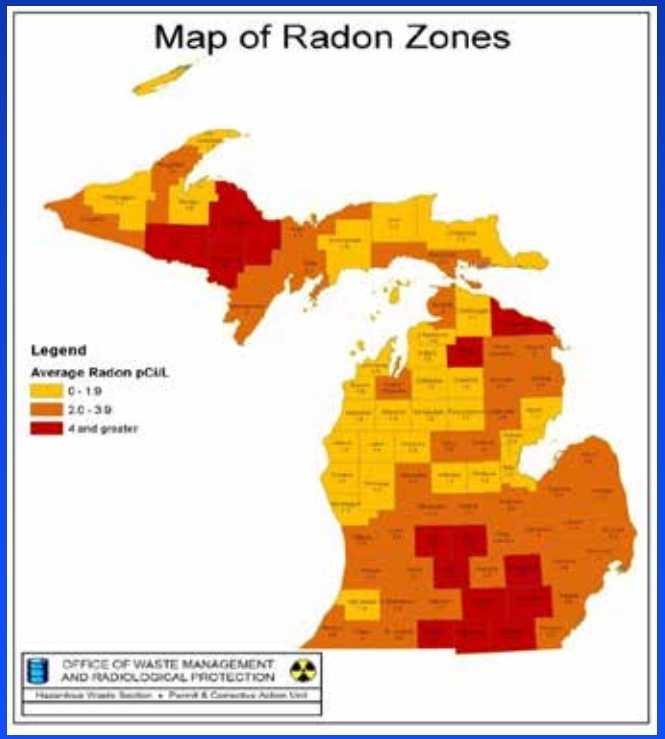
Radon Resistant New Construction

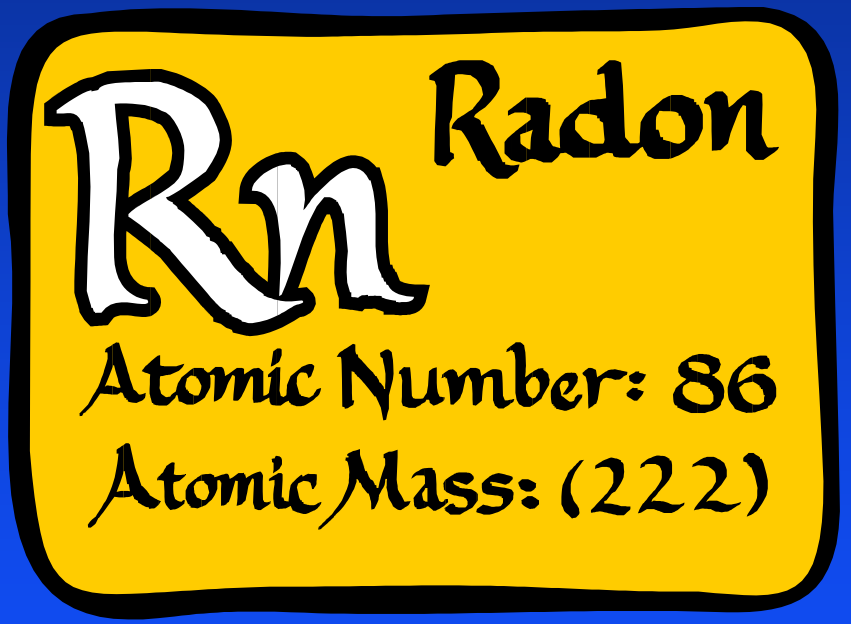
Leslie E. Smith, III
Michigan Department of Environmental Quality
Office of Waste Management and Radiological Protection



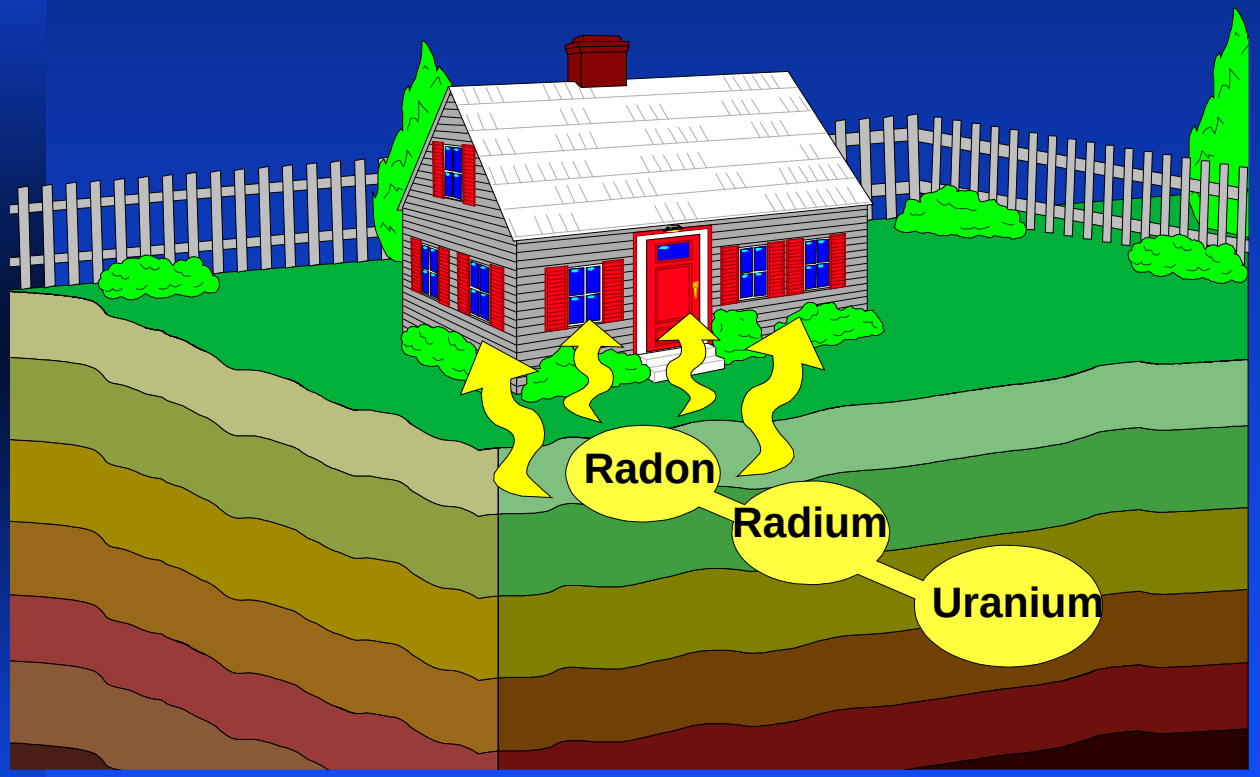
Radon:
What It Is and What to Do About It

We'll talk about:

- What it is!
- What it does to us!
- How it gets into our homes!
- How we measure it!
- How we make new homes radon-resistant!



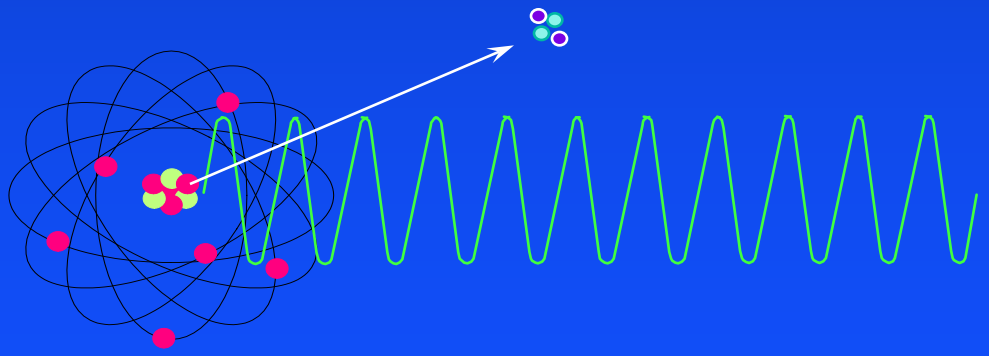
What Is Radon?



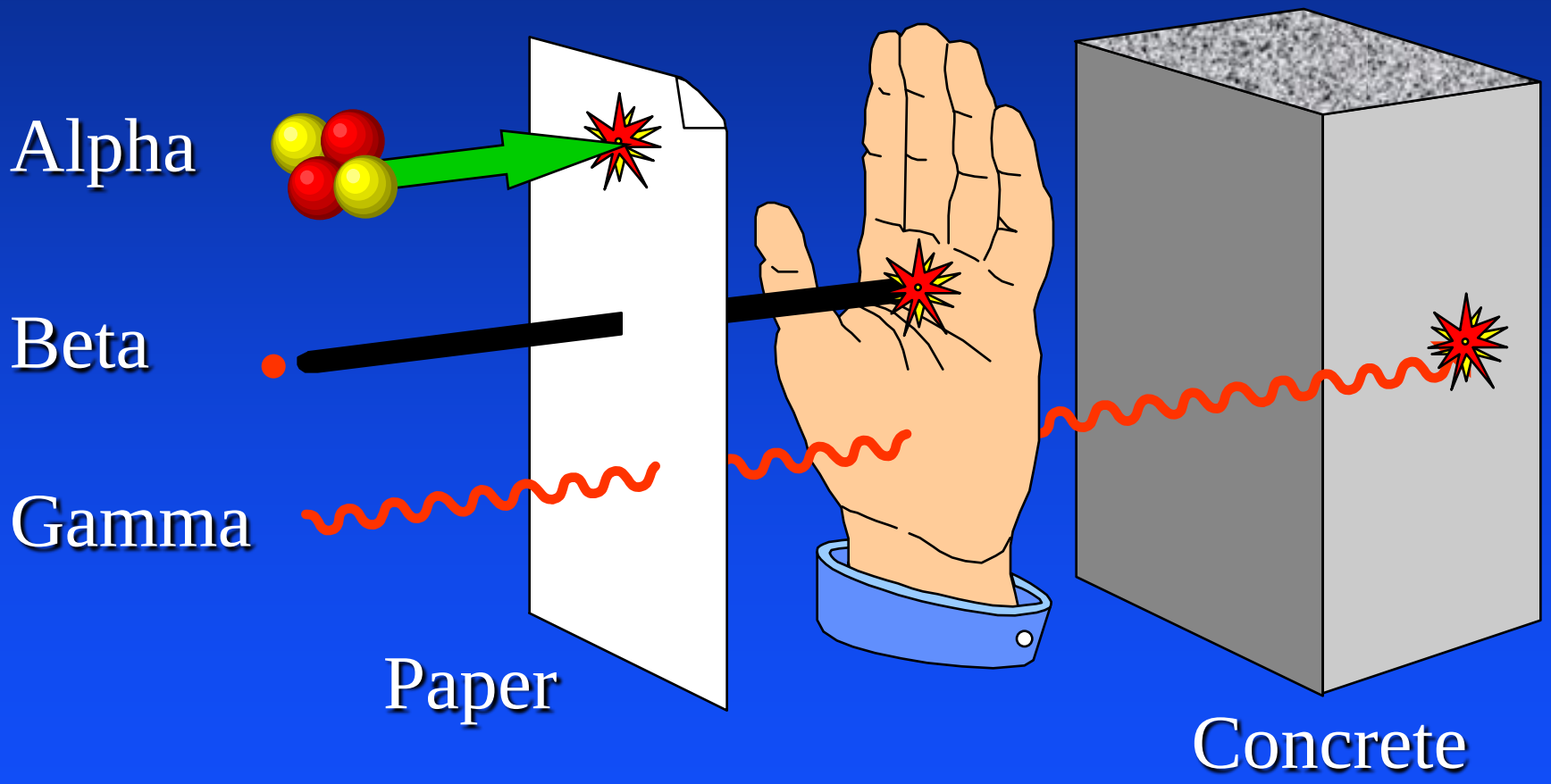
- Radon is a tasteless, odorless, colorless, radioactive gas.
- It is naturally occurring in soil and rock; comes from radioactive decay of uranium and radium.
- It enters buildings from the soil beneath them.

What Is Radioactivity?

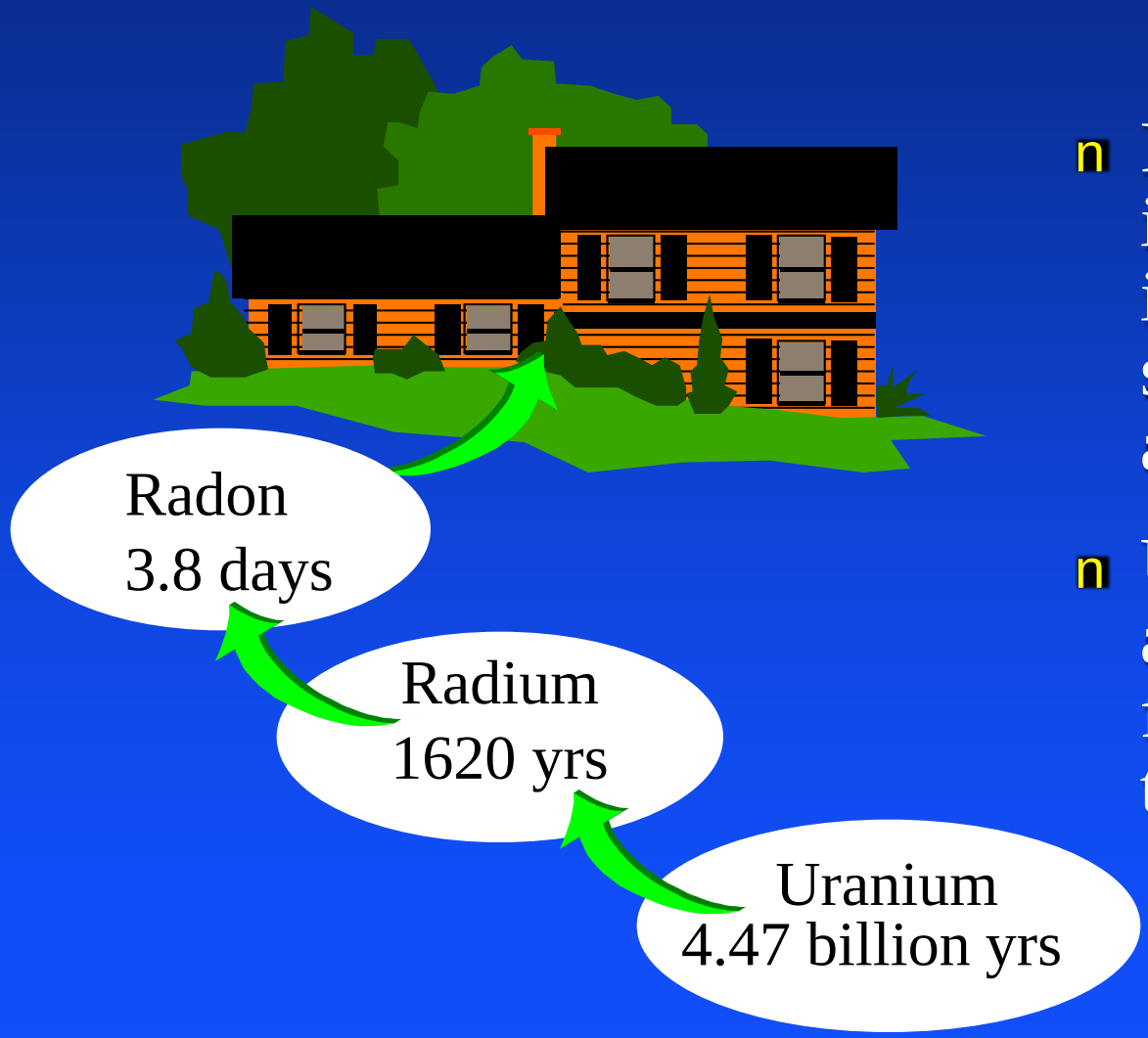
- The spontaneous emission of energy or particles from the nucleus of an atom in an effort to become more stable.
- The atom changes identity, releasing radiation.



3 Types of Ionizing Radiation

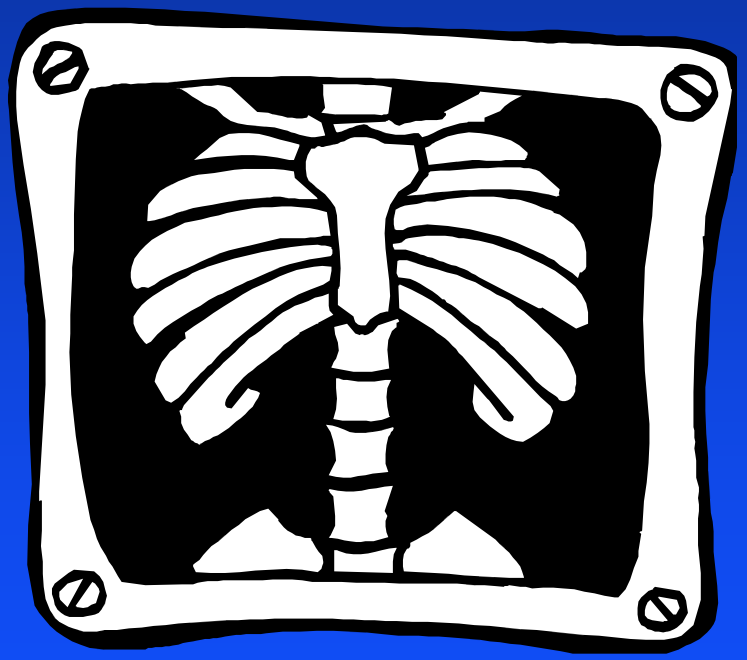


Radioactive Halflife

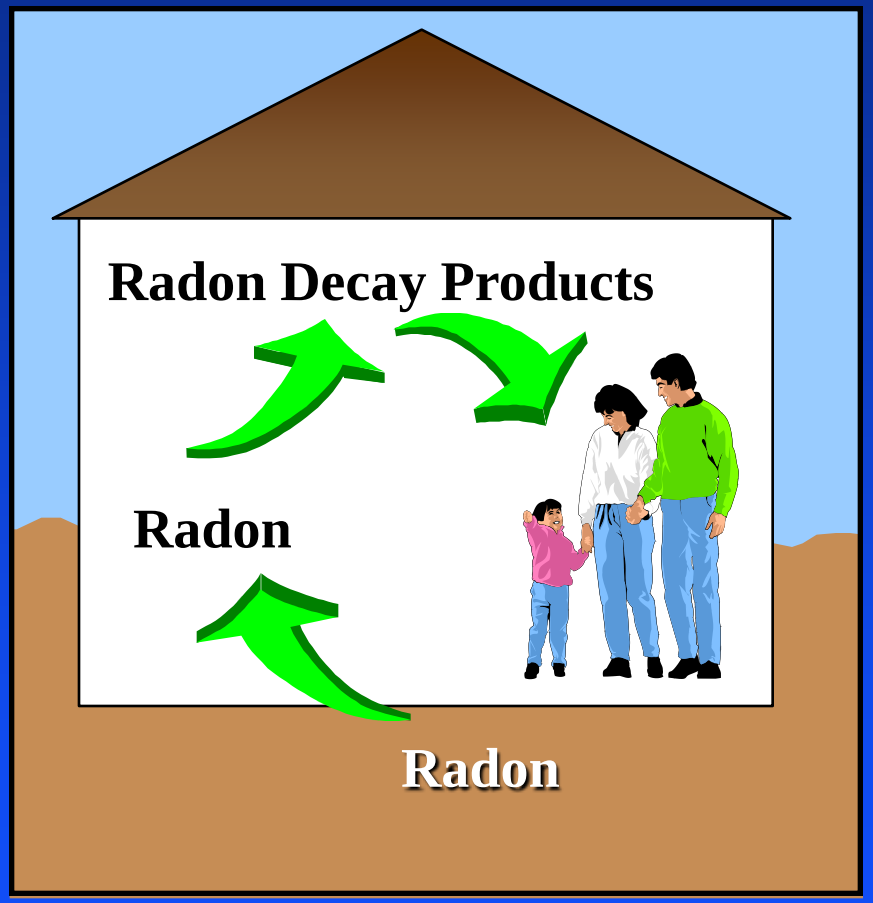


- Radioactive Half-life is the average time that it takes for half of a specified number of atoms to decay.
- Uranium and radium are going to be around for a LONG time, and therefore, so is radon!

Health Effects of Radon



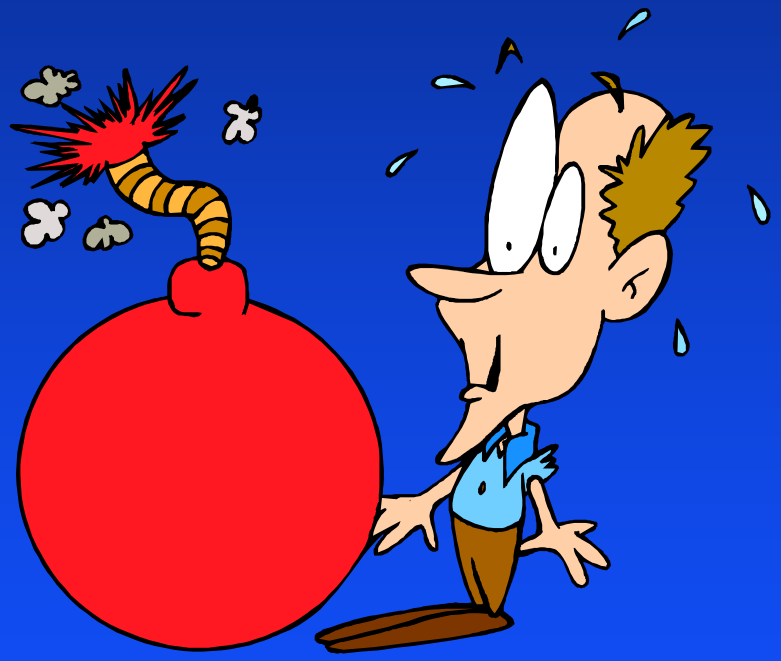
Why Is Radon A Concern?



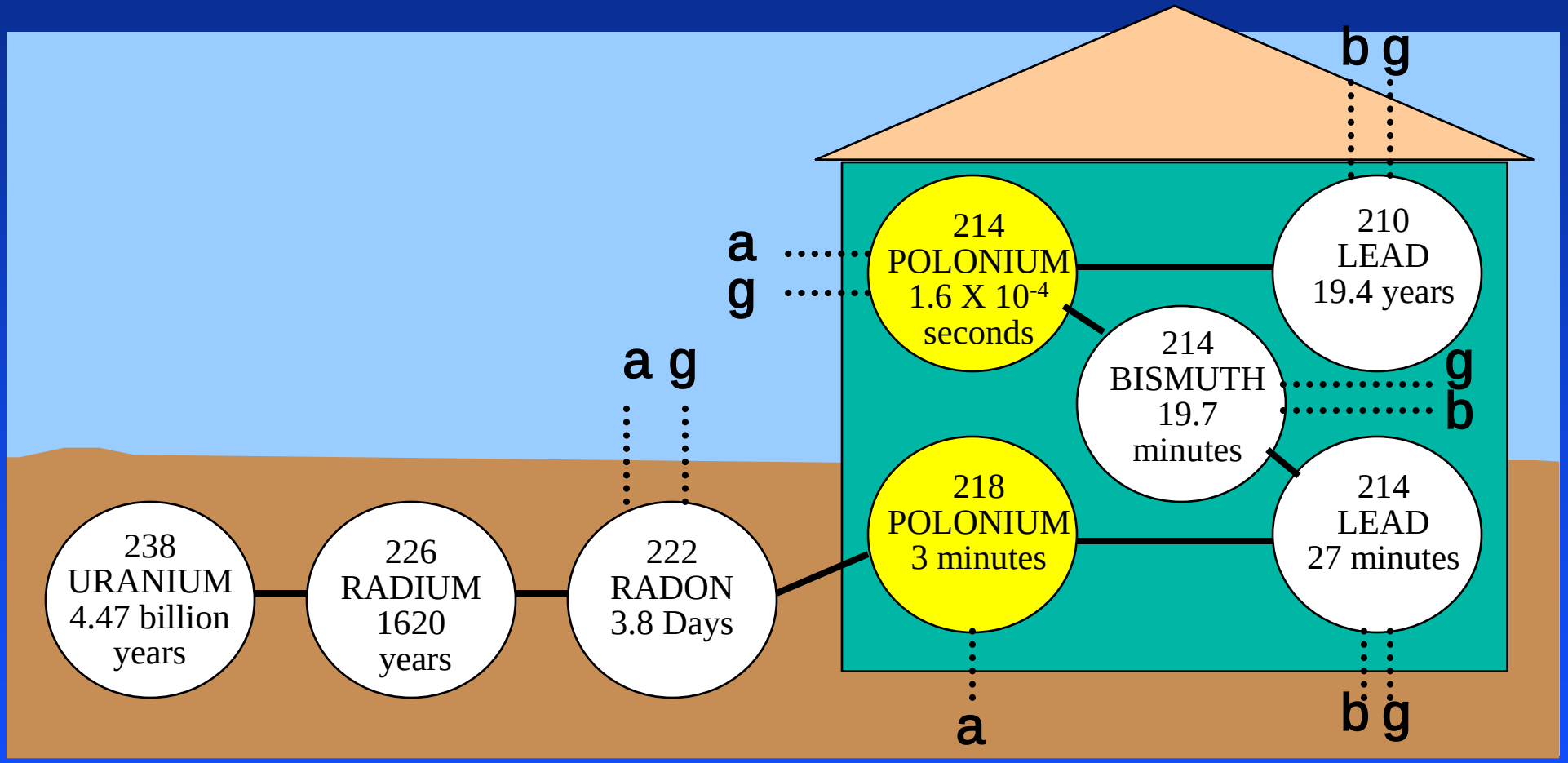
- Radon decays into radioactive particles known as radon decay products.
- These particles are easily inhaled and deposited in the lungs where they can damage sensitive lung tissue.

Radon Decay Products

- Solid particles / Heavy metals
- Have static charge
- Chemically reactive
- Source of cell damage in lungs
- Short-lived decay products most significant

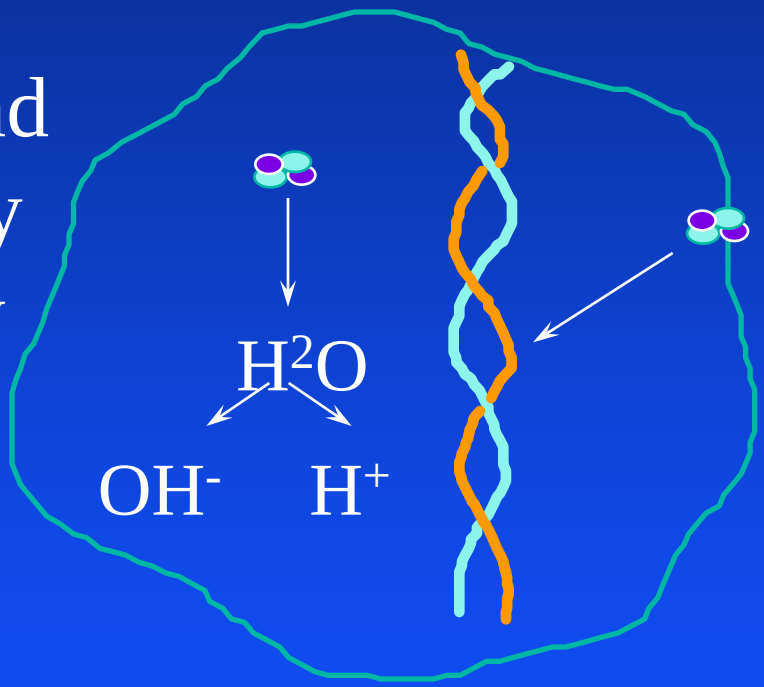


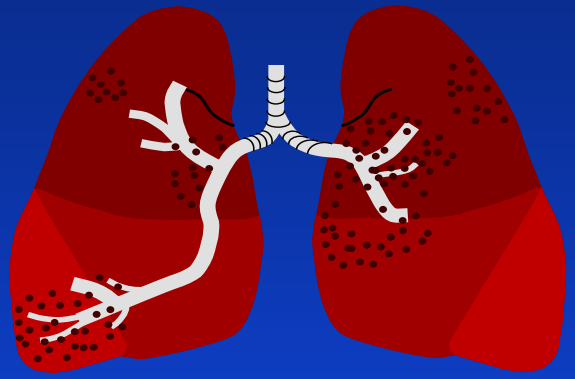
Radon Decay Products



Atomic Particles Can Damage Lung Cells

Double strand DNA split by alpha energy

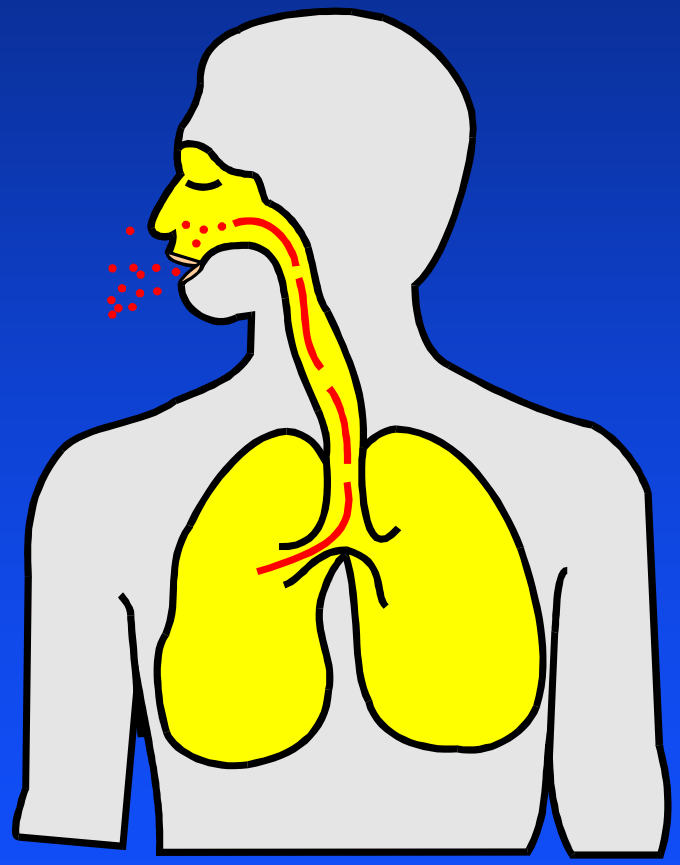




Lung cell will:
Die,
Heal Itself,
or
Become Cancerous

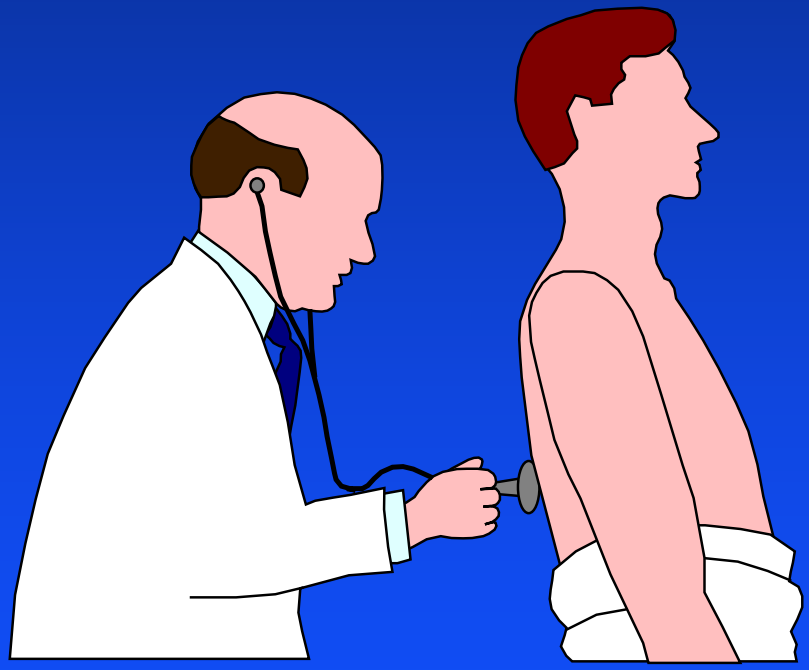
Radon Is the Second Leading Cause of Lung Cancer in the United States

- Radon is a KNOWN Human Carcinogen
  ("Class A" - like mustard gas, tobacco smoke, asbestos, benzene, and vinyl chloride)
- Only smoking causes more lung cancer deaths
- Radon results in approximately
  - 21,000 lung cancer deaths in U.S./yr
  - 600 lung cancer deaths in Michigan/yr
- **These deaths are preventable!**



Your Chances of Getting Lung Cancer?

- How much radon is in your home
- The amount of time you spend in your home (or any indoor environment w/elevated radon levels)
- Whether you are a smoker or have ever smoked



Scientific Basis For Radon Risk Estimates

- Studies on miners.
  - Uranium miners in U.S. and other countries
- Studies on residential occupants.
  - On-going and as a group confirm application of miner data to residential exposures
- Studies on laboratory animals.

EPA & Surgeon General Recommend That People Not Have Exposures Above 4 pCi/L On A Long-Term Basis

- Every home has some measureable level of radon.
- There is no known “safe” level
- 4 pCi/l is considered a “reasonably achievable” level
- Many homes can be reduced to below 2 pCi/l

"Radon Is A Serious National Health Problem"

- American Lung Association
- American Medical Association
- National Academy of Sciences
- National Council on Radiation Protection and Measurement
- U.S. Department of Health & Human Services
- World Health Organization

Lung Cancer Risk per 1000 People

Lifetime Avg.	Smoker	Non-Smoker
20 pCi/L	260	36
10 pCi/L	150	18
8 pCi/L	120	15
4 pCi/L	62	7
2 pCi/L	32	4
1.3 pCi/L	20	2

(Info from Citizen's and Home Buyers & Sellers Guides)

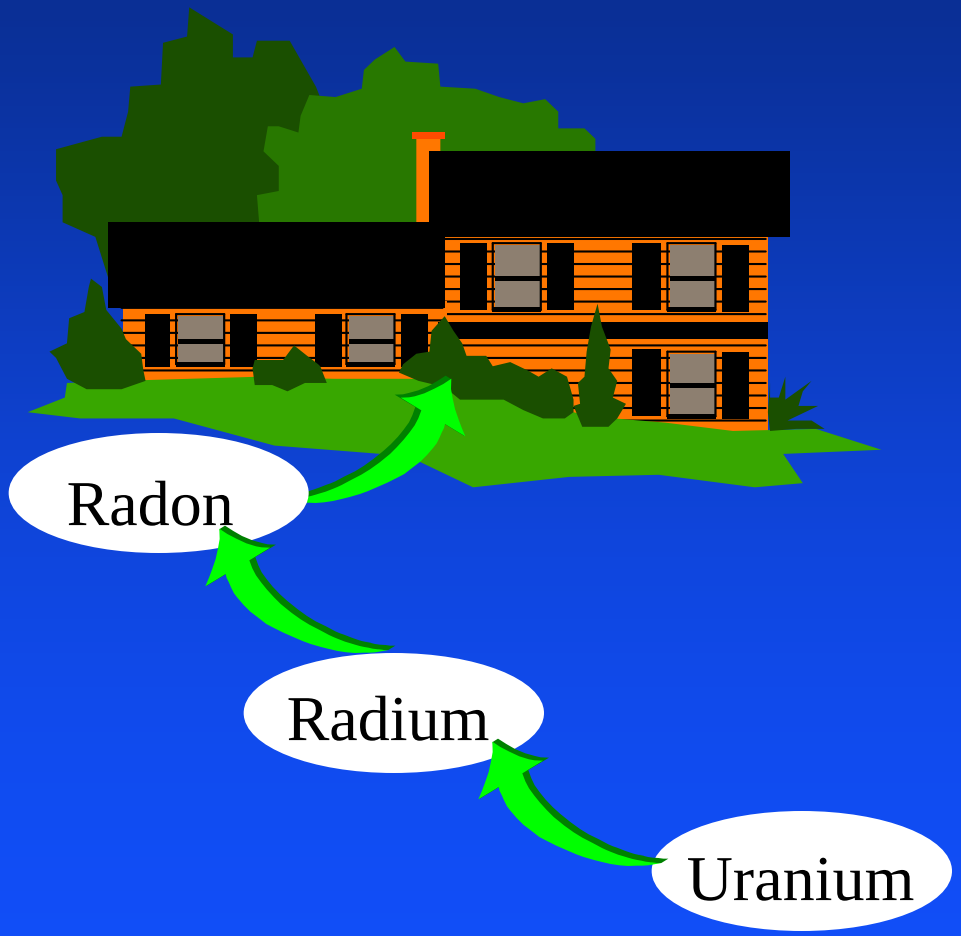
How Long Have We Known About Indoor Radon?

- 1900 – Radon was discovered by Friedrich Ernst Dorn who called it niton.
- 1920s & 30s – Radon was suspected as a cause of lung cancers; particular attention paid to underground miners.
- 1950s – Rn decay products were implicated as the causative agent

Stanley Watras at the Limerick nuclear power plant, 1984

- 1984 – Stanley Watras set off alarms at a Pennsylvania nuclear power plant still under construction. (His home tested at 2,700 picocuries/liter!)

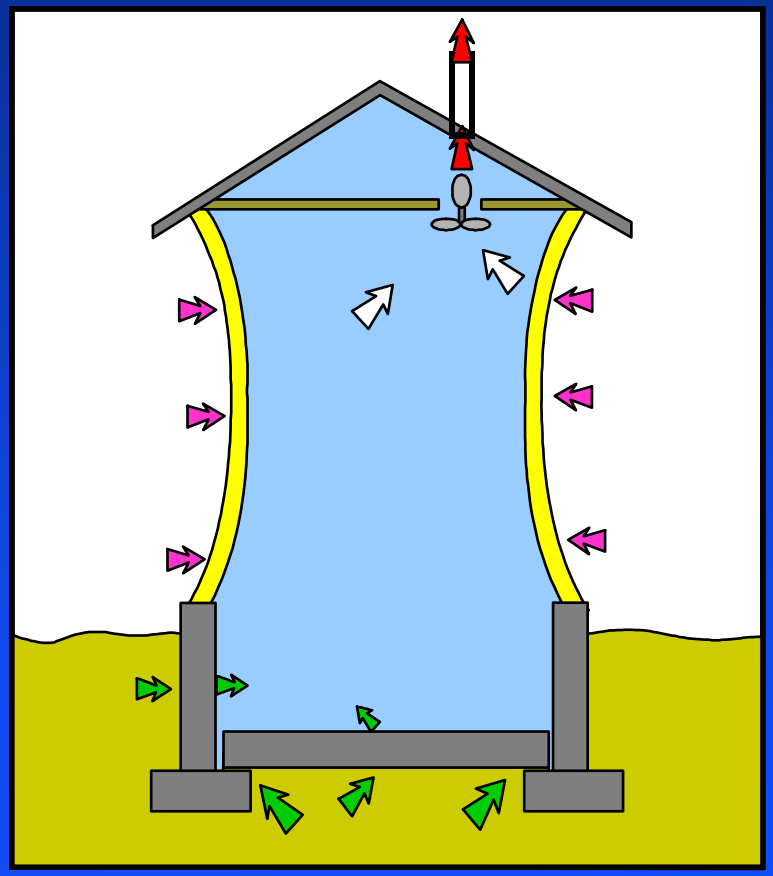
Radon Entry and Behavior



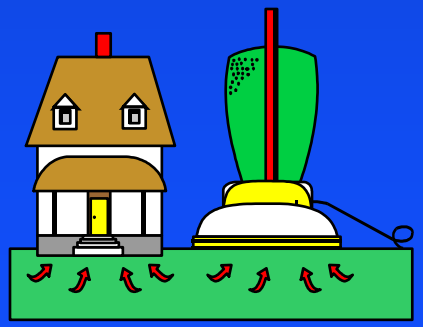
Indoor Radon Levels Depend On:

1. Radon Strength in the Soil
2. Soil Porosity
3. Building-to-Soil Pressure Difference
4. Building Ventilation Rate
5. Openings into the Soil (entry points)

Negative Pressures in Building Normally Cause Radon Entry

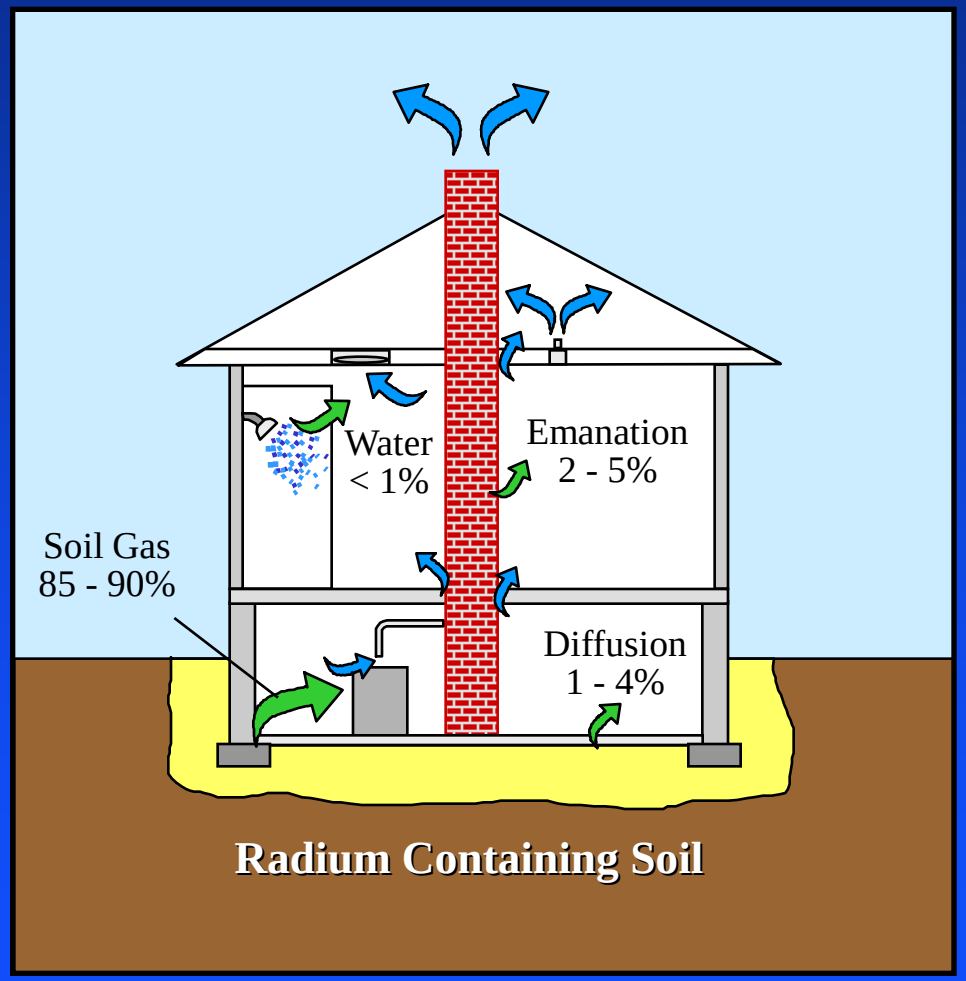


- The same factors that increase outside air infiltration can pull air from soil into home:
  - Stack effect
  - Exhaust systems
  - Weather



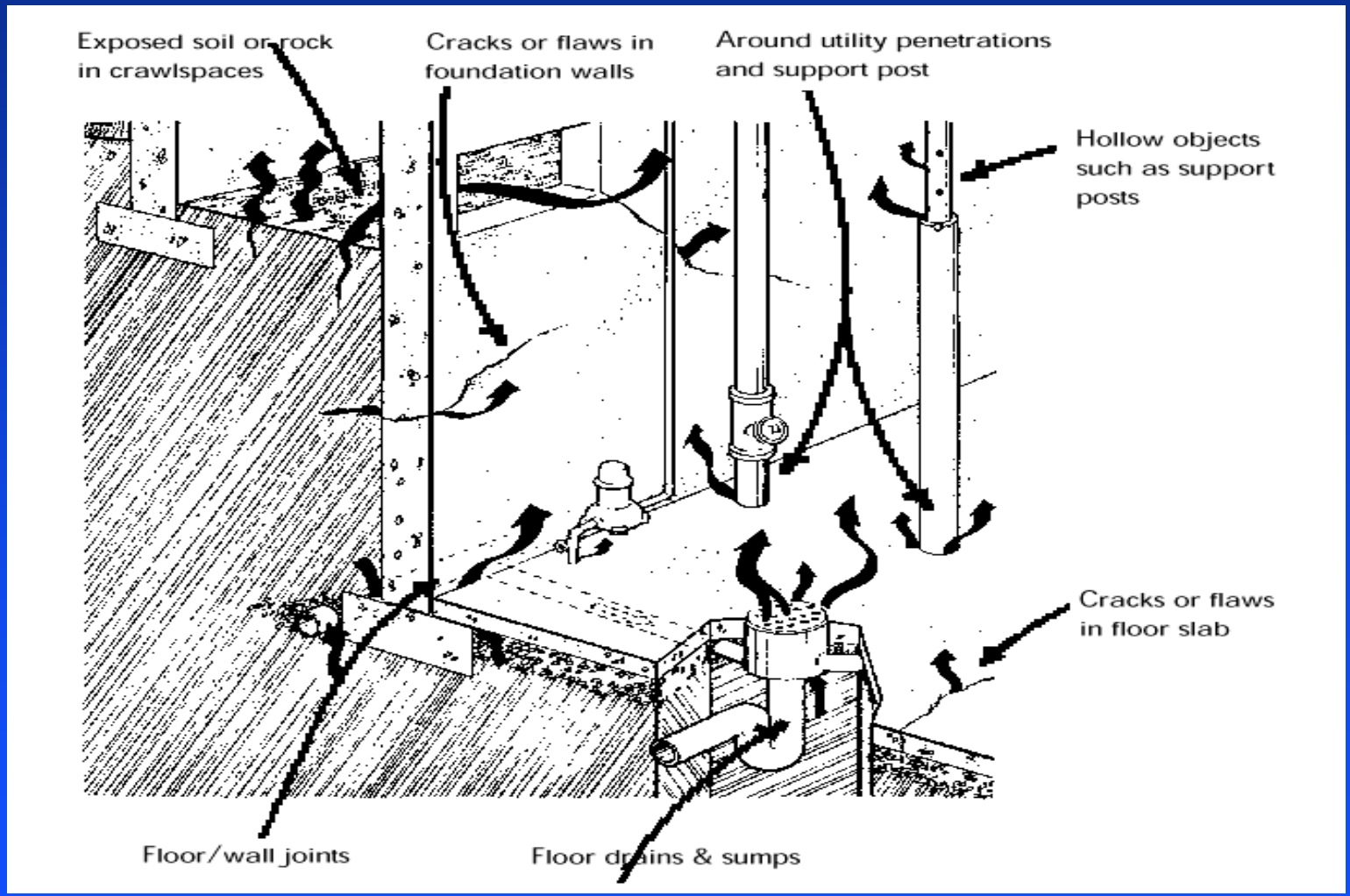
Houses are like soil vacuum cleaners...

How Does Radon Enter A Home?



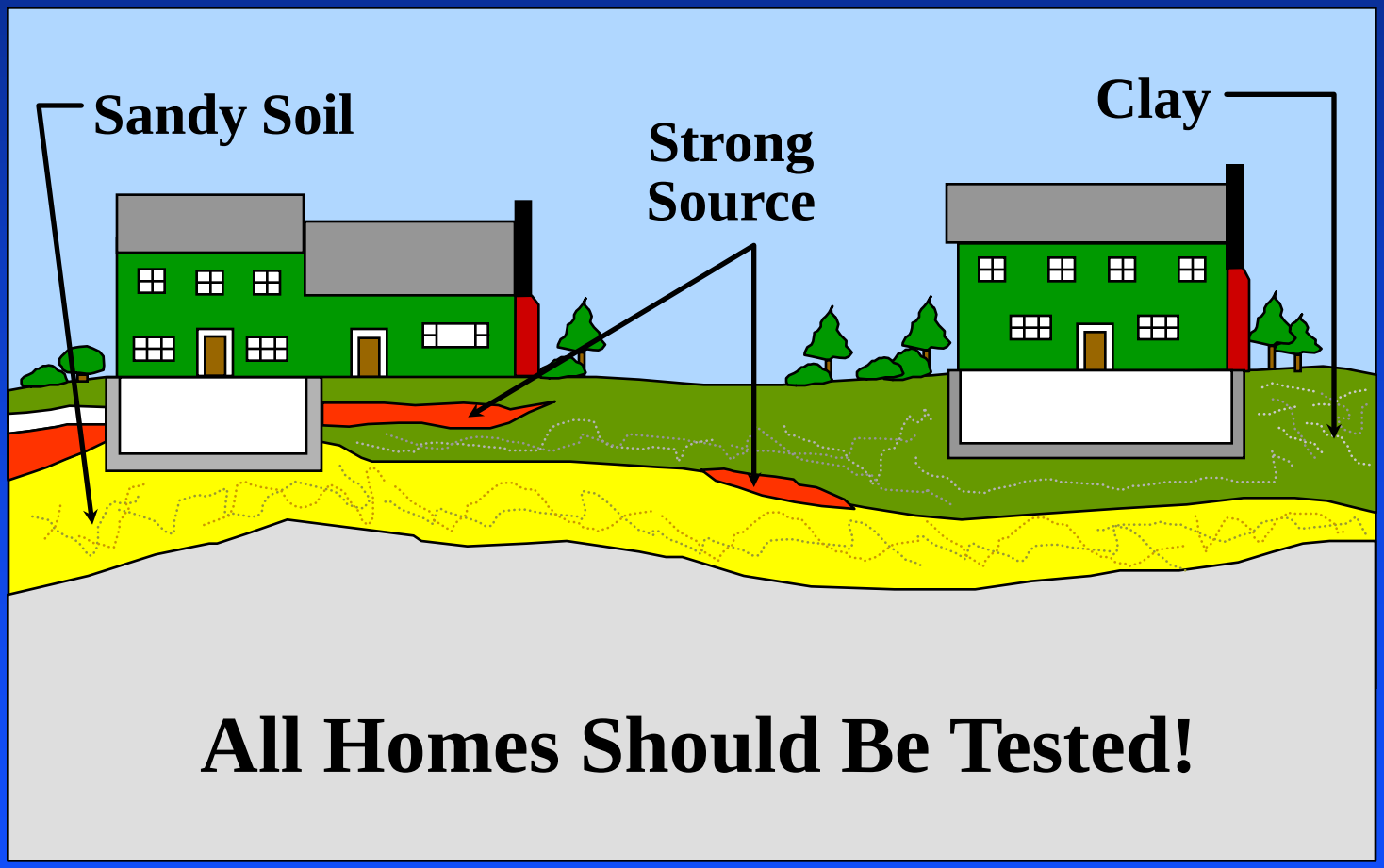
- Most radon comes from the soil and enters through openings in the foundation floor or walls
- Smaller concentrations can come from:
  - Emanation from building materials
  - Diffusion through concrete
  - Water supply

How Radon Enters Your Home



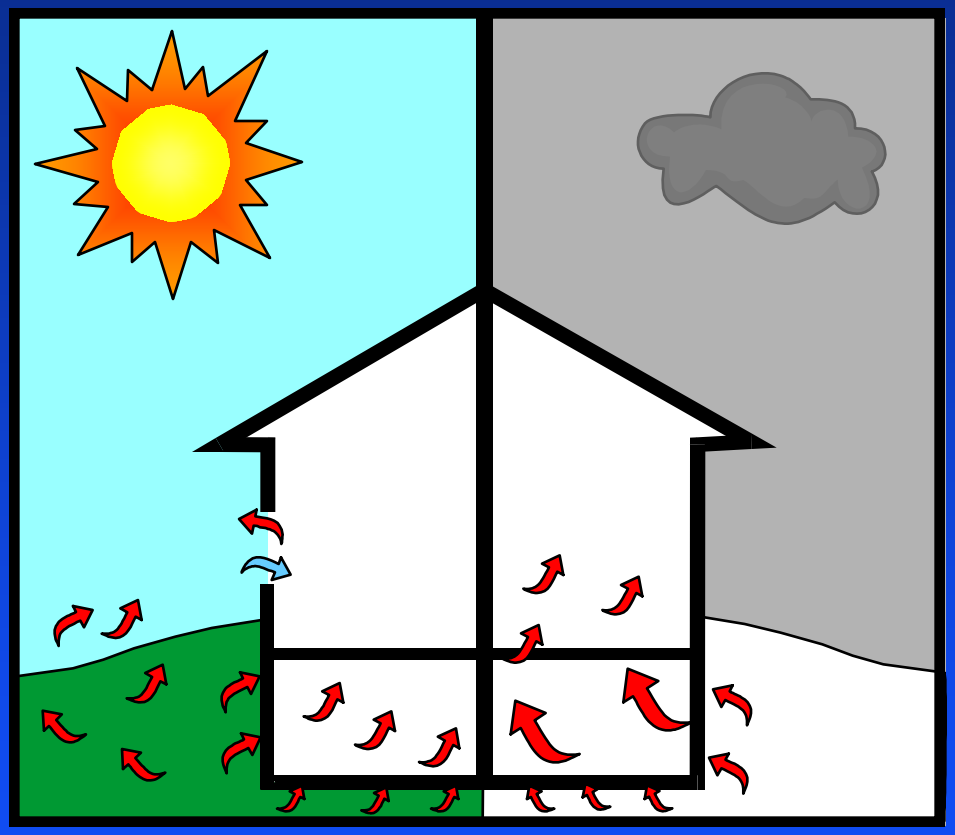
Some Entry Points May Be Hidden

Radon Entry Varies from Building to Building



All Homes Should Be Tested!

Radon Levels Fluctuate

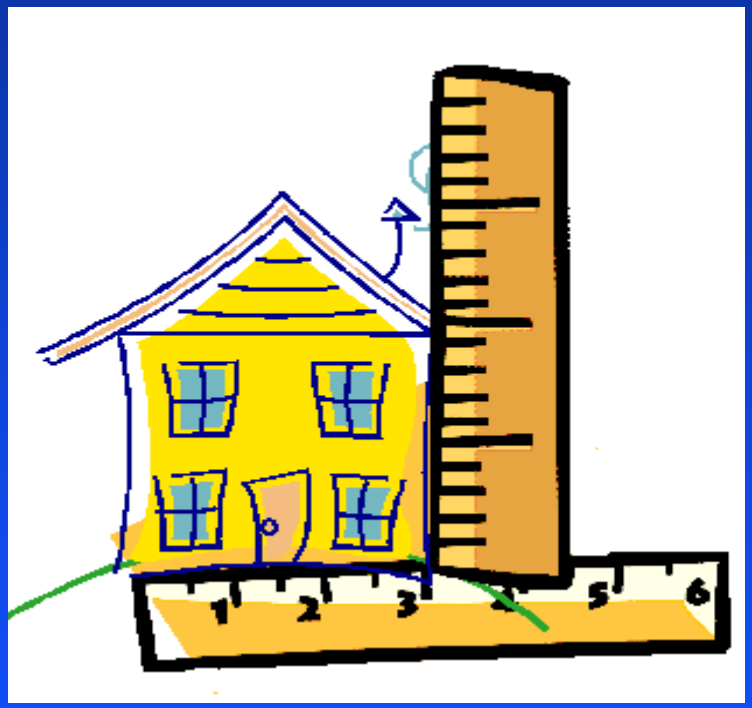


Summer
Open Windows

Winter
Closed Windows

- Radon levels fluctuate from morning to night, day to day, week to week, and season to season.
- Natural and mechanical ventilation can influence radon levels.
- Temperature, wind, barometric pressure and precipitation can influence radon levels.

Measuring Radon



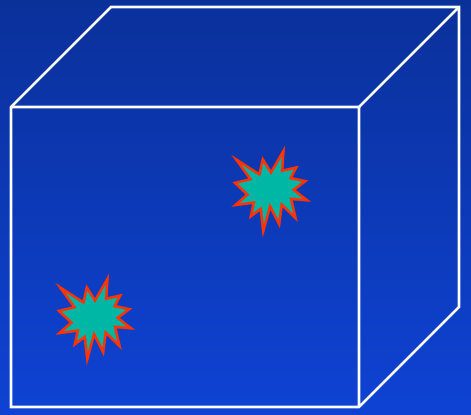
Radon Measurement Units

- Radon is measured in picocuries per liter of air - pCi/L
- The picocurie is named for French (Polish) physicist Marie Curie
  --A curie is a measure of radioactive decay
  --Pico is trillionth
  --Picocurie is a trillionth of a curie

Radon Measurement Units

- One picoCurie per liter (pCi/L) is 2.22 disintegrations per minute within a liter of air

- 4 pCi/L is equal to 8-9 atoms decaying every minute in every liter of air inside the house -- a 1,000 sq. ft. house at 4 pCi/L has 2 million decays per minute



Typical Radon Levels

- Radon in soil air ranges from 20 to 100,000 pCi/L
- Most soils range from 20 to 2000 pCi/L
- Outdoor air is 0.2 to 1 pCi/L
- Radon in indoor air ranges from less than 1 to 3,000 pCi/L
- Average indoor level is 1.3 pCi/L
- 4 pCi/L is EPA's guideline level

Testing Is Easy and Inexpensive

Charcoal canisters, vials, and bags

- Do-it-yourself screening measurement kits generally $10 or less from local health departments (a few charge more)
- $15 and up from hardware stores/home improvement centers ($25 is typical)
- Professional testers charge $50-$200

Other Devices

Alpha Track Detectors

(for long-term testing – 90-365 days)

Electret Ion Chambers

(Electret Passive Environmental Radon Monitor – E-PERM – for short or long tests; available to individuals but generally used by professional testers)

Continuous Radon Monitor

(generally for short tests; used by professionals and most often for real estate transactions)

Procedures for Measuring Radon

Measuring Radon is a scientific process. As such, there is a need to follow consistent procedures to assure accurate and reproducible measurements and to avoid the collection of unreliable or misleading data.

Screening Measurements
(Short-term: 2 - 90 days)

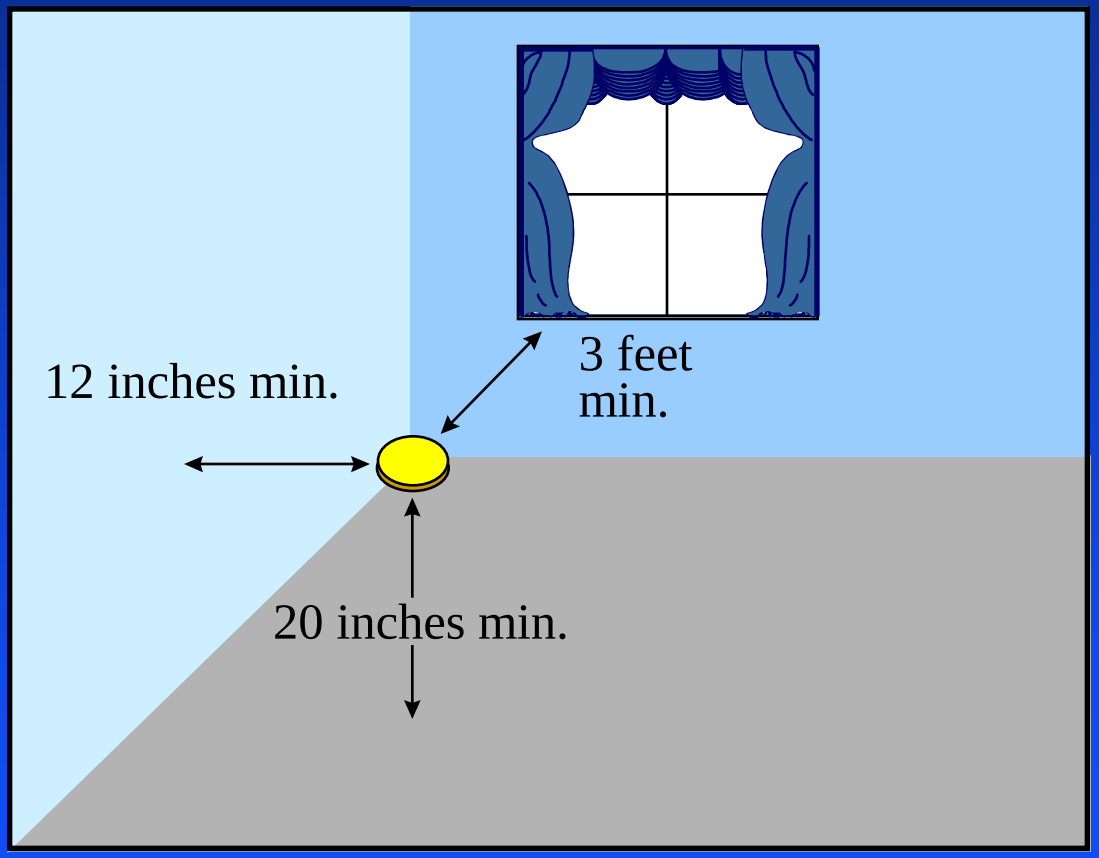
- All exterior doors and windows closed, except for normal entry and exit, prior to and during test.
- Place device in lowest livable level of home.
- Select a room where you do or could spend time.
- Avoid testing during severe storms or periods of high winds.

Testing Locations?

GOOD CHOICES: Bedroom, Family Room, Living Room, Office or Study

Don’t test in closets, bathrooms, kitchens, laundry rooms, storerooms, garages, crawl spaces, or attics

Test Placement Within A Room



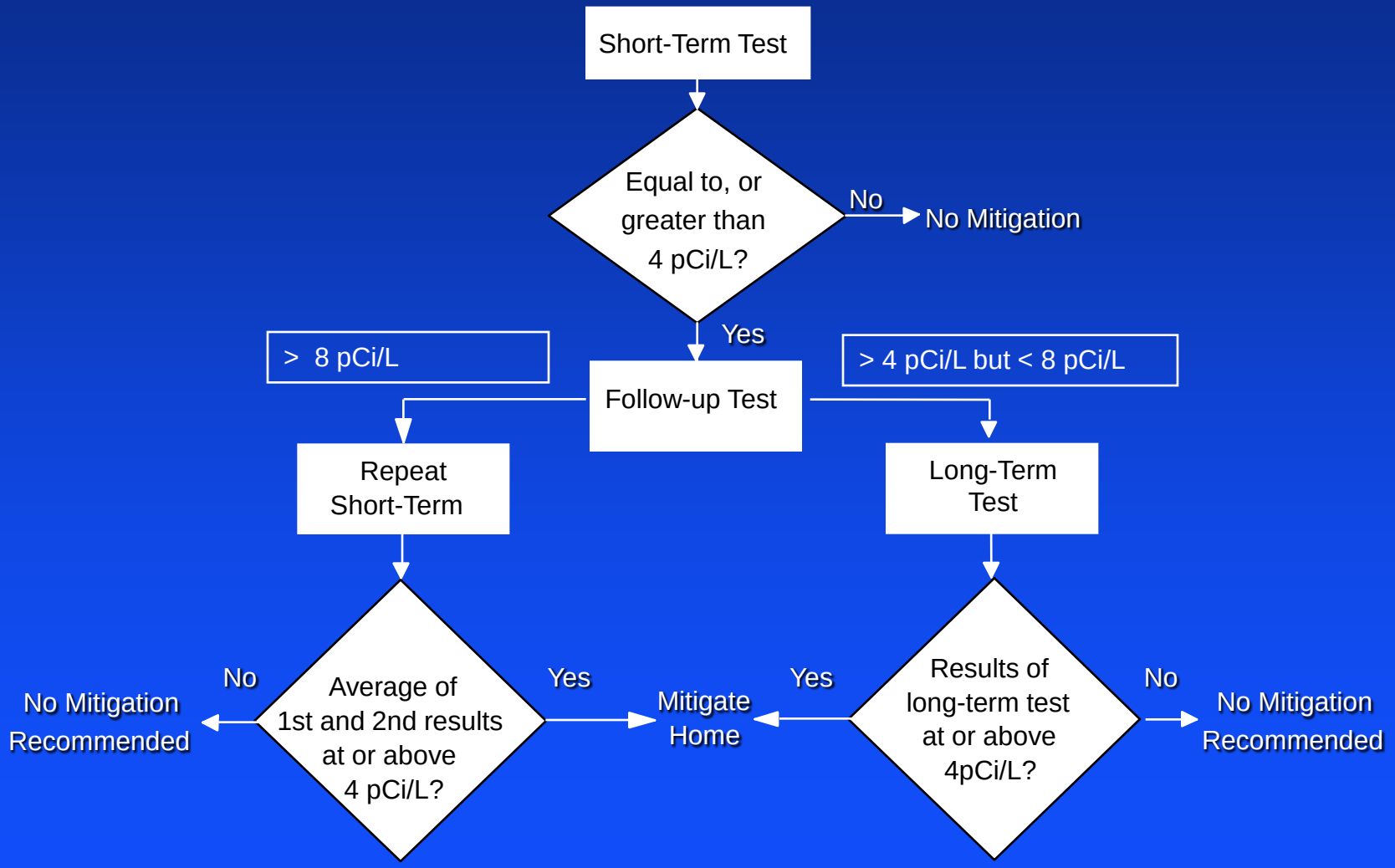
- At least 3 feet from windows, exterior doors, or other openings in foundation floor or walls.
- At least 20 inches above floor (preferably 3-6 feet – “breathing zone”).
- At least 12 inches from exterior walls and 4 inches from other objects.
- Away from air vents, drafts, or heat sources.
- Where it won’t be disturbed.

Long-Term Measurements
(91 days to 1 year)

Radon levels tend to be higher in winter and lower in summer, but risk actually comes from long-term exposure. A year-long test takes into account all changes in occupancy, as well as changes in wind, temperature, barometric pressure and precipitation. (When doing long-term tests, a full year is best!)

- Doors and windows opened or closed whenever you like. (Live the way you normally live!)
- Place device where original test was placed, as well as on any other levels you wish to test.
- Select a room where you do or could spend time.
- READ and FOLLOW instructions!

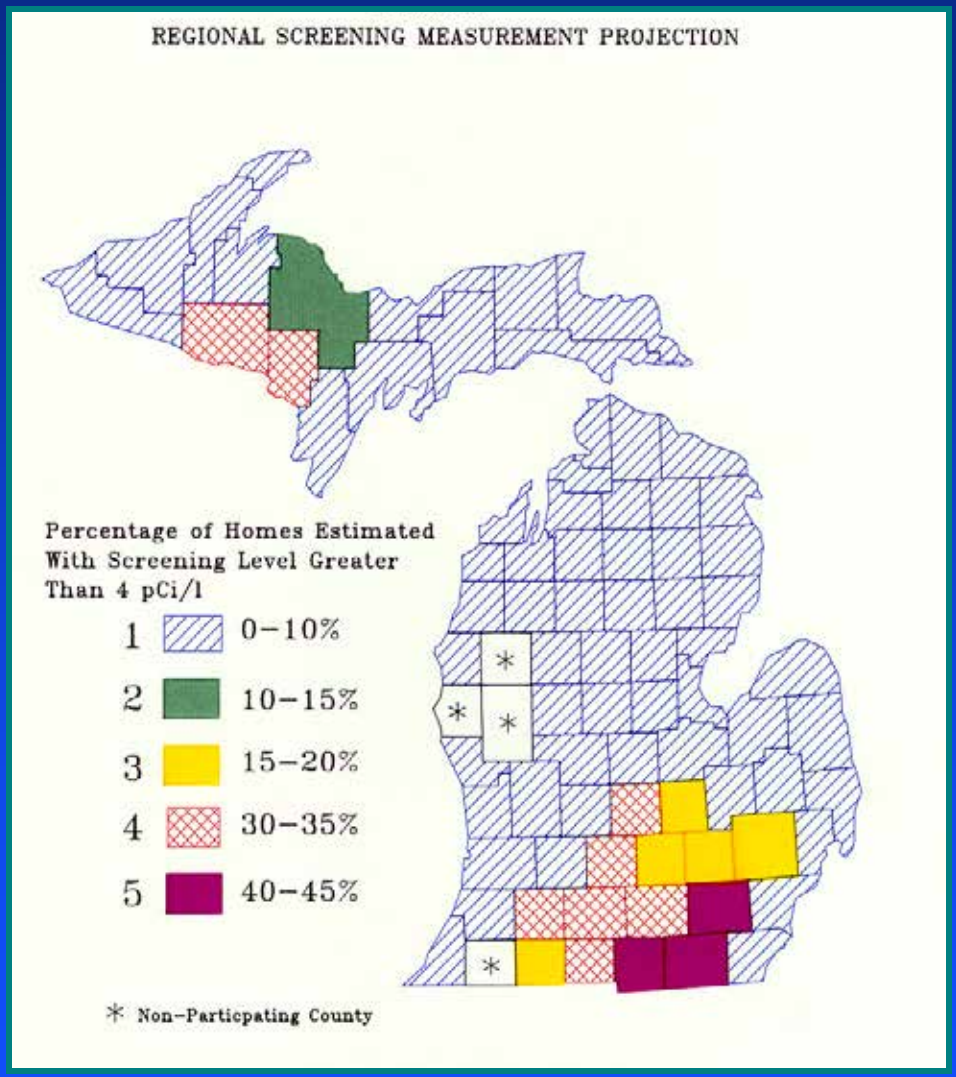
Interpreting Radon Results



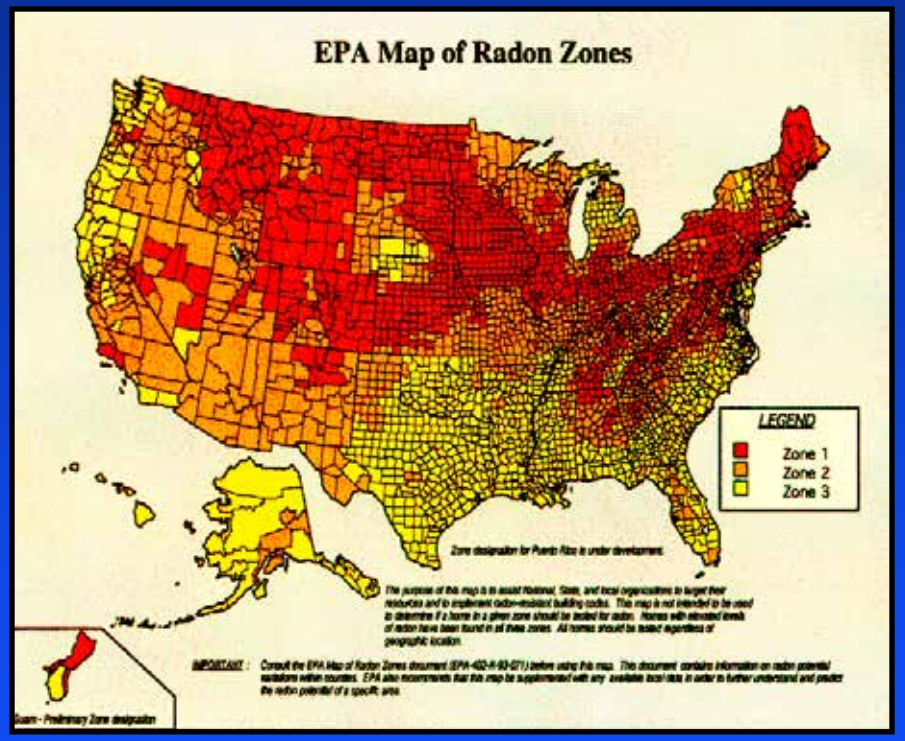
And The Survey Says...

MDPH worked with local health departments to conduct statewide residential radon survey in 1987-88:

- Tested more than 2,000 randomly selected homes
- 12% projected to have elevated indoor radon levels
- In some counties, more than 40% of homes could have a problem



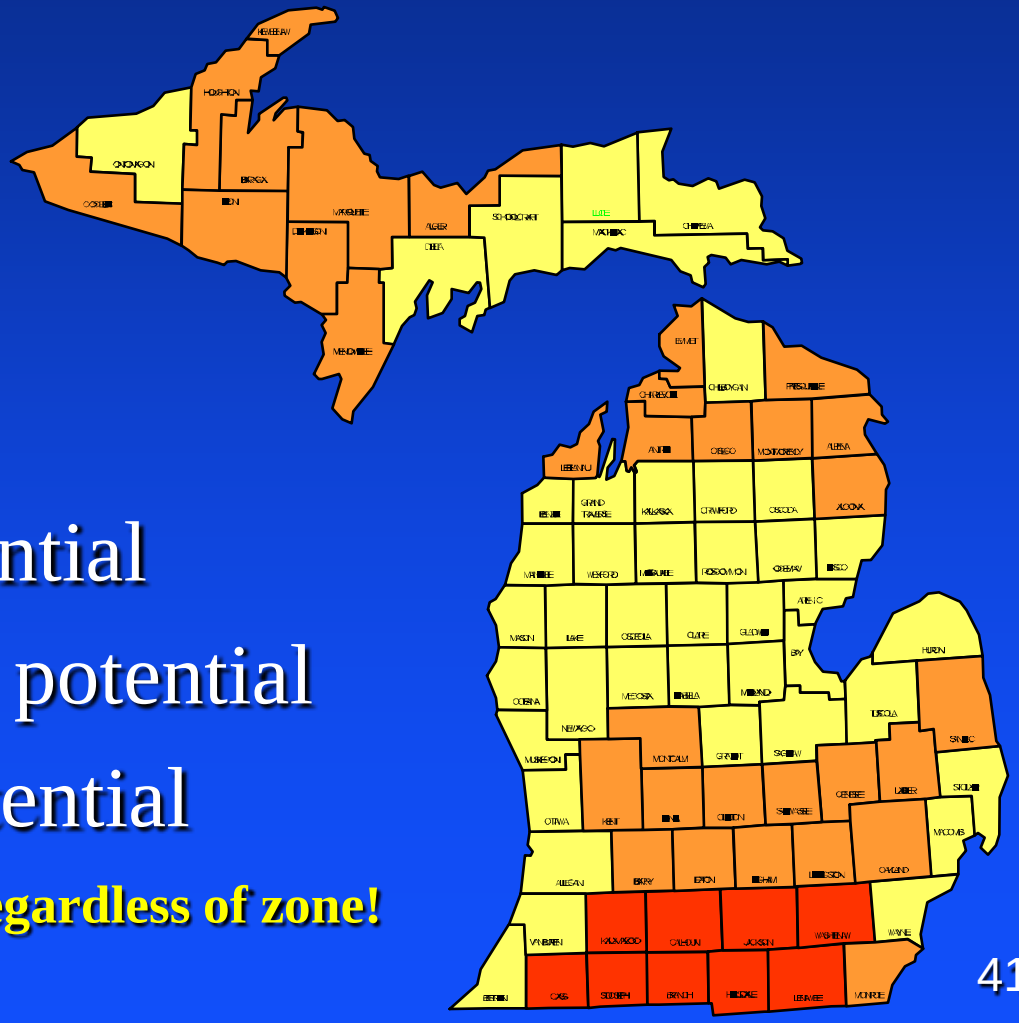
Map of Radon Zones By County



Map generated in 1993

- More than 3100 counties in the U.S.
- Zone designations based on indoor radon measurements, geology, aerial radioactivity, soil parameters, and foundation type.
- Expected short term Rn (pCi/L):
  - Zone 1: > 4.0
  - Zone 2: > 2 < 4.0
  - Zone 3: < 2.0

Michigan Radon Potential By County (1993)



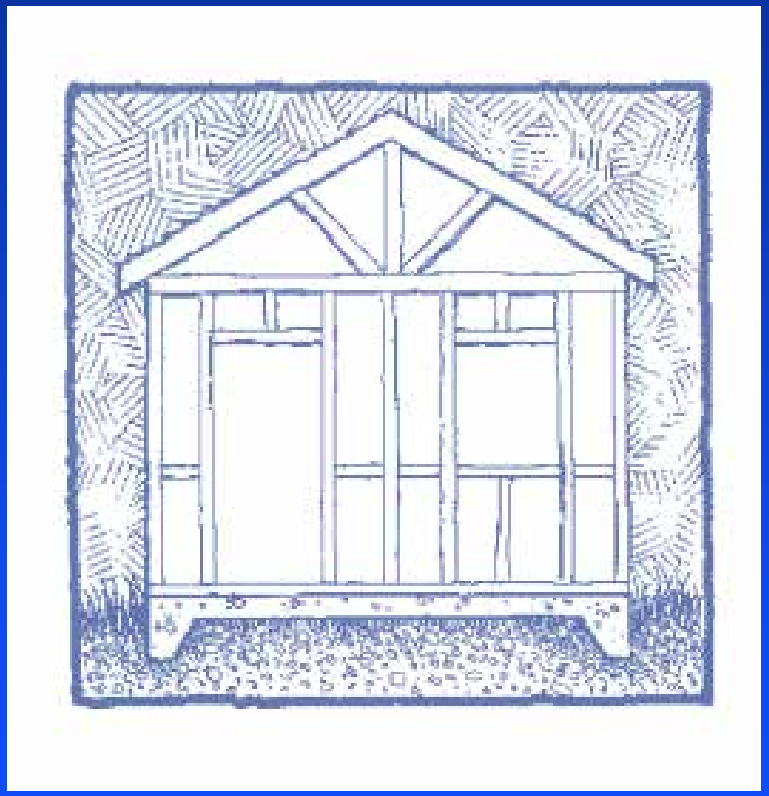
Zone 1: high potential

Zone 2: moderate potential

Zone 3: lower potential

NOTE: All homes should be tested, regardless of zone!

Building Radon-Resistant Homes



Basic Components of Passive System

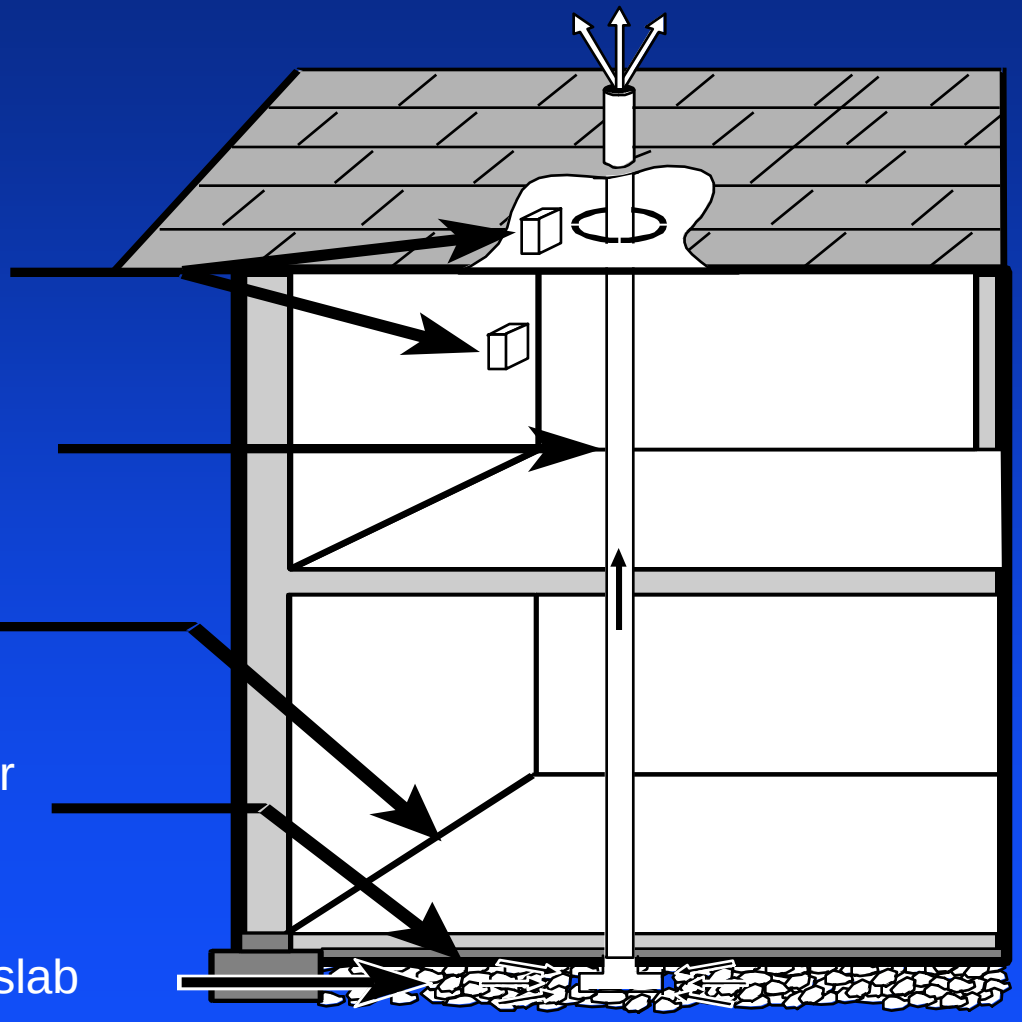
Junction Boxes
(to power fan and warning device, if needed)

Vent pipe running between sub-slab gravel and roof

Sealing and caulking

Polyethylene soil-gas retarder between slab and gravel

Large gravel beneath slab



Gas Permeable Layer

Ideally this is 4” of a clean 1” aggregate, but can be pea stone, or even sand,

Gas Permeable Layer

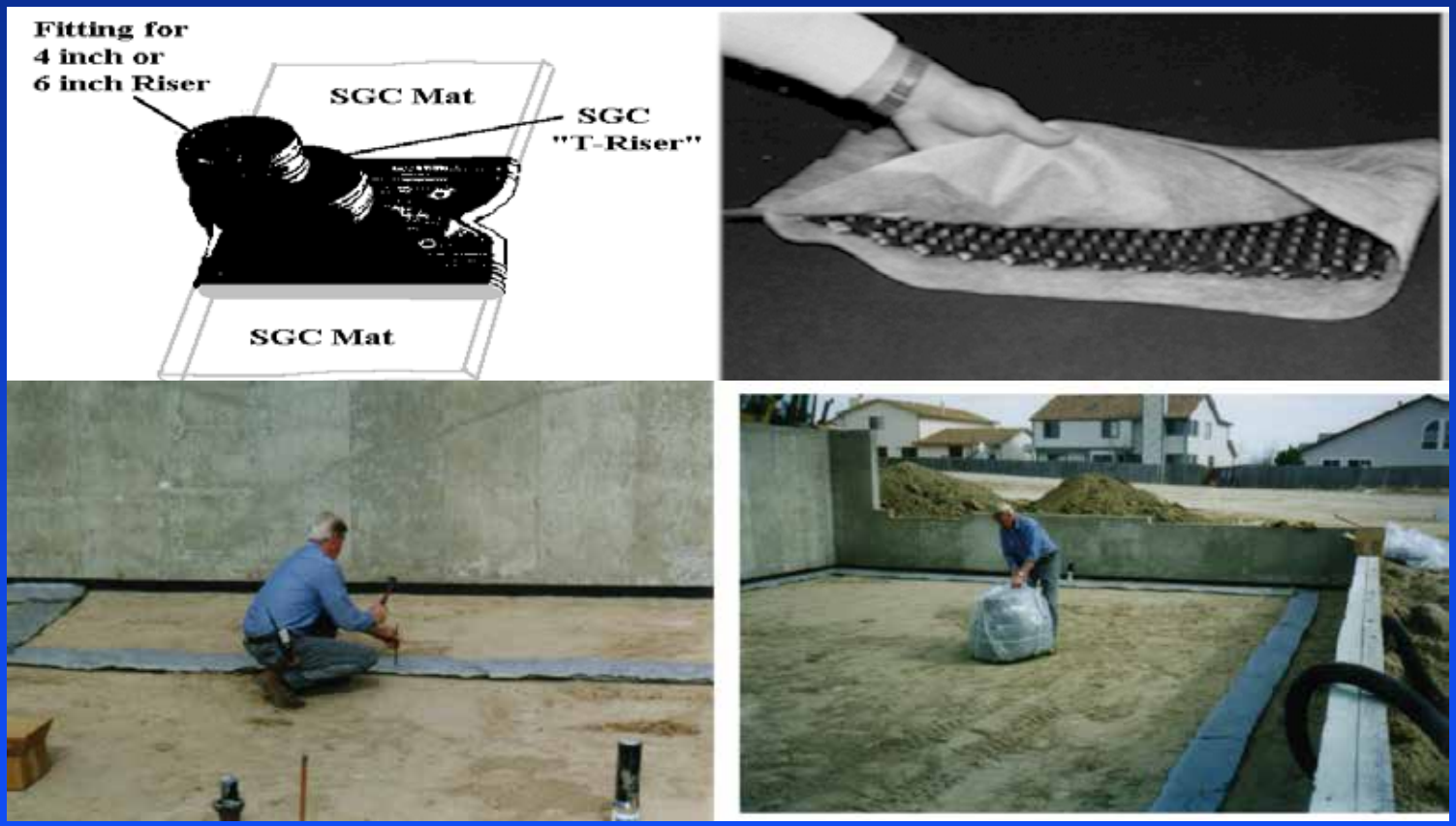
Perforated draintile improves air movement through native soils.

Pipe is trenched into fill beneath concrete, laid out in a loop.

Filter cloth can reduce silt blockage over time.

Gas Permeable Layer

Soil gas collection mat can be used in place of perforated draintile.



Soil Gas Retarder

Minimum 6 mil polyethylene sheeting (or 3 mil cross-laminated)

Soil Gas Retarder

overlap 12”
- does *not* need to be sealed

Caulking and Sealing

- Caulk and Seal all openings in the foundation floor or walls

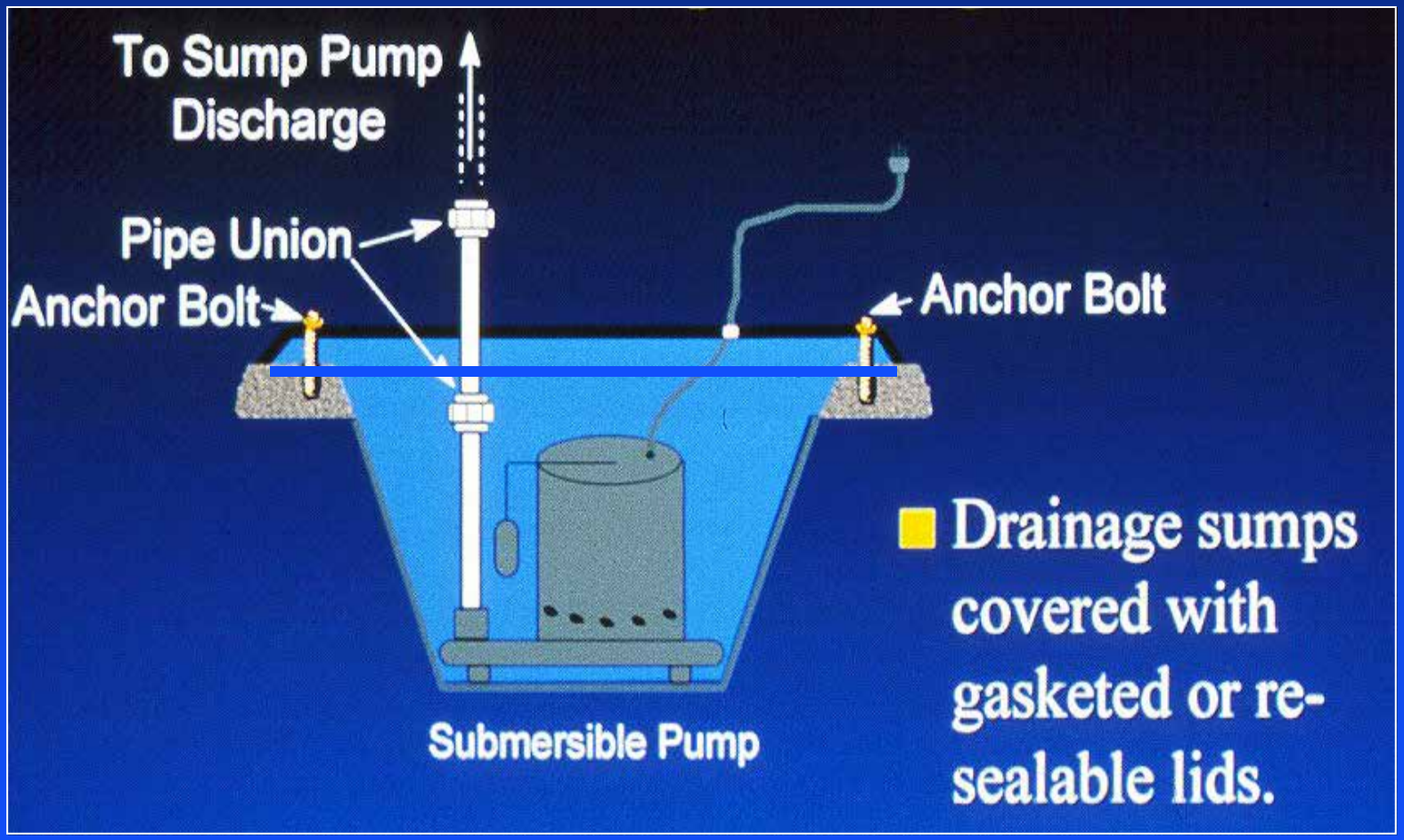
Seal Entry Routes

- Seal floor openings with polyurethane or equivalent sealant
- All floor, floor-wall joints sealed with polyurethane caulk or elastomeric sealant
- Trap condensate drains or route through non-perforated pipe to daylight
- Seal sumps with lid and vent pipe; if used as a floor drain have a trapped inlet

Seal Entry Routes

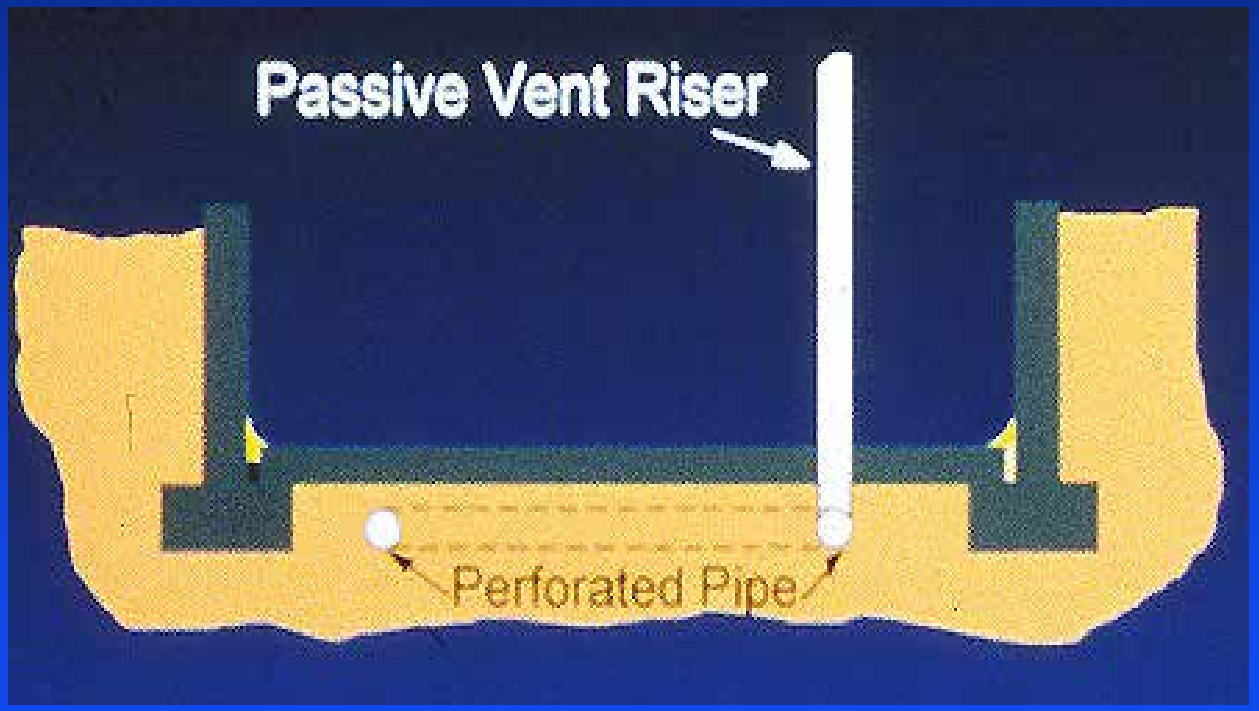
- Seal foundation walls with damp proofing
- Grout top course of hollow block masonry walls or lay with solid block
- Seal below brick veneer ledge
- Seal all penetrations below grade with polyurethane caulk or equivalent

Sealed Sump Cover



Passive Vent Riser

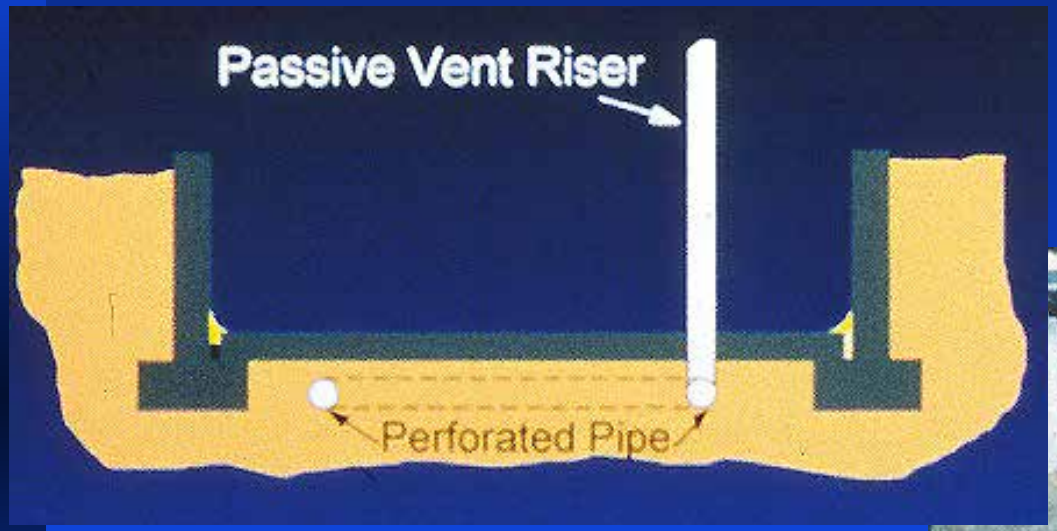
Minimum 3” (max. 4”) diameter PVC pipe



Passive Vent Riser

Tee fitting supports vent riser and keeps opening out of gravel

Tying Vent Pipe into Drain Tile Loop



Improves air movement through native soils

PVC Pipe with Plastic Sheeting

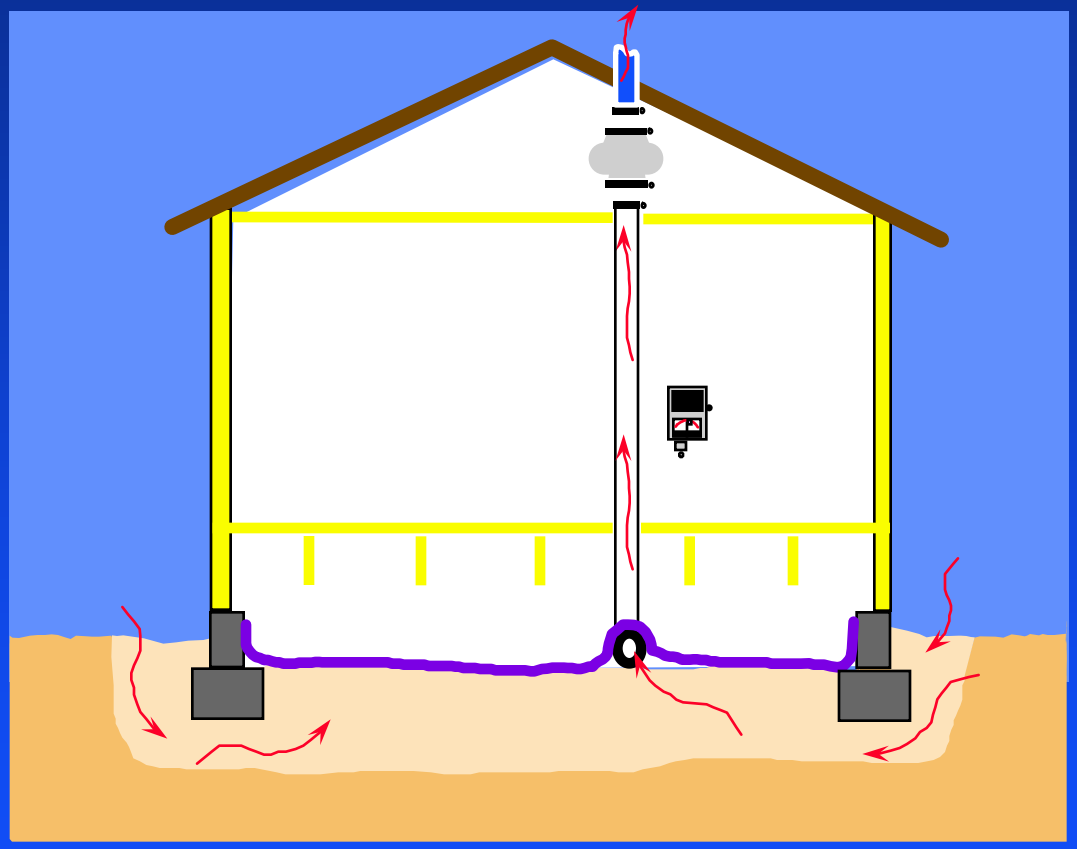
System Discharges Through Roof

- Discharge should be high enough to avoid radon re-entering building.
- No rain cap.
- 1/4 inch screen if appropriate.

Electrical Junction Box

Installed in attic so PASSIVE system can be ACTIVATED if necessary

Crawl Space System
Sub-Membrane Depressurization (SMD)



- Vacuum applied beneath plastic.
- Radon and moisture collected and exhausted away from building.

Polyethylene Sheeting in Crawlspace

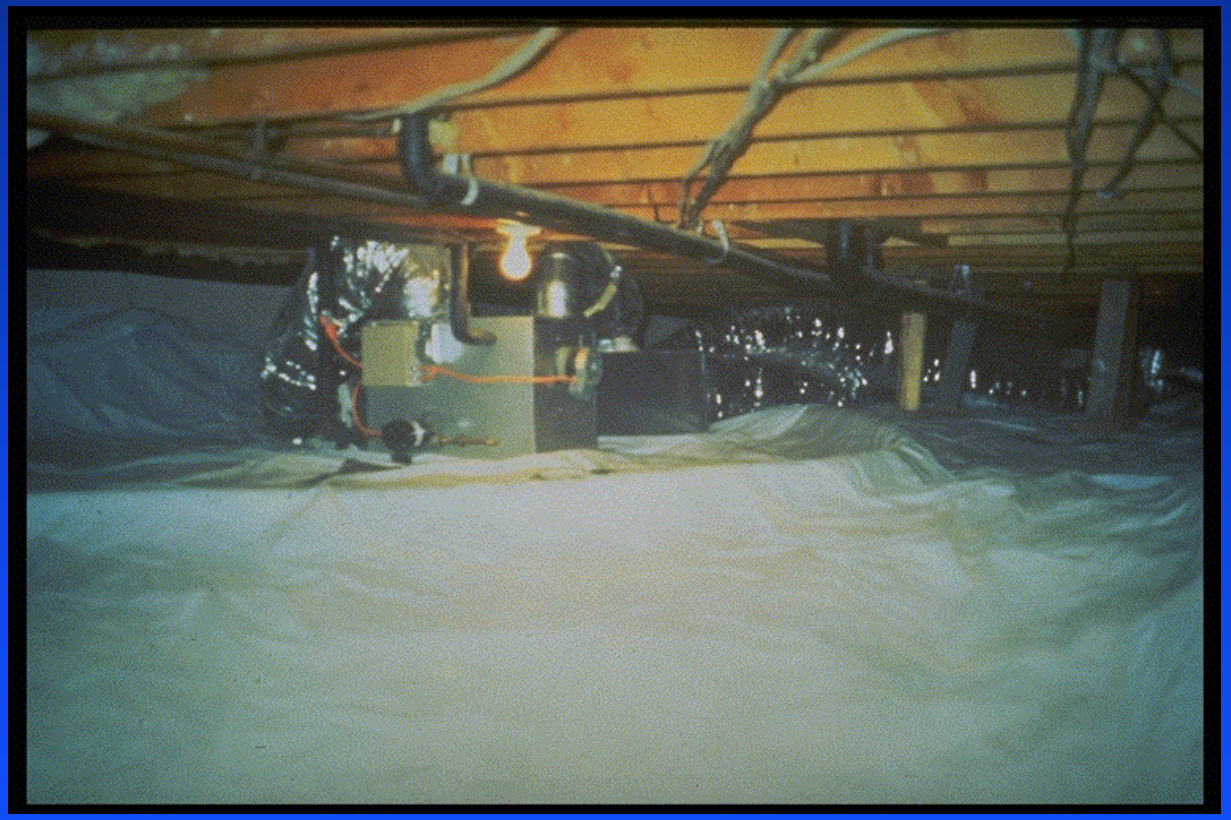
(***NOTE***: Duct tape is not adequate as a stand-alone sealant!)

Extended TEE in Crawlspace

Perforated Pipe on Soil

- Perforated pipe used to collect gas
- Laid on floor of crawl space

Plastic Spread Out in Crawl Space



- High density polyethylene laid on dirt.
- Edges and seams sealed.

Plastic Sealed to Wall with Caulk

Riser From Plastic

- Perforated pipe connected to solid PVC pipe.
- Sealed with 2 roof jacks sandwiched together.
- Riser routed to fan.

Crawl Space Issues

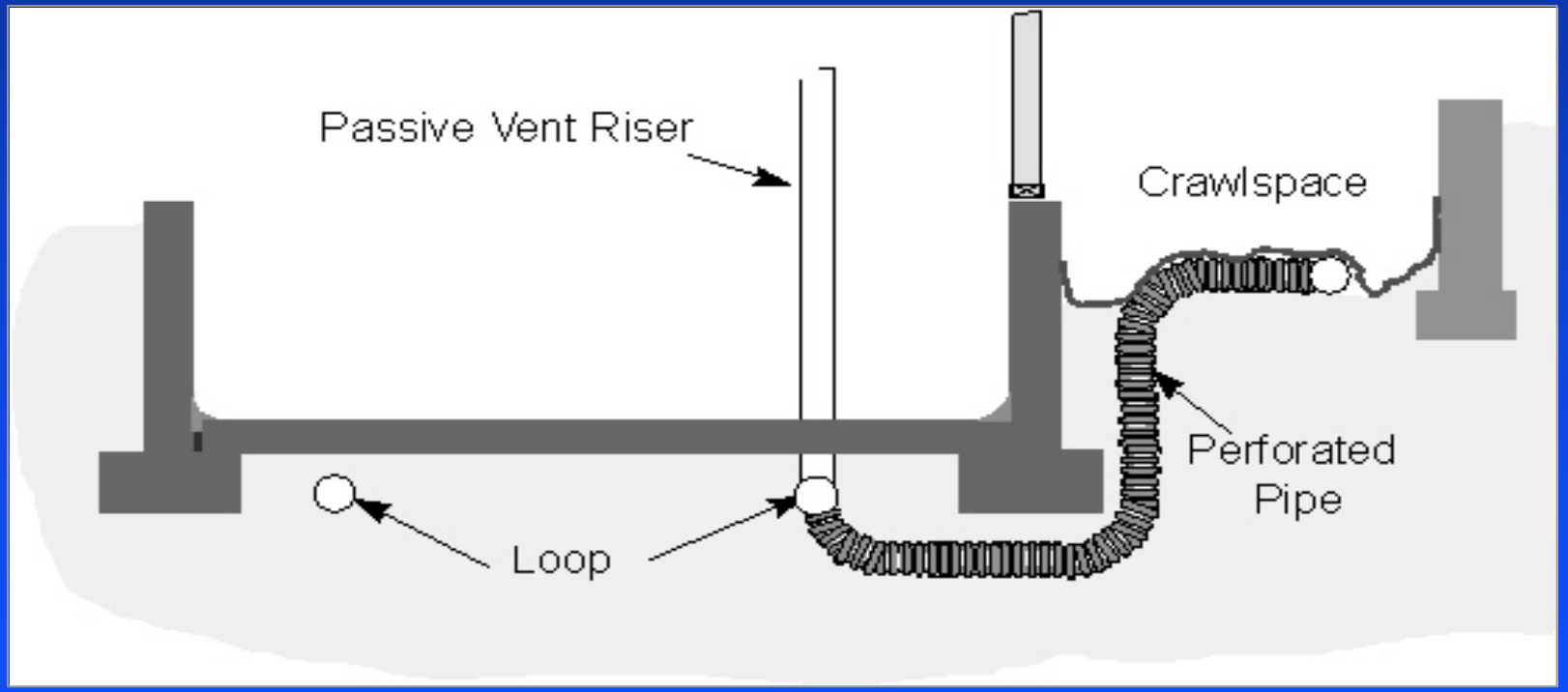
- Air handling units in crawl spaces must be sealed
- Ducts in crawl spaces must be sealed or under positive pressure
- Seal floor penetrations with caulk to prevent air leakage
- Seal access doors and openings between crawl spaces and basements

Crawl Space Issues

- Vent crawl spaces according to code
- Cover soil with 6 mil sheeting overlapped 12 inches, seal to all walls & footings/piers
- Extend 3- or 4-inch vent pipe from tee fitting up through building to terminate 12 inches above roof and 10 feet from opening into building or adjacent building

Other Issues

Vent for each separate foundation type



When to Activate a Passive System

The only way to know if the techniques are working is to test the house under *conditions for occupancy*. If the radon level is greater than 4 pCi/L, install a fan to activate the system.

Active System Components

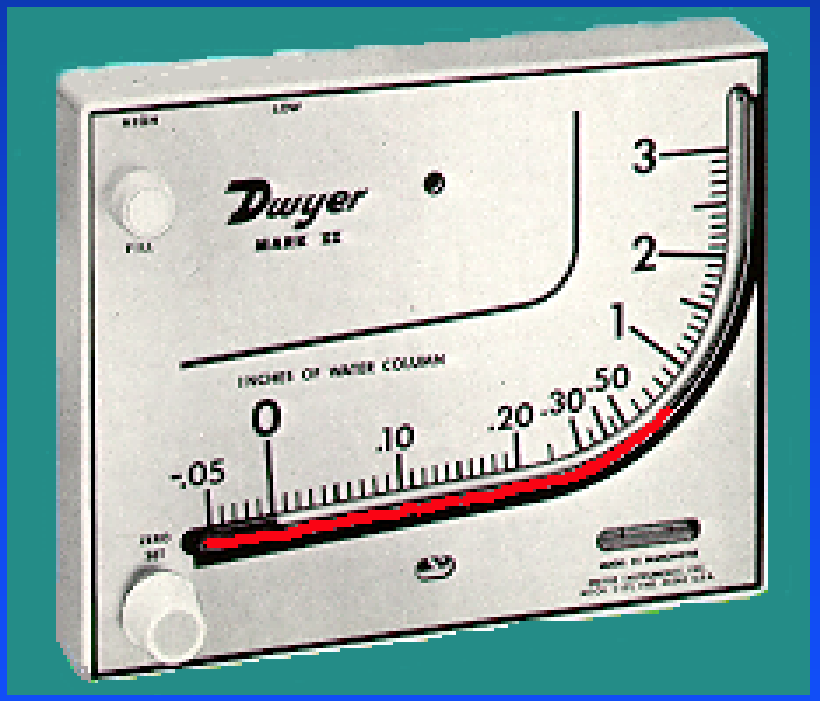
1. Exhaust Fan in the Vent Pipe

In-Line Fan

- Standard radon control fans consume 70-90 Watts and exhaust 10-40 CFM of conditioned air
- A small fan is generally all that's needed in new construction - 20 CFM at 10 Watts

Active System Components

2. A Visible or Audible Warning System



Four Unique Radon Control Items

- Passive vent pipe - $20-$40
- Two additional electrical junction boxes - $20-$40
- Sump pit cover, where sumps are installed - $25
- Layer of gas permeable material under slab - $100-$250

Other Building Practices That Help

- Tight Concrete Slab With Control Joints Minimizing Cracks
- Seal Hollow Block Walls
- Seal Joints in HVAC Ductwork
- Seal Other Potential Radon Entry Routes
- Reduce building depressurization through duct sealing in unconditioned spaces, air infiltration control and firestopping

Other Benefits of a Passive System

- Moisture control
- Estimated average energy savings of $65 per year due to sealing and caulking
- Helps reduce entry of other soil gases in the home (e.g., methane, pesticides, termiticides)
- Aesthetics and lower-cost when compared with fixing a radon problem in an existing home
- Resale value, especially as radon testing and mitigation are more frequently a part of real estate transactions

System Summary

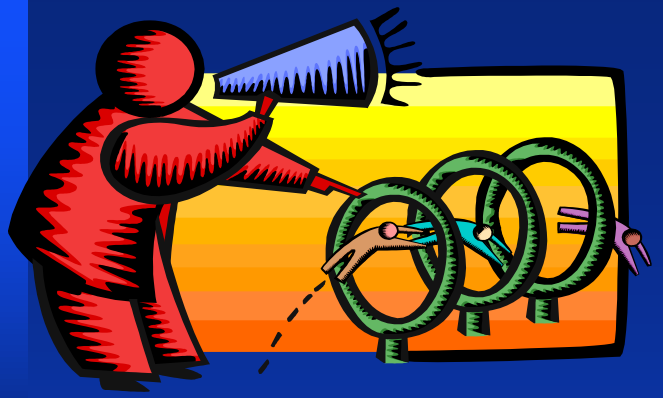
- Gas permeable layer four inches thick, greater than 1/4”, less than 2” sieve, or
- 4” sand overlain by gas permeable matting, or
- Other materials with capability to depressurize under entire floor area
- 6 mil poly or 3 mil cross-lam poly on top of gas permeable layer, lap 12” with close fit covering entire floor area

System Summary

- 3 inch minimum vent pipe in sub-slab material with tee fitting or equivalent to hold position in gravel, or
- 3” pipe in interior drain tile loop, or
- 3” pipe through sump cover where sump is connected to aggregate or drainage system
- Seal foundation openings
- Carry up through building to above roof termination

System Summary

- Vent each separate sub-slab area with individual vent or connect to single vent terminating above roof
- Install vent pipe to allow drainage to sub-slab
- Vent pipe shall be accessible for future fan in attic or outside habitable space
- Label vent pipe on each floor and in attic-RRS



Inspection Issues

- Plan Review
- Building Inspections
  - Footing
  - Slab
  - Backfill
  - Framing
  - Insulation
  - Final
- Electrical
  - Rough-in
  - Final
- Plumbing
  - Groundwork
  - Rough-in
  - Final

Code Enforcement Impact

- Gas-permeable layer and retarder inspected at slab inspection
- Sealed joints, openings and walls inspected at backfill or final inspection
- Vent pipe installation from basement through roof inspected at plumbing rough-in
- One or two electrical boxes for system activation inspected at electrical rough-in

Bob Brown - NCSBCS

Building Codes

- CABO approved RRNC techniques as Appendix F in 1995 (Appendix was optional)
- International Code Council - International Residential Code (IRC) - Appendix F
- Michigan Residential Code - Appendix F

Why Build Using Radon-Resistant Techniques?

- Low-cost
  - $350-$500 per home
  - Versus $800-$2,500 to retrofit
- Simple -- uses common building materials
- Effective -- reduces radon levels by about 50%
- RRNC protects families

Resource Documents

- Building Radon Out
- Model Standards and Techniques for Control of Radon in New Residential Buildings
- Radon Mitigation Standards
- Radon Prevention in the Design and Construction of Schools and Other Large Buildings

Need More Info?

- Outreach materials include general info, measurement, mitigation, real estate, and new construction
- More information:

  DEQ – 1-800-723-6642
  www.michigan.gov/radon

  EPA – 1-800-767-7236
  www.epa.gov/radon

Radon Program Contact Information

Mr. Leslie E. Smith, III
Michigan Indoor Radon Program

Ofc. Of Waste Management and Radiological Protection
Michigan Department of Environmental Quality

Telephone: 517-327-2618
E-Mail: smithL9@michigan.gov