DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Radiation Protection

DOCUMENT NUMBER:	294-2309-005
TITLE:	Radon Reduction Techniques for Existing Detached Houses
EFFECTIVE DATE:	Upon final publication in the *Pennsylvania Bulletin*
AUTHORITY:	This Policy is established under the authority of 25 Pa. Code Chapter 240 and the Radiation Protection Act, act of July 10, 1984, P.L. 688, No 147 (35 P.S. §§ 7110.101-7110.703).
POLICY:	This document provides guidance on radon reduction techniques for existing detached houses.
PURPOSE:	The purpose of this document is to provide guidance on radon reduction techniques for existing detached houses.
APPLICABILITY:	This document applies to all individuals seeking guidance on reduction techniques for existing detached houses.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
PAGE LENGTH:	9 Pages
LOCATION:	Volume 4, Tab 13
DEFINITIONS:	N/A

United States
Environmental Protection
Agency

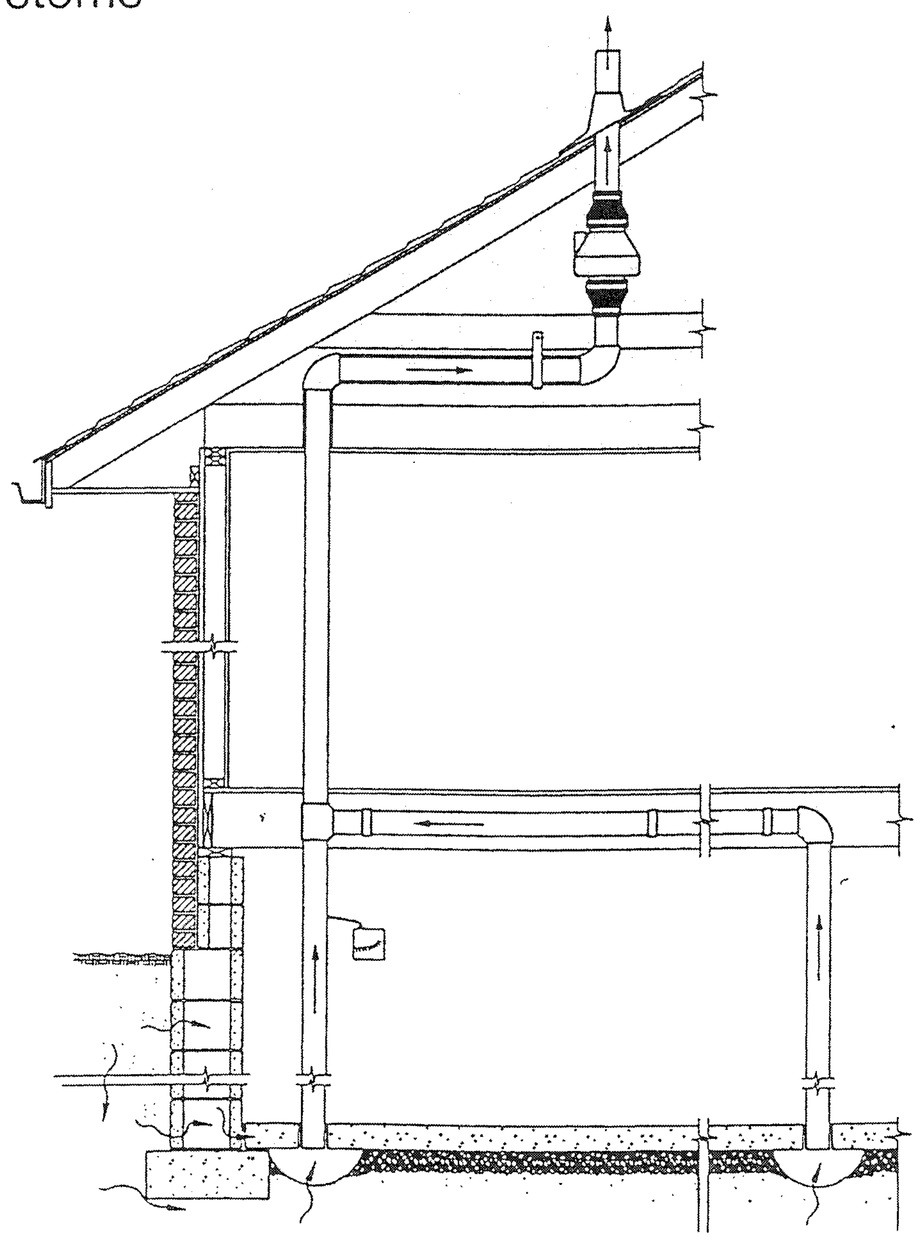
Office of Research and
Development
Washington DC 20460

EPA/625/R-93/011
October 1993

Radon Reduction Techniques for Existing Detached Houses

Technical Guidance (Third Edition) for Active Soil Depressurization Systems

SEALING



4.7 Slab Sealing in Conjunction with SSD Systems

House air will leak into the SSD system through any unclosed openings in the slab. Such leakage can interfere with the extension of the suction field beneath the slab (potentially reducing radon reduction performance). It will also increase the house heating and cooling penalty; heated or air-conditioned air will be drawn out of the house by the system through the unclosed cracks, and will be replaced by infiltration of outdoor air. If sufficient house air is drawn into the system via unclosed slab openings, the SSD system could also contribute to depressurization of the basement or house, thus potentially contributing to back-drafting of combustion appliances.

For the purposes of this discussion, slab openings are subdivided into three categories: "major" openings, which should always be sealed as part of SSD installation unless sealing is truly impractical; "intermediate" openings, which should generally be sealed, if this is reasonably possible; and hairline cracks, for which sealing can be helpful but is often not required.

Major openings. The sealing of *major* slab openings can be very important in achieving good performance and reducing operating costs. "Major" entry routes are defined here as those which are relatively large and distinct, such as perimeter channel drains, large openings through the slab around utility penetrations, floor drains connecting to the soil or the sub-slab region, and sump pits. Such major routes should always be sealed. In cases where such major routes are inaccessible -- such as a perimeter channel drain concealed behind floor and wall finish -- a conscious decision may sometimes be made to accept the penalties of leaving the opening unsealed, rather than incurring a cost that the homeowner would find unacceptable in trying to seal this opening. However, in such cases, the homeowner should be consulted on this decision, and advised of the reductions in performance and the increase in operating costs that may result.

Intermediate openings. In addition to the "major" slab openings discussed above, there will often be smaller, but still potentially important, openings of intermediate size. Examples of such "intermediate" openings include, e.g., the wall/floor joint when there is a modest but distinctly visible gap (perhaps 1/32 to 1/16 in. wide or greater), partially open expansion joints, and small openings through the slab (e.g., around individual utility pipes penetrating the slab). Such intermediate openings should routinely be sealed closed. However, where such intermediate openings are inaccessible, e.g., where a 1/32- to 1/16-in. wide wall/floor joint disappears behind wall finish in a finished part of the basement, the inability to seal this opening will be less of a concern, compared to major openings.

Hairline cracks. Hairline cracks include, for example, settling cracks or wall/floor joints which are tight, with no (or very little) separation. Given their length, the total leakage area represented by hairline cracks could be meaningful despite their narrow width. However, such cracks can be difficult to seal properly and effectively. Simply applying a bead of caulk on top of this crack in a basement may be helpful, but it is unclear how effective this sealing would be, or how durable. To seal such cracks effectively, a channel might have to be routed in the concrete along the crack, to provide adequate surface area for adhesion of the sealant (see Section 4 in Reference EPA88a); such a procedure would be time-consuming, and could significantly increase the cost of the installation.

Experience has indicated that a properly designed SSD system can usually handle the leakage from hairline cracks without a significant reduction in system performance. Therefore, since sealing the cracks is difficult and is often not necessary for good system performance, special efforts to seal hairline cracks will often not be warranted. Attempts to seal hairline cracks will likely be most warranted in cases where sub-slab communication is very poor and the cracks are near the SSD suction pipes. Any leakage through the cracks in poor-communication cases might reduce the performance of a marginal SSD system, which would be having a hard time extending a suction field even in the absence of such leakage.

Because caulking of hairline cracks may reduce the heating/cooling penalty and possibly improve system performance, mitigators who routinely apply a bead of caulk to accessible wall/floor joints, even when the crack is only a hairline and there is no gap, should continue to do so. Homeowners who are installing their own systems (and who are thus not concerned about the labor costs of applying the caulk) may wish to do this. However, it must be recognized that the seal may not be durable or fully effective, and that it may or may not be possible to detect the benefits of such caulking.

General comments on sealing. In the discussion here, the word "seal" is not used in the sense of a true air-tight seal. While such a true seal would be desirable, it is often difficult to achieve such a true seal, and almost impossible to maintain it permanently as the foundation shifts over the years. In the context here, where the objective is to significantly reduce house air flow into the SSD system, a seal is considered adequate if it closes the opening (and reduces the air flow through it) to a large degree, even if not 100%. Thus, for example, if an opening through the slab is sealed with caulk, and if the bond between the caulk and the surrounding concrete breaks over time (due, e.g., to foundation shifting), the caulk may still be blocking a large amount of the air flow through the opening.

Detailed procedures for sealing slab openings are discussed in Section 4 of Reference EPA88a. The discussion below reviews key features for sealing some of the openings of particular concern from the standpoint of SSD performance.

4.7.1 Perimeter Channel Drains

Perimeter channel drains, also known as canal drains or "French" drains, are 1- to 2-in. wide gaps around the perimeter of basements (i.e., 1- to 2-in. wide wall/floor joints). A perimeter channel drain is often intended primarily to drain water that enters the basement through the porous face of block foundation walls during wet weather; in some cases, holes are drilled through the face of the lower course of block, at a level below the top of the slab, to facilitate this water flow. The drains will also handle water entering from on top of the slab, e.g., due to a clothes washer overflow. Perimeter channel drains can also be specifically designed to handle water entering from beneath the slab, although many are not.

The water entering the perimeter channel drain is commonly routed to the region beneath the slab. In some cases, there are drain tiles under the slab, draining to an existing sump in the basement or to a remote discharge; much of the water from the perimeter channel drain would be expected to enter these tiles and drain to the sump or discharge. In other cases, there will be no drain tiles, in which case the sub-slab aggregate will be serving as a dry well. In still other cases, the perimeter channel drain may drain, via an underground channel of aggregate, to a dry well installed remote from the house. Where the basement is finished, the perimeter channel drain will be concealed behind the wall finish.

Perimeter channel drains can be expensive to seal properly, even when they are accessible. Accordingly, some mitigators have reported installing SSD systems without sealing the perimeter channel drain, and obtaining reasonably good radon reductions, at least when sub-slab communication is reasonably good. To avoid undue leakage of house air into the system, the SSD suction pipes were installed toward the center of the slab, away from the perimeter. No studies have been conducted to evaluate the effect of leaving the perimeter channel drain unsealed. But since the opening created by the perimeter channel drain is so large, so widely distributed, and so strategically located, some penalties might be expected to result from this approach. Indoor radon concentrations might be expected to rise during cold weather; the ability of the SSD treatment to extend to block foundation walls would seem to be greatly reduced; and the heating/cooling penalty would intuitively be greater than average.

Thus, serious consideration should always be given to properly sealing perimeter channel drains, except in those cases where they are concealed behind wall finish (so that the cost of sealing could be prohibitive) or where water drainage problems or code violations might be created by sealing. A decision not to seal part or all of the perimeter channel drain should be made with consultation from the homeowner. The mitigator should be prepared to seal the channel drain, or to otherwise modify the system to compensate for air leakage through the drain, if an initial mitigation system does not achieve adequate radon reductions due to the open drain.

In some locales, perimeter channel drains are required by code. In some cases, the drains have an important water drainage function, as discussed above. Thus, any steps to seal the drains must be taken with care to properly maintain the drainage function.

Where the perimeter channel drain is *known* to have no water drainage function either from above or below the slab and where codes do not require that the drain be left open, the 1- to 2-in. wide cap can simply be mortared closed. While mortaring the drain closed may be the simplest approach, it can be a risk for mitigators. The mitigator may be considered liable for any subsequent drainage problems that might be attributed to the closure of this supposedly non-functioning drain.

When the perimeter channel drain has a water drainage function, it can be sealed in a manner which maintains that function. See Figure 32A, and Section 4 of Reference EPA88a. The objective of this sealing approach is to install a caulk seal in the channel at a level beneath the top of the slab, so that there is still: a channel beneath the seal (to handle water entering through weep holes at the base of the block wall, or

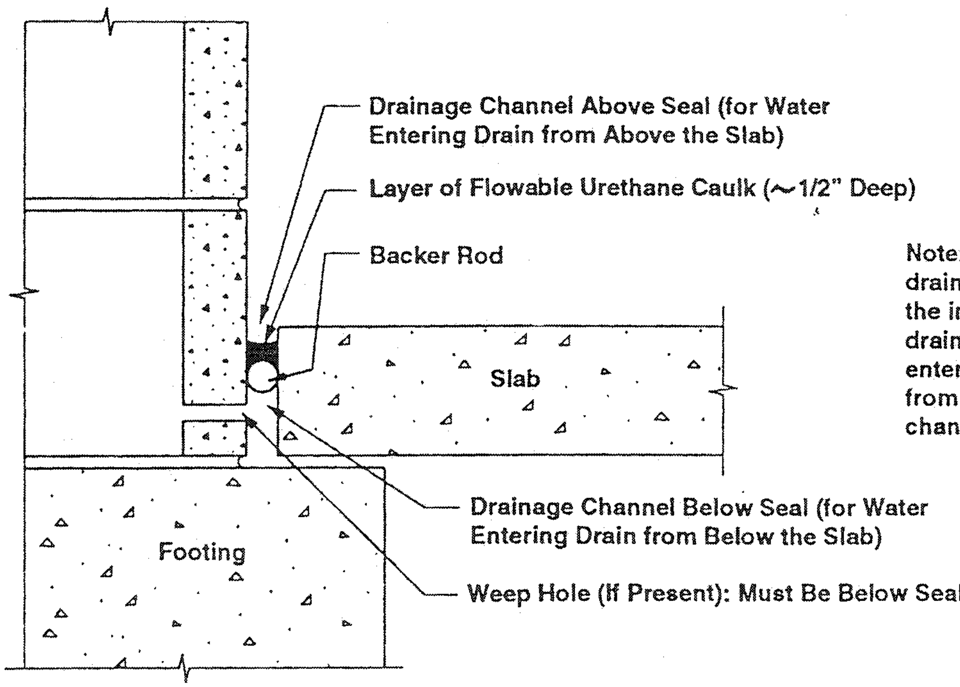


Figure 32A. Cross-section of a sealed perimeter channel drain, illustrating water drainage channels both above and below the seal.

otherwise entering from beneath the slab); and a channel above the seal (to handle water entering through the block face above the slab, or otherwise entering from on top of the slab).

By this approach, backer rod of a diameter slightly greater than the width of the perimeter channel drain (or some other appropriate material) must be stuffed down into the gap between the slab and the foundation wall, to support a layer of sealant. Backer rod is a compressible, closed-cell polyethylene foam material which is formed into cords of alternative diameters. The top of the backer rod must be at least 1/2 to 1 in. below the top of the slab; the bottom of the backer rod must be at least 1 to 2 in. above the bottom of the slab (or the top of the footing). If weep holes have been drilled through the face of the block wall at a level below the top of the slab, to allow water inside the block cavities to flow into the perimeter channel drain, the bottom of the backer rod must be above those holes, so that they remain open.

The top of the perimeter channel drain is then closed with an appropriate sealant, supported by the backer rod. The sides of the perimeter channel drain must be clean (and preferably should be dry) when the sealant is applied, to ensure a good adhesive bond between the sealant and the concrete. The preferred sealant is flowable urethane caulk, since this caulk will effectively fill in the irregular space between the top of the backer rod and the slab, and will adhere well to the concrete. The urethane caulk layer should not be more than about 1/2 in. deep, since it may not cure properly if it is much deeper than this; see the instructions from the manufacturer. The top of the urethane caulk sealing the drain must be below the top of the slab, by perhaps 1/2 in. or more, creating a channel on top of the seal.

This sealing approach prevents house air from flowing down through the perimeter channel drain into the sub-slab region. But at the same time, it permits water flowing through the weep holes beneath the seal to flow into the gap under the backer rod, and from there into the sub-slab aggregate (or to wherever the perimeter drain was originally designed to direct the water). Also, any water entering from above the slab has a channel in which to collect, on top of the caulk seal.

If a significant amount of water is expected to enter the drain from above the slab, the channel above the caulk seal will have to be designed in a manner which will allow this water to drain away. One approach could be to leave gaps in the seal at intervals around the perimeter, so that the water in the upper channel can drain down through those gaps into the sub-slab region as originally intended. These gaps should be located in particular along those walls where water flow from above the channel is expected to be heaviest. Such gaps in the seal would, of course, result in house air leakage into the SSD system through those gaps (and, potentially, radon entry into the house through the gaps). However, since most of the perimeter channel drain would be sealed, the seal would be significantly reducing the amount of air flow. Where a gap was left in the seal, the channel under the seal should be sealed on the sides of that gap, so that the sub-seal channel remains sealed off from the basement.

Another option if there is significant water entering from above the slab would be to utilize an existing sump, if present, or to retrofit a new sump into one corner of the basement to handle this water. See Figure 32B. This figure assumes that drain tiles had been installed under the slab during construction to collect water from the perimeter drain, and that the tiles drain to an existing sump. Use of a sump may not always be satisfactory in cases where water enters the top channel at points remote from the sump, since the water may not reliably flow through the shallow channel over extended distances to the point at which the sump is located, without overflowing onto the slab at some other location.

Whether an existing sump is available, or whether a new sump has to be installed, a channel would have to be routed in the top of the concrete slab, directing the water in the top channel of the sealed perimeter drain into the sump, as shown in the figure. Especially in cases such as that in Figure 32B, where the existing or new sump connects to the sub-slab region, the sump must be capped so that it is not a major unsealed slab opening (see Section 4.7.4). Because the top channel in the sealed perimeter channel drain will be routinely directing water into the sump from above, the sump cover will have to be fitted with a trap so that the water drainage function of the sump can continue while the cover remains air-tight. Sump covers are discussed in detail in Section 5.5.

The preceding discussion concerning the capping of the sump assumes the case where it has been decided not to draw suction directly on the sump, and where a SSD suction pipe through the slab remote from the sump is the preferred approach. If the sump is an existing sump with drain tiles emptying into it, as in Figure 32B, one might commonly elect to install sump/DTD instead of SSD, as discussed in Section 5. The steps for sealing the sump and the perimeter channel drain would be essentially the same if sump/DTD were the intended mitigation approach, as discussed in Section 5.7.

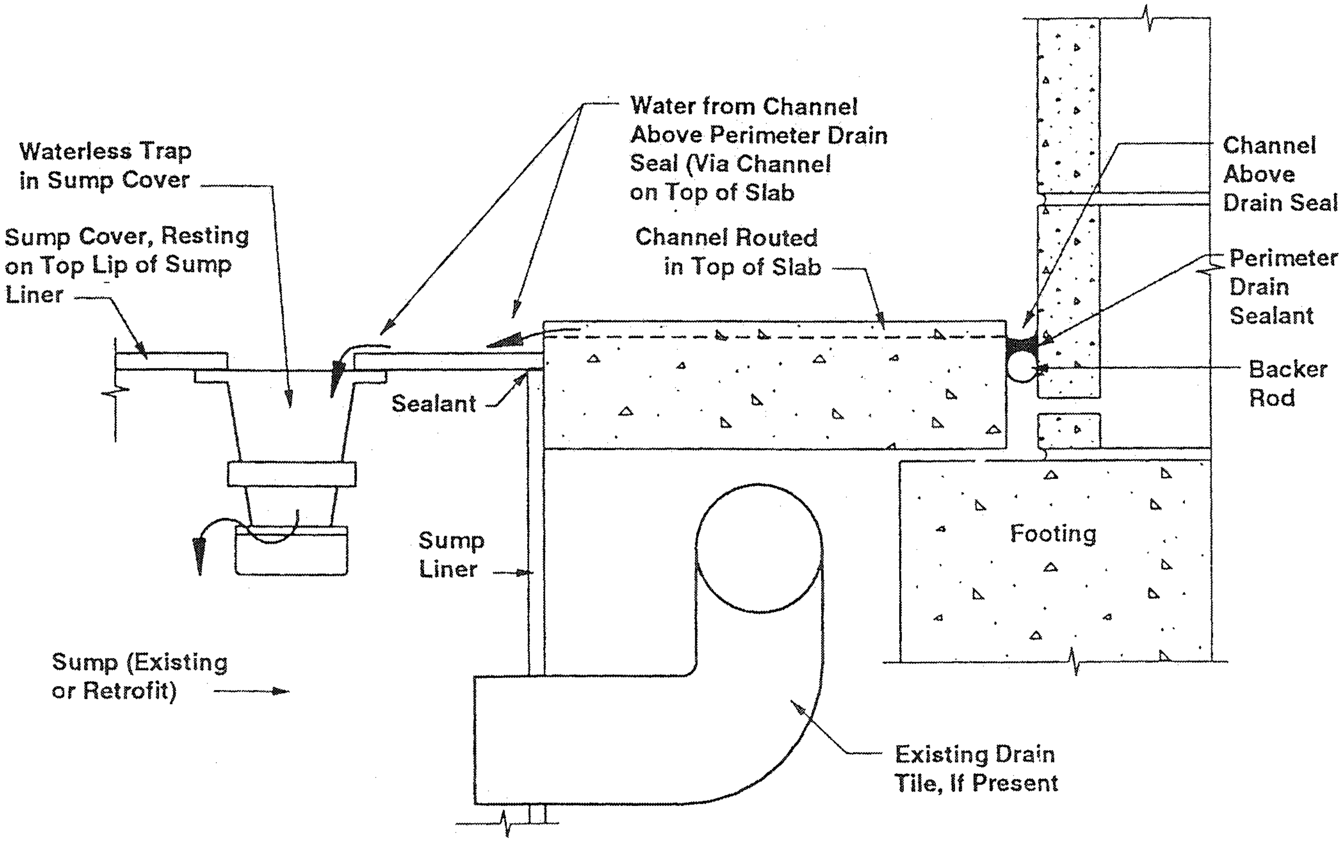


Figure 32B. Method for sealing the sump and the slab channel leading to the sump in cases where perimeter channel drains empty into a sump in the basement.

If a sump were not already present, and if a sump had to be retrofit in order to handle water from on top of the sealed perimeter channel drain, this would add to the SSD installation cost. In some cases, the perimeter channel drain will have initially been designed to route the water into the sub-slab aggregate with the aggregate serving as a dry well (i.e., with no drain tiles to handle the water); in other cases, the channel drain will route the water into a gravel channel leading to a remote dry well. In such cases, the sump installed as part of the channel drain sealing process could do the same, and it would not be necessary to install a sump pump and water discharge line in the sump.

In many cases, a portion of the perimeter channel drain may be inaccessible, for example, concealed behind wall finish. In such cases, it may be decided to seal the accessible portion of the perimeter channel drain (in the unfinished part of the basement), but to leave the inaccessible portion (in the finished part) unsealed, at least initially, due to the costs involved in removing and replacing the finish. When this is done, the exposed open ends of the sub-seal channel must be caulked shut where the seal ends, so that house air cannot leak into the sub-seal channel. When a portion of a channel drain is sealed, the mitigator should understand how that particular channel drain functions (e.g., using aggregate as dry well, or utilizing sub-slab drain tiles), to ensure that drainage problems will not be created.

4.7.2 Other Major Holes through Slab

In addition to perimeter channel drains, there will be other cases where major holes exist through the slab. One common example is the opening, commonly about 2 ft square, often left in the slab around the water and sewer lines that come up through the slab under bathtubs and shower stalls that are installed on slabs. This opening is intended to provide the plumber some flexibility when installing the bathtub. (There may also be openings around the water and sewer penetrations under sinks and commodes in the bathroom, but these will generally be smaller than that around the bathtub plumbing.) Some other examples include unused sump holes, or a hole at the site of some former structure in the basement. An extreme example of a large hole through the slab would be the case where some portion of the slab is missing, leaving bare earth exposed. This latter situation could occur, e.g., when small wings to the basement (such as root cellars or greenhouses) are left with bare-earth floors.

Slab holes around bathtub plumbing. Where a bathroom has been installed on a basement slab or a slab on grade, the plumbing for the bathtub (and the slab opening around this plumbing) is commonly accessible through an access door through the frame wall at the head of the tub. This slab hole could be mortared shut, with the water and sewer lines penetrating the new mortar. However, this could potentially interfere with any subsequent plumbing work that may have to be done on the system. A simpler approach might be to close the slab opening using an expandable closed-cell polyurethane foam. The foam expands as it hardens and cures, tightly closing the opening. If access to the plumbing below the slab is subsequently needed, portions of the foam can be cut away (e.g., with a utility knife) as necessary to expose the plumbing. After the plumbing repairs have been made, any holes cut in the hardened foam can be filled with new foam, or with caulk or other suitable sealant.

In some cases, no access door will be provided for the bathtub plumbing, and the major slab opening under the bathtub will not be as conveniently accessible. In such cases, a decision must be made regarding whether to leave the bathtub slab opening unclosed, or to incur the expense of creating and then restoring an opening in the wall to allow the sealing to be accomplished. Some mitigators routinely make the hole through the wall and seal the slab. One mitigator reports installing an air vent grille (such as those used with forced-air heating systems) in the wall hole after the slab is sealed, as a convenient and neat approach for restoring the wall hole (Ba92).

Other mitigators recommend postponing efforts to seal such inaccessible bathtub slab openings (Kl92). Where sub-slab communication is reasonably good and radon levels are not real high, it may sometimes be advisable to initially install the SSD system without closing the inaccessible bathtub opening, with the intent that that sealing step could be taken later if the initial SSD installation did not achieve adequate performance.

Miscellaneous major slab holes. Where holes of any significant size exist through the slab, and where these holes serve no function, the holes should be closed.

If the soil is not level beneath the slab at the location of the slab hole and if the hole is sufficiently large, it may be necessary to fill in the sub-slab region up to the underside of the slab, using some suitable fill material. To reduce subsequent settling of this fill, and cracking of the patch that will be applied on top, any such fill should be compacted.

Especially where the hole is in an exposed location where there will be foot traffic, the hole will best be closed using concrete or non-shrink mortar. Use of concrete or mortar may also provide the best appearance, blending in with the remainder of the slab. The sides of the slab around the perimeter of the opening should be cleaned, in an effort to improve the bond between the new and the old slab. New concrete or mortar is poured to fill the hole, and the perimeter of the patch (between the new and old concrete) is tooled to provide a channel about 1/2-in. deep. When the new concrete or mortar has hardened, this channel should be flooded with flowable urethane caulk, in and effort to plug any crack that may form as the new mortar shrinks and settles.

In some cases, when the hole is in a remote or less accessible location, one might elect to close it using expanding foam, as discussed previously for the case of slab openings under bathtubs.

Sections of missing slab. From time to time, entire sections of basement slab have been found to be missing in certain houses. For example, the basement may have a small earthen-floored wing which is used as a root cellar. Or, some significant portion of the basement floor may have been left unpaved, for one reason or another.

In such cases, the best course of action will be determined by the specific circumstances. Depending upon the size and use of the unpaved area, it may be recommended to the homeowner that a slab be poured (with aggregate beneath) for that section.

In other cases, perhaps the best approach would be to treat it as an unpaved crawl space wing adjoining the slab. In this case, plastic sheeting would be sealed over the exposed soil. If SSD on the paved portion of the basement proved to be insufficient to adequately reduce radon levels, the SSD system might be supplemented by a sub-membrane depressurization under this plastic sheeting (see Section 8).

4.7.3 Untrapped Floor Drains Connected to the Soil

Floor drains in a basement slab can present a significant problem, if they: a) drain to soil (e.g., via perforated drain tiles beneath the slab, or via pipes to a septic system); and b) are not trapped.

When the drain empties through perforated piping that passes through the sub-slab region and when the drain is not trapped, house air can be drawn into the SSD system through the untrapped drain and through the perforations in the drain tiles. The length of tiles leading from the drain could be "intercepting" the sub-slab suction field, providing a source of leakage air that could prevent the suction field from extending further beneath the slab.

Due to the amount of air that can move through the floor drain and drain tile, the SSD system may not be able to adequately depressurize the soil surrounding the drain tile. Thus, the untrapped floor drain may continue to serve as a significant radon entry route into the house.

One technique to determine whether a particular floor drain is untrapped would be to remove the top grille and inspect using a flashlight during the visual inspection of the house (Section 3.2). Other techniques include chemical smoke testing at the drain during the visual inspection, to assess whether air is flowing up through the drain; and radon grab sampling in the drain (Section 3.4). It can be difficult to independently determine whether the drain connects to drain tiles.

To address both the potential disruption of the suction field and the continued radon entry through the floor drain, the floor drain must be trapped. Even if the floor drain connects to a septic system by a solid pipe, rather than the perforated piping connection to the soil considered previously, trapping the drain will have the benefit of preventing radon entry into the house from the septic system.

If the floor drain already contains a trap, it must be ensured that this trap remains full of water. If the floor drain does not contain a trap, one can often be retrofit. Dranjer Corp. sells several models of plastic "waterless" traps for various applications, such as the "F-series" trap shown in the sump cover in Figure 32B. A slightly modified version of that trap, the DR-2, has been designed to fit into many standard floor drains ranging from 2 to 8 in. in diameter, beneath the existing floor drain grille. These units seal the existing drain, and direct all water through the throat of the Dranjer unit.

Although designs of the different models vary slightly, the principle of each is that, at the bottom of the throat, downward-flowing water encounters an impoundment which it must overflow before entering the sewer line. This impoundment may be a small bowl in which the base of the throat is submerged, as in Figure 32B or in the DR-2; or, in the "J-series" unit, the base of the throat may curve upward in the form of a simple P trap (see Figure 5 in Reference EPA88a). The opening at the top of the impoundment is covered by a weighted ring (as in Figure 32B) or a ball, which floats to permit the water to overflow. However, when no water is flowing, the ring or ball seats into the opening. The seating of the ring or ball prevents gas movement upward or downward through the drain; i.e., soil gas cannot move upward into the house, and house air cannot be drawn down through the drain by the SSD system. The floating ring or ball provides a seal even in cases where there is no water in the trap, hence the term "waterless."

If the floor drain is never used, an alternative approach would be to simply mortar the drain opening shut. This approach is not recommended unless it is certain that the drain will indeed never be needed, and is not required by code. The drain could also be plugged with a rubber stopper, which could be removed on any occasion when the drain were needed.

Sometimes when a floor drain drains to a septic system, there will be a clean-out plug in the drain line downstream of the trap. If this plug were missing, a situation which has sometimes been observed, soil gas could still flow up into the house, bypassing the trap, even when the floor drain trap is full of water. If this clean-out drain plug is missing, it must be replaced (e.g., with a rubber stopper).

4.7.4 Sumps

Sumps not only provide a major opening through the slab, but also, if drain tiles empty into the sump, as is often the case, they can connect widely to the aggregate and soil beneath the slab and around the foundation. As such, they can be major soil gas entry routes, and they can provide a major leakage path for house air or outdoor air to leak down into a SSD system.

In many cases where a sump is present and where drain tiles empty into the sump, a sump/DTD system will be installed rather than a SSD system. In this case, the sump would necessarily be sealed with an air-tight cover, in the manner described later in Section 5.5, as an inherent part of the sump/DTD system. Where there are no drain tiles entering the sump and no sump pump, the sump pit may be used as a ready-made hole through the slab for a SSD pipe, in which case the sump pit would also be fitted with an air-tight cover as part of the installation of the suction pipe.

In those cases where a sump exists and where SSD suction pipes will be installed independent of the sump, the sump opening must still be fitted with an air-tight cover as shown in Figure 3 and described in Section 5.5.1. Otherwise, a large amount of basement air can flow through the sump and drain tiles into the SSD system. If water will enter the sump from on top of the slab, a waterless trap must be installed through the sump cover. If a sump pump is present and if it is not a submersible pump, it must be replaced with a submersible pump.

4.7.5 Intermediate Openings Through the Slab

Slab openings defined here as being "intermediate" should be sealed whenever they are accessible. They are distinguished from the "major" openings discussed previously in that if the intermediate openings are inaccessible and inconvenient to seal, it will be less warranted to incur increased efforts and costs attempting to seal these openings.

Wall/floor joints wider than a hairline crack (but not perimeter channel drains). If the wall/floor joint is wider than a hairline crack (e.g., wider than roughly 1/32 to 1/16 in.), it should be caulked wherever accessible. Because of the nature of this crack, gun-grade (non-flowable) urethane caulk will generally be the best selection. Flowable caulk would tend to puddle on top of the slab, if the crack is narrow; or, it may disappear down under the slab, if the crack is wider but is still too narrow to allow some backer-rod type of support to be stuffed down before caulking.

The wall/floor joint should be wire-brushed to remove deposits and loose concrete, and should be vacuumed before caulking, to try to make the surface as clean as reasonably possible. The bead of gun-grade caulk should then be worked down into the crack to the extent possible.

Even where the entire wall/floor joint is readily accessible, caulking the joint in this manner can add more than $100 to a mitigator's installation cost, depending upon the basement size, the amount of preparation, and labor rates (He91b, He91c).

Gaps around utility pipes penetrating the slab. When utility pipes (e.g., water, sewer, and fuel lines) penetrate a slab, a crack or gap will usually exist between the concrete and the pipe perimeter. Sometimes, the concrete will have been poured flush against the pipe, and only a hairline crack will exist around the perimeter. Other times, a gap will be left around the utility line, often created by a sleeve of metal or packing around the pipe. This gap may be intended to provide subsequent flexibility in mounting a fixture (such as a sink or commode) on top of the pipe, or to protect the pipe when the concrete is poured.

If the gap around the perimeter is more than a hairline (e.g., wider than about 1/32 to 1/16 in.) but not wide enough to stuff down some supporting material, it should caulked with gun-grade urethane caulk, as discussed previously for wall/floor joints. If it is wide enough to accommodate some supporting material, this support should be provided, and flowable urethane caulk should be used. If there is still some packing material around the perimeter of the pipe, between the pipe and the concrete, the top layer of this packing should be scraped away to provide a channel for the caulk. In all cases, the surfaces should be vacuumed and cleaned to provide a reasonably good surface for adhesion of the caulk.

The utility lines usually having the biggest gaps (especially under commodes) will be inaccessible without removing the fixture. Unless communication is poor, SSD systems are usually able to handle air leakage through such gaps sufficiently well. It will probably not be cost-effective in most cases to remove the fixture and seal the gap, in an effort to improve SSD performance. (As discussed previously, these gaps around individual pipes are distinguished from the large holes commonly left around the plumbing for bathtubs, which are considered "major" openings.)

Expansion joints. Sometimes an expansion joint will be installed in a residential slab while the concrete slab is being poured. Expansion joints are strips of asphalt-impregnated compressible fibrous material about 1/2 in. wide. In some regions, they are installed around the perimeter of the slab, at the wall/floor joint, serving as a buffer between the slab and the foundation wall. In other cases, they are installed in the middle of the slab, across the width of the slab (perpendicular to the front and rear walls), often at points where there is a discontinuity in one of the walls. They are referred to as expansion joints because they will compress if the slab ever expanded, thus avoiding cracking from that cause. (In fact, wet concrete will shrink after being poured, and will usually never again reach its "wet" dimensions, except under unusual circumstances.) These joints also serve to isolate one slab segment from another, and may thus sometimes help control slab cracking by permitting independent movement of the segments.

Because the concrete will tend to shrink away from the expansion joint material as it cures, a gap may exist between the material and the adjoining concrete, enabling air leakage down through the joint into the SSD system. This leakage could inhibit the extension of the suction field generated by a SSD pipe from extending across the joint into a neighboring segment of the slab. Leakage through perimeter expansion joints could inhibit the suction field from extending to treat the block foundation walls. Even where there is no visible gap, the expansion joint material will probably not be creating an air-tight seal.

Sealing an expansion joint will be most important when: a) the suction pipe is installed near the joint, since nearby leaks have the greatest impact on suction field extension; b) sub-slab communication is not good, since it is under those conditions that marginal suction field extensions can least tolerate leakage; or c) the gap is wide. Thus, for example, one situation where sealing of expansion joints would likely be important would be the case where there is a perimeter joint, and where poor sub-slab communication encourages location of the suction pipes around the perimeter. Where communication is good, sealing these joints may be less crucial; however, even with good communication, sealing could potentially improve system radon reductions and reduce heat loss. A number of mitigators report that they routinely seal the accessible portions of expansion joints, especially perimeter joints (Br92, Bro92, Kl92).

One method for sealing an expansion joint would be to route or chip out the top 1/2 in. of expansion joint material, creating a channel along the length of the joint. After the debris is vacuumed up, this channel could then be filled with urethane caulk. Gun-grade (non-flowable) urethane caulk may be the best choice in some cases, since flowable caulk can disappear down into the porous material and any adjacent gaps (Bro92). Chipping out the top of the expansion material can be a time-consuming process, because the material is very pliable. In no case should a channel be created simply by compressing the joint material down, since the material will eventually return to its original shape and dislodge any caulk that had been applied on top of it (Kl92).

To avoid the effort involved in chipping out the top portion of the expansion material, the existing material might simply be trimmed down to the level of the slab using a wire brush or possibly a utility knife (if it extends above the slab). The surfaces would have to be vacuumed to remove debris that might reduce caulk adhesion. Gun-grade urethane would then be spread on top of the existing material without chipping, and worked down into any visible gap. This approach has reportedly worked well with perimeter expansion joints (Kl92). With the perimeter joint, a generous bead of gun-grade caulk is applied over the joint, and is forced down into any gaps around the material and attached to the slab and the wall beside the joint. Although the caulk does not bond well to the joint material itself, it will bond to the slab and wall, encasing the entire joint.

Sometimes expansion joints will be inaccessible. Joints around the perimeter can be concealed behind wall finish. Interior joints, perpendicular to the front and rear walls, will sometimes be concealed under frame walls. It will often not be worthwhile to disrupt the finish attempting to seal the expansion joint, although, as discussed previously, the final decision will depend on the location of the suction pipes, the sub-slab communication, and the width of the gap. If an initial mitigation system is not performing adequately, apparently as the result of an unsealed inaccessible expansion joint, the mitigator will need to consider taking steps to seal the joint or making other system modifications to compensate for the leakage through the unsealed joint.

Other, small slab holes. Occasionally, other small holes will be found through the slab. Such holes might result, for example, where some previously existing slab penetration may have been removed. Where such holes are observed, they should be mortared, foamed, and/or caulked closed.

4.7.6 Openings in Block Foundation Walls

In addition to the openings in the slab, there will also be openings in the foundation walls. Where the walls are hollow block, such air leakage paths into the wall could further reduce the ability of the SSD system to develop a suction field in the walls. The major wall openings which would be considered first for closure would be: the open voids in the top course of block, if there is not a course of solid cap blocks on top; gaps around utility line penetrations through the wall; and missing mortar or defects in the blocks.

As discussed in Sections 2.1, 2.2.1, and 2.3.1, SSD seems to "treat" block foundation walls, in large part, by intercepting soil gas before it enters the void network. It is not clear that SSD often treats the walls by establishing a measurable depressurization or flow inside the wall. Moreover, even when SSD pipes are located near block walls, the depressurizations/flows that would be maintained in the wall by a stand-alone SSD system appear to be very low. Under these conditions, it is unclear how often any practical degree of wall sealing (e.g., sealing of top voids) would have a significant effect, given that significant wall openings will still remain (such as the block pores and mortar joint cracks) which will still provide substantial cumulative leakage area.

Therefore, in cases where sub-slab communication is fairly good and where a stand-alone SSD system (with no BWD component) is expected to do a fairly good job in a given house, it is unclear whether significant improvement in SSD performance will often be achieved by an extensive effort to seal openings in the block foundation wall. Wall sealing will most likely be of significant value with stand-alone SSD systems in cases where sub-slab communication is marginal or poor, and/or where the block walls appear to be a particularly important entry route. Wall sealing can also be important in cases where a BWD component is going to be added to supplement a SSD system, as discussed in Section 7. A BWD component is most likely to be added for the same reasons just stated, namely, poor sub-slab communication and an important wall radon source.

When sub-slab communication is good and a stand-alone SSD system is planned, sealing of the most important wall openings might help to reduce soil gas entry through the walls, even if it does not aid in depressurization of the walls by the SSD system.

If wall sealing is attempted, the most important wall-related opening to close would be the open voids in the top course of block, if there is no course of cap block. The procedures for sealing the top voids and other wall openings are discussed in Section 7.7.1.

4.8 Gauges/Alarms and Labelling

Even where a first-class job has been done in installing a SSD system, the system will not continue to provide low indoor radon levels over the long term unless it is properly maintained by the occupant. Gauges or alarms are required to alert the occupant when the suctions or flows in the system piping fall to unacceptable levels. Labelling advises the homeowner who the installer was (in the event that service is needed), and which switches and circuit breakers control power to the fan. Labelling also indicates which pipes and other elements are components of the system, so that they are recognized by new occupants who may move into the house in the future, and by maintenance personnel. Labelling thus should reduce the risk of the system being inadvertently turned off or damaged by future owners or by service personnel.