United States
Environmental Protection
Agency

Offices of
Air and Radiation and
Research and Development
Washington DC 20460

August 1987
OPA-87-009

EPA

NAHB RESEARCH FOUNDATION, INC.

Radon Reduction in New Construction

An Interim Guide

Introduction

The U.S. Environmental Protection Agency (EPA) is concerned about the increased risk of developing lung cancer faced by persons exposed to radon in their homes. Because many families already face the problem, early emphasis was placed on identifying the danger in existing homes and developing cost-effective methods to make such housing safer. Based on this early research, EPA published three documents in 1986: *A Citizen's Guide to Radon: What It Is and What To Do About It*, *Radon Reduction Methods: A Homeowner's Guide*, and a more detailed manual, *Radon Reduction Techniques for Detached Houses: Technical Guidance*. These documents were designed to help homeowners determine if they have a radon problem and to present information on how to reduce elevated radon levels in their homes.

This pamphlet is the next step in attempting to reduce the radon hazard in homes. It is designed to provide radon information for those involved in new construction and to introduce methods that can be used during construction to minimize radon entry and facilitate its removal after construction is complete. If there is concern about the potential for elevated indoor radon levels, it may be prudent to use these construction techniques in new homes. The "Techniques for Site Evaluation" section of this pamphlet outlines several methods for assessing the potential for elevated indoor radon levels. The decision to incorporate these construction techniques rests solely with the builder or homeowner.

In addition to extensive internal EPA review, this pamphlet has been developed in coordination with the National Association of Home Builders Research Foundation, Inc. (NAHB-RF), a not for profit organization, and other federal agencies including the Department of Energy (DOE), Housing and Urban Development (HUD), United States Geological Survey (USGS), and the National Bureau of Standards (NBS). It also reflects comments solicited from a broad spectrum of individual experts in home construction and related industries.

It is potentially more cost-effective to build a home that resists radon entry than to remedy a radon problem after construction. The construction methods suggested in this pamphlet represent current knowledge and experience gained primarily from radon reduction tests and demonstrations on existing homes. Field tests are underway to develop and refine the most cost-effective new-home construction techniques. After completion of these field tests, a more detailed "Technical Guidance" manual will be published to expand and revise, as necessary, the interim guidance presented in this pamphlet. Accordingly, *this Interim Guide should not be referenced in codes and standards documents.*

Radon Facts

Radon is a colorless, odorless, tasteless, radioactive gas that occurs naturally in soil gas, underground water, and outdoor air. It exists at various levels throughout the United States. Prolonged exposure to elevated concentrations of radon decay products has been associated with increases in the risk of lung cancer. An elevated concentration is defined as being at or above the EPA suggested guidelines of 4 pCi/l or 0.02 WL average annual exposure.* Although exposures below this level do present some risk of lung cancer, reductions to lower levels may be difficult, and sometimes impossible to achieve.

Soil gas entering homes through exposed soil in crawl spaces, through cracks and openings in slab-on-grade floors, and through below-grade walls and floors is the primary source of elevated radon levels (Figure 1). Radon in outside air is diluted to such low concentrations that it does not present a health hazard. In some small public and private well-water supplies, radon is a hazard primarily to the extent that it contributes to indoor radon gas concentrations. When water is heated and agitated (aerated), as in a shower or washing machine, it will give off small** quantities of radon.

Radon moves through the small spaces that exist in all soils. The speed of movement depends on the permeability of the soil and the presence of a driving force caused when the pressure inside a home is lower than the pressure outside or in the surrounding and underlying soil. A lower pressure inside a home may result from:

- Heated air rising, which causes a stack effect.
- Wind blowing past a home, which causes a down-wind draft or Venturi effect.
- Air being used by fireplaces and wood stoves, which causes a vacuum effect.
- Air being vented to the outside by clothes dryers and exhaust fans in bathrooms, kitchens, or attics, which also causes a vacuum effect.

In homes, where a partial vacuum exists, outdoor air and soil gas are driven into the home.

New Construction Principles

The facts just discussed form the basis for the following new-construction principles:

- Homes should be designed and constructed to minimize pathways for soil gas to enter.
- Homes should be designed and built to maintain a neutral pressure differential between indoors and outdoors.
- Features can also be incorporated during construction that will facilitate radon removal after completion of the home if prevention techniques prove to be inadequate.

The following techniques for site evaluation and construction are based on these principles.

Techniques for Site Evaluation

The first step in building new radon-resistant homes is to determine, to the degree possible, the potential for radon problems at the building site. At this time, there are no standard soil tests or specific

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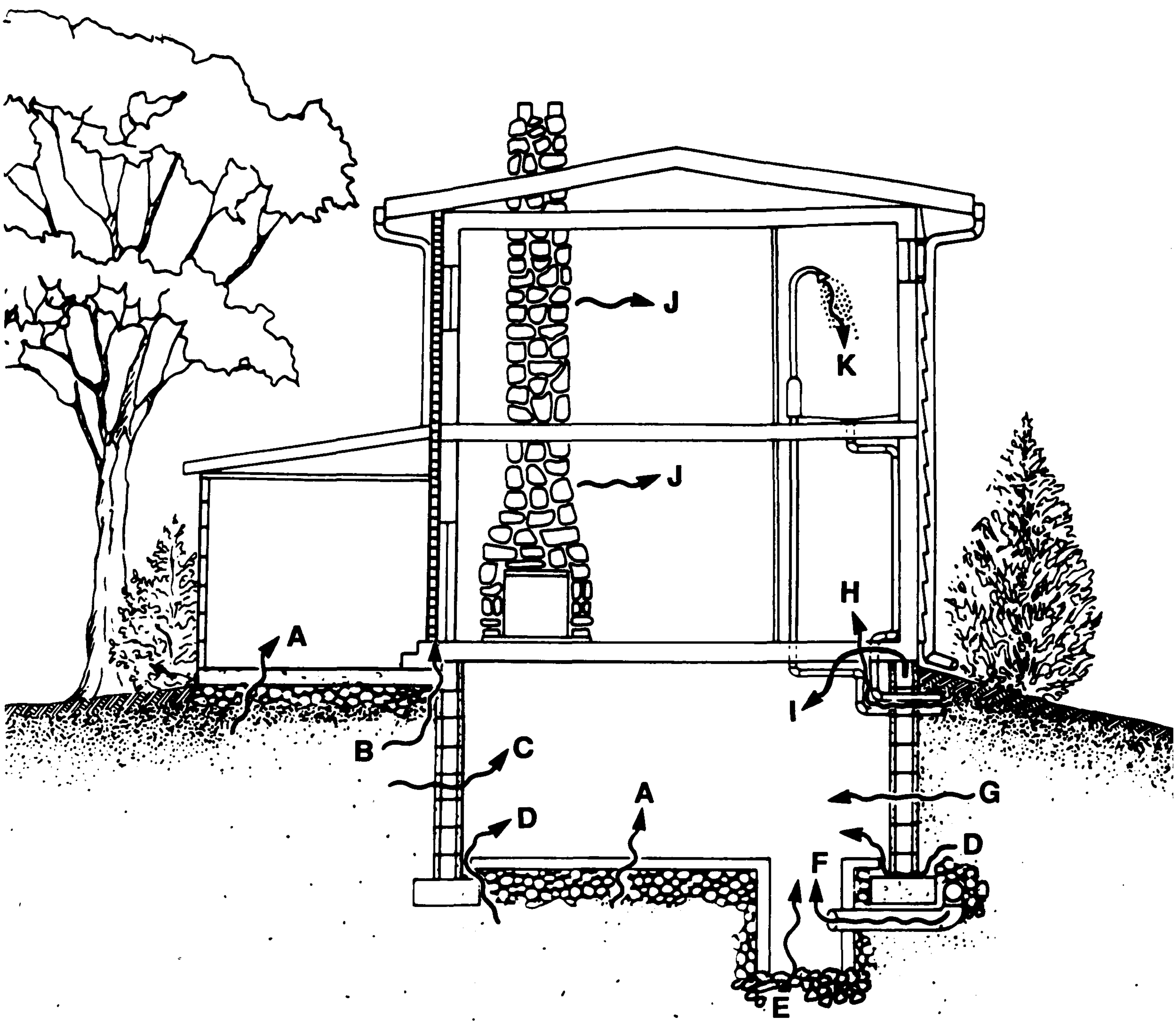
** pCi/l, the abbreviation for pico Curies per liter, is used as a radiation unit of measure for radon. The prefix "pico" means a multiplication factor of 1 trillionth. A Curie is a commonly used measurement of radioactivity. WL, the abbreviation for Working Level, is used as a radiation unit of measure for the decay products of radon. The relationship between the two terms is generally 200 pCi/l = 1 WL.*
*** The generally accepted rule of thumb for emanation of radon gas from water is: 10,000 pCi/l of radon in water will normally produce a concentration of about 1 pCi/l of radon in indoor air.*



MAJOR RADON ENTRY ROUTES

A. Cracks in concrete slabs
B. Spaces behind brick veneer walls that rest on uncapped hollow-block foundation
C. Pores and cracks in concrete blocks
D. Floor-wall joints
E. Exposed soil, as in a sump
F. Weeping (drain) tile, if drained to open sump
G. Mortar joints
H. Loose fitting pipe penetrations
I. Open tops of block walls
J. Building materials such as some rock
K. Water (from some wells)

Figure 1

standards for correlating the results of soil tests at a building site with subsequent indoor radon levels. The variety of geological conditions in the United States will probably continue to preclude establishment of any all-inclusive, nationwide standards for such correlation. We can, however, estimate the radon potential at a building site based on factors other than soil tests. If the answer to any of the following questions is yes, radon problems might be anticipated and radon reduction features should be considered for inclusion in construction plans.

- Have existing homes in the same geologic area experienced elevated radon levels? ("Same geologic area" is defined as an area having similar rock and soil composition characteristics.) State or regional EPA offices may be able to assist in obtaining this information.
- What are the general characteristics of the soil? State and local geological or agricultural offices can normally help in providing answers to the following questions on soil:
—Is the soil derived from underlying rock that normally contains above-average concentrations of uranium or radium, e.g., some granites, black shales, phosphates or phosphate limestones?
—Is the permeability of the soil and underlying rock conducive to the flow of radon gas? Note that soil permeability (influenced by grain size, porosity, and moisture content) and the degree to which underlying and adjacent rock structures are stable or fractured can significantly affect the amount of radon that can flow toward and into a home.
- If the source of water to the site is going to be a local or onsite well, have excessive levels of radon been detected in other wells within the same geologic area? (Levels measured above 40,000 pCi/l of water could alone produce indoor radon concentrations of about 4 pCi/l or above. Such levels are considered excessive.) State or local health agencies, departments of natural resources, or environmental protection offices may be able to assist in providing this information. Testing well water for radon before the home is built could provide an additional indication of a potential radon problem. If excessive radon levels are confirmed, a granular activated-carbon filtration system or an aeration system might be designed into the plumbing plan.

Construction Techniques

Some of the radon prevention techniques discussed below are common building practices in many areas and, in any case, are less costly if accomplished during construction. Costs to retrofit existing homes with the same features would be significantly higher. Although these construction techniques do not require any fundamental changes in building design, there is a continuing need for quality control, supervision, and more careful attention to certain construction details. Construction techniques for minimizing radon entry can be grouped into two basic categories:

- Methods to reduce pathways for radon entry.
- Methods to reduce the vacuum effect of a home on surrounding and underlying soil.

Typically, the techniques in both categories are used in conjunction with each other.

Methods to Reduce Pathways for Radon Entry (Figure 2)

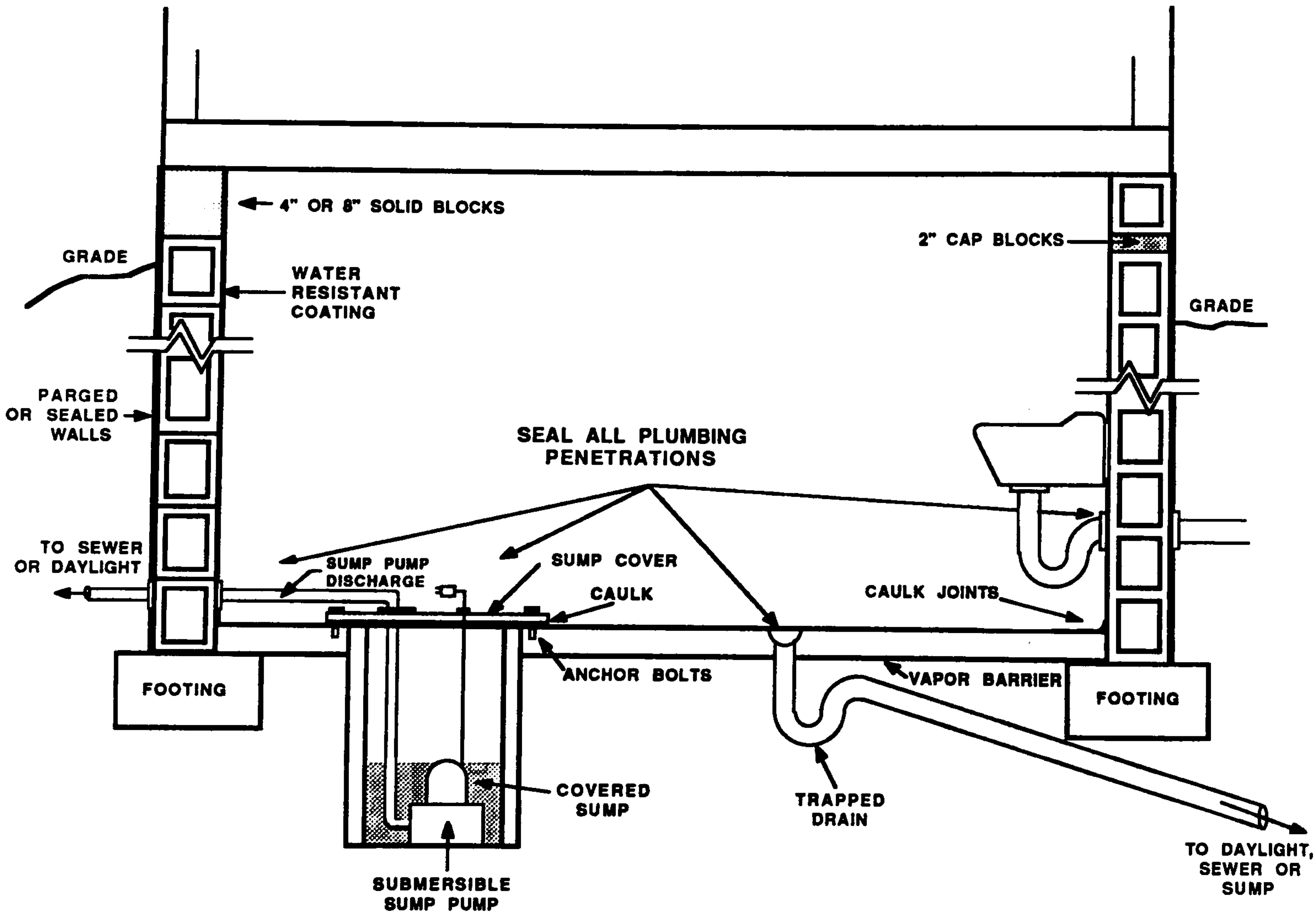
In Basement and Slab-on-Grade Construction:

- Place a 6-mil polyethylene vapor barrier under the slab. Overlap joints in the barrier 12 inches. Penetrations of the barrier by plumbing should be sealed or taped, and care should be taken to avoid puncturing the barrier when pouring the slab.
- To minimize shrinkage and cracks in slabs, use recommended water content in concrete mix and keep the slab covered and damp for several days after the pour.
- To help reduce major floor cracks, ensure that steel reinforcing mesh, if used, is imbedded in (and not under) the slab. Reducing major cracks in footings, block foundation, and poured-concrete walls will reduce the rate of radon entry. Radon can, however, enter homes through even the smallest of cracks in concrete slabs and walls if a driving pressure is applied to those surfaces.
- The most common radon-entry pathways are inside perimeter floor/wall joints and any control joints between separately poured slab sections. To reduce radon entry through these joints, install a common flexible expansion joint material around the perimeter of the slab and between any slab sections. After the slab has cured for several days, remove or depress the top 1/2 inch or so of this material and fill the gap with a good quality, non-cracking polyurethane or similar caulk. Similar techniques for sealing these joints may also be used.
- In some areas, basement slabs are poured with a French Drain channel around the slab perimeter. To be effective, this moisture control technique requires that the floor/wall joint be open to permit water to seep out into the sub-slab area. To reduce radon entry through such open joints, it may be necessary to install a perforated drain pipe loop under the slab, adjacent to the footing and imbedded in aggregate, and to tie this pipe into a sub-slab ventilation system to draw radon gas away from the French Drain joint (Figure 4). For additional information on water control techniques, refer to National Association of Home Builders (NAHB) publication *Basement Water Leakage: Causes, Prevention, and Correction.*
- When building slab-on-grade homes in warm climates, pour the foundation and slab as a single (monolithic) unit. If properly insulated below grade-level, shallow foundations and slabs can also be poured as a single unit in cold climates.
- Remove all grade stakes and screed boards and fill the holes as the slab is being finished. This will prevent future radon pathways through the slab, which might otherwise be created as imbedded wood eventually deteriorates.
- Carefully seal around all pipes and wires penetrating the slab, paying particular attention to bathtub, shower, and toilet openings around traps.
- Floor drains, if installed, should drain to daylight, a sewer, or to a sump with pump discharge. Floor drains should not be drained into a sump if such a pit will be used as part of a sub-slab ventilation system. Suction on the sump could be defeated by an open line to the floor drain.
- Sumps should be sealed at the top. In closed sumps used for sub-slab

ventilation systems, the continuous flow of moist air through the sump can cause rapid corrosion of exposed sump pump motors. For this reason, submersible-type sump pumps are recommended for closed-sump applications.

In Basement and Crawl space Construction:

- Seal or cap the tops of hollow-block foundation walls using one of the techniques shown in Figure 2.
- Carefully seal around any pipe or wire penetrations of below-grade walls.
- Exterior block walls should be parged and coated with high-quality vapor/water sealants or polyethelene films. For additional information on wall sealing, refer to NAHB publication *Basement Water Leakage: Causes, Prevention, and Correction.* Several new products for use on exterior walls are designed to provide an airway for soil gas to reach the surface outside the wall rather than being drawn through the wall. Similar materials may also be used in sub-slab ventilation applications.
- Interior surfaces of masonry foundations may be covered with a high-quality, water-resistant coating.
- Heating or air-conditioning ductwork that must be routed through a crawl space or beneath a slab should be properly taped or sealed. This is particularly important for return air ducting, which is under negative pressure. Due to difficulty in achieving permanent sealing of such ductwork, it may be advisable to redesign heating and ventilating systems to avoid ducting through sub-slab or crawl space areas, particularly in areas where elevated soil radon levels have been confirmed.
- Install air-tight seals on any doors or other openings between basements and adjoining crawl spaces.
- Seal around any ducting, pipe, or wire penetrations of walls between basements and adjoining crawl spaces, and close any openings between floor joists over the dividing wall.
- Place a 6-mil polyethelene vapor barrier on the soil in the crawl space. Use a 12-inch overlap and seal the seams between barrier sections. Seal edges to foundation walls.



METHODS TO REDUCE PATHWAYS FOR RADON ENTRY

Figure 2

Methods to Reduce the Vacuum Effect (Figure 3)

- Ensure that vents are installed in crawl space walls and are sized and located in accordance with local building practices. Adequate ventilation of crawl spaces is the best defense against radon entry in crawl space-type homes.
- Reduce air flow from the crawl space into living areas by closing and sealing any openings and penetrations of the floor over the crawlspace.
- To reduce the stack effect, close thermal bypasses such as spaces around chimney flues and plumbing chases. Attic access stairs should also be closed and sealed. (Note: Because of potential heat buildup, most codes prohibit insulating around recessed ceiling lights. Such lights should therefore be avoided in top-floor ceilings. As an alternative, use recessed ceiling lights designed to permit insulation or "hi-hat" covers and seal to minimize air leakage.)
- Install ducting to provide an external air supply for fireplace combustion.
- In areas frequently exposed to above-average winds, install extra weather sealing above the soil line to reduce depressurization caused by the Venturi effect. Such sealing will also save energy and reduce the stack effect.
- Air-to-air heat exchange systems are designed to increase ventilation and improve indoor air quality. They may also be adjusted to help neutralize any imbalance between indoor and outdoor air pressure and thus reduce the stack effect of the home. They should not, however, be relied upon as a stand-alone solution to radon reduction in new construction. (A slightly positive pressure, in the basement, may contribute to reducing radon flow into a home.)

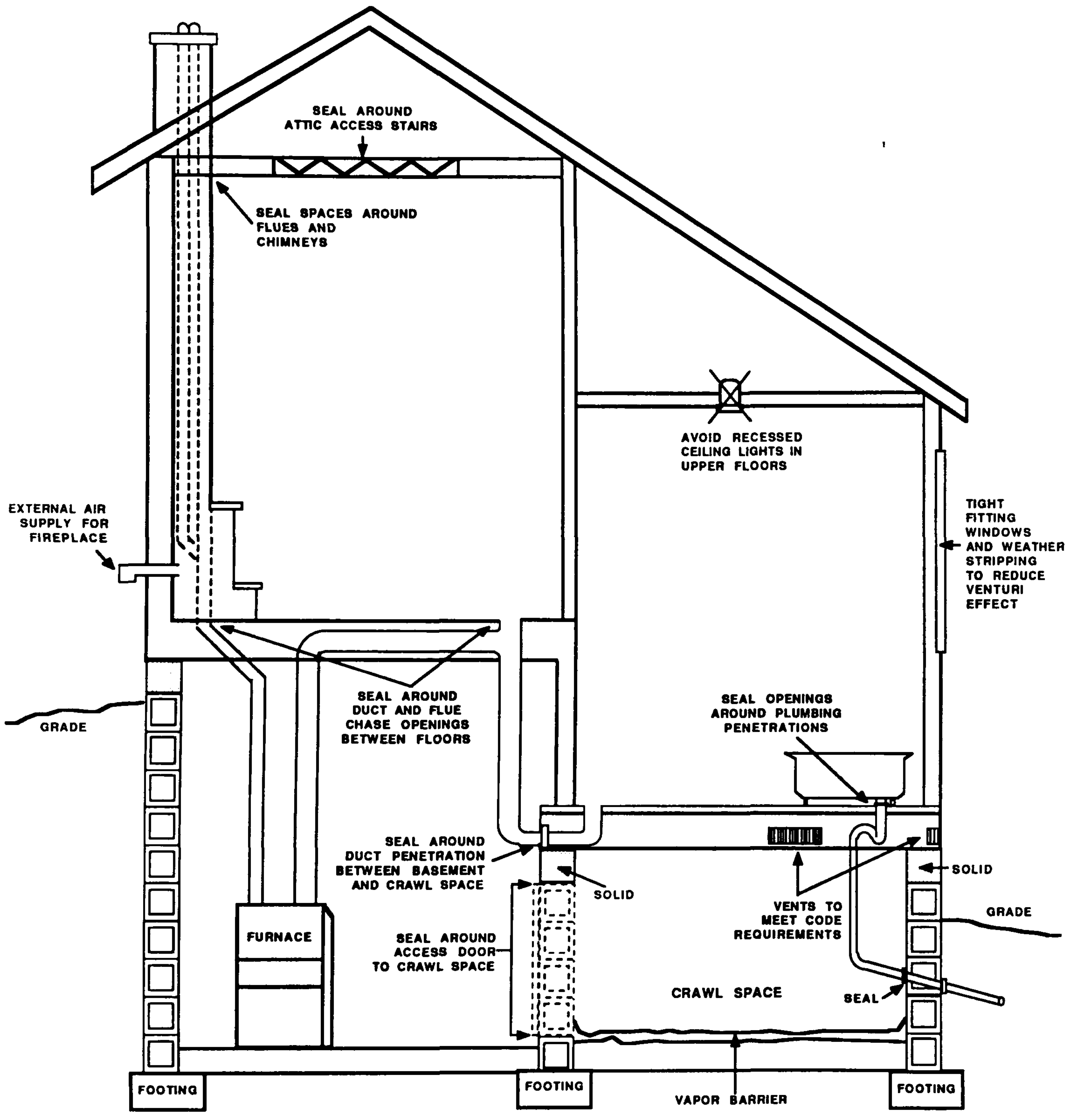
Construction Methods That Will Facilitate Post-Construction Radon Removal (Figure 4)

Recognizing that radon prevention techniques may not always result in radon levels below the suggested guideline of 4 pCi/l average annual exposure, there are several additional construction techniques that can be used to facilitate any post-construction radon removal that may be required.

- Before pouring a slab, fill the entire sub-floor area with a layer (4 inches thick) of pea gravel or larger, clean aggregate to facilitate installation of a sub-slab ventilation system.
- Lay a continuous loop of perforated 4-inch diameter drain pipe around the inside perimeter of the foundation footing. Run the vent from this loop into the side of a closed sump that can, if necessary, be equipped with a fan-driven vent to the outside. In this configuration, the drain pipe loop can aid in water seepage control as well as radon reduction.
- As an alternative to the vented interior drain pipe loop, a similarly vented exterior loop can be laid outside the foundation footing.
- In areas where water seepage into below-grade spaces is not a problem and sump pumps are not installed, exterior or interior drain pipe loops can be stubbed-up outside the home or through the slab and can be available for use as sub-slab ventilation points if needed.
- The soil beneath a slab can also be ventilated using the following technique: Prior to pouring the slab, insert (in a vertical position) one or more short (12-inch) lengths of 4-inch minimum diameter PVC pipe into the sub-slab aggregate and cap the top end. After construction is complete, these standpipes can, if necessary, be uncapped and connected to one or more convection stacks or fan-driven vent pipes. When positioning these standpipes, choose locations permitting venting to the roof through already planned flue or plumbing chases, interior walls, or closets. In homes where flue or other chases are restricted in size or not easily accessible, it may be less expensive to go ahead—during the framing and rough-in plumbing/electric phase of construction—and complete the vent pipe hookup, temporarily terminating the vent in the attic along with an electric outlet for future fan installation. Experience has shown that in homes with higher radon levels—above 20 pCi/1—convection (passive) venting may not produce acceptable radon reductions. If lower radon levels are expected and passive venting is attempted, performance is improved by using a 6-inch diameter vent routed straight from the floor through the roof, with minimum bends.

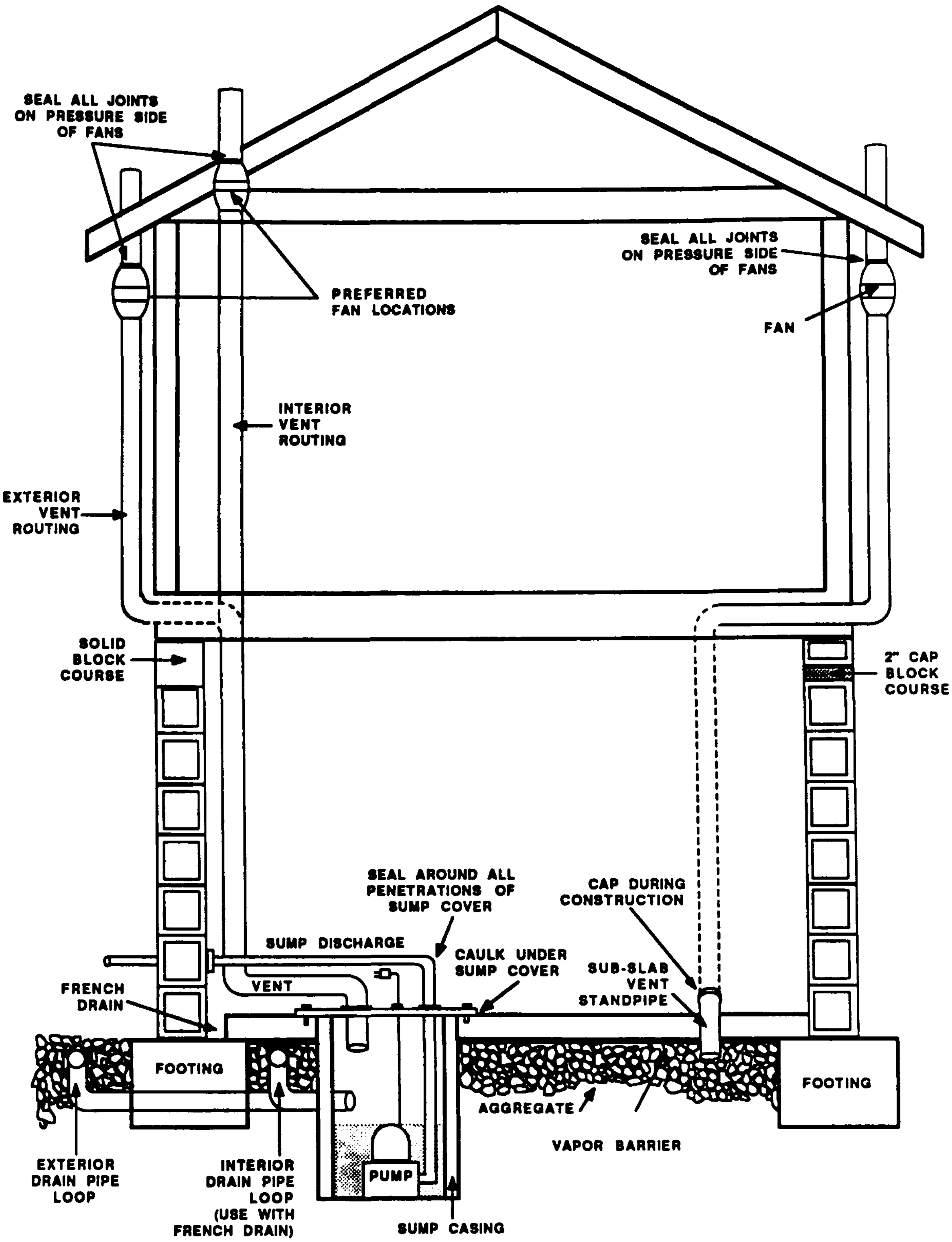
Drilling 4-inch holes through finished slabs for insertion of vent pipes is an alternative to this technique.

- To create the necessary convection flow, radon prevention techniques that involve passive venting normally require stacks that pass through the floors and roof. When active (fan-driven) systems are installed, venting through to the roof is still preferred. Recognizing, however, that active systems can be vented through the band joist or below-grade walls to the outside, it is considered advisable in such active systems to position the exit point of the vent pipe at or above the eave line of the roof and away from any doors or windows. This will preclude any possible recirculation of air containing concentrated radon gas back into the house.
- In homes where an active (fan-driven) sub-slab ventilation system has been installed, it may be necessary to provide make-up air to avoid back drafting.



METHODS TO REDUCE THE VACUUM EFFECT

Figure 3



METHODS TO FACILITATE POST-CONSTRUCTION RADON REMOVAL

Figure 4

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Source of Information

If you would like further information or explanation on any of the points mentioned in this booklet, you should contact your State radiation protection office or home builders association.

If you have difficulty locating these offices, you may call your EPA regional office listed below. They will be happy to provide you with the name, address, and telephone number of these contacts.

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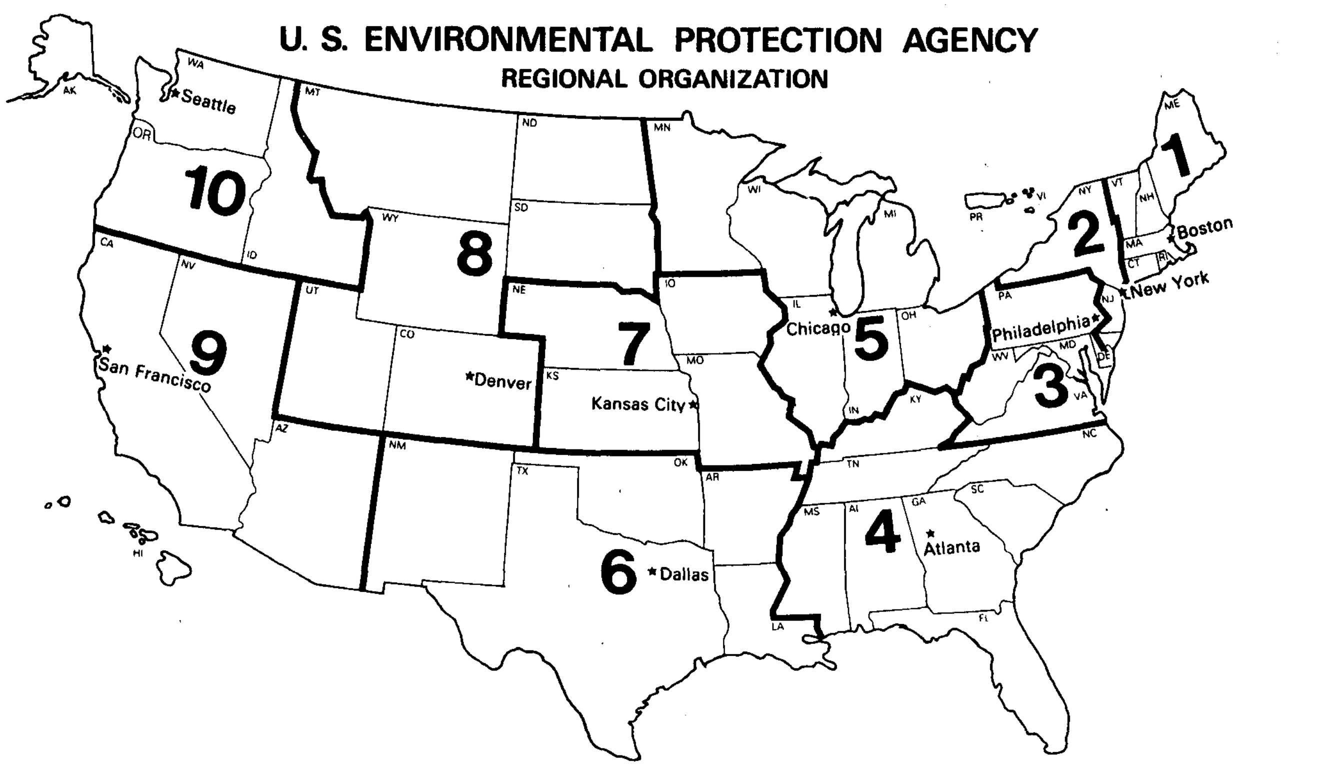

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