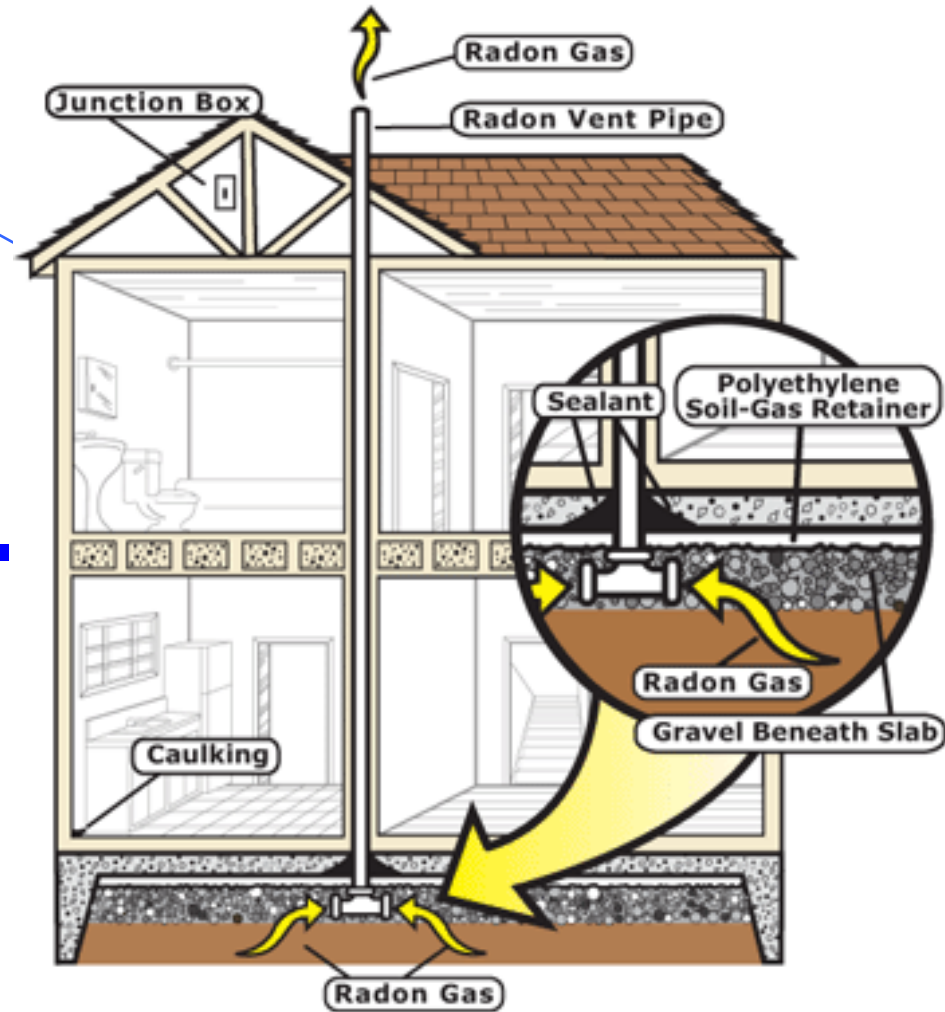


# Radon-Resistant New Construction - Basics for Code Officials



# Presenters

- **Bruce Snead, Kansas State University, Manhattan, KS**
- **Gary Hodgden, Executive Stakeholder Chair for the ANSI/AARST Consortium on National Radon Standards**
- **with thanks to many industry contributors!**

# Agenda

- **Radon Facts for Builders/Code Officials**
- **RRNC Applications**
- **Codes and Standards for RRNC**
- **RRNC Evaluation Results**
- **Appendix F Performance Issues**
- **ICC Codes and National Standards**
- **Q and A**

# **“Radon is a Serious National Health Problem”**

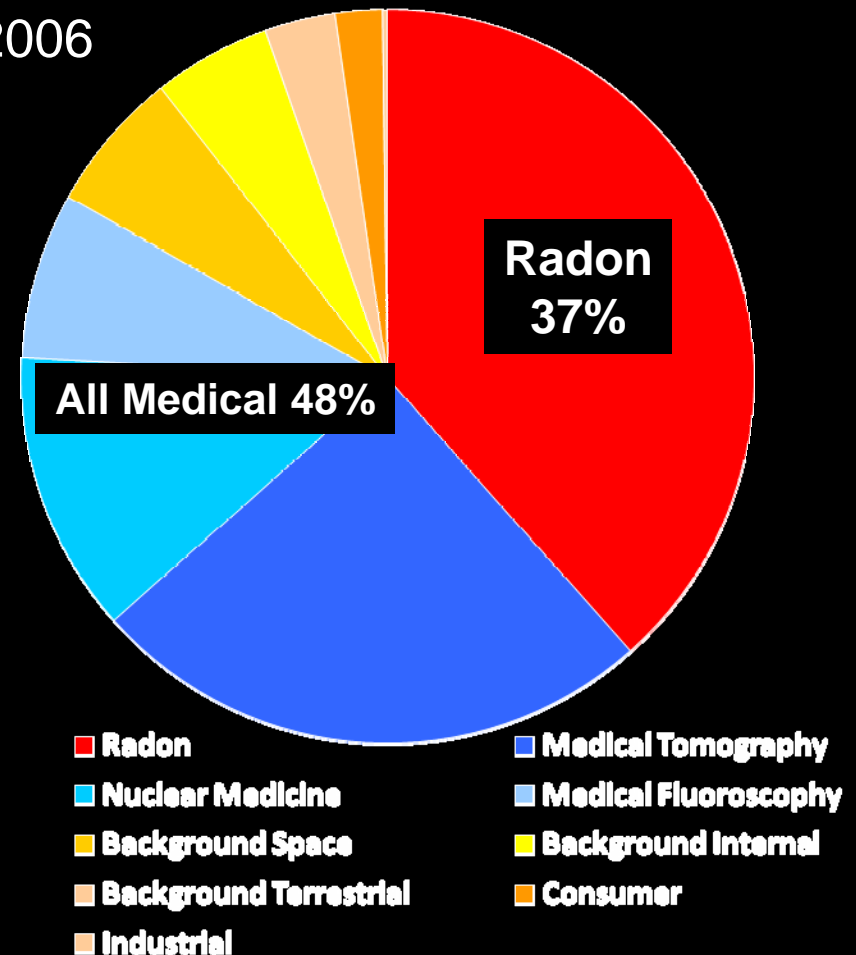
- **American Lung Association**
- **American Medical Association**
- **Environmental Protection Agency**
- **National Academy of Sciences**
- **National Council on Radiation Protection and Measurement**
- **U.S. Surgeon General**
- **World Health Organization**

# Radon Exposure in Homes Is Significant

Average annual radiation source exposures for US citizens

- **Radon 222 - Naturally Occurring Radioactive Gas Element**
  - **Not Detected by Human Senses**
  - **Indoor concentrations are created by the way we design, build, and operate buildings where we live, learn, and work**

2006



# Basic Facts

- **Radon is Everywhere!**
- **The only way to know the radon level is to test – it can't be predicted**
- **Your house may be low, your neighbor's may be high**
- **95-99 out of 100 high homes can be fixed with fan powered soil suction systems**

# Radon Entry and Common Concentrations

## EPA Action Level

4.0 pCi/L

The EPA's action level of 4.0 pCi/L is not a health based number.

EPA recommends mitigation at levels between 2.0 pCi/L and 3.9 pCi/L



0.4 pCi/L \*U.S. annual average outdoors –

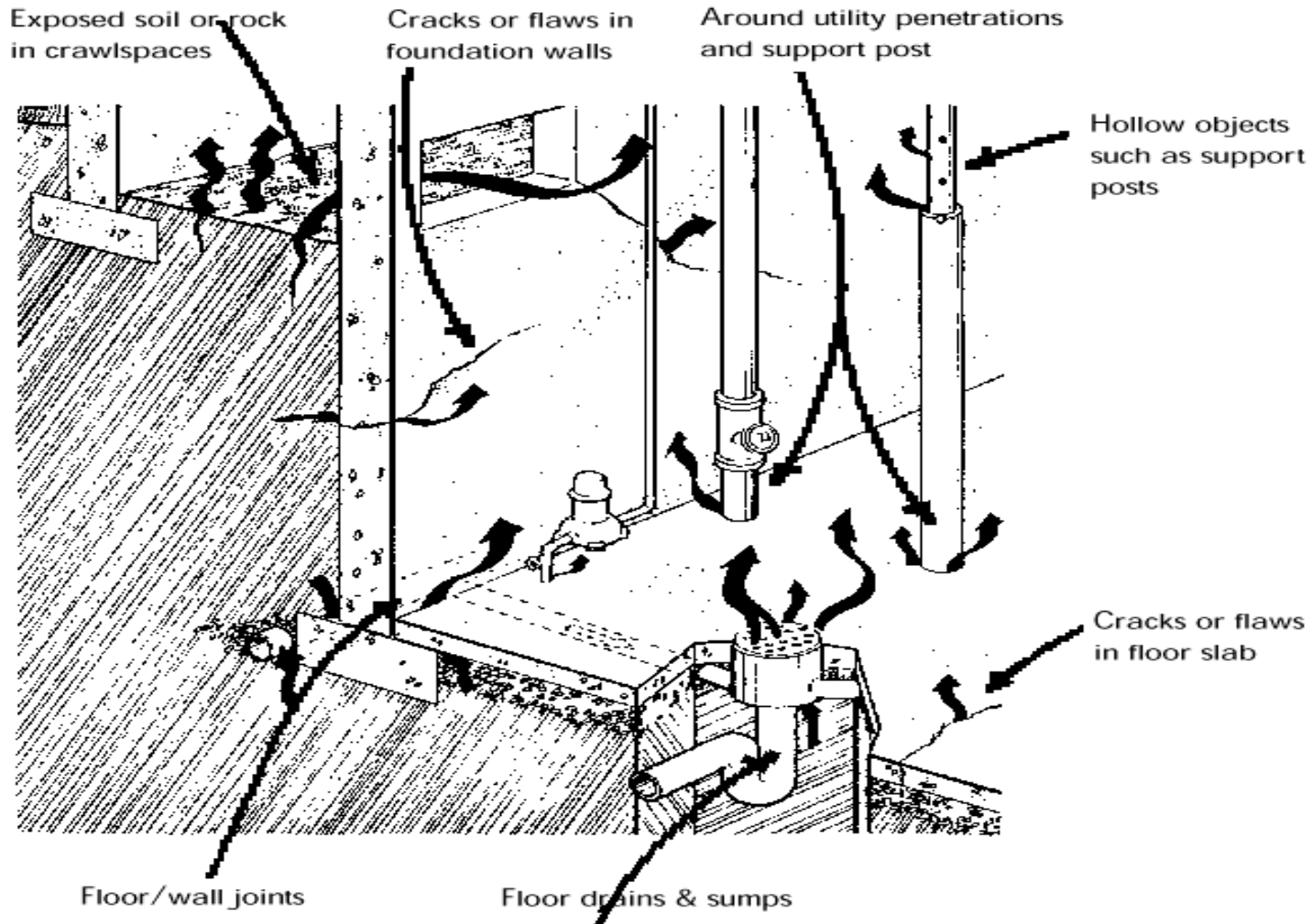
1.3 pCi/L \*-U.S. annual average indoors in homes (living areas) –

# **The Concentration of Radon in a Building Depends Upon:**

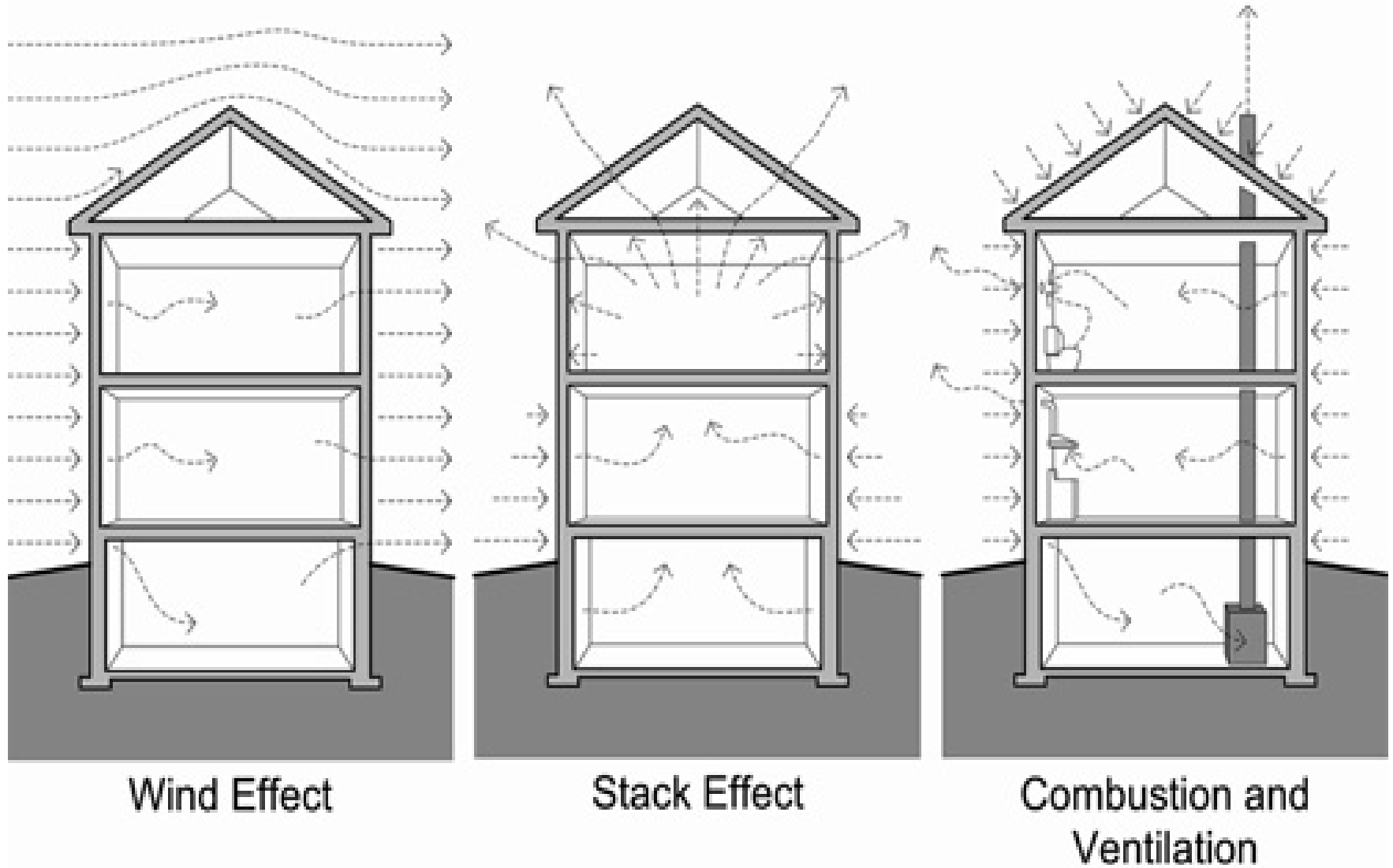
- **Source of radon and its strength**
- **Air pressure differences**
- **Air pathways in soil and through foundation**
- **Air changes per hour – ventilation rate**



# How Radon Enters Your Home



# Air Pressure Variables



Wind Effect

Stack Effect

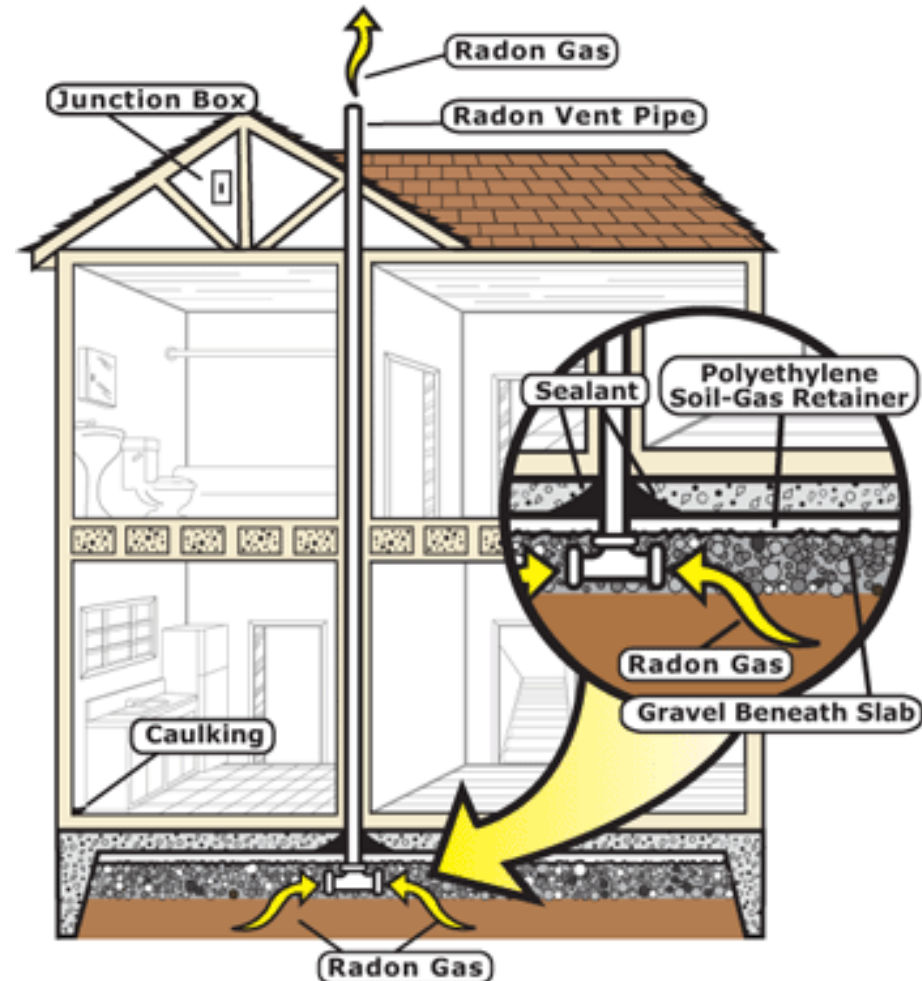
Combustion and Ventilation

# Effect of Ventilation Rates on Indoor Radon Concentrations

- **Just because a house is leaky or tight does not mean it will have low or high radon levels**
  - **In part, the indoor radon concentrations depend upon:**
    - **the percentage of air infiltrating that is soil gas (which can range from 1-20% of total infiltration)**
    - **the radon source strength in that soil gas, and**
    - **the overall air change rate of the structure**
- **Making homes tighter can increase the radon concentration due to decreased dilution from outdoor air**

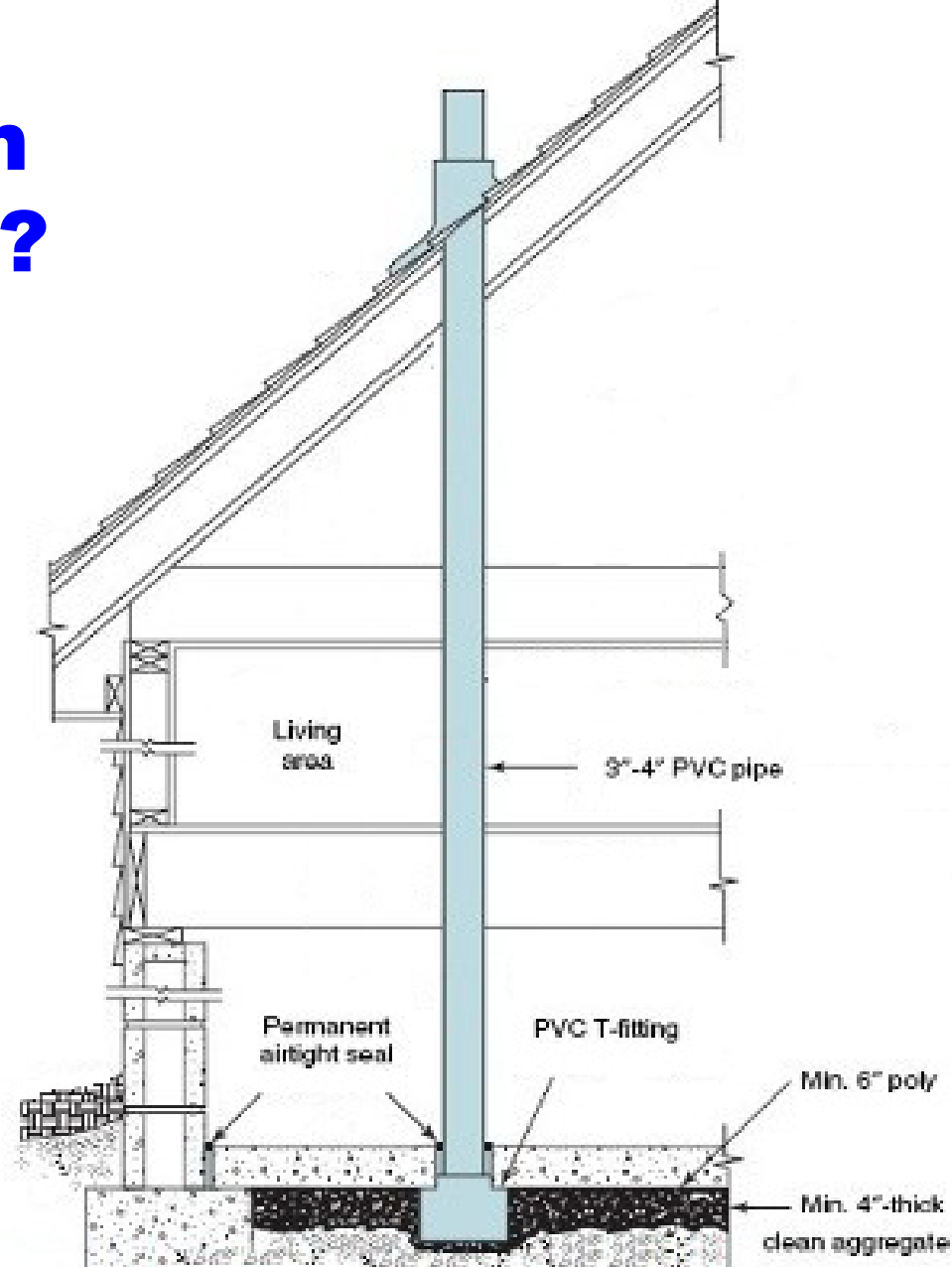
# What Does It Take to Build the House Radon Resistant?

- **Foundation gas collection system**
- **Pipe to convey gas through roof**
- **A closed barrier between soil gas and indoor air**
- **Provision to add fan if needed**



# How Is the System Supposed to Work?

- It is designed to vent radon from beneath the structure by use of a vent pipe routed through the conditioned space of a building, connecting the sub-slab area with outdoor air.
- When air in the pipe is more buoyant than outside air, the air escaping the pipe creates a slight vacuum (pressure differential) to pull soil gas towards the outside
- Known as Passive Soil Depressurization - PSD



# Two Major Reasons Passive Soil Depressurization is Used

## 1. To reduce indoor radon concentrations

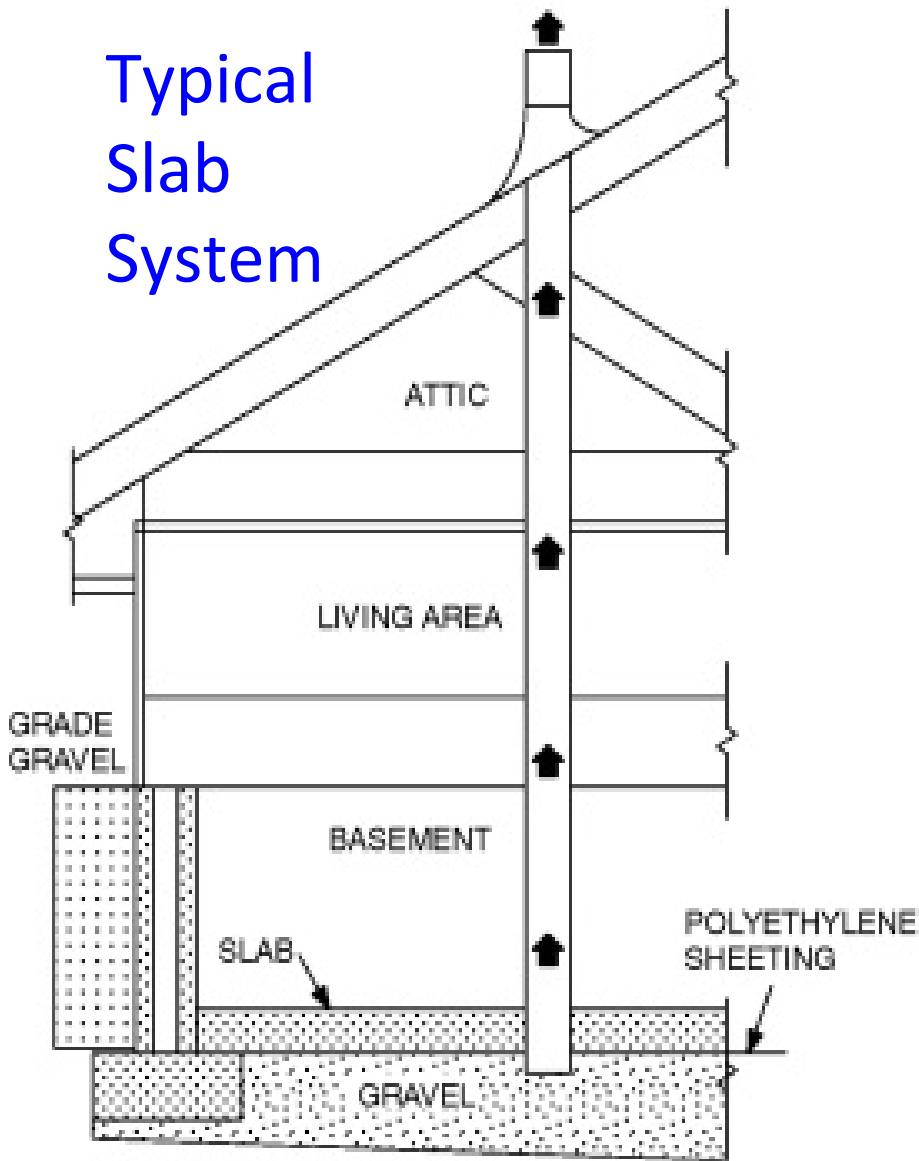
- In general, about 50% reduction over the course of a year is expected if properly installed

## 2. To make the house easy to fix if further radon reduction is needed

- By activation with a fan
  - Stack must easily accessible outside conditioned space for fan installation
  - Power must be available near fan
  - Major openings between soil and occupied space must be sealed

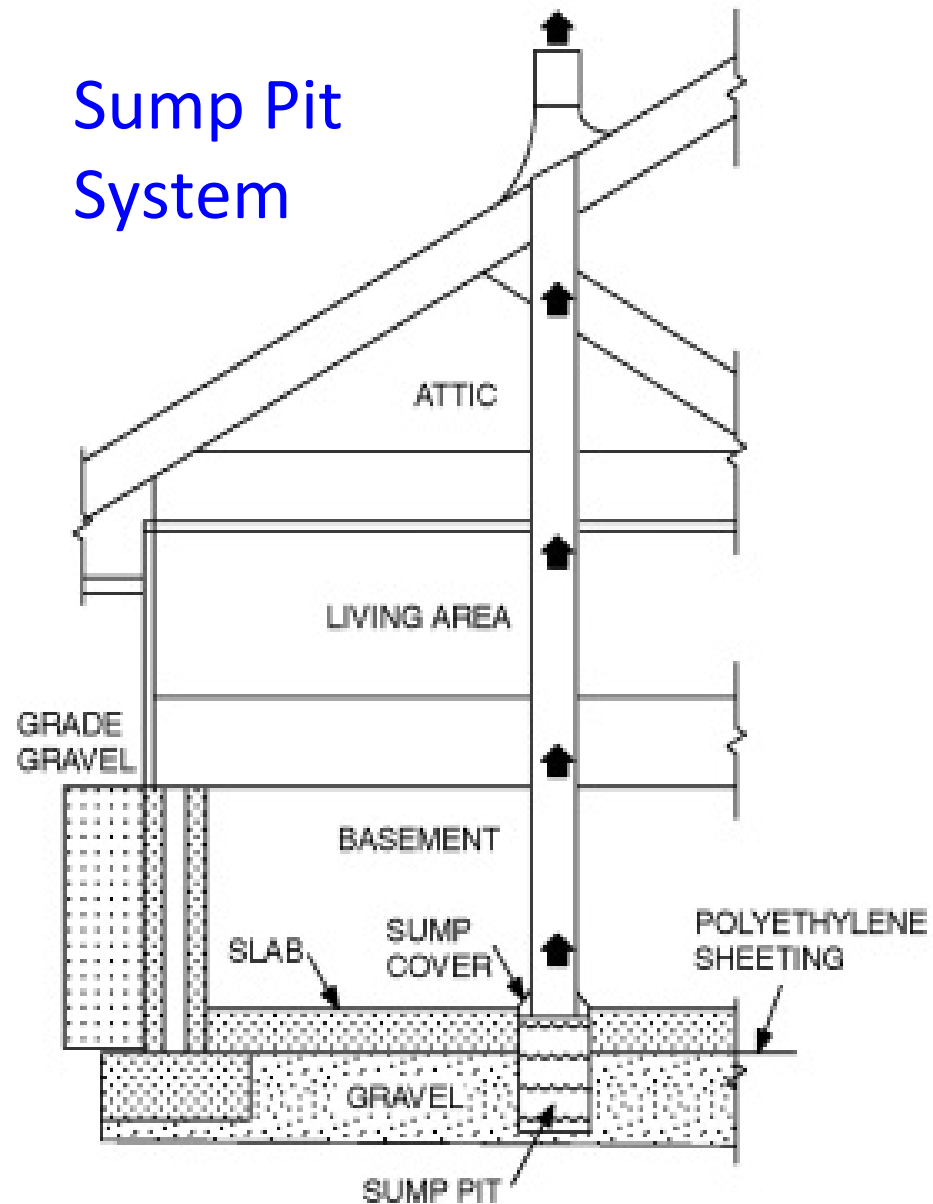
TYPICAL SUBSLAB DEPRESSURIZATION  
PASSIVE RADON SYSTEM

Typical  
Slab  
System



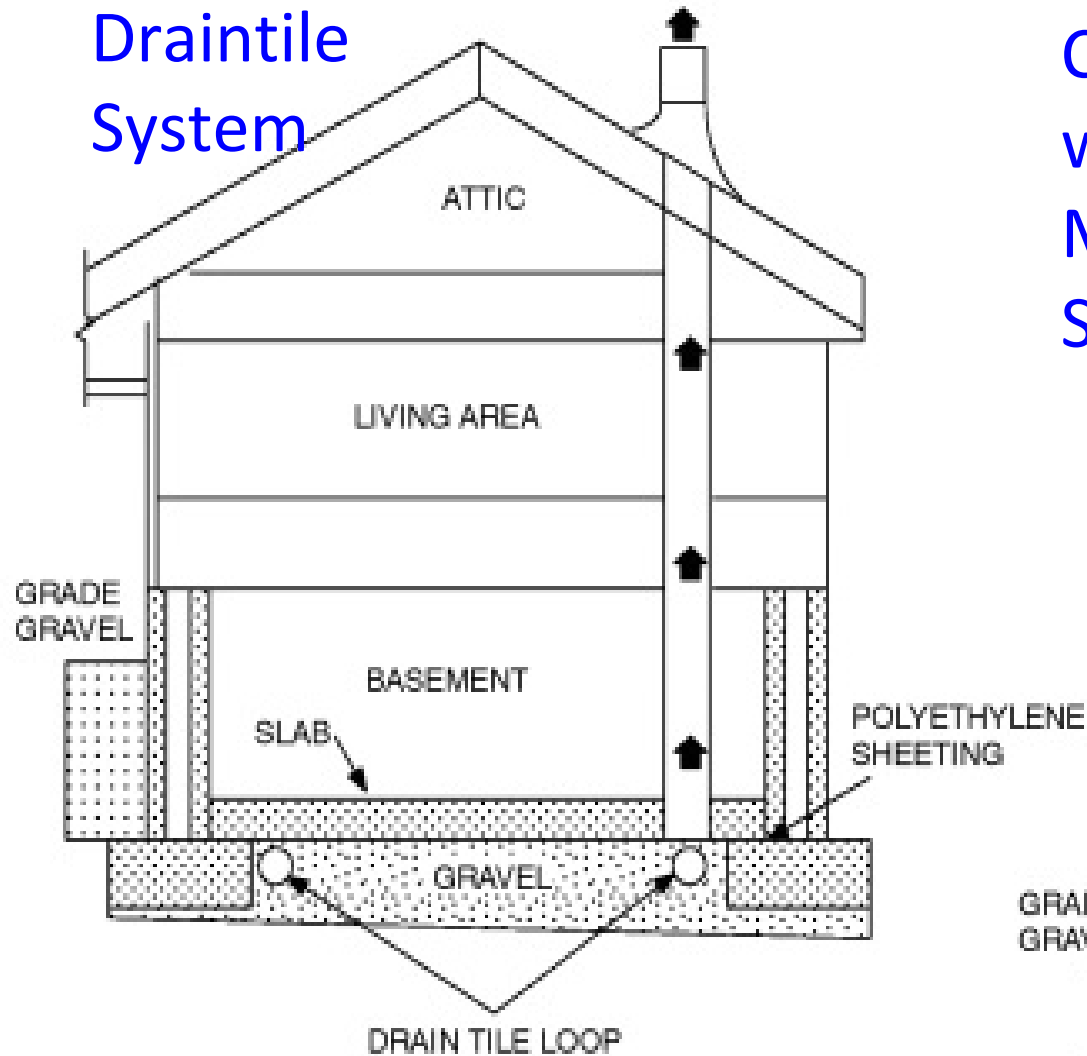
PASSIVE RADON SYSTEM VENTED  
THROUGH SUMP

Sump Pit  
System



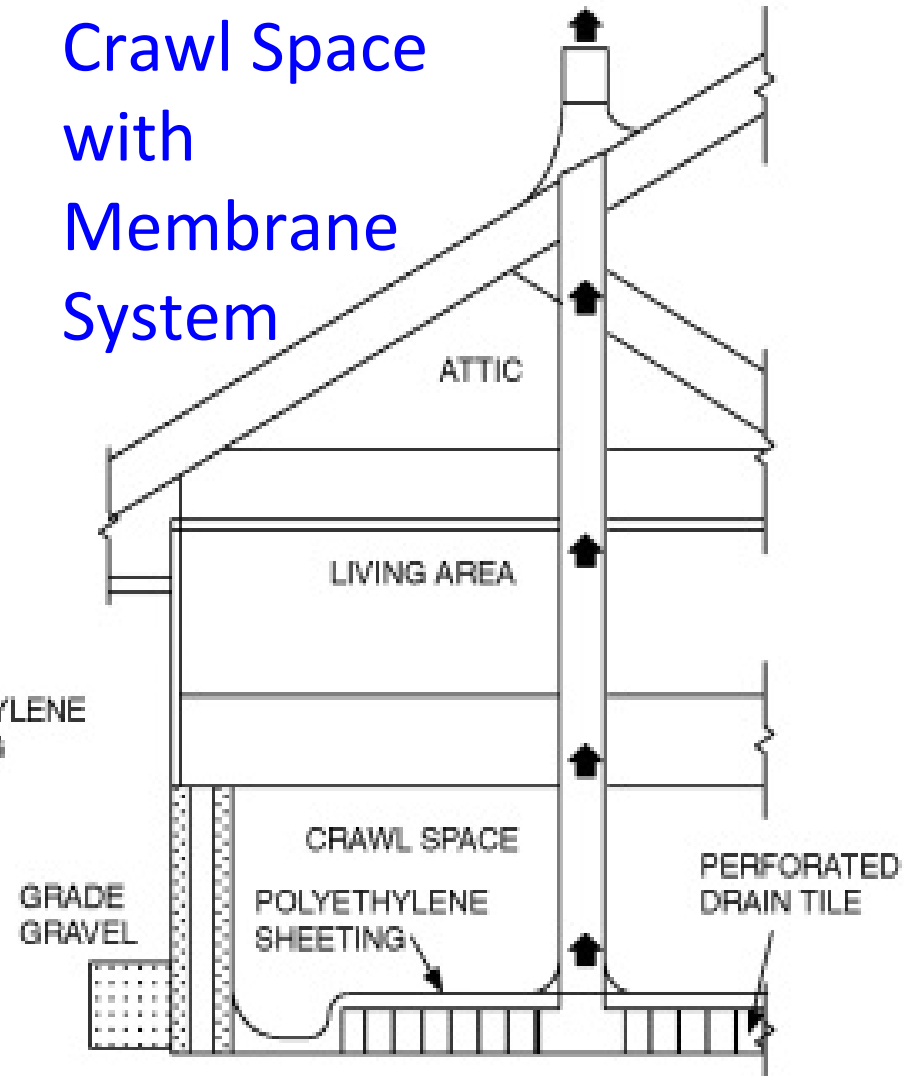
PASSIVE RADON SYSTEM USING DRAIN TILE LOOP

## Drain Tile System



SUBMEMBRANE DEPRESSURIZATION SYSTEM FOR CRAWL SPACE

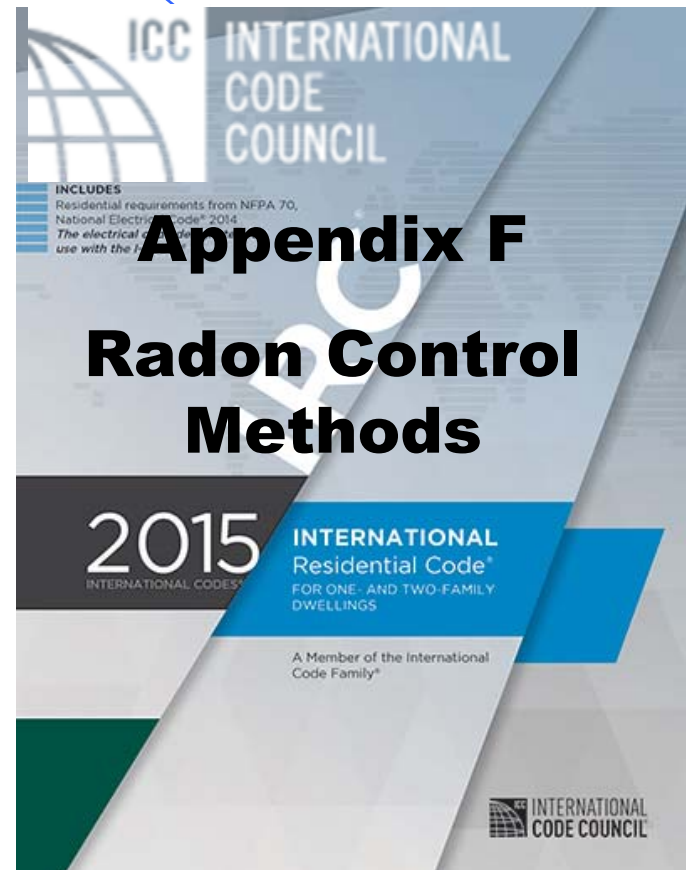
## Crawl Space with Membrane System





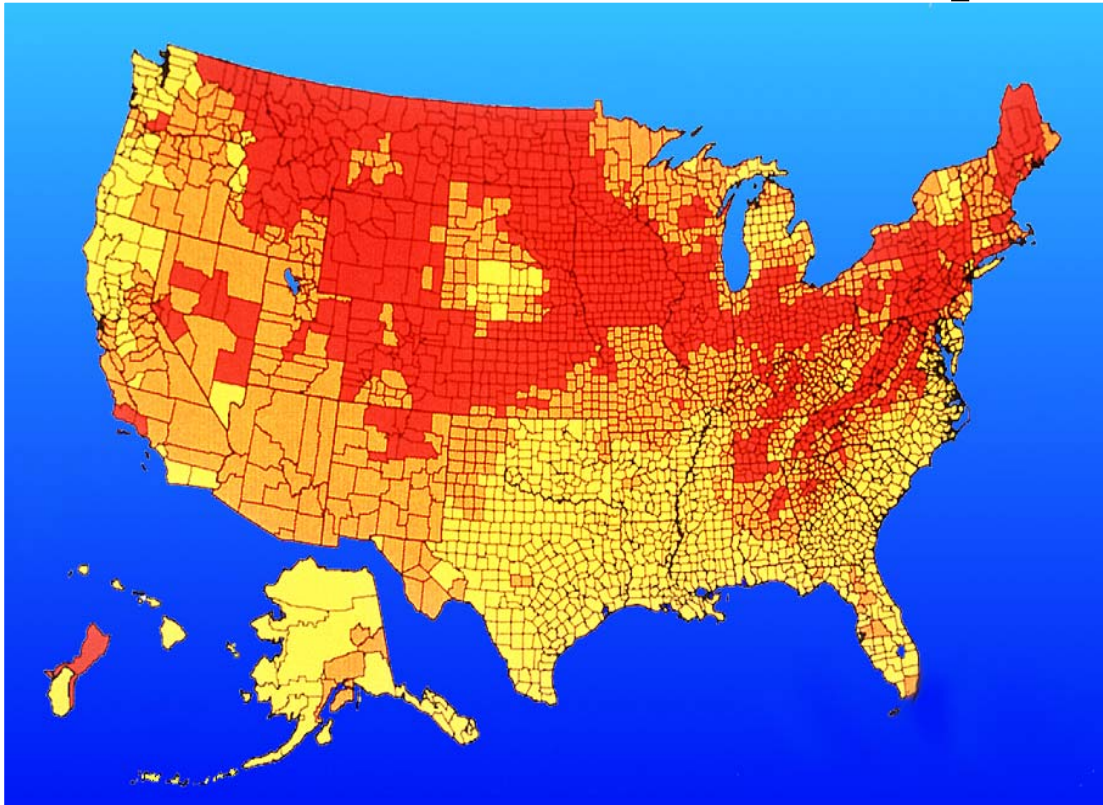
# What Are the Codes and Standards to Be Followed?

## There are primarily two:



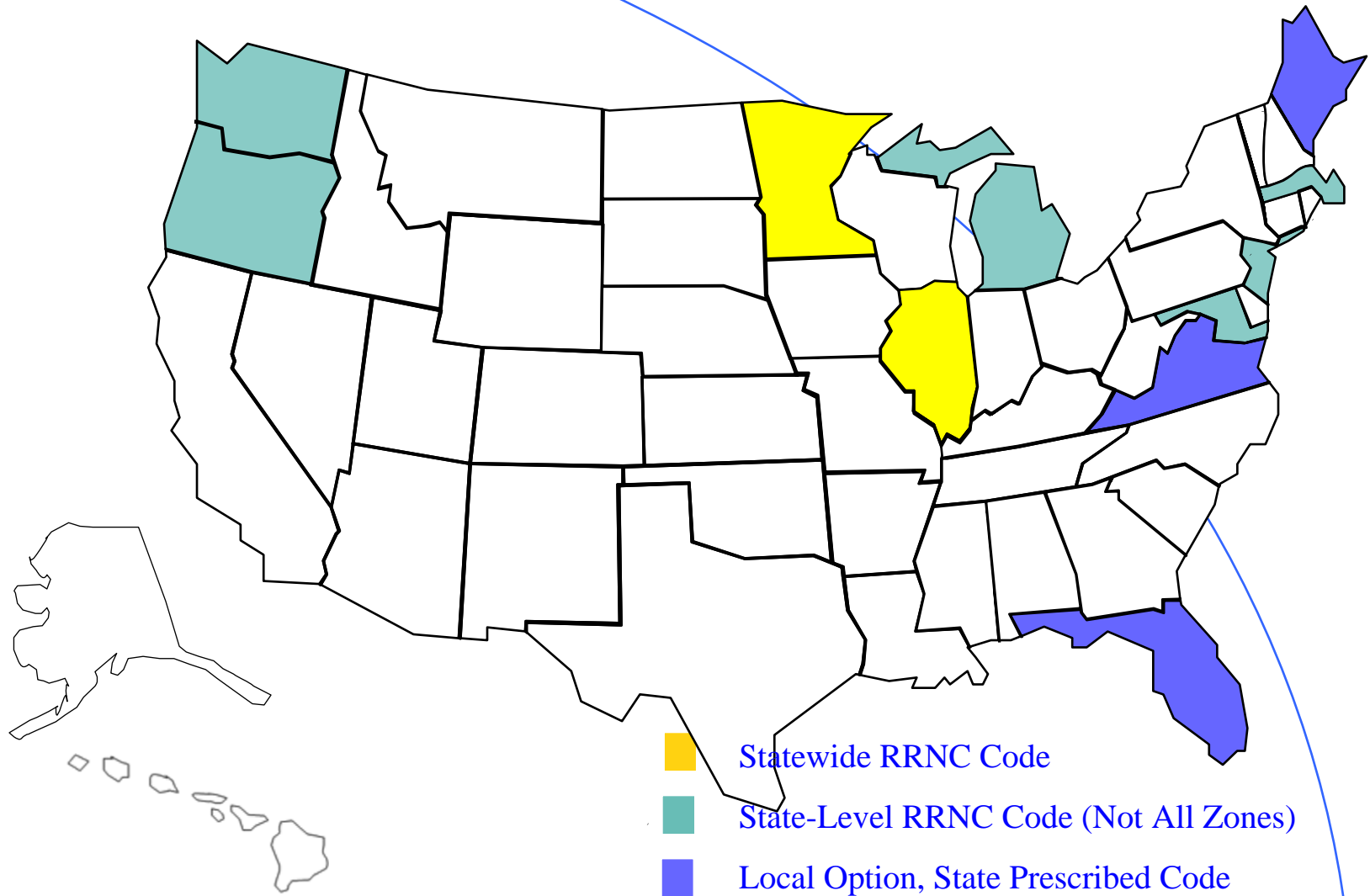
# International Residential Code (IRC) Appendix F: RRNC (Initially intended for Zone 1)

1993 EPA Radon Zone Map



- **Adoption is encouraged for all zones as risk has increased since 1993**
- **EPA Radon Zones**
  - **Red = High potential  
Zone 1 > 4.0 ave.**
  - **Orange = Medium potential  
Zone 2, 2.0 to 4.0 ave.**
  - **Yellow = Low potential  
Zone 3 < 2.0 ave.**

# RRNC Adoptions at the State Level



# Jurisdictions with Radon Control Building Code Requirements

- **States (statewide or zone 1 only)**

- **Illinois (statewide)**
- **Maryland**
- **Michigan**
- **New Jersey**
- **Washington**
- **Oregon**
- **Minnesota (statewide)**
- **Massachusetts**

- **States (statewide but need local adoption)**

- **Florida**
- **Maine**
- **Rhode Island**
- **Virginia**

- **States (where local jurisdictions have adopted)**

- **Alabama**
- **Colorado**
- **Georgia**
- **Idaho**
- **Iowa**
- **Kansas**
- **Montana**
- **Maryland**
- **Nebraska**
- **New Mexico**
- **New York**
- **Ohio**
- **Oklahoma**
- **Pennsylvania**
- **South Carolina**
- **Tennessee**
- **West Virginia**
- **Wisconsin**
- **Wyoming**

# **IRC Appendix F: Section 103 Requirements (Overview)**

- 1. General**
- 2. Subfloor Preparation**
- 3. Soil-Gas Retarder**
- 4. Entry Routes**
- 5. Passive Submembrane Depressurization (PSD) Systems: Crawlspace**
- 6. PSD Systems: Basements and Crawlspace**
- 7. Vent Pipe Drainage**
- 8. Vent Pipe Access**
- 9. Vent Pipe Identification**
- 10. Combination Foundations**
- 11. Building Depressurization**
- 12. Power Source**

# RRNC 2.0

- **Prescriptive Building Code with performance requirements**
- **Treat all foundation types (Rough In)**
  - **Soil Gas Collection Plenums**
  - **Piping**
  - **Electrical Junction Box**
- **True Radon Risk Reduction**
  - **Testing Required for Occupancy Permit**
  - **Activate System Rough In if Necessary**



# **RRNC 2.0 -Purposes**

- 1. To specify radon control methods and techniques for use in dwelling units to reduce indoor radon concentrations to below the National Action Level (NAL) of 4 pCi/L**
- 2. To provide minimum requirements for Rough-In of a Mitigation System and Activation of the Mitigation System, if required, in newly constructed dwelling units.**
- 3. To provide a model set of requirements for adoption by states and local jurisdictions.**
- 4. To provide a means for authorized personnel to inspect and evaluate a Mitigation System in new construction.**

# Radon-Resistant New Construction in 2014

Home Innovations Research Lab (NAHB)

- **All homes built: 1,001,200**
  - **573,000 single family, 427,500 multi-family**
- **The percentage and number of single family and multifamily homes built with radon-reducing features increased from 2013.**
  - **1 in 5, 119,000 single family homes (80% = passive)**
  - **Basement homes: 38%; Slab homes:**



# Radon-Resistant New Construction in 2014

## Home Innovations Research Lab (NAHB) Radon-Reducing Features

- **58% of homes with basements or slabs had 4" of aggregate**
- **45% of homes with basements were provided subslab membranes**
- **50% of homes with slabs were provided subslab membranes**
- **20% of homes with basements were sealed with caulking**
- **15% of homes with slabs were sealed with caulking**

# Radon-Resistant New Construction in 2014

Home Innovations Research Lab (NAHB)

- **Average installation cost was about the same as in 2013.**

Cost	Passive	ASD
Single Family	\$ 332	\$ 707
Multi-Family	\$ 295	\$ 794

# Summary of PSD Effectiveness Testing

Study	# Homes	Average Rn Capped	Average Rn Uncapped	Average % Rn Reduced	Comments
NAHB 1994	45	5.9	2.5	<b>57%</b>	Most built ~ EPA standards, some no poly, some no sealing; inspected during construction
East Moline, IL 1998	21	9.2	3.7	<b>59%</b>	Built ~ EPA standards but un-finished basements w/o poly; inspected during construction
Monroe Co., NY 2002	20	2.9	2.5	<b>12%</b>	<u>Vent stacks NOT through conditioned space, no poly under slab</u>
Muscatine, IA 2002	13	9.3	7.5	<b>20%</b>	12 homes had <u>sub-slab sand NOT permeable layer</u> , 1 home with sub-slab gravel had 51% radon reduction
Dane Co., WI 2003	7	11.1	4.7	<b>42%</b>	Built ~ EPA standards and inspected during construction; <u>1 house at 12 pCi/L with PSD had large leaks</u>
Manhattan, KS 2002-2005	19			<b>31 - 37%</b>	<u>Unsealed sump pits, vent stack NOT through conditioned space (1)</u>

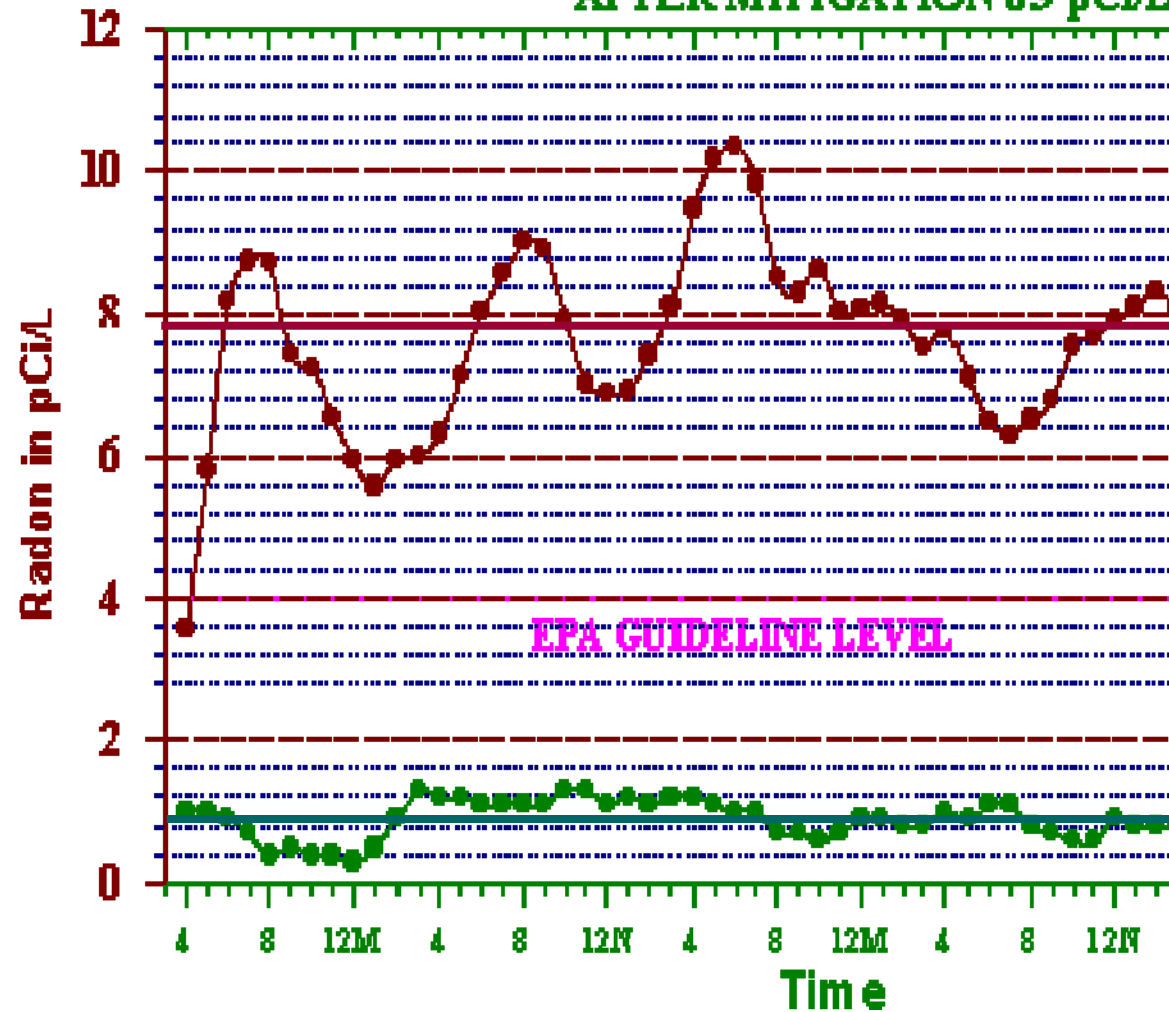
# PSD Can Work But ... It Needs To Be Done Correctly

- **If not done correctly . . .**
  - **May not provide much, if any, radon reduction**
  - **Can make future activation, if needed, difficult, impractical, or impossible**
- **It is *highly important* to test all new homes for radon, even those with PSD**
  - **PSD does not guarantee  $< 4$  pCi/l but . . .**
    - **It does reduce indoor radon and it provides a system ready for activation if needed**

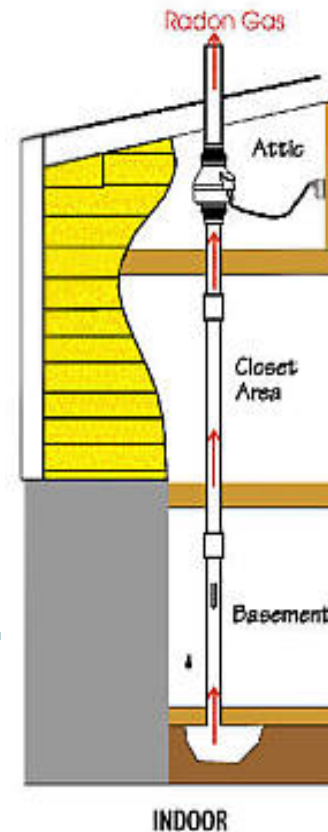
# Radon Levels Before and After Active Mitigation

AVERAGE RADON LEVEL 7.9 pCi/L

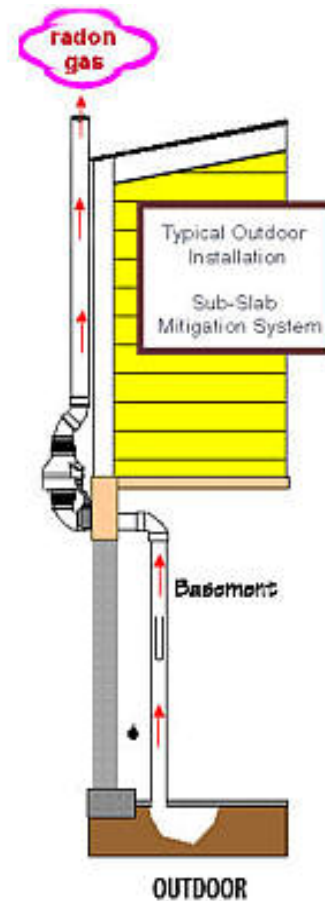
AFTER MITIGATION 0.9 pCi/L



Indoor  
Fan



Outdoor  
Fan



# Testing Reveals Performance!

- **Installing RRNC properly enhances the potential that radon levels will be low.**
- **The only way to know if the system is successful is to test.**
- **Testing can occur when ready for occupancy.**
- **If the house tests above 4 pCi/L the system should be activated with a fan and system pressure indicator added to the pipe.**

# Liability Concerns

- **This is a life safety system**
- **Buyer commonly assumes performance is assured just by presence of a system**
- **Untrained contractors doing work – no one to assume liability**
- **Lawsuits against builders for incorrectly installed systems**

# Appdx F Concerns

- No reliable passive or active mitigation occurs without all of the following components:
  - 1) a complete barrier between soil gas and enclosed airspaces [AF103.3 through AF103.4.10];
  - 2) a gas permeable layer [AF103.2] so that the migration path of soil gas is controllable; and
  - 3) components that allow venting of the gas permeable layer [AF103.5 through AF103.12].



# Appdx F Concerns

- **AF103.5 Passive submembrane depressurization system, and**
- **AF103.6 Passive subslab depressurization system**
- ***False interpretations that “radon resistant” equals “radon protection” and that passive systems induce lower pressure within the soil relative to indoor air on a continuous or prevailing basis.***
- ***False expectations that passive systems are sufficient to fully protect against radon hazards for most homes.***

# Appdx F Concerns

- **AF103.2 Subfloor Preparation,.....** The gas permeable layer .....
- ***Professional confusion when specifying appropriate aggregates.***
- ***Lack of specfications for professionals in specifying drainage mat configuration.***

# Appdx F Concerns

- **AF103.6.1 Vent Pipe.**
- ***Wide reporting of obstructions at the juncture where vent pipes are to be open to soil gas.***
- ***The open pipe or “tee” located within gravel aggregate is routinely found to be clogged with dirt, mud, gravel fines and often concrete.***

# Appdx F Concerns

- **AF103.3 Soil-gas-retarder.**
- ***Building designers and radon professionals have reported a variety of concerns over durability and physical properties of the cheapest 6 mil poly products available on the market.***

# Appdx F Concerns

- **AF103.4 Entry routes.**
- ***Consistent failure to implement stipulations that are essential to achieve a complete closed barrier between soil gas and indoor air.***

# Appdx F Concerns

- **AF103.8 Vent pipe accessibility.**
- ***Exhaust vent pipes are frequently found running up toward the roof within exterior walls and penetrating the roof near the gable end of the roof. Often less than 6-12 inches of pipe is visible and both physical access for workers and means to vertically configure a 12 inch tall fan are impossible.***

# Performance Issues

- **Pipes Blocked by Construction Debris**
- **Pipes Blocked by Soil**
- **Stack Pipe too Small**
- **Pipe Routed Through Unheated Space**
- **Pipe does not Discharge Above Roof**

# Performance Issues

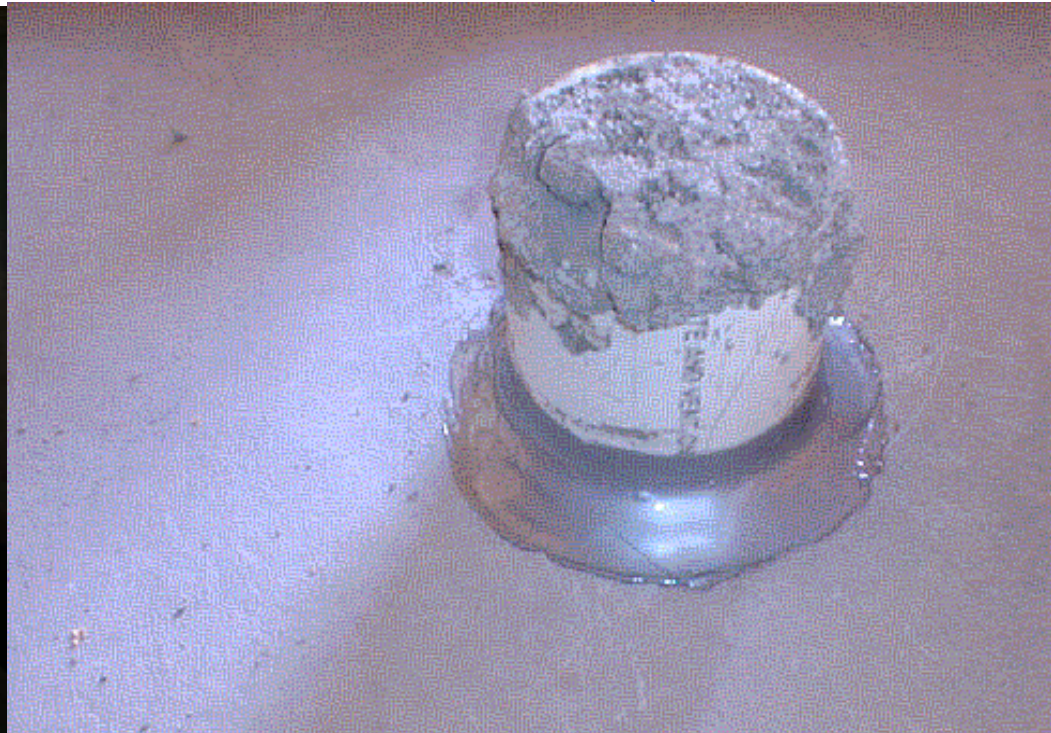
- **Pipe Joints Not Sealed**
- **Pipe installed at 45 degree angle in attic. No room for fan**
- **Pipe in attic installed without slope across top of ceiling joists. Water collects in pipe.**
- **Pipe inaccessible.**
- **System Labels Lacking**
- **Radon Performance Tests not Done**



# Performance Issues

- **Subslab Permeable Layer Missing or Incomplete**
- **Sealing Incomplete**
- **Sumps Unsealed**
- **Isolated Subslab or Submembrane Areas**
- **Air Leaks from sub slab to the Outdoors**

# Vent Stack Blocked by Concrete or Debris



# Pipe Run Through Interior Walls and Adjacent to Flue Chase is Optimum



**Labels are critical – entire bathrooms have been discharged into radon vent pipes!**



**Pipe is resting on soil blocking air flow and membrane is not sealed around pipe**





**The pipe comes out of the sealed sump pit, runs across the basement ceiling, and discharges at the exterior where you see the downturned PVC. This won't work!**



# Mitigator Comments About Activating Builder Installed PSD

- **My experience has been that about 25% of activations of builder installed systems work fine, and 75% must be altered or abandoned.**
- **The most common fixes needed are cleaning out the suction pit, correcting the pitch of the piping, filling holes under tubs and sealing wall/floor joints, altering piping to allow room for a fan, completing roof penetrations, and installing electrical service.**

# Why Build Using Radon Resistant Techniques

- **Radon-resistant new construction (RRNC) typically costs a builder between \$250 and \$750.**
- **RRNC could cost less than \$250 if the builder already uses some of the same techniques for moisture control.**
- **Energy and moisture reduction benefits**
- **To reduce incidence of lung cancer**
- **To reduce potential liability**

# Costs and Cost Saving

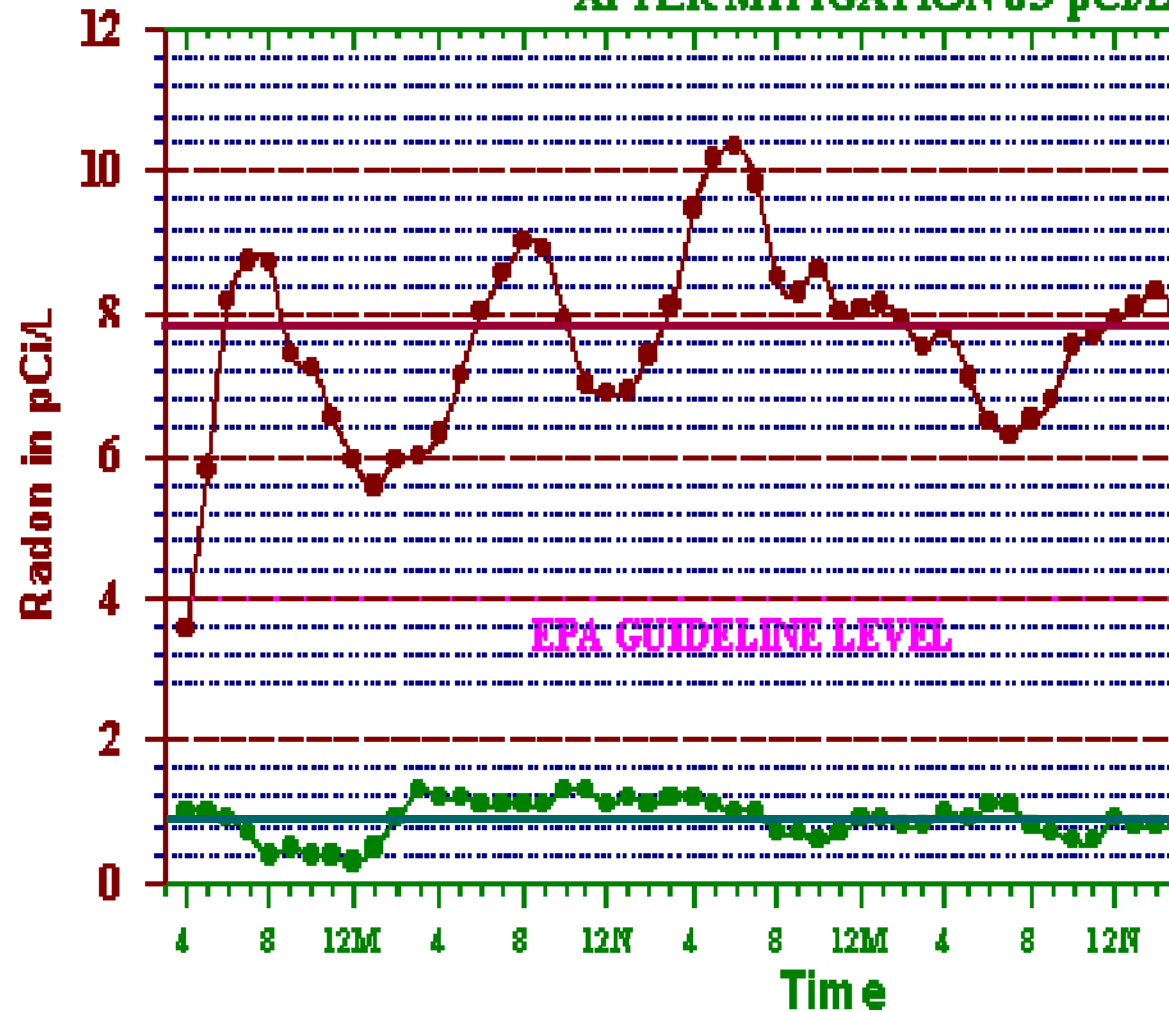
- **No RRNC can lead to systems being installed on the exterior**
- **Poor installation means redoing the work**
- **Poor installation means poor performance leading to more activations**
- **Electrical costs are less when run during construction**
- **Poor performance means more testing to clear the property**
- **Failed tests can delay closing on the property**



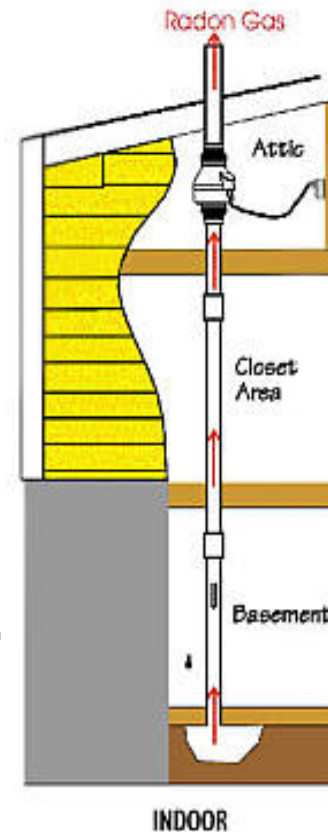
# Active Mitigation Is the Best Bet!

AVERAGE RADON LEVEL 7.9 pCi/L

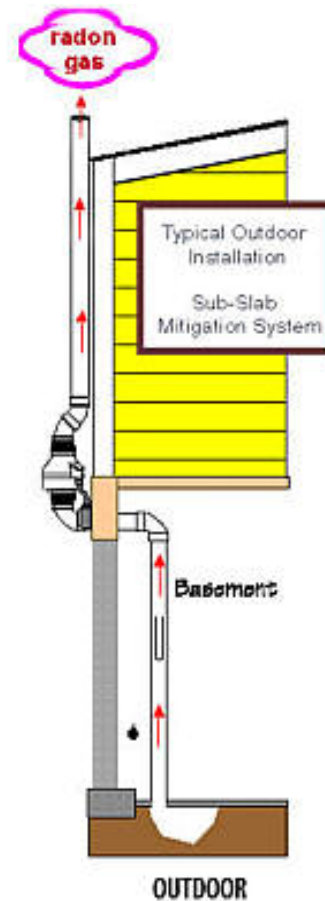
AFTER MITIGATION 0.9 pCi/L



Indoor  
Fan



Outdoor  
Fan



# RRNC Landscape

- **State and local codes can require RRNC for homes in high radon-prone areas - but most don't**
- **IBC needs an RRNC appendix**
- **IRC needs a better RRNC appendix**
- **Everyone who touches housing - homeowners, tenants, realtors, builders, code officials, radon professionals - has a self interest in RRNC done right the first time**

# RRNC Adoption Models

- **Added to state code as a state-wide requirement**
- **Added to state code as the model**
  - **Local jurisdictions choosing to require RRNC must adopt state-approved RRNC code**
- **Required by local code only**
- **Scoping**
  - **Single family + apartments (OR) all (IL NJ WA)**
  - **Homes in Zone 1, all zones**
- **“Next best step” ≠ the perfect solution**

# RRNC – Barriers to Adoption

## Technical Issues

- **Appendix F not credible**
  - **Radon & Building professionals**
- **Appendix F inept**
  - **Pipe connection**
  - **Space for fan**
  - **Submembrane sealing**
  - **Duplicative of some code provisions**
  - **Overall clarity**
- **Builders need training/guidance**
- **Plumbers need direction**
  - **Plumbing code?**

## Systems Issues

- **ICC Paralysis**
  - **Code updates occur place by place**
- **Appendix tradition**
  - **Local “can opt” to save lives**
  - **NAHB opposed to requirement**
- **Zone map tradition**
- **Environmental issues ban (ICC)**
- **Not incremental cost**



# Appendix F – Proposed Changes

- **Problem: the connection between the vertical radon vent pipe and the gas permeable layer below the crawl space or slab has suffered from consistent clogging with soil, concrete and/or gravel.**
  - **Solution: add detail on the vent pipe connector in AF103.3.3: add short lengths of perforated piping in the gas permeable layer, clarification that the tee fitting shall secure the vent pipe.**
- **Problem: vent piping is routed through the attic space without allowing access to the vent pipe and leaving insufficient headroom for a fan if system activation is required.**
  - **Solution: space considerations (but fan installation still not a requirement).**

# Appendix F – Proposed Changes

- **Problem: lack of sealing of the submembrane soil gas retarder creates problems in systems installed in homes with crawl spaces.**
  - **Solution: sealing is added (except for where the crawl space will be covered by concrete) to AF 103.4.1 and the required 12-inch lapping of joints is reduced to 6 inches.**
- **The definition of radon gas is simplified and includes radon's element number.**
- **Radon rough-in definition added, with the requirement portion of the definition moved to the applicable section**

# **Appendix F – Proposed Changes continued**

- **In AF103.3.1 Gas Permeable Layer, the specification allowing for "the lateral flow of gases" is moved to the final option since the first three options satisfy this need.**
- **The description of materials for vent pipes (AF103.5) was changed from "ABS, PVC or equivalent" to "comply with P3002.1"**
- **Redundancies with other code requirements for ventilation, foundation and condensate drains, damp proofing, and air handler sealing have been removed.**
- **An exception for sealing for floors above conditioned spaces is added in AF 103.6.1.**
- **Sealing requirements for control joints were eliminated in AF 103.6.2.**



# ICC Codes and National Standards

- **Appendix F remains barebones**
  - ***And does not cover large buildings***
- **A proposed Appendix N (IBC)**
  - **Not adopted in 2016.**
- **ANSI/AARST CC-1000 is slated for 2017 publication.**
  - **The first document to use the word “shall” with a scope of large bldgs.**

# ICC Codes and National Standards

- **So, whether one likes it or not, radon risk prevention via codes and standards is in our future.**
- **The radon community welcomes input for getting it right.**

# Questions/Discussion

# Resources/ Handout for You

<http://sosradon.org/rrnc>

## Radon Resistant New Construction (RRNC)

- Why Consider RRNC?
- Installing Radon-Resistant Features
- RRNC What Do I Give My Builder? - RRNC Codes and Standards
- RRNC Fact Sheets

<https://www.epa.gov/radon/building-codes-radon-resistant-new-construction-rrnc>

<http://www.nehacert.org/CDPHE/ColoRRNCVideo.html>

## Building In Radon Control

Radon is a tasteless, colorless and odorless gas

occurring naturally in soil and rock. Radon is a leading cause of lung cancer, second only to cigarette smoking.

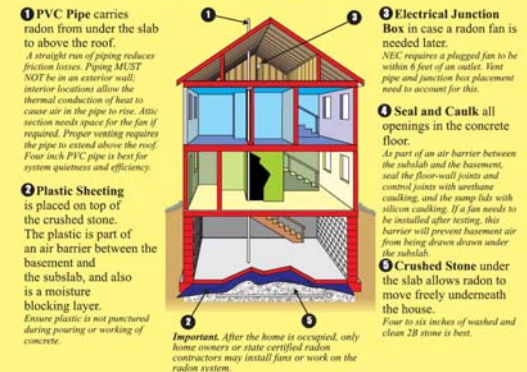
Installing a radon system during construction of a structure doesn't cost a lot, and enhances the value of the property.

**How a radon system works.**

Crushed stone under the house provides an

easy pathway for the radon to migrate towards the vent piping, where it is drawn upwards and released safely into the atmosphere.

The mitigation system will lower radon levels even without a fan, but it may not be enough. A fan may be required. A simple radon test will provide the answer.



A radon test should be performed immediately after the house is occupied, and a fan installed if results are greater than 4 pC/L.

For further information: IRC 2006 Appendix F, or Pa. Dept. of Environmental Protection, Radon Division, or [www.state.pa.us](http://www.state.pa.us) PA Keyword: radon or 1-800-23RADON

# Contacts

- **Bruce Snead, Kansas State University, Manhattan, KS**  
**[bsnead@ksu.edu](mailto:bsnead@ksu.edu)**
- **Gary Hodgden, Executive Stakeholder Chair for the ANSI/AARST Consortium on National Radon Standards**  
**[gary@air.com](mailto:gary@air.com)**