

RADON-RESISTANT CONSTRUCTION: LOW-RISE MULTI-FAMILY HOUSING

This fact sheet is intended to provide a basic understanding of strategies to reduce radon levels for people involved with the design and construction of low-rise (three stories or less) multi-family buildings. It is not all-inclusive and should not be used as a construction guide. For more details on radon-resistant construction techniques, read the United States Environmental Protection Agency (EPA) publication *Building Radon Out: A Step-by-Step Guide on How to Build Radon-Resistant Homes*, available at www.epa.gov/radon/pdfs/buildradonout.pdf. While this EPA publication is written for single-family homes, the same basic techniques apply to multi-family dwellings. This fact sheet will also help a building owner understand what the designer and builder should include in a radon-resistant multi-family building.

WHY RADON-RESISTANT CONSTRUCTION?

Radon, the second-leading cause of lung cancer, is a naturally-occurring radioactive gas found in the soil in most areas of the country. It is a natural component of the air we breathe.

Healthier Living Environments

Radon, the second-leading cause of lung cancer, is a naturally-occurring radioactive gas found in the soil in most areas of the country.¹ It is a natural component of the air we breathe. Outdoor air contains an average of 0.4 picoCuries of radon per liter of air (pCi/L) and everyone inhales radon in low levels everyday. However, radon can seep into homes, accumulate to high levels, and pose a health risk. To reduce the risk, multi-family homes should be built with radon-resistant construction techniques.

EPA has set 4 pCi/L as the level when property owners should take steps to

reduce indoor radon levels. Because there is no known safe level of radon, EPA also recommends that property owners take steps when indoor radon levels are between 2 pCi/L and 4 pCi/L.

Less Costly to Build Initially Than to Fix

Typical costs for installing a radon reduction system in a multi-family building after construction are \$800 to \$2,500 for each unit in contact with the ground.² Installation costs for new construction range from \$300–\$500 per unit in contact with the ground.

¹National Cancer Institute, U.S. National Institutes of Health. *Radon and Cancer: Questions and Answers*. July, 2004. Online. 30 March 2009. Available at www.cancer.gov/cancerTopics/factsheet/Risk/radon

²United States Environmental Protection Agency. *Consumer's Guide to Radon Reduction*. December 2006. Online. 14 April 2009. Available at www.epa.gov/radon/pubs/consguid.html#installtable



National Center for
Healthy Housing

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WHAT RADON-RESISTANT CONSTRUCTION TECHNIQUES SHOULD I USE?

Building Code Requirements

Depending on where you live, building codes may apply that require incorporating radon-resistant techniques in new construction. Always check with your local code officials.

If your local building code includes requirements for radon-resistant techniques in new construction, follow the requirements; otherwise follow the guidance in the EPA “Building Radon Out” publication referenced earlier in this document.

Radon Maps

EPA has developed a nationwide county-by-county map listing the potential for a home to contain elevated radon concentrations. Available at www.epa.gov/radon/zonemap.html, the maps list counties by zone, with Zone 1 counties having the highest potential, Zone 2 having moderate potential, and Zone 3 a low potential.

The purpose of the maps is to assist national, state, and local organizations to target their resources and to implement

radon-resistant building codes. The maps are not intended to be used to determine if a home in a given zone should be built with radon-resistant construction techniques or tested for radon after construction. Homes with elevated levels of radon have been found in all three zones.

U.S. Green Building Council (USGBC) and Other Green Programs

The USGBC Leadership in Energy and Environmental Design (LEED) for Homes Rating system requires radon-resistant construction techniques to be used in newly constructed buildings in EPA Zone 1 locations. In buildings outside Zone 1 areas, installing radon-resistant features results in an additional credit in the LEED rating system. Other green building programs, such as the Enterprise Green Communities program, require the installation of radon control systems in EPA Zones 1 and 2 for new construction and substantial rehab. Radon control systems are a step beyond radon-resistant features and are described below.

HOW DOES RADON GET INTO THE BUILDING?

Our buildings act like vacuum cleaners, drawing radon from the soil through cracks, holes, and other penetrations in the foundation and into the building.

Radon in the surrounding soil is the source of radon in most buildings. Because the air pressure inside most buildings, particularly at the basement and foundation level, is usually lower than the air pressure in the soil, radon gas permeates through the spaces between bits of soil and is drawn into the building. Simply put, our buildings act like vacuum cleaners, drawing radon from the soil through cracks, holes, and

other penetrations in the foundation and into the building. Sealing those cracks is important but usually not adequate.

Note: Occasionally, radon gas can also be found in well water. Currently there are no federal guidelines for safe levels of radon in water. However, developers of multi-family dwellings who will utilize wells for the water supply should be aware of this potential and have the well water tested for radon.

WHAT MAKES A BUILDING RADON-RESISTANT?

The most widely used radon-reduction method in new and existing buildings is sub-slab (or sub-membrane) depressurization. This system vents air from beneath the foundation slab or crawlspace ground cover membrane. This creates lower air pressure under the slab or membrane, reducing the entry of soil gases, including radon. The vent exhausts to a safe location outside the building. Passive systems without fans act like a flue in a chimney and rely on temperature differences to lower the air pressure under the slab; this may provide enough protection in buildings designed for radon-resistance. If not, passive systems can be turned into active systems by installing an in-line fan to power the exhaust.

Radon-resistant construction incorporates design and construction features that may result in low radon levels but also makes a sub-slab depressurization system effective if post-construction radon measurements reveal elevated concentrations and a fan is required. These features include:

- A gas-permeable layer installed beneath the floor slab to allow the soil gas to flow freely;
- A layer of impermeable plastic sheeting between the gas-permeable layer and the floor slab;
- A foundation designed and constructed to prevent radon entry;
- A gas-tight vent pipe that runs from the gas-permeable layer to a safe location above the roof of the building, and;
- A proper heating, ventilating, and air conditioning system design.

If post-construction radon measurements show that radon levels are above 4 pCi/L, a fan can be connected to exhaust radon actively from beneath the building. If fans are added to the system, use in-line centrifugal blowers designed for radon control systems. General exhaust blowers are less energy-efficient, have too much internal air leakage, and often are

not designed to handle the amount of condensation a radon system experiences. A pressure gauge should also be installed so that the owner or property manager can determine if the system is working properly.

Figure 1 illustrates a typical radon-resistant construction.

Gas-Permeable Layer

The gas-permeable layer is typically a 4-inch-deep layer of clean, coarse-crushed stone with very few fine particles (e.g., 1/2" to 3/4" stone pebbles with no fines mixed in; specified in ASTM Standard C-33 as DOT #1 or #2). The permeable layer is bounded by the undisturbed or compacted fill beneath, the footings at the perimeter, and the concrete floor slab above. Because air flows freely between the stone pebbles, a small amount of exhaust air is able to create a lower air pressure throughout the sub-slab layer. If the gas-permeable layer has sand, clay, or silt mixed in with the stone, air flow will be blocked and the low pressure field will not extend beneath the entire slab. If this detail is not installed correctly, it cannot be repaired later. Additional suction points and fan activation can be added as needed, but once the slab is poured and the sub-surface permeable layer is installed, it cannot be altered.

In locations where clean crushed stone is expensive or not readily available, other methods to improve movement of soil gases, such as placing a loop of perforated pipe or interconnected layers of drainage mat between the sub-soil and floor slab, may be used.

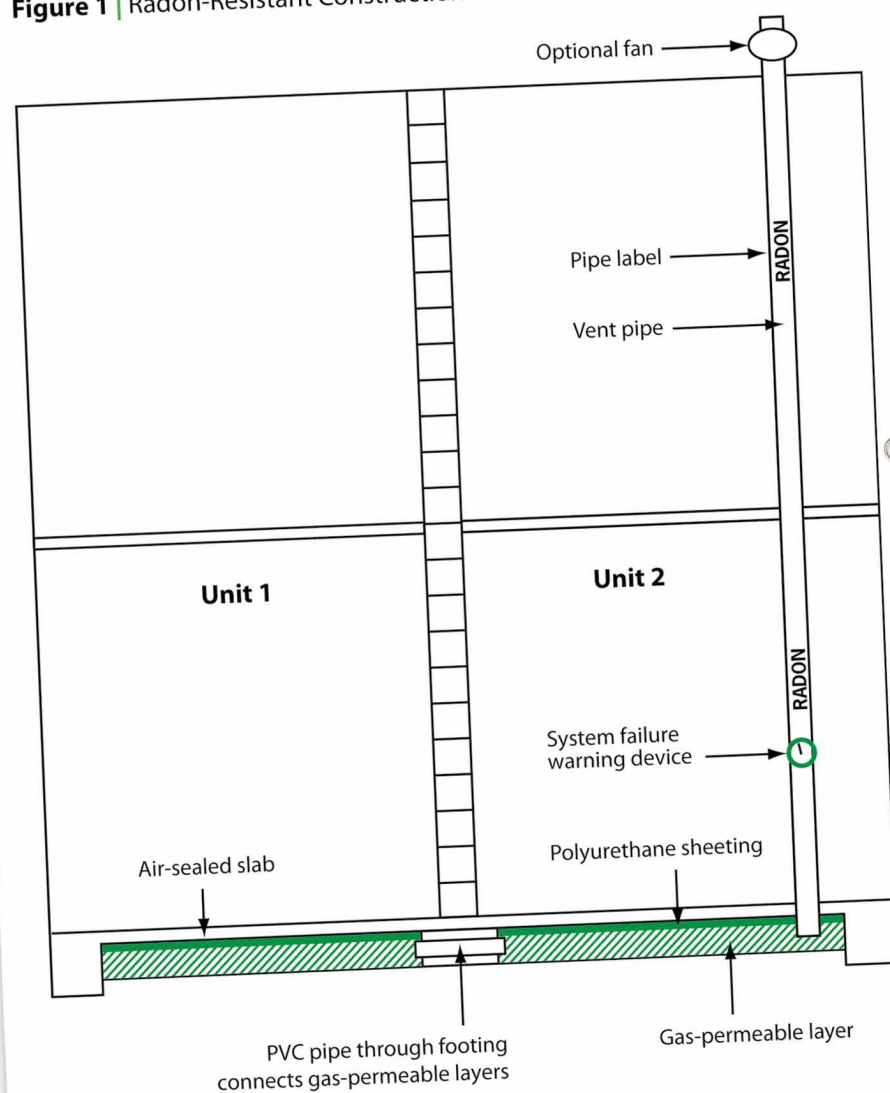
Plastic Sheetting

Laying plastic sheetting on top of the gas-permeable layer before pouring the concrete slab is important because it keeps the concrete from clogging the gas-permeable layer and bridges any cracks that may form as the concrete dries and ages. It may also reduce moisture and humidity in the finished building.

Limit Sub-Slab Barriers

A grade beam or intermediate footing is often installed beneath a slab to support a load-bearing wall. These can interfere with a depressurization system because they block the flow of soil gases from one section of the sub-soil to the collection point. Using post-and-beam construction on pads rather than continuous footings, installing

Figure 1 | Radon-Resistant Construction



Common Errors to Avoid

- Using the wrong materials for the gas-permeable layer
- Sealing off vent pipe at slab, preventing exhaust
- Running HVAC ducts under slab
- Omitting post-construction radon measurements

Radon can enter the building through the poured concrete or masonry block walls.

pipe sleeves through the grade beams to connect two areas or installing additional vent pipes on each side of the grade beam will prevent this problem.

Foundation Design and Construction

A foundation designed and built with radon-resistant features will go a long way to ensuring low radon levels in the building. Depending on the type of foundation your building will have, different techniques apply. For example, when constructing a building with a basement or a combination basement/slab-on-grade foundation, you not only have to consider the radon in the soil beneath the slab but also the radon in the soil outside the foundation walls. Radon can enter the building through the poured concrete or masonry block walls. The walls will need to be detailed to reduce radon entry and make it easier for sub-slab depressurization to work.

Typically, buildings with crawlspace foundations do not have a poured concrete slab covering the crawlspace soil. To prevent or reduce radon entry, a radon-resistant membrane such as 6-mil poly sheeting should be used to cover the soil.

Vent Pipe

The vent pipe runs from the permeable layer up through the slab and the building and exits above the roof. Do not leave the vent pipe open or capped at the slab. Use a minimum 3 diameter PVC pipe. A 4-inch diameter pipe is better if the system has to be activated later with a fan. Check with the local code official to make sure PVC is permitted for this use. The number of vent pipes needed depends on the area of the sub-slab being vented. A single 4-inch pipe can easily vent an area of 2,500 square feet. If interior footings divide the gas-permeable layer into isolated areas, a ventilation riser

is needed for each area. Openings through the footings so the gas-permeable layers are connected make it possible for a single vent pipe to affect much larger areas—e.g., 10,000–20,000 square feet. In one EPA research project on a newly constructed hospital, one vent pipe was able to depressurize 100,000 square feet of slab.

It is best to run the pipe up through warm spaces in the building, not outdoors, to increase the stack effect of warm air rising through the pipe. When it is below freezing outside water vapor from the sub-slab layer can turn to frost in the pipe.

The air exhausted by the system may contain very high levels of radon. To prevent radon from getting back into the building, run the pipe to a point at least 12 inches above the roof, at least 10 feet away from any windows or other openings in the building, including chimneys and exhaust pipes, and at least 10 feet away from windows or openings in adjacent buildings.

Label the exposed portions of the vent pipe so other people will know it is not part of the sewer system. Attach labels in a conspicuous location on each floor level.

Install a dedicated electrical circuit in the attic close to the vent pipe. This will allow for easy installation of an exhaust fan if post-construction radon measurements reveal elevated radon levels in the building.

Proper Heating, Ventilating, and Air Conditioning (HVAC) Design

It is very important to make sure the building's HVAC system does not cause a radon problem. Supply or return ducts should not be run beneath the floor slab. Supply sufficient make-up air to combustion devices and exhaust ventilated areas.

POST-CONSTRUCTION RADON MEASUREMENTS

Conduct post-construction radon measurements in accordance with EPA Radon measurement protocols available at www.epa.gov/radon/pubs/devprot1.html and the AARST procedures specified in *Protocol for Conducting Radon and Radon Decay Product Measurements in Multifamily Buildings* available at www.aarst.org/standards/messages/296/AARST_MAMF_DRAFT_08-13-09-2136.pdf.

If the radon measurements reveal elevated concentrations, install an exhaust fan to depressurize the soil below the slab actively and perform additional radon measurements. Add a pressure gauge to permit a determination that the system is operating properly.

RESOURCES

American Association of Radon Scientists and Technologists
www.aarst.org

Protocol for Conducting Radon and Radon Decay Product Measurements in Multifamily Buildings available at www.aarst.org/standards/messages/296/AARST_MAMF_DRAFT_08-13-09-2136.pdf

U.S. EPA Radon Program
www.epa.gov/radon

EPA radon measurement protocols available at www.epa.gov/radon/pubs/devprot1.html.

EPA radon maps available at www.epa.gov/radon/zonemap.html.

EPA consumer publications available at www.epa.gov/radon/pubs/

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