

Best Practices – Phase I

Sub-Structure Soil Depressurization System Summary

The house is under negative pressure, drawing in soil-gases, including water vapor, from the sub-slab area. No matter how well the {basement or crawlspace} floor is constructed, (adding capillary breaks, vapor barriers, properly mixed concrete) moisture and other soil-gases are still drawn into the house. The first thing the soil depressurization system does is reduce the suction on the sub-slab area just enough to limit the moisture drawn into the occupied space through the slab and its inevitable cracks. Sub-slab depressurization systems reverse the driving force caused by negative pressures at the bottom of buildings. The sub-slab area is then at a lower pressure than the inside of the basement. Once the negative pressure field under the slab is established, moisture can be controlled and directed out of the house rather than being drawn in. Active soil depressurization or active dampness control systems provide a flow-reversal of air at any slab openings {bypass} by use of a fan. This not only stops infiltration of saturated air but also introduces about 20cfm of much drier air under the basement floor. (HomeAire)

What about Radon? Should I test my home for radon?

Among soil-gases, radon is the only one for which testing is commonly done. Although it is possible to test a site for radon prior to construction, such testing is both expensive and not entirely reliable, because it can't predict how construction might affect the soils, or what pressures might draw radon into the building. For homes it usually makes more sense to install a passive stack and test after construction. If you have a test result of 4 pCi/L or more, a vent fan can easily be added to the passive system to make it an active system and further reduce radon levels. (EPA)

EPA recommends that all homes built in Zone 1 (high radon potential) areas have radon reduction systems. NAHB also recommends using the passive system in homes in high radon potential areas (Zone 1.) Zone 1 counties have a predicted average indoor screening level of 4.0 pCi/L or higher, Zone 2 counties have predicted levels between 2.0 and 4.0 pCi/L, and Zone 3 counties have predicted levels less than 2.0 pCi/L. Marion County, IN is classified as a Zone 1 high potential radon area. (EPA)

Every new home should be tested for radon after occupancy. Major renovations can change the level of radon in any home. Test again after the work is completed. Take two short-term passive tests at the same time in the same location for at least 48 hours, or take an initial short-term test for at least 48 hours. Immediately upon completing the first test, do a second test using an identical device in the same location as the first test. (EPA)

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Passive radon testing devices do not need power to function. These include **charcoal canisters**, **charcoal liquid scintillation devices**, (short-term tests, 2-90 days) and (long-term tests, more than 90 days) **electret ion chamber detectors**, and **alpha-track detectors** which are available in hardware, drug, and other stores; they can also be ordered by mail or phone. These devices are exposed to the air in the home for a specified period of time and then sent to a laboratory for analysis. Active radon testing devices require power to function. These include (short-term, test should be taken for at least 48 hours) **continuous radon monitors** and **continuous working level monitors**. Although these {active} tests may cost more, they may ensure a more reliable result. The test should include method(s) to prevent or detect interference with testing conditions or with the testing device itself. Be sure that you or the radon tester can demonstrate or provide information to ensure that the testing conditions were not violated during the testing period. (EPA)

EPA recommends that the test device(s) be placed in the lowest level of the home that could be used regularly, whether it is finished or unfinished. Conduct the test in any space that could be used by the buyer as a bedroom, play area, family room, den, exercise room, or workshop. Based on their client's intended use of the space, the qualified testing professional should identify the appropriate test location and inform their client (buyer). **Do not test in a closet, stairway, hallway, crawlspace, or in an enclosed area of high humidity or high air velocity. An enclosed area may include a kitchen, bathroom, laundry room or furnace room.** (EPA)

Your radon test results may be reported in either picocuries per liter of air (pCi/L) or working levels (WL). If your test result is in pCi/L, EPA recommends you fix your home if the radon level is 4 pCi/L or higher. If the test result is in WL, EPA recommends you fix the home if the working level is 0.016 WL or higher. Some states require WL results to be converted to pCi/L to minimize confusion. (EPA)

Why worry about other soil-gases, including water vapor?

Other soil-gases can pose health risks as significant as those associated with radon. Such gases include methane from decomposing organic matter or landfills, hydrocarbons from underground fuel spills, pesticides that have been used around buildings, other volatile organic compounds (VOCs), even water vapor. As we increasingly turn to already developed and brownfield sites for new building projects – a good thing to do from an environmental standpoint – addressing the non-radon soil-gases is a must. (EBN)

Water vapor in soil can be viewed as a potential contaminant when it raises humidity levels in a home contributing to the growth of fungi and other microbiologicals. And, the moisture doesn't just stay in lower levels, it moves through the whole house. In fact, a University of Illinois Building Research

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study found a strong correlation between attic moisture problems and wet basements and crawlspaces.

The removal of water vapor prior to entry into the home has several benefits: reduced growth of microbiologicals, reduced energy consumption for dehumidification, cost-savings for energy reduction, and greater assurance that a lower level {basement} can be used for living space. (HomeAire)

How do soil-gases, including radon and water vapor, get into my home?

No matter how various gases of concern get into the soil – whether by radioactive decay of radium, from decomposing organic matter, or from a chemical spill – once there they all get into the building in the same basic way: by infiltrating through the foundation walls or floor. Common leakage points include cracks in foundation walls, cracks in floor slabs, the joint between walls and slab edges, uncapped or poorly bonded concrete masonry units (CMUs), unsealed basement sumps, and piping penetrations through the walls or floors. (EBN)

How do I prevent soil-gases from entering my home?

The first line of defense in keeping soil-gases out of buildings, therefore, is to ensure a tight air barrier between the building and the soil. (EBN) **EPA does not recommend the use of sealing alone to limit radon entry.** Sealing alone has not been shown to lower radon levels significantly or consistently. Field research has shown that attempting to seal all of the openings in a foundation is both impractical and ineffective as a stand-alone technique. Sealing large cracks and openings is one of the key components of radon-resistant construction, but not the only technique that should be employed. (EPA)

The next line of defense is to avoid generating negative pressure in a basement that will tend to pull gases into the building. It may be easier to create negative pressure under the slab to offset indoor negative pressure from {the stack effect and} exhaust ventilation, rather than installing a ducted, balanced ventilation system. (EBN)

The third strategy is to passively ventilate the area under the floor slab. A **passive sub-slab depressurization system** can generate negative pressure beneath the floor slab, which will prevent most soil-gases from penetrating the slab and entering the building. (EBN) These sub-slab depressurization systems do not require major changes to your home. Similar systems can also be installed in homes with crawlspaces. These systems prevent radon gas from entering the home from below the concrete floor and from outside the foundation.

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When installed properly and completely, these simple and inexpensive passive techniques can help to reduce radon levels. In addition, installing them at the time of construction makes it easier to reduce radon levels further if the passive techniques don't reduce radon levels to below 4 pCi/L. Radon-resistant techniques may also help to lower moisture levels and those of other soil-gases. (EPA)

How does moisture get into basements and crawlspaces? Why don't common construction practices prevent this moisture movement?

A HUD Research Paper (#28) reported that without any moisture protection under a concrete slab, 80% of the moisture within the building originates from building site ground water. Basement humidity is continuous. One reason for basement dampness is that basements can only "dry in." The soil on the underside of the slab is always damp, so moisture {always} moves toward the drier basement air.

Wicking is one entry mechanism for moisture in a basement. A University of Minnesota Extension Service study showed up to 13 gallons of moisture migrating into a test home through wicking when the concrete slab was poured directly on sand. In response, builders often install a capillary break, a layer of porous material such as crushed rock, to reduce wicking through the slab.

Vapor pressure is another mechanism for moisture entry into basements. The soil under the slab is always roughly 55 °F and nearly 100% relative humidity, depending on the season and location in the country. The water vapor in the soil interstices under these conditions will exert a vapor pressure of 1,470 Pascals on the concrete slab. The air in the basement at 65 °F with a relative humidity of 50% has a vapor pressure of 1,046 Pascals. The differential between the two pressures is 424 Pascals and this pressure represents a driving force that moves moisture from below the {slab} into the basement. Obviously, if the water table is so high there's water pressure on the slab rather than vapor pressure, this system won't remedy that.

Builders usually install a polyethylene sheeting vapor barrier over the porous capillary break to reduce the amount of moisture that would enter the building through vapor pressure. This sheeting, however, will not stop air movement, especially when many building practices compromise the barrier: slashing the poly to allow the concrete to drain and cure more rapidly, puncturing for drain and other utility openings and simply walking on the material causing punctures.

Sub-slab capillary breaks and vapor "barriers" fail to treat moisture entry through {wicking and} air movement.

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Another dynamic that causes basements to be consistently damp is that house interiors are usually under negative pressure relative to the exterior due in part to the “stack effect,” the flow of air that results from warm air rising, creating a positive pressure area at the top of a building and a negative pressure area at the bottom of a building. The negative pressure draw of the home is a significant driving force for moisture to enter the home from the sub-slab area.

The air in the soil under the slab is often at 100% humidity and about 1% water by weight. That moisture will be drawn in as water vapor along with the sub-slab air drawn in by the house’s convective flow. A Canadian study found that the air coming through the slab in one test building when it was depressurized with a 125cfm fan drew 7-10 gallons of water into the basement. To stop air (soil-gas) movement, you would need an unbroken air barrier which is impractical if not impossible. (HomeAire)

Why install a sub-slab soil depressurization system?

Scientific data is being generated and field experiences are being collected to support the design and use of active soil depressurization or active dampness control as an inexpensive, low energy system for reducing moisture entrainment through the slab. Reducing moisture at its source reduces the need for more expensive, post-entry dehumidification, especially of the basement environment. **Hollow block foundation construction may also overtax a system and require additional dehumidification.**

{Sub-slab soil depressurization} counteracts the negative pressure inside the home by keeping the {sub-slab area} under a slight negative pressure so that water vapor and other contaminants are much less likely to be drawn into the house. {This system also} provides source removal of moisture, radon, soil-gases, and other contaminants. (HomeAire)

According to Michael P. Rogers of the Indoor Environments Division at EPA, such passive sub-slab depressurization systems result in an average reduction of indoor radon levels of 50% - which is usually enough to keep the radon level below the 4.0 pCi/L threshold for action. It is recommended to install this type of passive {vent} stack in all new construction, because if soil-gases do turn out to be a problem, a fan can be installed to convert the stack into an active system. (EBN)

It is believed that use of all the standards and techniques (both passive and active) will produce the lowest achievable levels of indoor radon in new homes (levels below 2 pCi/L have been achieved in over 90 percent of new homes). It is also believed that use of only selected (passive) standards and techniques

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will produce indoor radon levels below the current EPA action level of 4 pCi/L in most new homes, even in areas of high radon potential. (EPA)

{Sub-slab soil depressurization is different than a} mechanically vented crawlspace system, {which is} a system designed to increase ventilation within a crawlspace, achieve higher air pressure in the crawlspace relative to air pressure in the soil beneath the crawlspace, or achieve lower air pressure in the crawlspace relative to air pressure in the living spaces, by use of a fan. (EPA)

Crawlspace depressurization is usually not the first choice radon mitigation method for crawlspaces because of its greater potential for hazardous failure, that is, backdrafting, and the probability of a high energy loss associated with its operation during the colder and hotter months. Sub-slab and sub-membrane depressurization are the crawlspace mitigation methods that should be used whenever possible. (ASTM E2121)

How much does the system cost to install and operate?

Generally, it is less expensive to install a radon-reduction system before (or during) renovations rather than afterwards. Building radon-resistant features into the house during construction is easier and cheaper than fixing a radon problem from scratch later. In a **new home**, the cost to install passive radon-resistant features during construction is usually between \$350 and \$500. In some areas, the cost may be as low as \$100. A qualified mitigator will charge about \$300 to add a vent fan to a passive system, making it an active system and further reducing radon levels. (EPA) A high quality, quiet fan that is rated for continuous operation will cost \$150 to \$250, plus installation. (EBN) In an **existing home**, it usually costs between \$800 and \$2,500 to install a radon mitigation system. (EPA)

{Incremental material cost to install a passive sub-slab depressurization system} is roughly \$200 or less, the fan to activate the system is approximately \$150. Labor costs would be comparable to running a waste stack with the additional caulking of the perimeter floor/wall joint {as well as the soil-gas vent and any other mechanical penetrations.} (HomeAire)

These fans run continuously but use very little energy to accomplish the negative pressure and ventilation. They have a limited area they need to draw from and require only a small negative pressure to successfully reduce moisture entrainment. The cost of running the system would be about \$17.50 per year. This cost can be compared to the cost of post-entry dehumidification by whole house air conditioning systems. During hot, humid weather, a household air conditioner may require 50-87% of its energy for dehumidification. For

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example, on a 78 degree day, 75% of the HVAC function is dehumidification. (HomeAire)

What are the components of the system?

see IRC Appendix F (Radon Resistive Construction)

The objective of the system is to move toward achieving the lowest technologically achievable levels of indoor radon in new residential buildings in the most cost effective way. (EPA)

The model building standards and techniques for radon control in new residential buildings constructed on **basement and slab-on grade foundations** include a layer of permeable sub-slab material, the sealing of joints, cracks, and other penetrations of slabs, floor assemblies, and foundation walls below or in contact with the ground surface, providing a soil-gas-retarder under floors, and installing either an active or passive sub-slab depressurization system. (EPA)

The model building standards and techniques for radon control in new residential buildings constructed on **crawlspace foundations** include those systems that actively or passively vent the crawlspace to outside air, that divert radon before entry into the crawlspace, and that reduce radon entry into normally occupied spaces of the building through floor openings and ductwork. (EPA)

Proper installation of the radon-resistant features is very important. *Improper* installation could actually *increase* indoor radon levels.

- 1. gas-permeable layer** – this layer is placed beneath the slab or flooring system to allow the soil-gas to move freely underneath the house. In many cases, the material used is a 4" layer of clean gravel. This gas-permeable layer is used only in homes with basement and slab-on-grade foundations; it is not used in homes with crawlspace foundations. (EPA) The gravel or other material in the permeable layer should meet the following specifications to ensure adequate porosity: ½" - ¾" gravel or crushed stone, 80% ¾", over 40% free void space (e.g. #2 DOT gravel), even 4"-6" layer, clean no fines (HomeAire), The aggregate shall consist of material that will pass through a 2" sieve and be retained by a ¼" sieve (EPA)
- 2. soil-gas collector** – {for crawlspace sub-membrane ventilation} install a length of 3" or 4" diameter perforated drain tile horizontally beneath the sheeting and connect to the "T" with the vertical vent pipe through the soil-gas-retarder membrane, this horizontal pipe should normally be placed parallel to the long dimension of the house and should no closer than 6' to the foundation wall. (EPA) Sub-membrane suction point designs that bury a special intake end of a suction point pipe in a deep bed of clean 1" aggregate significantly

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reduce the noise associated with air entering the end of the suction point pipe. The special suction point pipe's intake end has eight or more horizontal or vertical slots, each being ½" wide, and cut into the lowest foot of the suction point pipe. If the slots are horizontal, they go half way through the pipe.

footing drains (loop of 4" perforated pipe buried in aggregate at perimeter of gas-permeable layer or base of foundation) are permitted to serve as soil-gas collectors (ASTM E1465) Internal sub-slab or external footing drain tile loops that terminate in a covered and sealed sump, or internal drain tile loops that {penetrate} the slab are also permitted to provide sub-slab depressurization capability. (EPA) All drain lines extending from the drain tile loop to daylight shall have a one-way flow valve, a water trap, or other control device installed to prevent outdoor air from entering the sub-slab area. The {intent} is to prevent air from entering the drain line but not prevent water from flowing out of the drain line. (ASTM E1465)

Some builders perform only the sub-slab preparation and stub the vent pipe above the slab. **This is not the recommended approach. (EPA) ASTM E1465 requires that an operational passive system be installed. (ASTM)** If you elect to "rough-in" a radon-reduction system, it is important to be clear with the homebuyer that the home is not equipped with a functioning system. Be sure to seal off the riser stub so that radon is not being vented into the living space. Also, label the stub so it is not used as a plumbing waste line. (EPA)

3. soil-gas-retarder membrane – a minimum 6-mil polyethylene or 3-mil cross-laminated polyethylene flexible sheeting material is used to help prevent the soil-gas from entering the home. Due to its significantly increased puncture resistance, the cross-laminated polyethylene is recommended. The high-density sheeting is also available in white, making the crawlspace brighter and most suitable for use as a storage space. (EPA)

sub-slab moisture barrier – install the membrane on top of the gas-permeable layer under the slab-on-grade or basement floor slab. Separate sections should overlap a minimum of 12" (300 mm), and the barrier should be tightly fitting around pipes and other penetrations. Any tears or punctures should be sealed or covered with additional sections of the sheeting. The membrane also helps to prevent concrete from entering the void spaces in aggregate base material. Some contractors will put a layer of sand on top of the polyethylene, both to protect it and to absorb water from the concrete mix. **This practice is not recommended.** The sand may become wet, from the concrete or rising ground water, and would have to dry to the interior through the concrete.

crawlspace membrane – for crawlspace or combination foundations, install the membrane {directly on top of} the entire crawlspace floor area. In this case, however, joints in the poly should be taped {sealed}. The poly should also be taped {sealed} to any piers, other penetrations, and foundation walls to ensure

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adequate depressurization of the sub-membrane area. Acoustical sealant, butyl rubber, or butyl acrylic caulks form a more durable bond with the plastic. Plan on using one 11oz. tube of caulk to attach an 8' length of plastic to the wall. It is critical to allow for enough excess plastic so if a vacuum is drawn underneath the membrane, the plastic can conform to the surface of the crawlspace floor (like vacuum packaging.) If the amount of excess plastic is insufficient, the plastic may stretch over the depression in the dirt like a trampoline {making it susceptible to puncture.} (EPA)

4. sealing and caulking – all below-grade openings in the foundation and walls are sealed to reduce soil-gas entry into the home (EPA), sealed at all penetrations, sealed to stem walls with continuous sealant bead

5. passive vent pipe – a 3" or 4" PVC pipe (or other gas-tight pipe) runs from the gas-permeable layer through the house to the roof, to safely vent radon and other soil-gases to the outside. (EPA) Because of the stack effect, the air in this {passive vent} pipe will tend to rise and pull air from beneath the slab, generating the desired negative pressure beneath the slab. (EBN)

On large buildings or buildings with interior footings that divide the floor slab into separate sections, provide multiple vent pipes for passive sub-slab depressurization (a minimum of one pipe per section of isolated sub-slab aggregate). Multiple vent pipes can be connected to a single vent that extends up through the building and terminates above the roof. Manifold piping to which two or more suction points are attached shall be at least 4" ID. (ASTM E2121) A design alternative is to install "connecting" {pass through} pipes through interior footings when they are poured, which allows the migration of soil-gases between the sub-slab sections to a single vent pipe.

min. 3"diameter, field results have indicated that passive systems tend to function better with 4" pipe, 4" pipe will also allow for a quieter system if the system is activated (EPA), Schedule 40 PVC, ABS or approved equal, cement all joints, terminate 12" above eaves, terminate 10' horizontally from chimneys & operable windows, sloped to drain as DWV, visibly labeled "Radon Reduction System" (EPA) at each floor to prevent plumbing mishaps, when mounting radon fans and when making removable connections which facilitate sump pit maintenance, rubber couplings suitable for use in sanitary sewer systems shall be used instead of cemented pipe joints. (ASTM E2121)

If the pipe is routed through warm space (such as an interior wall or the furnace or hot water heater flue chase, following local fire codes) the stack effect can create a natural draft in the pipe. (EPA) Vent should be located within thermal envelope to the extent practicable, maximizes the passive operation of the system, **in cold climates, do not install the vent pipe in exterior walls.** In cold climates, Insulate the pipe in the attic to reduce moisture condensation and

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maintain upward thermal draft in the pipe as it passes through the unconditioned space. (EPA)

The vent pipe should be installed in a vertical run, with the least number of elbows which could restrict air flow. Additional elbows and horizontal pipe length will restrict air flow through the pipe if the system is activated. Use 45-degree joints to reduce friction. **Do not install traps, intentional or accidental, in the pipe that will collect water and restrict or stop air movement.** (EPA)

To facilitate future installation of a vent fan {activate the system}, if needed, the radon vent pipe shall be routed through attics in a location that will allow sufficient room to install and maintain the fan. (EPA)

6. junction boxes & wiring – an electrical junction box is included in the attic to make the wiring and installation of a vent fan {system activation} easier. For example, you decide to activate the passive system because your test result showed an elevated radon level (4 pCi/L or more). A separate junction box is placed in the living space to power the vent fan alarm. An alarm is installed along with the vent fan to indicate when the vent fan is not operating properly. (EPA)

To facilitate installation of an active sub-membrane depressurization system, electrical junction boxes shall be installed during construction in proximity to the anticipated locations of vent pipe fans and system failure alarms. (EPA)

7. fan (activates a passive system) – install the fan in the vertical run of the vent pipe (EPA), requires 30" vertical run of pipe for installation, should be installed in an attic or some other location outside the conditioned space (EBN), all positively pressured portions of the vent pipe {on the outlet side of the fan} should be located outside the habitable space of the building (EPA), most contractors have found 90W {generally rated between 50W and 150W (ASTM E2121)} in-line fans to be adequate for most home styles, locations and sizes. You can also look for a fan capable of moving 100cfm at 1" water gauge, which should be sufficient for most applications. (EPA) Radon fans shall be mounted and secured in a manner that minimizes transfer of vibration to the structural framing of the building. When mounting radon fans and when making removable connections which facilitate sump pit maintenance, rubber couplings suitable for use in sanitary sewer systems shall be used instead of cemented pipe joints. (ASTM E2121)

Who can install the system?

IN requires that radon service providers (testers, laboratories, and mitigators) be certified by the Indiana State Department of Health (ISDH). ISDH certification requires National Environmental Health Association - National Radon

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Proficiency Program (NEHA-NRPP) certification. There are several radon service providers in the Indianapolis area. Complete information including a list of service providers is available from W. Phillip Eley, REHS, Radon Program Coordinator, Indoor Air and Radiological Health, Indiana State Department of Health, 2525 N. Shadeland Avenue, E-3, Indianapolis, IN, 46219, (317) 351-7190 x258, weley@isdh.in.gov,

EPA Region 5, 77 W Jackson Boulevard (AE-17J), Chicago, IL, 60604, (312) 353-6686, (312) 886-0617 (fax), www.epa.gov/iaq/wherewelive.html

Contractors that are installing passive radon control systems are not required to be certified. Only contractors testing radon levels (testers), converting passive systems to active radon control systems (mitigators), and laboratories must be certified according to Indiana Administrative Code, Title 410 State Department of Health, Article 5.1 Radon. (Eley)

Adopting radon-resistant building techniques should not increase your liability risks in any jurisdiction as long as due care is exercised in following the proper construction techniques. (EPA)

A system description label shall be placed on the mitigation system, the electric service entrance panel, or other prominent location. This prominently located label shall be legible from a distance of at least 3' and display the words "Radon Reduction System", the installer's name and phone number, the date of installation, and an advisory that the building should be tested for radon, by a person qualified by training and certification and licensure, or the occupant at least every two years or as required or recommended by state and local agencies.

Upon completion of radon mitigation work, contractors shall provide clients with information that includes copies of contracts and warranties, a description of the mitigation system installed and its basic operating principles, a description of the proper operating procedures of any mechanical or electrical systems installed, including manufacturer's operating and maintenance instructions, a list of appropriate actions for clients to take if the system failure warning device indicates system degradation or failure, the name, address, and phone number of the contractor. (ASTM E2121)

Who is installing these systems?

About one in every six homes is being built radon-resistant in the United States every year {2001}, averaging about 200,000 homes annually, according to annual surveys of homebuilder practices conducted by the NAHB Research Center over the past decade. In high radon areas, about one in every three homes is built with the features.

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