain or snow entry until the house is dried-in by installing the roof, wall sheathing, windows, and exterior doors.

The sample implementation process listed in Section 3 includes steps designed to prevent moisture problems during the construction process.

Providing Quality Assurance

Quality builders and installers care about the long-term performance of their closed crawl space system and will usually offer one or more of the following quality assurance options:

- A monitoring system to inform the homeowner of relative humidity levels in the crawl space
- A water alarm to inform the homeowner of a buildup of liquid water in the crawl space
- A posted sign or signs identifying the different components of the system and informing anyone entering the crawl space of the importance of maintaining the integrity of the system.
- A repair kit for fixing small areas of damage to the liner after the house is occupied
- An annual monitoring service to replace batteries in monitoring systems and check that the crawl space system is in good working order. This may include measurements of wood moisture content or air tightness, or a download and analysis of data logging equipment
- A guarantee or warranty that relative humidity will be maintained below an agreed-upon target (for example, a guarantee for relative humidity not to exceed 70% at a specified monitoring point for more than 7 consecutive days) with exceptions for water leaks or intrusion outside the installer's control

Basic Maintenance for Crawl Spaces

Most people don't like to go into crawl spaces, but periodic inspection of any crawl space helps to ensure that any problems are caught before they cause damage. Property owners can perform these inspections and basic maintenance checks themselves or hire a private home inspector or other contractor to do it for them.

Property owners should:

- Ensure that access doors are closed, especially during warm weather.
- Ensure that drains or sump pumps are functioning properly
- Ensure that dehumidifiers are maintained per the manufacturer's instructions and are in proper working order
- Ensure that there are no solvents, gasoline or other potentially hazardous materials in the crawl space.
- Inspect the crawl space regularly to:
  - ❍ Identify vapor retarder damage or water problems. Note that small water leaks in a crawl space may not be indicated by relative humidity sensors.
  - ❍ Ensure that no damage occurs when any contractors work in the crawl space.
  - ❍ Check and replace batteries as needed in sensors or alarms.
- Ensure that any water intrusion, especially flooding, is quickly drained or pumped out of the crawl space.

One of these items doesn't belong in a crawl space…
Photo credit: Indoor Environmental Systems.

- A guarantee or warranty against growth of visible mold for a specified period of time, with exceptions for water leaks or intrusion outside the installer's control
- References for quality assurance inspections by independent third parties
- Guidelines for basic maintenance of the crawl space system (see sidebar on page 22)

Establishing a Contract and Pricing

If you choose to hire an installer to implement a closed crawl space, the installer should have a contract or plan that clearly spells out what they are responsible for, and what the builder or other contractors are responsible for. Responsibilities for other contractors might include foundation waterproofing, foundation drains, grading, and/or installation of the drying mechanism if it requires a licensed electrician or mechanical contractor and the crawl space installer is not licensed.

Contracts may also specify financial incentives or penalties geared towards ensuring an efficient installation. For example, there may be a trip charge assessed when the builder calls the installer to the site but has not completed the work necessary for the installer to proceed, or a back charge assessed if the builder or other trades damage the crawl space system to the point that it requires repair or replacement of any component.

Currently in North Carolina, pricing from contractors providing closed crawl space systems to general contractors for new construction ranges from $1.00 to $3.50 per square foot of crawl space floor area for a variety of installations. Some factors that affect pricing are the number of piers in a crawl space, height above or below grade, height of perimeter walls, or the complexity of the foundation footprint. These sample installation costs do not take into account the cost reductions that the builder may realize from not having to install features like insulation or drainage, since they may be included in the pricing of the closed crawl space system.

Initial costs associated with building closed crawl spaces will generally be more than for traditional wall vented construction. As new construction methods are evaluated both by builders and researchers, it will be important to factor in the value of reduced callbacks due to moisture and mold issues, the perception of enhanced value by the consumer, and potential for increased sales price and reduced legal exposure. Reduced maintenance, a reduction in costly, long-term repairs, and significant energy savings enhance the value of closed crawl space construction to the consumer, appraisers and realtors. The future might even include insurance premium reductions for houses built on closed crawl spaces.

Summary

Successful implementation, whether by a property owner, builder, or professional closed crawl space installer, must address six main topics:

- Defining the design of the closed crawl space
- Working with code officials to ensure acceptance of the design
- Overcoming the conventional wisdom that favors venting with outside air
- Managing labor, including training and safety
- Managing job site logistics, especially moisture management and coordination with other trades
- Providing quality assurance

Finally, if you hire a professional installer, make sure to establish a well-defined plan and a contract that clearly specifies responsibilities and pricing.

Closed Crawl Spaces

Section 3

Sample Designs and Construction Process

Overview

Advanced Energy has field tested several closed crawl space designs. This section contains drawings for the designs that proved effective for moisture control and that meet the minimum requirements of the North Carolina residential building code described in Section 4. The numbered callouts refer to notes for each of the specific components in the drawing. This section also includes background information, advantages and disadvantages for the two humidity control strategies used in the sample designs, as well as a sample construction sequence based on processes Advanced Energy uses to have closed crawl spaces built in occupied homes for field research projects.

The designs presented here are not the only closed crawl space designs that are acceptable. They are simply examples that performed successfully in the field testing detailed in Section 6. These designs have been utilized in other Advanced Energy research projects and by professional installers in a variety of locations in North Carolina. There are many other designs that can perform acceptably and that meet the requirements of the North Carolina residential building code.

The sample designs and process presented here are not definitive specifications. If you are a builder, property owner, or other contractor planning to install closed crawl spaces, you will need to adjust these designs and processes to your local site conditions, code requirements, home design, construction processes and occupant needs to ensure success.

Recommended Humidity Control Methods

Some installers and researchers have theorized that the moisture control improvements of closed crawl spaces allow the mechanical contractor to down-size heating and cooling equipment. However, there are few commonly available tools at the time of this writing to calculate the impact of a closed crawl space on the sizing of mechanical equipment for the home, and Advanced Energy research projects have not investigated this aspect of performance.

Recommendation 1

Control humidity in the closed crawl space with dry air from the supply-side ductwork of the house air-conditioning system. Provide a backflow damper (for example, a gravity-operated butterfly damper) and either a balancing damper or constant airflow regulator to provide nominal airflow of 1 cubic foot per minute (0.5 liters per second) per 30 square feet (4.6 square meters). Traditional balancing dampers are adjustable over a range of flows. Constant airflow regulators provide a calibrated amount of flow without any need for adjustment. Multiple supply vents may be used to achieve the desired airflow and/or desired distribution of air. If necessary, adjust the airflow to control relative humidity in the crawl space to the desired level, typically 70% relative humidity or lower. Flow can be measured with a simple bag-fill method (for an example, see the Resources and References section under Canada Mortgage and Housing Corporation) an anemometer/digital air flow meter, a powered flow hood, or a passive flow hood. No return air vent is allowed with this method.

Metal strapping holds this 4 inch (102 mm) diameter supply duct horizontal to ensure proper operation of the butterfly backdraft damper. The balancing damper is visible behind the butterfly damper. The connection to the supply trunk duct is sealed with mastic.

This 4 inch (102 mm) diameter constant airflow regulator (CAR) uses a pressure-modulated, flexible bladder to deliver a constant rate of airflow over a wide range of duct system pressures. The model shown delivers 30 cubic feet per minute (15 liters per second). Operation is completely passive, with no electronic controls.

Advantages

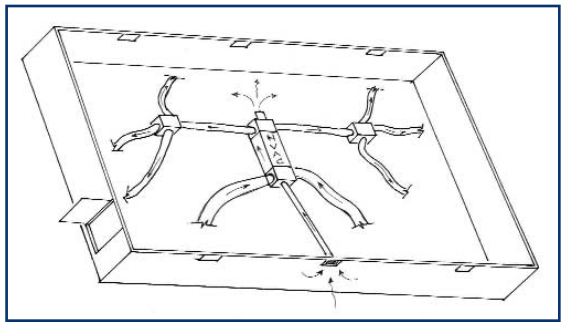
This system is inexpensive, simple to install, fully adjustable, and has no need for maintenance beyond a periodic inspection. It is unlikely to be affected by the operation of other exhaust fans in the house, including large exhausts like clothes dryers. If the central air conditioner fails, the homeowner is likely to repair it, thus guaranteeing operation of the drying mechanism for the closed crawl space. The lack of return duct or passive transfer grill from the crawl space to the house reduces the chance that the crawl space will affect the indoor air quality of the living space above.

Disadvantages

Relative humidity control appears to be less effective in the spring and fall when air-conditioner use is lower. If the air conditioner is not providing adequate dehumidification for the living space, then it may not provide adequate dehumidification for the crawl space. Over-sizing the air conditioner or setting the system fan to run after the air conditioner compressor has stopped are bad strategies because they can reduce the air conditioner's ability to dehumidify. Occupants can prevent the air conditioner from controlling humidity by generating excessive humidity in the house, choosing not to run the air conditioner, running the air handler fan continuously, and/or keeping windows and doors open to outside during humid weather. The lack of return duct or passive transfer grill from the crawl space to the house does not meet the requirements for an "unvented" crawl space specified in the 2004 Supplement to the International Codes. See Section 4 for more details.

What about Pressure Effects?

Theoretically, in a very tightly air-sealed house, operating the supply duct to the closed crawl space with no return to the house could create a small negative pressure in the house with reference to outside or to the crawl space. Some of the air supplied to the crawl space might then return to the living space. In Advanced Energy field tests, the small crawl space airflow causes a negligible pressure effect that is far exceeded by the effects of duct leakage, stack pressure or wind-induced pressures in the building. Sealing floor penetrations reduces the risk of crawl space air entering the living space. To help eliminate the possibility of negative pressure, an outside air intake can be properly sized and installed in the return side of the HVAC duct system. In such a system, the ventilation air slightly pressurizes the living space and then exits through the building envelope. The crawl space supply makes use of some of the exiting



Schematic representation of crawl space duct system with integrated outside air intake and crawl space supply duct. Drawing provided by Indoor Environmental Systems, ©2005.

This outside air intake replaces a standard-size concrete masonry unit (CMU) block or foundation vent and houses a washable filter.
Photo credit: Indoor Environmental Systems.

ventilation air by using it to dry the crawl space before it leaves the building. Section 6 has details on how this system was implemented in Advanced Energy's Princeville research project.

Recommendation 2

Control water vapor in the crawl space with one or more permanently installed dehumidifiers, each with a minimum 15 pint-per-day capacity. Adjust as needed to control relative humidity in the crawl space to desired level, typically 70% or lower. Pipe condensate per local code requirement to outdoors or to an interior pump that discharges to outdoors. Provide a dedicated, non-switched, GFCI-protected electrical outlet for the dehumidifier.

Advantages

Dehumidifiers are capable of rapidly removing large amounts of water vapor and are independent of the house conditioning system. They can maintain lower relative humidity levels than air conditioning equipment. Low-profile or horizontal-mount units are available to accommodate short crawl spaces.

Disadvantages

Dehumidifiers require periodic maintenance and may not be noticed when they fail. Some units must be re-activated manually after power outages. High-quality models can be expensive. Condensate drains require periodic inspection and, if they fail, can allow liquid water in the crawl space. There is currently no standard protocol for calculating the required dehumidifier capacity; manufacturers provide general sizing guidelines. Dehumidifier capacity decreases as ambient temperature decreases, so performance must be verified if dehumidification is needed in the winter months.

Sample Design: Supply Air and Floor Insulation

1. Seal exterior wall penetrations and mating surfaces at top and bottom of sill plate and at top and bottom of band joist. Crawl space access panel(s) or door(s) must be air-sealed.

2. No open foundation vents are allowed in exterior walls. Openings to ventilated porch foundations must be air-sealed with an access panel or permanent materials. Install flood vents per local residential code where required.

3. Slope finished grade away from building per local residential code or for 6 in. drop over 10 ft. Provide a method to transport roof runoff away from the house. Gutters and downspouts are one such method.

4. Dampproof or waterproof the exterior wall surface when the crawl space floor is below exterior grade.

5. It is not necessary to provide a capillary break (mortar admixture or physical barrier) between the footings and foundation walls or interior columns, but this may provide additional moisture control.

6. Provide foundation drain to daylight per local residential code requirements.

7. Seal all plumbing, electrical, duct, cable, and other penetrations through the sub-floor with fire-stop materials and sealants. Fiberglass or rock wool insulation alone are not sufficient.

8. Insulate floor joist cavities. Place insulation in full contact with the sub-floor and ensure that it is secured in place. Use R-value required by local residential code.

9. Leave a minimum 3″ termite inspection gap between the top of the wall vapor retarder and the top of the masonry wall. Seal the top of the vapor retarder to the wall with duct mastic or equivalent sealant. Optionally, apply a light colored paint or coating over the inspection gap to improve inspectability by pest control professionals.

10. Air seal all heating and cooling ductwork with a duct mastic system. Install all ductwork located in the crawl space with R-value per local code requirement.

11. Control moisture vapor in the crawl space with supply air from the house air-conditioning system. Set supply air volume per local residential code requirement. Adjust as needed to control relative humidity in crawl space to desired level. Provide a backflow damper and either a balancing damper or constant airflow regulator to control airflow. Multiple supply vents may be used to achieve the desired airflow and/or desired distribution of air. No return air vent is allowed in the crawl space.

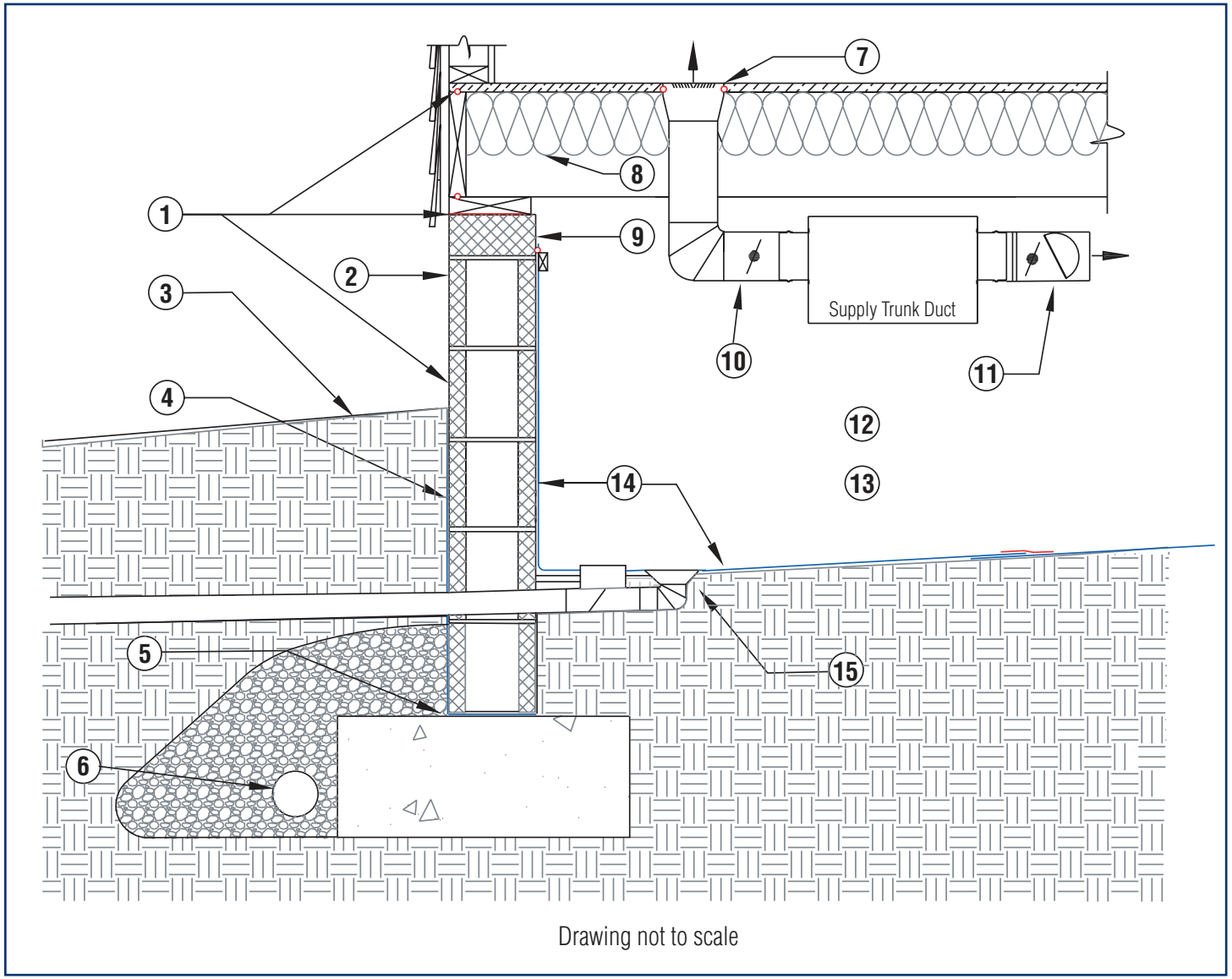
12. Terminate water heater drains, temperature/pressure relief pipes, and A/C condensate drains to outdoors or to an interior pump that discharges to outdoors. Terminate all kitchen, bathroom and clothes dryer vents to outdoors.

13. Any fuel-fired furnaces, water heaters, or other appliance in a closed crawl space should be of a “direct vent” or “two-pipe” design, meaning that all air for combustion is piped directly from outside to the appliance and all combustion exhaust gases are piped directly from the appliance to outside.

14. Cover 100% of the crawl space floor with a minimum 6-mil vapor retarder. Mechanically fasten and seal the vapor retarder material to the inside wall surfaces, leaving the required termite inspection gap at the top of the wall. Extend the vapor retarder up the interior columns at least 4 inches above the crawl space floor. Seal all seams and edges with fiberglass mesh tape and duct mastic or equivalent. Mechanically secure the ground vapor retarder as necessary.

15. Grade the crawl space floor to one or more low points. Provide crawl space drain(s) or sump pump(s) at lowest point(s). Slope drains to daylight and include an accessible backflow valve and 1/4-inch rodent screening. Gutter drains and foundation drains (interior or exterior) must not be connected to the crawl space drain.

Advanced Energy Sample Design: A Closed Crawl Space With Supply Air and Floor Insulation



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Sample Design: Supply Air and Wall Insulation

1. Seal exterior wall penetrations and mating surfaces at top and bottom of sill plate and at top and bottom of band joist. Crawl space access panel(s) or door(s) must be air-sealed.

2. No open foundation vents are allowed in exterior walls. Openings to ventilated porch foundations must be air-sealed with an access panel or permanent materials. Install flood vents per local residential code where required.

3. Slope finished grade away from building per local residential code or for 6 in. drop over 10 ft. Provide a method to transport roof runoff away from the house. Gutters and downspouts are one such method.

4. Dampproof or waterproof the exterior wall surface when the crawl space floor is below exterior grade.

5. It is not necessary to provide a capillary break (mortar admixture or physical barrier) between the footings and foundation walls or interior columns, but this may provide additional moisture control.

6. Provide foundation drain to daylight per local residential code requirements.

7. Seal all plumbing, electrical, duct, cable, and other penetrations through the sub-floor with fire-stop materials and sealants. Fiberglass or rock wool insulation alone are not sufficient.

8. Insulate the crawl space wall over the wall vapor retarder material with rigid foam or other non-porous insulation material. Leave a minimum 3″ termite inspection gap between the top of the wall insulation and the top of the masonry wall. Leave a minimum 3″ wicking gap between the bottom of the wall insulation and the crawl space floor surface. Obtain R-value from local residential code. Ensure that the insulation complies with local residential code requirements for installation without a thermal barrier or ignition barrier. Insulate the band joist with batt insulation to facilitate removal and reinsertion during pest control inspections. Ensure that batt facings comply with local fire requirements.

9. Leave a minimum 3″ termite inspection gap between the top of the wall vapor retarder and the top of the masonry wall. Seal the top of the vapor retarder to the wall with duct mastic or equivalent sealant. Optionally, apply a light colored paint or coating over the inspection gap to improve inspectability by pest control professionals.

10. Air seal all heating and cooling ductwork with a duct mastic system. Install all ductwork located in the crawl space with R-value per local code requirement.

11. Control moisture vapor in the crawl space with supply air from the house air-conditioning system. Set supply air volume per local residential code requirement. Adjust as needed to control relative humidity in crawl space to desired level. Provide a backflow damper and either a balancing damper or constant airflow regulator to control airflow. Multiple supply vents may be used to achieve the desired airflow and/or desired distribution of air. No return air vent is allowed in the crawl space.

12. Terminate water heater drains, temperature/pressure relief pipes, and A/C condensate drains to outdoors, or to an interior pump that discharges to outdoors. Terminate all kitchen, bathroom and clothes dryer vents to outdoors.

13. Any fuel-fired furnaces, water heaters, or other appliance in a closed crawl space should be of a “direct vent” or “two-pipe” design, meaning that all air for combustion is piped directly from outside to the appliance and all combustion exhaust gases are piped directly from the appliance to outside.

14. Cover 100% of the crawl space floor with a minimum 6-mil vapor retarder. Mechanically fasten and seal the vapor retarder material to the inside wall surfaces, leaving the required termite inspection gap at the top of the wall. Extend the vapor retarder up the interior columns at least 4 inches above the crawl space floor. Seal all seams and edges with fiberglass mesh tape and duct mastic or equivalent. Mechanically secure the ground vapor retarder as necessary.

15. Grade the crawl space floor to one or more low points. Provide crawl space drain(s) or sump pump(s) at lowest point(s). Slope drains to daylight and include an accessible backflow valve and 1/4-inch rodent screening. Gutter drains and foundation drains (interior or exterior) must not be connected to the crawl space drain.

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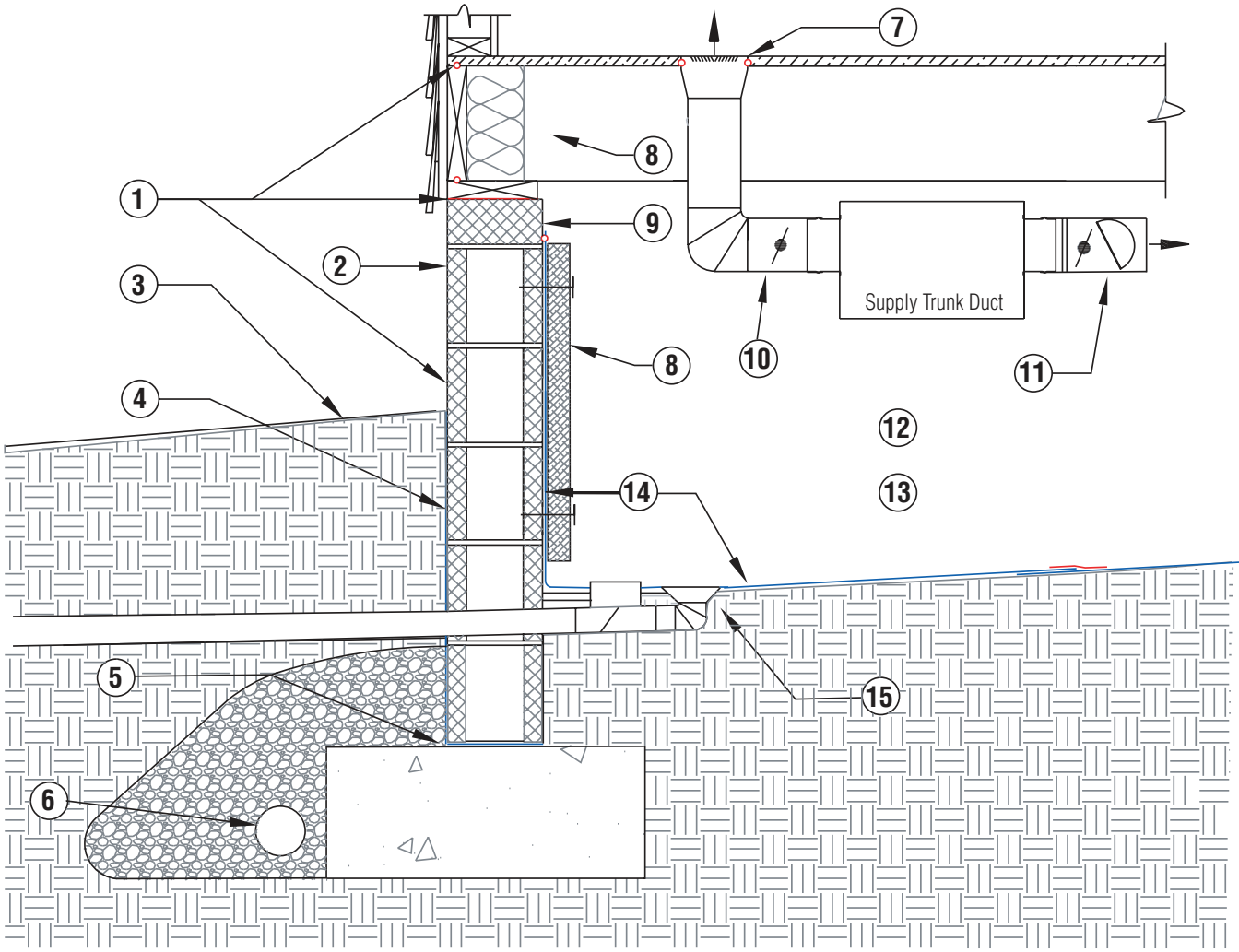

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Sample Design: Dehumidifier and Floor Insulation

1. Seal exterior wall penetrations and mating surfaces at top and bottom of sill plate and at top and bottom of band joist. Crawl space access panel(s) or door(s) must be air-sealed.

2. No open foundation vents are allowed in exterior walls. Openings to ventilated porch foundations must be air-sealed with an access panel or permanent materials. Install flood vents per local residential code where required.

3. Slope finished grade away from building per local residential code or for 6 in. drop over 10 ft. Provide a method to transport roof runoff away from the house. Gutters and downspouts are one such method.

4. Dampproof or waterproof the exterior wall surface when the crawl space floor is below exterior grade.

5. It is not necessary to provide a capillary break (mortar admixture or physical barrier) between the footings and foundation walls or interior columns, but this may provide additional moisture control.

6. Provide foundation drain to daylight per local residential code requirements.

7. Seal all plumbing, electrical, duct, cable, and other penetrations through the sub-floor with fire-stop materials and sealants. Fiberglass or rock wool insulation alone are not sufficient.

8. Insulate floor joist cavities. Place insulation in full contact with the sub-floor and ensure that it is secured in place. Use R-value required by local residential code.

9. Leave a minimum 3″ termite inspection gap between the top of the wall vapor retarder and the top of the masonry wall. Seal the top of the vapor retarder to the wall with duct mastic or equivalent sealant. Optionally, apply a light colored paint or coating over the inspection gap to improve inspectability by pest control professionals.

10. Air seal all heating and cooling ductwork with a duct mastic system. Install all ductwork located in the crawl space with R-value per local code requirement.

11. Control humidity in the crawl space with one or more permanently installed dehumidifiers, each with a minimum 15 pint-per-day capacity. Adjust as needed to control relative humidity in the crawl space to desired level. Pipe condensate per local code requirement to outdoors or to an interior pump that discharges to a drain or outdoors. Provide a dedicated, non-switched, GFCI-protected electrical outlet for the dehumidifier.

12. Terminate water heater drains, temperature/pressure relief pipes, and A/C condensate drains to outdoors or to an interior pump that discharges to outdoors. Terminate all kitchen, bathroom and clothes dryer vents to outdoors.

13. Any fuel-fired furnaces, water heaters, or other appliance in a closed crawl space should be of a “direct vent” or “two-pipe” design, meaning that all air for combustion is piped directly from outside to the appliance and all combustion exhaust gases are piped directly from the appliance to outside.

14. Cover 100% of the crawl space floor with a minimum 6-mil vapor retarder. Mechanically fasten and seal the vapor retarder material to the inside wall surfaces, leaving the required termite inspection gap at the top of the wall. Extend the vapor retarder up the interior columns at least 4 inches above the crawl space floor. Seal all seams and edges with fiberglass mesh tape and duct mastic or equivalent. Mechanically secure the ground vapor retarder as necessary.

15. Grade the crawl space floor to one or more low points. Provide crawl space drain(s) or sump pump(s) at lowest point(s). Slope drains to daylight and include an accessible backflow valve and 1/4-inch rodent screening. Gutter drains and foundation drains (interior or exterior) must not be connected to the crawl space drain.

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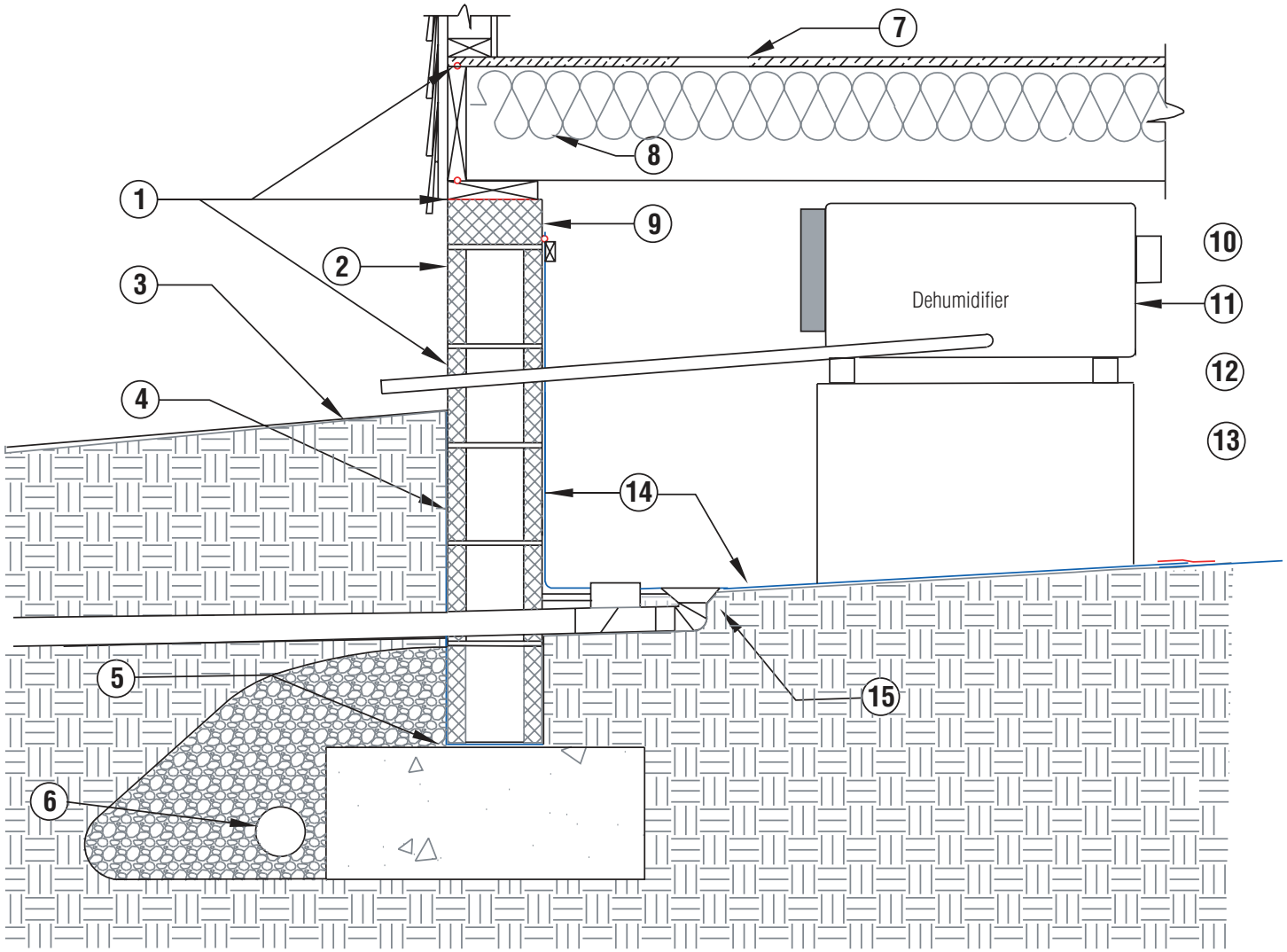

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4. Dampproof or waterproof the exterior wall surface when the crawl space floor is below exterior grade.

5. It is not necessary to provide a capillary break (mortar admixture or physical barrier) between the footings and foundation walls or interior columns, but this may provide additional moisture control.

6. Provide foundation drain to daylight per local residential code requirements.

7. Seal all plumbing, electrical, duct, cable, and other penetrations through the sub-floor with fire-stop materials and sealants. Fiberglass or rock wool insulation alone are not sufficient.

8. Insulate the crawl space wall over the wall vapor retarder material with rigid foam or other non-porous insulation material. Leave a minimum 3″ termite inspection gap between the top of the wall insulation and the top of the masonry wall. Leave a minimum 3″ wicking gap between the bottom of the wall insulation and the crawl space floor surface. Obtain R-value from local residential code. Ensure that the insulation complies with local residential code requirements for installation without a thermal barrier or ignition barrier. Insulate the band joist with batt insulation to facilitate removal and reinsertion during pest control inspections. Ensure that batt facings comply with local fire requirements.

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15. Grade the crawl space floor to one or more low points. Provide crawl space drain(s) or sump pump(s) at lowest point(s). Slope drains to daylight and include an accessible backflow valve and 1/4-inch rodent screening. Gutter drains and foundation drains (interior or exterior) must not be connected to the crawl space drain.