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POLICY:	This document provides guidance to individuals on the application of radon mitigation methods.
PURPOSE:	This document is intended to aid individuals in diagnosing and solving indoor radon problems.
APPLICABILITY:	This document applies to all individuals involved in radon mitigation.
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.
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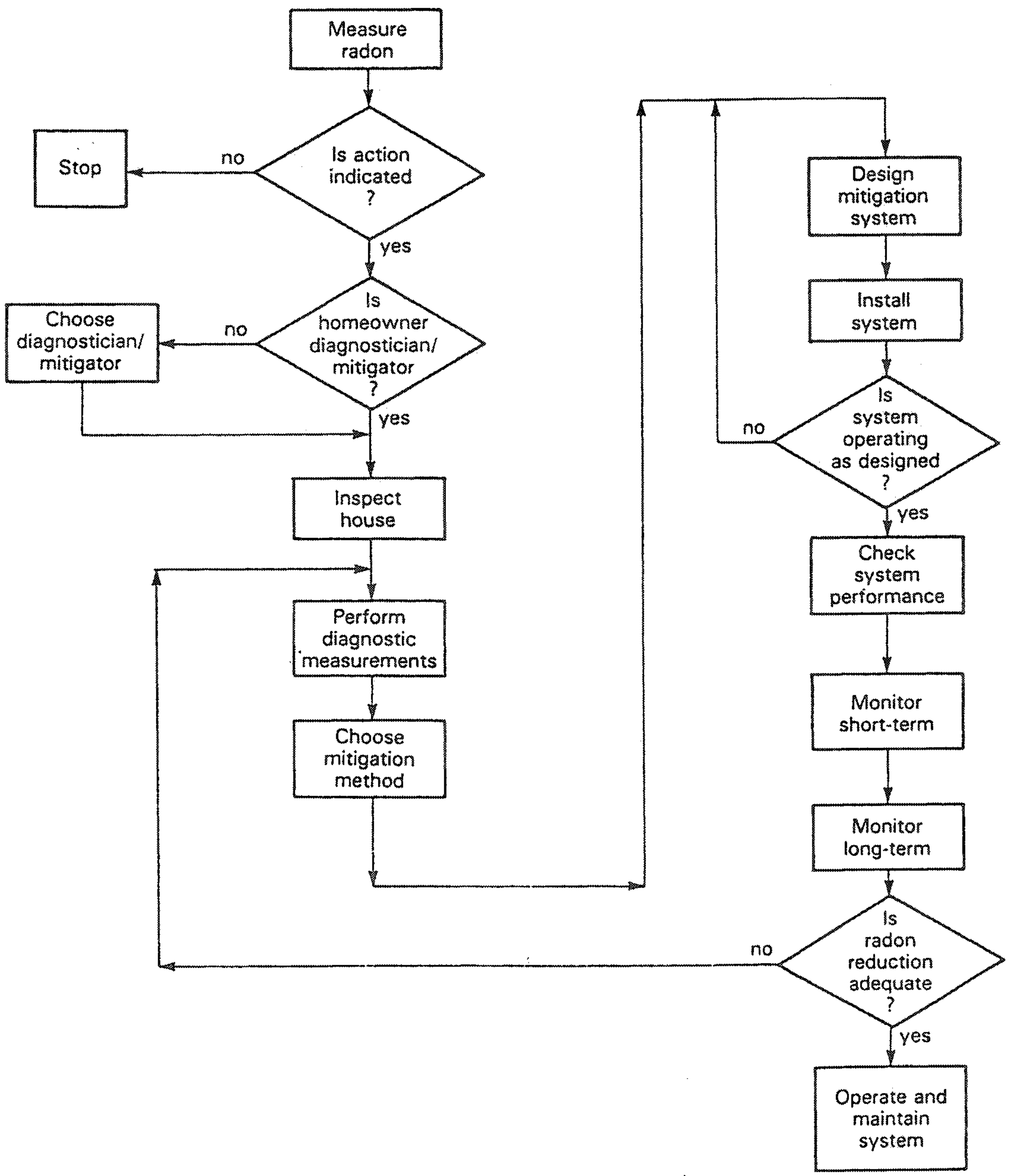

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Application of Radon Reduction Methods

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FOREWORD

This document is intended to aid homeowners and contractors in diagnosing and solving indoor radon problems. It will also be useful to State and Federal regulatory officials and many other persons who provide advice on the selection, design and operation of radon reduction methods for houses.

This document represents the third publication of EPA's technical guidance for indoor radon reduction methods. It is not intended to replace but rather to supplement the previous document, "Radon Reduction Techniques for Detached Houses: Technical Guidance (Second Edition)," (EPA/625/5-87-019) published in January 1988. While the present document incorporates updated information reflecting new results and perspectives gained since the previous document, its primary purpose is to address a broader audience by condensing and organizing the material to form a decision guidance instrument.

Several recent EPA publications on radon may be of interest to the reader. These publications and their contents are listed below:

- "A Citizen's Guide to Radon: What It Is and What to Do About It,"OPA-86-004 -- This brochure provides general information on radon and its associated health risks.

- "Radon Reduction Methods - A Homeowner's Guide (3rd Edition)," OPA-88-010 -- This booklet provides a concise overview of the radon reduction techniques available to homeowners who have discovered an indoor radon problem.

- "Radon Reduction Techniques for Detached Houses: Technical Guidance (Second Edition)," EPA/625/5-87/019 -- This reference manual provides detailed information on sources of radon and its health effects as well as guidance for selection, design, and installation of reduction techniques.

- "Application of Radon Reduction Methods," EPA/625/5-88/024 -- The current document is a decision guidance instrument intended to direct the user through the steps of diagnosing a radon problem and selecting a reduction method; followed by designing, installing, and operating a mitigation system.

- "Radon-Resistant Residential New Construction," EPA/600/8-88/087 -- This manual provides builders and new home buyers with information on materials and building techniques that are effective in reducing radon levels in new houses.

Copies of these documents can be obtained from the State agencies and the EPA Regional Offices listed in Section 11. Copies can also be obtained from EPA's Center for Environmental Research Information, Distribution, 26 W. Martin Luther King Drive, Cincinnati, OH 45268.

Section 7
Installing a Mitigation System

Some mitigators use local contractors to install the radon reduction system in a house. The installation process should be supervised by the diagnostician/mitigator, or by someone else familiar with the principles of the system being installed. While some steps might seem inconsequential to an installer who is unfamiliar with the principles of the technique, these steps might be very important in the system's ultimate performance. For instance, if an objective is to mortar closed the partially visible open top voids in a block foundation wall, then it is important that the mortar be forced all the way under the sill plate so that the entire void is closed. Mortaring only the exposed part of the void would greatly reduce the effectiveness of the closure. It would be very difficult to check on the completeness of this mortaring job, or to get mortar into any unclosed segment of the void under the sill plate, once the mortar in the visible part of the void had hardened.

As a practical matter, many detailed decisions regarding the precise configuration of the system will often be made during installation. For example, unanticipated obstacles might be encountered as the installers drill or dig into places the diagnostician could not see during inspection. A run of piping for an active soil ventilation system might not fit around existing features of the house exactly as visualized during initial design. Therefore, the supervisor of the installation crew must ensure that any detailed adjustments made during the installation phase are consistent with the principles of the technique, so that performance is not reduced, and installation is consistent with the desires of the homeowner for a neat, attractive appearance.

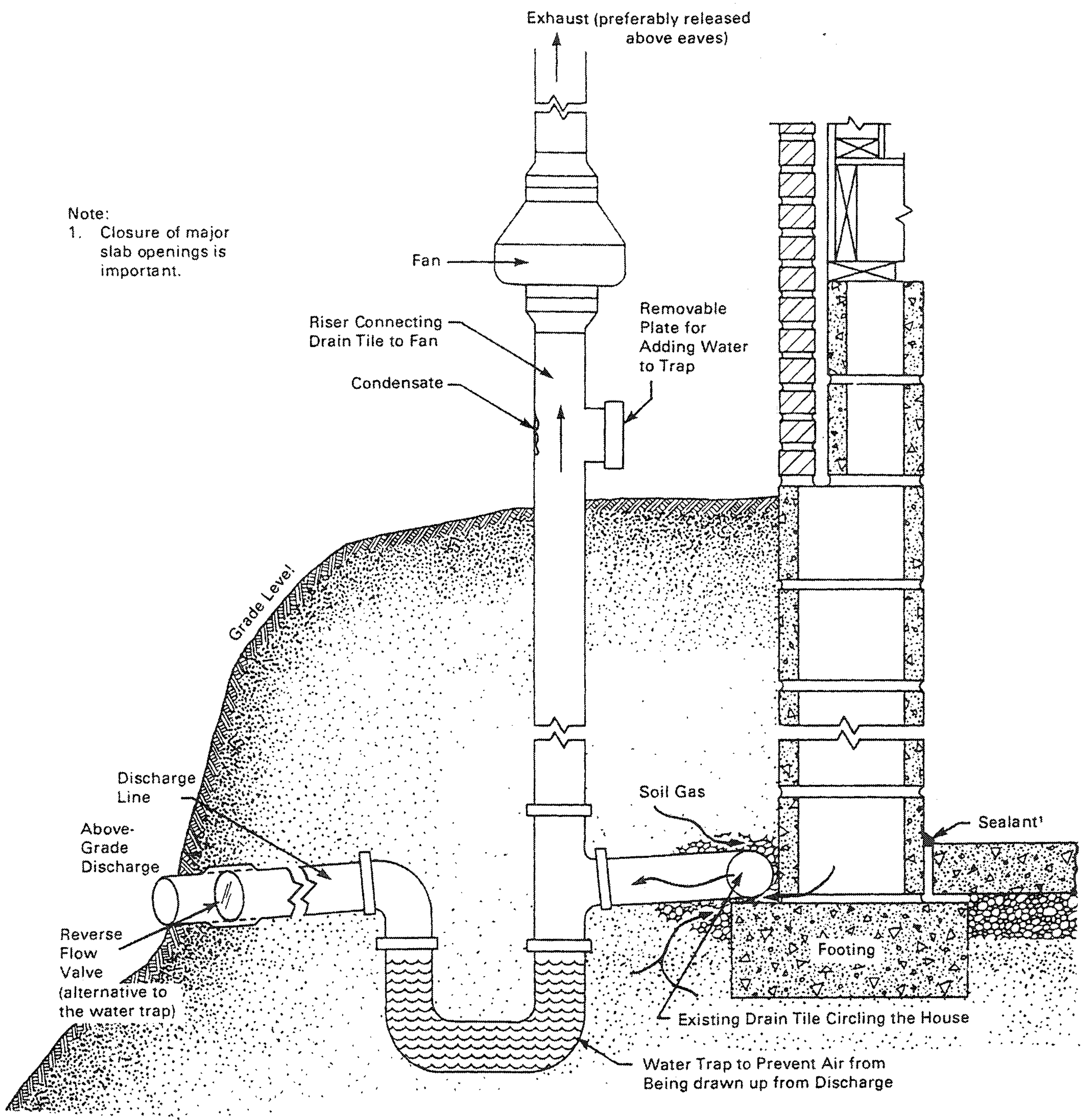
7.1 Drain Tile Ventilation Installed Outside

Drain tiles are pipes intended to collect water and drain it from around the foundation of a house. Because the drain tiles are located near the floor/wall joint, a prominent soil gas entry route, ventilation of these pipes is often very effective in reducing radon levels in the house. Sometimes drain tiles also extend under the slab. If the tiles extend under the slab, or if the communication under the slab is good, tile ventilation can effectively treat the entire sub-slab region. Water collected by the tile system will be drained to a point above grade, to a dry well, or to an interior sump. If an extensive drain-tile network is present, then drain-tile ventilation should be one of the first reduction techniques considered. Even if the drain-tile loop is not complete, this technique can be very effective in reducing the radon levels.

First consider the situation in which the tile system drains to a point above grade. Such an installation is illustrated in Figure 8. The circle beside the footing in Figure 8 represents the cross section of a drain tile which, ideally, forms a continuous loop around the perimeter of the house. The ventilation system, consisting of the trap and riser with the fan, is installed by the mitigator in the discharge line that drains the water from the collection loop. The trap ensures that the fan ventilates the loop near the footings rather than drawing air from the discharge point. The removable plate on the riser allows the homeowner to add water to the trap during dry periods. A water hose connection or even a permanent water line could be installed. The permanent water line should be installed underground to avoid freezing. If the trap becomes dry enough to allow air to pass through, the ventilation system will become ineffective. To decrease the likelihood that the trap will dry out, the vertical arms of the traps should be made as long as practicable. A useful alternative to the water trap is to install a reverse flow valve on the above-grade discharge end of the drain pipe. This reverse valve eliminates the concern over the trap's drying out. Some drain-tile systems have more than one discharge line. All discharge lines must have traps installed. So long as all the tiles are connected, only one fan is required. Note that the trap must always be on the drain discharge side of the fan. In fact, while the traps must be installed in the drain discharge lines, the fan can be installed as shown in Figure 8 or anywhere in the loop. However, it is usually cheaper to install the fan at the same location as the trap. Although one is not shown in the figure, it is advisable to install an alarm to announce if the trap goes dry, if the reverse valve fails, or if the fan becomes ineffective for any other reason.

Figure 8. Drain tile ventilation where tile drains to an above-grade discharge.

Note:
1. Closure of major slab openings is important.



After the discharge line is exposed, a section must be removed to allow the trap and riser to be inserted. The trap, riser, and connections must be airtight so that the effectiveness of the fan is not reduced. Consequently, the trap and riser cannot be made of perforated pipe like the drain tiles. The trap can be purchased as a unit or constructed from elbows and tee's cemented together. The longer the vertical arms of the trap, the longer the time required for all the water to evaporate.

The distance from the house to install the trap and fan depends on aesthetics (whether the riser can be hidden by shrubbery, etc.), whether the noise of the fan can be isolated by distance, and the length of electrical cable required to run the fan. Consideration should also be given to whether people will spend much time in the vicinity of the exhaust. If so, the exhaust should be elevated above breathing level to aid in dispersing radon-laden gas or made inaccessible by shubbery, etc. If the exhaust is near the house, it is recommended that it be extended above the eaves. Whether the exhaust is mounted on the roof or away from the house, consideration should be given to the possibility that it could become covered either by debris or by snow and ice. The fan should be durable and resistant to weather conditions, capable of sustaining a pressure differential of 0.5 - 1.0 in. WC (124 - 248 Pa) at a flow rate of 150 - 200 cfm (0.071 - 0.094 cms).

7.2 Drain Tile Ventilation Installed in a Sump

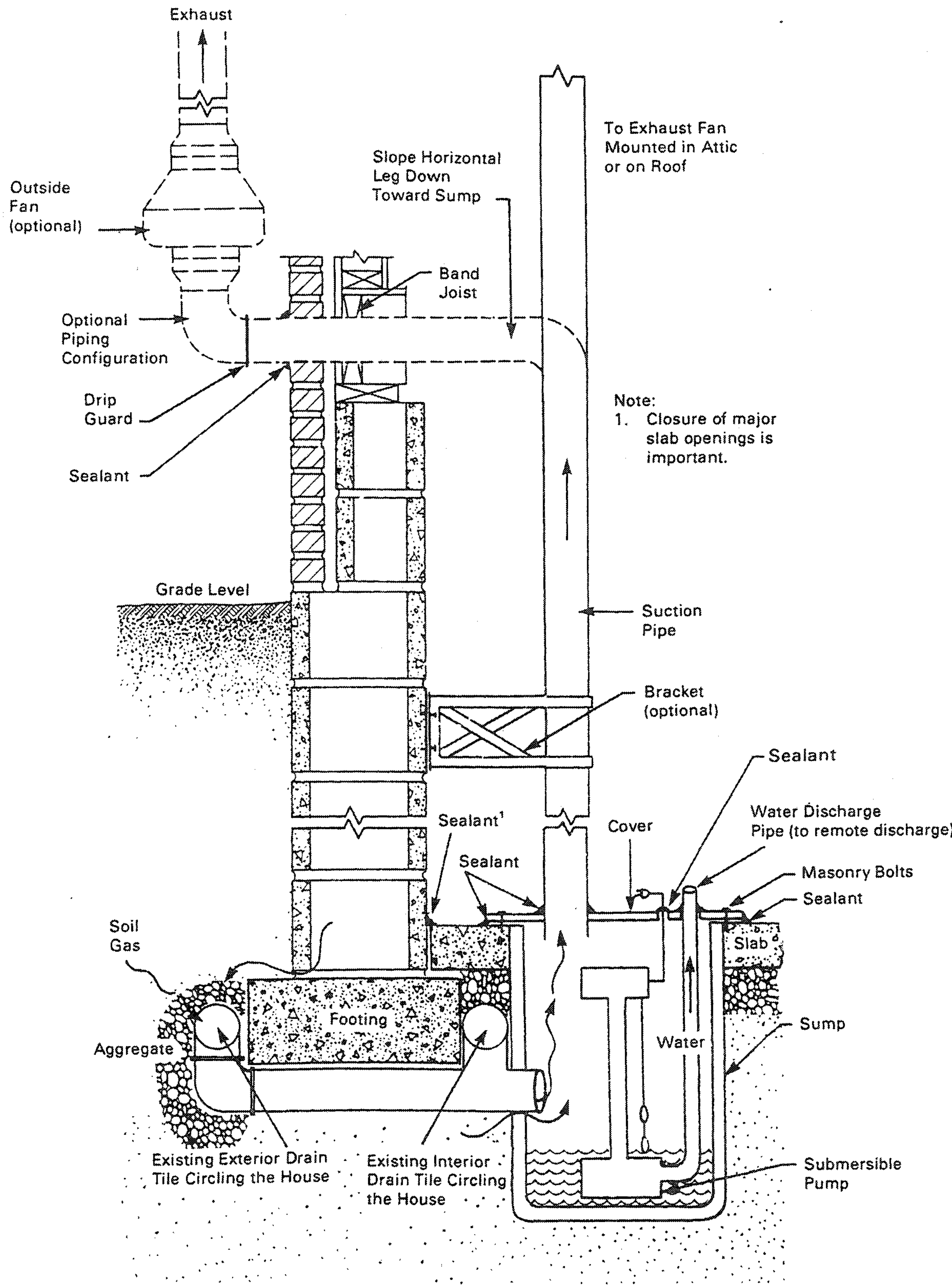
Drain tile ventilation systems are installed somewhat differently when the tiles drain to an interior sump. Figure 9 illustrates such an installation. Although the figure shows the tile loop outside the footings, it may be located on the inside or both. If there is a history of water problems, a sump pump is likely to have been installed already. However, just because a sump is present does not necessarily mean that the exterior tiles drain into the sump. If the homeowner does not know whether the tiles drain into the sump or if additional exterior drain lines exist, their presence can be learned only by observation and conducting tests such as those using tracer gases or a plumber's snake. When the sump is covered, as shown in Figure 9, it is recommended that the existing sump pump be replaced by a submersible pump if such a pump is not already present. The submersible pump is recommended to avoid problems with corrosion of the pump motor and/or for ease of sealing the sump.

For the sump ventilation to be effective, the cover must be sealed airtight. Figure 9 shows a flat cover with penetrations. This cover can be made of sheet metal, plywood, or another suitable material. It will usually be convenient to fabricate the cover in two pieces so it can be fitted around the pipes which penetrate the sump. The possibility of needing to service the sump pump should be taken into consideration when designing the sump cover. Caulk and sealants can be used to ensure an airtight fit. The cover should be secured to the floor with masonry bolts. If water sometimes enters the sump from the top of the slab, then an airtight seal that allows water to drain must be installed. A drain with a water trap can be used for this purpose (EPA88a, Br87, Bro87a, Sc87). While water traps are relatively simple to install, they are effective only so long as they retain water. Alternatively, waterless traps are also available. As an alternative to constructing a sump cover, complete airtight sump units can be purchased to replace leaky, incomplete sumps, or where sump holes have been left for sump installation at a later date.

The ventilation pipe that penetrates the sump cover must extend up through the house shell to exhaust the soil gas extracted through the sump. Figure 9 shows two alternative exits for the exhaust pipe. In one, the pipe penetrates the house shell through the band joist and extends up outside the house. It is recommended that the exhaust be above the eaves of the house and away from windows in such an instance. In the other case, the pipe extends up through the house to the roof and exhausts the soil gas above the roofline. Where the pipe penetrates the roof, the fan should be mounted either in the attic or on the roof. Mounting the fan on the roof is preferable because both noise and the risk of leaking radon back into the house are reduced (no part of the pipe inside the house is under positive pressure). However, the roof-mounted option is more expensive and exposes the fan housing to the elements.

To reduce pressure losses in the pipe, the number of turns and length of pipes should be held to a minimum. Unfortunately, one has limited control over the location of the ventilation point in the sump. Consequently, the least tortuous path acceptable to the homeowner should be chosen. Typically, the homeowner will insist that the exhaust pipe pass through an upstairs closet. The pipe must be supported with mounting brackets either on the basement wall or at the floor penetrations. Horizontal piping runs should be supported by clamps or brackets attached to floor joists. Pipe joints must be completely airtight and should be leak tested. Further, horizontal runs of pipe should be sloped slightly so that condensed water can drain to the ground or to an outside drain. It is imperative that no traps or low points exist in the line. If a natural trap exists in the exhaust line, condensed water can collect and block the air flow.

Figure 9. Drain tile ventilation where tile drains to sump.



7.3 Sub-Slab Ventilation Installed Through the Floor

While drain tile ventilation may be the first choice in some circumstances, sub-slab ventilation is by far the most widely applicable soil ventilation technique. In reality, the two techniques represent variations on the principle of diverting soil gas from entering the substructure by changing the direction of movement of the soil gas. The sub-slab ventilation technique attempts to treat the entire region under the slab, taking particular advantage of the communication in the aggregate bed when one is present. A typical penetration through the slab directly into the aggregate bed is illustrated in Figure 10. Options for exhausting the soil gas above the eaves of the house include either penetrating through the roof from inside the house or extending the exhaust pipe outside the house. The options for installing the exhaust are very similar to those discussed above for sump ventilation (Figure 9).

The greatest concern with sub-slab ventilation arises when the communication under the slab is poor. However, the inability to measure air movement under the slab is no guarantee that sub-slab ventilation will not work. It has been demonstrated on several occasions that sub-slab ventilation can be effective in spite of the failure of an air communication test. A similar instance recently occurred with four slab-on-grade houses in Dayton, Ohio. These houses have heating ducts under the slab which appear to block communication. However, installed sub-slab systems were effective.

If an unused sump is present with openings under the slab and communication under the slab is good, the simplest option is to cover and ventilate the sump. If no sump is present, or communication tests indicate that multiple ventilation points are needed, then it is necessary to make holes in the slab. A number of methods are available to do this. The difficulty of making a hole through the slab is determined by the size of the hole that is needed. In EPA's experience, the ventilation system usually consists of 4-in. PVC pipes.

The easiest way to cut holes of this size is with a coring drill, which removes a core of the proper size for the pipe to fit neatly in the hole. Holes cut this way are perhaps easier to seal around the pipe. Coring drills with diamond bits (and the operators to handle them) can usually be hired from local construction firms. The bits of these drills are usually continuously cooled with water and, consequently, tend to be somewhat messy for use in finished living areas. It is practical in most cases to make a 4-in. hole using small bits. For instance, a circular pattern can be made by drilling small (1/4 to 1/2 in.) holes with a masonry drill and then knocking the center out with a chisel or a rotary hammer (Sa87). If a larger hole (1 to 2 ft^2) is required, a jackhammer may be the proper tool. Although electrically driven hammers can be rented, they may not always be powerful enough to break through the concrete. In some cases a more powerful jackhammer handled by an experienced operator may be required. A jackhammer might be necessary when the sub-slab communication is so poor that an excavated pit around the ventilation point would improve the pressure field extension (EPA88a). This type of installation is illustrated in Figure 11. In this case a 2-ft^2 hole is made in the slab and a large cavity is excavated in the soil. Alternatively, if a core drill and 4-in. bit are available, eight 4-in. adjacent holes forming the outline of a 1-ft square can be quickly opened. The center can then be knocked out to open a 1-ft^2 hole. The pit is covered with plywood and the vent pipe installed with the end extending slightly into the pit. The hole in the slab is then repoured to seal the vent pipe in place. Note that the plywood is supported by aggregate and that the hole in the concrete was jackhammered with a slope around the edge so that the weight of the new concrete will ultimately be supported by the original slab. An alternative to leaving a large open pit would be to fill the pit with coarse aggregate (2-in. stone). The permeability of coarse aggregate is high enough that the pit's effectiveness would not be compromised significantly. If aggregate is used, it should be covered with a material such as polyethylene liner to keep wet concrete from plugging the aggregate. The vent pipe would penetrate the film. The purpose of the pit is to distribute the region of depressurization over a larger surface of the soil resulting in better extension of the pressure field into the surrounding soil. The diagnostician/mitigator and homeowner must weigh the advantages and disadvantages of aesthetics and cost of sub-slab ventilation pits against additional ventilation points installed in holes drilled in the slab. The type of pit excavation just described is expensive because it is labor intensive. If soil and not stone exist under the slab, it is practical to excavate a sizable pit through a 4-in. drill hole. In this case pits are probably less costly than extra ventilation points.

Piping used to construct ventilation systems should be made of plastic such as PVC (thin wall) sewer pipe for durability, as well as for corrosion and leak resistance. Flexible hose such as clothes dryer vent hose is not recommended because it is easily damaged and not conducive to draining water that condenses in the line. It will tend to sag under the weight of condensed water, forming traps which could result in reduced effectiveness of the ventilation system. PVC pipe is readily sealed with the appropriate cement familiar to contractors. It is critical that the joints in the system be airtight. Before a fan is installed in a line, it should be leak checked since the housings of many fans are not designed to be airtight. All the joints in a system including those

Figure 10. **Sub-slab ventilation using pipes inserted down through slab.**

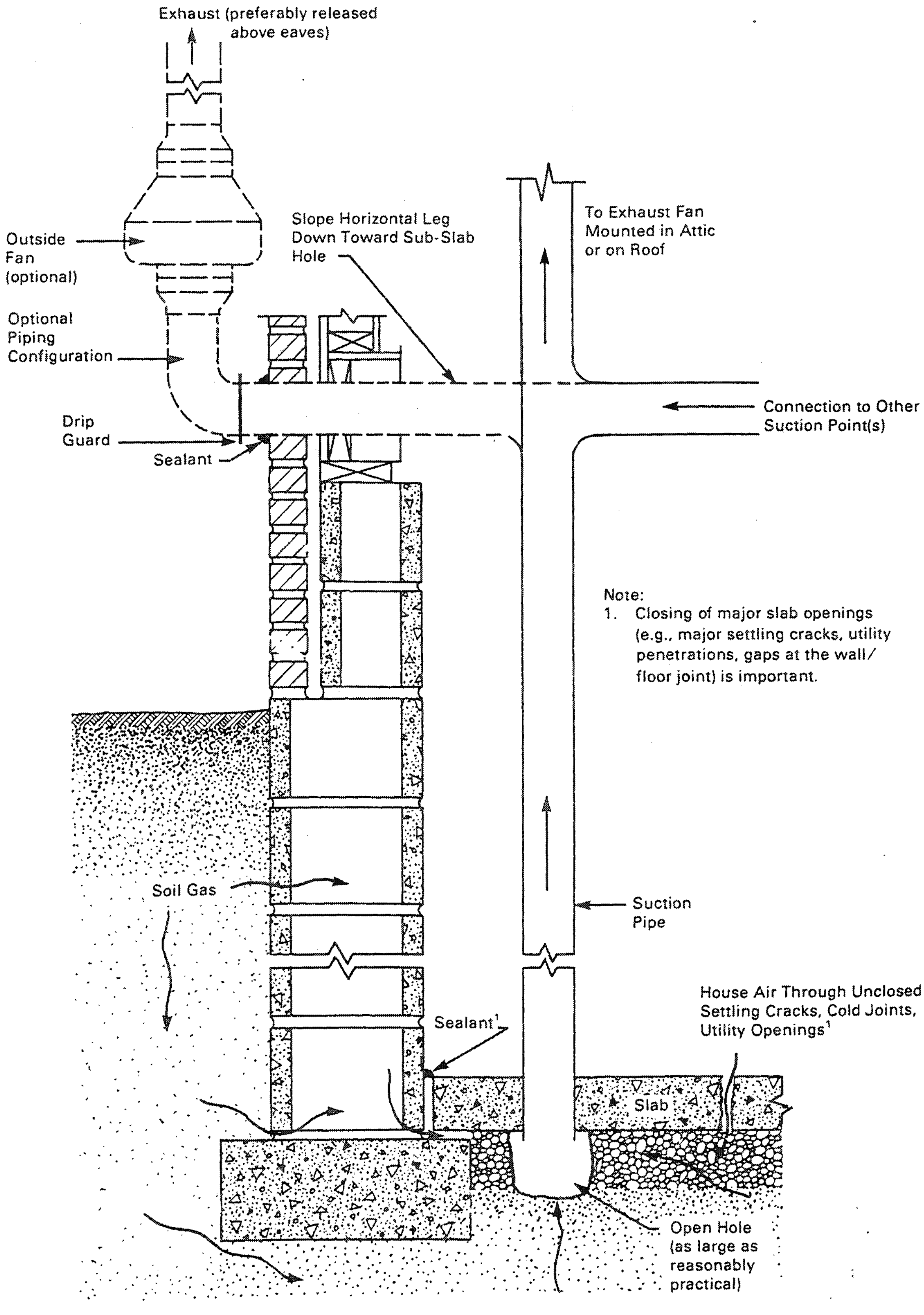
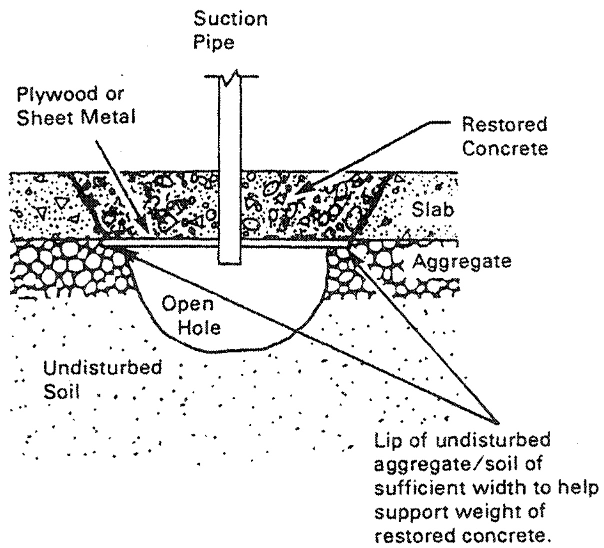


Figure 11. One method for creating open hole under sub-slab depressurization point when slab hole has been created by jackhammer.



where the vent penetrates the slab should be leak tested. If any part of the line on the exhaust side of the fan is indoors, it should be carefully leak tested because it will release radon in the house if it leaks. For this reason, the fan should be mounted in the attic, on the roof, or outside whenever possible. Leaks on the intake side of the fan will reduce the effectiveness of the system by reducing the capacity of the system to depressurize the soil.

The size of the pipe can also influence system performance. If the diameter of the pipe is too small, the fan cannot depressurize the soil because of increased pressure drop in the pipe. Long runs of pipe or turns and elbows have a similar effect. Since small diameter pipe takes up less space and is more easily hidden, it my be desirable to use small pipe in some instances. If using smaller diameter pipe is contemplated, the pressure drop at realistic flow rates should be computed to estimate its effects on system performance. In all cases, care should be taken to ensure adequate support for all pipes and fans installed. All fans should be mounted vertically to prevent water from collecting and all horizontal runs of pipe should be sloped toward the sub-slab vent point so that condensed water can drain back to the soil. If there are any low points in the line that cannot drain properly, a special drain with a water or waterless trap or a reverse valve must be installed to prevent accumulation of water that could impede performance. If the exhaust line penetrates through the band joist, the exterior penetration should be carefully sealed and a drip guard installed to prevent rainwater's running down the pipe and damaging the band joist. Consideration should be given to preventing the exhaust from blockage by birds' nests, bees' nests, or debris. Vents through the roof should be capped with a rain guard that does not impede flow. The possibility that the outlet could be covered by snow accumulation or drifts should also be considered. In cold climates, insulation might be needed on the exhaust pipe to prevent ice from blocking it.

7.4 Wall Ventilation

Although wall ventilation is discussed here as a stand-alone mitigation technique, it finds its widest application as a supplemental aid to methods such as sub-slab ventilation. Wall ventilation would be a preferred technique only in special situations such as no measurable communication under the slab or with the walls, no apparent entry routes in the slab, and high radon levels in the walls. For wall ventilation to be applicable, all major wall openings must be closed and there must be no major slab entry routes away from the wall. There are two types of wall ventilation installations: point-penetration systems and baseboard duct systems. Baseboard duct systems are more expensive and find fewer applications than point-penetrations systems.

Point-penetration systems attempt to ventilate the wall void networks by inserting individual pipes into void cavities at various points. Each block wall, interior or exterior, that rests on a footing should have at least one vent pipe. The fan can be oriented to either pressurize or depressurize the wall void network. Because of their high porosity, untreated block walls often require high flow rates to depressurize the void network, resulting in depressurization of the basement. Problems with backdrafting of combustion appliances and increased radon flow through slab entry routes can occur when the basement is highly depressurized by wall ventilation. There is some concern that pressurization of the wall might increase radon entry through some points. There have been some instances in which sub-slab pressurization increased radon entry (Se87), thus illustrating the potential for adverse effects of pressurization, even in block walls. Concerns also exist that wall or sub-slab pressurization could increase indoor air levels of other contaminants such as termiticides or biological components. Moisture condensation and freezing around footings is another potential concern with wall pressurization. Although the Agency's experience is limited, EPA has had some success in reducing radon levels by both pressurizing and depressurizing block walls (He87a, Sc88).

Usually one block wall does not communicate very well with the wall sharing a common corner. Consequently, at least one ventilation point per wall is recommended. EPA's limited experience with block wall ventilation suggests installing at least two ventilation points in a wall that is longer than about 25 ft (He87a, Sc88). Ventilation points in a wall are typically placed to treat equal surface areas (one point located in the center, two points located a quarter of the way from each end). Walls with fireplaces might need an extra vent point. If diagnostic measurements have identified certain walls as having particularly elevated radon concentrations, additional ventilation points might be advised for those walls. If the wall ventilation system is supplemental to a sub-slab system, only the identified "hot" walls may require a ventilation point. Wall ventilation points should be placed near the bottom of the wall to enhance the treatment there.

For installation, a hole will be drilled or chiseled through one face of a single block into one of the cavities of the block. The ventilation pipe inserted into the block cavity must be well sealed to prevent air leakage around the pipe. Caulk or asphaltic sealant should be worked into the gap to form a good seal. The considerations relating to sizing the pipes are same as those for the other ventilation techniques.

7.5 Methods of Closing the Top Row of Blocks

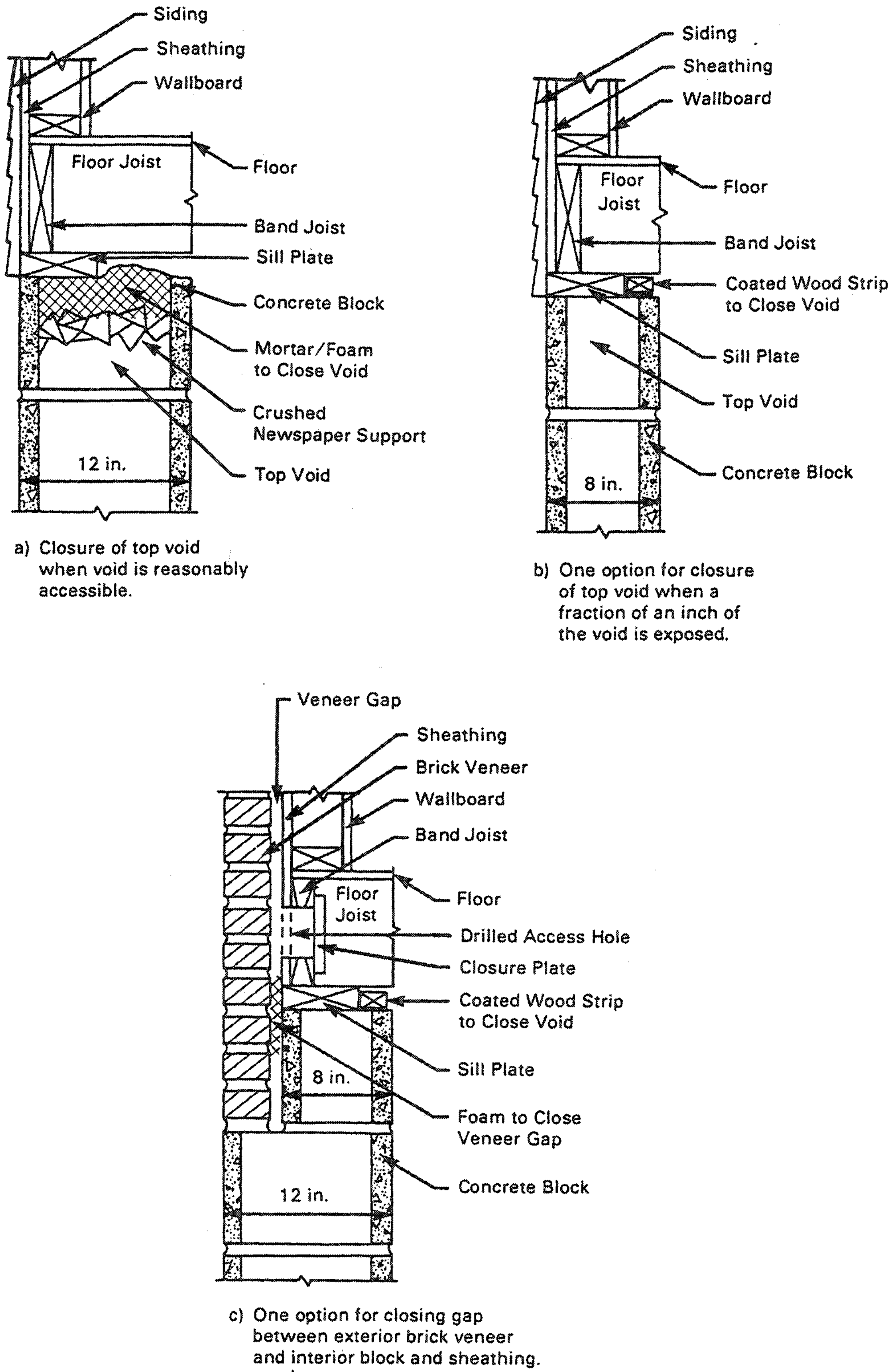
Closure of major openings is important in all soil ventilation systems. It is especially important with wall ventilation because the flow rates through the walls tend to be high anyway. Open voids at the top of the wall make wall ventilation impractical if they cannot be closed. Fortunately, in many areas, the building code requires a row of solid cap blocks. When cap blocks are not present, closing the openings can present quite a challenge.

If the sill plate leaves sufficient access to the openings (perhaps 4 in.), the recommended procedure is to stop each void with crumpled newspaper (or some other suitable support) and fill it with mortar to a depth of at least 2 in. The mortar must be forced under the sill plate and worked to ensure complete sealing of the hole. This procedure is illustrated in Figure 12a.

If the sill plate allows sufficient space (1 to 3 in.) to force newspapers into the void, but not sufficient working space to ensure that the mortar completely fills the void, an expanding foam such as a single-component urethane foam can be substituted for the mortar. These foams are available in aerosol cans or, for commercial applications, can be extruded through a hose and nozzle. Such a void is also illustrated in Figure 12a.

If the top of void is not sufficiently accessible to force newspaper or some equivalent supporting material into the opening, closure becomes much more difficult. A hole could be drilled in the block to inject the foam; however, the foams tested by EPA were not sufficiently self-supporting to remain in the top of the void while they cured. In some cases supports for the foam can be improvised. For instance, it has been suggested that balloons be inserted into the cavity through drilled holes and then inflated to support the foam. It has also been suggested that dowel pins be inserted through a series of small, closely spaced holes to support the expanding foam. Another suggestion was to saw out the first mortar joint to a depth of a few inches, allowing plastic, cardboard, or sheet metal supports to be inserted through the slots. Although some of these techniques could be made to work, they are judged to be too expensive to be practical.

Figure 12. Some options for closing major wall openings in conjunction with block wall ventilation.



a) Closure of top void when void is reasonably accessible.

b) One option for closure of top void when a fraction of an inch of the void is exposed.

c) One option for closing gap between exterior brick veneer and interior block and sheathing.

When the top void was inaccessible, EPA has successfully used the sill plate to close the tops. In cases in which the openings along the edge of the sill plate were sufficiently small, a bead of caulk was used to seal between the sill plate and the block. When the openings along the edge of the sill plate were too large to be caulked, but too small to work mortar into, a wood strip with caulk on two sides was nailed to the edge of the sill plate covering the openings. Both the edge along the block and the crack between the strip and the sill plate were then caulked. This technique is illustrated in Figures 12b and 12c. Although this technique is less effective than using foam (note that the outside edge of the sill plate is not accessible for caulking), it is less expensive and appears to be adequate in many cases (He87a, Sc88).

7.6 Closing the Gap Behind Brick Veneer

In houses with exterior brick veneer, a gap usually exists between the veneer and the sheathing, as well as between the veneer and the block behind it. This situation is illustrated in Figure 12c. This gap could reduce the effectiveness of wall ventilation systems by allowing air to flow into or out of the block void network, thus negating the wall depressurization or pressurization. While it is not clear how often this gap seriously limits the performance of wall ventilation, it is clear that effective wall ventilation can be accomplished in some cases without closing this gap. For at least one house in an EPA study an effort was made to close the veneer gap by drilling through the band joist and extruding urethane foam into the gap. This procedure is illustrated in Figure 12c. There was no clear evidence that the foam improved the performance of the ventilation system.

Obvious holes and cracks in the walls should be closed using grout, caulk, or other sealants. Examples are holes around utility penetrations, chinks in blocks, and mortar joint cracks where pieces of mortar are missing. Pores in the concrete blocks represent a significant amount of air leakage. Coating concrete block walls has not been a standard practice when installing a ventilation system. However, when installing a wall ventilation system on cinder block walls it is advisable to coat the wall to close the pores (pore closure will also help with concrete block walls). Cinder blocks are more porous than concrete blocks. For discussion of the options for closing the pores in a block wall see Reference EPA88a.

Openings in the slab should be closed to assist a wall ventilation system in extending the pressure field under the slab. Of particular concern is the wall/slab joint. Sumps and major cracks should be closed, while floor drains should be either trapped or closed.