

**RADON MITIGATION IN NEW CONSTRUCTION: FOUR CASE STUDIES**

John W. Spears and Mark S. Nowak  
NAHB National Research Center  
Upper Marlboro, Maryland

**ABSTRACT**

Policies, techniques, and costs relating to radon mitigation practices of builders are presented in the four case studies. The studies include construction details used by two custom builders and two large-volume builders that operate in a regional\national market.

**INTRODUCTION**

Recent reports (1,2) describing the widespread presence of radon in homes across the United States have presented the building community with a set of problems that did not exist several years ago. Since most early radon mitigation research concentrated on remediation of existing structures, technical information on reducing radon exposure in new construction was not initially available. The lack of a recognized procedure to correlate pre-construction radon soil levels to post-construction indoor levels further complicated matters. Builders were confronted with the responsibility to mitigate a naturally occurring potential health risk without the benefit of technical guidance from the regulatory community, and without a method to determine if a problem existed at their site.

In response to the building community's problem, the U.S. Environmental Protection Agency (EPA) established the Radon Information Clearinghouse (RICH) under the direction of the NAHB National Research Center (NAHB\NRC). An initial task of RICH was to work with EPA to develop builder guidelines for radon reduction in new construction. The result was the publication, Radon Reduction in New Construction-An Interim Guide (3), published jointly by NAHB\NRC and EPA. The Interim Guide provides guidance to builders for mitigating potential radon problems. The techniques presented in the guide recognize the need to keep housing affordable. Therefore, attention was focused on using conventional materials and construction practices that minimize both radon problems and costs.

## **BUILDER RESPONSE**

In order to document the effectiveness of EPA and NAHB\NRC programs, NAHB\NRC began tracking the response of builders across the United States. This paper examines the response of four home builders; two large-volume builders operating at the regional or national level, and two small-volume-custom home builders. Each case study discusses the builders basic view of radon, their sales approach, techniques used by the builder to reduce radon levels, and costs of the techniques used.

## **MITIGATION APPROACHES**

Radon mitigation techniques vary from builder to builder. Most builders generally combine one or more systems from the following three categories.

### **A. Passive Systems**

Passive systems provide a mitigation system designed to minimize entry routes, and may also provide a vent stack as a passive escape route for radon gas. Systems of this type sometimes include an electrical rough-in for installation of a fan at a later date, if required.

### **B. Active Systems**

An active system typically includes the basic features of a passive system, with the addition of some mechanical equipment to activate the system. An axial fan is usually installed in the vent stack at the time of construction. Other features, including Heat Recovery Ventilators (HRV), air cleaners, and other mechanical equipment also fall into this category.

### **C. Rough-in Systems**

With the rough-in approach, the builder includes components of a mitigation system that would be difficult or costly to retrofit. Typical steps include installing a vapor barrier and stone base under concrete slabs, and a short section of pipe extending from the stone base to a point just above the top of the slab. This approach recognizes that all homes do not need radon reduction systems. Thus the home is fitted with the minimum features necessary to install a complete, low-cost system at a later date, if required. This approach reduces the possibility of an implied warranty that a completed system might imply.

## **CASE STUDY 1 - GARNET HOMES, INC.**

Garnet Homes builds approximately 100 full-basement homes each year in the northern Virginia suburbs of Washington, DC. Their interest in radon mitigation was prompted in response to reports by the U.S.

Environmental Protection Agency (EPA) and the local media describing the dangers of elevated indoor radon levels. In late 1986 and early 1987, Garnet Homes conducted a pilot testing program on a number of homes to gain a better understanding of radon mitigation practices. Armed with this experience, Garnet Homes developed a Radon Abatement Package (RAP) with assistance from NAHB/NRC, EPA, and several local consultants. An eight-page, color information brochure was subsequently developed to inform buyers of the potential presence of radon, and to discuss a limited radon warranty offered by Garnet Homes as a condition of sale.

The limited warranty offered by Garnet Homes lists limitations on the purchaser's use and operation of the RAP package, and limits the builders responsibility and liability thereunder. The limited warranty agreement also outlines the actions Garnet Homes will take to assure proper operation of the RAP.

Garnet Homes tests Each home twice during the first year of operation and reports results to the homeowner. If either test indicates radon levels in excess of the EPA action level of 4.0 pCi/L, then corrective action necessary to reduce levels below the action level is performed within 30 days. Follow-up testing is provided after any corrections.

#### **MITIGATION TECHNIQUES**

The Garnet Homes approach to radon mitigation is divided into three parts: reduce entry routes; reduce negative pressure in the basement; and install subslab ventilation.

##### **Reducing Radon Entry Routes**

Garnet Homes procedures to reduce radon entry routes include caulking and sealing of slab edge joints, and penetrations through basement floors and walls. Specific precautions to minimize cracks and other radon routes include:

- o installing an air tight lid and gas-tight ejector pit for sump holes;
- o using plumbing traps on floor condensate lines;
- o tooling the slab edge to receive a bead of caulk;
- o caulking visible cracks in the slab;
- o sealing wall tie joints;
- o caulking basement floor and wall penetrations at sewer and water lines;
- o eliminating ash dump doors in basements;
- o installing support posts before pouring slabs;
- o adding 3/4" to 1" of sand on pier footings;
- o providing a poly sleeve around posts;
- o adding brick or block and reinforcing rods at the overdig near footings (see Figure 1).

### Reducing Negative Pressure

Reducing negative pressure in the basement is the second step in the Garnet Homes RAP. Pressure control consists primarily of reducing the stack effect, and providing fresh air intakes for heating equipment. Specific precautions include:

- o providing an outside air source to fireplaces, gas water heaters and furnaces;
- o installing a door sweep on the bottom of the basement door;
- o caulking and sealing around pipe and wire penetrations at the first floor level;
- o sealing around fixtures, windows, smoke detectors, and other holes or cracks that contribute to decreased basement pressures.

### Subslab Ventilation

The final step in Garnet Homes' RAP is the installation of a complete subslab ventilation system including 4-inches of stone and interior perimeter piping under the slab, a 4" vertical PVC riser vented through the roof with an exhaust fan in the attic, and a low-pressure warning device to signal a malfunction in the system. Figure 2 shows the layout of the typical Garnet Homes subslab ventilation system.

### **COST OF THE GARNET HOMES PROGRAM**

The total Garnet Homes package costs \$1,361 more than "typical" northern Virginia construction. A detailed break-down of costs for a three-level 2000 square foot home is provided in Table 1.

### **CASE STUDY 2 - NV RYAN HOMES**

NV Ryan Homes builds approximately 8400 homes each year throughout the U.S. In late 1987, NV Ryan announced plans to install radon mitigation features in selected new homes in the Maryland area. An extensive radon testing program with the cooperation of the USEPA is currently being conducted to determine the effectiveness of the abatement features. Plans to expand the radon program to divisions outside the Maryland area will be finalized as more information becomes available.

NV Ryan notifies their buyers of the potential presence of radon and suggests that the buyer may want to test the home after occupancy. If a home owner determines that the levels of radon are unacceptable, then the subslab vent can be completed and activated by the owner.

### **MITIGATION TECHNIQUES**

Since NV Ryan builds on different types of foundations, they have developed a mitigation strategy for each type. Foundation types used by NV Ryan include slab-on-grade, basement (partial and full depth); crawl

space; and attached crawl space. The NV Ryan radon abatement package for slabs-on-grade, and full and partial basements can be categorized as a rough-in system. It consists of a series of steps to reduce radon entry routes, and also provides a sub-slab vent "rough-in". Radon abatement for NV Ryan homes on crawl space foundations consists of a passive system relying on sealing of entry routes and ventilation.

#### Basement and Slab-on-grade

NV Ryan applies features to full depth and partial basement foundations that are designed to reduce radon entry routes, and enable a subslab ventilation system to be added later at minimal cost. In basement construction, a 6 mil polyethylene barrier lapped 12 inches at joints and 2 inches up walls is installed over a 4" bed of stone under the slab.

Specially molded sump crocks with gasketed covers are installed only if needed for water control. A sub-slab manifold of 4" perforated pipe is provided under the slab near the center of the foundation (see Figure 3). A tee fitting or 90° bend is used to extend the manifold 4" above the floor, where it is capped. If a sump is used, then the tee or 90° bend is eliminated, and the vertical riser is tapped into the sump lid. Joints in supply and return ducts in the basement are taped. The floor wall joint and other penetrations are tooled to accept a bead of urethane caulk. Grade stakes, plumbing supports, and other rough-in items are removed from the slab prior to finishing. A 4" solid PVC pipe is installed from the basement ceiling to the attic space or roof. Condensate drains that run to a sump crock or foundation drain tile use a 3/4" swing check valve. Where floor drains are provided, rubber or neoprene rings are used to seal around the pipe at the drain housing. On split level homes, 4 foot walls that adjoin a full basement are constructed with 4" solid top block, an "L" top block, or an "L" form on the top of poured walls to prevent a through joint between the area under the slab and the lower basement.

Slab-on-grade foundations are built using the same basic procedures. Bathtubs in slab-on-grade homes are fitted with above floor rough-ins. Pits for tub traps are sealed with poured asphalt or poured urethane as shown in Figure 4. Forms or spacers around water closet rough-ins are not used; Concrete is poured tight to the 4" riser. When installing the water closet, the 4" riser is trimmed to the floor line, and a bead of sealant is applied to the joint between the pipe and the floor (see Figure 5). A 3" hub flange (4" O.D.) is then inserted into the pipe.

#### Crawl Space Houses

Crawl spaces built by NV Ryan are non-conditioned. Radon abatement features include ventilation of the crawl space area and installation of a 6 mil polyethylene ground cover. All floor penetrations, including

rough cuts around heating registers, are tightly sealed. Joints in duct work within the crawl space are taped.

#### Attached Crawl Space

NV Ryan employs two options to treat an attached crawl space. With the first option, the crawl space area is treated as a typical crawl space, and the attached habitable area is treated as a basement. The wall between the two areas is tightly sealed and fitted with a gasketed access panel to reduce air flow into the habitable space. With the second option, the crawl space floor is covered with a thin concrete slab and the entire area is treated as a basement.

#### **COST OF THE NV RYAN RADON ABATEMENT PACKAGE**

NV Ryan's additional costs over conventional construction due to their radon abatement program in the Maryland area are shown in Table 2. Mitigation procedures for crawl spaces do not add to costs, since these procedures have always been standard practice for NV Ryan Homes.

#### **CASE STUDY 3 - CI/MITCHELL & BEST**

CI/Mitchell & Best builds 400 to 500 upper end homes each year in Montgomery county and surrounding areas of Maryland. All of their homes have full basements and sell from \$400,000 and up. In early 1987 CI/Mitchell & Best developed "Radon Reduction Construction Procedures" for their homes based on the EPA publication "Radon Reduction Methods. A Homeowners Guide" (4). The "Radon Reduction Construction Procedures" are being used in all CI/Mitchell & Best homes for which footings were poured after July 1, 1987. Before closing, buyers are given copies of the CI/Mitchell & Best procedures, EPA's Citizens Guide, (5) and the EPA Home Owners Guide. A form which acknowledges receipt of this information is included with the sales contract.

CI/Mitchell & Best has also modified their contract and sales agreements to cover modifications necessitated by their radon reduction practices. They do not accept radon test results as a condition of sale and do not test homes for radon. If buyers wish to test a home before closing, they may do so only after the sales contract has been signed. A "limited right to entry agreement for radon testing" is included in the contract to allow the purchaser to test the home, and to indemnify the builder against all liability associated with the test. CI/Mitchell & Best disclaims any warranty regarding the test condition or results, and states that the test results will not effect the sales contract.

If the buyers' test reveals an unacceptable level of radon, then follow-up work on the home is performed at the buyers' option. The cost of follow-up work is paid by the buyer, although CI/Mitchell & Best will perform the work at cost.

#### **MITIGATION TECHNIQUES**

The CI Mitchell & Best system includes caulking and sealing of radon entry routes in combination with a passive subslab ventilation system. The basement sub-slab soil ventilation system is installed using continuous perforated perimeter drain lines laid in 6-inches of gravel and connected to a sealed sump crock. A passive exhaust stack is provided from the sump through the roof or a side wall. All joints in basement concrete slabs are caulked with polyurethane where the slab abuts walls, columns, DWV lines and the sump crock. Fireplaces are supplied with an outside air source to minimize in-house depressurization. All walls are poured concrete with increased horizontal reinforcing steel. Plasticizers are added to concrete to minimize shrinkage cracks. Basement floors are treated with a concrete sealer unless a resilient floor covering is used. A rough-in is provided for an air-to-air heat exchanger in finished basements.

In addition, CI/Mitchell & Best offers several optional items that are available at builders' cost, including an air-to-air heat exchanger, an electric hot water heater in lieu of gas and a fan to activate the ventilation system.

#### **COST OF THE CI/MITCHELL & BEST RADON PROGRAM**

Total cost of the standard CI/Mitchell & Best radon features is approximately \$1381.00. A breakdown of costs for all standard and optional items is provided in Table 3. Costs include installation and are representative of a single-family detached home with an in-ground basement of approximately 1867 square feet.

#### **CASE STUDY 4 - RYLAND HOMES**

Ryland Homes, based in Columbia, Maryland, builds approximately 9500 homes per year in 13 states. In February 1988, Ryland began incorporating a standard set of details to reduce radon levels in all homes built in their mid-Atlantic region. Similar steps have more recently been taken in Ryland's Florida division. Other divisions of Ryland Homes are also preparing radon abatement packages tailored to meet local building practices.

The mid-Atlantic division of Ryland developed their basic package primarily for finished basements and conditioned crawl spaces (i.e., a crawl space with a 2 inch concrete "mud slab"). The same package is used for slab-on-grade homes, although all references relating to treatment of foundation walls and sump holes are deleted. The Florida division's program was developed solely for slab-on-grade foundations, since these are the only type that Ryland builds in Florida. In both divisions, a

package of specifications was prepared for each building trade to follow. A detailed checklist is used in the field to verify compliance with the specifications, and must be signed by the appropriate supervisor prior to payment for any work. Ryland does not test for radon before or after construction.

#### **MITIGATION TECHNIQUES**

The Ryland Homes radon package can be categorized as a passive system. It includes sealing and caulking of entry routes in combination with a passive subslab ventilation system. Details of the package used in their Mid-Atlantic and Florida divisions are presented below.

#### **Mid-Atlantic Region**

The Mid-Atlantic regional radon abatement package employs a passive mitigation system. Entry routes are sealed by caulking the joint around the slab perimeter, and around sump crocks, condensate lines, plumbing lines, and all other penetrations of the slab and walls. A 6 mil polyethylene barrier lapped 12 inches at joints is used under the slab. Polyethylene is also used as a wrap around pipes and other protrusions of the slab. Sump crocks and covers are designed to be air-tight.

The possibility of radon entry through cracks in the slab is reduced by adding wire mesh reinforcing. One-half by four inch expansion material is used at perimeter joints. Concrete is a minimum of 2500 psi compressive strength with a maximum 6-inch slump. Grade stakes are removed as the floor is poured. All foundation walls in the region are constructed of poured concrete, and are covered with a bituminous coating or other approved dampproofing material. In addition, a fresh air source is provided for all fireplaces.

A passive ventilation system is also included, consisting of a 4" PVC vent stack and a plumbing tee extended into a 4-inch layer of aggregate. Details of the Mid-Atlantic region's radon package are shown in Figures 6, 7, and 8.

#### **Florida Region (Slab-on-Grade)**

Radon mitigation in the Florida region is divided into two sub-regions: Orlando and South Florida, and the Tampa area. All Ryland homes in Florida are provided with a fresh air vent to the fireplace in addition to the features unique to each area.

The Orlando\South Florida area specifications were developed for a monolithic slab, and for a slab supported by a stem-wall. All monolithic slabs, including the garage, are poured over a continuous 6 mil polyethylene membrane lapped at least 12 inches at joints. All tears or punctures are sealed with clear vinyl pressure-sensitive tape before pouring. Protrusions through the slab are coated with a non-fibre asphalt base plastic cement. Specifications for stem wall slabs are essentially the same as for a monolithic slab with the exception that the top block

in the stem wall is filled solid at the time the slab is poured (See Figure 9).

Specifications for the Tampa area include those in the Orlando\South Florida area plus provisions for a passive subslab ventilation system. The subslab system differs from the typical system used in most areas due to the excessive local cost of stone (see Figure 10). A 4 inch gravel bed would cost approximately \$800 for the typical Ryland slab in Florida. Therefore, a 3 foot diameter by 2 foot deep centrally located gravel pit is used instead. A 4-inch tee set in the gravel connects to a 3-inch PVC stack that extends through the roof. This system is still under development and has not been finalized.

#### COST OF THE RYLAND HOMES RADON PROGRAM

A breakdown of incremental costs of the Ryland Homes radon program for detached-single-family homes and townhouses in the Mid-Atlantic region is provided in Table 4. Total cost of the Tampa subslab ventilation system is estimated to be approximately \$200.00. Other Florida costs were not available.

#### CONCLUSIONS

The case studies of radon mitigation programs of four builders produced the following important observations.

1. The builders relied on recommendations in the "Interim Guide" and other EPA literature to develop their radon mitigation programs.
2. Minimizing radon entry routes and subslab ventilation were the preferred techniques for radon mitigation among the builders studied.
3. The degree of response ranged from a minimal level consisting of sealing entry routes and a subslab rough-in (NV Ryan) to a maximum response level including an active subslab ventilation system, and a sealed combustion water heater and furnace (Garnet Homes).
4. Costs ranged from \$231 for a rough-in system (NV Ryan) to \$1,381 for the high end active system (CI/Mitchell & Best).
5. Florida builders need alternatives to the typical stone aggregate used in subslab ventilation systems.

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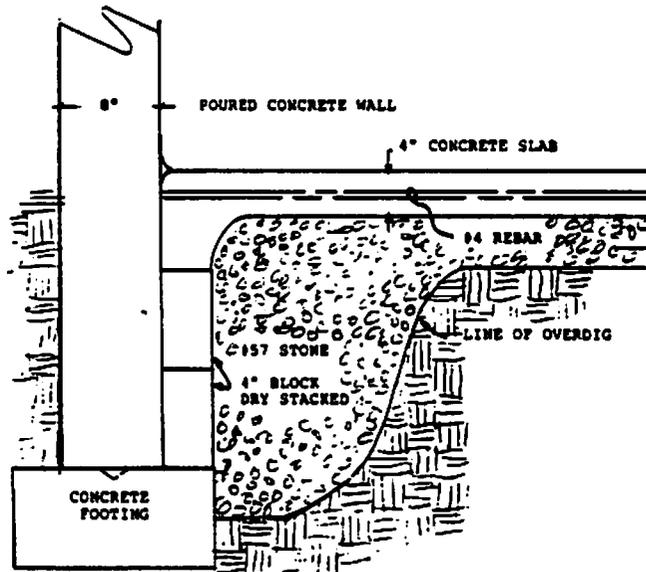


Figure 1

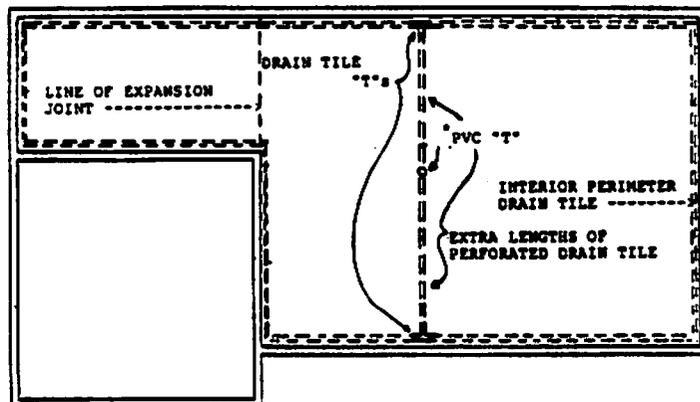


Figure 2

\*PVC "T" TO ACCEPT SUB SLAB VENT STACK

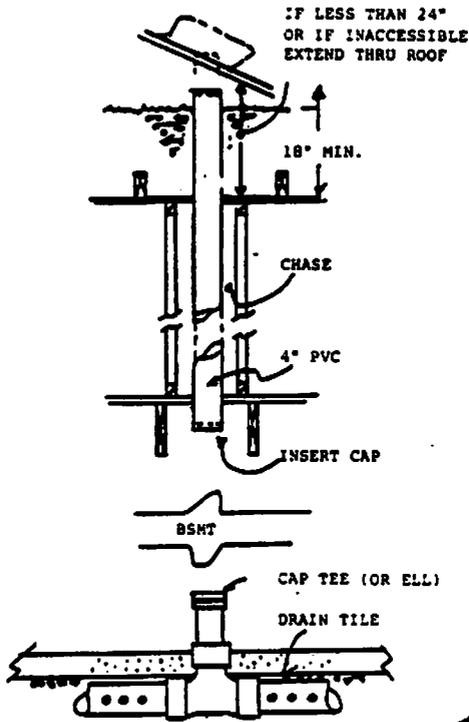


Figure 3

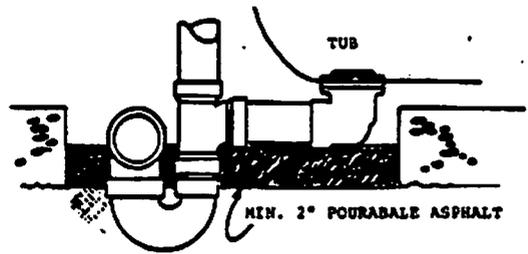


Figure 4

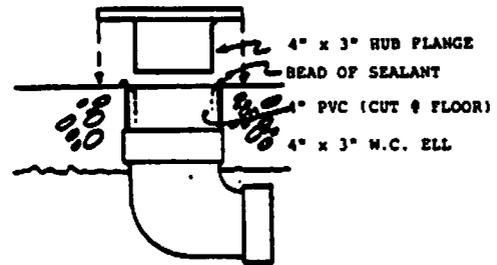


Figure 5

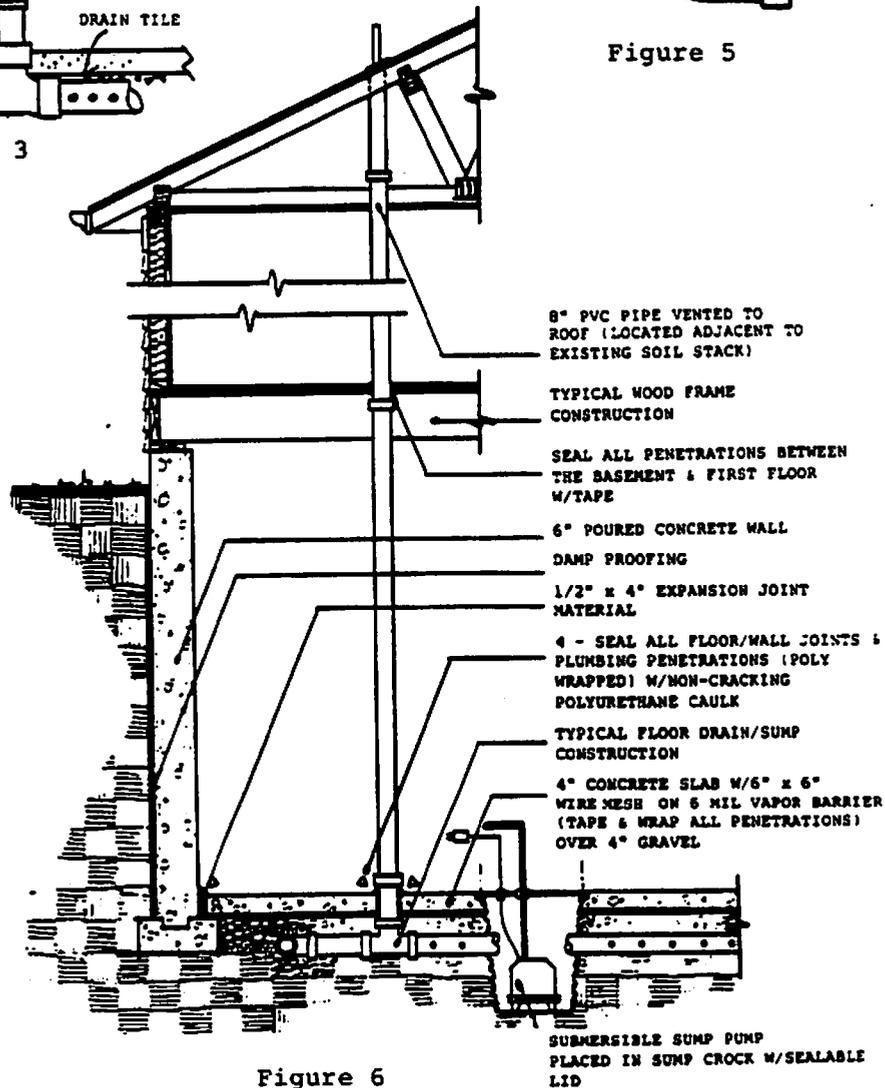


Figure 6

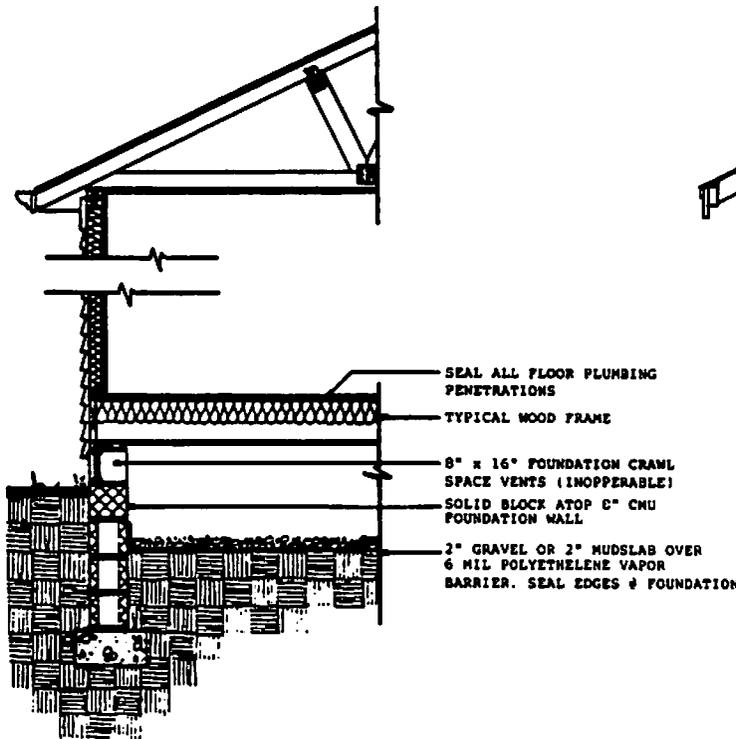


Figure 7

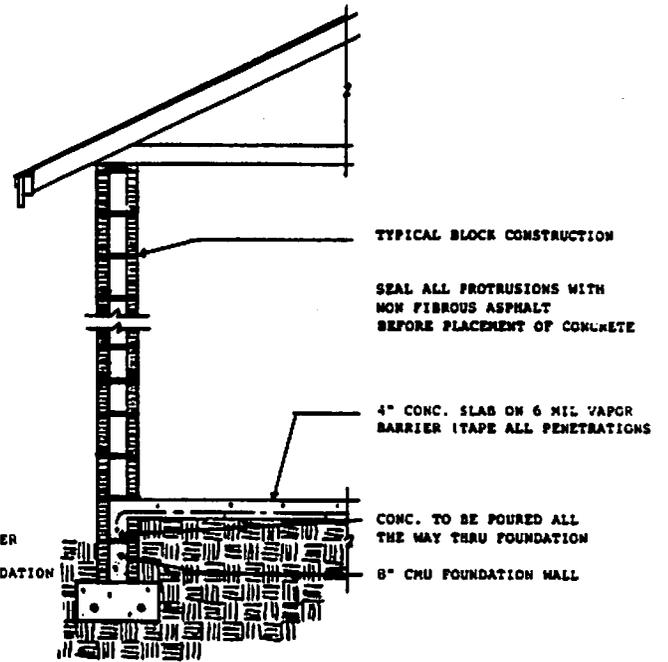


Figure 9

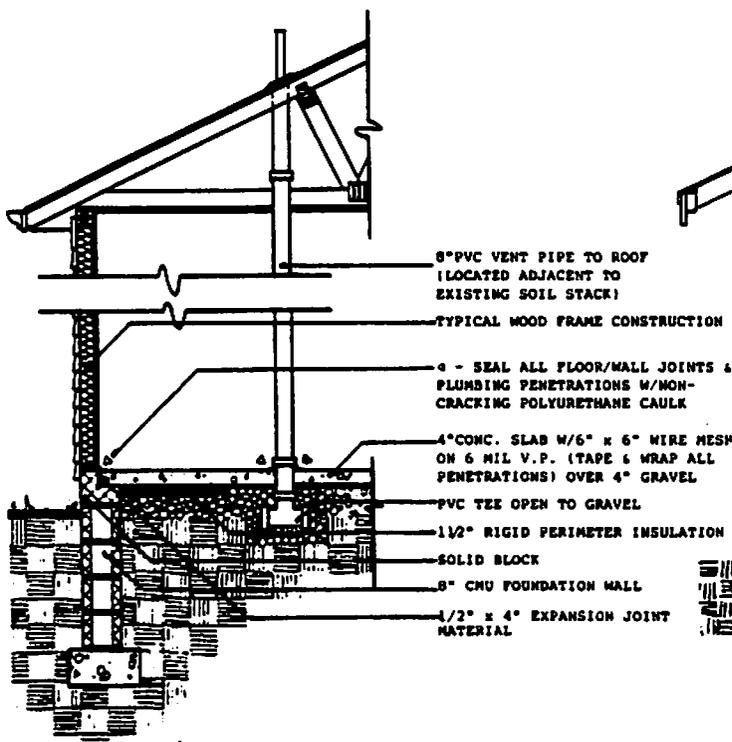


Figure 8

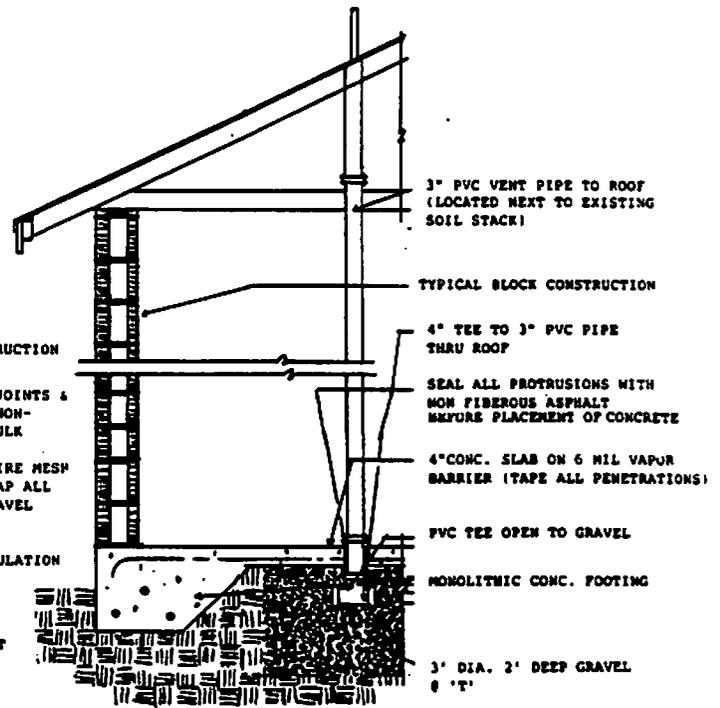


Figure 10

**TABLES**

**Table 1 Cost of the Garnet Homes Program  
(Source: Garnet Homes, Inc.)**

<u>Item</u>	<u>Sealing Entry Routes</u>	<u>Reducing Negative Pressure</u>	<u>Sub-Slab Ventilation System</u>	<u>Total</u>
Concrete	\$ 140	\$ 0	\$ 50	\$ 190
Plumbing*	0	155	125	280
Electrical	0	0	60	60
Heating**	0	395	0	395
Caulking	120	80	0	200
Roof Flashing	0	0	30	30
Fan and Decals	0	0	172	172
Weatherstripping	0	34	0	34
<b>TOTAL</b>	<b>\$ 260</b>	<b>\$ 664</b>	<b>\$ 437</b>	<b>\$ 1,361</b>

\*Includes direct vent water heater.

\*\*Includes direct vent furnace.

**Table 2 Cost for NV Ryan Homes Maryland Program**

<u>Feature</u>	<u>Cost</u>
4-inch PVC stack (basement ceiling to attic)	\$78.00
Caulk and seal wall\floor joint and other penetrations (also includes PVC fitting)	\$78.00
Check valve in condensate line	\$5.00
Sealed sump crock	<u>\$70.00</u>
<b>Total</b>	<b>\$231.00</b>

Table 3 Cost of CI/Mitchell & Best Radon Program

4 inch perforated drain in 2 inches additional gravel.	\$175.00
Sealed sump crock vented through the roof.	\$295.00
Caulking floor wall joint and penetrations.	\$75.00
Fireplace fresh air intake.	\$19.00
Additional foundation wall reinforcement and plasticizers and retarders added to concrete mix.	\$502.00
Concrete sealer.	\$280.00
Air-to-air heat exchanger rough in.	<u>\$35.00</u>
TOTAL	\$1,381.00
Optional equipment available to purchasers at cost:	
240 c.f.m. fan	\$175.00
NuTone AE-200 air-to-air heat exchanger.	\$1,265.00
83 gallon electric hot water heater in lieu of the standard 75 gallon gas heater.	\$70.00

Table 4 Costs for Ryland Homes Radon Program In the Mid-Atlantic Region

	Townhouse	Detached
Interior Concrete (Wire mesh and expansion material)	\$225	\$300
Plumbing tee, vent stack	\$125	\$130
Caulking	<u>\$160</u>	<u>\$200</u>
Total Cost	\$510	\$630