A Radon Guide *for* New Construction

by William Brodhead

Simple precautions can make your new homes radon-ready.

From the ever growing list of environmental concerns, radon has emerged as an unbeatable headline grabber. This leap to stardom is due, in part, to our basic fear of the unseen dangers of radiation. Radon can seep in unannounced into our sacred castle without a hint of its presence. Furthermore, high radon levels can zap us daily with the equivalent of multiple chest X-rays or dozens of packs of smoked cigarettes. The new home buyer who discovers that his dream house is uninhabitable due to high radon levels will be very upset with the building and its builder—a contractor's nightmare.

How likely is the scenario described above? In my area, the infamous Reading Prong, thousands of houses have been tested. Sixty percent have had radon readings in the basement during the heating season that are above the EPA recommended guideline of 4 pCi/l (4 pica-curies of radon per liter of air). It is likely that this average will carry over to new homes.

The courts have yet to decide whether the builder is liable for high radon readings in new homes. But if you want to stay on top as a builder, you'd be wise to learn how to build radon-resistant structures.

Unfortunately there are practically no research results out yet on radon-reduction techniques for new homes. But good research has been done on radon-reduction techniques in older houses, and the principles learned can be applied to new construction.

Learn the Basics

To effectively combat radon it is important to understand the principle of radiation and the forces that act on it. Radon is the by-product of the decay of radium in the soil. It is one of the noble gases, which means it doesn't like to "stick" to anything, but rather likes to float around for its short half-life of 3.8 days. Unfortunately this is just enough time for it to get up through the soil, into the lower level of the house, and upstairs into the kitchen and bedrooms. We measure this concentration in pico-curies per liter of air (pCi/l). The measurement of one pCi/l indicates approximately 2.2 alpha disintegrations per minute in a liter of air. What this means is that when the atom's life is over as radon, it doesn't die, but changes instead into another element, flinging an alpha particle out to crash into anything within an alpha's 1-inch range. Its new form, which will change four times in the next hour or so, we call a radon daughter. These daughters, or *progeny*, are charged, and unlike radon gas, they want to stick to anything they can grab on to. If it happens to be a piece of dust and that dust later gets stuck in a person's lungs, two more alpha particles could crash into some delicate lung cells. If this happens enough, over a long period of time, chances are that a lung cell could mutate and become cancerous. We measure radon progeny by collecting them on filter paper and counting the alphas coming off. This measure is called the *working level.*

The first concept to understand here is that radon is small and slippery. Compared to a hairline crack in the cellar floor, radon looks like a BB thrown into the Grand Canyon. Since it only takes a tiny concentration to get a basement over the EPA guideline of 4 pCi/l, you don't need much of an opening to let the gas in.

There are five basic ingredients necessary for radon to accumulate in the lower level of a house:

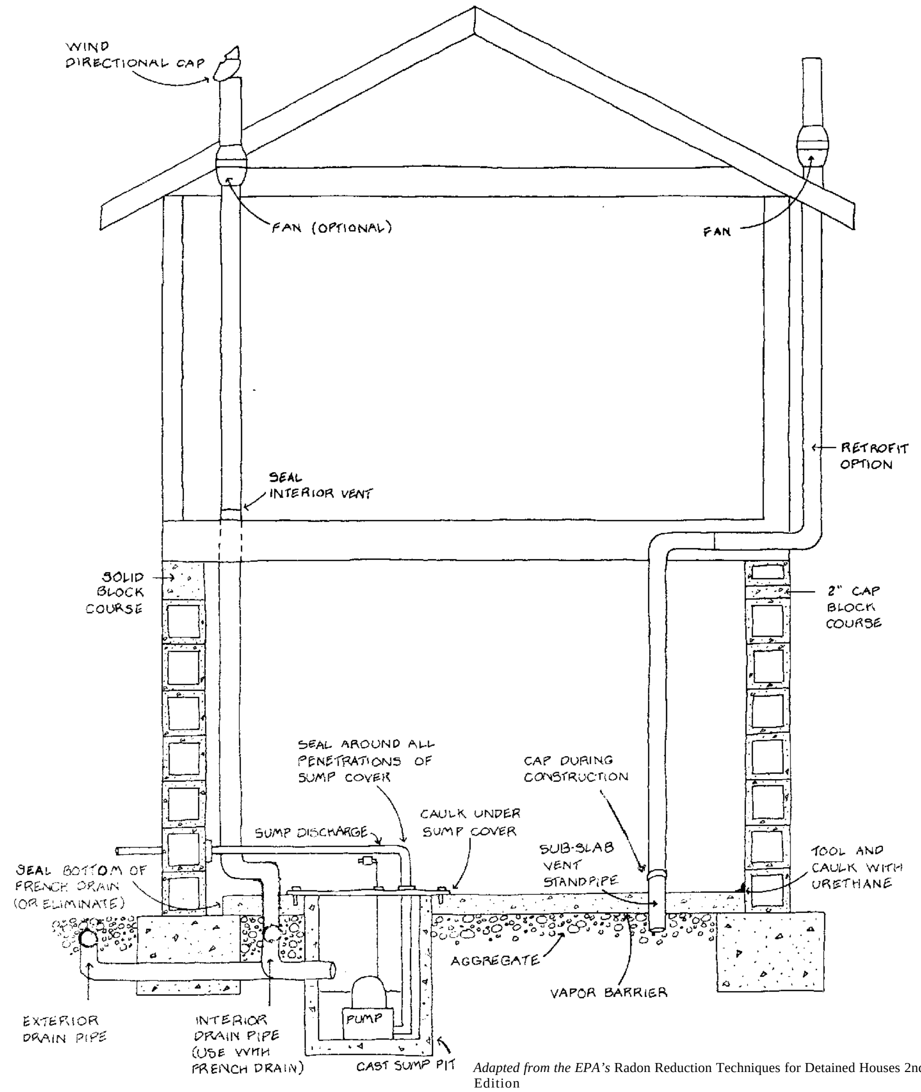
- Radon must be in the soil.
- The soil has to be porous.
- There have to be cracks in the floor or foundation large enough to let atoms through.
- The house must be negative in pressure compared to the sub-soil.
- The air changes in the house must be too few to carry pollutants away.

Of these factors, the one most people try to treat first is the cracks in the floor—that is, sealing up the entry routes by making the holes smaller or reducing their number (by caulking, parging, etc.). Although it's true that most radon enters a house by infiltration from the ground, sealing openings by itself has produced some of the worst results. These poor results indicate that the flow of gas into the house is determined more by the porosity of the ground than by the number of openings into the structure. Because the gas is often relatively free to move around under the slab, we may seal up 90 percent of the openings and find the same amount of gas coming in

Methods to Facilitate Later Radon Removal

In an area of known radon risk, you'll want to install the ductwork for a fan-forced suction system—to be installed later, if needed. Run a 4-inch PVC pipe from the perimeter drainage loop under the slab up through the roof. Cap with a wind-directional hood (such as the one made by Artis Products) to maximize wind-driven suction. Later add a fan in the attic if needed.

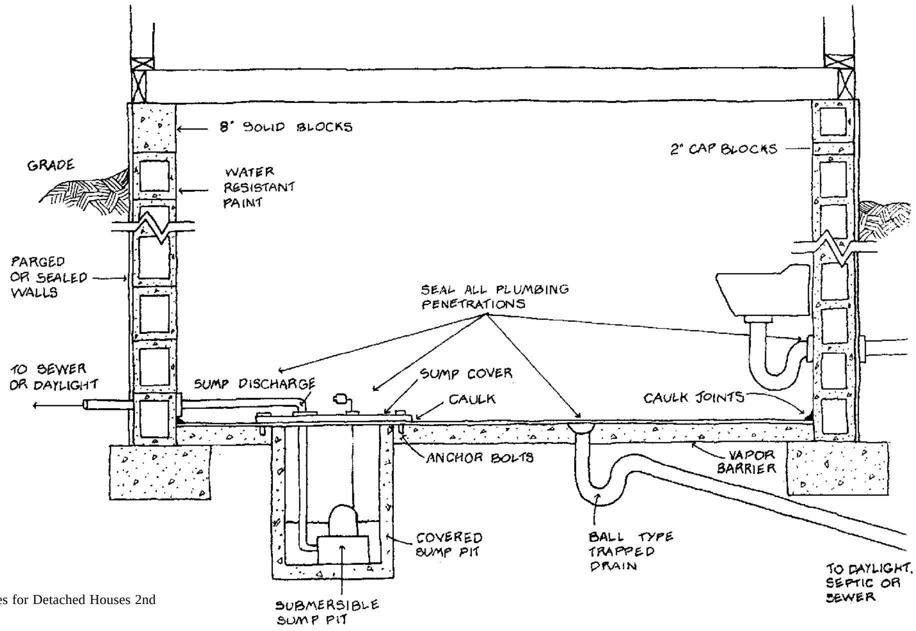
For lower risk areas, you can cap the PVC standpipe at the basement floor. Then, if later needed, vent the pipe through the band joist and up the side of the building (or out through the garage, etc.) Kanalflakt makes an exterior fan designed for this type of application.



Adapted from the EPA's Radon Reduction Techniques for Detained Houses 2nd Edition

Methods to Reduce Radon Entry

Take these steps during construction to seal radon out of the basement: (1) reinforce slab to avoid cracks; (2) make a v-joint where slab meets wall, and seal with urethane caulk; (3) caulk all plumbing penetrations; (4) caulk or gasket sump cover to slab; (4) drain floor drains to daylight or use an airtight drain such as the Dranjer (you can install the Dranjer right in the sump cower if the cover is recessed); (5) purge or seal block walls and cap top of wall with solid block. Avoid the use of French drains at the bottom of block walls, and concentrate instead on waterproofing. If necessary, however, you can seal the bottom of the French drain with flowable urethane sealant, and drain it to the sump through a channel.



Adapted from the EPA's Radon Reduction Techniques for Detached Houses 2nd Edition

*R*ADON *P*ERILS & *P*ROFITS

When the radon craze first struck in early 1985, and homes with high levels of radon were found in Pennsylvania and New Jersey, bogus operators went door to door checking for radon with dressed-up mayonnaise jars. One New Hampshire hustler went around offering senior citizens a radon remover that had to be renewed every two months. "It looked a lot like a Shell No-Pest Strip," said Jonathan Powell of Teledyne Isotopes, Inc., of Westwood, N.J., which manufactures residential and environmental radiation monitors.

To test a building for radon, start out with a low-cost, four-day monitor such as this $30 kit from Radon Testing Corporation of America (RTCA, 12 W. Main St., Elmsford, NY 10523.) If the reading is near or above the EPA action level of 4 pCi/l, then conduct more extensive tests.

But the radon problem has also created a healthy opportunity for a lot of legitimate businesses that can offer the expertise and hardware to diagnose and cure radon problems.

Just how widespread is the problem?

According to the latest estimates by the U.S. Environmental Protection Agency, from 5 to 7 million homes across the U.S. may need fixing. Also, because there's no reliable way to predict whether a given house will have a problem, they recommend that every house be tested. That's about 60 million radon tests for single-family detached houses. Add to that schools, housing authorities, and multifamily units, and it adds up to a multibillion-dollar business for radon testing and mitigation.

Many have recognized the market's potential. For example, when the EPA first began evaluating radon-testing companies in the spring of 1986, there were only about 35 applicants. After completing the latest round of evaluations, over 275 companies have been EPA-listed. "Anyone who takes a look at the number of homes in the U.S., the turnover rate, and the fact that radon testing is becoming routine in a sale—along with termite and structural inspections—has to see the enormous potential," said Teledyne's Powell.

After radon treatment is completed, the wary can find peace of mind with the At-Ease radon monitor from Sun Nuclear Corp. (415 Pineda Court, Melbourne, FL 32935). The monitor blinks red if average household radon levels exceed the EPA threshold. The cost: about $250.

Firms charge from $8 to more than $50 for the charcoal-type test used for short-term measurements (typically a few days). Alpha-track detectors, which are used for more long-term measurements, sell for $25 to $50. The hard cost of running a charcoal test is about $5, according to Andreas George, the Department of Energy Physicist who invented the method. And the necessary equipment can be obtained for as little as $6000 plus the cost of a personal computer—hence, the makings of a thriving cottage industry. One testing company, Air-check, based in Arden, N.C., grossed more than $1 million in the first year.

Once a radon problem has been discovered, someone has to get rid of it (so-called radon mitigation), which creates another business opportunity. Repair work can range from a few hundred dollars for caulking the basement cracks and opening a basement window to several thousand dollars for a fan-forced sub-slab ventilation system.

"Most mitigation work involves only basic construction skills," says David Murane, a scientist with the Radon Division of EPA. But to do a good job, he says, requires fairly sophisticated diagnostics. Many of the major companies now, he says, are evaluating the "sub-slab communication" prior to developing a strategy. What this means is finding how well air flows under and around the foundation—so that the workers can pop the right holes in the right places to get the best sub-slab suction.

"These techniques are a long way from being perfected," says radon authority Terry Brennan of Camroden Associates in Rome N.Y. "However, we can usually tell beforehand how successful a suction system will be." Brennan and others are working on developing a "decision tree" that will help choose the correct mitigation technique given a specific set of conditions.

Still, many companies push a single system and try to apply it to all situations, says Murane of EPA. To help clean up the business, says Murane, some states are working to develop training and certification programs. New Jersey, New York, and Pennsyslvania plan to have programs in place shortly.

For those seeking more information on radon-mitigation techniques, the EPA recommends that you contact your state radiation-health agency (each state now has an office in charge of radon). If you can't locate that office, or if you want additional information, contact the Radiation Division, U.S. EPA, 401 M Street, Washington D.C. 20460-ANR 464; 202/475-9605.

Two new EPA documents should be available from your state radiation-health office by press time: *Radon Reduction Techniques for Detached Houses 2nd Edition* and *Radon Reduction in New Construction.*

Another source of information is the 18-month old American Association of Radon Scientists and Technologists (AARST), in Westwood, NJ. For information, contact the executive secretary, James Crafey, at 52 Park Ave., Park Ridge, NJ 07656; 201/391-1552.

Finally, if you're serious about mastering the mysteries of radon and its safe removal, consider attending one of the three-day training seminars sponsored by the EPA in your region.

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through the remaining 10 percent. It seems like we have to attempt a 100 percent seal if we really want to stop the flow of radon—and this of course is very difficult to do.

The other factor some point to as the culprit is house tightness. It turns out, however, that there is no correlation between house tightness and radon concentrations. This is because the more significant factors are radon source strength and the pressure differential between the house and the sub-soil. Although a tight house has fewer air changes in an hour, it also puts less suction on the ground because it has less air escaping out the top. In some cases, sealing the upper part of a house actually reduces radon levels due to the reduced stack effect.

The highest and most consistent reductions have come from reversing the pressure differential between house and soil. We reverse this by installing a sub-floor suction system that can develop a stronger suction under the floor than the house is generating above. This causes all the many entry routes we haven't sealed up to have a downward airflow direction. Radon won't swim upstream against this downward-flowing air. The trick is to get this negative pressure gradient under the whole floor, even up the block wall cavities. Sub-slab suction systems use small in-line fans that put suction on the air space below the concrete floor. The gas is vented to the outside, away from windows and other infiltration points that might send it back into the house. The stronger the negative pressure developed under the floor, the better the results. To develop a good pressure gradient, you usually have to seal the cracks and holes. Otherwise, it's like trying to use a drinking straw with holes punched in the side.

An Ounce of Prevention

How can you tell beforehand if a new house is going to have a radon problem? To date, I am not aware of any correlations between soil testing and indoor radon concentrations. This is probably due to the limited testing you can do up at the surface and the large variability of soil layers and house construction. Testing the houses in the same area is a possible clue to what you might expect but it is by no means a guarantee. If you do pay the price to have your soil tested, a high soil gas reading should cause concern but a low reading doesn't mean that you won't have a problem.

Should you install a system in a new house that you know works, even though you don't know if there is going to be a problem? Since you can't be sure you *won't* have a problem, you might as well incorporate as many inexpensive preventive measures as you can, especially those that are good building practices anyway. The more expensive measures should be used as the site and customer dictate.

Following are some general recommendations for all new construction:

1) Use at least 4 inches of ½-inch or larger clean stone under all concrete floors. This allows you to later apply suction, if needed.

2) Lay a perforated 4-inch pipe in the gravel around the *interior* side of the footer. If the lot slopes enough, you can also lay a similar perforated pipe around the *outside* of the footer and slope it to daylight. Lay the pipe in a bed of gravel covered with straw or tar paper. If the outside pipe drains to daylight, don't connect it with the inside pipe or you might short-circuit a suction system installed at a later date.

If the lot doesn't have enough pitch to drain to daylight, then consider connecting the outside perimeter drain to an inside sump pit with a submersible pump. This puts a load on the sump pump but does relieve the hydrostatic pressure at the bottom of the foundation wall. Make sure all areas of the basement have their gravel bed and pipe connected to the sump pit.

3) Poly vapor barriers under the concrete floor are certainly important for moisture, but have questionable value for radon. We have found radon problems in a number of new houses that had a good poly barrier in place. Whether the poly made any difference is hard to say. As with water vapor, radon moves through a membrane such as poly more by air leakage at seams and edges than by diffusion. (And of course we all know that concrete flat-workers would never tear a vapor barrier while they dump ten yards of concrete on it!) A properly constructed 4-inch concrete floor will have a much better chance of being a radon barrier.

4) Do what you can to reduce the cracking in concrete floors. There are some new concrete additives to consider that reduce the likelihood of floor cracks. At this point the votes aren't all in on fiber and steel additives. We do know the old stand-by of wire mesh, if properly placed, helps reduce cracking. Some of our local concrete companies are also offering plasticizers in the concrete mix. The plasticizer gives the concrete more slump so extra water won't need to be added at the site. Since shrinkage is due to water evaporation, the less water added, the less shrinkage cracking. The problem here is not the cost of the plasticizer, typically about $4.00/yd., but convincing your concrete crew they don't need to add extra water at the site. Less water also means they can finish sooner and be home before dark.

To cure a slab, some builders will wet the concrete or spread a sheet of poly over the new floor, but this usually isn't practical in the rush to get the house done. Better to coat the surface of the concrete as soon as it gets hard with a concrete sealer to retard drying and shrinkage. Don't forget to pull out or pound down any grade stakes in the floor and never leave any framing though the concrete floor. With slab-on-grade construction, always pour the floor all the way out to the perimeter to seal off any soil gas entries.

5) Crawl spaces can't be left with a dirt floor. Lay 3 to 4 inches of gravel and at least one length of perforated pipe in the crawl space. Use a poly barrier and a minimum 2-inch concrete layer over the whole floor. Also follow the other recommendations made for basement floors. Crawl spaces should be insulated and sealed from the living spaces and ventilated according to BOCA guidelines.

6) It's a good idea to set up your own control joints. We often insert metal tee braces (sold for wall bracing) on edge into the concrete to force a break. These break lines, however, need a v-joint cut in the top surface of the concrete to accommodate a urethane caulking job when the joint later opens up. The perimeter wall/floor joint also needs a v-joint cut in with a sidewalk-edging tool to leave space for urethane caulk. A soft expansion-joint material such as 1/2 inch extruded polystyrene foam can be used at the perimeter if it is later chipped or depressed below the slab top and caulked with urethane. The large open French drains or floating slabs are out. In every case where there is radon in a basement with a French drain, we have had to seal the drain shut. If you must have a perimeter trench, then seal the bottom of it with a flowable urethane sealant.

7) Sump-pump holes must also be sealed shut. We use a submersible pump and seal the top by caulking (or gasketing and bolting) a pressure-treated plywood lid over the hole. The pipe and wire coming out of the hole are caulked at the plywood. It's a good idea to use a removable rubber coupling where the pipe connects to the pump to allow easier access for repairs. It also might be worth trying plexiglas as the lid so that you can visually inspect the pump.

8) The foundation walls are best constructed with poured concrete. If block is the only choice, then reinforce with wire mesh and decrease the length of long spans to reduce the chance of cracking. Use a solid block on the top course of the wall that is carefully grouted between the blocks. Parge both the outside and inside of the wall. Without the insurance of a French drain, extra precautions need to be taken waterproofing the outside of the foundation. After the outside of the foundation is damp-proofed, press 6-mil poly into the pitch to help span future cracks. You might also consider using one of the sprayed-on foundation coatings. Owens Coming Tuf-N-Dri, although expensive, actually guarantees its product as a waterproof barrier.

9) Plumbing and utility holes through the basement floor or foundation walls need to be sealed. This is especially true of basement shower and tub openings that are often framed with wood. After the wood or extruded foam has been removed and the plumbing put in place, seal the ground with two-part urethane foam or pour a good quality roofing cement over poly laid on top of the leveled gravel. Water lines are often protected with pipe insulation where they penetrate the concrete floor. Before pouring the floor, remove the pipe insulation at the floor level and pitch the pipe with asphalt sealant to protect them from concrete corrosion.

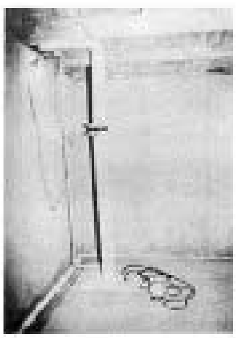
The condensation from the air-conditioning air handler should be run into a plumbing drain line or a condensation pump rather than allowing it to drip into a hole in the concrete floor. Floor drains are okay if they are carefully sealed and drain to daylight. To be on the safe side, it might be best to use a floor drain with an airtight seal like the Canadian Dranjer (Dranjer Corp. 1441 Pembina Highway, Winnipeg, Manitoba R3T 2C4; 204/474-0451) unit. Don't use sub-floor hot air heating ductwork unless you can absolutely seal it tight.

10) Reduce the normal negative pressure gradient between the house and the soil by sealing up all attic penetrations and by weatherstripping the attic hatchway and the insulated lid for the whole-house fan. Avoid recessed lighting in the ceiling below the attic or at least use lights made for direct burial in the insulation. Unfortunately, we can't recommend the popular down-draft cook-top ranges. They typically exhaust 200 to 300 cfm of air out of the house, severely depressurizing the house. All combustion appliances should have their own outside makeup air. Consider installing the new high-efficiency units that have make-up air piping built into them. Carefully seal all ductwork in the basement or crawl space, especially the return ducts. Run bathroom fans through a heat-recovery ventilator that provides balanced preconditioned outside air.

11) As a last precaution, be prepared to set up a fan-forced suction system. Run 4-inch solid PVC pipe from the basement perimeter PVC loop to the attic of the house. Carefully seal all the pipes and be sure all pipes are pitched downward to the gravel bed with no traps. Vent the pipe through an inconspicuous part of the roof. To get more passive wind-driven suction, install a wind directional roof cap such as those made by Artis Products, (Artis Metals Company, 3323 Chinden Blvd., Boise, ID 83714; 800/892-2277). Have the electrician wire a pull-chain light in the attic that can be used to provide power to run a small fan, if needed, at a later date. We typically use the 90-watt blower from R.B. Kanalflakt, Inc. (1121 Lewis Ave. Sarasota, FL 34237; 813/366-7505). Kanalflakt fans provide adequate suction at the static pressures you'll encounter and use minimal energy.

Other than the pipe system through the house and the caulking channels in the concrete floor, all the recommendations given here are those that distinguish a good builder from one who cuts corners. If marketed correctly, these radon reduction techniques will pay for themselves—and lessen greatly the likelihood of one building nightmare. ■

Up above, a Kanalflakt in-line duct fan, such as the one shown, provides strong suction with low energy consumption. Originally developed as a booster fan for heating and cooling, this one has become the first choice of many radon-busters.



Down below, a four-inch PVC pipe exhausts radon from the sump pit. Most vents, now, are installed through the slab, instead.

Bill Brodhead owns and operates Buffalo Homes of Pennsylvania, Bethlehem, Pa., which specializes in energy-efficient construction and radon mitigation. In addition, he conducts and helped develop radon workshops sponsored by the U.S. Environmental Protection Agency.