Section 1

Introduction
What is Radon and why is it an issue in homes?

Course Objective
When you have completed this course you should have the basis for designing or installing radon control systems during the construction of new homes with application to large buildings.
### Course Elements

- Factors influencing radon entry into homes
- Radon reduction through active soil depressurization
- Design and Installation details
- Comparison of aspects of Appendix F of the IRC and ASTM 1465

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### Radium Turns Into Radon, Which As a Gas, Can Leave the Soil and Enter a Home

- Radon is a gas
- It is naturally occurring
- It is inert
- It cannot be seen or smelled
- It enters a building from the soil beneath

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### How Is Radon Drawn Into A Building?

- Vacuum
- Exhaust systems
- Thermal stack effects

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Design and Installation of Radon Control Systems in New Buildings

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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 and increase the potential for lung cancer.

Radon Is A Lung Cancer Causing Gas

- Breathing air with high levels of radon over long periods of time can increase the risk of lung cancer.
- After smoking, radon is the second leading cause of lung cancer in the U.S.

“Radon is one of our major environmental toxicants in the United States” (W.F. Field 2008)

<table>
<thead>
<tr>
<th>CANCER TYPE</th>
<th>ESTIMATED U.S. DEATHS/yr</th>
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<td>161,840</td>
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<td>2. Colon and Rectum</td>
<td>49,960</td>
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<td>3. Breast Cancer</td>
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<td>10,690</td>
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<tr>
<td>15. Melanoma</td>
<td>8,420</td>
</tr>
</tbody>
</table>
Other Reasons Radon Can be a Concern

- Obstacle to resale
  - Relocation companies
  - Mortgage lines are now asking for radon
  - Why didn’t my builder include it ???
- Liability
  - Group A Carcinogen (known to cause cancer in humans)
  - Precedent for lawsuits against builders

Radon as a Value Added Feature

- Buyers are aware of it
  - May have sold a house where mitigation was required and do not want the hassle again.
- Perceived benefit
  - Indoor air quality/health
  - Ease of resale
  - Moisture reduction
  - Some builders either
    - Include in all homes, or at least as an option
Radon Can Be Elevated in:
- New homes
- Old homes
- Leaky homes
- Homes without basements
- Apartment buildings
- Schools
- Offices

Low Radon Potential Homes

Homes With Radon Concerns Can Be Fixed!

Active soil depressurization is a means of creating a vacuum beneath a slab or plastic sheet and collecting the radon before it enters a building.

Can’t We Just Seal The Cracks?
- Radon can enter through very small openings.
- Without affecting house pressures, sealing is not a stand-alone technique.

Unless you live on houseboat or in a tree house, your home or office can have elevated levels of radon!
Other Benefits of System

- **Moisture Reduction**
  - Soil moisture is vented through system.
  - Reduces mold and mildew, especially when activated.

- **Vapor Intrusion**
  - Active soil depressurization also resists entry of other soil gases
    - Volatile Organic Compounds
    - Requires special design and permitting considerations

Why Not Wait Until After House is Built to Install a System?

- Almost impossible to route inside
- Will always need fan
- Is that what a new homebuyer expects?

Pick Your System
New Homes Can Be Built With Radon Control Systems

Section 2
Radon Entry Factors
What we are fighting

Comparison of Relative Contributions to Indoor Radon
The movement of soil gas into a home is the predominant entry route for radon.

These are only averages - every home may be different!

- Water < 1%
- Soil Gas 85 - 90%
- Diffusion 1 - 4%
- Emanation 2 - 5%

Mechanism: Direct Entry of Soil Gas - Convective Air Flow

- Building’s vacuum or soil pressure causes air from soil to enter through openings in foundation.
- Soil gases enter all buildings. If the soil has radon, it enters with the soil gases.
- This is the primary entry mechanism!

Mechanism: Diffusion - Movement of Radon Through Materials

- Caused by gradients in concentration between building’s interior and underlying soil
- Generally a low entry rate
- Usually dissipated by normal ventilation
**Mechanism: Emanation - Release of Radon From Surface of Materials**

- Rocks and building materials can contain uranium and radium.
- Radon created on surface is emitted into room.
- Rate depends on radium content and surface area.
- Usually dissipated by normal ventilation.

**Mechanism: Outgassing From Well Water Supply**

- High radon entry may be isolated to well.
- Can be significant.
- More radon released during use of hot water.
- Buildings with water supplied from groundwater are of highest concern.

**Building Induced Suction on the Soil Is the Predominant Driving Force**

- Buildings can create vacuums that draw in soil gas.
- The vacuums are very small and are referred to as “air pressure differentials.”
Pressure Differential - Neutral

- Difference in pressure between inside and outside of the home
- Measured in inches of water column (or pascals)
- Distance between water level on one side versus the other side of a water filled manometer.
- In this case no difference in pressure

Pressure Differential - Negative

- Difference in pressure between inside and outside of the home
- In this case an exhaust fan has been turned on pulling air out of house.

Pressure Differential - Positive

- Difference in pressure between inside and outside of the home
- In this case an Air is being supplied into home from an evaporative (swamp) cooler
Pressure Differential - Interior to Subgrade

- A difference in pressure between house and subgrade impacts soil gas entry
- Interior vacuum
  - Brings radon in
- Sub grade pressure
  - Pushes radon in
- Interior pressure
  - Retards radon entry

Magnitude of Pressure Differentials in Homes

- Differential pressures in buildings are typically on the order of thousandths of an inch rather than full inches.
  - Area of soil influence relatively small
  - Easily impacted by weather, exhaust fans etc.

Micromanometers

- Used to measure pressure differences between subgrade and interior
- Have a sensitivity to 0.001 of an inch of water column
- Non-thermal smoke also used as qualitative indicator of air flow direction
Temperature Induced Pressure Differentials: Stack Effect

- Cold outside air is denser than warm interior air, causing inside air to leave home.
- Air entry via soil can entrain radon.

Stack Effect Induced Negative Pressure at Different Outdoor Temperatures

A soil gas collection system must be able to provide a vacuum under the slab that can overcome this negative pressure as well as effects of exhaust ventilation.

Under Slab Ductwork Can Draw in Soil Gas

- Leaks in ductwork pull radon laden soil gas in and distribute into home.
- Avoid buried ductwork!
Magnitude of Negative Pressure Created with Buried Ductwork

- Vacuum imparted under slab can be very high
- Radon systems cannot overcome this - especially passive systems

ASD would not be able to overcome vacuum applied to subgrade by buried return ducts.

ASHRAE 62.2-2003

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

A Ventilation Standard for Residential Structures

Effect Of Fresh Air Make-Up

Previous

Negative or Neutral Pressure

Allows entry of pollutants and moisture from outdoors and from beneath foundation

ASHRAE 62.2

Positive Pressure

Dilutes indoor pollutants and resists entry of outdoor and sub-grade pollutants

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### Impact of Outdoor Air Make-up

#### Hourly Variations

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#### Averages by Period

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<th>6-8</th>
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<td>0.4</td>
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<td>11.0</td>
<td>9.0</td>
<td>11.0</td>
<td>7.0</td>
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</table>

#### Outdoor Air Requirements

**Cubic Feet per Minute (cfm)**

- **Most Houses:**
  - Mechanical Systems!
  - 7.5 cfm per occupant
  - 1 cfm/100 square foot of occupied space

- **Exemptions:**
  - Houses in hot climates without air conditioning
  - Infrequent use (less than 876 hours per year, i.e. cabins, etc.)
  - Houses in hot dry climates where ventilation is via open windows.

### Ceilings as Return Air Plenums – Uh Oh!

- Ceiling
- Roof
- Exterior Wall
- Slab
- Occupied Space
- Radon

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**Design and Installation of Radon Control Systems in New Buildings**

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Air Handlers in Crawlspace

- Radon levels in crawlspace can be elevated
- Air is drawn into ductwork or cabinet and introduced into living space

Options
- Capture radon under poly sheeting before it enters crawlspace, or
- Use sealed cabinets and ductwork

Environmental Effects

Wind Effect

<table>
<thead>
<tr>
<th>Wind Direction</th>
<th>Sub slab pressures (mm, W.C. BHW)</th>
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</thead>
<tbody>
<tr>
<td>S.E.</td>
<td>-</td>
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<tr>
<td>N.E.</td>
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</tr>
<tr>
<td>East</td>
<td></td>
</tr>
</tbody>
</table>

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Vapor Intrusion

- Volatile Organic Compounds in soil or groundwater can migrate into buildings
- Transport mechanisms similar to radon transport

Differences Between Radon and Vapor Intrusion

- Water borne
  - VOCs in groundwater move with the groundwater
    - Few feet to 100 feet/year
  - If source stopped, finite amount of contaminant
    - Radon is essentially perpetual
- Some vapors can be flammable - radon is not
- Indoor measurements for VOCs is very expensive

Summary

- Many factors influence air movement from soil into home
- For a radon collection system to work it must:
  - Create a larger vacuum under foundation than vacuum applied to the soil by the home
  - Extract air at a faster rate than it is being supplied via the sub grade
  - Not be overcome by HVAC systems
Section 3
New Home Mitigation Techniques
Installation Video

Field Video of System Install

Section 4
Soil Gas Collection
Beneath Slabs
&
Within Crawlspace
Radon Zone Map by County

- Radon entry primarily a function of source.
- Based on geology and survey results
- Expected short term radon (pCi/L):
  - Zone 1 > 4.0
  - Zone 2 > 2 < 4.0
  - Zone 3 < 2.0

Used for determining where radon control techniques in new home construction would be of the greatest benefit.
Not for determining where to test.

Radon-Hazard Map of Utah

- High radon-hazard potential
- Moderate radon-hazard potential
- Low radon-hazard potential

ASTM 1465

- Requires testing prior to occupation
  - Active fan added if results ≥ 4.0 or buyers expectation
- More details on:
  - Active fan routing
  - Soil collector options
  - Labels

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Basic Concept and Terms

**Slab**
- Soil gas collector
- Soil gas retarder
- Gas permeable layer
- Sealed penetrations
- Sealed seams
- Sealed edges to walls
- Cap the top of the gas permeable layer

**Crawlspace**
- Soil gas collector
- Soil gas retarder
- Gas permeable layer
- Sealed penetrations
- Sealed seams
- Sealed edges to walls
- Cap the top of the gas permeable layer

Treat All Areas within Footprint

ASTM 1465
- Basement slabs
- Slab-on-grade
- Crawlspace
- Garages*

Logical Interpretation
- Enclosed patios
- Utility rooms
- Wine cellars
- Enclosed entry ways
- Storage vaults

* Per ASTM 1465, Appendix F of IRC does not require treatment of garage

Ground Cover

- Caps the top of the gas permeable layer
- Concrete Floors
  - Concrete floor serves as “cap” or Cover
- Earthen areas – Crawlspace
  - Membrane
    - Sealed seams, sealed penetrations, sealed edges to walls
    - Minimum: 6 mil poly or 3 mil high density
  - Concrete
    - If storage or light traffic planned: 2 inch rat slab
    - If equipment in crawlspace: Full 3 ½ inch slab

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Areas of High Permeability in Underlying Soil – Seal Bottom of Gas Permeable Layer

- Porous Native Soils
  - Karst
  - Decomposed granite
  - Blasting
- Plastic under gas permeable layer
  - Blocks air from below

Membrane under gas permeable layer not needed in cases where native soils are impermeable

Maintaining Lateral Flow in Gas Permeable Layer

- Horizontal runs of utility pipes and conduits (water, sewer, electric, phone, TV and so forth) and other barriers that restrict air flow to any part of the gas permeable membrane shall be avoided. (Section 6.4.1 ASTM 1465)
- Exception:
  - If interior perimeter drain is used as the soil gas collector

See next slide

Sub-Slab Utility Lines

- Soil gas collector
- Seal
- Soil gas retarder
- Minimum 4-inch

*Per ASTM 1465, allowed in App F of the IRC

Maintain full 4-inch area for soil gas movement

OK

Not OK *

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**Alternative to Trenching Utility Lines***

- If utility line does not completely cut-off portion of sub-grade
- Maintain minimum of 2 feet of clearance around utility line

* Personal recommendation of D. L. Kladder

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**Soil Gas Retarder**

- Slab:
  - Plastic sheet between bottom of concrete and Gas permeable Layer
  - Keeps concrete from entering GPL
  - Helps bridge future slab cracks
- Crawlspace:
  - Plastic sheet on top of soil, with Soil gas Collector & Membrane above it
  - Protects membrane
- Sealing:
  - No sealing required – seal provided by Ground Cover
  - Seams overlapped 12 inches
  - Installed as required for moisture barrier

---

**Gas Permeable Layer (GPL) - Slabs**

- Specification depends upon soil gas collector design
- Four types
- Common aspects:
  - 100% coverage of footprint
  - Aggregate with low fines when used
  - Located under Soil Gas Retarder

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Slabs – Type I Gas Permeable Layer
Larger Rock – Less Perforated Pipe

- 4-inch diameter soil gas collector
- Minimum 20 feet long
- Open ends

Slab
Soil gas retarder
4 inch layer washed stone
#4 (1 to 1½ inch)

Type I Layout

- Conform to footprint
- At least 24 inches from interior footing drains*
- Riser
  - Directly on pipe, or
  - Offset to wall with non-perforated 4-inch

*R. L. Kladder recommendation assumes interior drain not used as soil gas collector

Type I Allowing for Lateral Air Flow

Post and Beam
Foundation with Grade Beam

Do not draw air from one perforated pipe through another to a riser
**Slabs – Type II Gas Permeable Layer**

Moderate Sized Rock - Loop of Perforated Pipe

- 4-inch diameter soil gas collector
- Loop of perforated pipe

- Soil gas retarder
- 4 inch layer washed stone 06 (1/2 – 3/4 inch)

**Type II Layout**

- Conform to footprint
- At least 24 inches from interior footing drains*
- Riser
  - Directly on pipe, or
  - Offset to wall with non-perforated

* D.L. Kladder recommendation—assumes interior drain not used as soil gas collector

**Slabs – Type III Gas Permeable Layer**

Rock in Trench – Loop of Pipe

- 4-inch diameter soil gas collector
- Loop of perforated pipe
- Laid in trench

- Soil Gas Retarder
- Trench 1 feet wide x 4 inch deep layer washed stone #4 (1 to 1½ inch)
Perforated Pipe Option: Cross-Overs

- Make provisions for pipe to penetrate obstructions.
  - Short lengths laid in trenches
    - Tape ends to keep clear of debris - attach to main loop after grade beam finished
  - Pipe sleeves in intermediate footings.
    - Pass perforated pipe through.

Important: when passing under grade beams make sure that perforations of pipe allow drainage.

Perforated Pipe Option: Riser

Tee and Perforated Pipe Same Diameter as Vent pipe.

- SCH. 40 PVC or ABS Pipe
- PVC or ABS Pipe Coupling or flexible boot in expansive soils

Slabs – Type IV Gas Permeable Layer Drain Mat
No Aggregate Other than Normal

- 12 in. x 1 in. drain mat
- Rectilinear loop
Drain Mat (Proprietary Mat)

- More expensive
- Offset by:
  - Easier installation
  - No special aggregate

Laid on subgrade, with vapor retarder between it and bottom of slab

Mat Option: Layout

Riser

Garage Grade Beam Mat

Tee and mat to have same cross-sectional free flow area as vent pipe.

Installation of Mat

- Roll out Mat
- Make corners
- Pour concrete on top of mat
- Install Riser
- Place under re-bar
- Finish Slab

Photos: Compliments of professional Discount Supply

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### Cross-Overs

- Plan for mat to cross through barriers
  - Through intermediate foundation walls
  - Under grade beams
  - Insure that concrete does not enter mat and that water can drain into sub-grade!

Mat laid over footing prior to pouring of post-tension slab.

Mat being routed under intermediate foundation wall and to another slab level.

### Crawlspace

### Ground Cover for Crawlspace

#### Earthen Areas – Case A - No Traffic or Storage

- No traffic or storage
- Sealed Ground Cover membrane
  - 6 mil normal
  - 3 mil high density
- Vapor barrier beneath membrane*
- Additional sheet over ground cover membrane for occasional traffic area.

* ASTM 6.1.3.3
Soil Gas Collector – Crawlspace*

- If no aggregate added
  - Loop
- If 4-inch layer of aggregate added
  - 20 foot length allowed

*ASTM 1465, not stipulated in App. F of IRC

Ground Cover for Crawlspace Earthen Areas
Case B & C - Planned Traffic & Storage

- Planned traffic & Storage
- Poured slab
  - Equipment in crawl
    - water heaters, furnace, etc
    - 3 ½ inch slab
  - Storage and traffic expected
    - 2 inch rat slab

Use Type I, III, III or IV for slab design

Soil Gas Collector Materials
All 4 inch

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<thead>
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<th>Description</th>
<th>ASTM #</th>
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<tr>
<td>Polyethylene corrugated pipe with holes or slits</td>
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<tr>
<td>Rigid SDR pipe with holes</td>
<td>D 2731</td>
</tr>
<tr>
<td>Any schedule 40 PVC or ABS with holes, pressure rated</td>
<td>D1785, D2665, F891, D2282, D2661, F625</td>
</tr>
<tr>
<td>or non pressure rated</td>
<td></td>
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</table>

* D. L. Kladder Recommendation

Geotech Sock Recommended*
- Not specified in ASTM 1465

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Connecting Vent Pipe to Soil Gas Collector

- From Point of Connection:
  - Non perforated piping
  - Rigid PVS or ABS
  - Flexible connector at point of connection
  - Insure no traps for water to accumulate from this point upward.
    - Horizontal or slope to point of connection.

- Tee connection
  - Air flow from two directions
  - Not elbow on end of soil gas collector

Riser Connection

- Bring Soil gas collector to opposite sides of TEE
  - Allows air flow from two directions
  - Reduces pressure drop
  - Laterals to be equal or no less than 1 standard pipe size less than riser

<table>
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<th>Riser Sch</th>
<th>Riser Cross Section (sq. in.)</th>
<th>Smaller Lateral Size</th>
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<td>12-inch</td>
<td>10 inch</td>
<td>157.8</td>
</tr>
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ASTM 1465 says laterals should equal riser

SGC Connection Methods

Vertical & Offset Connection

- All portions of Tee and riser non-perforated
- Flexible boots for rigid soil gas collector
  - Allow movement
- Temporarily cap riser to avoid collection of debris or concrete.

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**Riser To Be Non-Perforated!**

- What’s wrong with this picture?
  1. Drain pipe was used as riser
  2. Hole in pipe above slab
- Piping connected to sub-grade soil gas collector to be:
  - Schedule 40
  - Rigid
  - Non-perforated

**Alternate Connection for Corrugated Sub-slab or Crawlspace**

- Hancor/ADS Single Wall-Annular Pipe
  - ASTM F 405 4" – 0401
- ADS Clay Snap Adapter 4" - 0462AA
  - 4-inch Tee
  - To Radon Vent System

- Pound in, Drill 3 - 1½”
- Sheet metal screws in

*Recommended by D.L. Kladder

**Below Ground Cover Manifolds**

- When two areas are treated
  - Connect riser to manifold between them
  - Do not connect to one system
  - Makes air run through systems in series
  - Reduces effectiveness

*Recommended by D.L. Kladder

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Multiple Levels

Caulk or grout penetration

Flexible Connector

Radon Vent

Through wall penetration
Caulk or grout

Other Methods*

- Separate foundation areas can be joined together.
  - In sub-grade
  - In house or attic
- Allows a single roof penetration

* City of Fort Collins

Stub Risers Up Before Floor-Pour
Common to All Sub-Grade Systems

- Short stub for vent.
- Secure in place.
- Tape over end to keep concrete out.
- Seal around joint after concrete cures.
- Label it!

- Temporarily cover end of riser to keep construction debris from disabling system.

Debris in bottom
Section 5
Sealing Slabs and Other Entry Points

Sealing Ground Cover

Slabs
Membrane in Crawlspace

Cold Joint-ASTM 1465*

- Floor-to-wall and isolation joints do not need to be caulked:
  - If poured tightly to wall
  - Does not shrink appreciably
  - App F requires caulking

* ASTM 1465 does not require cold joints to be caulked. Appendix F of IRC does require caulk

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Expansion Joints ASTM 1465

- Polyurethane caulk
  - 8 feet per 11 oz. tube
  - Vacuum/remove debris
  - ASTM 1465 calls out minimum 28 day cure time before caulking
  - Tool onto/into joint
- Expansion Joint
  - Must cut bed down flush with slab
- Isolation Joint
  - Recess joint down for smooth floor finish

Slab Control Joints

- Where slab is deliberately weakened to attempt to force slab cracks to occur.
- Both ASTM 1465 & App. F call out caulking control joints
  - Vacuum remove debris
  - Polyurethane caulk
    - 12 feet per 11 oz. tube / Tool into control joint

Other Places to Seal Slab

- Plumbing penetrations
- Radon vent riser
- Use polyurethane caulk
  - Polyurethane Type S
    - Sonolastic NP-1
- Large openings
  - Plumbing block outs
    - Liners
  - Openings in slab for support posts
    - Non-shrink grout

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Future Fixture Openings

- Seal with:
  - High density Polyethylene, or
  - Thin (2-inch) layer of grout

Membrane
Liner
2 inches grout

Bad Caulking/Sealing

- Wrong caulk
  - Caulked cream over run rather than joint
  - Should have been chipped back, then caulked

- Not tooled
- Still leaked
- With fan running
- Would not have been identified if passive system

- Cold joint
- Still leaked
- With fan running
- Would not have been identified if passive system
- Should cold joints be caulked?

More Inadequate Sealing

- Nice Job - Wrong Caulk
- Inadequate & Wrong Caulk
- Rough Liner
- Right Caulk – Inadequate Job
  - Did not span the expansion joint
Sealing Styrofoam Board Between Slab and Wall

- Board set-down, filled with grout and caulked around edge and over
- Float slab over top of board, or cut down and grout later and caulk

Soil Gas Collector

- Soil gas retarder
- Ground Cover
- Gas permeable layer
- Sealed penetrations

Crawlspace Membrane Sealing

- Placed on top of soil gas retarder
  - Unless slab used
- Sealed at seams
- Sealed at edges
  - Unspecified in ASTM 1465
  - 6 mil poly or 3 mil high density

- Specialty tape to wall and metal furring strips shot in

Sealing Crawl Membrane

- Perlite Pipe
- Tape on edge before Shot Pins
- Cover Pops

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Crawlspace Riser – Roof Jack Option
- Sealing plastic around riser is critical
1. Push roof Jack over tee
2. Make hole in plastic slightly smaller than pipe diameter.
3. Caulk roof jack plate
4. Push poly down around pipe and onto caulk
5. Caulk above plastic
6. Apply second roof jack
7. Screw together

Crawlspace Riser – Boot
- Tight fit around riser pipe
- Seal to main portion of membrane

Crawlspace Riser - Tape
- Specialty Tape from membrane manufacturers is pretty good
- Apply to clean surface
- Firmly apply around edge
Maintaining Membrane Integrity

- All trades need to be aware of care needed for membrane.
- May want to delay installation until at least sub-floor on.
- ASTM 1465 recommends concrete slab where equipment will be placed in crawlspace.

Water Drainage Systems

*They are either for ya or agin’ ya*

Interior Perimeter Drain

- Interior drain serves as soil gas collector.
- Connect Radon vent to:
  - Perforated pipe, or
  - Sump lid

---

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Interior P-Drain as Soil Gas Collector

- **Advantages**
  - Saves construction costs

- **Disadvantages**
  - Large concern of loss of interior air if lid is removed and not replaced
    - Appliance back draft
    - Energy penalty

Sump lid of drainage system used as soil gas collector-system activated

Suggestion: If done, connect radon vent to lid of sump

Connections to Under Drain System

- If overflow to under drain system use backwater valve.
  - Reduces unwanted air entry

Suggest separate SGC*

*By D.L. Kladder

Exterior P-Drain

- External connections can introduce large amounts of air and defeat a passive system.
- ASTM 1465 does not allow use of P-Drain as SGC if connected to exterior drain.
- Recommend separate SGC

Exterior drain connected to an interior P-Drain when interior is used as Soil Gas Collector
Exterior P-Drain as SGC

- Intent of ASTM 1465 is to make a passive system work well
  - Focus soil gas collection under foundation
  - Always requires fan if house has high radon
  - Not allowed with ASTM 1465

Suggested Practice
Interior and Exterior P-Drains

- Gravel between radon system and drain impedes air loss
  - Maintain at least 2 feet of separation
  - Use offset riser to move radon vent near wall for easier routing
  - Sump still has sealed lid

Sump Pit

- Isolate sump from interior
  - Reduces soil gas entry
  - Trap floor drains into sump
  - Run condensate into trapped floor drain
  - Seal lid
    - Gasketed cover
    - Uniseals for penetrations

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**Places to Seal at Sumps**

- Soil retarder to base of sump before slab pour
- Seal lid penetrations
  - Discharge Pipe
  - Electrical cord
- Label lid – Advising:
  - Part of radon system
  - Replace if removed
  - Turn off fan if active system
- Caulk base
- Gasket on lid
- Bolt down lid
- Label lid – Advising:
  - Part of radon system
  - Replace if removed
  - Turn off fan if active system

**Use of Water Drainage Systems as a Soil Gas Collection Methods**

- If the sump collects water from the area inside the foundation walls, it could be considered a soil gas collection method, if an interior vent pipe is connected to it.
- It may be prudent to keep water drainage separate from radon system.

**Foundation Walls**

- All walls
  - Damp-proofed
- Solid walls
  - Seal below grade penetrations
    - Electrical, plumbing, etc.
- Block walls
  - Barrier to vertical flow at point above grade
    - Continuous course of solid masonry, or
    - One course of fully grouted block
    - Solid beam above grade
- Brick veneer
  - Course immediately beneath brick ledge to be sealed

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**Sealing Brick Ledges & CMU Walls**

- **No Bond Beam**
  - Brick Ledge
  - Hollow Upper Course
  - Basement
- **With Bond Beam Above Grade & Below Brick Ledge**
  - Bond Beam
  - Basement

**Sealing Wall Penetrations**

- **Solid Walls**
  - Seal around penetrations on inside
- **Hollow Block Walls**
  - Seal penetration on both sides

**Section 6**

- Radon Vent Pipe
- Labeling
- Performance Indicators
**Radon Vent Pipe System**

- Connected after sub-grade system installed
- Pipe cannot be trapped
  - Provide space in chases
- Support at each floor level
- Discharge through roof behind ridge

**Routing Pipe Up Exterior Wall Is Problematic**

- Stack effect greatly reduced.
- No room for future fan if activation is needed.
  - Unless on roof
- Reduces wall insulation rating

**Route Pipe Through Warm Space**

- Passive stacks work best when pipe run through warm space
  - Furnace chases
    - Do not connect to flue
  - Plumbing chases
- Routing through cold spaces will reduce effectiveness
  - Garages
  - Outside or outside walls
- Larger diameters work better passively than smaller diameter
Routing Options

**Passive Routing**
- Riser through warm spaces
  - Interior chase
  - Fewer fittings
  - Less likely to need fan
  - Recommended by CT. Dept. of Health

**Fan Powered Routing**
- Riser through cold spaces
  - Garage or outer wall
  - More fittings allowed
  - More likely to need fan

Fan Locations*

- Concern: Potential leakage from portions under positive pressure
- Fan location not in occupied space
- Discharge piping not in occupied space

<table>
<thead>
<tr>
<th>Allowed Locations</th>
<th>Disallowed Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attic (unoccupied)</td>
<td>Utility room</td>
</tr>
<tr>
<td>Attic above garage</td>
<td>Crawlspace beneath occupied space</td>
</tr>
<tr>
<td>Fire rated ceiling</td>
<td>Garage*</td>
</tr>
<tr>
<td>Unoccupied space</td>
<td></td>
</tr>
<tr>
<td>On roof</td>
<td></td>
</tr>
<tr>
<td>May look strange-unless flat or parapet roof</td>
<td></td>
</tr>
</tbody>
</table>

* Per ASTM 1465. App. F of IRC allows fan in garage, provided no living space above garage

Geometrical Space for Potential Fan*

- Allow space (24"W x 36"H)
- Vertical fan
- Pipe supported above and below proposed fan location
- Insulate pipe where freezing can occur
- J-Box on dedicated circuit
- Considered Appliance?
  - Catwalk needed?
  - Light needed?
  - When?
    - As passive, or
    - When activated?

* ASTM 1465

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**Discharge Points**

- Vertical
- Through roof
  - 12 inches above surface
  - High roof
- Through gable end
  - 30" up
  - Extend vertically 12 inches above rake edge
- No obstruction on end
  - ½ in or larger screen recommended

**Termination Location Minimums:**

- 10 feet above grade
- 10 feet from an opening into the conditioned space that is 2 feet below plane of discharge
- Criteria applies to openings around corners and obstructions
- Chimney flues considered an opening
- 10 feet from any opening into an adjacent building

**Discharge**

- Back of ridge
- Roofer flashes around penetration
- Terminate 12 inches above roof
- Varmint guard on end*

*Recommend no less than ½ inch screen openings-D.L. Kladder

**OOOps!**

- Discharge through low roof, near upper story window
- No supports
- Not Vertical

---

*Design and Installation of Radon Control Systems in New Buildings*  
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**Electrical for Fan**

- Dedicated circuit
  - To J-Box within 6 feet of fan location
- Disconnect
  - In attic: Plug-in receptacle
  - Outdoors: Weatherproof switch
  - Permitted when installed after construction?
- Fans typically pull 1.0 amp at start-up
  - Less than 93 watts

---

**Radon Vent Pipe Construction**

- Schedule 40, PVC or ABS, DWV
- ASTM 1465 Minimum diameter: 4 inch*
- Terminate where exhaust gases will not reenter house (like chimney)
- Do not use sheet metal or flex duct!

---

* App F allows 3-inch. EPA publications cite 3-inch as minimum

---

**Allow For Condensation In Vent Pipe**

- Cold air temperatures on outer surface of pipe
- Condensate
- Install pipe with positive drainage back to sub-grade
- No Traps!
Pipe Slope Per ASTM 1465

- Horizontal runs
  - Slope back to SGC
- 3 inch pipe
  - 1.5 inches per foot of horizontal run
  - Not allowed for passive systems
- 4 inch pipe
  - 3/8 inch per foot
  - Recommended minimum diameter

Follow Plumbing Codes For Pipe Installation

- Follow local building codes, e.g.
  - If vent pipe is route through garage, a fire barrier will be needed

Supports, Etc.

- Slope back to suction point
- Avoid contacting rafters
### Insulation

<table>
<thead>
<tr>
<th>Location</th>
<th>Passive</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freezing Temp. Areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Attic</td>
<td>Yes</td>
<td>Yes-Pipe</td>
</tr>
<tr>
<td>• Outdoors</td>
<td>Yes-Fan</td>
<td></td>
</tr>
<tr>
<td>Interior of building</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Colder spaces</td>
<td>N/A</td>
<td>Yes</td>
</tr>
<tr>
<td>• Garages</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*ASTM 1465, App F, of IRC does not specify insulation.

### Passive vs. Active Summary

<table>
<thead>
<tr>
<th></th>
<th>Fan Powered</th>
<th>Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan</td>
<td>Installed</td>
<td>Allowed</td>
</tr>
<tr>
<td>Junction Box</td>
<td>Installed</td>
<td>Installed</td>
</tr>
<tr>
<td>Monitor</td>
<td>Installed</td>
<td>Allowed for</td>
</tr>
<tr>
<td>Horizontal run</td>
<td>Allowed</td>
<td>Allowed</td>
</tr>
<tr>
<td>Maximum changes in direction</td>
<td>As needed</td>
<td>Minimum: 1/4 in. rather than 5/8 in.</td>
</tr>
<tr>
<td>Outside wall routing</td>
<td>Allowed</td>
<td>NO</td>
</tr>
<tr>
<td>Exterior routing</td>
<td>Allowed</td>
<td>NO</td>
</tr>
<tr>
<td>Insulate pipe inside building</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Insulate in very cold spaces</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Minimum pipe size</td>
<td>1 inch</td>
<td>1.5 inch</td>
</tr>
<tr>
<td>Advantage</td>
<td>Flexible routing</td>
<td>May not need fan</td>
</tr>
<tr>
<td>Horizontal slope (min.)</td>
<td>3/8 inch</td>
<td>1.5 inch</td>
</tr>
</tbody>
</table>

### Performance Indicator Needed if Activated

- Liquid filled manometer
  - Measures vacuum NOT radon
  - Mounted on pipe when visible
  - Do not run tubing through cold space
- Electrical Type
  - Typically measure pressure rather than radon
- Common to both
  - Located in area where consumer will see
  - Install “Initial Indication” label after system running
- How to interpret
  - If pipe is hidden behind finished walls, route tubing to utility room or manometer can be connected to it later. Mount on board.
Pipe Labels

**Radon System**

Additional information about the radon control system can be found in the original purchase agreement and on the Radon Control System label located on the radon mitigation vent pipe.

LABEL: PIPING ON EACH FLOOR LEVEL IN THE ATTIC, VISIBLE FROM ACCESSIBLE LOCATIONS ALONG PIPING. PROVIDE A RADON REDUCTION SYSTEM LABEL ADJACENT TO THE PRESSURE MONITOR.

- Label:
  - Basement
  - Attic
  - Behind walls?

Sump Label

- Very important
  - Especially if radon system is connected to sump or P-Drain
- Install near completion of home

Label Membrane at Point of Entry

**Membrane Maintenance Required**

- Periodically inspect the plastic membrane on the crawlspace for tears, cuts, holes or leaks in the plastic and around the perimeter or penetration seals. Air leakage may reduce the performance of the radon control system. Damage may also void the radon membrane warranty. Inspect the integrity of the membrane by tapping on it. Any soundness indicates the membrane is intact.
- Periodic inspection is the responsibility of the homeowner and not the responsibility of the building contractor. The owner is responsible for any leaks, damaged or blown out areas in the membrane. The pembrane, if any, must be repaired by the owner at their own expense.
- Damage to the membrane and its seals should be promptly repaired. Should small tears occur in the plastic, repair with polyurethane caulk or compatible tape. If the plastic needs to be removed for any reason, de-energize fan at breaker indicated on the Radon Control System label. Turn fan back on after plastic is repaired or replaced. Protect membrane from damage when walking over it. Resting objects on the membrane may impede your ability to inspect and maintain the membrane.

Additional information about the radon control system can be found in the original purchase agreement and on the Radon Control System label located on the radon vent pipe.

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System Label
(Example)
- A system label should be located in a portion of the home advising occupant of the existence of a radon system.
- System Information
  - System description
  - Advice to test/re-test
  - Maintenance/Troubleshooting
  - Contact information
  - Run system continuously if activated

Breaker Labels – If Activated
- Label circuit radon fan is on
- System monitor
  - If electrical style
  - On separate circuit than fan operates on

Post Construction Testing and System Disclosure
- The proposed methods are prescriptive - not performance based.
- Testing is better performed after occupation.
- The need for further reductions is decision by occupant.
- Disclosure should be made to occupant (and future occupant) of systems existence and need to test to verify efficacy.
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**Documentation to Buyer ??**

- **Passive:**
  - Need to test
  - Do not assume radon levels are acceptable
  - Who activates?
- **Active**
  - Monitor/Indicator & retest
  - Fan to run continuously
- **Elements that impact performance**
  - Sump lid
  - Crawlspace membrane

---

**Active System Operation and Maintenance**

- Fan in attic
  - Runs continuously (60 watt)
  - No lubrication or maintenance required
  - Life: 10-15 years
  - Replacement cost: $150
- **Performance Indicator**
  - Shows vacuum in system
  - Not a radon monitor
- **Membrane tape for large tears in crawlspace barrier**
- **Retest**
  - Initial long-term (provided)
  - Retest every two years (homeowner)

---

**RADON COST ESTIMATE (Fort Collins)**

Passive: $1,270

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>Buyer Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FOUNDATION OPTIONS</td>
<td></td>
</tr>
<tr>
<td>(a) Sub-slab with gravel - standard builder practice at no added cost, Typical (60% - 75%)</td>
<td>0</td>
</tr>
<tr>
<td>(b) Sub-slab with gravel - buyer cost option.</td>
<td>400</td>
</tr>
<tr>
<td>2. VENT RISER - 3-in. pipe found, thru roof, fittings, roof jack, labels, etc.</td>
<td>450</td>
</tr>
<tr>
<td>3. SEALING - caulk, gaskets, etc.</td>
<td>315</td>
</tr>
<tr>
<td>4. FAN PREP. (Passive) - permanent access, electric supply, etc.</td>
<td>105</td>
</tr>
<tr>
<td>5. FAN INSTALLED (Active) - passive plus operation function indicator, service light, etc.</td>
<td>250</td>
</tr>
<tr>
<td>6. OTHER &amp; Misc. Builder markup</td>
<td>10 - 20%</td>
</tr>
</tbody>
</table>
What’s Wrong Here?

- Riser disconnected - gravel in SGC
- Untrapped drains into sump
- Riser stub waiting for gravel to enter
- System label and indicator behind vapor barrier
- Radiation Symbol Label??
- Riser label and indicator behind vapor barrier

Section 7
Design Considerations
Large Buildings
Case Study
Radon Testing

Drain Collection Pipe as Soil Gas Collector
- Corrugated and Perforated
  - Easy to install
  - Drain slots completely around pipe
- Rigid with drilled holes
  - Orient with one hole at 6:00
  - Allows water to drain out
- Soil gas collection pipe should be above water control elevation of sump
Passive Stack Considerations: Pipe Size

- Increasing Pipe Diameter
  - Increases air flow
  - Increases vacuum

Passive Stack Considerations: Stack Height

- The higher the stack - the greater the vacuum on soil
- Route up through high roof
  - Don’t discharge low

Passive Stack Considerations: Climate

- Passive Stack
  - Requires temperature difference
  - As outdoor temperatures increase - system capacity decreases
**Passive Stack Considerations: Isolating Subgrade**

- Leaks in slab or sub-membrane
  - Equalizes pressure between soil gas collector and house.
  - If they are at same pressure, no air flow.
- Not as critical with fan-powered systems since fan is creating mechanical vacuum in sub-grade.
  - Leaks increase loss of interior air.

**Passive Stack Considerations**

- Route through warm space
  - Little to no temperature differential or stack effect if air in pipe cools.
- Exhausting appliances compete with passive stack vacuum
  - Provide make-up air
    - Combustion appliances
    - Exhaust fans (especially true with kitchen hoods, etc).

**Differential Pressures on Passive Stack are Variable**

- Pressure in pipe must be lower than building pressure
- DP in pipe can fluctuate
  - Weather
  - Building operation

---

*Steve Drasco, The Passive Radon Mitigation System, Ernest Orlando Lawrence Berkeley Laboratory*
How Much Air Volume?

\[ V_{\text{total}} = V_{\text{indoor}} + V_{\text{outdoor}} + V_{\text{geology}} \]

- The soil gas collection layer is a box with leaks on all four sides.
- Minimizing leaks:
  - Improves pressure field extension
  - Less under slab piping
  - Reduces fan and pipe size

Where Does Air Come From
(Tracer Gas Studies - 3 Houses)

<table>
<thead>
<tr>
<th>House</th>
<th>Air Flow (CFM)</th>
<th>Overall Average Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>39%</td>
</tr>
<tr>
<td>B</td>
<td>30</td>
<td>45%</td>
</tr>
<tr>
<td>C</td>
<td>15</td>
<td>16%</td>
</tr>
</tbody>
</table>

- Basment
- Outside Foundation

Recent Fan Studies for RRNC

- What size fan?
  - Sealing reduces air flow
  - Gravel reduces need for higher suction.
  - ASTM 1465 suggests fan capable of 75 CFM @ 0.75 inches WC
  - Maintain 0.020 inches DP across slab
- Experiment:
  - Vary fan flow
  - Measure DP before and after caulking
### Preliminary Results – 4 Houses

- Only 0.020 inches of WC needed
- Accomplished with extracting only 12 CFM from slab!

### Impact of Caulking*

- Caulking reduced amount of air needed to be withdrawn to create the same vacuum beneath slab.

<table>
<thead>
<tr>
<th>Slab Condition</th>
<th>Extracted air flow needed to create 0.020 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncaulked</td>
<td>14.0 cfm</td>
</tr>
<tr>
<td>Caulked</td>
<td>9.1 cfm</td>
</tr>
</tbody>
</table>

* Home with expansion joints

### Large Buildings

Same concept just more of it!
Properly Design and Balance HVAC

- Design to pressurize building
- Feedback controls
- Fresh air make-up
  - Quality timers
- Interlock exhaust with fresh air make-up
  - Avoid periods of high negative pressure without air make-up
- Test building after completion
- Develop and implement maintenance program

Active Soil Depressurization

- Effective if subgrade communication well laid out
- Low resistance to air flow in sub-grade
- Well sealed slab (post-tension)
- If sub-grade well isolated ASD can operate without significant impact from HVAC system imbalance
  - Still a good idea to maintain for other IAQ concerns.

Slab Design: Aggregate Option

- Nominal 4 inches of ¾ inch clean gravel
- Means for restricting mud from entering gravel
  - Plastic
  - Two more inches of gravel
Methods To Allow Transverse Air Flow Through Footings

- Foam Block-Outs in Forms
- Alternating Turned Blocks in Foundation Wall Below Slab

Pits For Large Buildings

- Expanded Metal With Deck
- Radon Vent Pipe Connected
- Gravel Spread
- Concrete poured on top

Large Buildings
Post-Tension Slabs

- Large areas covered by mat.
- Lay mat after grade beams poured and sub-grade compacted but prior to pouring slab.
**Large Building Design Points**

- Lay soil gas collector in loops rather than crosses
- Single riser per loop
- Separate perforated pipe 15-20 feet on center

**Large Building Design Sequence**

1. Foundation plan of building
2. Estimate air flow
3. Determine number of risers
   - This defines number of loops
4. Orient loops to avoid interferences
5. Have architect suggest riser locations
6. Each end of loop connects to Tee of riser

**Extensive Sealing of Ground Cover**

- Used in some Vapor Intrusion projects
- Spray coatings seal:
  - Top of aggregate
  - Utility Penetrations
- Reduces air flow from interior
Aerated Floor Systems - Something New

- Large void space
- Supports high compression floors
- 100% coverage under slab
- Cupolex system
  - Well used in Europe

Aerated Floor Performance

- Small air volume extraction needed

Comparison of Aerated Floors to Other Approaches

<table>
<thead>
<tr>
<th></th>
<th>Conventional Vent</th>
<th>Heavy Vent</th>
<th>Aerated Floor</th>
<th>Aerated Floor with Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ft²)</td>
<td>30,000</td>
<td>29,000</td>
<td>40,000</td>
<td>42,000</td>
</tr>
<tr>
<td>Liner</td>
<td>6-mil PE</td>
<td>Liquid Film</td>
<td>water</td>
<td>water</td>
</tr>
<tr>
<td>Ventilating Layer</td>
<td>2½ gravel</td>
<td>1½ gravel</td>
<td>16° cold</td>
<td>16° cold</td>
</tr>
<tr>
<td>No. Fans</td>
<td>28</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total Air (cfm)</td>
<td>1700</td>
<td>215</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Total Flow (LPM)</td>
<td>2256</td>
<td>159</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Average radon</td>
<td></td>
<td>2.28</td>
<td>1.8</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Significant reduction in air flow requirements
Case Study

We will use the excel spreadsheet downloadable from the CERTI course for this exercise.

Case 1 New Hotel
3 story on Slab- 10 feet between floors
Flat roof behind parapet

Main Area: Lodging rooms off corridor on either side of lobby
Spa Area: On end of building with separate HVAC system (high exhaust)

Case 1: New Hotel
Calculating Air Flows

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Case 1: New Hotel -
# Soil Gas Collectors Riser Size

<table>
<thead>
<tr>
<th>Diameter (in)</th>
<th># of Bores</th>
<th>Velocity per ft</th>
<th>CEM</th>
<th>DP (in wg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>700</td>
<td>0.367</td>
<td>76</td>
<td>0.161</td>
</tr>
<tr>
<td>4</td>
<td>560</td>
<td>0.264</td>
<td>55</td>
<td>0.199</td>
</tr>
<tr>
<td>6</td>
<td>444</td>
<td>0.191</td>
<td>35</td>
<td>0.269</td>
</tr>
<tr>
<td>8</td>
<td>360</td>
<td>0.154</td>
<td>25</td>
<td>0.342</td>
</tr>
</tbody>
</table>

Minimum CEM @ 1000 CPM per pipe calculated:

- System A: 350 (in wg)
- System B: 500 (in wg)

Separate collector for Spa due to high exhaust rate (negative pressure)
4 inch ADS loops with geotech cloth laid in 6 inch layer of ¾ inch washed aggregate
Two 6 inch risers to roof

Case 1 New Hotel: Approach

Separate collector for Spa due to high exhaust rate (negative pressure)
4 inch ADS loops with geotech cloth laid in 6 inch layer of ¾ inch washed aggregate
Two 6 inch risers to roof

Case 1 New Hotel: Fan

Fan Selection

<table>
<thead>
<tr>
<th>Diameter (in)</th>
<th>Flow Rate (CFM)</th>
<th>Pressure Drop (in wg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>500</td>
<td>0.20</td>
</tr>
<tr>
<td>4</td>
<td>1000</td>
<td>0.40</td>
</tr>
<tr>
<td>6</td>
<td>1500</td>
<td>0.60</td>
</tr>
<tr>
<td>8</td>
<td>2000</td>
<td>0.80</td>
</tr>
</tbody>
</table>

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So Does It Work?
To answer this one must define success

Risk Reduction?
Features that reduce radon exposure by a Percentage
Programmatic Approach

Reduction to a Recognized Level of Risk?
Features that reduce radon to less than 4.0 pCi/L
Occupant expectation

How Well Do Passive and Active Systems Work?

COS Continuous Radon Measurements
Uncapped/capped - October 2000
- Affect clearly observed
- Fast response
Other Issues with Passive to Active

- Complex
- Buyer disappointment when system is non-functional in their mind
- Proper testing approaches
- Potential builder liability if levels not below guidance.

Install Passive System
Buyer Takes Possession
Buyer Conducts Test
Fan Installed if Elevated
Owner Conducts Test

Should we Consider an Active Approach Option?

- Greatest Reduction
- Higher Operating Cost
- Lower builder liability

Active
Passive

Reduced cost for homes that did not necessarily need it.

Short And Long-Term Testing Devices Help Determine the Need for, and Effectiveness of, Radon Mitigation
Closed House Conditions
For All Short-Term Tests
- All exterior doors and windows closed, except for normal entry and exit
- Internal-external air exchange systems off
  - Total internal recycle is allowed
  - Combustion or make-up air not closed
- Permanent radon mitigation systems remain on

Closed House Conditions-New Home
- System Running for 24 hours before test
- All exterior doors and windows closed other than normal entry and exit for 12 hours prior to and all during the minimum 48 hour test
  - Front door / Back patio door / Door to garage

Door closed but windows open
Post signs on all exterior doors

Radon Distribution
- Radon enters from beneath foundation and travels upward.
  - Diluted with outdoor air infiltrating building.
- If radon is less than 4 pCi/L in lower level, one can say with reasonable confidence that upper floors are also less than 4 pCi/L.
Passive Device Use in Real Estate Testing

- Deployed simultaneously
- Placed 4 inches apart
- Results are averaged
- If average is equal to, or greater than 4 pCi/L, mitigation is recommended*

* Both results would be reported in addition to the average, provided the results pass protocol for assessing duplicate measurements for real estate transactions.

Continuous Monitor Used in Real Estate Testing

- Single device
  - Must measure and report in hourly increments and be calibrated
- If average is equal to, or greater than 4 pCi/L, mitigation is recommended.

Variations can detect tampering

Successive 2-Day, Short-Term Measurement Results in Same House

Over a three-month period, short-term real estate style tests varied from 1.9 to 6.0 pCi/L.

Average for entire period was 3.8 pCi/L.

Source: Dr. Dan Steck, Minnesota Radon Project Jan-March 1995
Long-term Tests Indicate Occupant Exposure

- Placed for a minimum of 91 days
- No special closed building conditions
- Can be used for release of escrow funds
- If result is equal to, or greater than 4 pCi/L, mitigation is recommended.

Section 8

Considerations for Applying Radon Techniques For Vapor Intrusion Mitigation

Considerations For Applying Radon Control Systems To Vapor Intrusion Mitigation

Don Francis
EcoTech, LLC Portland, Oregon
© Center for Environmental Research and Technology, Inc. April 2012
What Is Vapor Intrusion?

What Causes Soil & Groundwater Contamination?

Why Do We Care?

The health of our families… and our environment.

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An ASD System May Be…

- A permanent solution to vapor intrusion
- An interim control while cleanup is underway

Portland Case Study: Spokane Street

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Excavation & Contamination
Pulling Tank
Free Product

Removal Of Highest Concentrations Of Petroleum Contaminated Soil
- Foundation walls had to be anchored in the excavation.

Engineered Design For The ASD System
Trenching For Piping

- Cutting floor to install piping
- Trench for ASDS piping

Installing Piping

- Laying of pipe in trenches
- Covering pipe in gravel and cloth

Piping Installed & Covered
Considerations For Installing An ASD System To Control VI

- Who designs the system?
- What standard do you use for construction?
  - ASTM? Engineer?
- What building codes apply?
- What permits are needed?
  - Mechanical? Electrical?
- Insurance coverage limit?

More Considerations:

- Explosive Discharges
  - What kind of fan should be used?
  - How is explosion potential mitigated?
  - Who is responsible if there is a problem later?

Considerations: Measures Of Success

- Pressure Field Extension?
- Sub-slab and soil-gas samples?
- Indoor air samples?
- Combination of the above?

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Soil-Gas Sampling To Assess VI Risk

Soil-gas sampling determines cancer risk from vapor intrusion

Sub-slab gas sampling in progress in basement

Considerations: Warranty

 Is your work warranted?
 Performance (did you design it)?
 Fan and parts?

Worker Safety & Training

OSHA requires that employees working on sites with hazardous substances receive 40-hour safety training and annual refresher courses.

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Are You Ready to Begin Mitigating Vapor Intrusion?

- Do you always obtain certificate of insurance from sub-contractors?
- Do you always use a written contract?
- Do you have a lawyer review your contracts and conditions and limitations?
- Does your company have a written health and safety manual?
- Do you have a safety committee?
- Do you track annual radon exposure of your field employees?
- Do your field employees have OSHA 10-hour construction training?
- Have your radon mitigation employees been through a ladder safety and fall protection training?
- Do you have a written fall protection safety manual or equivalent?
- Does your company have a written respirator manual?